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HALIFAX HARBOUR BRIDGES

Halifax Harbour Bridges Ten Year Projected Works and Projected Costs (2021-2030)

In Support of Nova Scotia Utility and Review Board Application

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0	2021 Jan 27	Final Report	Darryl Matson, P.Eng.

Executive Summary

1 Halifax Harbour Bridges (HHB) owns, operates, and maintains multiple bridges/structures in the Halifax area; these are critical infrastructure links for Nova Scotia's transportation network with over 100,000 crossings each weekday (pre-pandemic). The inventory includes the A. Murray MacKay suspension bridge, the Angus L. Macdonald suspension bridge, ancillary structures, and the approach roadways adjacent to the suspension bridges. Figure 1 provides a map of the location of each of HHB's structures.

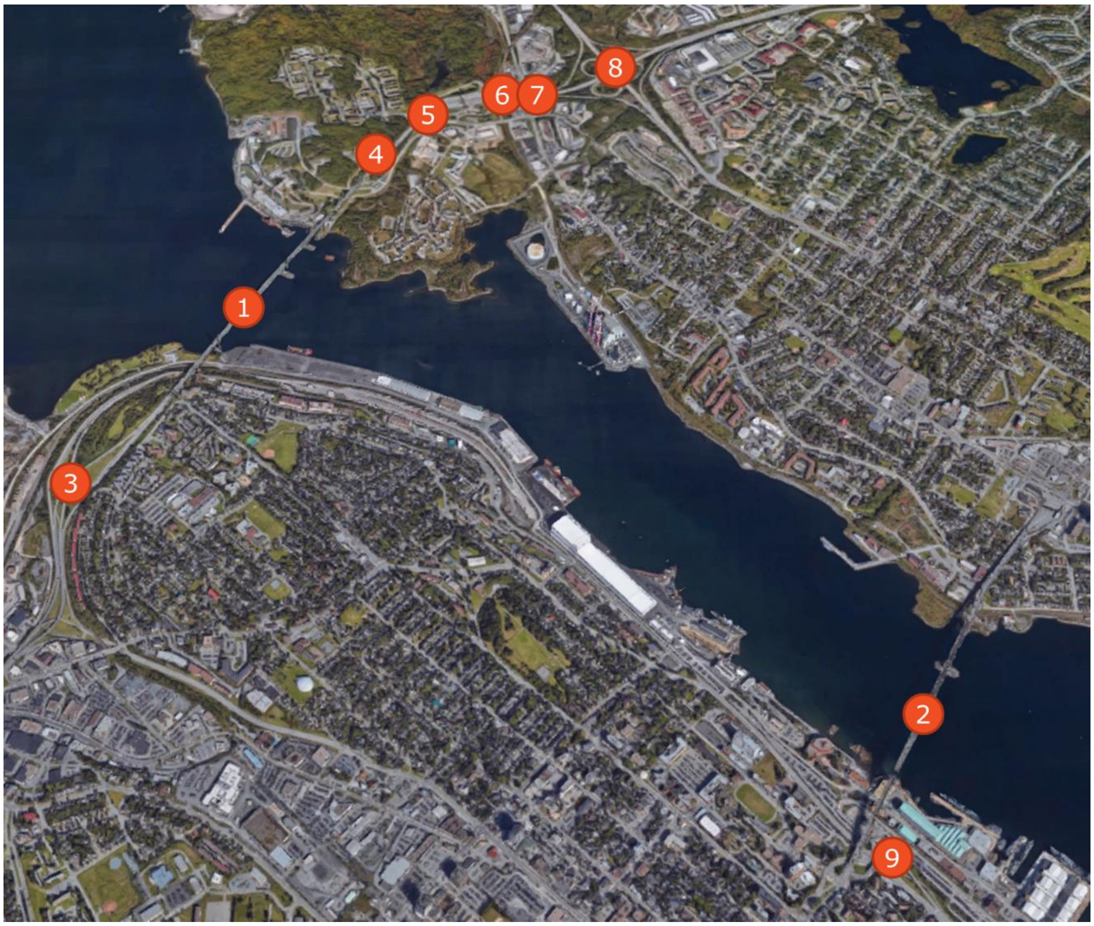

Figure 1: Map showing the location of HHB structures

1	*MacKay Bridge*	*6*	*Canadian National Railway Overpass*
2	*Macdonald Bridge*	*7*	*Windmill Road Overpass*
3	*Halifax Approach Retaining Wall*	*8*	*Victoria Road Overpass*
4	*Baffin Boulevard Retaining Wall*	*9*	*Barrington Street Ramp*
5	*Princess Margaret Overpass*		

2 On October 26, 2020, HHB retained COWI North America Ltd. (COWI) to support HHB's application to the Nova Scotia Utility and Review Board for a toll rate increase due to the significant spending requirements anticipated in the next ten years (2021-2030). COWI's role is to provide expert evidence regarding the major works budget requirements for HHB's bridge/structures inventory.

COWI's Qualifications

3 COWI North America Ltd. (COWI) is a prominent and award-winning speciality bridge, tunnel and marine engineering firm, built on 90 years of experience. Our parent company, COWI A/S, is a leading consulting group that provides state-of-the-art, multi-discipline engineering services with due consideration for the environment and society. With approximately 250 technical staff in 12 North American offices, including one in Halifax, and access to 6,400 employees worldwide, our team has maintained prestige as industry leaders producing ground-breaking techniques aimed at ensuring success for our clients.

4 COWI’s work with HHB began in 1996 when COWI was retained to provide expert review of the 3rd Lane deck-widening scheme for the Angus L. Macdonald Bridge (Macdonald). Since that initial assignment, COWI has been involved in almost every aspect of the engineering work on the Macdonald Bridge, including the Big Lift project. Since 2004, COWI has provided advice to HHB on various maintenance matters and modifications that extend the useful life of the A. Murray MacKay Bridge (MacKay), as well as HHB's ancillary structures. Throughout this period, COWI has been involved in the annual and detailed inspections of HHB's structures.

5 COWI actively works on some of the largest suspension bridges throughout Canada and around the world. For our local staff, this includes the Lions Gate, Waldo Hancock (old), Hagwilget, Seaway South Channel, Cahcao, Messina, Lower Liard, Golden Gate, Hudson Hope, Mackinac, and Canakkale Bridges among many others.

6 Within the Maritime Provinces, COWI is involved in bridge projects with a wide variety of clients including municipalities, the Province of Nova Scotia, Transport Canada and Project Services Procurement Canada. Our engineers work on inspection, rehabilitation, detailed design and construction support. COWI has a proven comprehensive approach to budget forecasting and knowledge of local costs for construction as they relate to HHB's inventory.

Bridge Expert

7 Darryl Matson, the co-author of this report, is Senior Vice President with COWI. Darryl has over 30 years of bridge engineering experience and has been responsible for leading design teams of several high-profile bridge projects across Canada and the US. Until recently, Darryl was responsible for COWI's bridge business in North America. From 2013-2016 he was the President and CEO of Buckland & Taylor (a COWI company). When COWI merged its four North American entities together at the start of 2016, he became the Senior Vice President responsible for the Bridge Group. In mid-2018, COWI North America re-organized. Darryl accelerated his plan to step away from managing the Company and step back into managing projects, which he has been doing for the last two years. Throughout his career, Darryl has remained very active in some of COWI's most significant projects.

8 Darryl's expertise is primarily focused on suspension bridges and asset management/rehabilitation of bridges. He was the Project Manager and Owner's Representative for the Lions' Gate Bridge suspended span replacement between 1997 and 2002. Darryl has been involved in Halifax Harbour Bridges projects for the last 15 years including most of the rehabilitation projects for the MacKay and Macdonald Bridges including the Big Lift project.

Anticipated Major Works Budget

9 Based on COWI's direct knowledge of HHB's structures, including historical maintenance needs, and based on COWI's knowledge of other similar structures, COWI worked closely with HHB's engineering department to develop a list of capital, rehabilitation and maintenance costs that are expected over the next ten years for each structure.

10 COWI then estimated the cost of each work item (in 2021 dollars) and built up an expected annual budget for each structure. The expected budget is shown in Table EXEC1. Using an annual inflation rate of 1.5%, the column on the right of table EXEC1 shows the expected cost, increased for inflation, based on the year they are expected.

Year	Macdonald Bridge	MacKay Bridge	Ancillary Structures	Subtotal (2021 dollars)	Subtotal (with annual inflation 1.5%)
2021	$11,550,000	$2,450,000	$200,000	$14,200,000	$14,200,000
2022	$20,350,000	$19,400,000	$1,650,000	$41,400,000	$42,021,000
2023	$20,500,000	$4,370,000	$2,400,000	$27,270,000	$28,094,236
2024	$15,500,000	$8,550,000	$2,900,000	$26,950,000	$28,181,032
2025	$11,000,000	$14,020,000	$5,650,000	$30,670,000	$32,552,020
2026	$12,700,000	$10,050,000	$3,880,000	$26,630,000	$28,688,073
2027	$500,000	$12,300,000	$2,630,000	$15,430,000	$16,871,830
2028	$3,750,000	$12,390,000	$930,000	$17,070,000	$18,945,053
2029	$2,250,000	$13,540,000	$1,980,000	$17,770,000	$20,017,773
2030	$0	$19,360,000	$1,250,000	$20,610,000	$23,565,267
Total	$98,100,000	$116,430,000	$23,470,000	$238,000,000	$253,136,284

Table EXEC1: Expected Annual Budget for Major Works (2021 dollars and inflated totals)

11 This report provides details of each component of the work that is expected over the next ten years, including when each item will be required. Specific individual work items identified in this report may be required earlier than outlined. Also, some work items could be delayed a year or two, though care needs to be taken in delaying any rehabilitation and maintenance items because the risk of more bridge closures increases as maintenance is delayed.

12 As can be seen in Table EXEC1, most of the anticipated budget over the next ten years will be spent on the Macdonald and MacKay bridges. However, the needs of each of the structures is significantly different.

13 Much of the ten-year budget for the Macdonald is needed to complete the major rehabilitation for the bridge elements that were not replaced during the Big Lift Project. This includes steel and concrete repairs of the approaches and painting of the portions of the bridge that were not replaced during the Big Lift, as well as regular resurfacing of the bridge deck.

14 The budget for the MacKay is primarily needed to maintain the ageing bridge. This includes deck repairs for the approach spans, resurfacing, main cable dehumidification, coatings, and repairs of anticipated fatigue cracks in the main span deck. Some additional funds are estimated for HHB to begin the process of the replacement of the MacKay for 2040, as detailed in the following paragraphs.

MacKay Bridge Replacement

15 Recently, COWI completed a feasibility study on behalf of HHB that determined that performing a major rehabilitation of the MacKay Bridge is not practicable (a copy of the feasibility study is provided in Appendix H). Therefore, while the bridge remains operationally and structurally safe, it is nearing the end of its useful life, and the ongoing maintenance and rehabilitation costs are expected to increase until it is replaced. COWI recommends that HHB plan on replacing the MacKay in 2040 and prepare for major interventions if a critical component needs repair earlier than expected. Replacement of the bridge is expected to take ten years due to the time needed for the environmental assessment, land acquisition, design, procurement and construction to take place within the required timelines.

16 Due to the uncertainty in the MacKay's remaining life, we have included the cost of some preliminary design work related to the replacement bridge in the capital plan. This is being included since the replacement of the bridge will take approximately ten years from start to finish. There is a risk that the fatigue issues of the bridge deck will happen sooner than expected and that the replacement bridge could be needed before 2040. The early preliminary design work will allow HHB to be prepared for an earlier than anticipated replacement if required.

17 HHB has not yet finalized the timing of this work, but for the capital plan, is proceeding on the basis that the design will start between 2025-2030 at the earliest. If the design were to begin in this period, it is assumed that it will extend beyond 2030. Therefore, additional costs are anticipated beyond 2030 for the design and the full construction cost impacts.

CONTENTS

APPENDICES

1 Introduction

COWI offers this report to the Nova Scotia Utility and Review Board to support HHB's application for a toll rate increase. The author will be available to testify at the hearing.

HHB owns, operates, and maintains multiple bridges in the Halifax area; these are critical infrastructure links for Nova Scotia's transportation network with over 100,000 crossings each weekday (pre-pandemic). The inventory includes the A. Murray MacKay suspension bridge, the Angus L. Macdonald suspension bridge, ancillary structures, and the approach roadways adjacent to the suspension bridges. Figure 1 shows a map of the location of these structures. Appendix A provides a map and respective photos for each of HHB's structures. The ancillary structures include:

- Barrington Street on Ramp;
- Windsor/Robie Street Exit K Ramp;
- Halifax Approach and Baffin Boulevard retaining walls;
- Princess Margret, Windmill Road, Canadian National Railway (CN), and Victoria Road overpasses; and
- Ramp D-Bin.

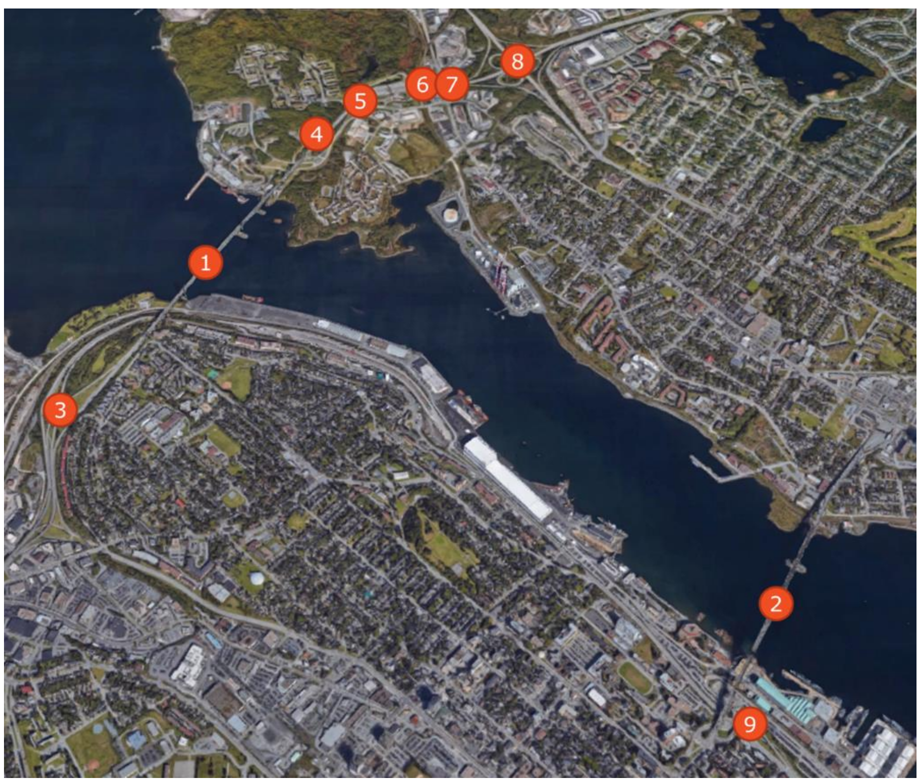

Figure 2: Map showing the location of HHB structures

1	*MacKay Bridge*	*6*	*Canadian National Railway Overpass*
2	*Macdonald Bridge*	*7*	*Windmill Road Overpass*
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4	*Baffin Boulevard Retaining Wall*	*9*	*Barrington Street Ramp*
5	*Princess Margaret Overpass*		

HHB retained COWI to support HHB's application to the Nova Scotia Utility and Review Board for a toll rate increase due to the significant spending requirements anticipated in the next ten years (2021-2030). COWI's role is to provide expert evidence as bridge engineers regarding the major works budget requirements for HHB's bridge/structures inventory. With historical records provided by HHB, together with COWI's knowledge regarding the specific structures and the industry in general, COWI developed the following report, outlining the anticipated major works items required for each of the bridges and ancillary structures in the next ten years (2021-2030). COWI has worked with HHB on maintenance and engineering projects for these structures for 25 years and has considerable experience and knowledge regarding their past performance and anticipated future needs.

Based on COWI's direct knowledge of HHB's structures, including historical maintenance needs, and based on COWI's knowledge of other similar structures, COWI worked closely with HHB's engineering department to develop a list of major works items that are expected over the next ten years for each structure.

COWI then estimated the cost of each work item (in 2021 dollars) and built up an expected annual budget for each structure. Development of the cost estimates was based on historical trends and COWI's experience with similar structures. Use of historical trend data is two-fold: utilizing past costs for similar work completed to date on these bridges, and an understanding of the bridges' past performance in the development of future need recommendations. COWI has worked across North America and internationally as bridge specialists for nearly 50 years and brought this knowledge forward to aid in developing these recommendations for maintenance and investigations.

Specific individual works identified in this report may be required earlier than outlined. Also, some elements could be delayed a year or two, though care needs to be taken in delaying any maintenance items because the risk of more bridge closures increases as maintenance is delayed.

As this significant infrastructure ages, the cost to maintain it in safe working order also increases. Most of the anticipated budget over the next ten years will be spent on the Macdonald and MacKay bridges. However, the needs of each of the structures are significantly different.

The Macdonald Bridge has undergone two major rehabilitation projects over its life: The Third Lane Project and the Big Lift Project. The majority of the ten-year budget for the Macdonald is needed to complete the major rehabilitation for the bridge elements that were not replaced during the Big Lift Project; mostly concrete and steel repairs, as well as painting. Once these are complete, HHB and COWI expect the maintenance effort needed for the Macdonald Bridge to level out for 30 or 40 years before another major rehabilitation is required.

The ten-year budget for the MacKay is primarily needed to maintain the ageing bridge. This includes deck repairs for the approach spans, coatings, pavements, main cable dehumidification, and repairs of anticipated fatigue cracks in the main span deck.

The seven ancillary structures are at a stage in their life that only regular maintenance is expected over the next ten years.

Consideration of the expected interventions has been built into the projected needs for the next ten years. In 2021 dollars, cost estimates have also been made for each element and then increased for inflation annually, to the year in which they are expected.

MacKay Bridge Replacement

Recently, COWI completed a feasibility study for the MacKay Bridge that determined that performing a major rehabilitation of the bridge is not practicable (a copy of the feasibility study is provided in Appendix H). While the bridge remains operationally and structurally safe, the suspended span deck of the bridge is prone to fatigue cracking. Therefore, the risk of major disruptions to the traffic is expected to increase significantly over the next 10 to 15 years.

The requirement to undertake either a significant rehabilitation or replacement of the bridge results from the original design being extremely light and having no reserve capacity for applying strengthening measures or re-decking. The bridge deck was designed significantly lighter than current bridge codes recommend, resulting in a carry-through effect of reduced capacity to take a replacement deck system if it were to be designed to current bridge code recommendations. This is different than the deck replacement recently undertaken for the Macdonald Bridge, where a lighter steel deck replaced the original concrete deck. Therefore, the MacKay Bridge is nearing the end of its useful life, and the ongoing maintenance costs are expected to increase until it is replaced.

As such, COWI has recommended that HHB plan on replacing the MacKay in 2040 and prepare for major interventions if a critical component needs repair earlier than expected.

1.1 Objectives

This report describes the major works and expected budget requirements anticipated during the next ten years in support of HHB's Application to the Nova Scotia Utilities and Review Board. Included in Appendices C through F are the following details for each line item on the 10-year plan:

- Background details for the line item, including past works and significance to the structure;
- Technical considerations; and
- Budget and timing recommendations.

A summary of the recommended schedule for implementing the major works and associated budget forecasts are provided in Section 2, followed by high-level overviews of the dominating projects within the major works plan.

1.2 COWI's Qualifications

1.2.1 COWI's Corporate Profile

COWI North America Ltd. (COWI) is a prominent and award-winning speciality bridge, tunnel and marine engineering firm, built on 90 years of experience. Our parent company, COWI A/S, is a leading consulting group that provides state-of-the-art, multi-discipline engineering services with due consideration for the environment and society. With approximately 250 technical staff in 12 North American offices and access to 6,400 employees worldwide, our team has maintained prestige as industry leaders producing ground-breaking techniques aimed at ensuring success for our clients.

In 2011, COWI opened a permanent office in Halifax, NS, to provide a higher level of service to our local clients. Currently, we are the Owner's Engineer for HHB on the Macdonald and MacKay bridges, a relationship that has developed and shown to be collaborative over the past 25 years. COWI’s work with HHB began in 1996 when COWI was retained to provide expert review of the 3rd Lane deck-widening scheme. Since that initial assignment, COWI has been involved in many aspects of the work on the Macdonald, including providing structural engineering services for the Big Lift. Since 2004, COWI has provided advice to HHB on various maintenance matters and modifications that extend the useful life of the MacKay. Throughout this period, COWI has been involved in the annual and detailed inspections of HHB's structures.

COWI actively works on some of the largest suspension bridges throughout Canada and internationally. This includes the Lions Gate Bridge, Waldo Hancock (old), Hagwilget, Seaway South Channel, Cahcao, Messina, Lower Liard, Golden Gate, Hudson Hope, Mackinac, and Canakkale Bridges among many others.

Within the Maritime Provinces, COWI is involved in bridge projects with a wide variety of clients including municipalities, the Province of Nova Scotia, Transport Canada and Project Services Procurement Canada. Our engineers work on inspection, rehabilitation, detailed design and construction support. COWI has a proven, comprehensive approach to budget forecasting and knowledge of local costs for construction as they relate to HHB's inventory.

1.2.2 Bridge Expert

Darryl Matson, the co-author of this report, is a Senior Vice President with COWI. Darryl has over 30 years of engineering experience specifically related to heavy transportation projects and has been responsible for leading design teams of several high-profile bridge projects across Canada and the US. Until recently, Darryl was responsible for COWI's bridge business in North America. From 2013-2016 he was the President and CEO of Buckland & Taylor (a COWI company). When COWI merged its four North American entities together at the start of 2016, he became the Senior Vice President responsible for the Bridge Group. In mid-2018, COWI North America re-organized. Darryl accelerated his plan to step away from managing the Company and step back into managing projects, which he has been doing for the last two years. Throughout his career, Darryl has remained very active in some of COWI's most significant projects.

Darryl's expertise is primarily focused on suspension bridges and asset management/rehabilitation of bridges. He was the Project Manager and Owner's Representative for the Lions' Gate Bridge suspended span replacement between 1997 and 2002. Darryl has been involved in HHB's projects for the last 25 years including most of the rehabilitation projects for the MacKay and Macdonald, including the Big Lift project.

For Darryl's complete curriculum vitae, please refer to Appendix G.

1.3 Descriptions of the Structures

HHB's structures inventory is wide-ranging in age and complexity. With the two suspension bridges crossing Halifax Harbour seeing approximately 100,000 vehicles each weekday (pre-pandemic), Halifax's transportation network is greatly affected by any reductions in traffic flow across the bridges. Similarly, many of the ancillary structures can affect the movement of traffic based on their function as interchanges between transportation routes and access to the harbour suspension bridges.

In the following sections, each structure is described. For reference, Appendix A provides a detailed map showing where each of the structures is located.

1.3.1 MacKay Bridge

The MacKay opened to traffic in 1970 and carries four lanes of traffic over the Halifax Harbour. There are no lanes for pedestrians or cyclists. The suspended spans are comprised of two side spans and a centre span measuring approximately 156.6 m and 426.7 m, respectively. The deck system of the suspended spans consists of a stiffening under-deck truss supporting transverse trusses. The floor beams, in turn, support an Orthotropic Steel Plate Deck (OSPD) and paving. Both the Halifax Main Tower and Dartmouth Main Tower are approximately 87.2 m tall.

The approach spans of the bridge have a concrete bridge deck supported on twin box girders and concrete piers. The Dartmouth and Halifax approach spans are approximately 114.3 m and 381.9 m long, respectively.

1.3.2 Macdonald Bridge

The Macdonald opened to traffic in 1955 and carries three lanes of traffic over the Halifax Harbour, and one lane each for Sidewalk and Bikeway on either side of the bridge. The suspended spans comprise two side spans and a centre span measuring approximately 160.5 m and 441.1 m, respectively. The suspended spans' deck system is a below-deck stiffening truss supporting transverse floorbeams, OSPD and paving. Both the Halifax Main Tower and Dartmouth Main Tower are approximately 91.6 m tall.

The bridge's approach spans were replaced with OSPD as part of the Third Lane project circa 1999 and are supported by trusses/girders and concrete piers. The Dartmouth (truss and girder arrangements) and Halifax approach (truss arrangement only) spans are approximately 436.6 m and 148.2 m long, respectively.

1.3.3 Ancillary Structures

BARRINGTON STREET RAMP

Located on the south side of the Macdonald Bridge, the Barrington Street Ramp is a 350 m long, eight span bridge supported on concrete piers and abutments. It is a concrete structure that carries one lane of traffic for Dartmouth-bound traffic travelling north on Barrington Street in Halifax.

WINDSOR/ROBIE ST. EXIT K RAMP

Located west of the MacKay Bridge, and forming part of the NS Highway 111 interchange system, the Windsor/Robie Street Exit is a 160 m long, four span bridge supported on concrete piers and concrete abutment walls. It is composed of a concrete deck supported by twin steel box girders and is curved in plan carrying two lanes of traffic.

PRINCESS MARGARET OVERPASS

Located east of the MacKay Bridge, the Princess Margaret Overpass is a 20.4 m long single-span concrete bridge supported on concrete abutment walls. It carries four lanes of traffic as part of the MacKay Dartmouth roadway approaches.

BAFFIN BOULEVARD RETAINING WALL

The Baffin Boulevard Retaining Wall is a concrete retaining wall along the south side of the MacKay roadway approaches.

CN OVERPASS

Located east of the MacKay toll plaza, the CN Overpass is a 17.9 m long single-span concrete bridge supported on concrete abutment walls. It carries six lanes of traffic as part of NS Highway 111 over the CN Railway.

WINDMILL ROAD OVERPASS

Located east of the MacKay Bridge, the Windmill Road Overpass is a twinned 59.1 m long, three span bridge supported on concrete piers and abutments. It is a concrete structure that carries six lanes of traffic as part of NS Highway 111 over Windmill Road.

VICTORIA ROAD OVERPASS

Located east of the MacKay Bridge, the Victoria Road Overpass is a twinned 61.3 m long, three span bridge supported on concrete piers and abutments. It is a concrete structure that carries six traffic lanes as part of Victoria Road over NS Highway 111.

2 Ten Year Capital Projects Forecast

2.1 Major Works Projects - Financial Forecast

The following is a summary table for the expected annual budgets of the anticipated major works projects of the Macdonald, MacKay and the seven ancillary structures over the next ten years. Detailed tables, organized per structure are provided in Appendix B with supporting information in Appendices C – F.

Year	Macdonald Bridge	MacKay Bridge	Ancillary Structures	Subtotal (2021 dollars)	Subtotal (with annual inflation 1.5%)
2021	$11,550,000	$2,450,000	$200,000	$14,200,000	$14,200,000
2022	$20,350,000	$19,400,000	$1,650,000	$41,400,000	$42,021,000
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2029	$2,250,000	$13,540,000	$1,980,000	$17,770,000	$20,017,773
2030	$0	$19,360,000	$1,250,000	$20,610,000	$23,565,267
Total	$98,100,000	$116,430,000	$23,470,000	$238,000,000	$253,136,284

Table 1: Expected Annual Budget for Major Works (2021 dollars and inflated totals)

2.2 Summary of Major Works Projects

HHB and COWI anticipate a wide variety of rehabilitation projects over the next ten years. The following sections provide high-level summaries of a selection of these projects, predominantly those that contain the bulk of the anticipated costs. For a complete set of details and assumptions used to build this major works plan, please refer to the Appendices C – F.

2.2.1 Macdonald Steel Repair and Paint Project

The Big Lift Project on the Macdonald replaced the bridge's superstructure; however, the approach spans and the towers/bents/foundations need to be rehabilitated to extend their life to match that of the new superstructure. A significant amount of the expected maintenance cost HHB will need to spend over the next ten years is related to steel repairs and painting of the structure's remaining steel.

A surface area of existing coatings has been determined for each of the components remaining to be addressed. Based on 2018-2020 projects undertaken by HHB, COWI estimated a cost per square metre for the remaining work, separated into paint costs and steel repair costs. These costs were then adjusted based on the complexity of access, total surface area, anticipated steel repairs, and staging requirements.

The schedule of work has been developed through consultation with HHB and a recommended priority sequence by COWI. COWI's understanding of the structure, paired with recent inspection information, provided the basis for our recommendations for which components should be addressed first and within what timing the work should be completed.

Refer to Appendix C.8 for additional details.

2.2.2 Macdonald Bridge Approach Span Bearings and Pier Rehabilitation

Bearing Rehabilitation

As a follow-up to the 2012 annual inspection findings, HHB installed movement monitoring devices at twelve out of the twenty-six sliding bearings to help quantify the observations from the inspection. Field measurements, including calculations and evaluations, revealed that various bearings were seized and restricted movement. The existing bearings are from the original construction (65 years old), which is well beyond their expected service life of 35-40 years.

Since 2015, HHB has replaced the bearings at twelve of eighteen pier or abutment locations. COWI used the actual replacement costs for these previous projects to estimate the cost of the remaining work, in coordination with an understanding of the complexity of upcoming work.

Refer to Appendix C.2 for additional information.

Pier Rehabilitation

In 2012, HHB performed a detailed condition assessment of the Macdonald substructure and foundations. This assessment identified that the majority of the concrete was experiencing alkali-aggregate reactivity coupled with cycling freezing and thawing damage. Additionally, the evaluation categorized each pier and abutment with a priority level. HHB has been repairing these piers and targets to rehabilitate High & Medium priority piers by 2024 and remaining piers by 2028.

Since 2012, HHB rehabilitated 14 piers along with portions of the Halifax and Dartmouth Abutments. The remaining work includes rehabilitation of the main tower and cable bent foundations, five piers and the remaining portions of the Halifax and Dartmouth abutments.

COWI estimated the cost of the remaining work based on actual project costs from 2014 and 2019, in coordination with an understanding of the complexity of upcoming work.

Refer to Appendix C.1 for additional information.

2.2.3 Macdonald Bridge Resurfacing

During the 2015-2017 suspended spans replacement on the Macdonald Bridge ("The Big Lift"), the side and centre spans were replaced with new orthotropic steel deck, which included new paving. The paving system is a proprietary epoxy asphalt with a nominal thickness of 45 mm.

Significant work on the suspended spans is not expected in the next ten years; however, some pavement resurfacing is expected in 2028.

Based on traffic volume, environmental exposures and substrate conditions, Pavement/Wearing Surface service life for the Macdonald is expected to be:

- Bridge: 10-15 years
- Approach Roadway: 20-25 years

The approach spans were not significantly impacted or modified during the Big Lift project. Therefore, the asphalt surfacing is approximately 20 years old. Longitudinal cracking is present near the wheel paths, and HHB has performed sizeable patch repairs where asphalt bond failure has occurred. COWI estimated the cost of a complete resurfacing of the approach spans based on the last repaving contract completed in 2009/2010 on the same spans. A comparison was also made to the recent 2019 paving on the MacKay and adjusted for complexity. Work is anticipated for 2022 and 2023.

The approach road surface is maintained according to criteria as per HHB standards and based on prior project execution/successes. COWI estimated the cost of asphalt resurfacing based on Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) tender prices for similar work. Work is anticipated for 2025 and 2026.

Refer to Appendices C.4 – C.6 for additional information.

2.2.4 MacKay Bridge Concrete Approach Deck Repairs

The cast in place concrete approach span deck has been observed to have increasing amounts of deterioration, including spalling concrete, exposed reinforcement, cracking and difficult to maintain the paving bond. These are all indications of a concrete deck that is experiencing active corrosion of the steel reinforcement.

Based on the visual inspection results to date, COWI anticipates significant concrete removals, particularly in the vicinity of cold joints and expansion joints along the deck. This work will require construction staging to keep traffic moving and engineering assistance throughout construction to determine the appropriate repair measures following concrete removals.

COWI recommends HHB allow for two construction seasons of significant concrete repairs widespread across the deck, during which two lanes would be addressed each year. This work will include mobilization of the contractor, protection of adjacent property and roadways, traffic control, demolition of the deck's deteriorated areas, and replacement of steel reinforcing and concrete.

Until the deck rehabilitation can take place, COWI recommends HHB be prepared to undertake localized repairs in 2023 and 2024 (when significant deterioration is anticipated to become difficult to contain) in interim emergency repairs to maintain the deck surface for the flow of traffic.

Refer to Appendix D.3 for additional information.

2.2.5 MacKay Bridge Main Cable Dehumidification

Since HHB intends to maintain the MacKay Bridge until 2040 or longer and based on COWI's understanding of the current condition of the main cable, COWI recommends installing a cable dehumidification system on the bridge. The main cable is a critical component of the bridge and one that is nearly impossible to strengthen or replace. Protection of its capacity is the most efficient and reasonable approach to maintaining it over the bridge's life. To date, all areas of the main cable that have been opened show significant amounts of moisture, with corrosion occurring at the low points and some observed broken wires. With the corrosion of the main cable anticipated to continue if no action is undertaken to protect it, the capacity of the main cable will continue to decrease. The rate of this deterioration is yet unknown due to only having a limited number of main cable internal inspections performed to date. However, COWI considers it appropriate to preserve as much capacity in the main cable as possible through the dehumidification system. While not currently a safety issue, frequent and invasive inspections would be required for HHB to maintain an appropriate level of understanding for the cable's changing condition. Therefore, in addition to preserving the main cable's capacity, COWI considers the dehumidification system's addition to be a good value for money.

Refer to Appendix D.9 for additional information.

2.2.6 MacKay Bridge Fatigue Repairs and Associated Component Replacements

The MacKay Bridge was designed in a time when less was known regarding the fatigue life of Orthotropic Steel Plate Decks (OSPDs). The deck top plate is 9.5 mm thick, in comparison to the minimum 14 mm, which is currently specified by the Canadian Highway Bridge Design Code (CHBDC). This thin plate leads to the deck's increased flexibility, resulting in a short fatigue life that can not be corrected. The deck's flexibility has also led to an increased rate of deterioration and cracking of the wearing surface, allowing water and de-icing salts to penetrate through to the steel and cause corrosion.

In 2009, HHB requested that COWI estimate the remaining life of the deck of the Bridge. It was noted that the Bridge has several deficiencies and that as far as practical, the deficiencies have been remedied, but that a complete “cure” would not be possible due to the inherent nature of the original design. COWI concluded there was no evidence of significant cracking of the OSPD in 2010, and that fatigue loading would not likely cause widespread cracking of the OSPD until 2028 to 2038 (15-25 years from 2013) and maybe longer. It was noted by COWI that it was possible that there would be intermittent cracking before that time.

In 2019, COWI performed a detailed inspection of the deck plate's top surface in both southbound lanes of the Bridge, covering half of the overall deck width. Four new cracks were identified in the top plate, suggesting that the expected fatigue cracking of the deck has now started, as projected in the 2010 study. While not yet considered widespread cracking, the rate of deck cracking is expected to accelerate.

Mitigating the risk due to fatigue cracking on an OSPD is undertaken by increased inspections to understand the location and extent of cracking, and by repairing cracks as soon as reasonably possible. In a period of infrequent cracking, repairs may be undertaken by removing the wearing surface, welding the crack closed, and replacing the wearing surface.

If cracks reappear consistently in the same locations, or multiple cracks occur within a short distance, the replacement of a section of OSPD begins to become a more appropriate action. The need for this approach is likely to occur within one to two years of being identified. Based on the complexity of replacing sections of the deck, this is considered a short timeframe for developing designs, installation procedures, and fabricating components. Therefore, COWI recommends HHB prefabricate sections of OSPD to have on hand for installation as emergency measures.

COWI has estimated the cost of designing and fabricating several deck sections based on experience with OSPD projects.

Refer to Appendix D.8 for additional information.

2.2.7 MacKay Bridge Replacement

As part of HHB's plan to replace the existing Bridge by 2040, COWI recommends HHB begin taking steps within the next several years to determine the scope of work, gather input and facilitate communication with the key stakeholders, and begin to communicate these plans to establish funding and support. COWI provided HHB with a feasibility report for the MacKay replacement options in 2020. A copy of the feasibility report is provided in Appendix H. This report summarizes COWI's recommendation to HHB regarding the options available for the long-term operation of the crossing, ultimately demonstrates why a replacement bridge is required, and why planning for the new bridge to be in service by 2040 provides the best value to HHB's mandate.

This process would proceed as follows:

- Scoping study for a new bridge;
- Communication with key stakeholders, i.e. nearby property owners (residential, commercial, federal) in the vicinity of the bridge; Federal, Provincial and Municipal Governments; Halifax Port Authority; Department of National Defense; etc.; and
- Assessment of land adjacent to the existing bridge to determine the most appropriate location for a replacement bridge, starting with environmental and land impact assessments. (Note, this work does not include land acquisition, but rather a high-level evaluation of potential acquisition processes and implications.)

Once the scoping study and the environmental and land impact assessments are complete, HHB can proceed with the design and construction of the replacement bridge.

For this capital plan, HHB is proceeding as if the early stages of the planning/design will start between 2025-2030. If the design were to begin in this period, it is assumed that it will extend beyond 2030. Therefore, additional costs are anticipated beyond 2030 for the design and the full construction cost impacts.

A representative cost estimate is provided below based on COWI's evaluation on HHB's anticipated scope of work and experience designing similar structures throughout North America.

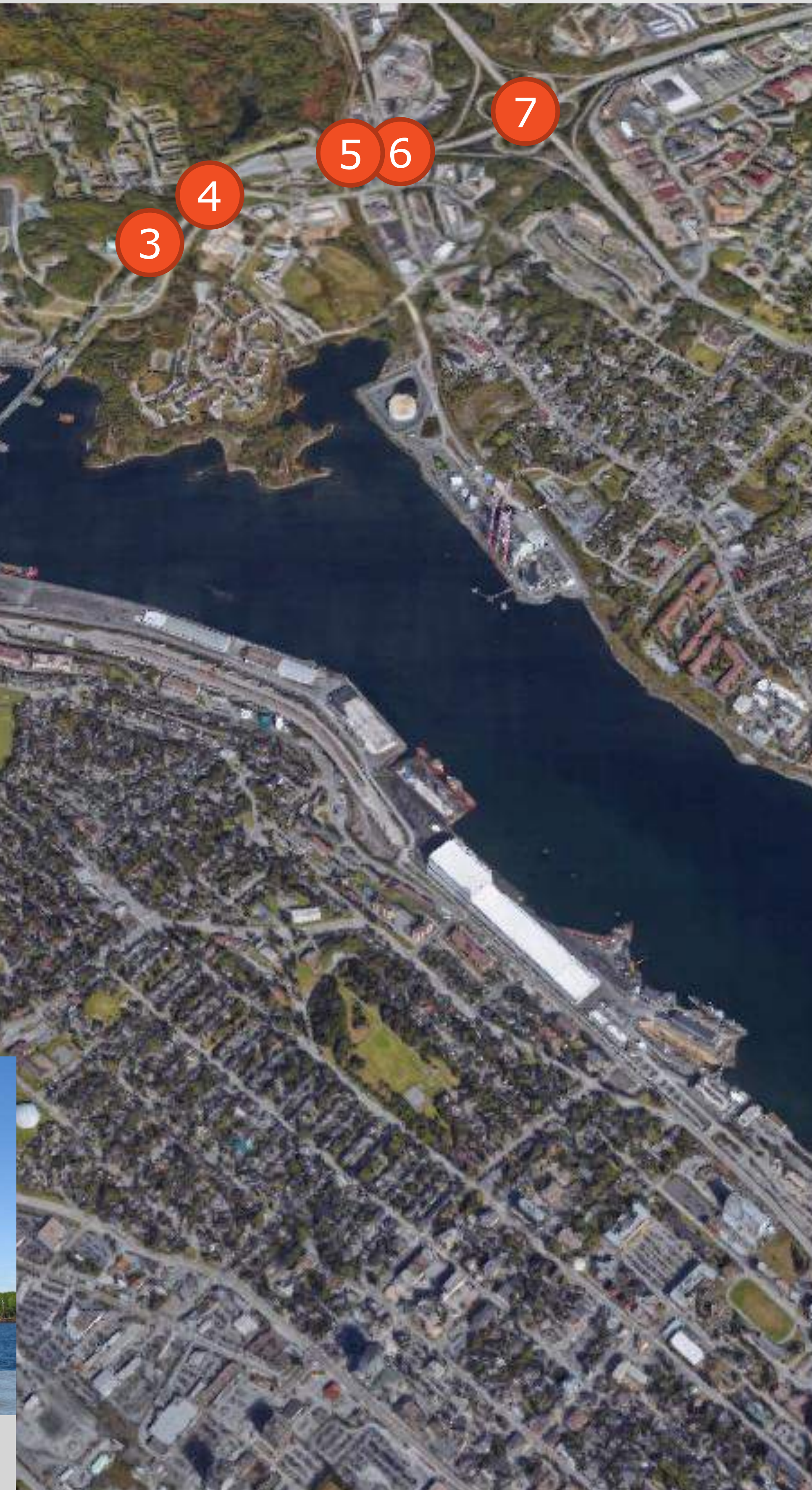
Refer to Appendix E for additional information.

APPENDICES

Appendix A Structures Map

STRUCTURES MAP

Halifax Harbour Bridges



2

WINDSOR/ROBIE ST. EXIT K RAMP

- CURVED, TWO-LANE, 4 SPAN, 160m LONG STEEL TWIN BOX GIRDER (NS HWY 111)

3

BAFFIN BOULEVARD RETAINING WALL

- CAST-IN-PLACE CONCRETE RETAINING WALL ALONG AMM DARTMOUTH APPROACH

4

PRINCESS MARGARET OVERPASS

- TAPERED, FOUR-LANE, SINGLE-SPAN, 20.4m LONG VOIDED CONCRETE SLAB

5

CN RAIL OVERPASS

- STRAIGHT, SIX-LANE, SINGLE-SPAN, 17.9m LONG VOIDED CONCRETE SLAB (NS HWY 111)

1

A. MURRAY MACKAY BRIDGE

- CONSTRUCTED IN 1970
- FOUR LANES; MULTI-SPANS
- 740m SUSPENDED SPANS; 1236m Total

9

ANGUS L. MACDONALD BRIDGE

- CONSTRUCTED IN 1955
- THREE LANES; MULTI-SPANS
- 762m SUSP. SPAN (NEW OSPD 2017); 1,347m total.

6

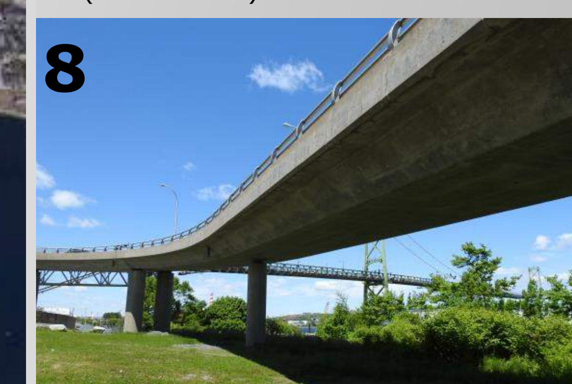
WINDMILL ROAD OVERPASS

- TWIN THREE-LANE, THREE SPAN, 59.1m LONG VOIDED CONCRETE SLAB (NS HWY 111)

7

VICTORIA ROAD OVERPASS

- TWIN THREE-LANE, THREE SPAN, 61.3m LONG VOIDED CONCRETE SLAB (NS HWY 111)



8

BARRINGTON STREET RAMP

- CURVED, SINGLE-LANE, EIGHT-SPAN, 350m LONG SOLID POST-TENSIONED SLAB

COWI

Appendix B Ten Year Forecast Tables – Detailed

B.1 Macdonald Bridge Projects

			2021	2022	2023	2024	2025	2021-2025
Macdonald Bridge								
Repairs and Rehabilitation	C.1	Concrete Restoration	$1,500,000	$2,300,000	$1,500,000	$2,500,000		$7,800,000
	C.2	Approach Spans Bearings	$3,000,000	$1,800,000	$500,000			$5,300,000
	C.3	Approach Spans Ejs		$500,000	$500,000			$1,000,000
	C.4	Approach Road Resurfacing					$1,000,000	$1,000,000
	C.5	Approach Span Resurfacing		$3,000,000	$1,000,000			$4,000,000
	C.6	Suspended Span Resurfacing						$0
	C.7	Sidewalk Bikeway Resurfacing	$1,000,000	$1,000,000	$1,000,000			$3,000,000
	C.8	Steel Repair and Paint Project	$6,000,000	$11,500,000	$16,000,000	$13,000,000	$10,000,000	$56,500,000
	C.9	Access Improvements	$50,000	$250,000				$300,000
Total			$11,550,000	$20,350,000	$20,500,000	$15,500,000	$11,000,000	**$78,900,000**

			2026	2027	2028	2029	2030	2026-2030
Macdonald Bridge								
Repairs and Rehabilitation	C.1	Concrete Restoration		$500,000	$500,000			$1,000,000
	C.2	Approach Spans Bearings						$0
	C.3	Approach Spans Ejs			$750,000	$750,000		$1,500,000
	C.4	Approach Road Resurfacing	$200,000					$200,000
	C.5	Approach Span Resurfacing						$0
	C.6	Suspended Span Resurfacing			$2,500,000	$1,500,000		$4,000,000
	C.7	Sidewalk Bikeway Resurfacing						$0
	C.8	Steel Repair and Paint Project	$12,500,000					$12,500,000
	C.9	Access Improvements						$0
Total			$12,700,000	$500,000	$3,750,000	$2,250,000	$0	$19,200,000

			2021-2030
Macdonald Bridge			
Repairs and Rehabilitation	C.1	Concrete Restoration	$8,800,000
	C.2	Approach Spans Bearings	$5,300,000
	C.3	Approach Spans Ejs	$2,500,000
	C.4	Approach Road Resurfacing	$1,200,000
	C.5	Approach Span Resurfacing	$4,000,000
	C.6	Suspended Span Resurfacing	$4,000,000
	C.7	Sidewalk Bikeway Resurfacing	$3,000,000
	C.8	Steel Repair and Paint Project	$69,000,000
	C.9	Access Improvements	$300,000
Total			**$98,100,000**

B.2 MacKay Bridge Projects

			2021	2022	2023	2024	2025	2021-2025
MacKay Bridge								
Repairs and Rehabilitation	D.1	Approach Spans Bearings					$1,000,000	$1,000,000
	D.2	Concrete Rehabilitation - Substructure	$1,000,000	$1,000,000	$1,000,000	$500,000		$3,500,000
	D.3	Concrete Approach Span Deck Rehabilitation		$500,000	$500,000		$6,000,000	$7,000,000
	D.4	Suspended Spans Resurfacing	$500,000	$4,000,000				$4,500,000
	D.5	Approach Spans Resurfacing	$250,000			$250,000	$1,500,000	$2,000,000
	D.6	Approach Road Resurfacing		$800,000		$5,000,000		$5,800,000
	D.7	Approach Span Expansion Joints		$430,000				$430,000
		Expansion Joints Glands					$100,000	$100,000
	D.8	Orthotropic Steel Plate Deck Fatigue (repairs)	$100,000	$200,000	$200,000	$200,000	$250,000	$950,000
		OSPD Replacements - emergency	$200,000	$300,000				$500,000
	D.9	Cable Dehumidification	$300,000	$10,000,000				$10,300,000
		Main Cable Inspection		$1,250,000				$1,250,000
	D.10	Hanger Replacements					$1,000,000	$1,000,000
		Hangers Coating		$150,000	$150,000	$150,000		$450,000
	D.11	Stiffener Trusses Steel repair					$1,000,000	$1,000,000
		Stiffening trusses coating			$450,000	$450,000	$450,000	$1,350,000
		Transverse Trusses coating						$0
	D.12	Main Tower Coatings						$0
		Tower Steel repairs (doors and seal splices)			$250,000			$250,000
		Cable Bents coatings						$0
	D.13	Steel Repairs and Access - Box Girder			$1,000,000	$1,000,000	$500,000	$2,500,000
		Box Girders Coatings						$0
	D.14	Int Floor Beams Coatings						$0
		Ext. Floor Beams coatings						$0
	D.15	Access Improvements	$100,000	$250,000	$500,000	$1,000,000		$1,850,000
	D.16	Roadway Signage					$2,000,000	$2,000,000
		Roadway Safety						$0
	-	Subtotal Rehabilitation:	$2,450,000	$18,880,000	$4,050,000	$8,550,000	$13,800,000	$47,730,000
New Bridge	E.1	New Bridge Scoping Study		$250,000	$100,000			$350,000
		New Bridge Stakeholders/Communications		$200,000	$200,000			$400,000
	E.2	New Bridge Environmental Assessment		$50,000			$200,000	$250,000
		New Bridge Land Impact Assesssments		$20,000	$20,000		$20,000	$60,000
		New Bridge Land Acquisition						$0
	E.3	New Bridge Design (not complete design)						$0
		New Bridge Construction						$0
	-	Subtotal New Bridge	$0	$520,000	$320,000	$0	$220,000	$1,060,000
Total			$2,450,000	$19,400,000	$4,370,000	$8,550,000	$14,020,000	**$48,790,000**

			2026	2027	2028	2029	2030	2026-2030
MacKay Bridge								
Repairs and Rehabilitation	D.1	Approach Spans Bearings	$1,000,000	$2,000,000			$2,000,000	$5,000,000
	D.2	Concrete Rehabilitation - Substructure				$1,500,000		$1,500,000
	D.3	Concrete Approach Span Deck Rehabilitation		$6,000,000				$6,000,000
	D.4	Suspended Spans Resurfacing			$4,500,000		$4,500,000	$9,000,000
	D.5	Approach Spans Resurfacing		$1,500,000				$1,500,000
	D.6	Approach Road Resurfacing						$0
	D.7	Approach Span Expansion Joints						$0
		Expansion Joints Glands					$100,000	$100,000
	D.8	Orthotropic Steel Plate Deck Fatigue (repairs)	$250,000	$300,000	$300,000	$400,000	$400,000	$1,650,000
		OSPD Replacements - emergency	$3,500,000			$3,500,000		$7,000,000
	D.9	Cable Dehumidification						$0
		Main Cable Inspection						$0
	D.10	Hanger Replacements					$1,000,000	$1,000,000
		Hangers Coating						$0
	D.11	Stiffener Trusses Steel repair					$1,800,000	$1,800,000
		Stiffening trusses coating			$450,000	$450,000	$450,000	$1,350,000
		Transverse Trusses coating			$290,000	$290,000	$290,000	$870,000
	D.12	Main Tower Coatings			$2,000,000	$2,000,000	$2,000,000	$6,000,000
		Tower Steel repairs (doors and seal splices)						$0
		Cable Bents coatings			$400,000	$400,000	$400,000	$1,200,000
	D.13	Steel Repairs and Access - Box Girder		$500,000			$1,200,000	$1,700,000
		Box Girders Coatings	$600,000		$600,000			$1,200,000
	D.14	Int Floor Beams Coatings	$350,000		$350,000			$700,000
		Ext. Floor Beams coatings	$500,000		$500,000			$1,000,000
	D.15	Access Improvements						$0
	D.16	Roadway Signage	$1,650,000					$1,650,000
		Roadway Safety	$2,000,000	$1,000,000	$2,000,000			$5,000,000
	-	Subtotal Rehabilitation:	$9,850,000	$11,300,000	$11,390,000	$8,540,000	$14,140,000	$55,220,000
New Bridge	E.1	New Bridge Scoping Study						$0
		New Bridge Stakeholders/Communications						$0
	E.2	New Bridge Environmental Assessment	$200,000				$200,000	$400,000
		New Bridge Land Impact Assesssments					$20,000	$20,000
		New Bridge Land Acquisition						$0
	E.3	New Bridge Design (not complete design)		$1,000,000	$1,000,000	$5,000,000	$5,000,000	$12,000,000
		New Bridge Construction						$0
	-	Subtotal New Bridge	$200,000	$1,000,000	$1,000,000	$5,000,000	$5,220,000	$12,420,000
Total			$10,050,000	$12,300,000	$12,390,000	$13,540,000	$19,360,000	**$67,640,000**

			2021-2030
MacKay Bridge			
Repairs and Rehabilitation	D.1	Approach Spans Bearings	$6,000,000
	D.2	Concrete Rehabilitation - Substructure	$5,000,000
	D.3	Concrete Approach Span Deck Rehabilitation	$13,000,000
	D.4	Suspended Spans Resurfacing	$13,500,000
	D.5	Approach Spans Resurfacing	$3,500,000
	D.6	Approach Road Resurfacing	$5,800,000
	D.7	Approach Span Expansion Joints	$430,000
		Expansion Joints Glands	$200,000
	D.8	Orthotropic Steel Plate Deck Fatigue (repairs)	$2,600,000
		OSPD Replacements - emergency	$7,500,000
	D.9	Cable Dehumidification	$10,300,000
		Main Cable Inspection	$1,250,000
	D.10	Hanger Replacements	$2,000,000
		Hangers Coating	$450,000
	D.11	Stiffener Trusses Steel repair	$2,800,000
		Stiffening trusses coating	$2,700,000
		Transverse Trusses coating	$870,000
	D.12	Main Tower Coatings	$6,000,000
		Tower Steel repairs (doors and seal splices)	$250,000
		Cable Bents coatings	$1,200,000
	D.13	Steel Repairs and Access - Box Girder	$4,200,000
		Box Girders Coatings	$1,200,000
	D.14	Int Floor Beams Coatings	$700,000
		Ext. Floor Beams coatings	$1,000,000
	D.15	Access Improvements	$1,850,000
	D.16	Roadway Signage	$3,650,000
		Roadway Safety	$5,000,000
	-	Subtotal Rehabilitation:	$102,950,000
New Bridge	E.1	New Bridge Scoping Study	$350,000
		New Bridge Stakeholders/Communications	$400,000
	E.2	New Bridge Environmental Assessment	$650,000
		New Bridge Land Impact Assesssments	$80,000
		New Bridge Land Acquisition	$0
	E.3	New Bridge Design (not complete design)	$12,000,000
		New Bridge Construction	$0
	-	Subtotal New Bridge	$13,480,000
Total			**$116,430,000**

B.3 Ancillary Structures

			2021	2022	2023	2024	2025	2021-2025
Ancillary Structures								
GENERAL	F.1	Barrington ramp resurfacing+waterproof					$2,000,000	$2,000,000
	F.2	Barrington ramp concrete works						$0
		Barrington ramp bearings replacement						$0
	F.3	Windsor/Robie Exit K Ramp	$150,000	$800,000	$200,000	$400,000		$1,550,000
	F.4	Halifax Approach Retaining Wall		$300,000				$300,000
	F.5	Princess Margaret Overpass		$150,000		$200,000	$1,150,000	$1,500,000
	F.6	Baffin Blvd Retaining wall					$100,000	$100,000
	F.7	CN Overpass					$100,000	$100,000
	F.8	Windmill Road Overpass		$200,000		$2,300,000	$2,300,000	$4,800,000
	F.9	Victoria Road Overpass	$50,000	$200,000	$2,200,000			$2,450,000
	F.10	Ramp D-Bin						$0
		Sub Total	$200,000	$1,650,000	$2,400,000	$2,900,000	$5,650,000	$12,800,000

			2026	2027	2028	2029	2030	2026-2030
Ancillary Structures								
GENERAL	F.1	Barrington ramp resurfacing+waterproof						$0
	F.2	Barrington ramp concrete works	$630,000	$630,000	$630,000	$630,000		$2,520,000
		Barrington ramp bearings replacement				$1,250,000	$1,250,000	$2,500,000
	F.3	Windsor/Robie Exit K Ramp		$2,000,000	$300,000	$50,000		$2,350,000
	F.4	Halifax Approach Retaining Wall				$50,000		$50,000
	F.5	Princess Margaret Overpass	$1,150,000					$1,150,000
	F.6	Baffin Blvd Retaining wall	$200,000					$200,000
	F.7	CN Overpass						$0
	F.8	Windmill Road Overpass						$0
	F.9	Victoria Road Overpass	$1,900,000					$1,900,000
	F.10	Ramp D-Bin						$0
		Sub Total	$3,880,000	$2,630,000	$930,000	$1,980,000	$1,250,000	$10,670,000

			2021-2030
Ancillary Structures			
GENERAL	F.1	Barrington ramp resurfacing+waterproof	$2,000,000
	F.2	Barrington ramp concrete works	$2,520,000
		Barrington ramp bearings replacement	$2,500,000
	F.3	Windsor/Robie Exit K Ramp	$3,900,000
	F.4	Halifax Approach Retaining Wall	$350,000
	F.5	Princess Margaret Overpass	$2,650,000
	F.6	Baffin Blvd Retaining wall	$300,000
	F.7	CN Overpass	$100,000
	F.8	Windmill Road Overpass	$4,800,000
	F.9	Victoria Road Overpass	$4,350,000
	F.10	Ramp D-Bin	$0
		Sub Total	**$23,470,000**

Appendix C Macdonald Bridge Projects

C.1 Concrete Restoration

Background

The Macdonald Bridge's concrete foundations are per their original design from the 1950s where concrete strengths were of low strength and quality compared to today's standards. Over the past decade, HHB has been rehabilitating the concrete surfaces to address deficiencies and cracking to enhance service life.

Technical Considerations

In 2012, HHB consulted W.S. Langley P.Eng. to perform a detailed condition assessment of the Macdonald substructure and foundations. This assessment identified the majority of the concrete was experiencing alkali-aggregate reactivity coupled with cycling freezing and thawing damage. Additionally, the evaluation categorized each pier and abutment with a priority level. HHB targets to rehabilitate High & Medium priority piers by 2024 and remaining piers by 2028.

Since 2012, HHB rehabilitated 14 piers along with portions of the Halifax and Dartmouth Abutments. The remaining work includes rehabilitation of the main tower and cable bent foundations, five piers and the remaining portions of the Halifax and Dartmouth abutments.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilization and demobilization.
- Temporary bracing (if required).
- Concrete removals, typically to 300 mm depth.
- Install additional reinforcement to reinstate corroded reinforcement and restore crack control per current standards.
- Replace concrete and cure.

Costs are based on tender prices from 2014 and 2019 at Piers H1, D2 and D5. Tender prices were used in preparing the cost estimates below, in coordination with an understanding of the complexity of the upcoming work. All historical costs are brought forward to 2020 data using a 2% inflation estimate.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate	Notes
2021	Piers D4, D12	$1,500,000	Pier D4 is similar to work completed on Pier D2, while Pier D12 is similar to work completed on H1.
2022	Piers D3, D7 and D8	$2,300,000	Piers D7 and D8 are assumed to be similar in complexity to D2 though shorter (less cost) while Pier D3 is similar to work completed on D2.
2023	Piers D1, D6,	$1,500,000	Pier D1 is assumed to be similar to Pier H1 while Pier D6 is similar to work completed on Pier D2.
2024	Halifax Main Tower and Dartmouth Main Tower	$2,500,000	The main tower costs are estimated based on the complexity of staging the

Year	Locations	Estimate	Notes
			work, access constraints and environmental considerations.
2027	TBD	$500,000	When repairing concrete substructures, it is prudent to assume some continued repair will be necessary.
2028	TBD	$500,000	

C.2 Approach Span Bearings

Background

During the 2012 annual inspection, bearing observations were made regarding concrete cracks on top of the pier at bearing seats, deformed anchor bolts, and evidence of the bearings' potential to be resisting longitudinal bridge movements.

Technical Considerations

As a follow-up to the 2012 annual inspection findings, HHB installed movement monitoring devices at 12 out of the 26 sliding bearings to quantify the observations from the inspection. Field measurements, including calculations and evaluations, revealed that various bearings were seized and restricting movement. The existing bearings are original from construction (65 years old), which is well beyond their expected service life of 35-40 years.

HHB started the bearing replacement program in 2015 with a target to replace all original bearings to be replaced by 2024. To date, bearings at 12 of the 18 pier or abutment locations have been replaced.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilize and demobilize.
- Traffic control.
- Concrete removal for existing pedestals.
- Grout for concrete replacement of bearing pedestals.
- Epoxy injection of cracking typical of pier caps.
- Install temporary structural supports, bearings and jacking system.
- Replace existing bearing with the new elastomeric bearing system.

Costs are based on tender prices from 2014, 2017 and 2020. Over this period, HHB performed bearing replacements at seven piers. Tender prices were used in preparing the cost estimates below, in coordination with an understanding of the complexity of the upcoming work. All historical costs are brought forward to 2020 data using a 2% inflation estimate.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate	Notes
2021	Halifax Cable Bent and Dartmouth Cable Bent	$3,000,000	Based on the complexity of the work, access constraints, the height of the piers (scaffolding) anticipated strengthening measures needed to perform the work. Design for these replacements is nearly complete. This includes two sets of bearings at each pier.
2022	Piers D1, D5 & D6	$1,800,000	Based on typical truss bearing replacements, with some added complexity due to dealing with the D1 steel bent (more complex than the concrete piers).
2023	Pier H1 (truss side)	$500,000	Replacement of truss side bearings (girder side completed in 2014). Costs based on the typical bearing replacement of truss span bearings with some added complexity due to the span's length.

C.3 Approach Span Expansion Joints

Background

Beyond the suspended spans, there are two and four strip seal expansion joints in the Halifax and Dartmouth approach spans, respectively. Within the past few years, HHB replaced the Halifax Abutment, Pier H1, and Dartmouth Abutment expansion joints. These joints were installed during the 1999 Third Lane Project and have reasonably outlived their useful life (30 years). The glands have required replacement over the joints' life, with the replacement of the steel armouring and adjacent concrete blockouts now being necessary due to deterioration and damage to components.

Technical Considerations

Replacing the strip seal expansion joints is not technically challenging work, but requires full roadway closures to remove the joint, install temporary traffic plates, and install the new joint.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Removal of existing expansion joint.
- Supply and installation of a temporary traffic plate during joint replacement.
- Supply and installation of a new expansion joint.

The costs are based on a representative expansion joint replacement. COWI has developed this recommendation using historical information for similar work, notably, a replacement in 2019.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate	Comment
2022	Piers D3 and D4	$500,000	Typical replacements
2023	Piers D6 and D9	$500,000	Typical replacements
2028	TBD	$750,000	Values for anticipated condition over time
2029	TBD	$750,000	Values for anticipated condition over time

C.4 Approach Road Resurfacing

Background

The approach span road is comprised of the area between the Dartmouth abutment and Wyse Road near the Dartmouth Toll Plaza and between Halifax Abutment and the first pedestrian crossing on North Street and its connecting off-ramp west of the Halifax Approach span.

Technical Considerations

These elements are non-structural but represent the asphalt roadway surface as part of the approach roadway to the Macdonald. The condition of the asphalt is maintained in alignment with criteria as per HHB standards and based on prior project execution / successes. It is anticipated that, by 2025, the condition will no longer meet the HHB standards and will require resurfacing.

Budget and Timing

COWI does not anticipate performing any repair or rehabilitation work before or during 2025. To date, HHB observed that the average service life is expected to be 20 – 25 years for this type of paving system with the traffic volume, environmental exposures and substrate conditions.

The following representative scope of work is considered for this repair and rehabilitation work:

- Traffic control in work zone.
- Milling and removal of the existing roadway surface.
- Supply and application of new roadway surface.
- Pavement markings.

A representative asphalt resurfacing cost was based on NSTIR's tender prices for similar work.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate
2025	Dartmouth Road Approach	$1,000,000
2026	Halifax Road Approach	$200,000

C.5 Approach Span Resurfacing

Background

The Halifax and Dartmouth approach spans support three lanes of traffic (two in one direction and one in the other that alternate) are approximately 148.2 m and 436.6 m long, respectively. During the 1999 “Third Lane Project”, the Sidewalk and Bikeway (SW/BW), the approach span deck was replaced with an orthotropic steel deck, including the SW/BW. During this work, traditional hot mix asphalt was applied as the roadway wearing surface.

During 2015-2017 “The Big Lift” suspended spans re-decking of the Bridge, the approach spans were not significantly impacted or modified, including the roadway wearing surface.

Technical Considerations

These elements are non-structural, but the applied asphalt is approximately 20 years old. Longitudinal cracking is present near the wheel paths, and HHB performed sizeable patch repairs where asphalt bond failure has occurred.

Budget and Timing

To date, HHB observed that the average service life is expected to be 20 - 25 years for this type of paving system with the traffic volume, environmental exposures and substrate conditions.

The following representative scope of work is considered for this repair and rehabilitation work:

- Traffic control in work zone.
- Milling and removal of the existing roadway surface.
- Waterproofing membrane removal.
- Surface preparation and primer application.
- Waterproof membrane supply and application.
- Supply and application of new roadway surface.
- Pavement markings.

A representative asphalt resurfacing lump sum cost, based on HHB’s tender prices for similar work performed in 2009/2010 on the same spans, with costs brought forward based on construction cost indices. A comparison was also made to the recent 2019 paving on the MacKay, and adjusted for complexity. These two values informed the estimate below.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Locations	Estimate
2022	Dartmouth Approach Span	$3,000,000
2023	Halifax Approach Span	$1,000,000

C.6 Suspended Span Resurfacing

Background

During 2015-2017 “The Big Lift” suspended spans re-decking of the Bridge, the side and centre spans were replaced with new orthotropic steel deck, including new paving. The paving system is a proprietary epoxy asphalt supplied by ChemCo systems with a nominal thickness of 45 mm.

Technical Considerations

Paving of orthotropic steel panel decks has never been easy, and there have been almost as many failures as successes. Paving of orthotropic deck panels that must carry traffic practically as soon as they are placed adds further challenges. A fundamental decision in the development of Macdonald's deck replacement is that "thin" paving layers of about 10 mm thickness are unreliable and should not be considered. Paving thickness must therefore be in the range of at least 37 to 50 mm.

When the suspended spans of the Lions' Gate Bridge were replaced, the system was changed. Aggregate chips were broadcast and rolled into an epoxy bond coat, which was well cured in the shop, and traffic ran over this "prepaving" for up to a year before a final lift of "final" paving was placed over the entire bridge, thus producing a smooth and durable running surface. The resulting road surface has been so much better than the system with paving stops that it is recommended for the Macdonald.

Budget and Timing

HHB does not anticipate performing any repair or rehabilitation work prior to or during 2025. The service life is anticipated to be 15 - 20 years for this type of paving system with the traffic volume, environmental exposures and substrate conditions.

The following representative scope of work is considered for this repair and rehabilitation work:

- Traffic control in work zone.
- Milling and removal of the existing asphalt and water proofing membrane.
- Surface preparation and primer.
- Tack coat supply and installation.
- Supply and application of new asphalt.
- Pavement markings.

A representative asphalt resurfacing lump sum cost was based on contract costs for the 2019 resurfacing of the MacKay's south lanes. The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate
2028	Two lanes	$2,500,000
2029	One lane	$1,500,000

C.7 Sidewalk Bikeway Resurfacing

Background

During the 1999 "Third Lane Project", the sidewalk and bikeway approach span deck was replaced with an orthotropic steel deck. The applied wearing surface was the Stonehard Epoplex, comprised of a primer, base coat, and finish coat. After approximately 6-7 years, failure of the wearing surface was observed. In 2013, HHB trailed seven repair products in various areas in order to select a preferred repair in two years based on their in-situ performance.

The 20-year old surface had been experiencing local failures for the past fourteen years, at increasing extents. To address the deterioration and continue to protect the deck top surface, HHB planned a resurfacing project. The project was budgeted to be performed in 2015-2017, but with the "The Big Lift" suspended spans re-decking occurring at the same time, HHB delayed its start until 2020.

Technical Considerations

Procuring a product to meet HHB's desired performance was challenging. The product had to be seamless, withstand mechanical and thermal effects (bridge movements), resist impact and wear of snowplows, waterproof, flexible, have high slip resistance, etc.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilizing/demobilizing.
- Removal and disposal of existing SW/BW wear surface of the approach spans.
- Supply and install a new wear surface system on the sidewalk and bikeway approach spans.

A representative restoration cost for resurfacing the remaining areas of the sidewalk or bikeway along both approach spans is based on the work undertaken in 2020 by HHB (repairs on the sidewalk beneath the deck's railing portion). It is understood that below the railings is the most complicated aspect of the work, due to railing removals and complicated access for blasting and coating. The remaining sections are less complicated as they are easily accessed and flat. Based on HHB's revised schedule and project estimates, the remaining project costs are $3,000,000 to complete the resurfacing by 2023.

HHB's budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Locations	Estimate	
2021	Bikeway	$1,000,000	Selected areas to be replaced
2022	Sidewalk	$1,000,000	Full surface completed (remaining sidewalk area)
2023	Bikeway	$1,000,000	Full surface completed (remaining bikeway area)

C.8 Steel Repair and Paint Project

Background

The original Macdonald Bridge was painted with a lead-based oil alkyd three-coat paint system. Around 1993, HHB transitioned to a zinc hydroxy phosphite paint system in place of the lead-based paints for painting repairs. Maintenance painting is conducted annually using needle scalers for surface preparation and recoating with a three-coat oil alkyd paint. In general, touch-up painting only is done, except on the main towers where a single finish coat was applied for colour uniformity and aesthetic floodlighting.

During the 1999 "Third Lane Project", the Macdonald approach span deck was replaced with prefabricated (shop coated) orthotropic steel deck segments, which are painted Ameron 68HS and PSX700.

During the 2015-2017 "The Big Lift" suspended spans re-decking project, the entire deck and truss was replaced in prefabricated deck segments, which were coated in a three-coat Organic Zinc/Epoxy/Polyurethane (OZ/EP/PU) system.

Technical Considerations

In 2013 and 2015 HHB retained two paint/coating consultants; Trans Canada Coatings and KTA-TATOR Inc., to examine the existing coating systems on both bridges and provide recommendations for the most cost-effective system that would best protect the bridges and minimize future maintenance.

Based on condition assessments for the integrity of the existing coating systems and degree of rusting, steel section losses, the coatings consultants independently stated the current coating system was no longer effective and recommended that it be replaced on the approach spans, cable bents and towers. This involved the paint system being removed by grit blasting to bare steel and coating with a new three-coat corrosion protection system.

A multicomponent zinc/epoxy/polyurethane system was recommended as the best candidate for long term maintenance-free corrosion protection. The coating works require full containment, special access, environmental control, abrasive blasting to remove old materials to bare metal, and spraying of new coatings.

A tentative steel repair and corrosion protection program was developed in 2017. HHB started the program with a pilot project on the Halifax Approach span in 2018, which included steel repairs and replacement of approximately 54,000 ft^2 of existing coatings and associated steel repairs. Following the 2017 work, HHB and COWI revised the coating program; accounting for increased section loss and strengthening requirements than initially anticipated. This increase was primarily due to the difference between estimating the extent of work before grit blasting the structure and the actual results observed during the pilot project (this was the intent of performing a pilot project).

In 2019, work on the Halifax Cable Bent was undertaken with similar scope, steel repairs and approximately 14,400 ft^2 of existing coatings. In 2020, the Halifax Cable Bent work was completed, along with interim strengthening measures to areas of the Dartmouth Cable Bent (selected based on the condition and findings during the Halifax Cable Bent work).

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilize and provide access through the entire component for containment of debris and protection during coating.
- Grit blast of all steel components to a white metal finish.
- Steel repairs, as determined following grit blast based on designs provided during tendering.
- Recoating with the selected three-part system.

A surface of existing coatings has been determined for each of the approach spans and steel substructure components (towers, bents). Based on the 2018 and 2019 projects, a cost per square foot was estimated for the remaining work. These costs were then adjusted based on the complexity of access, total surface area, anticipated steel repairs, and staging for the remaining components listed below.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate
2021	Dartmouth Cable Bent	$6,000,000
2022	Dartmouth and Halifax Main Towers (bottom ~50 feet)	$11,500,000
2023	Dartmouth Truss Span and Pier D1	$16,000,000
2024	Dartmouth Truss Span Halifax and Dartmouth Girder Spans	$6,500,000 $6,500,000
2025	Halifax and Dartmouth Girder Spans	$10,000,000
2026	Dartmouth and Halifax Main Towers (remainder)	$12,500,000

C.9 Access Improvements

Background

This item represents an all-encompassing item for HHB to improve and/or repair existing access systems (i.e. ladders, catwalks, lifelines, stairs, etc.), which can be required based on recent inspections or by a desire to improve access to new or existing locations of the bridge.

The scope of these items was based on annual inspection findings and rehabilitation programs implemented by HHB. In general, this work includes repair of ladder rungs (in-kind), new vertical lifelines inside cable bent legs, horizontal lifelines at the main towers and general access improvements.

Technical Considerations

For engineered safety systems, typically an inspection is required (intervals vary as required by the designer/supplier). It is assumed these specific inspections are separate from the annual inspections. Once inspected, repairs can be specified, or in other cases, a new system would need to be designed, fabricated, supplied and installed.

Budget and Timing

The following representative scope of work is considered for this work:

- Inspection of the as-built condition of select access systems.
- Specification of repair procedures, as necessary and applicable.
- Design of new access systems to replace the existing, including fabrication, supply, and installation.

A representative cost estimate is provided below was based on COWI's evaluation on HHB’s anticipated scope of work. The budget and anticipated schedule based on priority and timing are as follows:

Year	Estimate
2021	$50,000
2022	$250,000

Appendix D MacKay Bridge Projects

D.1 Approach Span Bearings

Background

During recent detailed inspections by COWI, the elastomeric bearings in the approach span between the abutments and cable bents were observed to be in fair condition and performing as intended. At the abutments, the bearings are skewed and feature minor cracks. Elsewhere in the approach spans, there is light bulging and cracking of the bearings.

Technical Considerations

Observations about the skewed abutment bearings and minor cracking of existing bearings are known, as noted in previous annual inspection reports. In 2016, COWI performed a detailed assessment of the bearings following the findings from the annual report where the inspecting engineers had recommended to replace the bearings in 1-3 years. COWI summarized a 2008 assessment of the same bearings, which concluded the distortion was likely predominantly due to concrete placement during construction, and displacement or rotation of the abutment toward the approach spans. As such, no work is considered necessary until 2025 or later (dependent on bearing performance).

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilize and demobilize.
- Traffic control.
- Concrete removal for existing pedestals.
- Grout for concrete replacement of bearing pedestals.
- Epoxy injection of cracking typical of pier caps.
- Install temporary structural supports, bearings and jacking system.
- Replace existing bearing with new elastomeric bearing system.

Costs were based on tender prices from 2014, 2017 and 2020. Over this period HHB performed bearing replacements at seven piers at the Macdonald, and work for the MacKay bearings is considered similar. Tender prices were used in preparing the cost estimates below, in coordination with an understanding of the complexity of the upcoming work. All historical costs were brought forward to 2020 data using a 2% inflation estimate.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate	Note
2025	Two piers	$1,000,000	Over five years, it is assumed most of the bearings will need replacement, with prioritization being structured around the bearings' condition at the time.
2026	Two piers	$1,000,000	
2027	Four piers	$2,000,000	
2030	Four piers	$2,000,000	

D.2 Concrete Rehabilitation - Substructure

Background

The concrete approach span substructure is generally performing well, with routine inspections and assessments conducted in a 3 – 5-year cycle. Deterioration to date has been shown to be primarily cracking and local delaminations. HHB is currently undertaking an underwater investigation for the main tower foundations.

Technical Considerations

In 2013, HHB engaged a concrete expert, W.S. Langley, P. Eng., to perform a detailed concrete assessment of the Mackay substructures and foundations. The evaluation noted that the concrete has suffered from alkali-aggregate reactivity, cyclic freezing and thawing damage, cracking, corrosion of reinforcing steel, and leaching. Encapsulation was recommended as the bridge foundation repair option.

In 2016, HHB performed concrete removal and rehabilitation by encapsulating the Halifax Cable Bent, and partial repairs of the Halifax Main Tower foundation. In 2019, HHB consulted W.S. Langley P.Eng. to assess the bridge substructure and foundations. The evaluation identified most of the concrete was experiencing some cracking, with no significant changes in the overall condition since a 2012 inspection. Additionally, the assessment categorized each pier and abutment with a priority with the highest priority locations being repaired soonest.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Mobilization and demobilization.
- Underwater inspection of the main tower foundations.
- Concrete removals, often localized, typically to 300 mm depth.
- Install additional reinforcement to reinstate corroded reinforcement.
- Crack injection.
- Replace concrete and cure.

Costs were based on tender prices from 2014 and 2019 at Macdonald Piers H1, D2 and D5. Tender prices were used in preparing the cost estimates below, in coordination with an understanding of the complexity of the upcoming work. All historical costs were brought forward to 2020 data using a 2% inflation estimate.

The budget and anticipated schedule based on priority and timing with other projects in the area is:

Year	Locations	Estimate	Notes
2021	Pier D5 (north), Pier D3 Pier D1 and Pier D2 foundations	$1,000,000	Repairs at the D5 and D3 piers are to address cracking and delamination observed during prior inspections. At Piers D1 and D2, wide-spread delamination and cracking are observed at the foundations, so the entire perimeter is recommended to be rehabilitated.
2022	Various Piers	$1,000,000	Locations to be determined through detailed inspections and performance of the piers, crack sealing and delamination repairs
2023		$1,000,000	
2024		$500,000	
2029		$1,500,000	

D.3 Concrete Approach Span Deck Rehabilitation

Background

The cast in place concrete approach span deck has been observed to have increasing amounts of deterioration, including spalling concrete, exposed reinforcement, cracking and difficulty to maintain the paving bond. These are all indications of a concrete deck where there are areas experiencing active corrosion of the steel reinforcing.

Technical Considerations

To maintain the concrete deck, it is anticipated that significant repairs will be required to address the areas of active corrosion. A testing program is also planned for 2021 to quantify the extent and severity of the deterioration presently occurring.

Based on the visual inspection results to date, COWI anticipates significant concrete removals, particularly in the vicinity of cold joints and expansion joints along the deck. This work will require construction staging to keep traffic moving and engineering assistance throughout construction to determine the appropriate measures for repair following concrete removals.

Budget and Timing

COWI recommends HHB estimate $6,000,000 for each construction season of the concrete repairs, during which two lanes are to be addressed. This work will include mobilization of the contractor, protection of adjacent property and roadways, traffic control, demolition of the deck's deteriorated areas, and replacement of steel reinforcing and concrete.

Until the deck rehabilitation can take place, COWI recommends HHB be prepared to spend $500,000 in 2023 and 2024 (when significant deterioration is anticipated to become difficult to contain) in interim emergency repairs to maintain the deck surface for the flow of traffic.

The estimate was based on COWI's understanding of the current condition and the level of efforts required to replace similar structures.

Year	Type	Estimate
2022	Emergency repairs for deck and barrier deterioration	$500,000
2023	Emergency repairs for deck and barrier deterioration	$500,000
2025	Two lanes concrete deck rehabilitation	$6,000,000
2027	Two lanes concrete deck rehabilitation	$6,000,000

D.4 Suspended Span Resurfacing

Background

HHB performed various levels of asphalt milling, local repairs, full lane replacements to the suspended spans throughout the structure's life. The 2019 suspended span south lane resurfacing experienced some failures in 2020 and HHB is currently undergoing QA/QC to determine the root cause before proceeding with the two north lanes' resurfacing.

The wearing surface on the MacKay has a short life due to the relatively flexible steel deck on the suspended spans, which results in cracking of the asphalt and eventual deterioration. The deck remains safe, but the asphalt deteriorates more quickly than typical and requires frequent repairs/replacement.

Technical Considerations

Throughout the years, HHB experimented with and investigated various asphalt mixes appropriate for the suspended spans orthotropic steel deck and the concrete approach deck with varying levels of success. Due to the thin top plate design of the orthotropic steel plate deck for the suspended spans, typical asphalt paving systems have difficulty remaining in place. To protect the steel deck, HHB maintains the paving system on approximately a seven-year cycle.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Traffic control in the work zone.
- Milling and removal of the existing roadway surface.
- Waterproofing membrane removal.
- Surface preparation and primer application.
- Waterproof membrane supply and application.
- Supply and application of new roadway surface.
- Pavement markings.

A representative asphalt resurfacing cost was based on HHB’s tender prices for similar work performed in 2019 on the south lanes.

Year	Estimate	Comment
2021	$500,000	Engineering services and Quality Assurance support anticipated for the repairs to the paving failures observed on the south lanes, and temporary measures to maintain the existing pavement on the north lanes until a complete replacement is undertaken.
2022	$4,000,000	Full paving system replacement on the north travel lanes
2028	$4,500,000	Replacement of paving in the south lanes
2030	$4,500,000	Replacement of paving in the north lanes

D.5 Approach Span Resurfacing

Background

HHB performed various asphalt milling, local repairs, full lane replacements, and the suspended spans, approach spans, and approach roadway throughout the past 10-15 years. HHB milled and replaced the paving on all lanes of the Halifax Approach in the Summer of 2020. The Dartmouth Approach span was last repaved in 2001.

Technical Considerations

The approach spans of the MacKay are cast in place concrete supported by steel box girders. As the concrete deck deteriorates (known from inspection findings), the asphalt system on the approach spans is anticipated to be more challenging to maintain.

To suit the anticipated concrete deck major rehabilitation (planned for 2026 and 2028), COWI is noting a mill and replace methodology to maintain the existing paving until full replacement following the concrete deck repairs. This technique involves a reduced timeline between work packages (four-year cycle rather than seven) but reduces overall cost as HHB prepares for significant repairs to the concrete deck beneath. A full-depth asphalt replacement is planned to coincide with the concrete deck repairs. This approach will also limit traffic interruptions and is developed based on the priority sequence of repairs to the suspended span deck.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work on the Dartmouth Approach span:

- Traffic control in the work zone.
- Milling and removal of the existing roadway surface.
- Waterproofing membrane removal (for full depth replacement only).
- Surface preparation (for full depth replacement only).
- Waterproof membrane supply and application (for full depth replacement only).
- Supply and application of new roadway surface.
- Pavement markings.

A representative asphalt resurfacing lump sum cost was based on tender prices for similar work performed in 2009/2010 on the same spans, with costs brought forward based on construction cost indices. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Locations	Estimate
2021	Mill and overlay of all four lanes	$250,000
2024	Mill and overlay of all four lanes	$250,000
2025	Replacement of approach span paving (phase 1 of 2)	$1,500,000
2027	Replacement of approach span paving (phase 2 of 2)	$1,500,000

D.6 Approach Road Resurfacing

Background

The approach span road extends approximately 2 km from the Dartmouth abutment and 1 km from the Halifax abutment. The approach road was last resurfaced in 2001.

Technical Considerations

These elements are non-structural but represent the asphalt roadway surface as part of the approach roadway to the Macdonald. The asphalt condition is maintained in alignment with criteria as per HHB standards and based on prior project execution / successes.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Traffic control in the work zone.
- Milling and removal of the existing roadway surface.
- Supply and application of new roadway surface.
- Pavement markings.

A representative asphalt resurfacing cost was based on NSTIR’s tender prices for similar work. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Locations	Estimate
2022	Localised repairs and crack sealing	$800,000
2024	Halifax and Dartmouth Approach Road full replacement	$5,000,000

D.7 Approach Span Expansion Joints

Background

There are three expansion joints associated with the approach spans. In 2020, HHB replaced the Halifax Abutment and Pier D5 expansion joints due to failure of the surrounding concrete and steel armouring. In 2021, HHB plans to replace the Dartmouth Abutment expansion joint (also due to steel armouring failures), thus replacing all approach span expansion joints.

HHB also anticipates, as an interim measure prior to replacing these expansion joints again, the replacement of the glands prior to 2030.

Technical Considerations

The approach span expansion joints are less complicated than the Cable Bent and Main Tower expansion joints in the suspended spans. Replacement of the approach span expansion joints is often required due to a deterioration of the adjacent concrete deck, and excessive wearing of the steel armouring. For example, recently, a section of the Dartmouth abutment steel armouring was removed due to deformation and damage from snowplows. Subsequently, this joint is now planned to be replaced with design underway with COWI.

Budget and Timing

The following representative scope of work is considered for this repair and rehabilitation work:

- Removal of existing expansion joint.
- Supply and installation of a temporary traffic plate during joint replacement.
- Supply and installation of a new expansion joint.

A representative expansion joint replacement (unit cost) was based on tender prices for similar work performed in 2020 for the Halifax Abutment and Pier D5 expansion joint replacements. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	EJ Replacement	EJ Gland Replacement	Comment
2022	$430,000	-	Dartmouth Abutment
2025	-	$100,000	Expansion joint gland replacement, as required.
2030	-	$100,000	Expansion joint gland replacement, as required.

D.8 Orthotropic Steel Deck Plate Fatigue Repairs and Emergency Panel Replacements

Background

The Bridge was designed when less was known regarding the fatigue life of Orthotropic Steel Plate Decks (OSPDs). The deck top plate is 9.5 mm thick compared to the minimum 14 mm, which is currently specified by the Canadian Highway Bridge Design Code (CHBDC). The thin plate leads to the deck's increased flexibility, often resulting in a shorter fatigue life that can not be corrected. This deck's flexibility has led to increased deterioration and cracking of the wearing surface, allowing water and de-icing salts to penetrate through to the steel and cause corrosion. COWI hypothesises that where cracks are present, water will collect and corrosion will probably occur in the longitudinal troughs.

In 2009, HHB requested that COWI estimate the remaining life of the deck of the Bridge. COWI concluded that the OSPD would continue to perform, in conjunction with increasing maintenance, until about 2024. It was noted that the Bridge has several deficiencies and that as far as practical, the deficiencies have been remedied, but that a complete “cure” would not be possible due to the inherent nature of the original design. COWI concluded there was no evidence of significant cracking of the OSPD in 2010, and that fatigue loading would not likely cause widespread cracking of the OSPD until 2028 to 2038 (15-25 years from 2013) and maybe longer. It was noted that it was possible that there would be intermittent cracking before that time.

In 2019, COWI performed a detailed inspection of the deck plate's top surface in both southbound lanes of the Bridge, covering half of the overall deck width. In general, most panels were in fair condition, although a significant degree of pitting corrosion was typical in the wheel paths. Four new cracks were identified in the top plate, suggesting a change in the behaviour of the OSPD into a period of increasing cracking due to fatigue damage, as projected in the 2010 study. While not yet considered widespread cracking, the condition of the OSPD may be shifting into a time of increasing rate of deterioration.

COWI recommended that the asphalt condition be closely monitored with annual inspections to enable early detection of future cracks and defects. The asphalt condition cross-referenced with the 2019 inspection notes may help predict future crack locations. Cracks must be repaired to slow their growth, and COWI recommends this repair occur as soon as reasonably possible within one year of crack discovery.

Technical Considerations

Mitigating the risk due to fatigue cracking on an OSPD is undertaken by increased inspections to understand the location and extent of cracking and repair cracks as soon as reasonably possible. In a period of infrequent cracking, repairs may be undertaken by removing the wearing surface, welding the crack closed, and replacing the wearing surface.

If a period exists where cracks reappear consistently in the same locations, or multiple cracks occur within a short distance, replacement of a section of OSPD begins to become a more appropriate action. The need for this approach is likely to occur for one to two years. Based on the complexity of replacing sections of the deck, this is considered a short timeframe for developing designs, installation procedures, and fabricating components. Therefore, COWI recommends HHB prefabricate sections of OSPD to have on hand for installation as emergency measures.

Budget and Timing

OSPD Repairs

For localized weld repairs along the deck, COWI recommends HHB anticipate annual requirements, increasing in number and extent throughout the next ten years. The following representative scope of work is considered for this repair and rehabilitation work would be:

- Mobilization and traffic control (single or double lane closure depending on the location of the crack).
- Localized removal of the paving system.
- Non-destructive testing to assess the extent of the crack.
- Welding the crack closed, and non-destructive testing to confirm weld quality.
- Replacement of the paving system.

Unit prices and anticipated levels of effort are based on COWI's experience with similar deterioration processes and our understanding of the requirements during the 2019 repair of four cracks on this bridge deck.

OSPD Emergency Replacements

If HHB needs to replace a section of the OSPD, the following is a representative scope of work:

- Design of a replacement OSPD segment and conceptual erection procedures.
- Fabrication of one or two OSPD segments to have on hand.
- Once a crack or series of cracks are identified that requires a segment replacement:
  - Mobilization and traffic control.
  - Modification of the prefabricated segment to suit the specific location.
  - Removal of the deteriorated segment.
  - Installation of the new segment.
  - Finishing works such as pavement and line painting.

Unit prices and anticipated levels of effort are high-level recommendations based on COWI's experience and judgement.

Year	Local Crack Repair	Emergency Installation	Comment
2021	$100,000	$200,000	Design of a replacement segment and development of concept erection procedures
2022	$200,000	$300,000	Pre-fabrication of 1 or 2 segments
2023 & 2024	$200,000	-	Each year
2025	$250,000	-	
2026	$250,000	$3,500,000	Possible emergency replacement of a segment, fabrication of replacement 'on hand' segment.
2027 & 2028	$300,000	-	Each year
2029	$400,000	$3,500,000	Possible emergency replacement of a segment, fabrication of replacement 'on hand' segment.
2030	$400,000	-	

D.9 Main Cable Dehumidification Design and Installation

Background

Installation of a dehumidification system is based on HHB's intention to maintain the existing structure until 2040 or longer, and COWI's recommendation based on our current understanding of the condition of the cable. To date, all areas of the main cable that have been opened show significant amounts of moisture, with corrosion occurring at the low points and some observed broken wires. With the corrosion of the main cable anticipated to continue if no action is undertaken to protect it, the main cable's capacity will continue to decrease. The rate of this deterioration is yet unknown due to only having a limited number of main cable internal inspections performed to date. Still, COWI considers it appropriate to preserve as much capacity in the main cable as possible, through the addition of the dehumidification system. While not currently a safety issue, frequent and invasive inspections would be required for HHB to maintain an appropriate level of understanding for the cable's changing condition. Therefore, in addition to preserving the main cable's capacity, COWI considers the dehumidification system's addition to be a good value for money.

Technical Considerations

Dehumidification has been utilized as corrosion protection over the last 50 years. The main principle is that steel does not corrode when the relative humidity (RH) is below 40%. Between 40% and 60%, corrosion can occur, though at a very low rate. In practice, short periods with a relative humidity of up to about 50% are acceptable. The dehumidification system will comprise: a dehumidification plant in the Halifax anchorage (dry air supply), ducting from the Halifax anchorage to the centre of the bridge where it is injected into the main cable, cable wrapping along the existing cable to ensure an airtight seal, and a control and monitoring system that will record and report critical data of the dehumidification plant.

Prior to wrapping the main cable, COWI recommends HHB undertake main cable openings during which the condition of the strands may be assessed for corrosion and any additional wire breaks.

Budget and Timing

The following representative scope of work is considered for this work:

- Design of the main cable dehumidification system.
- Supply, installation, and initial operation of the main cable dehumidification system.
- Design, supply, and installation of temporary access systems (i.e. two new cable crawlers) to perform the wrapping work on the main cable.

A representative cost estimate is provided below based on COWI's rough order of magnitude cost estimate for the work (pre-detailed design) and our experience on similar projects such as the Macdonald bridge. The cost estimate for the main cable inspections is based on prior inspection work undertaken by HHB in 2018 and 2019.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Hanger Replacement	Comment
2021	$300,000	Detailed design
2022	$1,250,000	Main cable inspection prior to wrapping
2022	$10,000,000	Construction / installation

D.10 Hanger Replacement and Coatings

Background

In 2012, HHB replaced nine suspended span vertical hangers with new galvanized hangers that were field coated to match the existing hangers. Based on recent inspections, the hangers are in fair condition with the volume of coating heavy, especially near deck level. On most hangers, the 3-4 m of length near the deck is continuously affected by splashing from traffic, thus significantly reducing the service life of the corrosion protection (paint).

It is not anticipated that significant hanger replacements will be necessary by 2030 if the painting system's current performance continues. Amounts are budgeted to account for the potential for increasing paint deterioration and a subsequent hanger deterioration. Additionally, HHB continues to perform deck-level hanger repairs in conjunction with their suspended span truss coating work with in-house painters.

Technical Considerations

HHB replaced hangers in 2012 such that the replacement scheme is already known for future work. The challenge is that the hangers are procured by specific suppliers and need to be fabricated to tension tolerances to achieve its installed length in the field where each hanger has a unique hanger length. Therefore, a supply of hangers cannot be pre-supplied to HHB to have in storage.

Budget and Timing

The following representative scope of work is considered for this work:

- Mobilization and demobilization of access systems.
- Procurement, fabrication, and supply of socketed wire hangers.
- Installation of socketed wire hangers.

A representative cost estimate is provided below based on hanger replacement work in 2012 and the anticipated efforts in the future (specific hanger locations TBD). The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Hanger Replacement	Hanger Coatings	Comment
2022	-	$150,000	An active program to maintain the hanger coatings, limiting the need for replacement
2023	-	$150,000	
2024	-	$150,000	
2025	$1,000,000	-	
2030	$1,000,000	-	

D.11 Suspended Spans Coatings and Repair

Background

Throughout the past ten years or so, the suspended spans have undergone various localized coating repairs by HHB painting crews. Recent inspection reports have identified varying levels of corrosion and coating failure. However, the bulk of it is along the stiffening truss, which receives deck run-off from the roadway above. The transverse trusses and plan bracing are sheltered from the deck and typically free of corrosion but with varying coating quality levels.

During such coating work, is it expected that steel repairs would be required to the stiffening truss where corrosion is heaviest, typically at the gusset plates and at the bottom chords (where debris can collect).

Technical Considerations

Currently, access to these areas is through HHB moveable access platforms which should permit a dynamic working front independent of traffic.

To protect the steel and maintain the structural integrity of the MacKay for another twenty years, coatings and steel repairs are anticipated.

Budget and Timing

The following representative scope of work is considered for this work:

- Mobilization and demobilization of access systems.
- Coating restoration of select areas (percentages noted on the following table).
- Design, supply, and installation of steel reinforcement.

A representative cost estimate is provided below based on coating and steel repair work ongoing at the Macdonald for the approach span trusses and substructure (cable bents and main tower) recoating project. The timing and extent of the repairs and coating work are based on engineering judgement and assessing the current condition through the detailed inspection. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Stiffening Truss Steel Repair	Stiffening Truss Coatings	Transverse Truss Coatings	Comment
2023	-	$450,000	-	The stiffening truss coatings are based on a 10% zone recoating program, undertaken over three years (2023-2025), to be repeated on a five-year cycle.
2024	-	$450,000	-	
2025	$1,000,000	$450,000	-	Steel repair assumes of 1 – 3% zone repairs required within the next five years.
2028	-	$450,000	$290,000	The stiffening truss coatings are based on a 10% zone recoating program, undertaken over three years (2028-2030).
2029	-	$450,000	$290,000	
2030	$1,800,000	$450,000	$290,000	Steel repair assumes of an additional 3 – 5% zone repairs required within the next ten years.

D.12 Main Tower/Cable Bent Coatings and Repairs

Background

The Main Tower and Cable Bent coatings are typically in good condition based on the detailed inspection findings. The coating on each interior is in good condition with localized water ingress locations typically at splices where caulking has failed. The Main Tower exterior is in good condition with it being recently painted in 2003-2005. The Cable Bent exterior is in slightly worse condition that the Main Towers but still fair condition. The splices at the cable bent top strut with the legs has corrosion and coating failure due to the deck runoff in these areas. The recoating work's focus would be for full recoating of components that have been identified with coating deficiencies and not a full recoating of the full height of each Main Tower and Cable Bent like the Macdonald painting program. The coatings and steel repairs are recommended to maintain this critical component of the structural system; these are preventative measures to limit the type of deterioration observed on the Macdonald bridge steel substructures.

Multiple door hatches in the Cable Bent and Main Towers are inoperable (jammed or unable to be fully closed), and all of them have deficient sealing systems such that they are a source of water ingress.

Technical Considerations

Currently, access to these areas is difficult. The Main Tower top strut has a bosun’s chair rail, otherwise, temporary access would be required to re-coat these areas.

Budget and Timing

The following representative scope of work is considered for this work:

- Mobilization and demobilization of access systems in select areas.
- Coating restoration of select areas (percentages shown in the following table), including splice sealing at failed caulking.
- Supply and installation of new steel doors.

A representative cost estimate is provided below based on HHB’s coating work on the Macdonald approach span recoating projects with increased unit costs to accommodate not having a full component enclosed. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Main Tower Coatings	Main Tower Repairs (Doors/Sealing)	Cable Bent Coatings	Comment
2023	-	$250,000	-	Replacement of steel doors and sealing of failed caulking at splices
2028	$2,000,000	-	$400,000	Main Tower and Cable Bent recoating spread over 3 years, assumes a 10% zone recoating.
2029	$2,000,000	-	$400,000	
2030	$2,000,000	-	$400,000	

D.13 Box Girder Repairs and Coatings

Background

The approach span concrete deck provides substantial protection from the elements such that the coatings of the approach span box girders are typically in fair condition. At deck construction joints, water is penetrating the deck and rust is visible on the deck soffit at the floorbeams, including the box girders at those locations. Furthermore, recent inspections have identified pinhole corrosion in the box girder top flange, indicating water penetration of the approach deck leading to corrosion. Repairs may be necessary to the box girders; a study is ongoing to confirm this need. Access for these areas is limited due to out of commission travellers and fixed catwalks.

The recoating and repairs timing is intended to be concurrent with the approach span deck rehabilitation work, i.e. when the deck is removed and box girders are accessible, where access may be more feasible if concurrent with traffic control. Additional benefits of this approach include recoating the box girders following deck repairs, during which damage may be incurred due to demolition of the concrete above.

Technical Considerations

Access to these areas currently is challenging. The approach span catwalk is only wide enough to fit one person to access a limited portion of the interior floorbeams. The cantilevered portions of the floorbeams are only accessible through an aerial work platform or the existing travellers. However, the travellers are not fit for use at this time and require significant repairs or replacement before use.

Budget and Timing

The following representative scope of work is considered for this work:

- Mobilization and demobilization of access systems.
- Coating restoration of select areas (percentages shown in the following table).
- Design, supply, and installation of steel reinforcement.

A representative cost estimate is provided below based on HHB’s coating work on the Macdonald approach span recoating projects. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Steel Repairs	Coatings	Comment
2023	$1,000,000	-	Select repairs and access systems
2024	$1,000,000	-	Select repairs and access systems
2025	$500,000	-	Select repairs (concurrent with deck rehabilitation)
2026	-	$600,000	Paint repairs (after deck rehabilitation), 10% zone recoating assumed
2027	$500,000	-	Select repairs (concurrent with deck rehabilitation)
2028	-	$600,000	Paint repairs, 10% zone recoating assumed
2030	$1,200,000	-	Steel repairs for the box girders (3-5%) and associated floorbeams (1-3% for interior, 6-9% exterior).

D.14 Approach Span Floorbeam Coatings (Interior/Exterior)

Background

The approach span concrete deck provides substantial protection from the elements such that the coatings of the approach span floorbeams are typically in fair condition. At deck construction joints, water is penetrating the deck and rust is visible on the deck soffit at the floorbeams, which has been identified in recent inspections. Modifications to the approach span access are assumed within the box girder repairs (D.13).

Technical Considerations

Based on the observed deterioration and planned concrete deck rehabilitation, it is assumed that a considerable percentage of the floorbeams will require recoating. This recoating is planned to be a local zone approach as section loss, or capacity concerns are not presently anticipated. The recoating is intended to maintain the existing structural capacity for the duration of the foreseeable service life.

Budget and Timing

The following representative scope of work is considered for this work: paint abatement and coating select areas.

A representative cost estimate is provided below based on HHB’s coating work on the Macdonald approach span recoating projects. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Interior Floorbeams	Exterior Floorbeams	Comment
2026	$350,000	$500,000	Phase 1 of 2
2028	$350,000	$500,000	Phase 2 of 2

D.15 Access Improvements

Background

The access improvements represent an inclusive item for HHB to improve or repair existing access systems (i.e. ladders, catwalks, lifelines, stairs, etc.), which can be required based on recent inspections or by a desire to improve access to new or existing locations of the bridge.

The scope of these items is based on annual inspection findings and rehabilitation programs implemented by HHB. In general, this work may include catwalk railings, vertical lifelines and access to the main tower foundations.

Technical Considerations

For engineered safety systems, typically an inspection is required (intervals vary as required by the designer/supplier). It is assumed these specific inspections are separate to the annual inspections. Once inspected, repairs can be specified, or in other cases, a new system needs to be designed, fabricated, supplied and installed.

Budget and Timing

The following representative scope of work is considered for this work:

- Inspection of the as-built condition of select access systems.
- Specification of repair procedures, as necessary and applicable.
- Design of new access systems to replace the existing, including fabrication, supply, and installation.
- Some of the detailed systems include:
  - Main Tower horizontal lifelines ($150,000)
  - Work platform guards ($50,000)
  - Suspended spans bottom chord access bracket system ($200,000)
  - Approach spans catwalk deck replacement ($150,000)
  - Side traveller improvements ($1,000,000)
  - Approach span bearing access ($300,000)

A representative cost estimate is provided below based on COWI's evaluation of HHB’s anticipated scope of work. The budget and anticipated schedule based on priority and timing are as follows:

Year	Estimate
2021	$100,000
2022	$250,000
2023	$500,000
2024	$1,000,000

D.16 Roadway Signage and Safety Program

Background

As part of the HHB's Transportation Engineering Services project in 2011, HHB is proceeding with improvements and replacements of existing signage (Guide, Regulatory and Waring signs) and sign structures. This is based on findings from a human factors' assessment, road safety review, a review of signage on the MacKay and Macdonald Bridges and an assessment of speed management on the approaches to the MacKay toll plaza.

The implementation of a new signage system was put on hold until the completion of Big Lift and All Electronic Tolling projects.

Technical Considerations

As part of the signage evaluation and design process, the following elements were considered: driver information requirements, driver workload issues related to sign reading, lane changing, and characteristics of traffic operations (including operating speeds, speed differentials, and areas of merging and weaving).

The report recommends HHB to implement an integrated roadway system that includes road safety, speed management and signage with clarity and consistency.

The program was developed to be implemented in different projects and phases:

- Roadway Lighting Upgrade – completed by 2017
- Roadside Safety improvements – Phase-1 completed by 2014, Phase-2

Budget and Timing

The following representative scope of work is considered for this work:

- Demolition of the current toll plaza.
- New gantry for AET sensors.
- Modification of roadway at the existing toll plaza.

HHB's budget and anticipated schedule based on priority and timing are as follows:

Year	Roadway Signage	Roadway Safety
2025	$2,000,000	-
2026	$1,650,000	$2,000,000
2027	-	$1,000,000
2028	-	$2,000,000

Appendix E MacKay Bridge Replacement

E.1 Scoping Study/Stakeholders/Communications

Background

As part of HHB's plan to replace the existing Bridge, HHB is recommended to begin taking steps approximately ten years before construction to determine the scope of work, gather input and facilitate communication with the key stakeholders, as well as begin to communicate these plans to establish funding and support. COWI provided HHB with a draft feasibility report for the MacKay replacement options, finalized to HHB in 2020. A copy of the feasibility report is provided in Appendix H.

Technical Considerations

At the stages before the preliminary design of any new bridge, the technical considerations are minimal. The primary focus is on commercial aspects, i.e. securing funding, determining the scope of work, land acquisitions, etc.

Budget and Timing

The following representative scope of work is considered for this work:

- Scoping study for a new bridge.
- Communication with key stakeholders:
  - nearby property owners (residential, commercial, federal) in vicinity of bridge,
  - Halifax Port Authority
  - Department of National Defense
  - Federal, Provincial and Municipal governments
  - Transport Canada
  - Fisheries and Oceans Canada
  - Environment Canada / Nova Scotia Environment
  - Crown-Indigenous Relations and Northern Affairs Canada
  - Nova Scotia Communities, Culture and Heritage

A representative cost estimate is provided below based on COWI's recommendations for HHB's anticipated scope of work and experience for similar studies across Canada.

HHB's budget and anticipated schedule based on priority and timing are as follows:

Year	Scoping Study	Stakeholders/Communication
2022	$250,000	$200,000
2023	$100,000	$200,000

E.2 Environmental Assessment/Land Impact Assessments/Land Acquisition

Background

Concurrent with the scoping studying, land adjacent to the existing bridge requires assessment to determine the most appropriate location for a replacement bridge, starting with environmental and land impact assessments. Both activities will help HHB determine if any adjacent sites next to the existing bridge are best suitable to support a replacement structure. However, it is acknowledged that the environmental assessment (suitability of area) and land impact assessment (suitability of impact of the bridge on an area) are mutually exclusive exercises that may yield different results requiring a compromise to be made.

HHB does not anticipate acquiring any land for the work before 2030.

Technical Considerations

At the stages before the preliminary design of any new bridge, the technical considerations are minimal as the primary focus is on commercial impacts.

Budget and Timing

The following representative scope of work is considered for this work:

- Environmental assessment/application of potential new bridge sites.
- Land impact assessment due to the potential locations of a new bridge.
- Acquiring land (as necessary) to position the new bridge.

A representative cost estimate is provided below based on COWI's recommendations for HHB's anticipated scope of work and experience. The budget and anticipated schedule based on priority and timing are as follows:

Year	Enviro. Assessment/Application	Land Impact Assessments	Land Acquisition
2022	$50,000	$20,000	-
2023	-	$20,000	-
2024	-	-	-
2025	$200,000	$20,000	-
2026	$200,000	-	-
2030	$200,000	$20,000	-

E.3 Bridge Design (Partial) and Construction

Background

Once the scoping study and the environmental and land impact assessments are complete, HHB can proceed with their selected consultant on the new bridge's design to replace the existing MacKay.

HHB has not yet finalized the timing of this work but, for purposes of the capital plan, is proceeding as if the design will start between 2025-2030 at the earliest. If the design were to begin in this period, it is assumed that it will extend beyond 2030. Therefore, additional costs are anticipated beyond 2030 for the design and the full construction cost impacts.

Technical Considerations

With the necessary assessments complete and the new bridge location nearly known (i.e., major commercial factors are resolved), HHB's selected consultant can proceed with the new bridge's design. At this stage, without knowing the chosen bridge type, it isn't easy to define or discuss the technical considerations. However, the design team will have to address those challenges as-and-when they occur. It is worth noting that a new bridge will have fewer unknowns to deal with being new construction rather than rehabilitation work.

Budget and Timing

The following representative scope of work is considered for this work:

- Begin design of the new bridge (full scope not anticipated to be complete by 2030).
- Construction of the new bridge, including demolition of the existing bridge (not anticipated to start before 2030).

A representative cost estimate is provided below based on COWI's evaluation of HHB's anticipated work and experience scope. The budget and anticipated schedule based on priority and timing are as follows:

Year	Begin New Bridge Design	New Bridge Construction
2027	$1,000,000	-
2028	$1,000,000	-
2029	$5,000,000	-
2030	$5,000,000	-

Appendix F Ancillary Structures Projects

F.1 Barrington Street Ramp Resurfacing

Background

Located on the south side of the Macdonald Halifax approach span, the Barrington Street Ramp carries one lane of traffic for Dartmouth-bound traffic travelling north on Barrington Street in Halifax. HHB performed periodic inspections and concrete repair work within the past 10-15 years.

Technical Considerations

Previous inspection reports have noted the wearing surface is in fair to poor condition. There are potholes concentrated near expansion joints, and the wearing surface does not extend the full width of the deck at the turn. There are longitudinal cracks, and there is medium rutting in the wheel paths. However, previously patched areas are in good condition.

Budget and Timing

The following representative scope of work is considered for this work:

- Roadway resurfacing and waterproofing.
- Traffic control in the work zone.
- Milling and removal of the existing asphalt.
- Waterproofing membrane removal.
- Surface preparation and primer.
- Tack coat supply and installation.
- Supply and application of new asphalt.
- Pavement markings.

A representative asphalt resurfacing lump sum cost based on tender prices for similar work performed in 2009/2010 on the Macdonald (considered similar in scope), with costs brought forward based on construction cost indices. A comparison was also made to the recent 2019 paving on the MacKay, and adjusted for complexity. These two values informed the estimate below.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate
2025	Roadway Resurfacing and Waterproofing	$2,000,000

F.2 Barrington Street Ramp Bearings

Background

Located on the south side of the Macdonald Halifax approach span, the Barrington Street Ramp carries one lane of traffic for Dartmouth-bound traffic travelling north on Barrington Street in Halifax. HHB performed periodic inspections and concrete repair work within the past 10-15 years.

Technical Considerations

Based on previous inspections, concrete rehabilitation is required before anticipated bearing replacements in 2029. To accommodate the work's staging, the project will take place over a series of four years. Included in this work scope will be an assessment on the most effective manner to strengthen the structure in preparation of bearing replacements (no jacking beam currently exists).

Work to replace the bearings is currently assumed on a preventative maintenance schedule rather than observed deterioration. This will be re-assessed as the schedule progresses.

Budget and Timing

The following representative scope of work considered for this work is based on assumed access and concrete work requirements. Starting in 2026, two piers per year are planned within the work sequence for concrete repairs, followed by two piers per year for bearing replacements beginning in 2029.

Cost estimates were developed based on project costs for concrete rehabilitation works on the Macdonald and MacKay bridges, recent Macdonald bearing replacements, and historical data for bearing replacements along the overpass ancillary structures.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Pier Repairs to Prepare for Bearing Replacements	Bearing Replacements	Estimate
2026	$630,000	-	Two piers - concrete
2027	$630,000	-	Two piers - concrete
2028	$630,000	-	Two piers - concrete
2029	$630,000	$1,250,000	Two piers - concrete Two piers – bearings
2030	-	$1,250,000	One pier - concrete Two piers – bearings

F.3 Windsor / Robie Exit K

Background

Located west of the MacKay Halifax abutment adjacent as part of the NS Highway 111 interchange system, the Windsor/Robie Street Exit structure (New Ramp "K") carries two lanes of traffic (both westbound) as part of NS Highway 111. The structure is a four-span, twin steel box girder bridge with concrete deck and asphalt pavement. HHB performed periodic inspections and concrete repair work within the past 10-15 years.

Technical Considerations

HHB's recent inspection of the structure revealed that deformation is present along the steel girder webs at diaphragm and bearing stiffener locations. As this condition was previously unknown to COWI and HHB's current personnel, an investigation is planned to assess the influence these deformations have on the structural performance. Additional inspection findings note that the bearings, while currently sufficient for the bridge needs, are likely to require replacement within the next ten years.

There are indications that the abutments or structure have shifted slightly to the south, based on the remaining gaps observed in the expansion joints. This may result in having to address the abutment back wall geometry to allow for adequate joint movement, and fixity of the abutment foundations to limit future movements. Given the recent nature of these findings, COWI recommends HHB maintain adequate budget forecasts to address a range of possible outcomes. The budget recommendations provided in this report reflect COWI's assumed maximum reasonable extents of work.

Budget and Timing

The following representative scope of work is considered for this work:

- Perform a detailed inspection of the findings from HHB's 2020 November inspection to confirm the extent of deformation observed in the girder webs and jacking beam.
- Assess deformation observed in the structure to determine if strengthening is required urgently or prior to a bearing replacement.
- If required, repair the box girder webs, and paint around the girder ends.
- Bearing replacement (including additional jacking strengthening and temporary works)
- Additional steel repairs or deterioration mitigation based on roadway leakage observed.

Cost estimates were developed based on project costs for concrete rehabilitation works on the Macdonald and MacKay bridges, recent Macdonald bearing replacements, and historical data for bearing replacements along the overpass ancillary structures.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate	Notes
2021	Detailed Inspection	$50,000	Based on findings during 2020 November inspection, recommended that a consultant perform a detailed inspection.

Year	Type	Estimate	Notes
	Box girder web and end diaphragm deformation	$100,000	Assessment at the bearing locations for deformation observed at the jacking stiffeners and jacking frame.
2022	Box girder web repairs	$300,000	Assumed based on web deformations during HHB Nov. 2020 walkthrough inspection.
	Painting and expansion joint	$500,000	Expansion joint replacement and recoating in the immediately adjacent areas.
2023	Deck sealing	$200,000	Based on observed deterioration
2024	Abutment fixity repairs	$400,000	Pinning the abutment to limit future movements.
2027	Bearing replacement	$2,000,000	Based on observed deterioration to date and anticipated requirements in seven years at the west abutment bearings and wind guide.
2028	Miscellaneous steel repairs	$300,000	Steel repairs based on condition and observed deterioration to date. At span ends and concrete deck construction joints leakage has been observed.
2029	Expansion joint	$50,000	Expansion joint gland replacement based on use and wear.

F.4 Halifax Approach Retaining Wall

Background

The Halifax Approach Retaining wall is located along the approach road, south of the structure.

Technical Considerations

During the previous inspection (2012), map cracking and localized spalling were observed. Based on these findings, COWI anticipates some needs for concrete repairs. Total scope to be verified following the next inspection (2021).

A verticality survey was last performed for the wall in 2007. In 2012, recommendations were made to perform a subsequent survey in 4–7 years to capture the wall's possible movement, particularly at the east end where a bulge was noted.

Budget and Timing

The following representative scope of work is considered for this work:

- Concrete removal and repairs.
- Verticality survey.

A representative cost estimate is provided below based on COWI's recommendations for localized concrete repairs and access. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate
2022	Concrete Repairs	$250,000
	Verticality Survey	$50,000
2029	Verticality Survey	$50,000

F.5 Princess Margaret Overpass

Background

Located east of the MacKay Dartmouth Abutment adjacent to the MacKay Dartmouth toll plaza, the Princess Margaret Overpass carries four lanes of traffic (two in either direction) as part of the MacKay Dartmouth roadway approaches. HHB performed periodic inspections and concrete repair work within the past 10-15 years and various concrete repairs and replaced the existing pot bearings with elastomeric bearings in 2010.

Technical Considerations

The free abutment and pier bearings have some signs of distress, but nothing that would yet warrant a bearing replacement. However, there are signs of potential overloading on the bearing pad material (bulging), which may reduce the assemblies' overall lifespan.

The fixed abutment bearings, initially replaced in 2010, were again replaced in 2011 to address significant distress (tears, bulging and general distortion). This second replacement did not improve the situation as the bearings also have considerable distress. A desktop study was undertaken for HHB by another consultant in 2017 to help understand the situation, with no conclusive findings.

Currently, the impact and influence of the failed fixed abutment bearings are not known. Therefore, COWI recommends HHB plan for significant bearing replacements within this 10-year capital plan. Following a more detailed assessment of the current bearing conditions and performance, this anticipated work may very well be reduced.

Budget and Timing

The following representative scope of work is considered for this work:

- Expansion joint replacement.
- Bearing replacement.
- Concrete repairs.

A representative cost estimate is provided below based on historical data from the 2010 expansion joint and bearing replacements and adjustments to the values based on inflation and an assumed increase in complexity to mitigate future bearing failures.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate	Notes
2022	Bearing assessment and re-design	$150,000	Assessment of prior bearing failures and design of a replacement plan to mitigate the risk of future failures.
2024	Concrete repairs	$200,000	General repairs based on observed conditions
2025	Expansion joint /bearing replacement	$1,150,000	Phase 1, ½ of structure (seven bearings)
2026	Expansion joint /bearing replacement	$1,150,000	Phase 2, ½ of structure (seven bearings)

F.6 Baffin Boulevard Retaining Wall

Background

Located between the MacKay Dartmouth Abutment and the Princess Margaret Overpass, Baffin Boulevard Retaining Wall is a cast-in-place concrete retaining wall along the south side of the MacKay roadway approaches. HHB last performed an inspection of the wall in 2012.

Technical Considerations

During the 2012 inspection, the concrete was in good condition with some vertical cracking and efflorescence. Based on the images provided and details contained in the inspection report, COWI recommends HHB consider some localized repairs may be required, to be confirmed following the next inspection.

Budget and Timing

The following representative scope of work is considered for this work: concrete repairs and verticality survey.

A representative cost estimate is provided below based on COWI's understanding of repairs required. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate	
2025	Concrete repairs	$100,000	Bin wall partial replacement based on observed conditions.
2026	Concrete repairs	$200,000	Bin wall partial replacement based on observed conditions and verticality survey.

F.7 CN Overpass

Background

Located east of the MacKay toll plaza in Dartmouth, the CN Overpass carries six lanes of traffic (three in either direction) as part of NS Highway 111 over the CN Railway below. HHB performed periodic inspections and concrete repair work within the past 10-15 years in addition to various concrete repairs completed in 2008.

Technical Considerations

During the 2014 inspection, the concrete was in good condition with some vertical cracking and efflorescence. Based on the images provided and details contained in the inspection report, COWI recommends HHB consider some localized repairs may be required, to be confirmed following the next inspection.

Budget and Timing

The following representative scope of work is considered for this work: concrete repairs.

A representative cost estimate is provided below based on COWI's understanding of repairs required. The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate
2025	Concrete Repairs	$100,000

F.8 Windmill Road Overpass

Background

Located east of the MacKay toll plaza in Dartmouth, the Windmill Road Overpass is a twinned structure that carries six lanes of traffic as part of NS Highway 111 over Windmill Road. HHB performed periodic inspections and concrete repair work within the past 10-15 years and various concrete repairs and replacing the existing pot bearings with elastomeric bearings in 2010.

Technical Considerations

The free abutment and pier bearings have some signs of distress, but nothing that would yet warrant a bearing replacement. However, there are signs of potential overloading on the bearing pad material (bulging), which may reduce the assemblies' overall lifespan.

The fixed abutment bearings, initially replaced in 2010, were again replaced in 2011 to address significant distress (tears, bulging and general distortion). This second replacement did not improve the situation as the bearings also have considerable distress. A desktop study was undertaken for HHB by another consultant in 2017 to help understand the situation, with no conclusive findings.

Currently, the impact and influence of the failed fixed abutment bearings are not known. Therefore, COWI recommends HHB plan for significant bearing replacements within this 10-year capital plan. Following a more detailed assessment of the current bearing conditions and performance, this anticipated work may very well be reduced.

Budget and Timing

The following representative scope of work is considered for this work:

- Expansion joint replacement.
- Bearing replacement.
- Concrete repairs.

A representative cost estimate is provided below based historical data from the 2010 expansion joint and bearing replacements and adjustments to the values based on inflation and an assumed increase in complexity to mitigate future bearing failures.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate	Notes
2022	Bearing Assessment and re-design	$200,000	Assessment of prior bearing failures and design of a replacement plan to mitigate the risk of future failures.
2024	EJ/bearing replacement and concrete repairs	$2,300,000	Ten bearings, concrete repairs of the abutment wall and expansion joint on Structure 1
2025	EJ/bearing replacement and concrete repairs	$2,300,000	Ten bearings, concrete repairs of the abutment wall and expansion joint on Structure 2

F.9 Victoria Road Overpass

Background

Located east of the MacKay toll plaza and Windmill Road in Dartmouth, the Victoria Road Overpass carries six lanes of traffic (three in either direction on each structure) as part of Victoria Road over NS Highway 111. HHB performed periodic inspections and concrete repair work within the past 10-15 years and various concrete repairs and replaced the existing pot bearings with elastomeric bearings in 2010.

Technical Considerations

The free abutment and pier bearings have some signs of distress, but nothing that would yet warrant a bearing replacement. However, there are signs of potential overloading on the bearing pad material (bulging), which may reduce the assemblies' overall lifespan.

The fixed abutment bearings, initially replaced in 2010, were again replaced in 2011 to address significant distress (tears, bulging and general distortion). This second replacement did not improve the situation as the bearings also have considerable distress. A desktop study was undertaken for HHB by another consultant in 2017 to help understand the situation, with no conclusive findings.

Currently, the impact and influence of the failed fixed abutment bearings are not known. Therefore, COWI recommends HHB plan for significant bearing replacements within this 10-year capital plan. Following a more detailed assessment of the current bearing conditions and performance, this anticipated work may very well be reduced.

Budget and Timing

The following representative scope of work is considered for this work:

- Expansion joint gland replacement.
- Bearing replacement.
- Concrete repairs.

A representative cost estimate is provided below based on historical data from the 2010 expansion joint and bearing replacements and adjustments to the values based on inflation and an assumed increase in complexity to mitigate future bearing failures.

The budget and anticipated schedule based on priority and timing with other projects in the area are as follows:

Year	Type	Estimate	
2021	Expansion joint gland	$50,000	Based on the observed condition
2022	Bearing Assessment and re-design	$200,000	Assessment of prior bearing failures and design of a replacement plan to mitigate the risk of future failures.
2023	Bearing replacement	$2,200,000	Ten bearings, repairs to the substructure and bearing preliminary work.
2026	Bearing replacement	$1,900,000	Ten bearings, repairs to the substructure and bearing preliminary work.

Appendix G Resume: Darryl Matson, Bridge Expert

DARRYL MATSON, P.ENG., PE

Senior Vice President

EDUCATION	M.A.Sc. University of British Columbia, Canada. 1989 B.A.Sc. University of British Columbia, Canada. 1987
PROFESSIONAL REGISTRATIONS	Assn. of Professional Engineers of BC, NB, AB, SK, MB and NS Professional Engineer, California, Washington, Maine, North Carolina, Kansas and Michigan
YEARS OF EXPERIENCE	31
KEY QUALIFICATIONS	Darryl brings over 30 years of engineering experience specifically related to heavy civil infrastructure projects. He has been responsible for leading design teams of several high-profile bridge projects in British Columbia, across Canada and in the US. Darryl started his career as a seismic specialist, leading retrofit strategies and detailed designs for signature bridges like the Golden Gate, Iron Workers, Lions Gate, and Cold Spring Canyon Bridges. He has also been involved in some significant bridge rehabilitation projects including the suspended span replacements of the Macdonald and Lions' Gate Bridges, and the evaluation and monitoring of the Champlain Bridge as it neared the end of its useful life. Darryl has worked for both Contractors and Owners and has always focused on providing the best value for money on his projects. Darryl was the President & CEO of Buckland & Taylor Ltd. (a COWI Company) from 2013-2016, and since 2018 has been stepping out of management of the Company and back into managing engineering projects.

SELECTED PROJECTS

2015-PRESENT	6TH STREET BRIDGE, LOS ANGELES, CA. ENGINEER OF RECORD. COWI is providing the construction engineering, including the sequential analysis and camber design, for this complex, multi span post-tensioned concrete bridge. The bridge geometry is complicated by the seismic isolation bearings and the fact that the arches act more like beams than arches. Darryl is the Engineer of Record of the construction engineering.
2015-2019	3RD STREET BRIDGE, SAN FRANCISCO, CA. ENGINEER OF RECORD. COWI completed the detailed design (final Plans, Specifications and Estimates) for the rehabilitation of the open grating deck of this moveable bridge. Darryl was the Engineer of Record for the rehabilitation design. GROAT ROAD BRIDGE, EDMONTON, AB, CANADA. CO-ENGINEER OF RECORD. COWI performed the erection engineering for the superstructure removal and replacement for the Groat Road Bridge. The bridge is a seven-span structure, and the concrete girders were removed and replaced with new steel girders using an

innovative gantry system. Darryl was the co-Engineer of Record for the construction engineering.

2019-PRESENT R.W. BRUHN BRIDGE REPLACEMENT, SICAMOUS BC. PROJECT PRINCIPAL.

Design of the replacement of an existing two-lane bridge with a new five-lane bridge, including four lanes dedicated to through Trans-Canada traffic. Darryl was the Project Principal for the design.

2015-2020 ADMIRALS-MCKENZIE INTERCHANGE, VICTORIA, BC. PROJECT PRINCIPAL.

Design of grade separation structures for Admirals Avenue and McKenzie Avenue over the TransCanada Highway #1, including replacement of existing pedestrian structure, new overpass, and new pedestrian structure. Darryl was the Project Principal for the design.

2012-2014 248TH STREET UNDERPASS, LANGLEY, BC. PROJECT PRINCIPAL AND REVIEW ENGINEER.

Design of a new underpass over Highway 1. COWI undertook the conceptual and detailed design of the new structure, produced design drawings, special provisions, cost estimates, and developed tender documents. Darryl was the Project Principal and Review Engineer for the design.

2019-PRESENT TECHNICAL SERVICES FOR GEORGE MASSEY CROSSING PROJECT, RICHMOND/DELTA, BC, CANADA. OVERALL TECHNICAL LEAD AND PROJECT MANAGER.

The George Massey Tunnel carries four lanes of traffic under the Fraser River. The BC Government is investigating options to increase capacity to eight lanes, as well as add multi-use paths for cyclists and pedestrians at the crossing. Working for the BC Ministry of Transportation and Infrastructure, COWI was the Prime Consultant responsible for a multi-disciplinary team that provided technical services and conceptual level design services to develop different crossing options. Working with Local Stakeholders, the Ministry started with 18 options, and quickly narrowed this down to 6 options – two bored tunnel options, two immersed tube tunnel options, and two bridge options. COWI developed technical solutions for all six short-listed options, including alignment, structure configurations, property impacts, and approximate total project costs for each. The Ministry and Local Stakeholders then selected the recommended option to move forward with to public consultation and into the business case development. The BC Transportation Investment Corporation then developed the Business Case for the project, and the COWI team continued to refine the options, including investigating additional bridge and immersed tube tunnel options, as the Business Case was developed.

Darryl was the overall Project Manager and Technical Lead for both assignments.

2018-2019 PATTULLO BRIDGE REPLACEMENT (BID DESIGN), VANCOUVER, BC, CANADA. PROJECT MANAGER.

COWI was the lead designer for the Dragados/Carlson Construction team bidding on the Design-Build-Finance replacement of the 83-year-old Pattullo Bridge, which joins the communities of New Westminster and Surrey, BC. The new bridge carries two pedestrian/cyclist pathways, and will initially be a 4-lane crossing, and is designed to be expandable to six lanes in the future. The single tower cable-stayed bridge had a main span of 325 m, and the project included significant upgrades to the road network and interchanges on both sides of the river. Darryl was the Project Manager for the bid design.

1995 LIONS GATE BRIDGE, VANCOUVER, BC, CANADA. PROJECT MANAGER.

Darryl was the Project Manager for the seismic retrofit strategy of the North Approach spans of the bridge. The North Approach is a 670m (2200 ft) long, multi-span plate girder bridge with an orthotropic deck, which is supported on multiple steel bents. The retrofit strategy employed an innovative solution of allowing the concrete footings to lift during the seismic event – effectively allowing the bridge to rock back and forth – rather than adding significant strengthening to the steel bents and superstructure. The retrofit strategy was ultimately given as the base design for a design build contract, and a similar concept was used by the designer.

2009 LOWER LIARD SUSPENSION BRIDGE, ON ALASKA HIGHWAY NEAR LOWER LIARD, BC, CANADA. PROJECT PRINCIPAL.

Part of an "As and When" contract for which COWI Bridge is a subconsultant to EBA Engineering. Darryl was the Principal for inspection and assessment of deteriorated concrete bridge deck. Work involved developing deck replacement concepts for consideration by PWGSC. This is a three-span, two-lane suspension bridge with a 166 m (543 ft.) main span; constructed in 1943.

2007-2008 WALDO HANCOCK BRIDGE, BUCKSPORT, MAINE, USA. PROJECT PRINCIPAL, REVIEW ENGINEER.

Darryl was the Project Principal and Review Engineer for the field investigation of the existing structure, which has a 244 m (800 ft.) main suspended span. The project involved development of a full demolition sequence for the suspension bridge.

2006-PRESENT ANGUS L. MACDONALD BRIDGE, HALIFAX, NS, CANADA. PRINCIPAL, REVIEW ENGINEER.

Constructed in 1955, the bridge comprises a 762 m (2500 ft.) suspension bridge, with main span of 441 m (1447 ft.), and 585 m (1918 ft.) long approaches. Darryl was the Principal and Review Engineer for the Options Analysis for extending the life of the crossing. Options investigated included major rehabilitation as well as full replacement. The rehabilitation option was selected, and COWI led a multi-disciplined team that developed the detailed rehabilitation plans and specifications for the replacement of the entire suspended spans, including the deck, sidewalks, trusses and suspender, during short night and weekend closures while traffic continued to use the bridge during peak hours. A new orthotropic steel deck system was used to manage the weight of the suspended spans, and therefore eliminating the need to retrofit the towers, main cables and foundations with the exception of some minor local strengthening of the main towers. In addition, a new dehumidification system was added to the main suspension cables of the bridge – one of the first such applications in North America. Darryl was the review Principal for the rehabilitation design. During construction, Darryl was the design representative on the senior oversight committee for the project that also included a representative of the Owner and the Contractor. This senior team reviewed the progress of the project monthly for the duration of construction and worked together to resolve issues as they happened. The rehabilitation cost less than 20% of the cost of a new crossing, resulted in a completely new suspended structure, and had limited impacts on traffic and the resulting toll revenue.

2006-PRESENT A. MURRAY MACKAY BRIDGE, HALIFAX, NS, CANADA. REVIEW ENGINEER.

Constructed in 1970, the main span of the A. Murray MacKay Suspension Bridge measures 426 m (1397 ft.) and its total length is 1.2 km (7250 ft.). This bridge was the first suspension bridge in North America to have an orthotropic steel deck, the first in the world to utilize the deck as the top chord of the stiffening trusses and was the first bridge ever to be wind tunnel tested in turbulent flow. Darryl was the Review Engineer for the options study, including rehabilitation and replacement options and an assessment of the remaining life of the existing bridge. He was also the Principal and Review Engineer for the annual inspection and miscellaneous maintenance designs for the bridge.

2003-2005 EAST BAY BRIDGE (BID DESIGN), SAN FRANCISCO, CA, USA. PROJECT MANAGER.

Project Manager for the pre-bid construction engineering of the new self-anchored suspension bridge for the Kiewit/Koch-Skanska team.

2002 HAGWILGET BRIDGE, NEW HAZELTON, BC, CANADA. PROJECT PRINCIPAL.

The Hagwilget suspension bridge is a 140m (460 ft) long single lane suspension bridge. COWI designed load path improvements and provided support and advice during construction. Darryl was the Project Principal for the project.

1997-1998 LIONS GATE BRIDGE, VANCOUVER, BC, CANADA. PROJECT MANAGER.

Darryl was the Project Manager for the development of a conversion scheme to re-articulate a 1.5 km (1 mile) long suspension bridge to a cable-stayed bridge while maintaining traffic. The main span of the three-lane suspension bridge is 472 m (1550 ft.) and the total suspended span length is 847 m (2779 ft.).

1993-1994 GOLDEN GATE BRIDGE, SAN FRANCISCO, CA, USA. PROJECT MANAGER.

Working with Sverdrup, COWI developed the seismic retrofit strategy and the detailed design for seismically upgrading the south approaches of the Golden Gate Bridge. There are four separate segments of the bridge that Sverdrup/COWI was responsible for: the south approach steel truss spans (including the steel towers), the concrete anchor chamber building (that several approach span towers sit on top of), the historic Fort Point steel arch, and the massive south concrete pylons (two of which act as the cable bent for the main suspension bridge cable). Darryl was the Project Manager and lead designer for the COWI team.

1997-2002 LIONS GATE BRIDGE, VANCOUVER, BC, CANADA. PROJECT MANAGER, OWNER'S BRIDGE ENGINEERING REPRESENTATIVE.

The main span of the three-lane suspension bridge is 472 m (1550 ft.) and the total suspended span length is 847 m (2779 ft.). Darryl was the Project Manager, Engineer of Record and Owner's Bridge Engineering Representative during construction of the suspended spans super structure replacement (deck, trusses, and suspenders) during short night-time bridge closures. This is the first time a complete replacement of a suspended structure has been accomplished while maintaining traffic during peak periods. The new orthotropic deck was made composite with the new trusses to reduce weight. In addition to the superstructure replacement, the suspended spans were seismically upgraded. This was an award-winning project.

2008 HUDSON HOPE BRIDGE, HUDSON'S HOPE, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the detailed inspection of this prestressed concrete suspension bridge with a 207 m (679 ft.) main span. The project included a complete survey of the bridge deck profile and tower alignment to monitor cable movement, visual inspection of bridge deck overlay, steel railings, rocker bearings and abutment as well as hammer sounding areas of the bridge deck soffit.

2007-2008 PORT MANN BRIDGE REPLACEMENT (PRE-BID), VANCOUVER, BC, CANADA. PROJECT MANAGER.

Darryl was the Project Manager for the bid design for the steel plate girder approach spans of the new Port Mann Bridge for the Bilfinger Berger Team. The approach structure was approximately 913 m (2995 ft.) long.

2002-2003 ESPLANADE RIEL, WINNIPEG, MB, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal of the erection engineering of this concrete cable-stayed pedestrian bridge with a main span of 106 m (348 ft.) and an 86 m (282 ft.) long back span. Some of the unique features of this bridge include a 69 m (226 ft.) tall architectural composite post-tensioned pylon and a cable-stayed semi-circular plaza area at the base of the tower.

1991 GLEBE ISLAND BRIDGE (BID DESIGN), SYDNEY, AUSTRALIA. TEAM MEMBER.

	Darryl was the Team member for the composite design alternative for a 345 m (1132 ft.) span cable-stayed bridge.
2002, 2005-2007, 2009, 2009-2010	PATTULLO BRIDGE, VANCOUVER, BC, CANADA. PROJECT PRINCIPAL. Darryl was the Project Principal for preparation of economic evaluation study report (life-cycle costing), inspection report, and live load evaluation report. He was also Project Principal for preparation of sandblasting, painting, and design of Phase II member strengthening contract documents (special provisions, construction schedule and cost estimate). Darryl was the Project Principal for the design and construction of the emergency replacement of a timber span due to fire. COWI Bridge located a spare steel/concrete composite structure in a local construction yard that could be modified to bridge the 20 m (67 ft.) gap. He was also Project Principal for COWI Bridge's role as Technical Consultant for all bridge-related issues for the Owner as part of a larger project to replace Pattullo Bridge.
2009-2011	CAPILANO RIVER BRIDGE, WEST VANCOUVER, BC, CANADA. PROJECT PRINCIPAL AND ENGINEER OF RECORD. Replacement design of the west bound Marine Drive bridge across the Capilano River, including laterally launching the existing bridge onto temporary piers to serve as a detour during the construction of the new bridge. The replacement bridge is 116 m long with two spans, has three safer lanes, shoulders, and a 4m-wide pedestrian and cycle path, as well as steel girders, a concrete deck with stainless steel reinforcing, integral abutments with no bearings, and no deck joints. Darryl sealed revised drawings as engineer of record.
2009-2011	MARINE DRIVE OVERPASS, WEST VANCOUVER, BC. PROJECT PRINCIPAL. Replacement of the existing Marine Drive Overpass with a five-lane structure and dedicated bus lane to the south bound approach to the Lions Gate Bridge. COWI was responsible for all structural engineering, including concept design, detailed design, preliminary construction staging and engineering services during construction, including the structural design associated with the temporary Acrow structure. Darryl was the Project Principal and co-engineer of record for the design.
2009	SIX TRUSS BRIDGES, SOUTHERN INTERIOR REGION, BC, CANADA. PROJECT PRINCIPAL. Darryl was the Project Principal for enhanced inspection and load capacity evaluation of three timber and three steel truss bridges. The bridges are located in Lillooet (Bridge River Bridge, Turnbill Bridge and Canal/Seton Lake Road Bridge); Walhachin (Walhachin Road Bridge); Clearwater (Clearwater Station Bridge); and Quesnel (Rudy Johnson Bridge).
1990-1991, 2007, 2008-2012, 2009, 2013-2019	CHAMPLAIN BRIDGE, MONTREAL, QC, CANADA. PROJECT PRINCIPAL. This six-lane, 3.5 km long bridge is the most travelled in Canada carrying 160,000 vehicles per day and consists of 50 concrete approach spans with a steel cantilever truss crossing the St. Lawrence Seaway. Built in 1962, the bridge's post-tensioned girders in the 50 approach spans began to show signs of corrosion in the 1980s and continued to deteriorate over the next 30 years. Conducted the review of erection procedures for the replacement of the existing concrete deck with a new orthotropic steel deck. Fatigue vulnerability assessment of the replacement deck. Darryl was the Project Principal for evaluation of the concept of strengthening the prestressed bulb-T concrete girders in a section of the bridge by below deck queen-post tendons.

He was also Project Principal of the above-deck emergency support girder and under-deck emergency support truss, which would be installed above or below the deck to quickly stabilize a failed permanent bridge girder. This project also included an external Queen-Post strengthening for the concrete girders of the approach spans to increase the shear capacity of the bridge girders near their supports. Both of these tasks included technical assistance during construction, as-built drawings, and shop drawing review. The emergency support girder and below deck truss were both fabricated and stored in the turnabout at the end of the bridge, and following the failure of one of the bridge girders several years later, were employed on the bridge – allowing the bridge to be closed for only two weeks during the installation rather than many months that it would have taken had the system not been available.

Darryl was the Project Principal for assessment and conceptual design for the remedial works to the precast concrete edge barriers attached to the orthotropic deck of the main span.

For the six years prior to the replacement bridge being open, COWI was the lead engineer responsible for monitoring and strengthening the bridge to allow it to remain open to traffic. The bridge had deteriorated prematurely due to detailing issues of the original design, and significant cracking of the approach span girders was evident, as was significant section loss of the post-tensioning tendons in the girders. COWI performed a detailed assessment and strengthening of the approach spans to the bridge, including extensive monitoring, inspection and evaluations of the existing condition of the bridge; emergency measures including the use of the previously designed "super-beam" and underdeck emergency truss; adding FRP and external post-tensioning to the existing girders; and adding new trusses to support the exterior girders. Darryl was the Project Principal for the work, which included monthly in-person updates to the Board of Directors of the Owner.

2008 JACQUES CARTIER BRIDGE, MONTREAL, QC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the assessment of feasibility and risk involved in tunnel work just south of the main span tie-down pier (Pier 26) of the bridge. The work involved developing technical requirements for the works such that it would not compromise the structural integrity of the bridge. This 2.7 km (1.7 mi.) long steel truss cantilever bridge has a 334 m (1095 ft.) main span that carries five lanes of traffic.

1991-1995, 2007, 2008-2009 GRANVILLE STREET BRIDGE, VANCOUVER, BC, CANADA. TEAM MEMBER, PROJECT PRINCIPAL, REVIEW ENGINEER.

Darryl was a Team member for the final seismic retrofit design of the 31 m (102 ft.), 157 m (515 ft.), and 350 m (1148 ft.) long steel trusses in the bridge.

He was also Project Principal and Review Engineer of the review and assessment of the damage sustained to the Hemlock Ramp, as a result of vehicle impact. The project also included the development of a repair design for the damaged sections and site services during the subsequent construction.

Darryl was the Project Principal for load assessments and preliminary design of shear capacity upgrades for the concrete girder spans.

1991-1992, 2007 IRON WORKERS (SECOND NARROWS) BRIDGE, VANCOUVER, BC, CANADA. DESIGN LEAD.

Darryl was a Design Lead for the widening and seismic retrofit study of the bridge. Preliminary design, feasibility and cost estimates for the 620 m (2034 ft.) long main truss, the four 85 m (278 ft.) long steel approach trusses, and the nine 36 m (118 ft.) long concrete approach spans. The approach spans are supported on massive concrete piers and the main span is concrete caissons.

2003-2006 FISHERMAN'S TRAIL BRIDGE, NORTH VANCOUVER, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for several inspections and the analytical assessment and development of recommendations for continued maintenance of this 35 m (115 m) through truss bridge.

2005 COQUITLAM DAM BRIDGE, COQUITLAM, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for assessment of alternate dis-assembly procedures for two 38 m (126 ft.) steel trusses.

2004 HAISLA BRIDGE, KITIMAT, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the inspection and live load capacity evaluation of this 216 m (709 ft.) steel truss bridge.

2001-2002 ALEXANDRA INTERPROVINCIAL BRIDGE, OTTAWA/HULL, ON/ QC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal of the evaluation and load capacity rating; seismic evaluation; and vibration analysis of the 438 m (1437 ft.) long true pin type truss bridge.

1990-1995 BURRARD STREET BRIDGE, VANCOUVER, BC, CANADA. TEAM MEMBER.

Darryl was a Team Member for the final seismic retrofit design of the two 54 m (177 ft.), two 66 m (216 ft.), and one 90 m (295 ft.) long steel trusses in the bridge. Base isolation bearings were used in the design.

1992 ROCK CREEK CANYON BRIDGE, BC, CANADA. TEAM MEMBER.

Darryl was a Team Member for the evaluation, conceptual design and final deck replacement design of this 286 m (938 ft.) long bridge situated over a deep canyon. The original stringer supported deck was replaced with a wider, more durable cast-in-place concrete deck. The bridge capacity was increased and at least one lane of traffic was retained throughout the construction period.

1992 TESLIN RIVER BRIDGE, YT, CANADA. TEAM MEMBER AND LEAD TEAM ANALYST.

Darryl was a Team Member and Lead Analyst for the final seismic retrofit and widening design of the multiple truss span bridge. It is the second longest bridge on the Alaska Highway (337 m (1106 ft.) long with a main span of 79 m (259 ft.)).

2009 AMELIA EARHART BRIDGE, KANSAS TO MISSOURI, USA. PROJECT PRINCIPAL.

The main span of this new four-lane, steel tied arch bridge is 161 m (527 ft.) and is being erected by cantilevering with tiebacks. Darryl was the Project Principal for the design of the temporary works for the erection engineering.

2008 NORRIDGEWOCK COVERED BRIDGE (PRE-BID), SOMMERSET COUNTY, MAINE, USA. PROJECT PRINCIPAL, REVIEW ENGINEER.

Darryl was the Project Principal and Review Engineer of providing pre-bid construction engineering of a 91 m (300 ft.) span concrete tied arch bridge over the Kennebec River in Sommerset County, Maine.

2004 PORT MANN BRIDGE, VANCOUVER, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the investigation into fatigue crack status in the north and south approach spans girders. It has a 366 m (1200 ft.) main span and total length of 2093 m (6867 ft.) and was the first orthotropic steel deck constructed in North America.

2005-2008 COLD SPRING CANYON BRIDGE, NEAR SANTA BARBARA, CA, USA. PROJECT MANAGER AND ENGINEER OF RECORD.

Two lane, steel arch bridge with main span of 213 m (700 ft.). Darryl was the Project Manager and Engineer of Record for the final seismic retrofit design, including field reviews during construction. In addition to the seismic upgrade, CALTRANS took to opportunity to encase the concrete foundations at the springing points of the arch that were significantly deteriorated due to Alkali Aggregate Reaction (AAR), which COWI also designed. This was an award-winning project.

2008-Present

PUBLIC WORKS CANADA PROJECTS, BC, AB, SK, CANADA. PROJECT PRINCIPAL, REVIEW ENGINEER.

Darryl was the Project Principal and Review Engineer of a one to two year "As and When" contract for PWGSC Bridges and Roads in British Columbia, Alberta and Saskatchewan.

THE LOWER LIARD RIVER BRIDGE. PROJECT PRINCIPAL AND REVIEW ENGINEER.

The Lower Liard River Bridge, constructed in 1943, is located on the Alaska Highway 300 km west of Fort Nelson, BC. The two-lane bridge consists of a three-span suspension structure, with spans measuring 70.92 m, 165.46 m and 70.92 m. Darryl was the Project Principal and Review Engineer for the evaluation of the bridge.

2011

ICE FIELDS INTERCHANGE PROJECT. PROJECT PRINCIPAL.

Ice Fields Interchange Project is located along 3 km (9.8 mi.) of the Trans-Canada Highway. The Design-Build includes demolition and removal of the existing Interchange Bridge, construction of a new Interchange Bridge and associated ramps, lighting of the Interchange and a new Bow River Bridge at km 76 for new eastbound lanes of the twinned Trans-Canada Highway. COWI was the Owner's Engineer and Darryl was the Project Principal

2011

SR 520 FLOATING BRIDGE (PRE-BID), SEATTLE, WA, USA. PROJECT PRINCIPAL AND REVIEW ENGINEER.

Darryl was the co-Project Manager for the Co-Lead bid design of this floating structure (with HNTB) for the Flatiron/Skanska/Traylor team. The existing bridge is the longest floating bridge on Earth at 2300 m (7500 ft.). It carries State Route 520 across Lake Washington from Seattle to Medina, WA.

2009-2010

SOUTHERN REGION BRIDGES, SOUTHERN BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the General Bridge Engineering Services contract to perform engineering work for selected and miscellaneous bridge projects in the Southern Interior Region (2009-2010), including:

St. Mary’s Wycliffe Bridge, Southern BC, Canada. Timber rehab design of the 118 m (387 ft.) multi-span timber truss and trestle. Darryl was the Project Principal for the detailed timber design for abutment/span/pier/deck/component rehab of the bridge

Old Spences Bridge, BC, Canada. Detailed inspection, evaluation and conceptual rehabilitation design for a 232 m (761 ft.) long multi-span bridge. It is composed of five steel deck truss spans and two steel plate girder spans supported on concrete piers and abutments. Darryl was the Project Principal for the project.

Carney Mill Bridge, Salamo, BC, Canada. Detailed timber design for replacement of 24 m Bailey bridge. Darryl was the Project Principal for the design.

	Howser Bridge, Highway 31, Southern Interior, BC, Canada. Preliminary evaluation of timber bridge with damaged glulam girder. Darryl was the Project Principal for the Project.
2008-Present	NORTHERN REGION BRIDGES, NORTHERN BC, CANADA. PROJECT PRINCIPAL.
	Darryl was the Project Principal of the enhanced bridge inspections and evaluations in Northern BC. This assignment consists of detailed inspections of 12 bridges and load rating of three bridges for modern traffic plans. MoTI has requested that the bridges be rated for the 85 tonne load criteria. This project includes tied arch, truss and suspension bridges.
2009	SIERRA YOYO DESAN ROAD, BC, CANADA. PROJECT PRINCIPAL, REVIEW ENGINEER.
	Darryl was the Project Principal, Review Engineer and Structural Design Reviewer for the structural design review of the bridges along the road for the Sierra Yoyo Desan Upgrade.
2007 and 2009	156TH STREET OVERPASS, SURREY, BC, CANADA. PROJECT PRINCIPAL.
	Darryl was the Project Principal for Design-Build project involving the design of two new 38 m (125 ft.) long twin concrete bridges, including retaining walls, to allow the continuation of 156th Street under Highway 1.
2009	TRANS-CANADA TWINNING / ICEFIELDS INTERCHANGE, BANFF NATIONAL PARK, AB, CANADA. OWNER'S REPRESENTATIVE, PROJECT PRINCIPAL.
	COWI was the Owner's Representative, in conjunction with EBA Engineering Consultants, for the development of Design-Build packages for the twinning of the Trans-Canada Highway. Darryl was the Project Principal for provision of reference designs for bridge structures and input for RFP documents, as well as evaluation of proponent submissions.
2009	THELON RIVER BRIDGE, BAKER LAKE - KIGGAVIK NUNAVUT, CANADA. PROJECT PRINCIPAL, REVIEW ENGINEER.
	Darryl was the Principal and Review Engineer for the feasibility assessment of constructing an access road crossing the Thelon River to the Kiggavik Sissons Uranium Mine Project.
2009	KINGCOME BRIDGE, KINGCOME INLET, BC, CANADA. PROJECT PRINCIPAL, REVIEW ENGINEER.
	Darryl was the Project Principal and Review Engineer of the project team which developed structural concepts and cost estimates for a bridge structure over the Kingcome River to the west side of the valley.
2009	BRIDGE LOAD RATING FOR OVERLOAD 3307, REVELSTOKE, BC, CANADA. PROJECT PRINCIPAL.
	Darryl was the Project Principal for the load rating of 21 bridges on Highways 16, 5 and 1 for a heavy load of a thrust block. COWI Bridge was retained to carry out these load capacity evaluations in two phases for the proposed overload.
2008-2009	BC MOT MAJOR STRUCTURES FUNDING ANALYSIS, LOWER MAINLAND, BC, CANADA. PROJECT PRINCIPAL.
	Darryl was the Project Principal for the rehabilitation funding needs analysis to determine the funds required to cost-effectively maintain the Major Bridge Structures in the Lower Mainland such that they remain able to carry all traffic safely and efficiently without an unplanned interruption. The anticipated funding needs were established for a 10-year period in order to support a request for funds from MoT’s Executive and Provincial Treasury Board.
2007-2009	SIMON FRASER BRIDGE, PRINCE GEORGE, BC, CANADA. PROJECT PRINCIPAL.

A two-lane, 400 m (1312 ft.) five-span continuous plate girder composite delta-leg bridge (estimated at $27 M). The new bridge twin of the existing two-lane bridge. Darryl was the Project Principal responsible for setting up the design contract and subconsultant agreements, and for ensuring that the bridge design is managed effectively, which includes effective coordination of the various engineering disciplines (structural, geotechnical, highway, hydraulics and electrical).

2005-2009 WILLIAM R. BENNETT BRIDGE, KELOWNA, BC, CANADA. PROJECT PRINCIPAL AND CO-ENGINEER OF RECORD.

Darryl was the Project Principal and co-Engineer of Record for the design of the Design-Build replacement of the original Okanagan Lake floating bridge. The new crossing is approximately 1060 m (3478 ft.) in length, consisting of: 690 m (2263 ft.) of floating concrete pontoons with an elevated deck; two 54 m (177 ft.) transition spans; and a 277 m (909 ft.) long west approach ramp structure.

2008 ATHABASCA RIVER BRIDGE (PRE-BID), FORT MCMURRAY, AB, CANADA. PROJECT PRINCIPAL.

The bridge will be a 472 m (1549 ft.) long structure with four 61 m (200 ft.) spans and three 76 m (249 ft.) spans. Darryl was the Project Principal for a complete redesign of another firm's design of the structural steelwork in order to reduce the weight of the structural steel due to the Contractor's new, less-demanding erection procedure.

2008 COURTENAY RIVER BRIDGE CROSSING (STUDY), COURTENAY, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for COWI Bridge's work in determining the top three potential sites for the new crossing, with focus on developing bridge concepts for three geometric arrangements. The work involved providing bridge cost estimates for all three selected options.

2008 KINNAIRD BRIDGE, CASTLEGAR, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal of a load capacity evaluation considering the effects of new utilities added on the bridge. Five live load models were considered. Constructed 1965, the bridge has five spans with three centre spans of 80 m (262 ft.) each and two side spans of 62.5 m (205 ft.) each.

2008 IZOK MINE ACCESS ROAD BRIDGES, NUNAVIT, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for development of conceptual designs for approximately 50 bridges on a 300 km (186 mile) long access road from Izok Mine to the Arctic Ocean. Developed designs for several typical bridge spans (30 m (98 ft.), 50 m (164 ft.) and 100 m (328 ft.) spans) to allow more accurate assessment of the types and sizes of bridge components required and of estimated construction costs.

2008 KOREAN GUIDE TO DOUBLE-SKINNED COMPOSITE CONSTRUCTION, KOREA. PROJECT PRINCIPAL, REVIEW ENGINEER.

Darryl was the Project Principal and Review Engineer for input provided to the SCI to write reports to the Korean Hydro and Nuclear Power Company (KHNP) on the KHNP design guidance for double and single Skin Composite construction. COWI Bridge reviewed the draft guide, created recommendations, and checked the IRWST design using Bi-Steel.

2008 LOAD RATING OF SEVEN BRIDGES, ROUTES 16, 3 AND 29, BC, CANADA. PROJECT PRINCIPAL.

Project Principal for load capacity evaluation of seven bridges for the CL1-625 truck or lane load, three 85 tonne permit truck configurations, and a six-axle mobile crane configuration. The bridges consisted of concrete arch, precast prestressed concrete girder, and steel plate girder bridges, ranging from 87 m (285 ft.) to 433 m (1421 ft.).

2008 IsKUT RIVER BRIDGE AND MUSKWIE CREEK CROSSING, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal and Review Engineer of a second opinion on necessity of upgrades to the piers due to insufficient uplift resistance. The assessment consisted of a review of the pile loadings on the centre piers of the two Galore Creek Mine bridges for compliance with the dead and wind loads in S6-00, of the intensity of wind loads required by other standards, and of the effectiveness of designer's proposed mitigation strategies.

2008 JEMSEG RIVER BRIDGE, JEMSEG, NB, CANADA. REVIEW PRINCIPAL.

Darryl was the Review Principal of the settlement issue at abutment A-1 on the Jemseg River Bridge. The Jemseg River Bridge is an eleven-span bridge with a curved alignment and comprises twin composite plate girder structures each carrying two lanes of traffic. It has a maximum span of 140 m (459 ft.) and a total length of 976 m (3202 ft.), making it the second longest bridge on the new Fredericton-Moncton Design-Build Highway Project. Since construction of the A-1 abutment, the west end of the bridge has settled more and faster than anticipated by the geotechnical designers. This has resulted in differential settlement between the A-1 abutment and Pier P-1 in excess of that allowed for in the design.

2007-2008 MORE CANYON BRIDGE, NEAR STEWART, BC, CANADA. PROJECT PRINCIPAL.

As part of the development of the Galore Creek Mine, COWI Bridge completed a design of a 205 m (673 ft.) long truss bridge across the 100 m (328 ft.) deep More Canyon. The design allowed the bridge to be launched from one side. Due to the schedule, the bridge site had no road access, so every piece of the bridge was to be shipped via helicopter. Due to escalating development costs, the project was shelved for one year, however, construction of the access road continued. When the bridge project was revived, there was an access road to the site, so COWI Bridge re-designed the crossing with a more economical 199 m (653 ft.) long arch bridge. The design of the arch reached the 50% stage before the project was again shelved due to the world-wide economic slowdown in 2008. Darryl was the Project Principal for both the design of the three-span steel truss with two inclined piers and the steel thrust arch bridge.

2007-2008 CITY OF PRINCE GEORGE BRIDGES, PRINCE GEORGE, BC, CANADA. PROJECT PRINCIPAL, REVIEW ENGINEER.

Darry was the Project Principal and Review Engineer of inspections and load evaluations for four overpass/ underpass structures in the city: River Road, Cameron Street, Otway, and 15th Avenue Overpasses. These concrete structures ranged in total length from 39 m (128 ft.) to 75 m (246 ft.).

2007 WEASELHEAD FLATS BRIDGE - CALGARY SW RING ROAD (STUDY), CALGARY, AB, CANADA. PROJECT PRINCIPAL, PROJECT MANAGER.

Darryl was the Project Principal and Project Manager for developing five bridge options across the 1200 m (3993 ft.) Weaselhead Flats.

2006 COAST MERIDIAN OVERPASS (PRE-BID), PORT COQUITLAM, BC, CANADA. PROJECT MANAGER.

Darryl was the Project Manager responsible for development of the base design for the Owner for approximately 570 m (1870 ft.) long overpass of railroad tracks that was procured through Design-Build tendering process. This bid design was also for the Bilfinger Berger Design-Build team.

2006 PITT RIVER BRIDGE AND MARY HILL INTERCHANGE (BID DESIGN), VANCOUVER, BC, CANADA. PROJECT PRINCIPAL.

Pre-bid design to replace the existing river crossing and interchange for the Flatiron/Graham team as part of their Design-Build proposal. COWI's bridge design included a main river crossing a 9-steel plate girder arrangement to accommodate seven design lanes of traffic; the superstructure could be readily widened to a future eight-lane configuration by the addition of a 10th girder line. Darryl was the Project Principal for the bid design.

2005 WANETA BRIDGE, WANETA, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for bridge inspection and floorbeam rehabilitation conceptual design. It is a three-span steel truss bridge (cantilever type) with a 76 m (249 ft.) main span. Constructed in 1893, it is one of the oldest bridges the province.

2005 EAST BAY BRIDGE - TEMPORARY BY-PASS, SAN FRANCISCO, CA, USA.

Imbsen & Associates was the designer of the temporary by-pass for the East Bay Bridge Replacement. Darryl assisted I&A with the design of the East tie in portion of the project.

2005 HEATLEY OVERPASS, VANCOUVER, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal responsible for the seismic assessment and retrofit concept design of this 14-span concrete overpass. The geometry of the structure created many different problems in the assessment. The bridge includes a bifurcation point and a tight horizontal curved section. The project involved the preparation of the tender pack-age (design drawings and specifications) and the construction cost estimate.

1989-1991 PEACE RIVER BRIDGE, PEACE RIVER, AB, CANADA. LEAD ANALYST AND FIELD ENGINEER.

Darryl was the Lead Analyst and Field Engineer for the design and analysis of the scheme to erect by launching four continuous plate girders, also on-site during launching. The girders are 4.5 m (15 ft.) deep, 734 m (0.5 mi.) long, with five spans at 112 m (367 ft.), one each at 82 m (269 ft.) and 92 m (302 ft.). The structure comprises 4470 tonnes of steel.

2006 WOODCHUCK BRIDGE, SALMO, BC, CANADA. PRINCIPAL.

Darryl was the Project Principal for inspection of existing expansion joints and conceptual design of expansion joint rehabilitation. The bridge is a precast prestressed concrete girder type, total length of 78 m (256 ft.).

2006 TAGHUM BRIDGE, NELSON, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Principal for inspection of existing expansion joints and conceptual design of expansion joint rehabilitation. The bridge comprises trapezoidal steel girders with 290 m (951 ft.) main span.

2000 ARTHUR RAVENEL JR. BRIDGE, CHARLESTON, SC, USA.

Eight-lane cable-stayed bridge with total length of 3 km (1.9 miles). Six curved ramps, varying in length from 283 m (928 ft.) to 540 m (177 ft.), provide access to the crossing. The majority of the ramps are two-lane structures, and all are curved steel plate girders with a composite concrete deck. Darryl provided internal review and direction for the analysis of six curved composite approach ramps.

2005 BIRCH ISLAND BRIDGE, NEAR CLEARWATER, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for detailed condition inspection and live load evaluation for this approximately 100 m (328 ft.) long bridge. It is composed of two timber trestle spans and two timber Howe truss spans supported on timber pile piers and abutments. Project Principal for the replacement design of the bridge due to severe damage to the centre pier by ice flow. The single lane replacement structure consisted of three continuous spans, two at 30 m (98 ft.) and one at 40 m (131 ft.), supported on two plate girders.

2005 HIGHWAY 63 REALIGNMENT STUDY, FORT MCMURRAY. PROJECT PRINCIPAL.

Darryl was the Project Principal for study to develop conceptual bridge designs for an investigation into reducing congestion at the river crossing in Fort McMurray.

2001 EDMONTON SOUTHWEST TRANSPORT IMPLEMENTATION STUDY, EDMONTON, AB, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for study to develop an implementation strategy for the construction of new bridges and for upgrading the existing bridges in the Southwest quadrant of the city as part of a study to improve the capacity of the transportation network.

2001 FRUITVALE AVENUE BRIDGE, ALAMEDA COUNTY, CA, USA. INDEPENDENT QUALITY ASSURANCE MANAGER.

Darryl was the Independent Quality Assurance Manager for the lifeline seismic retrofit design of the bascule bridge.

2001 CALTRANS, PHASE II RETROFITS, CA, USA. PROJECT MANAGER.

Darryl was the Project Manager for final seismic retrofit design strategy for 22 bridges between Monterey and Santa Barbara. Included were the famous Bixby Creek Arch Bridge and the Cold Spring Canyon Arch Bridge, and six other arch bridges along the Monterey coast.

2005 ENGLISHMAN RIVER BRIDGE, PARKSVILLE, BC, CANADA. PROJECT PRINCIPAL.

The bridge, which spans the 30 m (100 ft.) deep gorge of the Englishman River, is 152 m (497 ft.) long. Darryl was the Project Principal for the site investigation and seismic assessment.

2001 SAN LUIS OBISPO CREEK BRIDGE, SAN LUIS OBISPO, CA, USA. PROJECT PRINCIPAL.

Darryl was the Project Principal for the provision of construction services for the seismic retrofit of this bridge.

2004 PETITCODIAC BRIDGE, NB, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal to develop, analyze, check and draw up an erection scheme for this 320 m (1050 ft.) long bridge.

2002-2003 EEL RIVER BRIDGE, WOODSTOCK, NB, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal of erection engineering for the girders including the design of stability truss for three span continuous twin steel girder bridges. The South Structure spans are 56 m (184 ft.), 80 m (262 ft.), and 80 m (262 ft.). The North Structure spans are 60 m (197 ft.), 90 m (295 ft.), and 75 m (246 ft.).

2008 SALMON RIVER PIPELINE BRIDGE, NEAR PRINCE GEORGE, BC, CANADA. REVIEW ENGINEER.

Darryl was the Review Engineer for feasibility level bridge design for a pipeline bridge across the Salmon River. The work involved providing a preliminary erection scheme, quantities and a cost estimate for the bridge.

2007 NORTH SASKATCHEWAN RIVER (ENBRIDGE) PIPELINE CROSSING, AB, CANADA. REVIEW ENGINEER.

Darryl was the Review Engineer for assistance with assessment of a bridge option to carry pipelines for the Enbridge Stonefell Merchant Terminal Access Project across the North Saskatchewan River. The scope of the work included development of a conceptual design for a 300 m (984 ft.) suspension bridge, and associated construction costs and schedule.

KOOTENAY RIVER CROSSINGS, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for an engineering assessment of the vibration of the Kootenay River Highway Bridge at Creston, which holds a natural gas pipeline. In addition, the Kootenay River crossing at Shoreacres and Columbia River crossing at Castlegar, which are cable-supported aerial pipelines, were assessed to develop a scope and construction cost estimates for refurbishment. 2005.

BC SOUTHERN CROSSING PROJECT, KETTLE RIVER AERIAL CROSSINGS, GRAND FORKS, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for inspection vehicle evaluation for 303 km (188 miles) of 610 mm gas pipeline from Yahk to Oliver.

VANCOUVER ISLAND GAS PIPELINE BRIDGES, BC, CANADA. LEAD ANALYST.

Darryl was the Lead Analyst for the design and analysis of four gas line suspension bridges for BC Gas.

TRANSMISSION AERIAL PIPELINE CROSSINGS FOR DUKE ENERGY, BETWEEN TAYLOR AND AGASSIZ, BC, CANADA. PROJECT PRINCIPAL.

Darryl was the Project Principal for engineering support, technical advice and leadership for inspection of seven pipeline crossings and design of remedial work. Two of the crossings have pipe supported by a highway bridge, while the other five crossings are aerial suspension bridge type structures.

1991 PEACE RIVER BRIDGE, PEACE RIVER, AB, CANADA. SITE ENGINEER.

Darryl was the Site Engineer during launching of 4.5 m (15 ft.) deep plate girders.

1990 HAGWILGET SUSPENSION BRIDGE, HAZELTON, BC, CANADA. SITE ENGINEER.

Darryl was the Site Engineer for deck replacement during night closures of the 140 m (459 ft.) long suspended span and the 56 m (184 ft.) long approaches.

AWARDS AND RECOGNITION

2004 THE JOHN HENRY GARROOD KING MEDAL.

(British) Institution of Civil Engineers, for paper co-authored with Peter Buckland on "The reconstructed Lions Gate Bridge", awarded for the best paper of the year on bridges, tunnels or soil mechanics.

2003 AWARD FOR ENGINEERING ACHIEVEMENT FOR THE CANADIAN COUNCIL OF ENGINEERS.

COWI Bridge received the Award for Engineering Achievement for the Canadian Council of Engineers for its work on the rehabilitation of the Lions Gate Bridge.

2002 CANADIAN INSTITUTE OF STEEL CONSTRUCTION'S KRENTZ AWARD.

COWI Bridge was presented with the Canadian Institute of Steel Construction's Krentz Award for the innovative rehabilitation of the Lions Gate Bridge.

2002 2002 SCHREYER AWARD.

The Association of Consulting Engineers of Canada presented the 2002 Schreyer Award, Canada's highest honour for Consulting Engineers, to COWI Bridge for the Lions Gate Bridge Deck Replacement.

2002 2002 GEORGE S. RICHARDSON MEDALOK.

COWI Bridge was one the recipients of the 2002 George S. Richardson Medal. The Lions Gate Bridge Renovation was selected to receive this prestigious prize, which is awarded for a single recent outstanding achievement.

2002 LIEUTENANT GOVERNOR'S AWARD OF EXCELLENCE.

COWI Bridge was selected by the Consulting Engineers of British Columbia (CEBC) to receive the prestigious Lieutenant Governor's Award of Excellence for the design of the replacement of the entire suspended span of Lions Gate Bridge. The project also won an Award of Excellence.

1999 CELSOC ENGINEERING EXCELLENCE AWARD OF MERIT.

CELSOC Engineering Excellence Award of Merit was awarded to COWI Bridge for the Cold Spring Canyon and Arroyo Quemado Arch Bridges Project.

1999 ACEC ENGINEERING EXCELLENCE HONOR AWARD.

COWI Bridge was awarded an ACEC Engineering Excellence Honor Award for the Cold Spring Canyon and Arroyo Quemado Arch Bridges Project.

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Matson, D.D. 2000: Lions Gate Suspension Bridge Deck and Stiffening Truss Replacement, International Bridge Conference 2000, 2000 June 12-14.

Frank, Manfred, Matson, Darryl. 2000: Lions Gate Suspension Bridge Fabrication of Replacement Deck Sections, International Bridge Conference 2000, Engineers Society of Western Pennsylvania, 2000 June 12-14.

Matson, Darryl, Queen, David and Buckland, Peter. 1999: Restoring the Lions Gate: Preserving Vancouver's Heritage Landmark, Innovation - Journal of the Association of Professional Engineers and Geoscientists of BC, May 1999.

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Benoit, J.M., Matson, D.D., Sobash, V. 1996: Buckling Considerations for Cold Spring Canyon Arch Bridge, U.C. Berkeley Conference, November 1996.

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Matson, D.D., Taylor, P.R. 1995: Experience with Seismic Retrofit of Major Bridges, IABSE Symposium, San Francisco, 1995.

Appendix H A. Murray MacKay Bridge Feasibility Study

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HALIFAX HARBOUR BRIDGES

A. MURRAY MACKAY BRIDGE FEASIBILITY STUDY

REHABILITATE OR REPLACE

REGISTERED PROFESSIONAL ENGINEER
DATE 2020 Nov. 6
E. E. Redmond
9091
PROVINCE OF NOVA SCOTIA

PROJECT NO.	DOCUMENT NO.
A102894	A102894-REP-AMM COWI Feasibility Report

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
0	2020 Nov. 06	Report	JOLV/JGPR/DNMC	DURC/DDM	EER

Executive Summary

The A. Murray MacKay Bridge opened to traffic in 1970 and the deck system is approaching the end of its service life, driven by predicted fatigue failure of the orthotropic deck system. Halifax Harbour Bridges (HHB) are exploring options to rehabilitate or replace the MacKay Bridge.

HHB retained COWI to complete this feasibility study with a mandate to generate and evaluate options. COWI was to provide HHB with a report summarizing the assessment and additional details regarding two preferred options moving forward; one for a rehabilitation approach and another for a replacement approach.

This report presents nine options based on these two categories of solutions (rehabilitate versus replace), and evaluates all options, using a scoring system, against criteria developed with HHB's Steering Committee. Following the evaluation, risk mitigation measures are discussed for the two highest scoring options.

The highest scoring rehabilitation option involves rehabilitation of the existing bridge, keeping the four existing traffic lanes and adding two Active Transportation lanes (pedestrian/cyclist lanes). The rehabilitation of the bridge includes reinforcement of the towers, cable bents, approach spans piers, supplementing the main cables, and replacement of the approach spans and suspended spans superstructures with wider decks.

The overall preferred option and highest scoring replacement option is to replace the existing bridge with six traffic lanes and two Active Transportation lanes, likely a 500 m long main span cable-stayed bridge, on an alignment parallel to the existing bridge along its north side. The existing bridge would then be demolished. This option would require some property acquisition and relocation of the Canada Food Inspection Agency building in Dartmouth adjacent to the existing bridge.

Due to the complexity of the rehabilitation and replacement options outlined in this report, eight to ten years or more will likely be required from initiation of the planning, preliminary design to opening the bridge to traffic.

CONTENTS

APPENDICES

1 Intention of the Feasibility Study

Halifax Harbour Bridges (HHB) requested a study of solutions to address the future needs of the A. Murray MacKay (MacKay) Bridge that crosses Halifax Harbour in Nova Scotia.

The study considers two options: rehabilitate the existing structure or construct a replacement bridge in its place. For the rehabilitation options, increasing the vehicle capacity by adding lanes and providing active transportation options such as sidewalks and bicycle lanes were considered. For the replacement bridge options, various structural forms were assessed, as were the number of lanes and alternative transportation options.

HHB's requested outcome of the Feasibility study was for COWI to define two options: highest scoring rehabilitation and highest scoring replacement, concluding with an overall preferred option.

The service life considerations for the options range from 75 years to 100 years for rehabilitation and replacement design respectively. For context, 100 years ago the crossing of the Halifax Harbour was by ferry only as the previous two bridges had been swept away. The City itself was a significantly different environment with different traffic patterns, demands and functionality. This feasibility study assesses the requirements of the MacKay Bridge throughout its service life, understanding from the past that this may be considerably different from the current needs.

There were two governing elements in carrying out the work:

- Addressing the efficient structural design of the existing bridge (which does not leave a great deal of reserve capacity for future retrofits), particularly in light of the increases in design traffic loadings that have occurred since the construction of the bridge; and
- Geometric and construction method challenges associated with locating a replacement bridge adjacent to the existing one.

Regardless of the structural solution, this study also considered the need for additional capacity of the crossing for future traffic demand, which could include lanes for dedicated transit operation and active transportation. The inclusion of sustainable modes of transportation consider HRM's planning and policy documents including the Integrated Mobility Plan and the Active Transportation Priorities Plan.

The scope of this study does not consider tunnel alternatives or sites away from the current MacKay Bridge.

1.1 Project Background

The MacKay Bridge opened to traffic in 1970 and is approaching the end of its service life. Details used in the original design, particularly those in the orthotropic deck, have led to earlier than anticipated fatigue issues that will not be easily repaired. HHB expects the MacKay Bridge would require significant rehabilitation work between 2030 and 2040 if it were to continue safely carry traffic, primarily because of the flexible deck system and associated fatigue vulnerabilities, and the amount of work required is expected to grow every year the bridge remains open beyond 2033.

HHB is exploring options to rehabilitate or replace the MacKay Bridge and has retained COWI North America Ltd. (COWI) to conduct this Feasibility Study of options to provide a crossing with allowance for future traffic demands. COWI's team includes CBCL Ltd. and Singleton Environmental Consulting (SEC). CBCL defined roadway alignments, analyzed traffic data, and provided recommendations relating to the approach roadways and ancillary structures. SEC advised on permitting and environmental considerations. COWI's team worked with HHB on the option selection strategy, as well as the development of key desired criteria.

The initial stage of this Feasibility Study involved assembling and reviewing available information including drawings, various reports, and publicly available information. COWI summarized the findings from the initial phase of this Feasibility Study in a Briefing Report [1], dated 2018 Jan 19.

1.2 Challenges Facing the Existing Bridge

This section summarizes many of the challenges associated with extending the life of the existing MacKay Bridge and provides some of the context for why HHB is undertaking this feasibility study. For further details and additional background information, please refer to the Briefing Report [1].

- Suspended spans deck plates are significantly thinner than current codes allow, resulting in excessive deflections (strains) with truck passage and associated fatigue issues;

- Many of the stiffening truss elements in the suspended spans likely require strengthening to meet current standards: the truss diagonals and bottom chords are at their capacity, and the top truss chords would need to be carefully evaluated and strengthening is likely. Strengthening these elements would require additional weight be added to the bridge, for which there is no current capacity. This in turn can create a cycle of strengthening elements to support the strengthening components

- When considering rehabilitation options, it is not practical or cost effective to strengthen the existing orthotropic deck system due to the details of the existing design, and therefore, rehabilitation options are only practical if the suspended span superstructure of the bridge is replaced. Since a replacement suspended span would be significantly heavier than the existing superstructure (due primarily to the added deck plate thickness and larger trusses), it is highly likely that the main cables would need to be supplemented with additional strands, and the towers and bents would also require significant strengthening;

- Previous inspections have found corrosion throughout the structure, both in the suspended spans and the approaches. These locations include the orthotropic deck plate top surface, main cable strands, and the top flanges of the approach box girders. The corrosion observed in some of these locations is significant, and significantly more than would typically be observed on a 50 year old bridge. Substantial maintenance would be needed in the future to extend the life of the bridge;

- Main cable inspections have confirmed the presence of moisture within the cable bundle, up to Stage 4 corrosion (NCHRP scale) on strand wires, and some broken wires. To limit future deterioration of the steel, cable dehumidification would be recommended to extend the life of the main cables if they are kept in service;

- Tower foundations would need to be evaluated for increased loads including possible impact by Panamax/Post-Panamax vessels;

- Raising the deck to achieve increased navigational channel clearance would be limited by the distance between the deck and main cables; and

- Deck widening to add additional traffic lanes would be difficult due to the configuration of the stiffening trusses and cable bents. Active Transportation (AT) lanes are feasible as they can deviate around the towers and cable bents.

1.3 Path Forward

To assist in the future planning process and to engage critical stakeholders in the early stages of the project, HHB formed a Steering Committee comprising personnel from HHB, Halifax Regional Municipality (HRM) and Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR).

During the development of this Feasibility Report, COWI met with the Steering Committee to identify HHB's requirements for the crossing. Two major options identified to achieve HHB's requirements and studied in this report include:

- Option 1: Rehabilitate the existing bridge to solve its already known deficiencies and extend its design life by 75 years, with options including widening the deck and adding AT lanes.

- Option 2: Replace the existing bridge with a new bridge which has a 100 year design life, with options considering bridge form (cable-stayed or suspension), main span length (500 m or 800 m), and lane configuration (four or six lane options, with and without AT lanes).

This report presents nine options, highlights the reasoning and assumptions behind the proposed alignments and options for rehabilitation and replacement, and provides an evaluation and comparison matrix among options based on a multi-criteria assessment. The highest scoring rehabilitation option and replacement option are summarized, allowing HHB to narrow the focus for future evaluations. In addition, the overall preferred option is discussed.

2 HHB Desired Key Features

HHB's Steering Committee has defined key features for incorporation into the rehabilitated or replacement design, if possible. These features represent HHB's desires for the final product but are not required design criteria. The flexibility of a new design to incorporate some of these features versus rehabilitation differs significantly and not all options in this study incorporate all of the features.

To evaluate the differences in the features and their importance for each option, COWI performed a multi-criteria assessment (see Section 4), which assigned an importance factor to each feature, and evaluated each option based on the criteria.

HHB's preferred design features are listed below:

- Six traffic lanes
  - To provide HHB with the flexibility to accommodate changing traffic demands during the Bridge's design life, HHB's Steering Committee requested that both rehabilitation and replacement options consider six traffic lanes. Each direction (eastbound/westbound) would have two regular travel lanes, and one reserve lane for emergency/demand management/HOV/Transit. For comparison, two four lane configurations with no reserve lane have also been considered.

- Two Active Transportation (AT) lanes
  - All widening or new six lane options incorporate two active transportation lanes for pedestrian and cyclist traffic. This study assumes the AT lanes to be 3.0 m wide to accommodate flexibility of a shared use path in the future or maintenance vehicle access. For comparison, the two four lane options do not include AT lanes.

- Increased navigation channel vertical clearance
  - The study assumes a desirable increase of vertical clearance of 10 m compared to the existing bridge, measured from high-high water level (HHWL) to underside of the deck truss, at the edges of the 110 m wide navigation channel.
  - The 10 m increase in vertical clearance is based on Halifax Port Authority's request to increase the navigation channel vertical clearance by 8 m and forecasted potential sea level rise of 2 m over the next 100 years (based on 2014 DFO estimates for a high sea level rise scenario based on IPCC AR5 RCP8.5).

- Increased navigation channel horizontal clearance
  - Although there is no indication that the available width of the navigation channel requires widening, the study investigates the possibility of locating the piers out of the water, eliminating potential for ship collision and any restraint for potential future widening of the navigation channel.

- Continued use of approach roads
  - To minimize the impact on the traffic and communities near the bridge, design options should prioritize the use of the existing approach roads rather than demolition of existing, and construction of new roads on similar alignments.

- HHB land ownership
  - HHB owns a limited amount of land near the existing MacKay Bridge. Design options minimizing the necessity of acquiring new land would be preferred.

- Integration with municipal, provincial and federal planning.
  - The design options for the MacKay crossing should be consistent with all current planning strategies within the various levels of government.
  - The MacKay Bridge is located in an urban environment, with adjacent land use already defined. Design options minimizing the necessity of modifying the use of land would be preferred.

- Extended design life
  - Rehabilitation options would continue to use the existing towers and bents, as well as other substructure elements. Therefore, the design life requirement for the rehabilitation options is 75 years (which is in line with the Canadian Highway Bridge Design Code CAN/CSA S6). However, in order to address current deck fatigue concerns and to minimize future maintenance costs or potential durability problems, this study assumes the full replacement of the superstructure in the suspended spans.
  - All new design options must provide an extended design life of 100 years.

- Capacity for future traffic growth (widening) beyond six traffic lanes
  - HHB's Steering Committee has not identified this as a necessity; HRM and NSTIR's current planning does not indicate an intention to widen the adjacent infrastructure (Highway 111, Robie Street, Barrington Street and the Bedford Highway) as these are undesirable locations to add capacity. The design options do not contemplate future widening possibilities beyond six traffic lanes and two AT lanes. Future studies or preliminary design may need to accommodate changes to the surrounding roadway uses.

- Enhanced Inspection and Maintenance Access
  - HHB would operate and maintain a new crossing and all design options must consider safe and easy hands on access to all parts of the structure.

3 Bridge Options

3.1 Development

Refinement of the rehabilitation and replacement options was undertaken by assessing various design characteristics with consideration given to HHB's noted key features, which included:

- Roadway and bridge deck cross section
  - Lane geometry
  - Lane use
  - Shoulder and median geometry

- Alignment (replacement options only)
  - Horizontal alignment
  - Vertical alignment

- Location of piers in the water (main span length - replacement options only)
  - 500 m
  - 800 m

- Bridge form (replacement options only)
  - Cable-stayed bridge
  - Suspension bridge

After an assessment of the desired bridge features and the above listed design characteristics for the new and rehabilitated crossings, the number of options considered in this study was shortlisted to seven:

- Option 1 – Rehabilitate the Existing Bridge
  - Option 1A - Rehabilitate - No added features – 4 lane
  - Option 1B - Rehabilitate - Add two AT lanes – 4 lane + AT
  - Option 1C - Rehabilitate and twin the existing bridge – 6 lane + AT

- Option 2 – Replacement
  - Option 2A - New 500 m main span - 6 lane + AT - cable-stayed bridge
  - Option 2B - New 500 m main span - 6 lane + AT - suspension bridge
  - Option 2C - New 800 m main span - 6 lane + AT - cable-stayed bridge
  - Option 2D - New 800 m main span - 6 lane + AT - suspension bridge
  - Option 2E - New 500 m main span - 4 lane - cable-stayed bridge
  - Option 2F - New 500 m main span - 4 lane – suspension bridge

3.2 Characteristics Assessed

Each rehabilitation and replacement option was evaluated based on a wide variety of characteristics, utilizing a matrix approach that is further described in Section 4.

Table 1 describes the characteristics assessed for this study and references the relevant appendices where discussions are provided for each of the items listed. The discussions in these appendices provide the context and justification for the evaluation of the various options. A summary of each option with regards to these characteristics is provided Section 0.

Table 1: Option Characteristics

Characteristic		**Appendix**
Alignment	Three alignments were assessed for their impact on land and infrastructure, as well as suitability for the horizontal and vertical alignment for the replacement bridge. The criteria used was also based on providing adequate clearance from the existing bridge, allowing construction to proceed while maintaining traffic flow and minimizing impact on the adjacent land. Three horizontal alignments were considered for the replacement options. › **Alignment 1:** immediately north of the existing bridge and south (or over) the Canadian Food Inspection Agency (CFIA) building. › **Alignment 2:** north of the CFIA building. › **Alignment 3:** immediately south of the existing bridge For the rehabilitation options, the vertical navigational clearance can be increased by about 1 - 4 m depending on the configuration of the trusses and deck. The vertical alignment for all replacement options would increase the navigational channel vertical clearance by 10 m. This allows 8 m for increased heights of commercial vessels and 2 m for sea level rise.	A

Characteristic		Appendix
Cross Section	The current MacKay Bridge has four traffic lanes and no sidewalks or bike lanes. The roadway can feel narrow due to the narrow outside shoulders and a lack of centre separation between lanes of opposing traffic. For the rehabilitation options, the width of the deck is limited by the clear width between the existing tower legs. The result of this is that options 1A and 1B retain the current four lanes and narrow shoulders. Option 1B sees the addition of AT lanes, which would be cantilevered around the tower and cable bent legs. For the twinned bridge option (1C), the existing bridge would provide three lanes of Dartmouth bound traffic and one AT lane, while the new bridge immediately adjacent would provide three Halifax bound lanes and one AT lane. Replacement bridge options 2A-2D comprise three traffic lanes per direction with vehicles separated by a rigid median barrier. Two AT lanes would also be included in the design. Replacement bridge options 2E and 2F comprise of two traffic lanes per direction with vehicles separated by a rigid median barrier and no AT lanes.	B
Impact to Traffic	The intersections examined as part of the analyses are: • Bedford Highway and Windsor Street interchange (signalized); • Kempt Road and Lady Hammond Road (signalized); • MacKay Bridge toll booths.	C

Characteristic		Appendix
	In general, under existing traffic levels, the intersections show poor Levels of Service (LOS) (E and F) on many of the approaches during the AM peak period when the majority of the traffic is inbound to Halifax. During the PM peak period, conditions are generally better at the two signalized intersections, however there are still some approaches that show poor LOS (E). For bridge operation, it is important to note that the presence of the toll booths currently causes some delays and congestion as all vehicles are required to slow down for the barrier control. Looking at the impacts of the estimated future traffic volumes, most of the intersection approaches are now at LOS F during the AM peak period. The PM period also shows a deterioration in LOS and an increase in queue lengths showing more LOS E and a few LOS F on some of the approaches. These results are the same for all future bridge options as HRM and NSTIR have indicated that they do not have any planned changes to the lane configurations at either of the intersections analyzed. As this is a high-level analysis and the project is still in the early stages of planning, we recommend that a detailed transportation impact analysis is undertaken once the preferred option has been selected.	
Land Use	The construction of a replacement bridge on land not presently owned by HHB would present some challenges. These include: › The need to acquire the required land and/or buildings, most of which are occupied by the Federal Government. › Impact to urban planning, with potential changes in land use, such as Africville or the Wallace Heights Residential Area.	D

Characteristic		Appendix
	› Conflict with HRM's intended planning and land use due to realignment of roads or use of lands not presently intended for a harbour crossing.	
Ancillary Structures	The rehabilitation and replacement options studied have minimal impact on the existing alignment of approach roads, and the locations of the existing ancillary structures would remain unchanged. 2016 and 2017 inspection reports for the ancillary structures owned by HHB were reviewed. The elements inspected during those years were limited but the general condition of the structures appeared fair with typical maintenance items (i.e. joints and bearings) requiring work along with some various locations of deteriorated concrete. The development of future AT lanes needs to be considered, and accommodation of these lanes would not necessarily be required at the ancillary structure locations; this would depend upon the planning of the AT network. The proposed alignment options are well suited to re-use the existing structures to accommodate six lanes of traffic. The does not apply to Princess Margaret Overpass where the structure would have to be widened or replaced to accommodate additional lanes. Considering the minimal impact the studied options have on the use of the ancillary structures, it is reasonable to conclude that HHB should continue its current maintenance program to, assumingly, prolong the life of these structures as much as possible. The exception, as discussed, is Princess Margaret Overpass for which only safety repairs could be completed considering potential future replacement.	E
Marine Structures	The impact of a replacement bridge on the Halifax shoreline would be relatively minor. New piers could be located near the shoreline and would not affect the navigational channel.	F

Characteristic		Appendix
	On the Dartmouth side, options 1A and 2B would have limited impact except for the land associated with construction of the ship collision mitigation (if required). Construction of a twinned or replacement bridge of similar length (options 1C, 2A,2B, 2E and 2F) would result in a new tower being constructed adjacent to the existing. This results in a potential impact to the marine structures of DFO and the Coast Guard.	
Environmental Permitting	Halifax Harbour is one of the most economically important inlets on the Eastern Seaboard. Any large infrastructure project including the rehabilitation or replacement of the MacKay Bridge is likely to impact many stakeholders and therefore be regulated under a number of federal, provincial and municipal laws requiring permits and approvals be issued prior to the work commencing.	G
Rehabilitated Bridge Design	It is expected that the existing bridge would require significant effort to provide reinforcing or replacement of components. A new deck system would be required as the current orthotropic deck plate is significantly thinner and therefore more flexible than permitted by current code requirements. Due to the interconnectivity of the deck and stiffening truss, the new deck necessitates a new stiffening truss. These components would be heavier than the current system. Due to the added weight, it is anticipated that additional components in both the suspended spans and approach spans would require reinforcing. In the suspended spans, main cables would require strengthening and it is likely that the tower and cable bents would need reinforcing (this study did not formally assess these elements but based on engineering judgement it is highly likely that they will be inadequate without strengthening).	H

Characteristic		Appendix
	To achieve the required design life, this study assumes that the approach superstructure would need to be replaced based on its current condition. Rehabilitating the existing structure would have an impact on traffic and would involve more than simply the addition or removal of components. In particular, suspended spans main cable, deck system, and approach spans superstructure replacement would require the roadway to be closed for significant periods during the rehabilitation process. For the twinning option, an additional bridge would be constructed adjacent to the existing with traffic being shared between the two bridges in the final condition. In the twinning option, the rehabilitation of the existing bridge would be simplified as the twinned bridge would be constructed first and would carry all the traffic demands during rehabilitation of the existing.	
Replacement Bridge Design	Two design approaches were explored for the replacement options: keeping the main span length similar to that of the existing bridge and increasing the main span so that tower piers are not required in the waterway. This resulted in approximately 500 m and 800 m main spans respectively. Cable-stayed and suspension bridge design options were assessed, with economic and design benefits associated with each depending on the span lengths considered. Replacement bridge construction allows the bridge to be built alongside the existing bridge, resulting in limited traffic interruptions. New construction would have its own challenges, generally related to access to the site around an active roadway.	I

3.4 Summary Sheets

The following sections describe the options and provide an opinion on their life-cycle costs, constructability, and how each option addresses HHB's desired features.

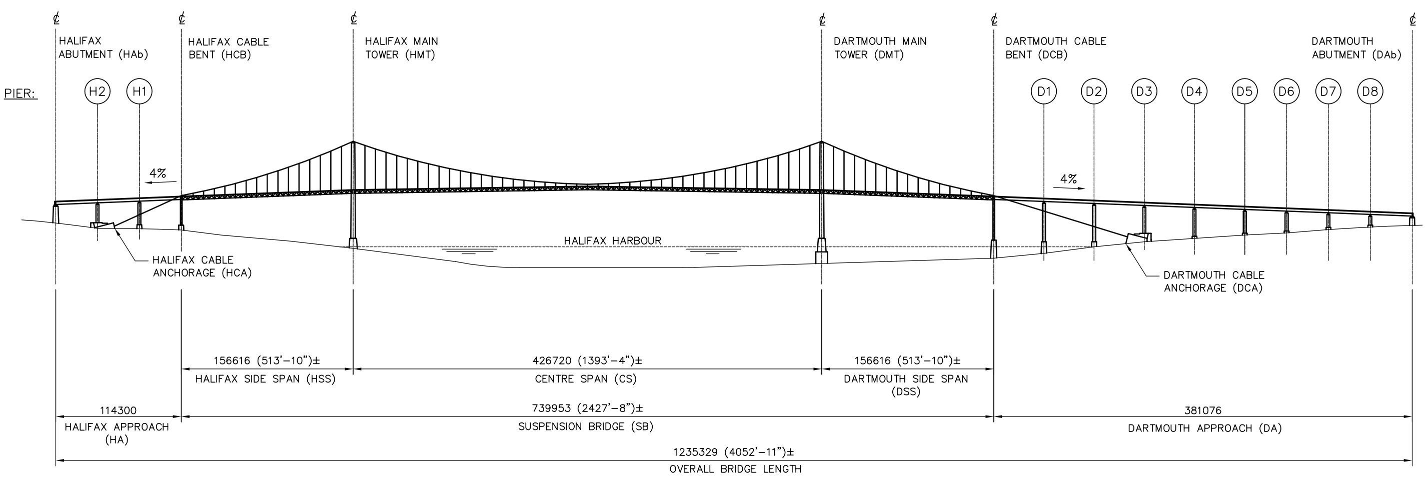
Each of the seven options evaluated within this study are presented in the following pages and described in regards to the following characteristics:

- Design features
- Challenges
- Main span cross section and lane designations
- Tower geometry
- Rehabilitation and/or twinning sequence
- Costs over the life of the bridge
- Constructability and traffic impact
- Environmental permitting

OPTION 1A

REHABILITATED BRIDGE

- Lowest cost rehabilitated bridge
- Maintain existing alignment
- Limited key features achieved



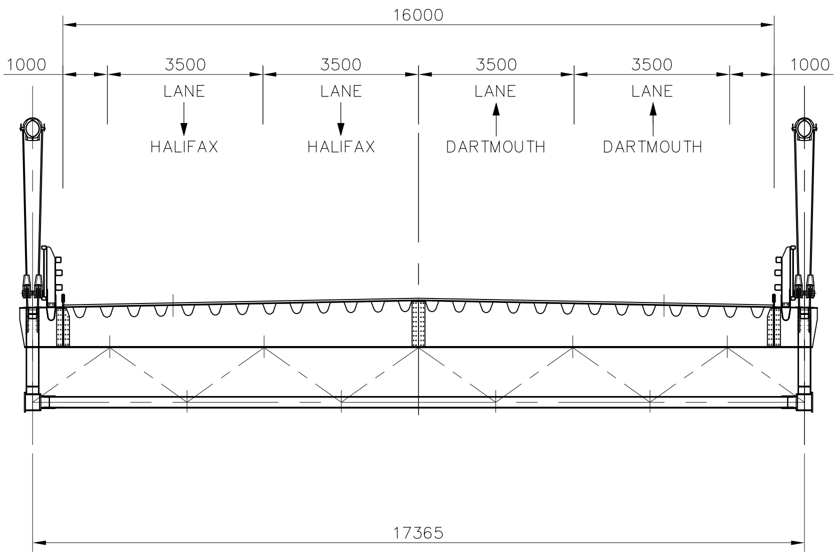
DESIGN FEATURES

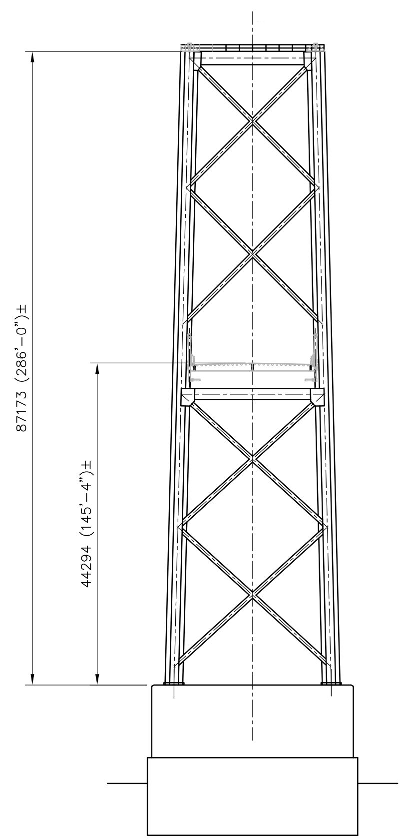
- Increased vertical navigational clearance by 1 to 4 m
- Reuse of existing approach roadways
- Improved inspection and maintenance access
- No change in alignment
- Minimal impact on adjacent properties and land acquisition requirements
- Familiar aesthetic looks
- New approach spans

CHALLENGES

- Significant costs for limited gain in features
- Challenging structure to rehabilitate while maintaining traffic
- 75 year design life
- Main cables to be replaced, or additional cables added
- No additional AT lanes
- Bridge continues to use present lane configuration with narrow shoulders
- Significant impact to travelling public due to lengthy road closures

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 1A TOWER

REHABILITATION AND TWINNING SEQUENCE

- Strengthen foundations, towers and piers on suspended spans and approach spans
- Modify cable anchorages and install new tower saddles
- Install new or supplementary cables
- Replace suspended spans deck system
- Replace approach spans deck system

COST

Direct Construction	$	522,000,000
Owner's Construction	$	151,000,000
Lifecycle Maintenance	$	169,000,000
Total Cost	**$**	**840,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The existing bridge would be rehabilitated, resulting in numerous length traffic interruptions, likely more extensive than Macdonald.

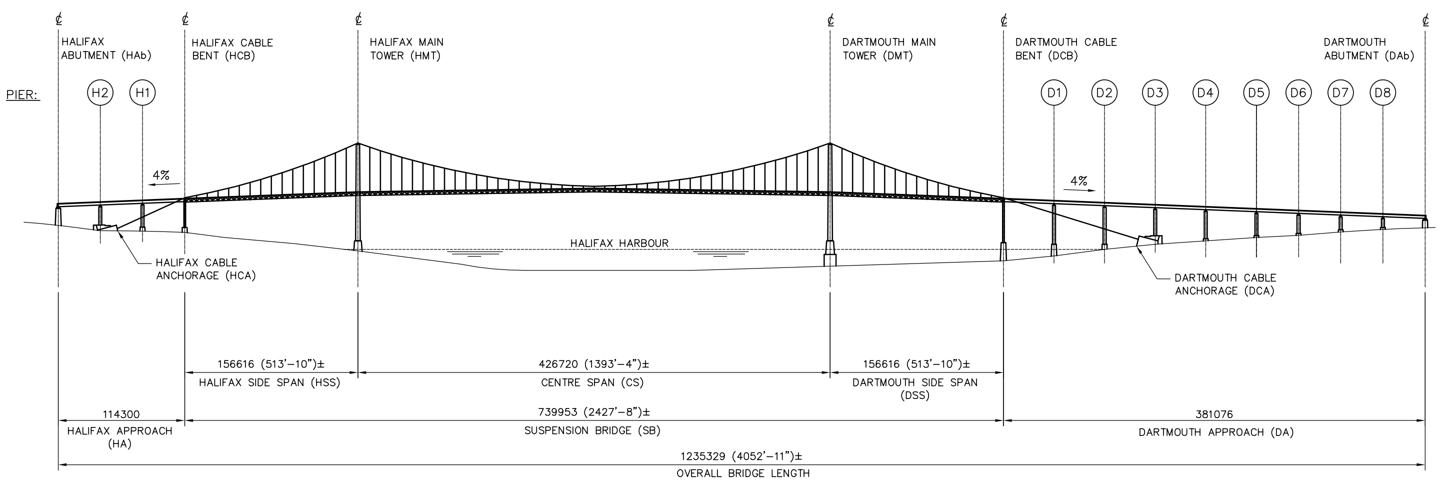
ENVIRONMENTAL PERMITTING

Rehabilitation work on piers in the water will require Navigational Protection Act Approval, and a Project Description for HPA and PSPC. An Environmental Assessment under CEAA 2012 is unlikely to be required.

OPTION 1B

REHABILITATED BRIDGE WITH AT LANES

- Lowest cost rehabilitated bridge with AT lanes
- Maintain existing alignment
- Familiar silhouette



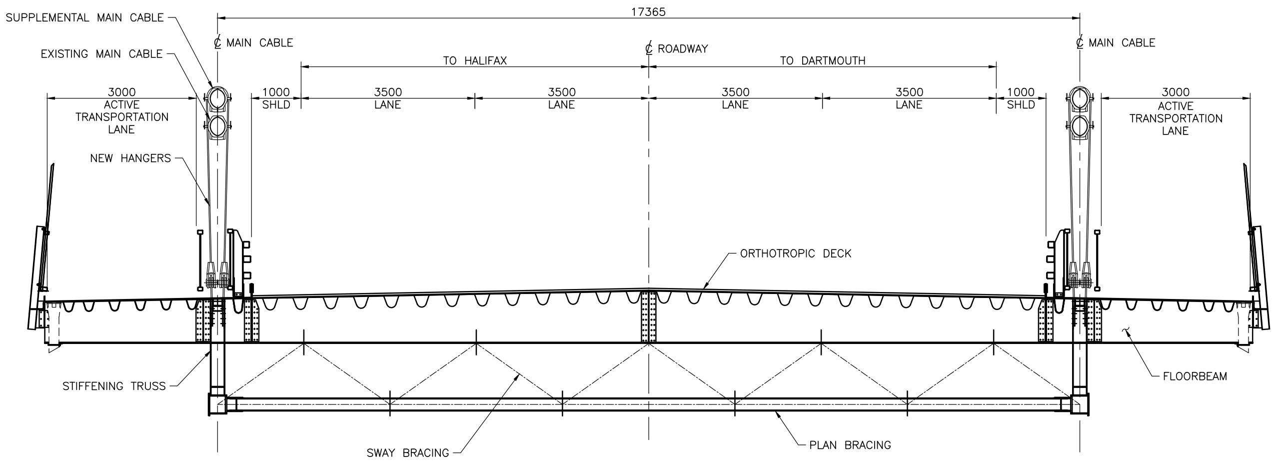
DESIGN FEATURES

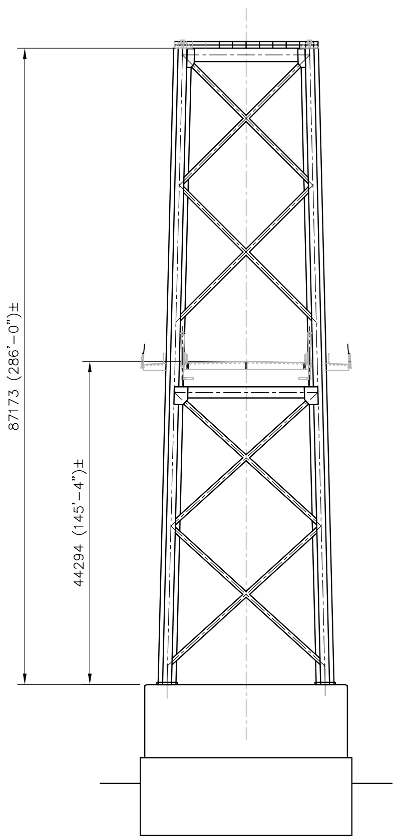
- Two AT lanes
- Increased vertical navigational clearance by 1 to 4 m
- Reuse of existing approach roadways
- Improved inspection and maintenance access
- No change in alignment
- Minimal impact on adjacent properties
- New approach spans

CHALLENGES

- 75 year design life
- Bridge continues to use present lane configuration with narrow shoulders
- Minor land acquisition required for AT lane tie-ins
- Challenging structure to rehabilitate while maintaining traffic
- Main cables require replacement or supplementing
- Significant impact to travelling public due to lengthy road closures
- More significant than Option 1A due to the added weight of the AT lanes

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 1B TOWER

REHABILITATION SEQUENCE

- Strengthen foundations, towers and piers on suspended spans and approach spans
- Modify cable anchorages and install new tower saddles
- Install new or supplementary cables
- Replace suspended spans deck system
- Replace approach spans deck system
- Install cantilevered AT lanes along the outsides of the new deck system and around the towers

COST

Direct Construction	$	594,000,000
Owner's Construction	$	172,000,000
Lifecycle Maintenance	$	203,000,000
Total Cost	**$**	**970,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The existing bridge would be rehabilitated, resulting in numerous length traffic interruptions, likely more extensive than Macdonald.

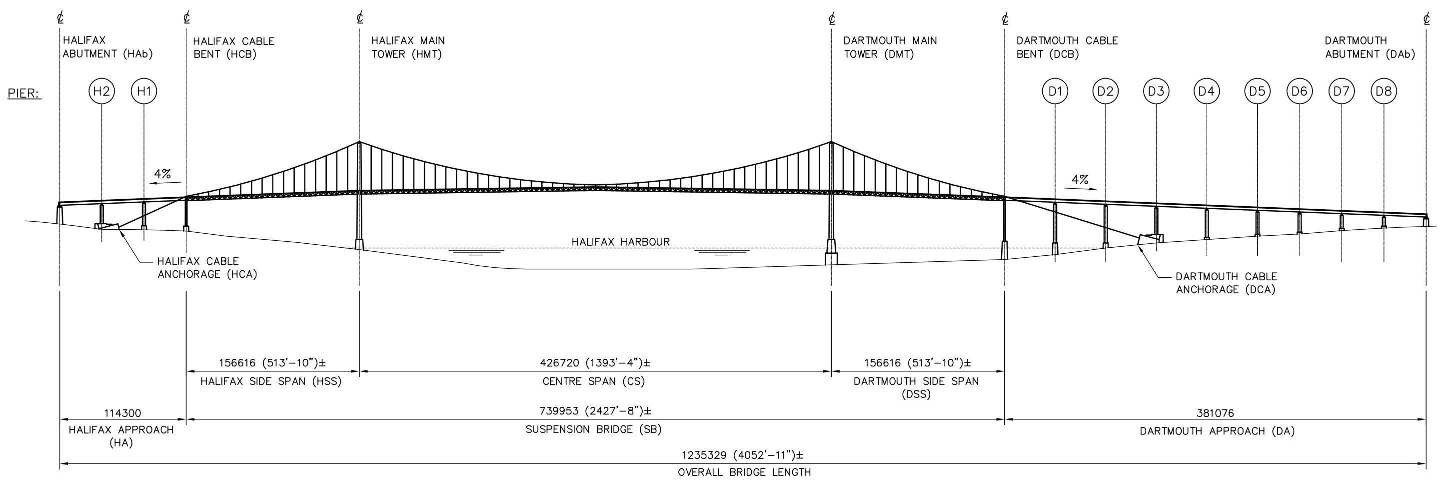
ENVIRONMENTAL PERMITTING

Rehabilitation work on piers in the water will require Navigational Protection Act Approval, and a Project Description for HPA and PSPC. An Environmental Assessment under CEAA 2012 is unlikely to be required.

OPTION 1C

REHABILITATED AND TWINNED BRIDGE

- Highest cost rehabilitated bridge option
- Maintain continuous traffic throughout construction
- Familiar silhouette (assumes suspension twin)



DESIGN FEATURES

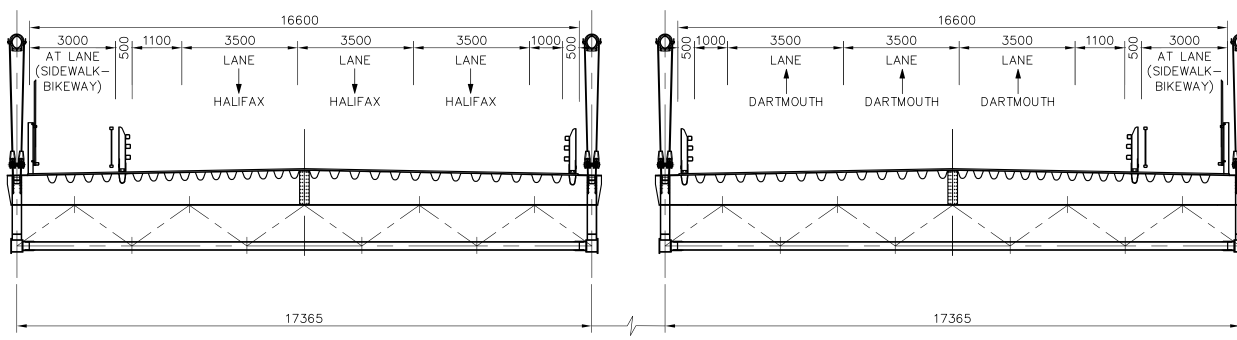
- 75-100 year design life
- Bridge acts as an arterial roadway based on lane and shoulder design
- Two AT lanes
- Increased vertical navigational clearance by 1 m to 4 m
- Capacity for flexible lane designations
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction
- Rehabilitation of existing bridge simplified because traffic can be moved to new 'twin' bridge

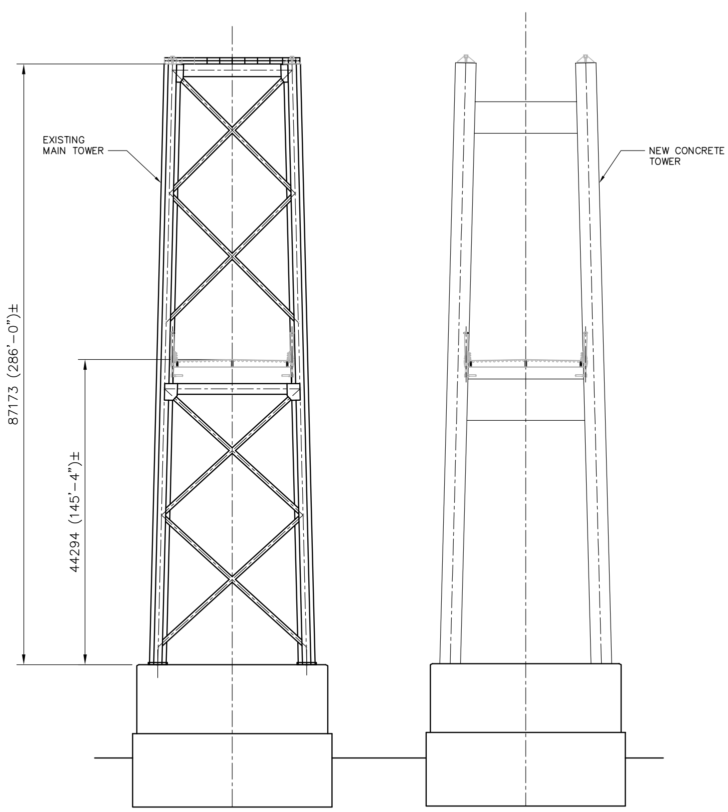
CHALLENGES

- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment requires relocating the CFIA building
- An S-curve in the roadway is required on the Halifax side
- Close proximity to the existing structure results in challenges during construction
- Approach spans on BIO property will require piers
- East tower is in the water; requiring ship impact protection

TWINNED ALIGNMENT NORTH OF THE EXISTING BRIDGE

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 1C TOWERS

REHABILITATION AND TWINNING SEQUENCE

- Construct new suspension bridge immediately north of the existing bridge
- Transfer all traffic to the new bridge and rehabilitate the existing bridge
  - Strengthen foundations, towers and piers on suspended spans and approach spans
  - Modify cable anchorages and install new tower saddles
  - Install new or supplementary cables
  - Replace suspended spans deck system
  - Replace approach spans deck system

COST

Direct Construction	$	813,000,000
Owner's Construction	$	219,000,000
Lifecycle Maintenance	$	315,000,000
Total Cost	**$**	**1,350,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The twin bridge would be built alongside the existing bridge before rehabilitation of the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

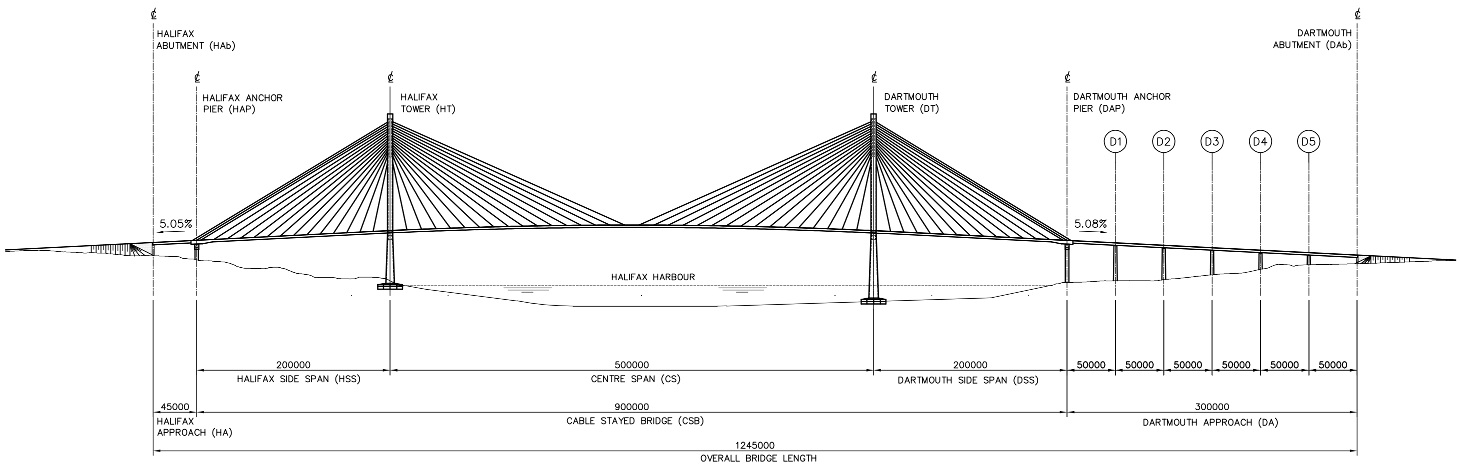
New piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2A

REPLACEMENT BRIDGE – CABLE STAYED

6 LANE 500 M MAIN SPAN

- Lowest cost 6 lane replacement bridge
- Designed for long-term maintenance
- New silhouette



DESIGN FEATURES

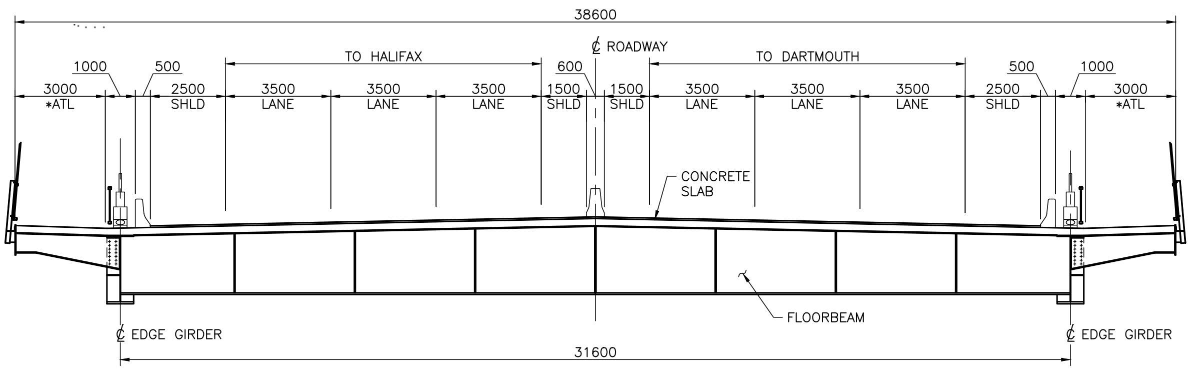
- 100 year design life
- Bridge acts as an arterial roadway based on lane and shoulder design
- Two AT lanes
- Increased vertical navigational clearance by 10 m
- Capacity for flexible lane designations
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction
- Alignment reduces impact on adjacent stakeholders and is shorter than other options

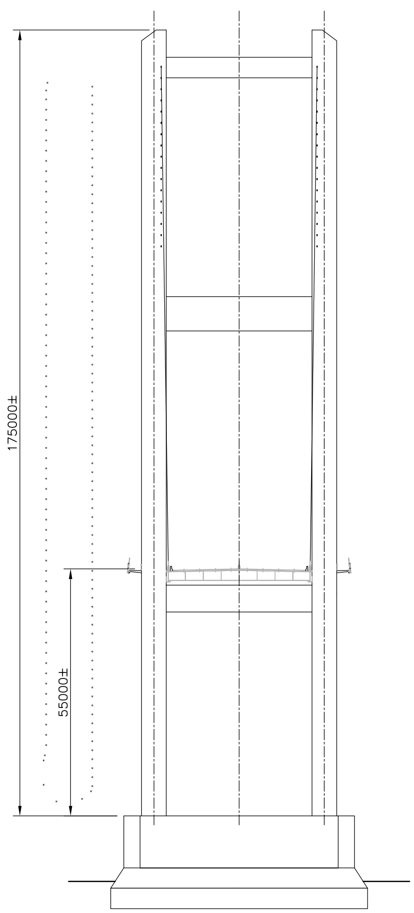
CHALLENGES

- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment requires relocating the CFIA building
- An S-curve in the roadway is required on the Halifax side
- Close proximity to the existing structure results in challenges during construction
- Approach spans on BIO property will require piers
- East tower is in the water; requiring ship impact protection

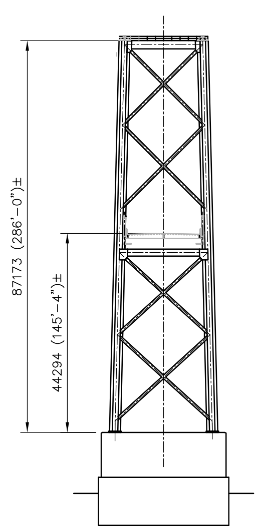
ALIGNMENT NORTH OF THE EXISTING BRIDGE

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 2A TOWER



EXISTING TOWER

COST

Direct Construction	$	724,000,000
Owner's Construction	$	174,000,000
Lifecycle Maintenance	$	156,000,000
Total Cost	**$**	**1,050,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

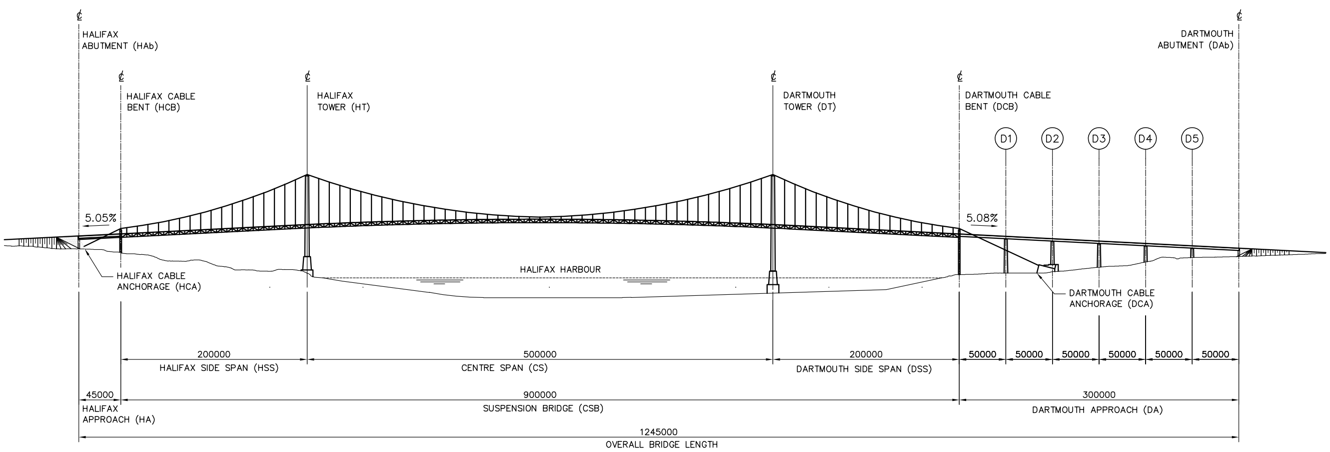
New piers and removal of existing piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2B

REPLACEMENT BRIDGE – SUSPENSION

6 LANE 500 M MAIN SPAN

- Flexible Lane Designations
- Designed for long-term maintenance
- Familiar silhouette



DESIGN FEATURES

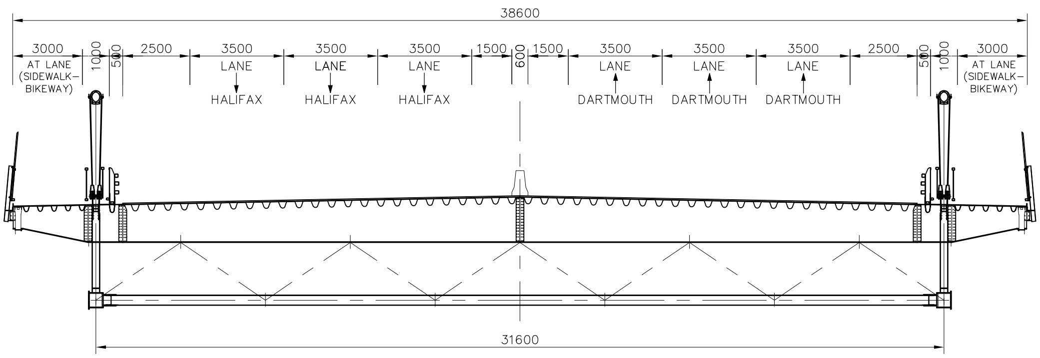
- 100 year design life
- Bridge acts as an arterial roadway based on lane and shoulder design
- Two AT lanes
- Increased vertical navigational clearance by 10 m
- Capacity for flexible lane designations
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction
- Alignment reduces impact on adjacent stakeholders and is shorter than other options

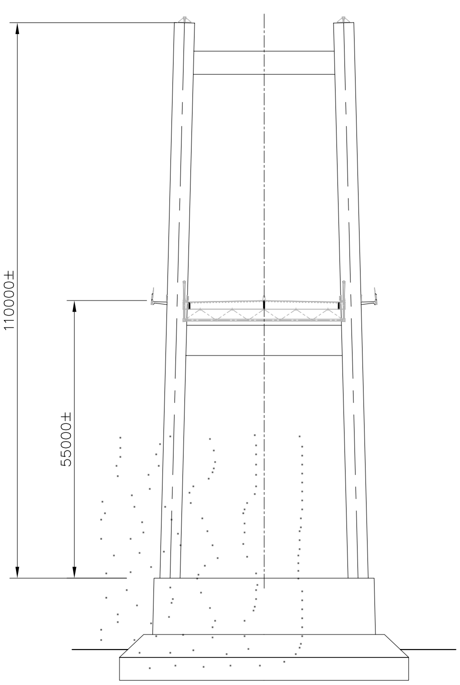
CHALLENGES

- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment requires relocating the CFIA building
- An S-curve in the roadway is required on the Halifax side
- Close proximity to the existing structure results in challenges during construction
- Approach spans on BIO property will require piers
- East tower is in the water; requiring ship impact protection

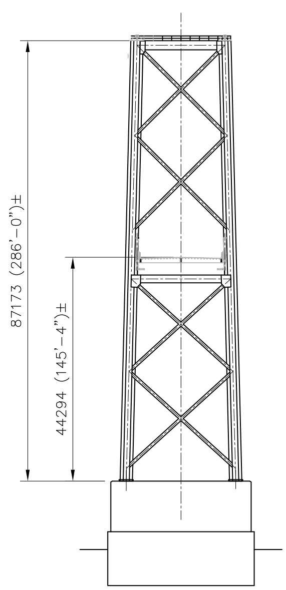
ALIGNMENT NORTH OF THE EXISTING BRIDGE

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 2B TOWER



EXISTING TOWER

COST

Direct Construction	$	891,000,000
Owner's Construction	$	214,000,000
Lifecycle Maintenance	$	254,000,000
Total Cost	**$**	**1,360,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

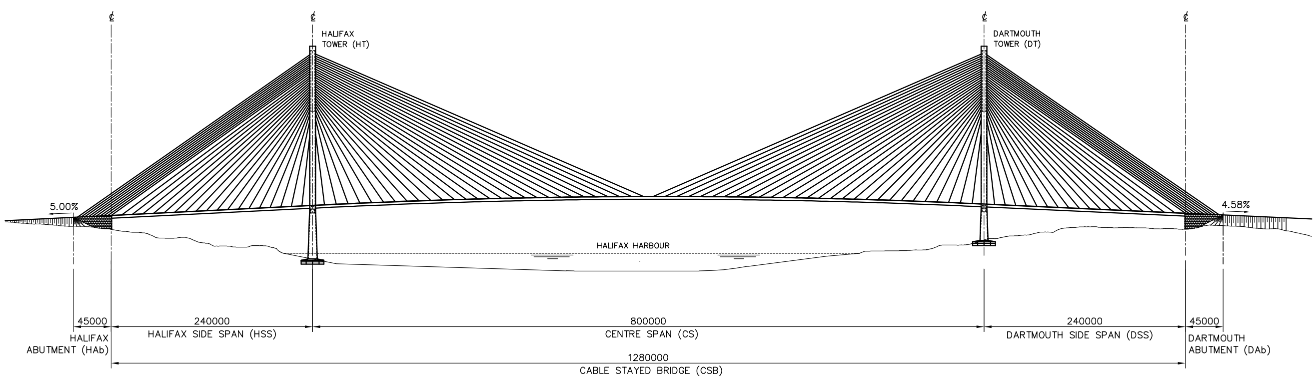
New piers and removal of existing piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2C

REPLACEMENT BRIDGE – CABLE STAYED

6 LANE 800 M MAIN SPAN

- Towers out of the water
- Designed for long-term maintenance
- New silhouette



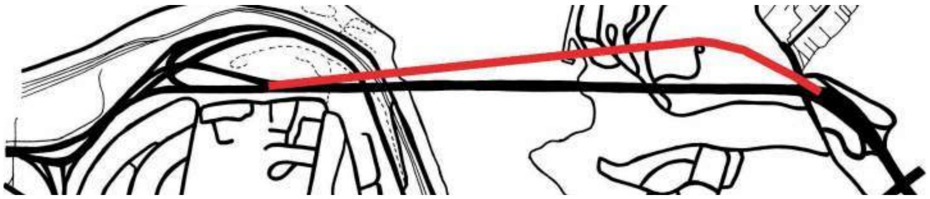
DESIGN FEATURES

- 100 year design life
- Towers are not in harbour, minimizing environmental and ship impact risk
- Bridge acts as an arterial roadway based on lane and shoulder design
- Two AT lanes
- Increased vertical navigational clearance by 10 m
- Capacity for flexible lane designations
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction

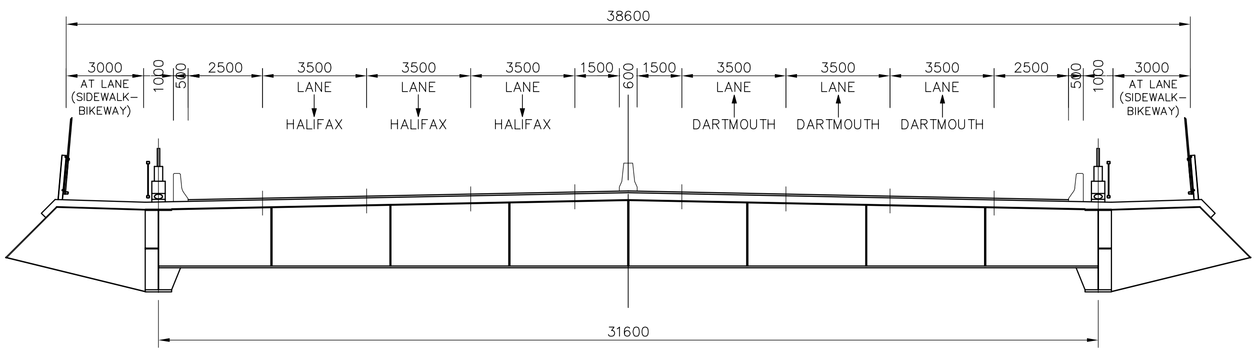
CHALLENGES

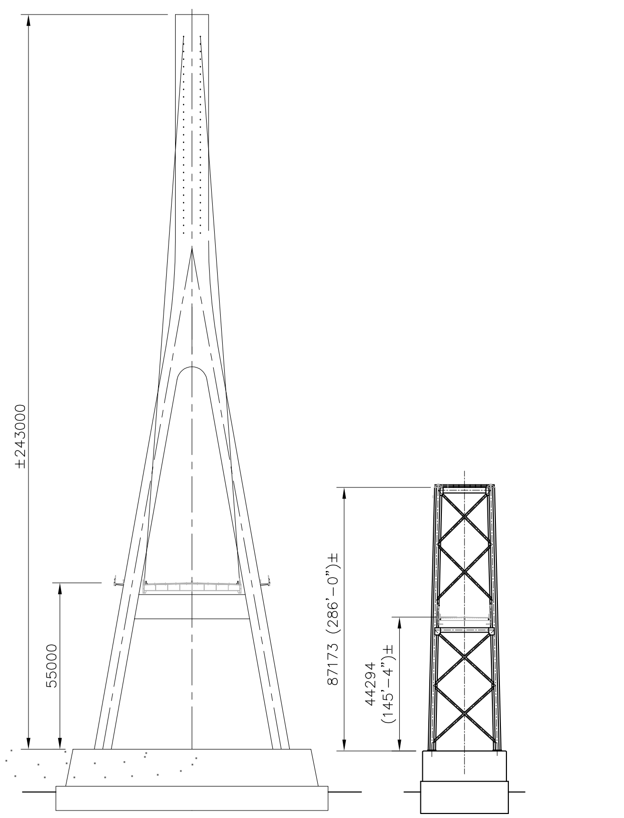
- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment flies over BIO wharves
- Alignment has significant impact on adjacent stakeholders
- Approach spans on BIO property will require few piers

ALIGNMENT NORTH OF THE EXISTING BRIDGE



MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 2C TOWER EXISTING TOWER

COST

Direct Construction	$	1,106,000,000
Owner's Construction	$	265,000,000
Lifecycle Maintenance	$	159,000,000
Total Cost	**$**	**1,530,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions

ENVIRONMENTAL PERMITTING

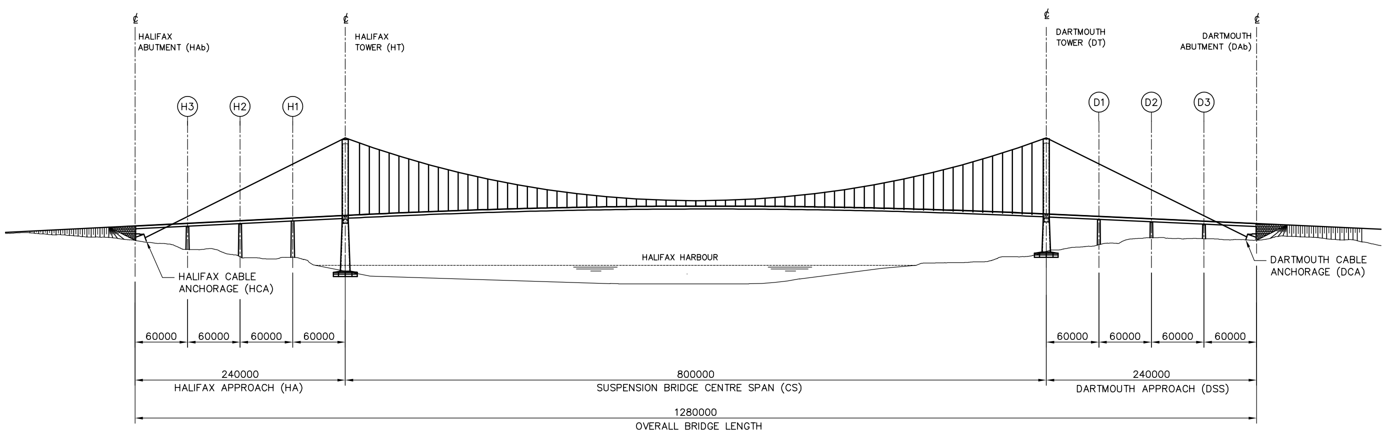
Removal of piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2D

REPLACEMENT BRIDGE – SUSPENSION

6 LANE 800 M MAIN SPAN

- Towers out of the water
- Designed for long-term maintenance
- Familiar silhouette



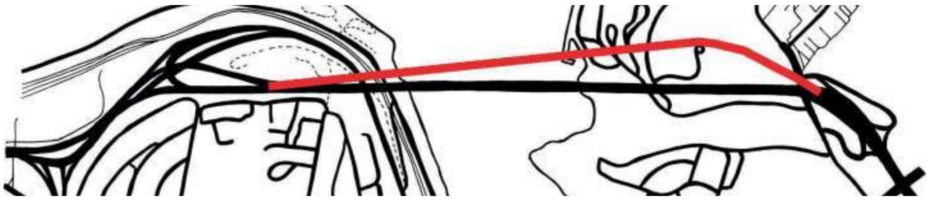
DESIGN FEATURES

- 100 year design life
- Towers are not in harbour, minimizing environmental and ship impact risk
- Bridge acts as an arterial roadway based on lane and shoulder design
- Two AT lanes
- Increased vertical navigational clearance by 10 m
- Capacity for flexible lane designations
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction

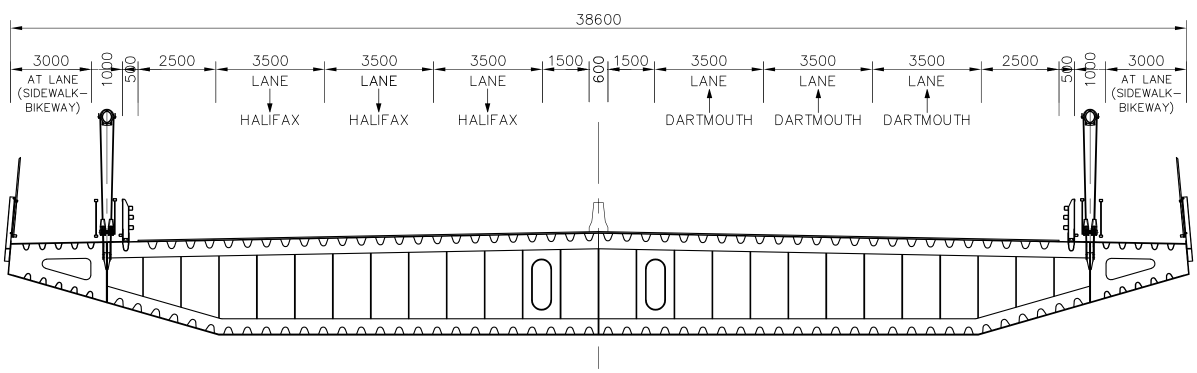
CHALLENGES

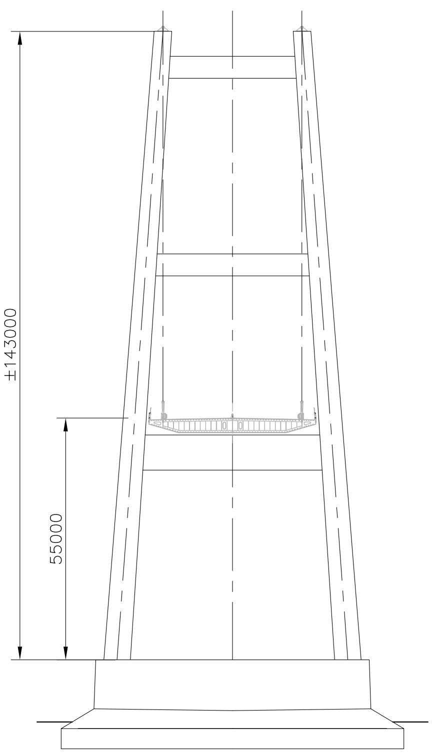
- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment flies over BIO wharves
- Alignment has significant impact on adjacent stakeholders
- Approach spans on BIO property will require a few piers

ALIGNMENT NORTH OF THE EXISTING BRIDGE

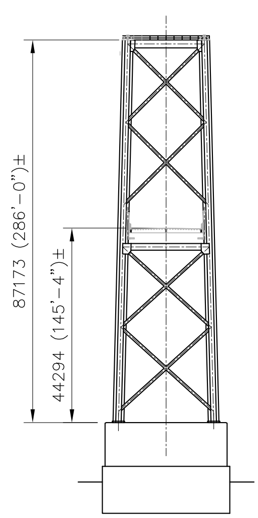


MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 2D TOWER



EXISTING TOWER

COST

Direct Construction	$	949,000,000
Owner's Construction	$	228,000,000
Lifecycle Maintenance	$	234,000,000
Total Cost	**$**	**1,410,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

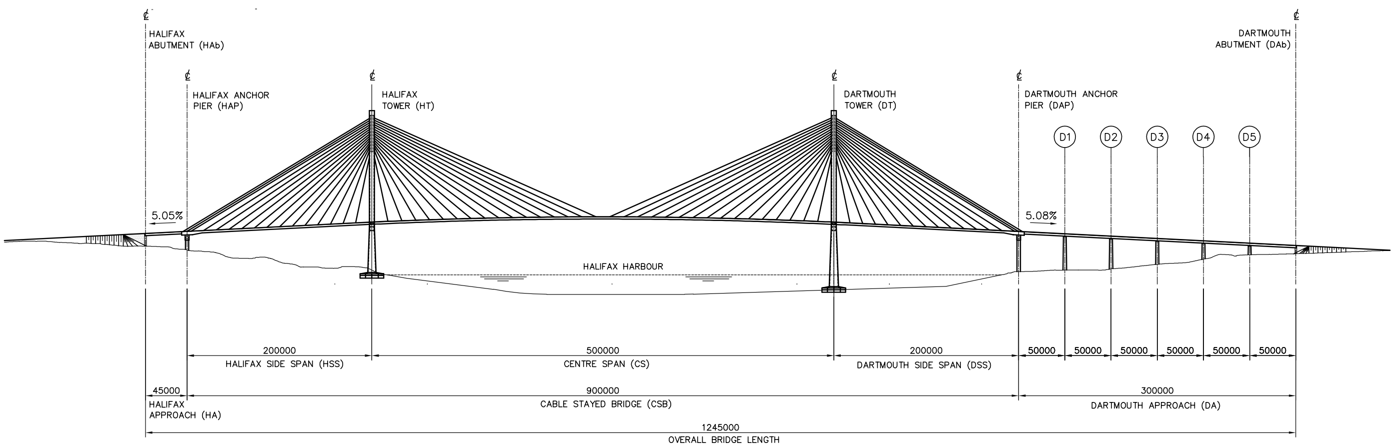
Removal of piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2E

REPLACEMENT BRIDGE – CABLE STAYED

4 LANE 500 M MAIN SPAN

- Lowest cost replacement bridge
- Designed for long-term maintenance
- New silhouette



DESIGN FEATURES

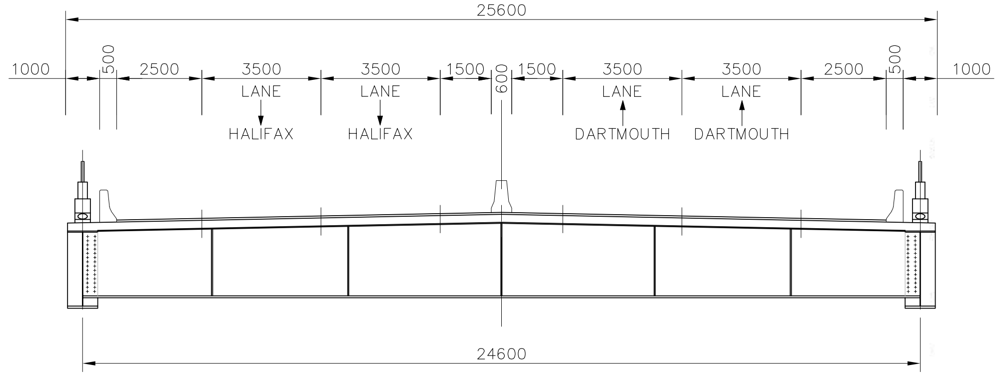
- 100 year design life
- Bridge acts as an arterial roadway based on lane and shoulder design
- Increased vertical navigational clearance by 10 m
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction
- Alignment reduces impact on adjacent stakeholders and is shorter than other options

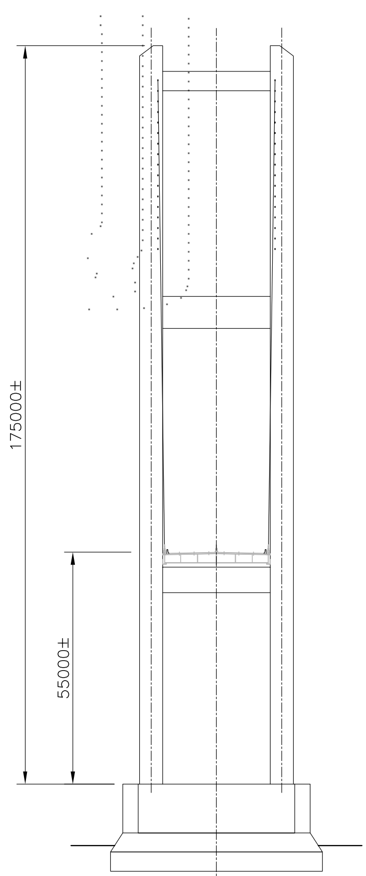
CHALLENGES

- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment requires relocating the CFIA building
- An S-curve in the roadway is required on the Halifax side
- Close proximity to the existing structure results in challenges during construction
- Approach spans on BIO property will require piers
- East tower is in the water; requiring ship impact protection

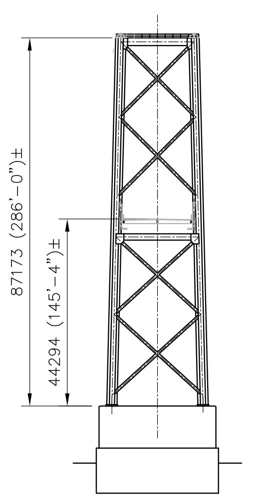
ALIGNMENT NORTH OF THE EXISTING BRIDGE

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS





OPTION 2E TOWER



EXISTING TOWER

COST

Direct Construction	$	514,000,000
Owner's Construction	$	123,000,000
Lifecycle Maintenance	$	122,000,000
Total Cost	**$**	**760,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

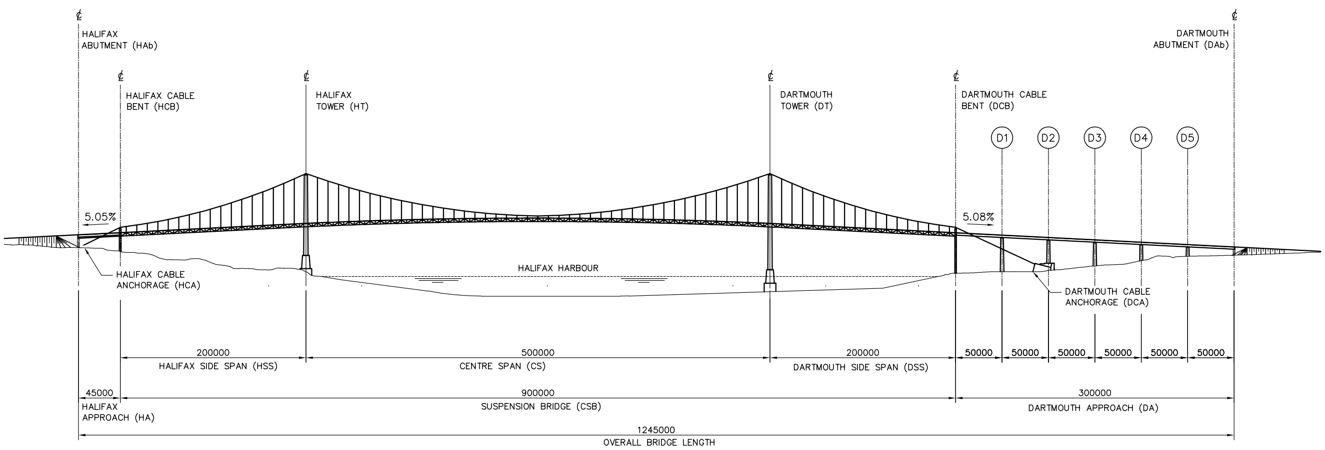
New piers and removal of existing piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.

OPTION 2F

REPLACEMENT BRIDGE – SUSPENSION

4 LANE 500 M MAIN SPAN

- Highest cost per lane
- Designed for long-term maintenance
- Familiar silhouette



DESIGN FEATURES

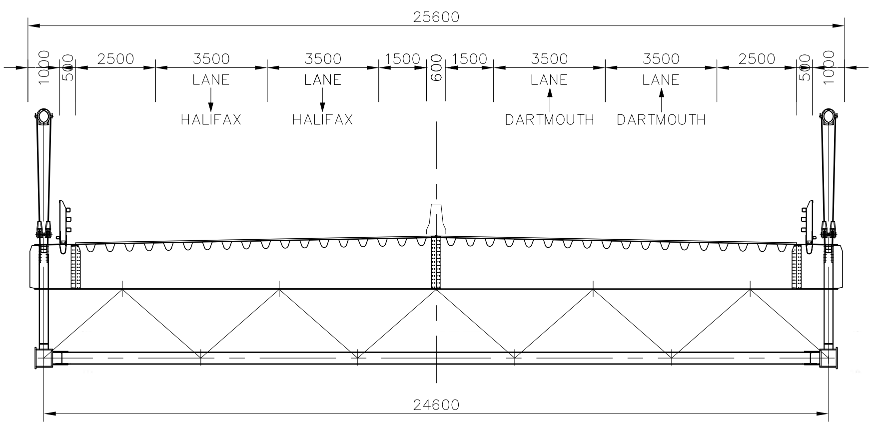
- 100 year design life
- Bridge acts as an arterial roadway based on lane and shoulder design
- Increased vertical navigational clearance by 10 m
- Enhanced inspection and maintenance access
- Significant use of existing approach roadways
- Minimal traffic interruptions during construction
- Alignment reduces impact on adjacent stakeholders and is shorter than other options

CHALLENGES

- Acquisition of adjacent properties will require significant discussions with stakeholders and cost to HHB
- The alignment requires relocating the CFIA building
- An S-curve in the roadway is required on the Halifax side
- Close proximity to the existing structure results in challenges during construction
- Approach spans on BIO property will require piers
- East tower is in the water; requiring ship impact protection

ALIGNMENT NORTH OF THE EXISTING BRIDGE

MAIN SPAN CROSS SECTION AND LANE DESIGNATIONS



COST

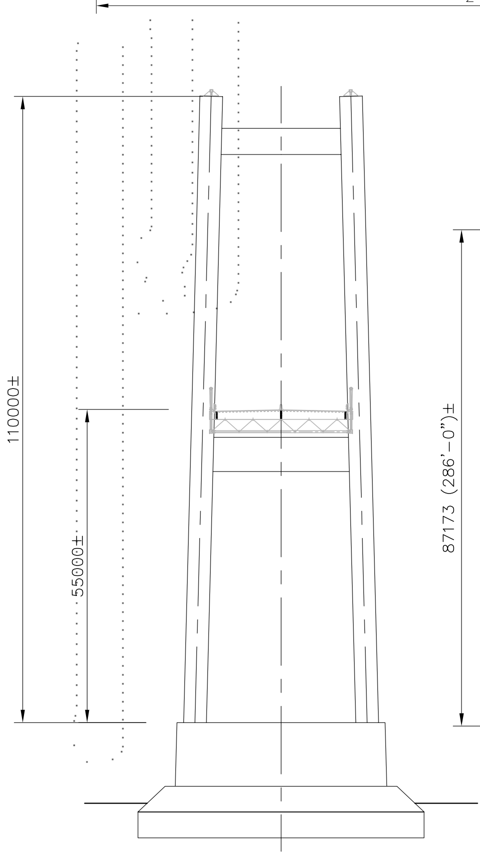
Direct Construction	$	646,000,000
Owner's Construction	$	155,000,000
Lifecycle Maintenance	$	210,000,000
Total Cost	**$**	**1,010,000,000**

CONSTRUCTABILITY AND TRAFFIC IMPACT

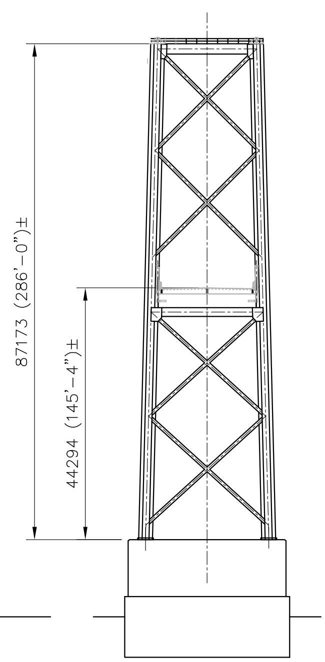
The new bridge would be built alongside the existing bridge, resulting in limited traffic interruptions.

ENVIRONMENTAL PERMITTING

New piers and removal of existing piers in the water will require Navigational Protection Act Approval and an Authorization / Offsetting compensation by DFO. A Project Description for HPA and PSPC, and an Environmental Assessment under CEAA 2012 are likely required.



OPTION 2F TOWER



EXISTING TOWER

4 Evaluation

In consultation with HHB's Steering Committee, COWI developed a multi-criteria assessment model to evaluate the seven options through consultation with HHB's Steering Committee.

The purpose of the multi-criteria assessment was to identify a preferred rehabilitation option and a replacement option. This section presents the outcome of the evaluation and discusses some of the issues/risks specific to the two preferred options. For each issue a high-level discussion is provided.

At a high level, each option was evaluated for its ability to satisfy criteria for the following categories:

1. **Life Cycle Cost:** The Life-cycle cost comprises the construction, maintenance demolition of the existing bridge and building relocation costs.

2. **Features:** HHB's Steering Committee has defined key features for the rehabilitated or replacement structure designs.

3. **Risks and Opportunities:** Risk are events that could negatively impact the project cost or schedule, while opportunities are events that have the potential to improve the project, generally through added features or possible future benefits.

4. **Social Implications:** These are impacts to the community and the environment during construction and over the lifespan of the structure.

4.1 Detailed Results

The assessment comprises criteria that are not directly comparable; therefore, the criteria are grouped into four main categories that would be scored separately. Each category was assigned a maximum number of points with the total number of points available to each option being 100.

After consultation with HHB's Steering Committee, the categories under evaluation and their total number of points are:

- Category 1. Life-cycle cost → 50 points
- Category 2. Features → 25 points
- Category 3. Risk/Opportunity → 15 points
- Category 4. Social implications → 10 points.

The following subsections describe the four categories, and how points were assigned within each category for the evaluation.

Category 1: Life-Cycle Cost

The cost of the project is a key driver in the evaluation criteria. Costs for each option are based upon recent and indicative projects in North America and are considered a reasonable assumption with this study's level of detail.

The Life-cycle cost comprises the construction cost, the maintenance cost throughout the design life of the bridge, the demolition cost of the existing bridge (as applicable), and building relocation costs (option 2A and 2B).

Table 2: Category 1. Cost - Criteria

No.	**Feature**	**Description**
2.1	Initial Cost	The cost to construct the bridge
2.2	Demolition Cost	Cost to demolish the existing MacKay Bridge
2.3	Relocation of CFIA Building	Cost to demolish and rebuild the CFIA Building
2.4	Maintenance	The cost to maintain the bridge, assuming a 0% discount rate

Land acquisition has been considered as a risk in the present evaluation but has not been included as a direct cost. Our analysis indicates that, provided the land acquisition costs are below 50 million dollars, the outcome of the cost implications would not change the ranking outcome. These costs are anticipated to be similar for all new bridge options; however, the costs are largely dependent on negotiation between HHB and various other agencies, making an estimate not reliable at this time. A more detailed land cost comparison should include assessment methods to account for the various structures' life spans from an economic perspective (e.g. accounting for equivalent annual cost, life-cycle revenue, salvage cost at the end of the assumed design life).

Not all options have the same design life; based on discussions between COWI and HHB, it was decided that the rehabilitate options have a 75-year design life, while new options have a 100-design year life. For the purposes of this study, no direct comparison is necessary, so estimates for remaining value of the bridge, at end of life, have not been made.

Maintenance costs for the structure include annual expenses such as paint repairs and cleaning, as well as larger occasional expenses such as expansion joint and bearing replacements.

Details of the cost breakdowns included with the evaluation are presented in Appendix H.

Scoring System

Options are scored by assigning the total maximum points (50) to the least expensive option. A lower limit of 25 points was assigned to the most expensive option; other options are assigned points proportional to their costs. Final Category 1 cost scores are shown in Table 3:

Table 3 Category 1. COST Scores

Category 1. COST (Million CAD)			Rehabilitate Existing Bridge 1A	1B	1C	Replacement Bridge 2A	2B	2C	2D	2E	2F
Direct Construction Cost			522	594	813	724	891	1106	949	514	646
Owner's Construction Cost			151	172	219	174	214	265	228	123	155
Lifecycle Maintenance			169	203	315	156	254	159	234	122	210
Total Cost (Rounded to nearest 10 Million CAD)			**840**	**970**	**1350**	**1050**	**1360**	**1530**	**1410**	**760**	**1010**
MAX TOTAL POINTS	**50**	**SCORE**	**48**	**44**	**31**	**41**	**31**	**25**	**29**	**50**	**42**

An alternative to this cost-based scoring system would be to examine value provided by each option in terms of points/$$$ or $$$/lane – this is discussed and applied further in Section 4.3.

Category 2: Features

HHB's Steering Committee has defined key features that are to be considered and incorporated into the rehabilitated or new structure designs. Each option incorporates some of the key features, but not all, and not all key features have the same importance. The key features are described in Table 4.

Table 4: Category 2. Key Features

No.	Feature	Description
2.1	Six traffic lanes	Increase the deck width to accommodate three lanes in each direction
2.2	Two-Active Transportation lanes	Increase the deck width to accommodate two bicycle/sidewalk lanes
2.3	Increased vertical navigation channel clearance (air gap) by 10 m	Raise the deck to accommodate taller ships and sea level rise
2.4	Increased horizontal navigation channel clearance (channel width)	Move main towers further apart
2.5	Re-use of approach roads	Minimize disruptions to traffic on approach roads during construction
2.6	HHB owns required land	Minimize necessary land acquisitions
2.7	Avoids impacts to urban planning	Minimize impact on surrounding roadways and properties
2.8	Extended design life	Continue to use the crossing beyond current life expectancy of the existing structure

Scoring System

Importance Factors for each feature were defined through consultation with HHB's Steering Committee. Each option is scored relative to one another. Importance factors are ranked either Low, Moderate or High and they are assigned a corresponding numerical value from 1 to 3 respectively. Then each design option was assessed to determine if it provided HHB with the desired feature. The design option was assigned points corresponding to the Importance Factor if the feature was present. The total number of points for each option was scaled to the total number of points assigned to Category 2 (25 points).

Final scores for Category 2 are shown in Table 5.

Table 5: Category 2. FEATURES Scores

		Rehabilitate Existing Bridge			Replacement Bridge					
Category 2. FEATURES	**Importance Factor**	**1A**	**1B**	**1C**	**2A**	**2B**	**2C**	**2D**	**2E**	**2F**
6 Traffic Lanes	High	No	No	Yes	Yes	Yes	Yes	Yes	No	No
2 Active Transportation Lanes	High	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Increased Ship Vertical Clearance by 8+ m (air gap)	High	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Increased Ship Horizontal Clearance (channel width)	Low	No	No	No	No	No	Yes	Yes	No	No
Reuse of approach roads	Moderate	Yes	Yes	Yes	No	No	No	No	No	No
HHB owns required land	Moderate	Yes	Yes	No	No	No	No	No	No	No
Avoids Impacts to Urban Planning	Low	Yes	Yes	No	No	No	No	No	No	No
Extended Service Life Beyond 75 Years	Moderate	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
MAX TOTAL POINTS 25	**SCORE**	8	12	12	17	17	18	18	8	8

Category 3: Risk/Opportunity

Each project has an inherent series of risks, as well as the potential to provide opportunities that would otherwise be unobtainable. These two categories are grouped together because of their similar nature; however, the scoring is presented separately to demonstrate that each structural option has some amount of inherent risk and opportunity.

For this study, risk was understood as factors that could occur and negatively impact the project cost or schedule, even assuming the project would incorporate all pertinent mitigation measures. For instance, even with appropriate mitigation measures in place during construction, rehabilitation options have a greater risk of affecting the traffic due to unforeseen issues than a new bridge. Some risks go beyond initial construction, such as ship impact and the effects on public spaces below the bridge. Risks evaluated in this process are described in Table 6.

In a similar manner, opportunities are understood as factors that have the potential to improve the project, generally through added features or possible future benefits. These opportunities are described in Table 7.

Table 6: Category 3A - Risks

No.	**Risk**	**Description**
3.1	Impact to vehicular traffic during construction	Possibility of unplanned interruptions to cross-harbour traffic, due to delays in construction. Planned interruptions are considered in Category 4.
3.2	Impact to marine traffic during construction	Possibility of unplanned interruptions to harbor access, due to delays in construction within the harbor channel
3.3	Constructability / Complexity of design and erection sequence	Increased level of effort necessary to ensure construction continues as planned, may result in schedule delays or cost increases
3.4	Unknown structural constraints	Possibility of in-situ conditions being different from planned, resulting in additional design and construction time and cost.
3.5	Geotechnical	Possibility of discovering negative geotechnical conditions during design/construction, which would lead to further cost and delays
3.6	Vessel impact risk	Possibility of the bridge being impacted by a ship during its life, which can be mitigated through design, but could increase cost
3.7	Permitting complexity and timelines	Possibility of the permitting process delaying design and construction, extending the schedule
3.8	Unusual resource requirements	Possibility of requiring specialist personnel, equipment or procedures, which would increase cost and possibly extend schedule
3.9	Operational issues during design life	Likelihood of major maintenance being required during the life of the bridge

Table 7: Category 3B - Opportunities

No.	**Opportunity**	**Description**
3.10	Use of modern bridge design methods and materials	Ability to optimization of materials and minimization of maintenance
3.11	Safety features	Ability to fully bring structure and roadway up to current codes
3.12	Technological gains	Ability to improve knowledge base of local engineers, and update HHB's structural inventory.
3.13	Structural health monitoring implementation	Ability to implement a system to better understand and maintain the structure

While risks need to be considered and mitigated, the opportunities are possible positive consequences that can be incorporated into the design.

Scoring System

Similar to 'Category 2. Features', each Risk was assigned a Severity Factor based on discussions with HHB's Steering Committee. Risks have Low, Moderate or High Severity based on the potential consequences of the event and are assigned a value of 3, 2 or 1 respectively. Each risk was evaluated for each design option and assigned a likelihood of occurrence of Low, Moderate or High. If the likelihood of occurrence for one of the criteria was 'Low' the design option was assigned all points corresponding to the 'Severity Factor', 'Moderate' probability of occurrence would result in half of the points, and High' probability no points. Final Risk scores under Category 3A are shown in Table 8.

Table 8: Category 3A. RISK Scores

		Rehabilitate Existing Bridge			Replacement Bridge					
		1A	1B	1C	2A	2B	2C	2D	2E	2F
Category 3A. RISK	**Severity**	**Probability of Occurrence**								
Impact to vehicular traffic during construction	High	High	High	Moderate	Low	Low	Low	Low	Low	Low
Impact to marine traffic during construction	High	High	High	High	Moderate	Moderate	Low	Low	Moderate	Moderate
Constructability / Complexity of erection sequence	High	High	High	High	Low	Moderate	Low	Moderate	Low	Moderate
Unknown Structural Constraints	High	High	High	High	Low	Low	Low	Low	Low	Low
Geotechnical	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Vessel impact risk	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate
Permitting complexity and timelines	Moderate	Low	Low	Moderate	High	High	High	High	High	High
Unusual Resource Requirements (technology, equipment, materials, specialists)	Low	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate	Low	Low
Operational Issues during Service Life (due to the type of bridge)	Moderate	High	High	High	Low	Moderate	Low	Moderate	Low	Moderate
MAX TOTAL POINTS 10	**SCORE**	5	5	5	8	7	8	7	8	7

Similar to the risks, there are opportunities to get additional benefit from the design and construction of a particular option. In this case the scoring system, assigns points to design options with a higher likelihood of providing beneficial opportunities.

Each Opportunity criteria was assigned an importance factor, defined here as 'Benefit Factor'. Opportunities would have Low, Moderate or High Benefit based on the potential consequences of the event, corresponding to a value of 1, 2 or 3 respectively. Each design option was then evaluated for the likelihood of realising the opportunity, with a likelihood of Low, Moderate or High. If the likelihood of occurrence for one of the criteria is 'High' the design option was assigned all points corresponding to the 'Benefit Factor', 'Moderate' probability of occurrence would assign half of the points, and 'Low' probability results in no points. Final Opportunity scores under Category 3B are shown in Table 9.

Table 9: Category 3B. OPPORTUNITY Scores

Category 3B. OPPORTUNITY		Benefit	Rehabilitate Existing Bridge			Replacement Bridge					
			1A	1B	1C	2A	2B	2C	2D	2E	2F
			Probability of Occurrence								
Use of modern bridge design / methods and materials		Low	Low	Low	Moderate	High	High	High	High	High	High
Safety features		High	Low	Low	High	High	High	High	High	Moderate	Moderate
Technological gains		Low	Low	Moderate	Moderate	Moderate	Moderate	High	High	Moderate	Moderate
Structural Health Monitoring Implementation		Moderate	Moderate	High	High	High	High	High	High	High	High
MAX TOTAL POINTS	5	SCORE	1	2	5	5	5	5	5	4	4

Social Implications

The preceding sections valuated quantitative aspects of the project such as cost, or addition of lanes. This final evaluation category focusses on the impacts to the community and the environment. HHB's Steering Committee is acutely aware of the effect replacing or rehabilitating the MacKay Bridge with have on the community, both during construction, and over the lifespan of the structure. In recognition of the importance of the public to this project, the category has received a weighting of 10% of the evaluation score.

Within this category anticipated public opinion is used to evaluate several project aspects including the public's perception of the project as a whole, and the effect of traffic disruptions on the community. A brief description of the social considerations are provided in Table 10.

Table 10: Category 4 – Social Implications

No.	Feature	Description
4.1	Public perception	How the public feels about the project as a whole
4.2	Impact on Community	General effect on quality of life in the surrounding neighbourhoods, including noise and traffic disruptions
4.3	Stakeholder impact	The effect (interruptions, access, property ownership) of the project on impacted groups, such as HHB, HPA, HRM, NSTIR, DFO, etc.
4.4	Architectural and aesthetics	Lasting effect of the physical structure
4.5	Cultural implications	Impact to areas of cultural importance around the bridge
4.6	Environmental consideration	The change in impact of the structure on the environment
4.7	Archeological implications	Likelihood that the construction work would uncover something that necessitates work stoppage

Scoring System

Each of the considerations contained within this category were assigned an importance factor of low, medium or high, corresponding to a value of 1 to 3 respectively. The effect on the public, and their opinion of different aspects of the project are difficult to quantify, so each option was compared to a baseline, option 1A - rehabilitating the existing bridge, resulting in better, neutral or worse public perception. Table 11 summarizes scores for the considerations explored within this study.

Table 11. Category 3B. SOCIAL IMPLICATIONS Scores

			Rehabilitate Existing Bridge			Replacement Bridge					
Category 4. SOCIAL IMPLICATIONS		Importance Factor	1A	1B	1C	2A	2B	2C	2D	2E	2F
Public Perception		High	Neutral	Better	Neutral	Better	Better	Better	Better	Worse	Worse
Impact on Community		High	Neutral	Better	Better	Better	Better	Better	Better	Neutral	Neutral
Stakeholder impact		High	Neutral	Better	Better	Neutral	Neutral	Neutral	Neutral	Worse	Worse
Architectural and Aesthetics		Moderate	Neutral	Neutral	Better	Better	Better	Better	Better	Better	Better
Cultural Implications		Low	Neutral	Neutral	Worse	Worse	Worse	Worse	Worse	Worse	Worse
Environmental considerations		Moderate	Neutral	Neutral	Neutral	Neutral	Neutral	Better	Better	Neutral	Neutral
Archeological Implications		Low	Neutral	Neutral	Worse	Worse	Worse	Worse	Worse	Worse	Worse
MAX TOTAL POINTS	10	SCORE	5	8	7	7	7	8	8	3	3

4.2 Outcome

Following the detailed assessment of the various criteria, the maximum total points for each of the categories were added together to provide a global assessment of options. A summary of the evaluation matrix is presented in Table 12, with the full matrix presented in Appendix K. The highest-scoring and preferred option is Option 2A: 500 m long main span cable-stayed bridge. The highest scoring rehabilitation option is Option 1B: Rehabilitate the existing and provide AT lanes.

Table 12: Evaluation Matrix Summary

		Rehabilitate Existing Bridge			Replacement Bridge					
	Score / Points	1A	1B	1C	2A	2B	2C	2D	2E	2F
Category 1. COST (Million CAD)	50	48	44	31	41	31	25	29	50	42
Category 2. FEATURES	25	8	12	12	17	17	18	18	8	8
Category 3A. RISK	10	5	5	5	8	7	8	7	8	7
Category 3B. OPPORTUNITY	5	1	2	5	5	5	5	5	4	4
Category 4. SOCIAL IMPLICATIONS	10	5	8	7	7	7	8	8	3	3
TOTAL SCORE		67	71	60	78	67	64	67	73	64

COWI has prepared General Arrangement Drawings for the highest scoring rehabilitation and replacement options. These General Arrangement Drawings are provided in Appendix L.

These two options do not have the same set of desired features or associated risks. A detailed economic comparison between the two options, based on preliminary designs, would provide more accurate cost assessments. The purpose of this study was not to directly compare rehabilitation costs to replacement costs, rather to determine the preferred option for each.

While both the highest scoring rehabilitation option and replacement option will be discussed, the final preferred option is the replacement option 2A. Replacing the current structure with a 6 lane, 500 m main span, cable stayed bridge scores the highest overall. This structure scores 20% higher (5 points) in the "features" category than the rehabilitation options and almost 40% higher (9 points) than the next best replacement option.

Option 2E also had a high score of 73 points, only five points lower than the highest replacement option and only two points higher than the highest scoring rehabilitation option. It is important to note that while the cost of the option is the lowest, it scores substantially lower than the other options in the "features" categories. COWI believes that the significant amount of effort and costs required to build a new bridge, only to provide no apparent added features outside of longevity, would not be well perceived.

4.3 Value Assessment

An alternative method for examining value of options is to perform an assessment based on cost/benefits ratios. Comparing the cost of the individual options with their score (excluding costs) produces Table 13. This provides a quantitative cost associated for the combination of features, risks, opportunities and social implications, which demonstrates that some amount of additional cost can bring additional benefits.

Alternatively, the value could be associated with the number of lanes provided. This is often used when comparing options for replacements. Assuming that each AT lane is equivalent to a half lane, the resulting cost/lane is shown in Table 13.

The highest value and lowest cost/lane is still option 2A, a replacement 500 m main span cable-stayed bridge. The next highest value and lowest cost/lane is option 2E, however, as mentioned in Section 4.2, this option is undesirable due to its lack of perceived improvement from the current conditions. This evaluation demonstrates that the preferred option is option 2A, as it is leading in both project value and cost per lane.

Table 13: Value Summary

	Score Points	Rehabilitate Existing Bridge			Replacement Bridge					
		1A	**1B**	**1C**	**2A**	**2B**	**2C**	**2D**	**2E**	**2F**
Category 2. FEATURES	**25**	**8**	**12**	**12**	**17**	**17**	**18**	**18**	**8**	**8**
Category 3A. RISK	**10**	**5**	**5**	**5**	**8**	**7**	**8**	**7**	**8**	**7**
Category 3B. OPPORTUNITY	**5**	**1**	**2**	**5**	**5**	**5**	**5**	**5**	**4**	**4**
Category 4. SOCIAL IMPLICATIONS	**10**	**5**	**8**	**7**	**7**	**7**	**8**	**8**	**3**	**3**
TOTAL SCORE (EXCLUDES COST)		19	27	29	37	36	39	38	23	22
TOTAL COST (MILLION CAD)		840	970	1350	1050	1360	1530	1410	760	1010
PROJECT VALUE (PTS/$100M)		2.3	**2.8**	2.1	**3.5**	2.6	2.5	2.7	3.0	2.2
No. Lanes (1 AT lane = 0.5 lanes)		4	5	7	7	7	7	7	4	4
COST PER LANE ($1M/No. Lanes)		210	**194**	193	**150**	194	219	201	190	253

4.4 Anticipated Schedule

There are many reasons why owners replace bridges. These reasons can often be categorized into: functional deficiencies (e.g.: not enough lanes, poor alignment, safety related issues), cost of maintenance (which typically increases as the structure ages), or operational impacts (e.g.: increased maintenance and inspection time as structure ages). However, there is typically no definitive time at which an existing bridge must be replaced.

Provided the structure has sufficient lanes to carry the necessary traffic, the replacement decision is seldom driven by the ability of a bridge to carry traffic as it can almost always be maintained through increasingly expensive and disruptive rehabilitation. Instead, the decision is often driven by the increasing cost of maintenance or the increased frequency of traffic disruptions.

Since HHB's mandate is to provide safe, efficient and reliable cross harbour transportation infrastructure at an appropriate cost, the timing for rehabilitation or replacement of the existing bridge will likely be driven by both cost and operational impacts. Both of these factors are expected to increase with time as the bridge ages, and neither can be predicted with precision.

Due to the complexity of the rehabilitation and replacement options outlined in this report, eight to ten years will be required from initiation of preliminary design to opening the bridge to traffic. This is due to the time needed for design, environmental assessment, land acquisition, procurement and construction to take place within their required timelines. As such, the planning for rehabilitation or replacement needs to account for this relatively lengthy process, and it also needs to be flexible enough to accommodate unexpected changes that could occur as the existing bridge ages.

5 Preferred Option Risk Mitigation

The following sections describe in further detail the highest scoring rehabilitation and replacement bridge options along with relevant mitigation techniques for addressing the known risks.

5.1 Rehabilitated Bridge: Option 1B

The highest scoring option for rehabilitating the bridge is option 1B (rehabilitation with the addition of AT lanes) which also has a higher project value compared to the other rehabilitation options. This option is slightly more expensive per lane than a basic rehabilitation, and significantly less expensive per lane than twinning the bridge. By reusing components of the existing bridge, the roadway alignment remains the same as existing and difficulties associated with acquiring additional land are minimized.

This section describes in further detail relevant mitigation techniques for addressing the known risks.

This option involves the full replacement of the deck and trusses in the suspended spans as well as the deck and girders in the approach spans, strengthening the towers and cable bents, modifying the cable anchorages, supplementing the main cable, and adding two new AT lanes.

The significant issues and impacts that have been identified are:

- Constructability;
- Unknown structural constraints;
- Impact to vehicular traffic during construction;
- Impact to marine traffic during construction;
- Operational issues during the life of the bridge; and
- Environmental permitting.

Mitigation Measures

This section discusses some of the major issues associated with the preferred rehabilitation option and the associated mitigation measures.

<u>Constructability</u>

COWI has designed the replacement of the suspended spans of two major suspension bridges during short traffic closures (Lions' Gate Bridge in Vancouver, and Macdonald Bridge in Halifax). In both cases, we were able to design the replacement of the superstructure of the bridges while traffic effectively continued to use the bridge. Supplementing the main cable of a suspension bridge is not simple, but it has been done and we see no reason why it cannot be accomplished on the MacKay Bridge. If a rehabilitation option is chosen by HHB, we recommend a preliminary design be undertaken to better understand the project issues and constraints, and more accurately assess costs to replace the suspended spans of the MacKay Bridge.

If a similar approach to the Macdonald Bridge was undertaken for a MacKay Bridge rehabilitation, there would be new challenges specific to this structure, such as:

- An increased width of the MacKay Bridge in comparison to the Macdonald Bridge;
- Higher traffic demands; and
- The new deck weight would be significantly heavier than the existing based on current code requirements.

These design challenges result in a probable need to supplement the main cable, significant reinforcement of the tower and cable bents, and replacement of the approach spans. Supplementing a main cable on an in-service bridge has been previously accomplished; however, the engineering that has to go into this approach is substantial.

In addition to the design challenges, it is important to understand that the design of the MacKay Bridge was less conservative than the Macdonald Bridge, meaning it has less reserve capacity, requiring more modifications to the existing structure than required for rehabilitation of the Macdonald Bridge. This is due to differences in the approach to design between the 1950s and late 1960s. As design engineering technology and information developed, engineers were able to reduce the redundancy and conservativeness in their designs, lowering overall initial costs. The impact of this change in design approach is that the MacKay Bridge has less reserve capacity than that of the Macdonald Bridge.

Unknown structural constraints

HHB have compiled valuable information about the MacKay Bridge in the form of original design and shop drawings, record drawings for repairs and retrofits performed on the bridge, and inspection reports. However, there is still a risk that there are situations where the structural conditions were not accurately reflected on drawings, subsequent unrecorded changes, or deterioration that has continued with time. Each of these aspects can cause changes to the design parameters resulting in delays and additional costs during construction.

One of the most effective ways to mitigate the impact of unknown conditions would be to keep open communication and access between the design team and the owner (maintenance and inspection teams) during the design phase. This allows the designer to make themselves familiar with the bridge's current condition. It is recommended that the designers perform a detailed inspection of the bridge components, so that they are not relying solely on past inspections and can identify potential conflicts and other issues such as loss of steel due to corrosion early in the design phase.

Impact to vehicular traffic during construction

Assuming the suspended span replacement is feasible, the contractor will need full weekend or extended night closures to replace sections of the bridge. As such, there is likely more than a year of traffic disruption associated with this rehabilitation option.

A detailed design for the construction sequence allows for close coordination during the execution of the work between HHB, the designers and the contractor. This can also allow the stakeholders and the public to be engaged in understanding the process as extended periods of closure can be expected.

The duration of the closures to tie-in the approaches needs to be carefully thought through to give the contractor enough time to complete the work, but also to not give more than is needed to minimize the impact on the public.

Impact to marine traffic during construction

Rehabilitation work is expected to involve removal of existing segments and installation of new deck segments from barges in the harbour, as well as overhead hot work and possibly reduced navigational channel clearances. Early coordination with Halifax Port Authority (HPA) is recommended to understand HPA's operational requirements during construction to minimize impact on marine traffic.

Operational issues during the life of the bridge

Rehabilitation assumes that several elements of the existing structure would remain in place after all of the work is complete, including the main cable, towers, cable bents, and the foundations. The maintenance cost assumed in the multi-criteria assessment accounted for these elements requiring a higher level of maintenance throughout the life of the bridge. A specific monitoring program for structural components could be implemented to monitor the condition of the remaining elements. A specific plan should be developed to determine the intended application of the data collected and how best to collect that data, otherwise the program has potential to be expensive with minimal benefit. In order to extend the service life of the main cables, COWI recommends installation of a dehumidification system on the main cables as soon as reasonably possible (prior to rehabilitation) if the existing cables are to remain.

Environmental permitting

Work associated with Option 1B includes construction work above the harbour, strengthening of the main piers and cable bents, replacement of the approach span superstructure and possible repairs to the existing piers. Regulatory permitting requirements are therefore likely to include a Transport Canada Approval under the NPA and the submission of a Project Description outlining the project, potential environmental impacts and proposed mitigation to the Halifax Port Authority to allow them to determine if significant environmental effects are likely to occur from the project. An Environmental Assessment under CEAA 2012 is unlikely due to anticipated limited impacts of in water work.

In this case, the environmental regulatory permitting process is therefore likely to be similar to that completed for the Macdonald Bridge Redecking Project. Major tasks in that process included the following:

- Regulatory Stakeholder Consultation program;
- Field Programs – Avian Survey;
- Project Description preparation; and
- Navigation Protection Act Approval Submission Process

The regulatory process for the MacDonald Redecking Project progressed along the similar timelines to that of the preliminary and details design programs between 2011 and 2012.

5.2 Replacement Bridge: Option 2A

A cable-stayed bridge with a main span of approximately 500 m was the highest scoring replacement option and highest scoring option over all. This option is significantly less expensive than a similar-sized suspension bridge, while also providing for lower anticipated maintenance costs.

The major issues identified are:

- CFIA Building demolition and reconstruction;
- Land acquisition;
- Navigational channel requirements due to towers in water;
- Impact to marine traffic during construction and demolition;
- Permitting complexity and timelines; and
- Operational issues over the life of the bridge (maintenance over existing structures and parking lots).

Mitigation Measures

This section discusses possible mitigation measures for each of these issues.

CFIA Building Relocation

Relocating the building is necessary to locate the replacement bridge to the north of the existing MacKay and as close as practical to the existing alignment. An estimate of the cost for relocating the CFIA building was included in the evaluation.

Specific consultation with CFIA would be required to understand the feasibility of relocating the CFIA building. If relocation were not practical, the alignment would require modification with subsequent potential impacts to the estimated cost.

Land acquisition

HHB does not own the land under the new 500 m main span cable-stayed bridge alignment and it is anticipated that the replacement bridge would significantly impact existing facilities, especially the CFIA building on the Dartmouth side. The specific impacts could be adjusted based on pier locations.

Discussions between the current owners of the land and HHB would help to narrow the estimates for acquisition costs and implications.

Navigational channel clearance

The new 500 m main span cable-stayed bridge option would provide approximately 60 m of vertical navigational channel clearance, a 10 m increase compared to the existing bridge and 8 m more than the current Macdonald Bridge. The main span length in this option is slightly greater than the existing MacKay main span, but only to enhance the constructability of the main towers by separating them longitudinally from the existing towers and leaving additional space for construction equipment. The main span increase does result in a slightly wider navigational channel between the two main towers.

This study assumes that HPA's expectations for the navigational channel are similar to those for the Macdonald Bridge. During preliminary and detailed design, it is expected that these expectations would be clarified. Increasing the channel width may be desired to address future marine traffic demands and reduce the risk of vessel impacts. Regardless of tower locations, the risk of vessel impacts to the structure are mitigated through the use of dolphins, construction of an island around the main tower foundation (most likely option) or other means of vessel impact protection.

Construction work around the Dartmouth tower would have an impact on the BIO/Coast Guard wharf. This work would need to be discussed with the Canadian Coast Guard to understand the implications.

Impact to marine traffic during construction and demolition

Bridge construction and demolition is expected to involve installation and removal of deck segments from barges in the harbour. Early coordination with Halifax Port Authority (HPA) is recommended to understand HPA's operational requirements during construction and demolition to minimize impact on marine traffic.

Permitting Complexity and Timelines

The environmental regulatory process for Option 2A is likely to include:

- Transport Canada Approval under the Navigation Protection Act;
- DFO Serious Harm Authorization/Off setting compensation under the Fisheries Act;
- High potential for an EA under CEAA 2012 likely given the nature of the work in the harbour and the permanent (significant effect) changes to federal lands at the BIO and the CFIA sites;
- NSDRN – Beaches/Crown Lands Act Approval; and
- NSCCH - Archaeological sign-off under The Special Places Protection Act.

Major regulatory tasks for this process are likely to include the following:

- Regulatory Stakeholder Consultation program;
- Field Programs – Avian Survey; Fish Habitat survey, land-based and marine archaeological surveys;
- Project Description preparation;
- Navigation Protection Act Approval Submission Process;
- CEAA 2012 EA preparation; and
- Federal Authorities Review Process.

This regulatory process is also likely to progress along the similar timelines to that of the preliminary and details design programs taking two-three years to complete.

To mitigate project risks, primarily related to schedule delay, it is imperative to proactively plan for permitting. A specialist familiar with the local permitting processes would assemble applications as early as possible. Minimizing work in sensitive areas may reduce or ease permitting requirements, but some amount of unknown, and therefore risk, remains until project completion.

Operation issues over the life of the bridge

Current cable-stayed bridge technology utilizes stay cables that would last for the entire design life of the structure without major rehabilitation work. It is also customary to design the bridge to allow replacement of stay cables with minimal interruptions to traffic in the event that they are damaged or excessively deteriorate during service. Some stay cable components, such as dampers, will however require regular inspections and maintenance to keep them operational.

One known adverse attribute of cable-stayed bridges in areas with weather similar to Halifax is the possibility of ice build-up on the cables and falling to the deck below. In these cases, ice may fall off the cable in large sheets and can create a hazard for bridge users and cause traffic disruptions. However, for a 500 m main span bridge, this situation should not have increased risk than that of the current situation on the suspended spans in which ice and snow may accumulate on the existing ALM and AMM main cables.

To reduce the risk, the proposed tower design in option 2A avoids having the stay cables directly above traffic lanes and it is recommended that the final bridge design maintain this criteria.

Another unknown regarding cable-stayed bridges is the long term durability of the concrete deck. Since the deck is a structural member (it carries the compression from the cables), if the reinforcing in the deck is compromised, it is very difficult to replace and or repair. It is therefore recommended that, if HHB choose a cable-stayed option, that HHB consider requiring all deck reinforcement to be stainless steel. These additional costs are not included in the cost assessment portion of this study. It is anticipated that they would not change the conclusions for the preferred option selection.

6 Conclusions

This report presents several rehabilitation and replacement options for the existing MacKay Bridge. Nine options were compared using evaluation matrices that included bridge deck features, life-cycle costs, social impacts, risks and opportunities associated with each of the options.

The purpose of this study was to determine the preferred options for a rehabilitation approach and for a replacement approach as well as provide an overall recommended option.

- The highest scoring rehabilitation approach is option 1B - rehabilitate the existing bridge and add AT lanes. This option would be somewhat similar to the project recently completed on Macdonald Bridge. The engineering and construction effort for rehabilitating the MacKay Bridge are anticipated to be significantly greater than for the Macdonald Bridge because of the efficient original design which will result in significantly more reinforcing, the need to supplement the main cables and to replace the approach spans.

- Results of the evaluation indicate that the highest scoring solution, both overall and for the replacement approach, is option 2A, a new cable-stayed bridge with approximately a 500 m long main span, slightly longer than the existing MacKay Bridge. This replacement bridge would be located on an alignment parallel and slightly to the north of the existing bridge. The solution would require construction of new approach spans but would largely avoid realignment of the approach roadways. The CFIA structure on the Dartmouth side would need to be relocated. This option is recommended as the preferred solution.

7 Acknowledgements

COWI wishes to acknowledge the cooperation and assistance provided by the Halifax Harbour Bridges, in particular: Mr. Ahsan Chowdhury, Chief Bridge Engineer, Daniel Sanchez, Project Engineer, and Joshua Levy, Project Engineer. Participation and input from HHB's Steering Committee was greatly appreciated, in particular the involvement from Tanya Davis with the Halifax Regional Municipality and Rob Hird with the Nova Scotia Department of Transportation and Infrastructure.

8 References

[1] COWI, "MacKay Bridge Feasibility Study: Briefing Report," 2018.

Appendix A Alignments

For replacement options, a new alignment would be necessary so that the existing bridge remains open during construction. Building on the Delphi-MRC Twinning Study described in the Briefing Report [1], three alignments to the north and south of the existing structure were considered, as shown in Figure 1.

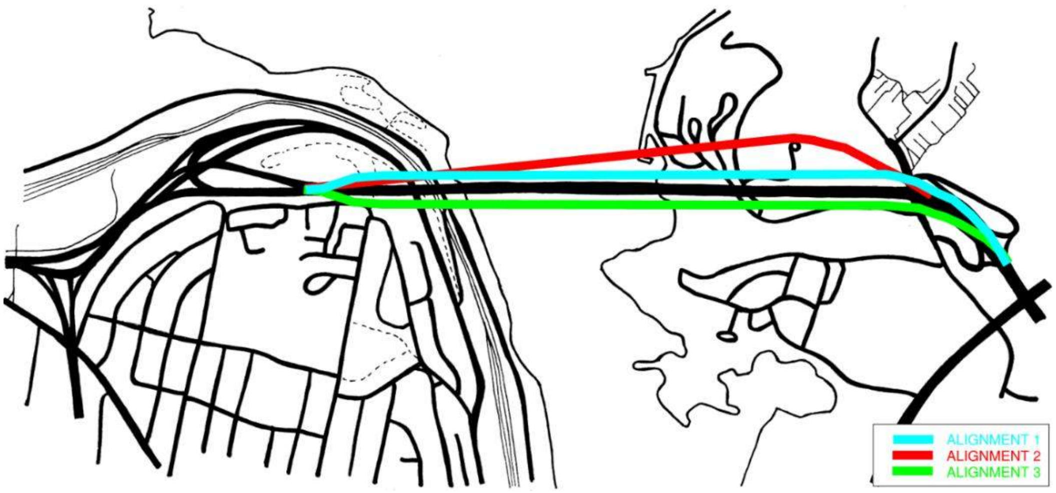


Figure 1: Preliminary Alignment Options

These three horizontal alignments were assessed for their relatively low impact on existing land and infrastructure, as well as suitability for a well-designed horizontal and vertical alignment for the future new bridge. The criteria used in the alignment selection was based on providing adequate clearance from the existing MacKay Bridge. This would allow construction to proceed while maintaining traffic flow and minimizing impact on the adjacent land (including the Bedford Institute of Oceanography (BIO) on the Dartmouth side, the Africville Park and north end homes on the Halifax side, as well as cross-harbour transmission lines).

The scope of this study was limited to investigating alignment options in relative proximity to the existing structure. As such, COWI has not reviewed existing information on alternate locations previously studied (Georges Island); this alternate location was described briefly in the Briefing Report [1].

Horizontal Alignment 1 – North of the existing bridge, immediately adjacent

Alignment 1 would run to the north of the existing bridge, but south of (or through) the CFIA Building. The alignment would be parallel to the existing bridge with a minimum 15 m clearance between decks. Being a parallel alignment, an S-curve would be necessary on the Halifax approach to tie in into the existing roadways. On the Dartmouth side, a single curve to tie in north of the existing curve near the current toll plaza would be possible.

This alignment has the least impact on the approach roadways and is used for the 500 m main span options (1C, 2A, 2B, 2E and 2F). An 800 m main span would not be possible on this alignment because the larger towers associated with the longer span would conflict with the existing bridge. The 800 m span would also require an S-curve on the Dartmouth side to reconnect to existing approach roads, which is not desired.

Alignment 1 is shown in detail in Figure A1.

Horizontal Alignment 2 – North of the CFIA building

Alignment 2 would run to the north the existing bridge and CFIA building. The existing marine and wharf facilities make it difficult to accommodate the piers of a 500 m span bridge. A 500 m main span would also result in approach piers conflicting with existing infrastructure. Therefore, for the purpose of this study, COWI has assumed that for alignment 2, the length of the main span for the replacement bridge would be approximately 800 m.

This alignment positions the towers out of the harbour and places the east tower on land between existing driveways. The bridge would pass over top of the BIO/Canadian Coast Guard wharf structure at a high elevation (about 60 m above water), thereby avoiding conflicts.

Positioning the towers out of the water also eliminates conflicts with vessels using the wharf. The side spans of the replacement bridge would provide a pier-free span over the remaining developed BIO lands, thus reducing impact on that property. The alignment would tie into the existing Dartmouth approach road alignment close to the west side of the existing toll plaza. There would be impacts on buildings within Wallace Heights (Ocean Breeze Village) with this alignment. One townhouse complex would likely have to be replaced and another would require the construction of a retaining wall to prevent impact. On the Halifax side, the tie in to the existing approach road would only require a single curve, and would be designed to blend with the existing Barrington St. eastbound lane. A simple curve is made possible by the new alignment merging diagonally with the existing alignment.

Alignment 2 is shown in detail in Figure A2.

Horizontal Alignment 3 – South of the existing bridge, immediately adjacent

Alignment 3 would run to the south of the existing bridge, through the adjacent streets, several homes, an apartment complex and the tower supporting the cross-harbour transmission lines. Being a parallel alignment, an S-curve would be necessary on the Halifax approach to tie in into the existing roadways. On the Dartmouth side, a single curve to tie in north of the existing curve near the current toll plaza would be possible. For this alignment, the replacement bridge main span could be approximately 500 m, or could be adjusted to clear the harbour, about 700 m.

A number of factors make alignment 3 less desirable the alignments 1 and 2. Alignment 3 results in significant challenges due to impacts with owners of homes and at least one apartment complex, at least one municipal road in each Halifax and Dartmouth, and Nova Scotia Power's principle high-voltage power lines crossing the harbour. New developments and archaeological concerns are also of note in the former Shannon Park lands, south of the existing bridge. In contrast, to the north of MacKay there is a municipal park (albeit with historical concerns), and the Federal facilities on the Dartmouth side. These considerations are in agreement with previous alignment studies (Twinning Report) where options to the north were also preferred [1].

Therefore, alignment 3 is not pursued further in this report.

Vertical Alignment

For the rehabilitation options, the vertical navigational clearance can be increased by about 1 m if the new deck and trusses are configured similar to Macdonald Bridge. Alternatively, the deck system could be reconfigured with the trusses slightly inboard of the main cables allowing the main cable to pass through the deck, and support the truss via truss outriggers in the midspan area. This would result in the possibility to increase the vertical clearance by up to about 4 m.

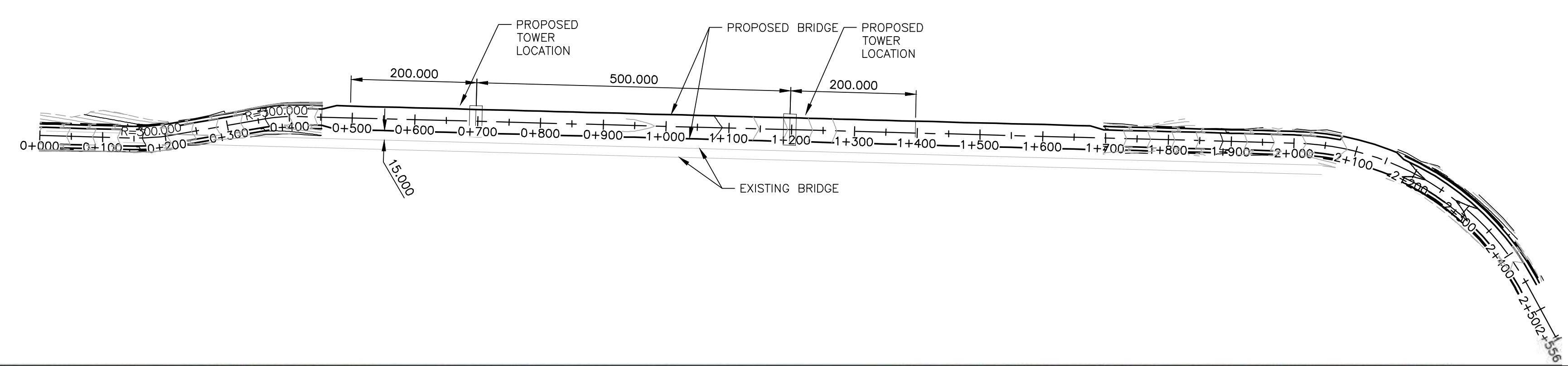
The vertical alignment for all replacement options would increase the navigational channel vertical clearance beneath the replacement bridge by approximately 10 m when compared to the existing bridge. This allows 8 m for increased heights of commercial vessels, and approximately 2 m for sea level rise. The approach gradients would be approximately 5% in each case.

AT Lane Alignment for Rehabilitation Options 1B and 1C

AT lane alignment on the Halifax and Dartmouth approach roads would intrude on adjacent properties and would require negotiation with stakeholders regarding land acquisition. Both the potential outcome of the negotiations with affected land owners and the land acquisition cost remain uncertain at this time.

It is understood that HRM is undertaking an Africville pedestrian and bike access study in 2018. This would look at connections from Novalea, Barrington and Lady Hammond to Africville Park, all of which might be impacted by a replacement bridge.

Figure A1: Alignment 1 (Parallel (North))



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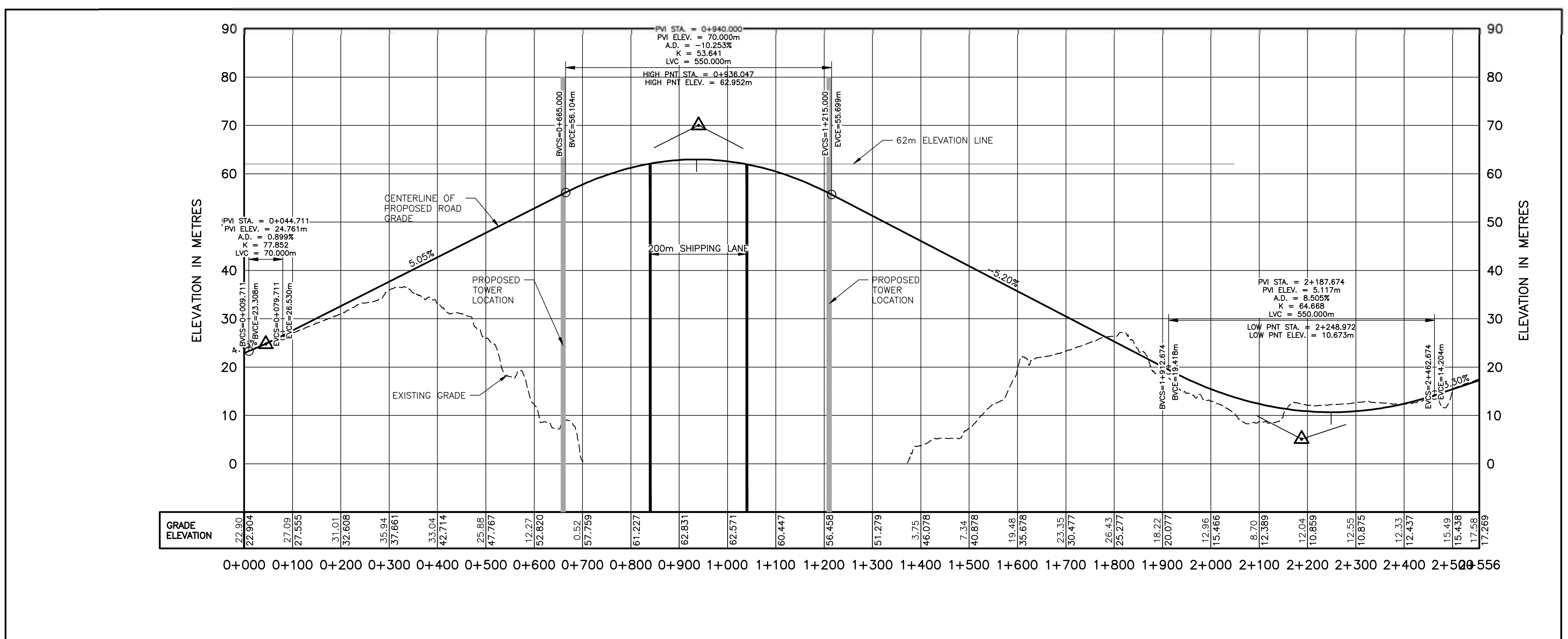

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Revision or Issue

HALIFAX HARBOUR BRIDGES

MCKAY BRIDGE FEASIBILITY STUDY

PARALLEL ALIGNMENT

CBCL LIMITED
Consulting Engineers

CBCL No	Contract No	Date	Scale
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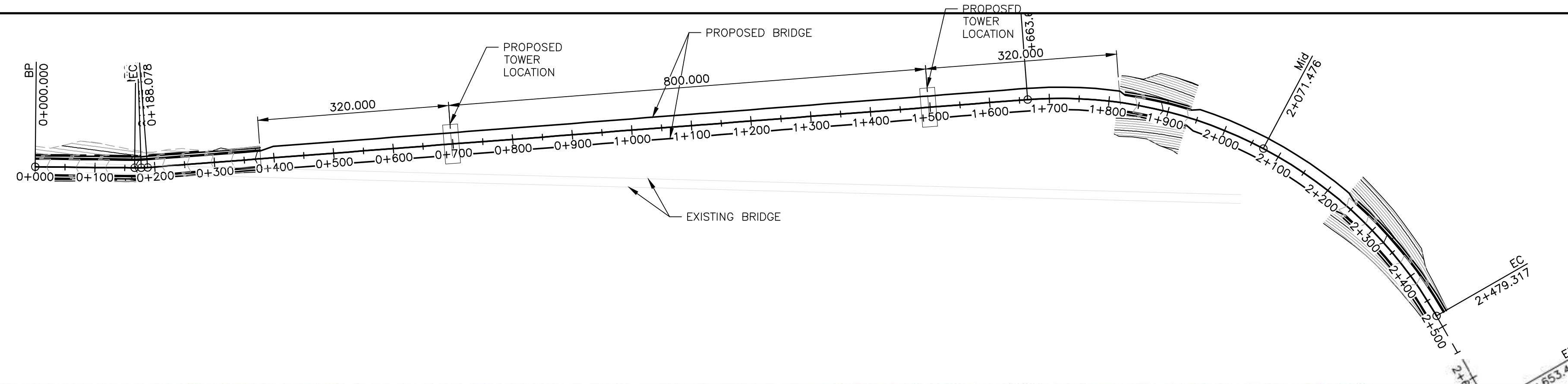
Drawing No: C02

Figure A2: Alignment 2 (North)



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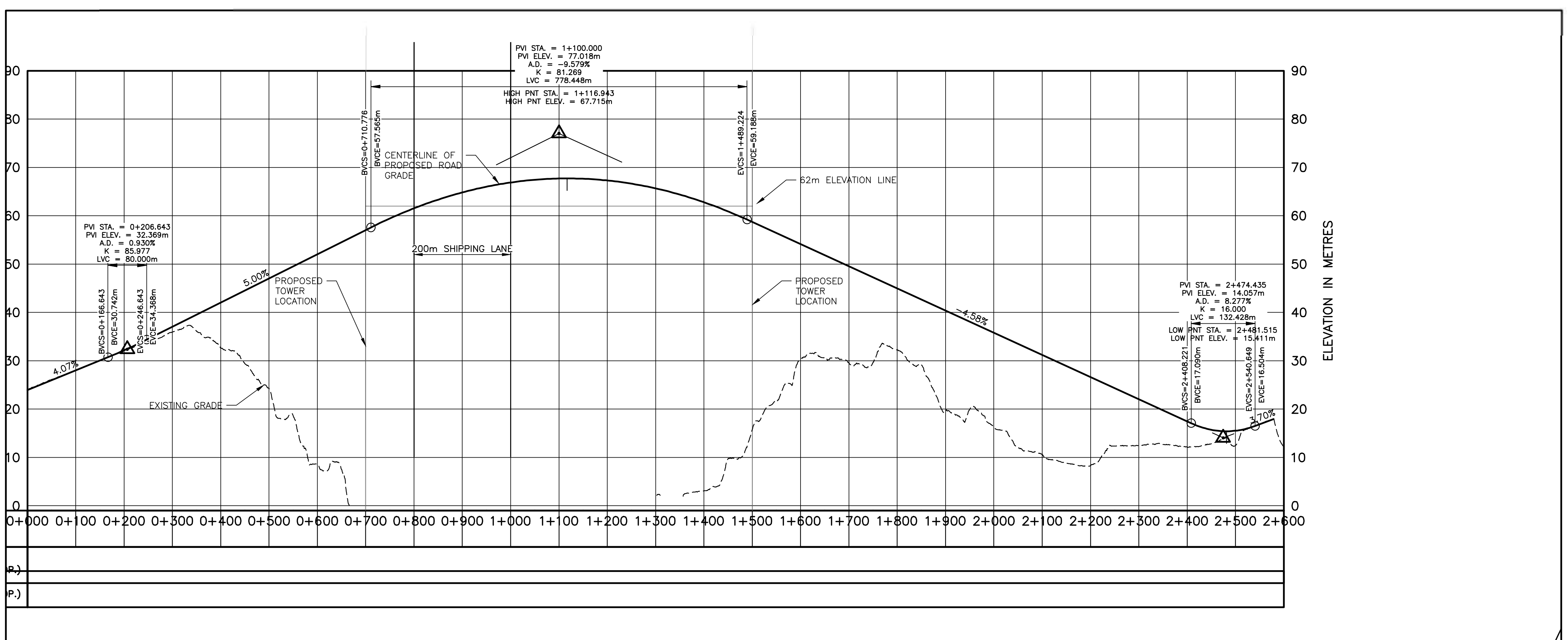

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Revision or Issue

HALIFAX HARBOUR BRIDGES

MCKAY BRIDGE FEASIBILITY STUDY

NORTH ALIGNMENT

CBCL LIMITED
Consulting Engineers

CBCL No	Contract No	Date	Scale
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Appendix B Superstructure Cross Sections

The current MacKay Bridge has four traffic lanes and no sidewalks or bike lanes. The traffic lanes are 3.6 m wide with 0.6 m wide shoulders. The roadway can feel narrow due to the narrow outside shoulders and a lack of centre separation between lanes of opposing traffic.

- Option 1A – Rehabilitate the existing bridge:

  The width of the deck is limited by the clear width between the existing tower legs, so this rehabilitated option would retain four 3.6 m wide traffic lanes with two 0.6 m wide outside shoulders. The total width of the roadway would remain the same as on the existing deck, approximately 15.6 m between the inside faces of the traffic barriers.

- Option 1B - Rehabilitate the existing bridge and add two AT lanes:

  This option involves four 3.6 m wide traffic lanes with two 0.6 m wide outside shoulders as in option 1A. In addition, the deck would be widened to accommodate two 3.0 m wide AT lanes. At the towers and cable bents, the AT lanes would be cantilevered around the tower/ and cable bent legs.

- Option 1C - Rehabilitate and twin the existing bridge:

  The existing suspension bridge superstructure would be replaced with a deck that would provide three 3.5 m wide traffic lanes with inside and outside shoulders, and one 3.0 m wide AT lane. Lane widths of 3.5 m for the twin bridge are based on discussions with HHB's Steering Committee and are consistent with HRM's arterial roadway design. Since the existing tower is not wide enough to accommodate full shoulder widths, shoulder widths of 1.0 m and 1.5 m for the inside and outside shoulders respectively, would be used for the existing bridge.

- Options 2A – 2D – Replacement bridges:

  These replacement designs comprise three traffic lanes per direction, each 3.5 m wide, with 1.5 m and 2.5 m wide inside and outside shoulders respectively. A rigid median barrier would separate oncoming traffic. In the event that 3.6 m lanes are required during later stages of development of the project, the overall conclusions in this report would not be affected. The replacement design options have 38.6 m wide decks including two AT lanes.

- Options 2E – 2F – Replacement bridges

  These replacement designs comprise of two lanes of traffic per direction, each 3.5 m wide, with 1.5 m and 2.5 m inside and outside shoulder respectively. A rigid median barrier would separate oncoming traffic. In the event that 3.6 m lanes are required during later stages of development of the project, the overall conclusions in this report would not be affected. Options 2E and 2F have overall deck widths of 25.6 m with no AT lanes.

Appendix C Traffic Analysis

At the commencement of the study, and as outlined in the Briefing Report, traffic count data was requested from HHB, HRM and NSTIR - the key stakeholders involved in the project. Any available historic and up to date data on the Mackay Bridge, the adjacent surface streets, and the 100-series highway network was requested.

From a traffic and transportation perspective, the key objectives of the analysis were:

- Assessing the impact of various options on traffic flow at adjacent intersections;
- To increase traffic capacity through two options - by modifying the existing structure and replacing the bridge;
- Taking account of increases in design traffic loading that have occurred since the opening of the bridge in 1970; and
- Considering the need for additional capacity for future traffic demand, which could include lanes for dedicated transit operation and active transportation.

Under existing conditions and current traffic levels, the analysis shows poor levels of service (E and F) on many intersection approaches during the AM peak period. Results are slightly better during PM peak periods, although some intersections still present poor levels of service. Analysis of future traffic volumes shows poor on all approaches. This is consistent across all studied options as there are no plans for changes to lane configurations at the intersections reviewed.

C.1 Traffic Demands

The following traffic data was received from the stakeholders:

- From HHB: Weekday AM and PM directional traffic volumes for 2014 and 2015.
- From HRM: Weekday AM and PM turning movement counts for 2014 and 2016, and directional traffic volumes for 2017.
- From NSTIR: Weekday AM and PM directional traffic volumes for 2016.

Since all traffic data received were for different years, a standard traffic baseline of 2017 was developed by applying an estimate of background growth in the area. Based on previous studies undertaken within HRM, and applying engineering judgment, a growth rate of 0.75% per year was applied. This rate was applied to all data received to create a consistent starting point for future growth and is presented in Figures C1 and C2.

Using the baseline 2017 traffic volumes, capacity analyses were carried out for all study area intersections. Synchro 9 modelling software was used to develop models of the road network for AM and PM traffic volumes to assess intersection capacity and operations. HRM also provided current signal timings for the relevant study intersections and this was coded into the AM and PM models.

C.2 Intersection Performance Analysis

Level of Service (LOS) is the key indicator of intersection performance with respect to traffic movement, and is defined by the average amount of delay experienced by motorists using each of the various intersection movements. Higher delays result in increased driver discomfort, fuel consumption, and travel time. LOS gives an indication of speed, travel time, traffic interruptions, traffic flow, comfort, and convenience, and is expressed on a scale from level 'A' to level 'F'. LOS A represents conditions approaching free-flow, while LOS F represents a level of delay generally unacceptable to drivers, where traffic demand usually exceeds available capacity.

C.2.1 Level of Service Thresholds

A LOS D is generally found to be the minimum accepted level of service during peak periods and, in agreement with NSTIR's standard roadway requirements, therefore LOS A to D were used as the acceptable range for this study. The criteria associated with each LOS are found in Table C3. The delays listed for signalized intersections are higher than for the same level of service at unsignalized intersections. This is because motorists are typically more tolerant of extended delays at signalized intersections.

Table C3 Level of Service Criteria for Signalized and Unsignalized Intersections

Level of Service (LOS)	**Average Delay per Vehicle (sec)**	
	Signalized	Unsignalized
A	<10	<10
B	>10 and <20	>10 and <15
C	>20 and <35	>15 and <25
D	>35 and <55	>25 and <35
E	>55 and <80	>35 and <50
F	>80	>50

In addition to LOS, the Volume-to-Capacity (V/C) ratio is a key indicator of intersection performance. The V/C ratio is the relationship between estimated traffic volumes and the maximum theoretical capacity of an intersection or traffic movement. As the V/C ratio approaches 1.0, the intersection has less ability to accommodate additional traffic. Adjustments to intersection geometry or traffic control can be implemented to increase capacity and therefore reduce the V/C ratio.

Vehicle queue lengths have been evaluated individually based on the specific operational constraints that may be present at the study area intersections.

C.2.2 Baseline Intersection Level of Service

Using the existing peak hour traffic volumes, Synchro modelling software was used to perform the LOS analysis of the study area intersections for weekday AM and PM peak hours. The protocols for this type of analysis are outlined in the Highway Capacity Manual, 2010 Edition, which is published by the Transportation Research

Board (TRB). Synchro was also used to estimate the intersection volume to capacity (V/C) ratio and typical queue lengths for each intersection during the AM and PM peak periods.

To allow a comparison of the existing conditions against future conditions with a replacement bridge structure in place, the resulting Synchro analyses of existing conditions at the Bedford Highway/Windsor Street signalized interchange, and the Kempt Road/Lady Hammond Road signalized intersection is shown in Table C4. Also included are results at the existing toll booths on the Mackay Bridge as vehicles experience some delay and congestion passing through the barriers. The table summarizes the results of the Synchro LOS analysis for 2017 baseline conditions. Figures C1 and C2 provide the graphical output from the analysis.

The existing intersections show poor level of service on many of the approaches during the AM peak period. PM conditions are generally better at the two signalized intersections, however still show LOS E and F on some approaches.

Table C4: Synchro Analysis Results: Existing - 2017 AM and PM

Intersection [Synchro Node No.]	Lane / Movement	AM Peak Hour				PM Peak Hour			
		95th % Q[1] (m)	V/C Ratio[2]	Average Delay[3] (s)	LOS[4]	95th % Q[1] (m)	V/C Ratio[2]	Average Delay[3] (s)	LOS[4]
Bedford & Windsor [5] (Signalized)	EB Left	316.3	1.05	74.5	E	185.1	0.93	60.9	E
	EB Thru/Right	296.3	1.00	95.0	F	96.3	0.57	41.5	D
	WB Left	18.1	0.61	87.4	F	17.0	0.23	52.0	D
	WB Thru	17.4	0.58	85.8	F	46.9	0.70	54.1	D
	NB Left	23.5	0.35	39.5	D	53.1	0.60	36.5	D
	NB Thru/Right	104.0	0.66	46.5	D	75.1	0.44	35.5	D
	SB Left	74.8	0.98	149.0	F	21.8	0.30	57.8	E
	SB Thru	85.8	0.75	64.0	E	80.7	0.77	65.6	E
	Overall			**78.0**	E			**50.5**	D
Kempt & Lady Hammond [7] (Signalized)	EB Thru	297.8	1.06	70.5	E	251.1	1.00	66.3	E
	EB Right	6.7	0.55	4.4	A	5.8	0.63	5.4	A
	WB Left/Thru	98.0	1.47	276.1	F	95.0	0.94	85.4	F
	NB Left/Right	36.0	0.27	24.0	C	103.8	0.58	35.7	D
	Overall			**85.1**	F			**49.6**	D
Mackay Bridge Toll Booth [15] (Signalized)	EB Thru	44.5	0.76	13.2	B	72.0	0.94	20.0	B
	WB Thru	77.4	0.98	25.3	C	46.6	0.78	13.7	B
	Overall			**20.1**	C			**17.1**	B

Notes:
Analysis by CBCL Limited using Synchro 9.0
1. 95% Queue - 95th percentile queue [highlighted if >100m or if available storage is exceeded]
2. V/C Ratio - Volume to Capacity Ratio [highlighted if >0.85]
3. Average Delay - average total delay per vehicle [highlighted for LOS E or F]
4. LOS - Level of Service [highlighted for LOS E or F]

It is assumed that construction would commence in 2032, and be completed in 2035. For the purposes of analyses, 2035 is assumed as the opening year. Figure C3 and C4 show the resulting traffic volumes for the assumed opening year of 2035. The resulting and comparable Synchro analyses for each bridge option is included in Section C.2.3, below.

It is important to note that the presence of the toll booths currently causes some delays and congestion as all vehicles are required to slow down for the barrier control. Based on discussions with HHB's Steering Committee, it is understood that the toll booths and barriers would be removed before construction of the replacement bridge and automatic tolling would be installed, therefore current delays at these locations would not exist once the replacement bridge is in place, and traffic should be operating in free-flow conditions.

Table C4 summarizes the results of the Synchro analysis for all options during 2035 AM and PM peak hours. Figures C3 and C4 provide the graphical output from the analysis. As can be seen, most of the approaches now show LOS F during the AM peak period. The PM period also shows a deterioration in level of service and an increase in queue lengths and shows more LOS E on some approaches.

These results are the same as for all future options as it has been identified that both HRM and NSTIR have no planned changes to the lane configurations at these intersections in the future. With the removal of the toll booths, there is nothing to report in Synchro at this location, therefore, free-flow conditions have been assumed across the bridge. It is understood that free flow meters traffic less and therefore may result in poorer results at downstream locations. This has been taken into account in the Synchro analysis at the adjacent intersection.

Table C4: Synchro Analysis Results: Future Options - 2035 AM and PM

Intersection [Synchro Node No.]	Lane / Movement	AM Peak Hour				PM Peak Hour			
		95th % Q[1] (m)	V/C Ratio[2]	Average Delay[3] (s)	LOS[4]	95th % Q[1] (m)	V/C Ratio[2]	Average Delay[3] (s)	LOS[4]
Bedford & Windsor [5] (Signalized)	EB Left	386.2	1.20	130.7	F	227.1	1.07	93.3	F
	EB Thru/Right	365.5	1.14	106.8	F	111.4	0.65	44.8	D
	WB Left	18.7	0.70	87.9	F	17.4	0.26	53.2	D
	WB Thru	17.7	0.66	87.1	F	48.8	0.80	58.5	E
	NB Left	26.4	0.44	41.1	D	60.6	0.71	39.6	D
	NB Thru/Right	121.2	0.75	50.3	D	86.4	0.49	36.5	D
	SB Left	95.3	1.46	299.7	F	24.4	0.35	60.7	E
	SB Thru	102.7	0.84	69.9	E	93.5	0.85	70.8	E
	Overall			**105.8**	F			**62.1**	E
Kempt & Lady Hammond [7] (Signalized)	EB Thru	286.2	1.19	108.7	F	292.2	1.14	108.1	F
	EB Right	7.2	0.61	6.5	A	9.5	0.71	7.7	A
	WB Left/Thru	112.6	1.70	373.4	F	113.2	1.08	126.6	F
	NB Left/Right	41.4	0.30	26.2	C	120.5	0.64	38.1	D
	Overall			**121.4**	F			**73.6**	E

Notes:
Analysis by CBCL Limited using Synchro 9.0
1. 95% Queue - 95th percentile queue [highlighted if >100m or if available storage is exceeded]
2. V/C Ratio - Volume to Capacity Ratio [highlighted if >0.85]
3. Average Delay - average total delay per vehicle [highlighted for LOS E or F]
4. LOS - Level of Service [highlighted for LOS E or F]

This is a high-level analysis at this early stage in the planning process; therefore, a detailed transportation impact analysis is recommended once the preferred option has been chosen. There are a number of important factors to consider when trying to understand traffic demand and operations so far into the future. For example, technologically enabled/controlled vehicles are advancing at a fast pace and in another 15 years or so when construction is anticipated to commence, would no doubt be common and would bring with it its own impact on the road networks and driver behaviour, also travel demand and trip patterns. Another possibility to consider is that many more people may be working from home instead of commuting to work every day.

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AM Peak Hour Traffic Volumes

Total

Background Growth Rate r
yr 2017
(1+r)^n

Note: Total volume includes lights, mediums, articulated trucks, and buses

	Bedford	Lady Hammond	Massachusetts	Barrington	Barrington	Mackay	Hwy 111
r	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%
n	1	3	0	2	0	3	1
(1+r)^n	1.01	1.02	1.00	1.02	1.00	1.02	1.01

N

Note: 1. Street network not drawn to scale.

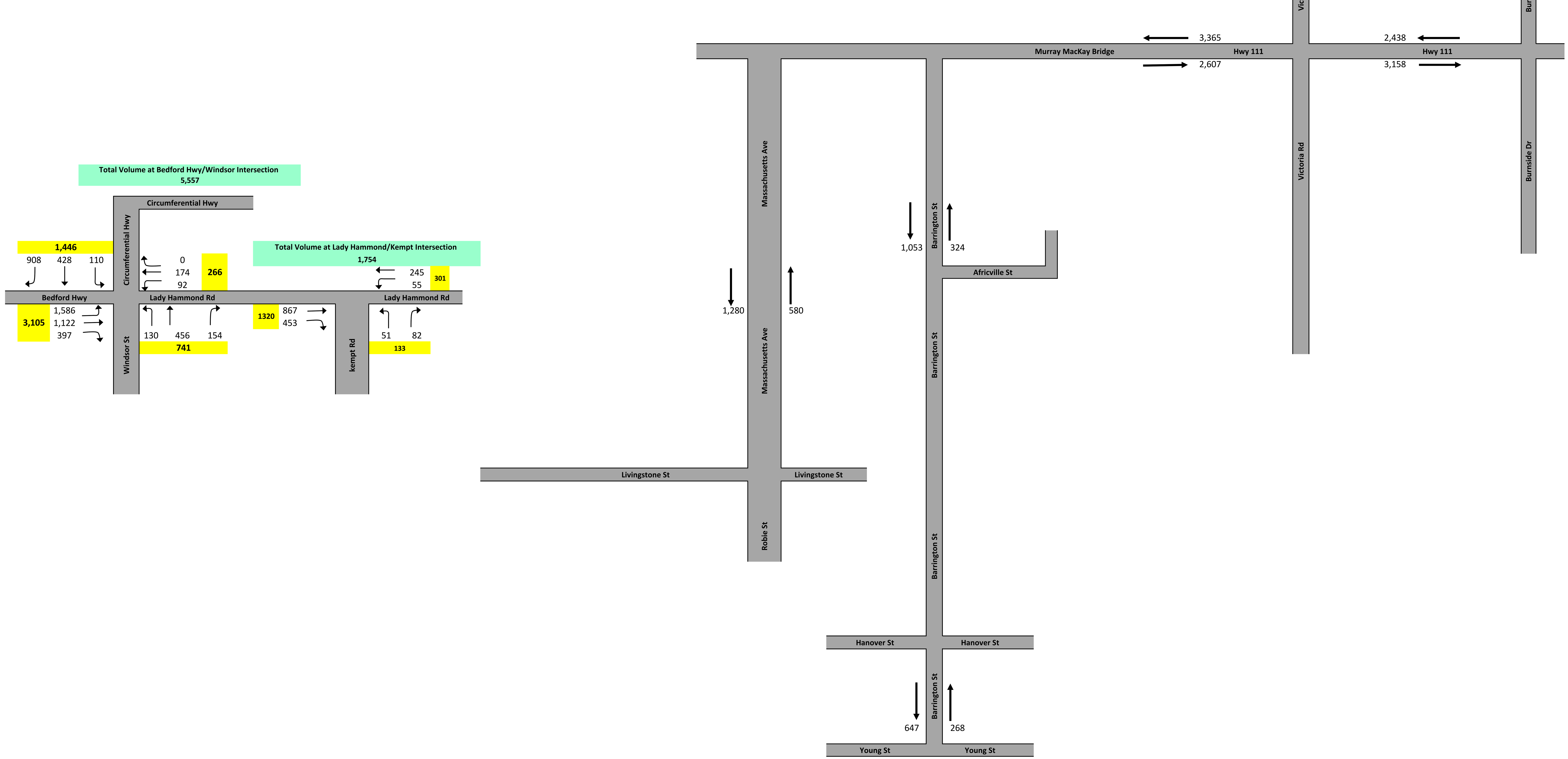

Figure C1: 2017 AM Peak Traffic

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PM Peak Hour Traffic Volumes

Note: Total volume includes lights, mediums, articulated trucks, and buses

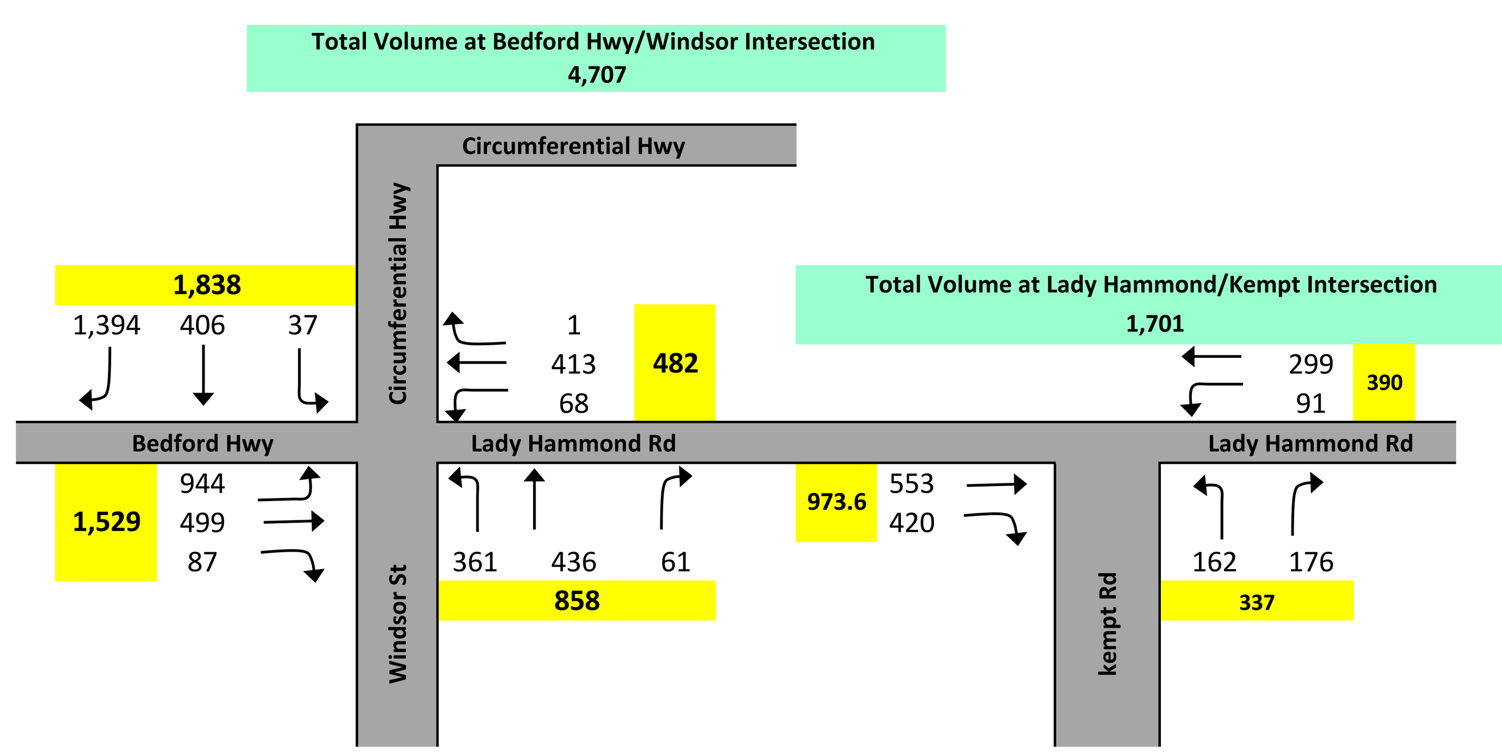
Total

Background Growth Rate r
yr 2017
(1+r)^n

	Bedford	Lady Hammond	Massachusetts	Barrington	Barrington	Mackay	Hwy 111
r	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%
n	1	3	0	2	0	3	1
(1+r)^n	1.01	1.02	1.00	1.02	1.00	1.02	1.01

N

Note: 1. Street network not drawn to scale.



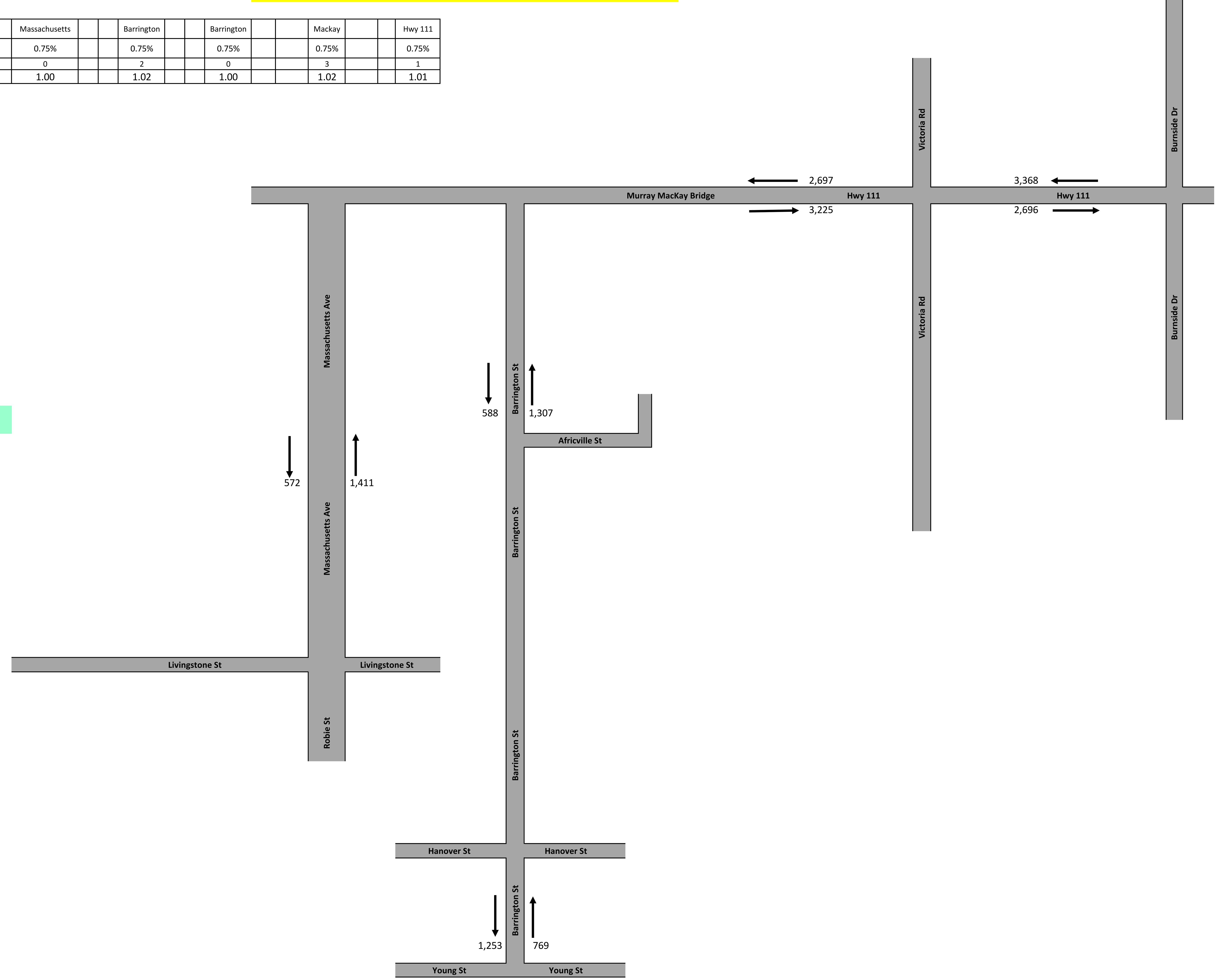


Figure C2: 2017 PM Peak Traffic

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AM Peak Hour Traffic Volumes

Total

Background Growth Rate r
yr 2035
(1+r)^n

Note: 1. Street network not drawn to scale.

Note: Total volume includes lights, mediums, articulated trucks, and buses

	Bedford	Lady Hammond	Massachusetts	Barrington	Barrington	Mackay	Hwy 111
r	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%
n	18	18	18	18	18	18	18
(1+r)^n	1.14	1.14	1.14	1.14	1.14	1.14	1.14

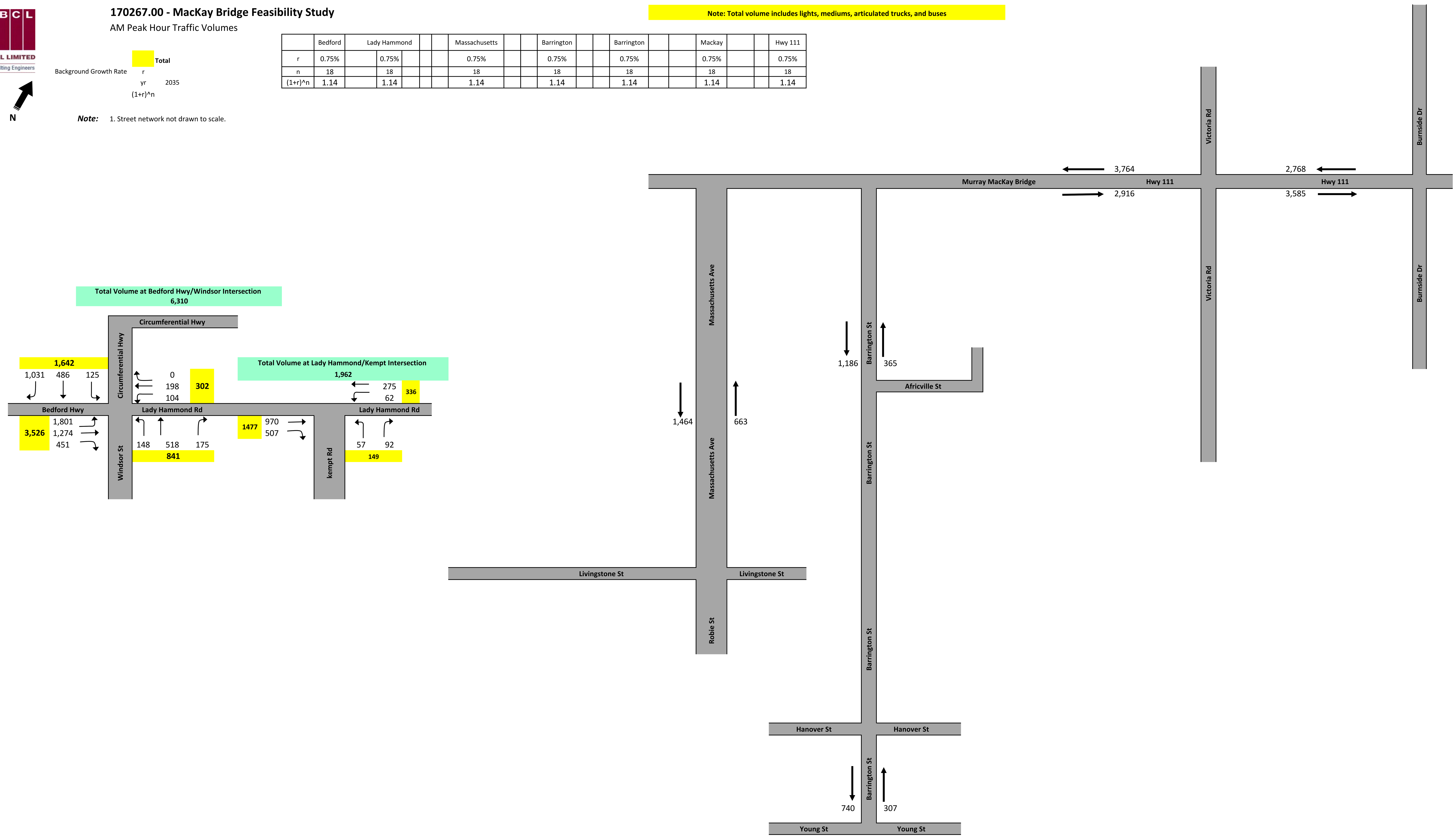

Figure C3: 2035 AM Peak Traffic

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PM Peak Hour Traffic Volumes

Note: Total volume includes lights, mediums, articulated trucks, and buses

Total

Background Growth Rate r
yr 2035
(1+r)^n

	Bedford	Lady Hammond	Massachusetts	Barrington	Barrington	Mackay	Hwy 111
r	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%	0.75%
n	18	18	18	18	18	18	18
(1+r)^n	1.14	1.14	1.14	1.14	1.14	1.14	1.14

N

Note: 1. Street network not drawn to scale.

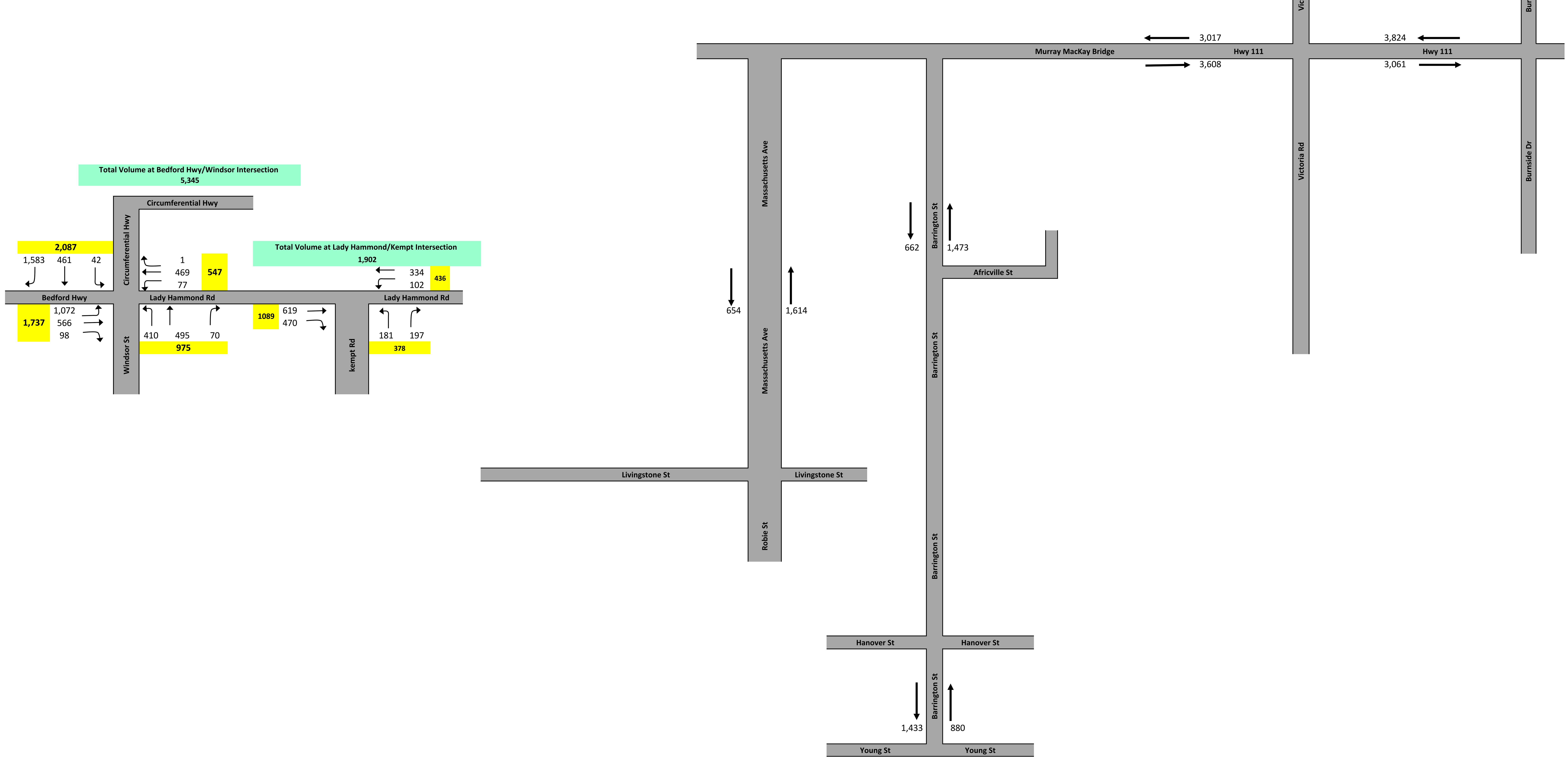


Figure C4: 2035 PM Peak Traffic

C.2.4 Traffic Analysis

As summarized in the paragraphs below, study has demonstrated that there is no impact to the traffic modeling. The following section provides background information on the existing conditions.

Due to this being a high-level assessment, and considering the limitations in the modelling software, not all locations identified in the road network generated an output report. The only material differences at this stage are the number of lanes per option on the bridge section; options 1A and 1B, these were coded with four lanes while options 1C and 2 were coded with six lanes. As a guide, lane capacities are determined by road category, the number of lanes, and the posted speed limit. For the bridge options, these are considered to be operating at free-flow once vehicles have passed through the toll booths. If the bridge lanes are assumed equivalent to an arterial road, then the lane capacity is estimated to be 1,100 vehicles per lane per hour (vplph). Currently the four lanes on the bridge operate with more than 1,100 vplph, so increasing the number of bridge lanes to six would be able to accommodate future traffic volumes in 2035.

Signal timing/phasing and lane configurations for the two signalized intersections within the study area are assumed to remain as existing. The existing cycle lengths were also maintained, as per discussion with HRM, so that coordinated patterns would not be interrupted. When more detailed design work is undertaken, it is anticipated that it would be necessary to revise the models to reflect future design decisions.

Appendix D Land Use

All of the rehabilitated or replacement options that increase the capacity of the bridge through either additional traffic or AT lanes would require the use of more land, either for construction laydown areas or a widened bridge footprint. HHB does not own all of the land around the MacKay Bridge, so each option would require HHB to work with adjacent landowners and users provides for temporary lease of the land, trade, or acquisition.

Replacement bridge construction is proposed on the north side of the MacKay Bridge, minimizing impact on the Memorial Drive residential area on the Halifax side. The additional land requirements on the north side include a modest area of Africville Lookoff Park to allow for relocation of the abutment. There is a NS Power transmission tower that confines the north side of the Barrington Street ramp, where an existing structure avoids the tower foundation.

On the Dartmouth side, there are at least four buildings to the north of the existing MacKay Bridge that would be affected by options to widen or replace the bridge. A fifth building in the Ocean Breeze Village neighbourhood could likely be avoided with a small retaining wall. The affected buildings are:

- Argo building on the Bedford Institute of Oceanography (BIO) property that is a 38 m x 22 m one storey building with Department of Fisheries and Oceans offices. It would be directly affected by alignment 2 and option 2B. While a preference would be to construct the replacement bridge above the building and avoid conflicting pier placement, further study would be required to determine if the building should be removed due to construction and maintenance risks.

- BIO is an oceanographic research facility with a campus of interconnected buildings that house offices, laboratories and pavilions. The facility has over 600 employees working for various federal government departments. While the main building complex should not be directly conflicted by the bridge project, the property would be affected by overhead bridge clearance and revisions to site development such as parking lots and landscaping.

- Canadian Food Inspection Agency (CFIA) building is a 55,000 square foot, multi-storey building that provides offices and laboratories to approximately 75 CFIA employees. The building conflicts directly with the replacement bridge alignment 1 (options 1C, 2A, 2B, 2E and 2F). Replacement bridge alignment 2 (options 2C and 2D) would avoid the building itself but affect the facility property.

- At least one residential building in the Ocean Breeze Village neighbourhood (Wallace Heights) and a maintenance building. The residential buildings are typically two storey townhouses and apartments. These buildings may be affected by alignment 1.

Appendix E Ancillary Structures

Ancillary structures include the overpasses and retaining walls along the approaches to the bridge. Most of the ancillary bridges in the vicinity of the MacKay Bridge are post-tensioned voided slab prestressed concrete structures. The exceptions are the two bridges over MacKintosh Street which are prestressed concrete girders and the Windsor/Robie Street exit ramp structure which is a steel box girder bridge, upgraded from a one lane bridge to a two lane structure in the 1980's. A summary of the structures is provided in Table E1.

Table E1: Ancillary Bridge Structures in the Study Area

	Length (m)	Type	Date Built	Lanes Over	Lanes Under	Bridge Ownership
Halifax Side						
Barrington St over Massachusetts Ave ramp	60	VS	~1970	2	1	HRM (BR081)/ NSTIR (HFX456)
Barrington St over Massachusetts Ave ramp	40	VS	~1970	1	1	HRM (BR083)/ NSTIR (HFX455)
Barrington St over Massachusetts Ave ramp	82	VS	~1970	2	1	HRM (BR084)/ NSTIR (HFX454)
Barrington St inbound over Barrington St	63	VS	~1970	2	2	HRM (BR128)/ NSTIR (HFX458)
Windsor/Robie St Exit Ramp	150	SBG	~1980's	2	2, 2	HHB (WRSE)/ NSTIR (HFX457)
Barrington St over MacKintosh St	20	PG	~1970	3	2	HRM (BR080)/ NSTIR (HFX452)
Barrington St over MacKintosh St	20	PG	~1970	2.5	2	HRM (BR127)/ NSTIR (HFX453)
Barrington St over NS Power Foundation	24	PG	~1970	~2	Tower Founda-tion	HRM (BR130)
Barrington St over CN Rail	89	?	~1970	2	CN Railway	HRM (BR131)/ NSTIR (HFX451)
Lady Hammond Rd over Massachusetts Ave	33	VS	~1970	2	4	HRM BR026)
Dartmouth Side						
Princess Margaret Overpass	20	VS	~1970	4	2+	HHB (PMOP)
CN Rail Overpass	17	?	~1970	4 + 2A	rail	HRM (BR115)/ CN (?)
Windmill Rd Overpass	59	VS	~1970	4 + 2A	2 + 2A	HHB (WROP)
Victoria Rd Overpass	61	VS	~1970	4 + 2A	4 +2A	HHB (VROP)

1) *Bridge types* are voided concrete slab (VS), steel box girder (SBG), prestressed concrete girder (PG).
2) Auxiliary Lanes or lanes associated with on/off ramps are denoted by A.

These bridges are showing their age with numerous deficiencies at the parapet walls, bearings and joints. The voided slab bridges do not lend themselves readily to modification (e.g. widening) and are difficult to demolish due to a lack of structural redundancy. The ancillary bridges would be about 60 years old when the MacKay Bridge is replaced or rehabilitated and would be nearing the end of their service lives. Where a replacement is necessary, detour arrangements may be difficult since the horizontal geometry is limited, and in the vertical direction, there are two locations with three-level grade separations.

The rehabilitation options studied have minimal impact on the existing alignment of approach roads, and the locations of the existing ancillary structures would remain unchanged. Assuming that the number of lanes remains sufficient, the design life of the structures would be unaffected by the options analysis and independent of the studied bridge options. Therefore, costs associated with the replacement of structures due to end of design life, age or condition has not been included in this report.

Notwithstanding the age of the ancillary structures, the layout of several of the existing ancillary structures may be inadequate where the bridge and nearby roadway cross section is increased to six basic lanes. The development of future AT lanes needs to be considered, and accommodation of these lanes would not necessarily be required at the ancillary structure locations; this would depend upon the planning of the AT network on both the Dartmouth and Halifax sides.

The implementation of a six lane bridge, whether through rehabilitation or new construction would warrant the widening of some ancillary structures depending on the requirements for transit only or high occupancy lanes. This would clearly affect the structure over Princess Margaret Boulevard which is currently four lanes wide and would need to be modified/replaced for any option reusing the existing alignment and carrying six lanes. Both HRM and NSTIR have indicated that there are no current plans for an increase in capacity on Highway 111 or the Halifax side approach roads. Further study is needed to determine if operation of a new six lane bridge would be significantly restricted by the existing lane configuration on the ancillary structures and approaches.

Appendix F Marine Structures

The impact of a replacement bridge on the Halifax shoreline would be relatively minor. New piers could be located near the shoreline and would not affect the navigational channel. Should the adjacent shoreline be developed for berthing of large vessels, the piers could be well back from anticipated face of the marine structures. A public boat launch on the shoreline to the north in Africville Park, used for small recreational vessels, should not be adversely affected.

On the Dartmouth side, options 1A and 2B would have limited impact except for the land associated with construction of the ship collision mitigation (if required). Construction of a twinned or replacement bridge of similar length (options 1C, 2A, 2B, 2E and 2F) would result in a new tower being constructed adjacent to the existing. This results in a potential impact to the marine structures of DFO and the Coast Guard. While this area is considered away from the main navigational channel, the water is still over 10 m deep that underlines the need to provide pier protection to mitigate possible ship collision.

The present wharf facilities at BIO accommodate Fisheries and Oceans and Canadian Coast Guard vessels. If a replacement bridge (options 2A-2F) was constructed, the marine facilities would remain operational, but would be affected by overhead construction and an easement would be needed for a bridge structure overhead.

Appendix G Regulatory Considerations

This section describes environmental and permitting requirements in place during the assessment period of this scope (2018). These requirements would possibly change prior to construction, and therefore would need to be updated through the planning/design/construction process.

Halifax Harbour is one of the most economically important inlets on the Eastern Seaboard. Any large infrastructure project including the rehabilitation or replacement of the MacKay Bridge is likely to impact many stakeholders and therefore be regulated under a number of federal, provincial and municipal laws requiring permits and approvals be issued prior to the work commencing. The following is a summary of the likely stakeholders and their regulatory requirements.

G.1 Existing Project Environment

Halifax Harbour is a major inlet of the Atlantic Ocean. It is composed of outer and inner divisions and the Bedford Basin. The inner harbour includes a slender passage called The Narrows, where the MacKay Bridge is located at the mouth of the Bedford Basin. The harbour shorelines adjacent to the MacKay Bridge on both the Halifax and Dartmouth sides are almost entirely altered by the placement of man--made, urban infrastructure.

A large infrastructure project, such as building or renovating the MacKay Bridge, may be regulated under a number of federal, provincial and municipal regulations and by-laws requiring permits and approvals to be issued prior to project start.

G.2 Federal Regulations

Under the current Canadian Environmental Assessment Act 2012 (CEAA 2012), an environmental assessment focuses on potential adverse environmental effects that are within federal jurisdiction, including:

- Fish and fish habitat;
- Other aquatic species;
- Migratory birds;
- Federal lands;
- Effects that cross provincial or international boundaries;
- Effects that impact on Aboriginal peoples, such as their use of lands and resources for traditional purposes; and
- Changes to the environment that are directly linked to or necessarily incidental to any federal decisions about a project.

An environmental assessment (EA) considers a comprehensive set of factors that include identification of mitigation measures, significant adverse environmental effects, cumulative effects, and comments and concerns of the general public and the Indigenous Peoples in Canada.

Under CEAA 2012 Section 67, Federal Authorities (FAs) have a duty to determine whether or not a project is likely to cause significant adverse environmental effects on federal land prior to carrying out an EA.

In the case of the proposed MacKay Bridge rehabilitation or replacement options based on the Project's potential to cause significant adverse environmental effects on lands under federal jurisdiction, Relevant FAs are likely to include the Halifax Port Authority, Public Services and Procurement Canada and Transport Canada.

G.2.1 Halifax Port Authority

Halifax Port Authority (HPA), a Crown Corporation, manages vessel movement within Halifax Harbour. HPA's mandate under the Canada Marine Act is to manage all Port of Halifax activities related to shipping, navigation, transportation of passengers and goods, handling of goods and storage of goods.

HPA a federal authority under CEAA 2012 and is required to determine whether or not carrying out a proposed project is likely to cause significant adverse environmental effects on federal lands. Other HPA's concerns are likely to be associated with the project's potential impact to navigation, and potential economic losses that could result from it.

G.2.2 Public Services and Procurement Canada

Public Services and Procurement Canada (PSPC) plays an important role in the daily operations of the Government of Canada as a key provider of services for federal departments and agencies. Supporting them as their central purchasing agent, linguistic authority, real property manager, treasurer, accountant, integrity adviser, and pay and pension administrator.

With respect to the MacKay Bridge rehabilitation or replacement options, PSPC is responsible for the management of the Bedford Institute of Oceanography and the Canadian Food Inspection Agency sites, neighbouring properties to the MacKay Bridge. As a FA under CEAA 2012, PSPC would be required to determine whether or not carrying out a proposed project is likely to cause significant adverse environmental effects on these federal sites.

G.2.3 Transport Canada

Transport Canada's mandate under the Navigation Protection Act (NPA) is to protect the public right of navigation—the right to use navigable waters as a highway. As result of amendments made to the Act in 2012, those watercourses now protected under the Act are listed as "Scheduled Waters". Those regulated in Nova Scotia include the Lahave River, the Bras d'Or Lakes and the Atlantic Ocean i.e. coastal sections of rivers under tidal influence (i.e. Halifax Harbour).

Under the NPA, TC requires that a Notice to the Minister be submitted by any owner who proposes to construct, place, alter, repair, rebuild, remove or decommission a "work" in a waterway on the List of Scheduled Waters.

When TC receives a Notice to the Minister, the Notice is first screened to make sure that the work is subject to the NPA and all required information has been provided.

Following the initial screening, the Notice to the Minister is assigned to an Officer and the work is assessed for likelihood of interference with navigation. Sometimes other steps may be required, such as an environmental review, Aboriginal consultation, or public advertising.

Following this review, the work may be issued an approval or deemed a permitted work. Approval may be denied if the impacts to navigation are unacceptable. Terms and conditions may apply to an approved work or a permitted work.

- Approved works are works that are approved by the Minister after being assessed as likely to substantially interfere with navigation.

- Permitted works are works that may proceed in accordance with the *Act* without the Minister's approval, after determination by the Minister that they are not likely to substantially interfere with navigation. These works are deemed compliant with the *NPA* if they meet regulatory requirements and any terms and conditions applied to the project.

G.2.4 Fisheries and Oceans Canada

The Fisheries Act contains two key provisions on conservation and protection of fish habitat essential to sustaining freshwater and marine fish species. Section 35 is discussed here and Section 36 noted in Section 2.1.5. The Department of Fisheries and Oceans Canada (DFO) administers Section 35, the key habitat protection provision, prohibiting any work or undertaking that would cause the harmful alteration, disruption or destruction of fish habitat.

Currently, Projects requiring authorization under the Fisheries Act are assessed on a project-by-project basis, which can be a complex process.

Following DFO review, Projects deemed unlikely to cause a harmful alteration, disruption or destruction of fish habitat is issued Letter of Advice. While those deemed likely to cause a harmful alteration, disruption or destruction of fish habitat must apply for ministerial authorizations under the Fisheries Act (a Serious Harm Authorization) that may include compensation (Offsetting) for lost fish habitat, often associated with marine infrastructure projects.

G.2.5 Environment Canada

Environment and Climate Change Canada (ECCC) administers the following legislation: Canadian Environmental Assessment Act 2012; Fisheries Act - Section 36 – Prohibition of deleterious substances, Canadian Environmental Protection Act (CEPA), Species at Risk Act (SARA) and Migratory Birds Convention Act (MBCA) relevant to the proposed project. Although unlikely to trigger federal authority in the MacKay Bridge options, ECCC assists other FAs with environmental analysis, advice and, where required, enforcement.

G.2.6 2.1.6 Crown-Indigenous Relations and Northern Affairs Canada

The Government of Canada has a duty to consult, and where appropriate, accommodate Aboriginal groups when it considers conduct that might adversely impact potential or established Aboriginal or treaty rights. In August 2017, the Prime Minister announced the dissolution of Indigenous and Northern Affairs Canada (INAC) and the creation of two new departments: Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). CIRNAC's role includes the duty to consult with Aboriginal groups regarding federal government activities, including for regulatory project approvals, licensing and authorization of permits, operational decisions, policy development, negotiations and more.

Prior to the Halifax Explosion in 1917, Tuft's Cove, just east of the MacKay Bridge was the Mi'kmaq community of Turtle Grove. The waters in that area are long part of the Mi'kmaq trade route connecting inland communities to the harbour. At the time of the Halifax explosion, at least six Mi'kmaq families were living at Turtle Grove. The resulting blast and tidal wave razed Turtle Grove, killing many of its residents and destroying the settlement; it was never rebuilt. Some of Turtle Grove descendants, now members of the Millbrook First Nation, want to see that land designated as "reserve land" and developed with a mix of residential and commercial properties. It is anticipated that CIRNAC and NS Mi'kmaq will be stakeholders in any regulatory process.

G.3 Provincial Regulations

G.3.1 Nova Scotia Environment

Schedule "A" of the Nova Scotia Environmental Assessment Regulations under the Nova Scotia Environmental Act identifies only the following transportation related projects as requiring a provincial environmental assessment and therefore not applicable to the proposed work:

› The construction of a new paved highway that is longer than 2 km and is designed for 4 or more lanes of traffic.

› The construction of a new paved highway that is longer than 10 km and is designed for 2 or more lanes of traffic.

According the Nova Scotia Department of Environment, the Department has no jurisdiction over the Port of Halifax and therefore permitting requirements under the Activities Designation Regulations of the Provincial Environment Act, i.e. a Watercourse Alteration Approval are not required.

However, should the Project require the construction of marine infrastructure, e.g. sheet pile bulkheads, a permit under the Crown Land/Beaches Act might be required from the Nova Scotia Department of Natural Resources (NSDNR).

G.3.2 Nova Scotia Communities, Culture and Heritage

The Special Places Protection Act (R.S., c. 438, s. 1.) governs archaeological assessment of development projects in Nova Scotia. Through the issuance of a Category C Heritage Research Permit by Communities, Culture and Heritage (CCH), in advance of real or proposed development activity, the Act functions to protect significant archaeological sites. Based on public record, it is understood that the Halifax Harbour shoreline is recognized as a site with high potential for historic Native and historic Euro-Canadian archaeological resources.

As a component of the 2005 Halifax-Dartmouth Bridge Capacity Study: The Twinning Option, described in the Briefing Report, Delphi-MRC consulted with CCH with regards to likely archaeological interests. CCH responded with the following:

We (CCH) would highly recommend that an archaeological impact assessment with the following components be undertaken early in the planning phase, with the following components:

› *A background documentary study of property and local land use patterns including a detailed examination of historical cartography associated with the study area.*

- *Build an archaeological potential model to determine probability of archaeological resource locations throughout the impact area.*
- *Conduct a program of archaeological investigation to locate, assess the condition and determine the significance of archaeological resources present. This investigation would involve sub-surface archaeological testing and some archaeological monitoring of development activities.*
- *Include a marine archaeology component to the archaeological impact assessment.*
- *Recommend mitigation options regarding for any archaeological sites found.*

G.4 Municipal Regulations

Although exempt from the HRM Noise By-law, HHB is still required to give 48 hours written notice prior to commencing any night-time work to residents of properties located within 100 feet of the property on which non-emergency work is to be carried out.

G.5 Non-Regulatory Stakeholder Consultation

Interested parties without regulatory authority are recognized as Project stakeholders. Although they do not hold formal decision-making power, stakeholder consultation is recognized as an important component of an environmental assessment process. Stakeholders associated with the Project include:

- HRM staff (in particular HRM Council Members, Planning and Active Transportation Departments)
- Residents living near the bridge,
- Metro Transit;
- Bridge commuters;
- The Halifax Cycling Coalition; and
- Halifax Harbour users.

G.6 Options General Permitting

G.6.1 Option 1A & 1B – Rehabilitation of Existing or Rehabilitate and Add Sidewalks

Environmental regulatory permitting associated with options 1A and 1B are likely to include only work above the harbour with possibly limited repairs to the existing piers. Regulatory permitting requirements are therefore likely limited to a Transport Canada Navigation Protection Act approval and review of a Project Description outlining the project, potential environmental impacts and proposed mitigation by the Halifax Port Authority. An Environmental Assessment under CEAA 2012 is unlikely.

G.6.2 Option 1C– Rehabilitate and Twin

Environmental regulatory permitting associated with option 1C will require in water work for the construction of additional pier structures. This work will result in the requirement of Transport Canada NPA approval, as well as review/authorization/offsetting compensation by DFO for in-water work and potentially loss of fish habitat due to the footprint of the new pier. A Project Description outlining the project, potential environmental impacts and proposed mitigation is likely to be required for review by the HPA while the triggering of an EA under CEAA 2012 is possible depending on project details, fish habitat loss area and mitigation proposed.

G.6.3 New Bridge Options: 2A – 2F

New piers in the water and additional marine infrastructure for a new highway alignment on the Dartmouth side will require a Transport Canada NPA approval and an Authorization/Off setting compensation by DFO under DFO's Fisheries Act. A Project Description outlining the project, potential environmental impacts and proposed mitigation is likely to be required for review by the HPA and PSPC, and requirements for an Environmental Assessment under CEAA 2012 is likely given the nature of the work in the harbour and its proximity to the BIO and the CFIA sites.

Appendix H Rehabilitated Bridge Considerations

The rehabilitation options include replacing the existing deck and suspended structure. The remaining structure would need to be retrofitted to align the bridge with current design standards, with the exception of lane and shoulder widths which are constrained by available width between the main cables, tower and cable bent legs.

H.1 Suspended Spans

It is expected that the MacKay Bridge would require significant effort to provide reinforcing to remaining components, based on information in the Briefing Report [1], which summarized the previous load rating of the suspended and approach spans. For example, a new deck system would be required as the current orthotropic deck plate is significantly thinner and therefore more flexible than permitted by current code requirements, and therefore prone to fatigue. Based on the integral nature of the deck/truss connection and the level of effort needed to reinforce the existing stiffening truss, COWI's experience is that replacing the existing deck plate alone is not feasible. Coupled with the general deterioration of the structure (specifically the trusses), a full suspended spans deck replacement is the recommended solution. Since a new suspended span would need to meet the current code requirements, the orthotropic plate would be 14 mm (compared to the existing 9.5 mm plate) and the trusses would be heavier due to the overall increase in dead load. Therefore, the new superstructure would be significantly heavier than the existing.

Due to the added weight, it is anticipated that additional components in both the suspended spans and approach spans, would require reinforcing. In the suspended spans, main cables would require strengthening and it is highly likely that the tower and cable bents would need reinforcing. The main cables would need to be inspected prior to or at the start of the project to provide input to regarding the condition of the cables and would help in determining the amount of cable strengthening required. The cable anchorages would be evaluated in future assessments and may need to be modified to accept the added cables.

Previous reports do not indicate that an updated ship collision study has been performed for the bridge. For the purpose of this study, COWI has assumed that no additional armouring is required for the towers in the water. If additional armouring is required, it is not expected to change the conclusions of the report, as similar armouring would be required for each of the replacement bridge options.

H.2 Approach Spans

To achieve the required design life, this study assumes that the approach superstructure would need to be replaced based on its current condition. Recent inspection reports of the superstructure and substructure describe the approach spans box girders as experiencing increasing amounts of pinhole corrosion caused by probable leaking through the deck, and possible fatigue cracking at bottom flange stiffeners.

The approach spans replacement could be accelerated by constructing temporary piers adjacent to the existing and sliding most of the new spans into their final position. The sliding of the approach spans adjacent to the cable bents would be significantly more difficult, if possible at all. As a result, replacing the approach spans may result in several extended bridge closures.

A recent concrete assessment report (as noted in the Briefing Report [1]) prepared for HHB describes the approach span piers and shows 13 of 18 concrete elements with sufficient concrete deterioration to require repair in the next 10 years. The report outlines a program for rehabilitating the piers.

H.3 Constructability

Rehabilitating the existing structure would have an impact on traffic and would involve more than simply the addition or removal of components. In particular, suspended spans' main cable, deck system, and approach spans superstructure replacement would require the roadway to be closed for significant periods. These closures could be several weeks long and may need to include nighttime, weekend or longer closures depending on erection sequences selected. However, the aim during the design phase would be to shorten the closure time to an absolute minimum to keep the traffic flowing across the bridge.

The following lists describe the possible sequences of construction for the suspended spans and approach spans.

Suspended Spans:

- Reinforce existing foundations (if required);
- Modify and reinforce main cable anchorages (if required);
- Reinforce existing towers and cable bents;
- Install supplemental main cables; and
- Replace existing suspended spans deck system.

Approach Spans:

- Construct temporary approach spans piers adjacent to existing;
- Construct new approach spans superstructure on temporary piers;
- Transfer traffic onto new superstructure (next to existing roadway and tied into the approach roadway and the suspended spans);

- Demolish existing approach spans superstructure;
- Rehabilitate existing approach spans piers; and
- Slide new approach spans superstructure onto rehabilitated piers (during extended closures) and complete tie-ins at the main span and abutment.

Replacement or supplementing the existing main cables and strengthening of the towers would be some of the most difficult elements of construction; there are no typical processes for main cable replacement and strengthening and the bridge dead loads would need to be transferred to the strengthened cables while keeping the deck intact. Additionally, this work would be completed prior to superstructure replacement due to the increased dead load of the new deck. The towers would be reinforced and modified to accept additional cables as the original design did not include capacity to accept another cable and the new cables cannot be placed inboard of the existing because of conflicts with the roadway. Additional hangers from the supplemental cables would help to support the new deck.

The weight of the deck system would be transferred to the new cables or shared between the existing and new cables. Transferring load from the existing main cable to the supplemental cables is an iterative process that would require either new hangers, new cable bands on the existing main cable, or both. Complicating the process is the need for the structure to remain open (when feasible) to traffic throughout the rehabilitation.

From a design and construction perspective, strengthening the towers would be complicated. For engineering design, the existing material is under load and the new material would not have these built in stresses; special care would be needed when determining capacities. For construction, welding to the existing towers would not be desirable (since the existing material in highly stressed), so extensive bolting would be required.

Once the substructure is reinforced and the cables replaced or supplemented, the suspended spans deck system would need to be removed and replaced. COWI anticipates that this process would be similar to that implemented for the Macdonald Bridge Redecking project. It is expected that the existing trusses would need reinforcing to resist the demands during construction.

Coordination between the approach spans and suspended spans work would help to optimize bridge closures. Where feasible, work that requires a full bridge closure would be scheduled at the same time, provided activity on one section of the bridge did not hinder a critical path activity on another.

H.4 Main Cable Condition

Recent inspections of the main cables have indicated presence of moisture in low-lying sections and loss of tension in some wires. Stage 4 corrosion (NCHRP scale) and a few broken wires have been observed in some locations. Based on the current limited number of inspected locations, the current understanding is that this condition is not significantly affecting the capacity of the cable to carry the bridge loads at the moment. However, COWI understands that HHB is prudently taking steps to limit future degradation of the main cables so that it does not become a capacity concern prior to the rehabilitation project. HHB is also increasing inspections of the cables to gain a better understanding of their condition should it continue to change. If the rehabilitation option is selected for further development by HHB, careful consideration of the condition of the main cables should be included in the planning phases so designers can plan on whether or not to include a full cable replacement scenario in the rehabilitation strategy.

H.5 Twinning (Option 1C)

For the twinning option, an additional bridge would be constructed adjacent to the existing with traffic being shared between the two bridges in the final condition. For this study, the second bridge is assumed to be a suspension bridge to retain visual similarity with the existing bridge. A new cable-stayed bridge would be a lower cost alternative; however, the new cable-stayed bridge towers would be considerably taller than the existing towers and this may not be desired aesthetically.

Alignment

The additional bridge would be constructed immediately adjacent and parallel to the existing bridge along its north side, on an alignment similar to alignment 1. The main difference would be that the cross sectional width of the approach roads would be about half of that for the new six lane bridge, possibly allowing for minor adjustments to the alignment to reduce or eliminate the impact on the CFIA building. On the Halifax side, the replacement bridge would tie into the existing approach in a similar fashion to that presented in options 2A, 2B, 2E and 2F. Tie-ins for AT trails would be coordinated with HRM to ensure compatibility with the Integrated Mobility Plan.

Constructability and Impact on Traffic

Construction of the new twin bridge would proceed with current industry practice provided an experienced contractor is selected, and the new twin bridge would be completed before the existing bridge is rehabilitated. Rehabilitating the existing structure would be significantly less expensive than in options 1A or 1B since the rehabilitation works would be undertaken without having to accommodate traffic on the existing bridge during rehabilitation. This allows for four lanes to remain open to traffic through the construction period, with minor interruptions. After completion of rehabilitation, the rehabilitated and new bridge would each be arranged for three traffic lanes and one AT lane.

Appendix I Replacement Bridge Considerations

All of the replacement options consider construction of a single bridge. As the replacement bridge would be located on a different alignment, new approach spans and roadway tie-ins are also required. Traffic would continue to use the existing bridge during the construction phase. Following completion of traffic change-over to the replacement bridge, the existing MacKay Bridge would be demolished.

For details regarding the various structural forms discussed in the sections below, refer to the option summary sheets in Section 0.

I.1 Design Approach

Two design approaches were explored for the replacement options: keeping the main spans similar to the existing bridge spans and increasing the main span so that tower piers are not required in the waterway.

Keeping a similar main span length as the existing bridge results in one tower located on the Halifax shore and the Dartmouth tower located in the water. This configuration of the towers leads to a main span of approximately 500 m. This span length provides some longitudinal separation between the new and existing Dartmouth towers to facilitate foundation construction. Based on COWI's experience, for a 500 m main span, a cable-stayed bridge is the most efficient solution using current construction technologies. However, in addition to investigating a cable-stayed bridge, the study considers a 500 m main span suspension bridge option for aesthetic consistency with the existing bridge. A new 500 m suspension bridge would bear a resemblance to the existing bridge, and the Macdonald Bridge to the south.

The second design approach locates the towers on the Halifax and Dartmouth shorelines, avoiding a tower in the water. This configuration requires a main span of approximately 800 m to avoid conflicts with the existing Coast Guard wharves. For this span, a cable-stayed bridge is still generally more cost effective than an equivalent conventional suspension bridge based on COWI's experience. However, HHB has requested that a suspension bridge be considered. In order to reduce the cost of the suspension bridge option and take advantage of the side spans being located over land, the side spans have been replaced with conventional approach spans, altering the aesthetic somewhat from the present condition. This longer 800 m main span suspension bridge would also use a trapezoidal steel box girder for aerodynamic stability and efficiency.

I.2 Design Assumptions

I.2.1 Tower and Pier Construction

With the current construction technology, concrete piers are more cost effective than comparable steel towers; therefore, concrete towers and anchor piers are assumed for all of the replacement options. Towers are assumed to be an 'H' configuration with vertical legs and horizontal struts below and above the roadway deck for the 500 m main span options. The 800 m main span cable-stayed tower would likely be an inverted "Y" or a delta frame to provide the required aerodynamic stability of the superstructure. The selected “H” (500 m main span) and inverted “Y” (800 m main span) tower shapes were selected for the purpose of this study as they are considered to be most cost efficient based on COWI’s experience.

I.2.2 Cable-Stayed Bridge Deck

For cable-stayed bridges with main spans of 500 m, open composite decks are an efficient and cost effective solution. COWI's recent experiences have successfully demonstrated an open composite deck is also feasible and cost competitive for an 800 m main span cable-stayed bridge. Therefore, both cable-stayed bridge options assume use of open deck sections. The open composite deck comprises two longitudinal steel plate "I" girders coinciding with the stay planes and a series of transverse floorbeams. A composite cast-in-place concrete deck slab completes the deck system.

The AT lanes would cantilever from the longitudinal girders outboard of the stay cables, which would result in improved deck aerodynamic stability. The need for additional wind fairings would be proven by aerodynamic testing, particularly for the 800 m main span option due to the aerodynamic stability of the deck for these geometries.

I.2.3 Suspension Bridge Deck

For a suspension bridge with a 500 m main span, a deck system comprising longitudinal stiffening trusses, transverse floorbeams and an orthotropic steel plate deck is assumed. This results in a section similar to the new Macdonald Bridge, although it would be somewhat larger to accommodate six lanes of traffic.

The 800 m main span option would use an aerodynamically shaped steel box to achieve the required aerodynamic stability. The box girder would be cheaper to maintain than a truss-based superstructure during the life of the bridge. However, the inside of the box girder would need to be dehumidified to minimize maintenance costs during the bridge service life.

I.2.4 Approach Spans

New approach spans would likely be in the range of 40 to 50 m and consist of precast concrete girders on concrete piers. If spans are increased to the range of 80 m to 90 m, steel I girders could be used.

I.3 Constructability

Replacement bridge construction allows the bridge to be built alongside the existing bridge, resulting in limited traffic interruptions. New construction would have its own challenges, generally related to access to the site around an active roadway. Sufficient space is required between the two structures so that equipment and materials can be moved into place and foundations do not overlap.

I.4 Traffic Impact

During construction of a replacement bridge traffic can continue to utilise the existing bridge. Once the bridge is completed, it would be opened to traffic. Tying the replacement bridge into the roadway network would be completed at approach roadways, so the transition of traffic from the existing bridge would not be overly complicated. Once traffic is transferred to the replacement, the existing bridge would be demolished.

I.5 Span Arrangements

The following sections explain the span arrangements and impacts of pier placement for each of the replacement bridge options

I.5.1 Option 2A – New 6 Lane 500 m Main Span Cable-Stayed Bridge

- Parallel alignment to the north of the existing Bridge (alignment 1).
- The clear horizontal distance between the new and existing bridge decks was assumed to be 15 m. The replacement would have an increased vertical navigational channel clearance by 10 m, which would allow for 2 m of sea level rise.
- The arrangement of bridge spans would be:
  - Dartmouth approach spans: 300 m total length
  - Cable supported spans: 200 + 500 + 200 m
  - Halifax approach spans: 45 m
- On the Halifax side, the abutment would be located near the existing abutment and the Halifax tower at the shoreline.
- On the Dartmouth side, the tower would be located in the water, just to the northeast of the existing tower. The anchor pier would be located in the BIO/Coast Guard parking lot, along the shoreline.

- The Dartmouth approach piers are located to the north of the existing piers, and the abutment would be located near the present location of the CFIA building.

I.5.2 Option 2B – New 6 Lane 500 m Main Span Suspension Bridge

- The span arrangement would be similar to the 6 lane 500 m main span cable-stayed bridge.

I.5.3 Option 2C – New 6 Lane 800 m Main Span Cable-Stayed Bridge

- Utilises an alignment further to the north of the existing bridge (alignment 2).
- This configuration minimizes the number of piers that would be required on property not currently owned by HHB.
- The arrangement of bridge spans would be:
  - Dartmouth approach spans: 45 m
  - Cable supported spans: 240 + 800 + 240 m
  - Halifax approach spans: 45 m
- On the Halifax side, the abutment/anchor pier would be located near the existing abutment and the tower at the shoreline.
- On the Dartmouth side, the tower would be in the median east of the Coast Guard parking lots, with the anchor pier/abutment located north of the CFIA building.

I.5.4 Option 2D – New 6 Lane 800 m Main Span Suspension Bridge

- The towers would be in locations similar to those of a 6 lane 800 m main span cable-stayed bridge.
- Due to topography, we have assumed that only the span between the main towers would be suspended. Conventional approach spans would be used beyond the towers to minimize bridge cost.
- The approach piers on the Halifax side would be located to the north of the existing piers, with the anchorage/abutment near the existing abutment.
- The Dartmouth approach spans would pass over BIO facilities, ending to the north of the CFIA building.
- The arrangement of bridge spans would be:
  - Dartmouth approach spans: 240 m total, 60m each span
  - Cable supported main span: 800 m; no suspended side spans
  - Halifax approach spans: 240 m total, 60m each span

I.5.5 Option 2E – New 4 Lane 500 m Main Span Cable-Stayed Bridge

- The span arrangement would be similar to the 6 Lane 500 m main span cable stayed bridge.

I.5.6 Option 2B – New 4 Lane 500 m Main Span Suspension Bridge

- The span arrangement would be similar to the 6 Lane 500 m main span cable-stayed bridge.

Appendix J Cost Estimate Details

A high-level cost estimate was performed for this study based on rates from other projects. While COWI expects that the costs are indicative of the actual cost of each option, they should not be used for financial planning purposes. A summary of the rates is provided below, with additional detail available in Appendix H. All costs are in Canadian Dollar corresponding to the year 2018:

- Rehabilitation:
  - Existing suspended spans rehabilitation (without traffic): $19,000 /m²
  - Existing suspended spans rehabilitation (with traffic): $25,000 /m²
  - Adding AT lanes (option 1B): $9,000 /m²
  - Approach spans replacement: $6,000 /m²
  - Existing approach spans demolition: $15M
  - Approach Roadway (new for option 1C): $6,400 /m

- Replacement:
  - 500 m main span cable-stayed bridge: $13,000 /m²
  - 500 m main span suspension bridge: $17,000 /m²
  - 800 m main span cable-stayed bridge: $16,000 /m²
  - 800 m main span suspension bridge: $19,000 /m²
  - Approach spans: $5,000 /m²
  - Approach roadway (inc. demolition of existing roadway): $8,400 /m (alignment 1), $14,600 /m (alignment 2)

- Demolition of the existing bridge
  - Main span: $33M
  - Approach Spans: $15M

- Adjacent structure costs
  - Demolition of CFIA building: $2M
  - Construction of new CFIA building: $29M

- Permitting
  - Rehabilitation: $ 50,000
  - Replacement: $ 100,000

Costs per "m²" are costs per unit area of bridge deck. Costs per "m" are costs per unit length of bridge.

Contingency values of 30% and 20% for the rehabilitation and replacement options respectively were used in this assessment. The higher contingency for rehabilitation corresponds to increased uncertainty of the condition of the structure at time of rehabilitation when compared to constructing a replacement.

Apparent in the cost summary above is that a rehabilitation of the existing suspended spans carries a higher unit rate than the replacement design options. Rehabilitation of an in-service structure, with traffic running during the day, presents significant additional challenges not present with new design.

The construction and maintenance costs for all bridge options are based on high-level estimates. The construction costs for this study are based on COWI's previous experience, known costs from the industry, and are high-level cost estimates per square metre of bridge deck, as this approach is deemed reasonable for this level of feasibility study. Maintenance costs were developed based on exposed steel surface area and HHB's maintenance cost records for the existing MacKay Bridge. Owner's costs were developed based on varying percentages of total construction costs depending on the level of complexity associated with each option.

Land acquisition has been considered as a risk in the present evaluation but has not been included as a direct cost. Our analysis indicates that, provided the land acquisition costs are below 50 million dollars, the outcome of the cost implications would not change the ranking outcome. These costs are anticipated to be similar for all new bridge options, however the costs are largely dependent on negotiation between HHB and various other agencies, making an estimate not reliable at this time. A more detailed land cost comparison should include assessment methods to account for the various structures' life spans from an economic perspective (e.g. accounting for equivalent annual cost, life-cycle revenue, salvage cost at the end of the assumed design life).

Costs are intended to be sufficient in detail for comparison purposes only – these costs should not be used for budgeting purposes. To prepare a detailed cost estimate for the purposes of budgeting and financing, preliminary design of the structure and erection sequences are required.

Detailed cost breakdowns are included in this section for each bridge option in Tables J1 – J9.

COWI

Table J1: Option 1A

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 1A: Rehabilitate Existing**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20

Item No.		**Bid Item Description**	**Unit**	**Quantity**	**Length (m)**	**Width (m)**	**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
1	Direct Construction Cost	Halifax Approach Spans	m²	1	114.30	18.00	2057	$ 6,000	$ 12,345,000	30%	$ 3,704,000	$ 16,049,000
2		Suspended Spans Rehabilitation	m²	1	739.95	18.00	13319	$ 25,000	$ 332,979,000	30%	$ 99,894,000	$ 432,873,000
3		Dartmouth Approach Spans	m²	1	381.00	18.00	6858	$ 6,000	$ 41,148,000	30%	$ 12,345,000	$ 53,493,000
4		Roadworks Approaches	m	0			0	$ -	$ -	0%	$ -	$ -
5		Existing Main Bridge Demolition	LS	0			0	$ 33,000,000	$ -	0%	$ -	$ -
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	30%	$ 4,500,000	$ 19,500,000
7		Demolition of CFIA Building	LS	0			0	$ 2,000,000	$ -	0%	$ -	$ -
8		Construction of New CFIA Building	LS	0			0	$ 29,000,000	$ -	0%	$ -	$ -
9											**Subtotal Direct Construction Cost**	**$ 521,915,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
10	Owner's Cost	Engineering (12% Const)	LS	1	12.0%			$ 521,915,000	$ 62,630,000	-	-	$ 62,630,000
11		Construction Supervision (7% Const)	LS	1	7.0%			$ 521,915,000	$ 36,535,000	-	-	$ 36,535,000
12		Other Owner's Costs (10% Const)	LS	1	10.0%			$ 521,915,000	$ 52,192,000	-	-	$ 52,192,000
13											**Subtotal Owner's Construction Cost**	**$ 151,357,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
14	Maintenace	General Maintenance per year (N years)	LS	75			75	$ 500,000	$ 37,500,000	-	-	$ 37,500,000
15		Extraordinary Maint. - Repainting (every 25 years)	LS	2			2	$ 32,000,000	$ 64,000,000	-	-	$ 64,000,000
16		Extraordinary Maint. - EJs (every 25 years)	LS	2			2	$ 6,000,000	$ 12,000,000	-	-	$ 12,000,000
17		Extraordinary Maint. - Bearings (every 40 years)	LS	1			1	$ 8,250,000	$ 8,250,000	-	-	$ 8,250,000
18		Extraordinary Maint. - Paving (every 20 years)	LS	3			3	$ 11,000,000	$ 33,000,000	-	-	$ 33,000,000
19		Extraordinary Maint. - Dehumidification	LS	2			2	$ 7,000,000	$ 14,000,000	-	-	$ 14,000,000
20											**Subtotal Maintenance Cost**	**$ 168,750,000**
21											**Total Cost**	**$ 842,022,000**
22											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 843,000,000**

COWI

Table J2: Option 1B

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 1B: Widen Existing with AT Lanes**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	114.30	23.20	2652	$ 6,000	$ 15,911,000	30%	$ 4,774,000	$ 20,685,000
2		Suspended Spans Rehabilitation	m²	1	739.95	18.00	13319	$ 25,000	$ 332,979,000	30%	$ 99,894,000	$ 432,873,000
3		Suspended Spans AT Lanes	m²	2	739.95	3.00	4440	$ 9,000	$ 39,958,000	30%	$ 11,988,000	$ 51,946,000
4		Dartmouth Approach Spans	m²	1	381.00	23.20	8839	$ 6,000	$ 53,036,000	30%	$ 15,911,000	$ 68,947,000
5		Roadworks Approaches	m	0			0	$ -	$ -	0%	$ -	$ -
6		Existing Main Bridge Demolition	LS	0			0	$ 33,000,000	$ -	0%	$ -	$ -
7		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	30%	$ 4,500,000	$ 19,500,000
8		Demolition of CFIA Building	LS	0			0	$ 2,000,000	$ -	0%	$ -	$ -
9		Construction of New CFIA Building	LS	0			0	$ 29,000,000	$ -	0%	$ -	$ -
10											**Subtotal Direct Construction Cost**	**$ 593,951,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
11	Owner's Cost	Engineering (12% Const)	LS	1	12.00%			$ 593,951,000	$ 71,275,000	-	-	$ 71,275,000
12		Construction Supervision (7% Const)	LS	1	7.00%			$ 593,951,000	$ 41,577,000	-	-	$ 41,577,000
13		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 593,951,000	$ 59,396,000	-	-	$ 59,396,000
14											**Subtotal Owner's Construction Cost**	**$ 172,248,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
15	Maintenace	General Maintenance per year (N years)	LS	75			75	$ 500,000	$ 37,500,000	-	-	$ 37,500,000
16		Extraordinary Maint. - Repainting (every 25 years)	LS	2			2	$ 41,778,000	$ 83,556,000	-	-	$ 83,556,000
17		Extraordinary Maint. - EJs (every 25 years)	LS	2			2	$ 7,000,000	$ 14,000,000	-	-	$ 14,000,000
18		Extraordinary Maint. - Bearings (every 40 years)	LS	1			1	$ 10,771,000	$ 10,771,000	-	-	$ 10,771,000
19		Extraordinary Maint. - Paving (every 20 years)	LS	3			3	$ 14,361,000	$ 43,083,000	-	-	$ 43,083,000
20		Extraordinary Maint. - Dehumidification	LS	2			2	$ 7,000,000	$ 14,000,000	-	-	$ 14,000,000
21											**Subtotal Maintenance Cost**	**$ 202,910,000**
22											**Total Cost**	**$ 969,109,000**
23											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 970,000,000**

COWI

Table J3: Option 1C

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 1C: Rehabilitate and Twin**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost - Rehabilitate Existing	Halifax Approach Spans	m²	1	114.30	18.00	2057	$ 6,000	$ 12,345,000	30%	$ 3,704,000	$ 16,049,000
2		Suspended Spans Rehabilitation	m²	1	739.95	18.00	13319	$ 19,000	$ 253,064,000	30%	$ 75,920,000	$ 328,984,000
3		Dartmouth Approach Spans	m²	1	381.00	18.00	6858	$ 6,000	$ 41,148,000	30%	$ 12,345,000	$ 53,493,000
4		Roadworks Approaches	m	0			0		$ -	30%	$ -	$ -
5		Existing Main Bridge Demolition	LS	0			0	$ 33,000,000	$ -	0%	$ -	$ -
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	30%	$ 4,500,000	$ 19,500,000
7		Demolition of CFIA Building	LS	0			0	$ 2,000,000	$ -	0%	$ -	$ -
8		Construction of CFIA Building	LS	0			0	$ 29,000,000	$ -	0%	$ -	$ -
9	Direct Construction Cost - New 426 m Suspension Bridge	Halifax Approach Spans	m²	1	114.30	18.40	2103	$ 5,000	$ 10,516,000	20%	$ 2,104,000	$ 12,620,000
10		Suspended Spans Suspension Bridge	m²	1	739.95	18.40	13615	$ 18,000	$ 245,073,000	20%	$ 49,015,000	$ 294,088,000
11		Dartmouth Approach Spans	m²	1	381.00	18.40	7010	$ 5,000	$ 35,052,000	20%	$ 7,011,000	$ 42,063,000
12		Roadworks Approaches	m	1	1129.75		1130	$ 6,400	$ 7,231,000	20%	$ 1,447,000	$ 8,678,000
13		Existing Main Bridge Demolition	LS	0			0	$ 33,000,000	$ -	0%	$ -	$ -
14		Existing Approach Spans Demolition	LS	0			0	$ 15,000,000	$ -	0%	$ -	$ -
15		Demolition of CFIA Building	LS	1			1	$ 2,000,000	$ 2,000,000	20%	$ 400,000	$ 2,400,000
16		Construction of New CFIA Building	LS	1			1	$ 29,000,000	$ 29,000,000	20%	$ 5,800,000	$ 34,800,000
17											**Subtotal Direct Construction Cost**	**$ 812,675,000**

Item No.		Bid Item Description	Unit	Quantity	% Construction	Estimated Unit Price	Estimated Cost	Contingency		Cost
18	Owner's Cost	Engineering (10% Const)	LS	1	10.00%	$ 812,675,000	$ 81,268,000	-	-	$ 81,268,000
19		Construction Supervision (7% Const)	LS	1	7.00%	$ 812,675,000	$ 56,888,000	-	-	$ 56,888,000
20		Other Owner's Costs (10% Const)	LS	1	10.00%	$ 812,675,000	$ 81,268,000	-	-	$ 81,268,000
21									**Subtotal Owner's Construction Cost**	**$ 219,424,000**

Item No.		Bid Item Description	Unit	Quantity			Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
22	Maintenance	General Maintenance per year (N years)	LS	75			75	$ 700,000	$ 52,500,000	-	-	$ 52,500,000
23		Extraordinary Maint. - Repainting (every 25 years)	LS	2			2	$ 64,000,000	$ 128,000,000	-	-	$ 128,000,000
24		Extraordinary Maint. - EJs (every 25 years)	LS	2			2	$ 12,000,000	$ 24,000,000	-	-	$ 24,000,000
25		Extraordinary Maint. - Bearings (every 40 years)	LS	1			1	$ 16,500,000	$ 16,500,000	-	-	$ 16,500,000
26		Extraordinary Maint. - Paving (every 20 years)	LS	3			3	$ 22,000,000	$ 66,000,000	-	-	$ 66,000,000
27		Extraordinary Maint. - Dehumidification	LS	2			2	$ 14,000,000	$ 28,000,000	-	-	$ 28,000,000
28											**Subtotal Maintenance Cost**	**$ 315,000,000**
29											**Total Cost**	**$ 1,347,099,000**
30											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 1,348,000,000**

COWI

Table J4: Option 2A

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 2A: 500 m Cable-Stayed - 6 Lane**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency	Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	45.00	36.60	1647	$ 5,000	$ 8,235,000	20% $ 1,647,000	$ 9,882,000
2		Suspended Span (Cable Stayed)	m²	1	900.00	38.60	34740	$ 13,000	$ 451,620,000	20% $ 90,324,000	$ 541,944,000
3		Dartmouth Approach Spans	m²	1	300.00	36.60	10980	$ 5,000	$ 54,900,000	20% $ 10,980,000	$ 65,880,000
4		Roadworks Approaches	m	1	1120.00		1120	$ 8,400	$ 9,408,000	20% $ 1,882,000	$ 11,290,000
5		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20% $ 6,600,000	$ 39,600,000
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20% $ 3,000,000	$ 18,000,000
7		Demolition of CFIA Building	LS	1			1	$ 2,000,000	$ 2,000,000	20% $ 400,000	$ 2,400,000
8		Construction of New CFIA Building	LS	1			1	$ 29,000,000	$ 29,000,000	20% $ 5,800,000	$ 34,800,000
9										**Subtotal Direct Construction Cost**	**$ 723,796,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**	**Cost**
10	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 723,796,000	$ 50,666,000	- -	$ 50,666,000
11		Construction Supervision (7% Const)	LS	1	7.00%			$ 723,796,000	$ 50,666,000	- -	$ 50,666,000
12		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 723,796,000	$ 72,380,000	- -	$ 72,380,000
13										**Subtotal Owner's Construction Cost**	**$ 173,712,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**	**Cost**
14	Maintenance	General Maintenance per year (N years)	LS	100			100	$ 200,000	$ 20,000,000	- -	$ 20,000,000
15		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 15,000,000	$ 45,000,000	- -	$ 45,000,000
16		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 3,000,000	$ 9,000,000	- -	$ 9,000,000
17		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 5,150,000	$ 10,300,000	- -	$ 10,300,000
		Extraordinary Maint. - Paving (every 40 years)	LS	2			2	$ 36,000,000	$ 72,000,000	- -	$ 72,000,000
18										**Subtotal Maintenance Cost**	**$ 156,300,000**
19										**Total Cost**	**$ 1,053,808,000**
20		**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**									**$ 1,054,000,000**

COWI

Table J5: Option 2B

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 2B: 500 m Suspension - 6 Lane**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	45.00	36.60	1647	$ 5,000	$ 8,235,000	20%	$ 1,647,000	$ 9,882,000
2		Suspended Span (Suspension)	m²	1	900.00	38.60	34740	$ 17,000	$ 590,580,000	20%	$ 118,116,000	$ 708,696,000
3		Dartmouth Approach Spans	m²	1	300.00	36.60	10980	$ 5,000	$ 54,900,000	20%	$ 10,980,000	$ 65,880,000
4		Roadworks Approaches	m	1	1120.00		1120	$ 8,400	$ 9,408,000	20%	$ 1,882,000	$ 11,290,000
5		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20%	$ 6,600,000	$ 39,600,000
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20%	$ 3,000,000	$ 18,000,000
7		Demolition of CFIA Building	LS	1			1	$ 2,000,000	$ 2,000,000	20%	$ 400,000	$ 2,400,000
8		Construction of New CFIA Building	LS	1			1	$ 29,000,000	$ 29,000,000	20%	$ 5,800,000	$ 34,800,000
9											**Subtotal Direct Construction Cost**	**$ 890,548,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
10	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 890,548,000	$ 62,339,000	-	-	$ 62,339,000
11		Construction Supervision (7% Const)	LS	1	7.00%			$ 890,548,000	$ 62,339,000	-	-	$ 62,339,000
12		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 890,548,000	$ 89,055,000	-	-	$ 89,055,000
13											**Subtotal Owner's Construction Cost**	**$ 213,733,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
14	Maintenace	General Maintenance per year (N years)	LS	100			100	$ 400,000	$ 40,000,000	-	-	$ 40,000,000
15		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 25,000,000	$ 75,000,000	-	-	$ 75,000,000
16		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 6,000,000	$ 18,000,000	-	-	$ 18,000,000
17		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 6,150,000	$ 12,300,000	-	-	$ 12,300,000
18		Extraordinary Maint. - Paving (every 20 years)	LS	4			4	$ 22,000,000	$ 88,000,000	-	-	$ 88,000,000
19		Extraordinary Maint. - Dehumidification	LS	3			3	$ 7,000,000	$ 21,000,000	-	-	$ 21,000,000
20											**Subtotal Maintenance Cost**	**$ 254,300,000**
21											**Total Cost**	**$ 1,358,581,000**
22											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 1,359,000,000**

COWI

Table J6: Option 2C

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 2C: 800 m Cable-Stayed - 6 Lane**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost	Halifax Approach Spans (Counterweight)	m²	1	45.00	36.60	1647	$ 5,000	$ 8,235,000	20%	$ 1,647,000	$ 9,882,000
2		Suspended Span (Cable Stayed)	m²	1	1280.00	38.60	49408	$ 16,000	$ 790,528,000	20%	$ 158,106,000	$ 948,634,000
3		Dartmouth Approach Spans (Counterweight)	m²	1	45.00	36.60	1647	$ 5,000	$ 8,235,000	20%	$ 1,647,000	$ 9,882,000
4		Dartmouth Approach Overpass	m²	1	300.00	36.60	10980	$ 5,000	$ 54,900,000	20%	$ 10,980,000	$ 65,880,000
5		Roadworks Approaches	m	1	815.00		815	$ 14,600	$ 11,899,000	20%	$ 2,380,000	$ 14,279,000
6		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20%	$ 6,600,000	$ 39,600,000
7		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20%	$ 3,000,000	$ 18,000,000
8		Demolition of CFIA Building	LS	1			0	$ 2,000,000	$ -	20%	$ -	$ -
9		Construction of New CFIA Building	LS	1			0	$ 29,000,000	$ -	20%	$ -	$ -
10											**Subtotal Direct Construction Cost**	**$ 1,106,157,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
11	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 1,106,157,000	$ 77,431,000	-	-	$ 77,431,000
12		Construction Supervision (7% Const)	LS	1	7.00%			$ 1,106,157,000	$ 77,431,000	-	-	$ 77,431,000
13		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 1,106,157,000	$ 110,616,000	-	-	$ 110,616,000
14											**Subtotal Owner's Construction Cost**	**$ 265,478,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
15	Maintenance	General Maintenance per year (i%, n years)	LS	100			100	$ 200,000	$ 20,000,000	-	-	$ 20,000,000
16		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 15,000,000	$ 45,000,000	-	-	$ 45,000,000
17		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 3,973,333	$ 11,920,000	-	-	$ 11,920,000
18		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 5,150,000	$ 10,300,000	-	-	$ 10,300,000
19		Extraordinary Maint. - Paving (every 40 years)	LS	2			2	$ 36,000,000	$ 72,000,000	-	-	$ 72,000,000
20											**Subtotal Maintenance Cost**	**$ 159,220,000**
21											**Total Cost**	**$ 1,530,855,000**
22											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 1,531,000,000**

COWI

Table J7: Option 2D

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	JOLV	Date:	2018 APR 20
Location :	**Halifax**	Checker:	JGPR	Date:	2018 APR 20
Bridge:	**Option 2D: 800 m Suspension - 6 Lane**	Reviewer:	DURC	Date:	2018 APR 20
Client :	**HHB**	Approver:	THMT	Date:	2018 APR 20
		Revised:	JOLV	Date:	2018 JUL 03 *revised for 3.0 m AT lanes*
		Checker / Approver:	EER	Date:	2018 JUL 03

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency	Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	240.00	36.60	8784	$ 5,000	$ 43,920,000	20% $ 8,784,000	$ 52,704,000
2		Suspended Span (Suspension)	m²	1	800.00	38.60	30880	$ 19,000	$ 586,720,000	20% $ 117,344,000	$ 704,064,000
3		Dartmouth Approach Spans	m²	1	240.00	36.60	8784	$ 5,000	$ 43,920,000	20% $ 8,784,000	$ 52,704,000
4		Dartmouth Approach Overpass	m²	1	300.00	36.60	10980	$ 5,000	$ 54,900,000	20% $ 10,980,000	$ 65,880,000
5		Roadworks Approaches	m	1	905.00		905	$ 14,600	$ 13,213,000	20% $ 2,643,000	$ 15,856,000
6		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20% $ 6,600,000	$ 39,600,000
7		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20% $ 3,000,000	$ 18,000,000
8		Demolition of CFIA Building	LS	1			0	$ 2,000,000	$ -	20% $ -	$ -
9		Construction of New CFIA Building	LS	1			0	$ 29,000,000	$ -	20% $ -	$ -
10										**Subtotal Direct Construction Cost**	**$ 948,808,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**Estimated Quantity**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**	**Cost**
11	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 948,808,000	$ 66,417,000	- -	$ 66,417,000
12		Construction Supervision (7% Const)	LS	1	7.00%			$ 948,808,000	$ 66,417,000	- -	$ 66,417,000
13		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 948,808,000	$ 94,881,000	- -	$ 94,881,000
14										**Subtotal Owner's Construction Cost**	**$ 227,715,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**	**Cost**
15	Maintenance	General Maintenance per year (N years)	LS	100			100	$ 400,000	$ 40,000,000	- -	$ 40,000,000
16		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 15,000,000	$ 45,000,000	- -	$ 45,000,000
17		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 7,000,000	$ 21,000,000	- -	$ 21,000,000
18		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 2,000,000	$ 4,000,000	- -	$ 4,000,000
19		Extraordinary Maint. - Paving (every 20 years)	LS	4			4	$ 22,000,000	$ 88,000,000	- -	$ 88,000,000
20		Extraordinary Maint. - Dehumidification	LS	3			3	$ 12,000,000	$ 36,000,000	- -	$ 36,000,000
21										**Subtotal Maintenance Cost**	**$ 234,000,000**
22										**Total Cost**	**$ 1,410,523,000**
23										**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 1,411,000,000**

COWI

Table J8: Option 2E

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	DNMC	Date:	2020 APR 06
Location :	**Halifax**	Checker:	EER	Date:	2020 APR 06
Bridge:	**Option 2E: 500 m Cable-Stayed - 4 Lane**	Reviewer:	DDM	Date:	2020 APR 06
Client :	**HHB**	Approver:	EER	Date:	2020 APR 06

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	45.00	23.60	1062	$ 5,000	$ 5,310,000	20%	$ 1,062,000	$ 6,372,000
2		Suspended Span (Cable Stayed)	m²	1	900.00	25.60	23040	$ 13,000	$ 299,520,000	20%	$ 59,904,000	$ 359,424,000
3		Dartmouth Approach Spans	m²	1	300.00	23.60	7080	$ 5,000	$ 35,400,000	20%	$ 7,080,000	$ 42,480,000
4		Roadworks Approaches	m	1	1120.00		1120	$ 8,400	$ 9,408,000	20%	$ 1,882,000	$ 11,290,000
5		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20%	$ 6,600,000	$ 39,600,000
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20%	$ 3,000,000	$ 18,000,000
7		Demolition of CFIA Building	LS	1			1	$ 2,000,000	$ 2,000,000	20%	$ 400,000	$ 2,400,000
8		Construction of New CFIA Building	LS	1			1	$ 29,000,000	$ 29,000,000	20%	$ 5,800,000	$ 34,800,000
9											**Subtotal Direct Construction Cost**	**$ 514,366,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
10	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 514,366,000	$ 36,006,000	-	-	$ 36,006,000
11		Construction Supervision (7% Const)	LS	1	7.00%			$ 514,366,000	$ 36,006,000	-	-	$ 36,006,000
12		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 514,366,000	$ 51,437,000	-	-	$ 51,437,000
13											**Subtotal Owner's Construction Cost**	**$ 123,449,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
14	Maintenance	General Maintenance per year (N years)	LS	100			100	$ 200,000	$ 20,000,000	-	-	$ 20,000,000
15		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 12,000,000	$ 36,000,000	-	-	$ 36,000,000
16		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 3,000,000	$ 9,000,000	-	-	$ 9,000,000
17		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 5,150,000	$ 10,300,000	-	-	$ 10,300,000
		Extraordinary Maint. - Paving (every 40 years)	LS	2			2	$ 23,213,115	$ 46,427,000	-	-	$ 46,427,000
18											**Subtotal Maintenance Cost**	**$ 121,727,000**
19											**Total Cost**	**$ 759,542,000**
20											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 760,000,000**

Table J9: Option 2F

Consultant :	COWI North America Ltd	Estimate Type :	**Preliminary**	File No :	A102894
Project :	AMM Feasibility Study	Originator:	DNMC	Date:	2020 APR 06
Location :	**Halifax**	Checker:	EER	Date:	2020 APR 06
Bridge:	**Option 2F: 500 m Suspension - 4 Lane**	Reviewer:	EER	Date:	2020 APR 06
Client :	**HHB**	Approver:	EER	Date:	2020 APR 06

Item No.		Bid Item Description	Unit	Quantity	Length (m)	Width (m)	Estimated Quantity	Estimated Unit Price	Estimated Cost	Contingency		Cost
1	Direct Construction Cost	Halifax Approach Spans	m²	1	45.00	23.60	1062	$ 5,000	$ 5,310,000	20%	$ 1,062,000	$ 6,372,000
2		Suspended Spans Suspension Bridge	m²	1	900.00	25.60	23040	$ 18,000	$ 414,720,000	20%	$ 82,944,000	$ 497,664,000
3		Dartmouth Approach Spans	m²	1	300.00	23.60	7080	$ 5,000	$ 35,400,000	20%	$ 7,080,000	$ 42,480,000
4		Roadworks Approaches	m	1	1120.00		1120	$ 8,400	$ 9,408,000	20%	$ 1,882,000	$ 11,290,000
5		Existing Main Bridge Demolition	LS	1			1	$ 33,000,000	$ 33,000,000	20%	$ 6,600,000	$ 39,600,000
6		Existing Approach Spans Demolition	LS	1			1	$ 15,000,000	$ 15,000,000	20%	$ 3,000,000	$ 18,000,000
7		Demolition of CFIA Building	LS	1			1	$ 2,000,000	$ 2,000,000	0%	$ -	$ 2,000,000
8		Construction of New CFIA Building	LS	1			1	$ 29,000,000	$ 29,000,000	0%	$ -	$ 29,000,000
											Subtotal Direct Construction Cost	**$ 646,406,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**	**% Construction**			**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
9	Owner's Cost	Engineering (7% Const)	LS	1	7.00%			$ 646,406,000	$ 45,249,000	-	-	$ 45,249,000
10		Construction Supervision (7% Const)	LS	1	7.00%			$ 646,406,000	$ 45,249,000	-	-	$ 45,249,000
11		Other Owner's Costs (10% Const)	LS	1	10.00%			$ 646,406,000	$ 64,641,000	-	-	$ 64,641,000
											Subtotal Owner's Construction Cost	**$ 155,139,000**
Item No.		**Bid Item Description**	**Unit**	**Quantity**			**Estimated Quantity**	**Estimated Unit Price**	**Estimated Cost**	**Contingency**		**Cost**
12	Maintenance	General Maintenance per year (N years)	LS	100			100	$ 400,000	$ 40,000,000	-	-	$ 40,000,000
13		Extraordinary Maint. - Repainting (every 25 years)	LS	3			3	$ 20,000,000	$ 60,000,000	-	-	$ 60,000,000
14		Extraordinary Maint. - EJs (every 25 years)	LS	3			3	$ 6,000,000	$ 18,000,000	-	-	$ 18,000,000
15		Extraordinary Maint. - Bearings (every 40 years)	LS	2			2	$ 6,150,000	$ 12,300,000	-	-	$ 12,300,000
16		Extraordinary Maint. - Paving (every 20 years)	LS	4			4	$ 14,590,674	$ 58,363,000	-	-	$ 58,363,000
17		Extraordinary Maint. - Dehumidification	LS	3			3	$ 7,000,000	$ 21,000,000	-	-	$ 21,000,000
											Subtotal Maintenance Cost	**$ 209,663,000**
18											**Total Cost**	**$ 1,011,208,000**
19											**GRAND TOTAL: Opinion of Probable Total Project Cost in 2018 CAD (Rounded up to next million)**	**$ 1,012,000,000**

Appendix K Evaluation Matrix Summary

This appendix includes the full evaluation matrix.

Comparison Matrix

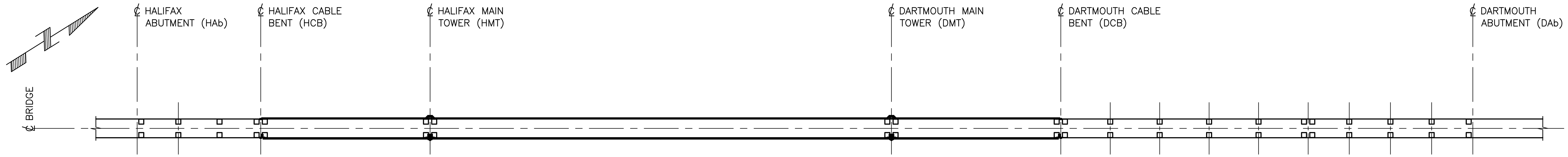
Rev 1

Prepared by: JGPR/JOLV/DNMC   Date: 2020 October 20

			Rehabilitate Existing Bridge			Replacement Bridge					
			1A	1B	1C	2A	2B	2C	2D	2E	2F
	TOTAL SCORE		67	71	60	78	67	64	67	73	64
		Weight	Score								
	Category 1. COST (Million CAD)	50	48	44	31	41	31	25	29	50	42
	Total Cost (Rounded to nearest 10 Million CAD)		840	970	1350	1050	1360	1530	1410	760	1010
1.1	Direct Construction Cost		522	594	813	724	891	1106	949	514	646
1.2	Owner's Construction Cost		151	172	219	174	214	265	228	123	155
1.3	Lifecycle Maintenance		169	203	315	156	254	159	234	122	210
		Weight / Importance	Score								
	Category 2. FEATURES	25	8	12	12	17	17	18	18	8	8
2.1	6 Traffic Lanes	High	No	No	Yes	Yes	Yes	Yes	Yes	No	No
2.2	2 Active Transportation Lanes	High	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
2.3	Increased Ship Vertical Clearance by 8+ m (air gap)	High	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2.4	Increased Ship Horizontal Clearance (channel width)	Low	No	No	No	No	No	Yes	Yes	No	No
2.5	Reuse of approach roads	Moderate	Yes	Yes	Yes	No	No	No	No	No	No
2.6	HHB owns required land	Moderate	Yes	Yes	No	No	No	No	No	No	No
2.7	Avoids Impacts to Urban Planning	Low	Yes	Yes	No	No	No	No	No	No	No
2.8	Extended Service Life Beyond 75 Years	Moderate	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
		Weight / Severity	Score								
	Category 3A. RISK	10	5	5	5	8	7	8	7	8	7
			Probability of Occurrence								
3.1	Impact to vehicular traffic during construction	High	High	High	Moderate	Low	Low	Low	Low	Low	Low
3.2	Impact to marine traffic during construction	High	High	High	High	Moderate	Moderate	Low	Low	Moderate	Moderate
3.3	Constructability / Complexity of erection sequence	High	High	High	High	Low	Moderate	Low	Moderate	Low	Moderate
3.4	Unknown Structural Constraints	High	High	High	High	Low	Low	Low	Low	Low	Low
3.5	Geotechnical	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
3.6	Vessel impact risk	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate
3.7	Permitting complexity and timelines	Moderate	Low	Low	Moderate	High	High	High	High	High	High
3.8	Unusual Resource Requirements	Low	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate	Low	Low
3.9	Operational Issues during Service Life	Moderate	High	High	High	Low	Moderate	Low	Moderate	Low	Moderate
		Weight / Gain	Score								
	Category 3B. OPPORTUNITY	5	1	2	5	5	5	5	5	4	4
			Probability of Occurrence								
3.10	Use of modern bridge design / methods and materials	Low	Low	Low	Moderate	High	High	High	High	High	High
3.11	Safety features	High	Low	Low	High	High	High	High	High	Moderate	Moderate
3.12	Technological gains	Low	Low	Moderate	Moderate	Moderate	Moderate	High	High	Moderate	Moderate
3.13	Structural Health Monitoring Implementation	High	Moderate	High	High	High	High	High	High	High	High
		Weight / Importance	Score								
	Category 4. SOCIAL IMPLICATIONS	10	5	8	7	7	7	8	8	3	3
			Assessment in Comparison with Social Perception of Existing Structure Rehabilitation								
4.1	Public Perception	High	Neutral	Better	Neutral	Better	Better	Better	Better	Worse	Worse
4.2	Impact on Community	High	Neutral	Better	Better	Better	Better	Better	Better	Neutral	Neutral
4.3	Stakeholder impact	High	Neutral	Better	Better	Neutral	Neutral	Neutral	Neutral	Worse	Worse
4.4	Architectural and Aesthetics	Moderate	Neutral	Neutral	Better	Better	Better	Better	Better	Better	Better
4.5	Cultural Implications	Low	Neutral	Neutral	Worse	Worse	Worse	Worse	Worse	Worse	Worse
4.6	Environmental considerations	Moderate	Neutral	Neutral	Neutral	Neutral	Neutral	Better	Better	Neutral	Neutral
4.7	Archeological Implications	Low	Neutral	Neutral	Worse	Worse	Worse	Worse	Worse	Worse	Worse

Appendix L General Arrangement Drawings

This appendix includes the general arrangement drawings for the two preferred options.



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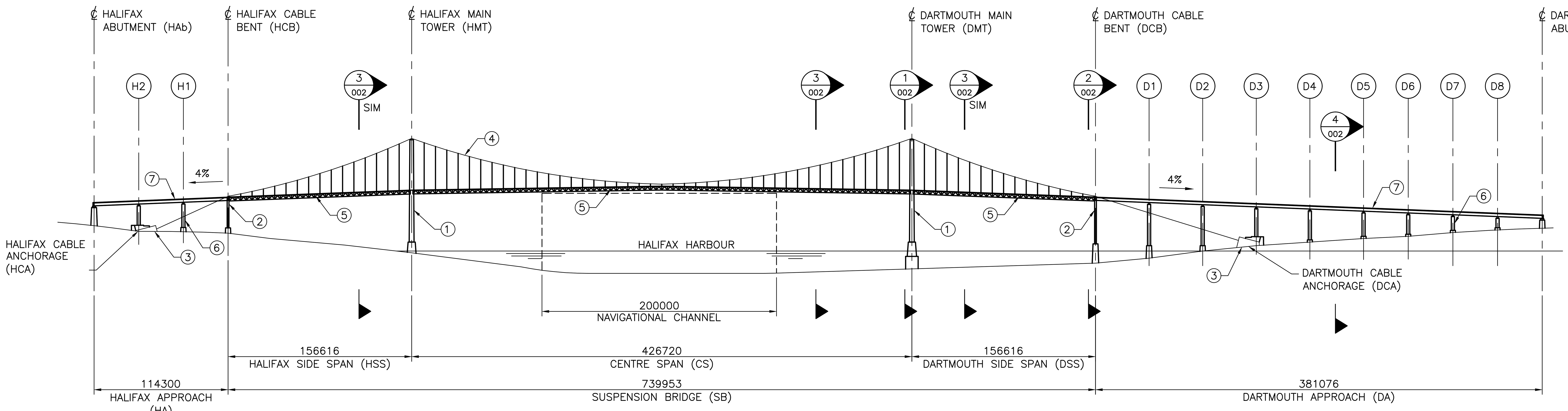

ELEVATION

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REHABILITATION DESCRIPTION:

1. REINFORCE MAIN TOWERS.
2. REINFORCE CABLE BENTS.
3. REINFORCE AND MODIFY CABLE ANCHORAGES.
4. SUPPLEMENT MAIN CABLE.
5. REPLACE SUPERSTRUCTURE SEGMENTS ON SUSPENDED SPANS. NEW SEGMENTS TO INCLUDE TWO NEW ACTIVE TRANSPORTATION LANES (SIDEWALKS/BIKEWAYS).
6. REHABILITATE AND REINFORCE PIERS ON APPROACH SPANS.
7. REPLACE SUPERSTRUCTURE ON APPROACH SPANS. NEW SUPERSTRUCTURE TO INCLUDE TWO NEW ACTIVE TRANSPORTATION LANES (SIDEWALK/BIKEWAY).

REV.	DESCRIPTION	DR.	APP.	DATE
0	ISSUED FOR REPORT	JEMC	EER	2020 MAY 22

CLIENT: Halifax Harbour Bridges

PROJECT: A. MURRAY MACKAY BRIDGE FEASIBILITY STUDY – REHABILITATE OR REPLACE

TITLE: OPTION 1B REHABILITATE AND ADD TWO AT LANES GENERAL ARRANGEMENT – 1

COWI

DRAWN	KECH/JEMC	DESIGNED	JGPR
CHECKED	–	CHECKED	–
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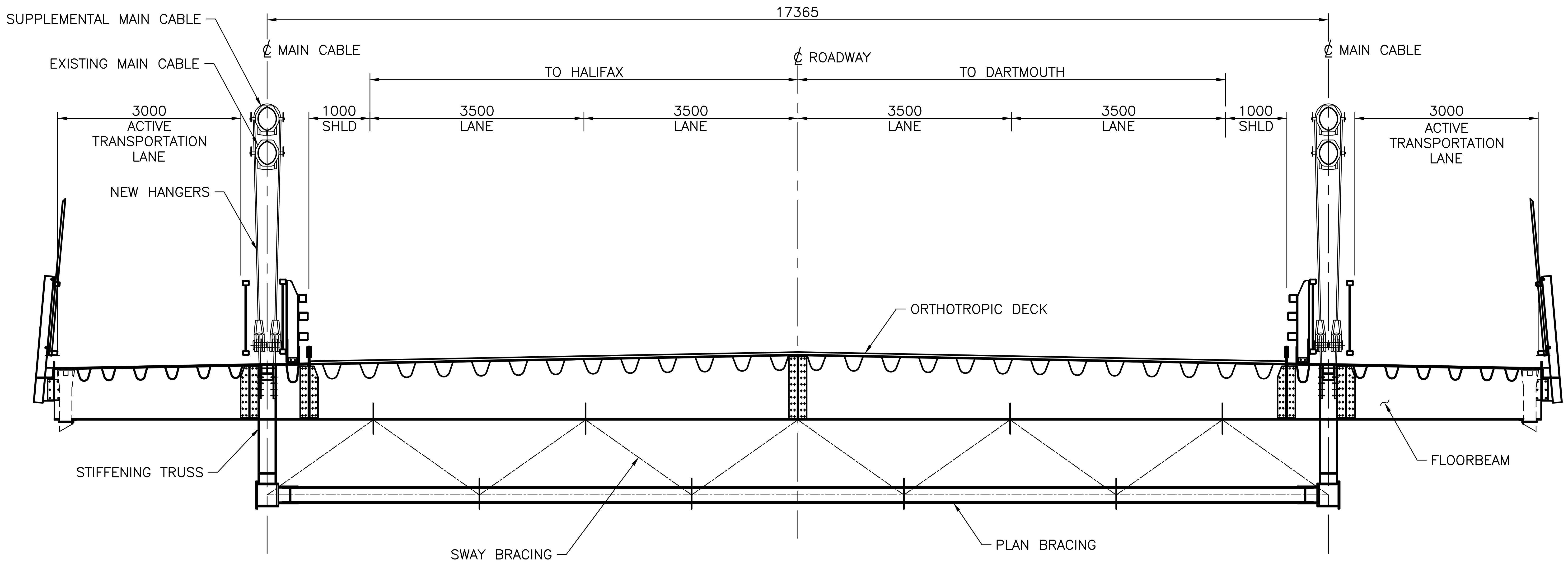
DATE	2020 MAY 22	REVIEWED	–
DRAWING No.	A102894–S–001	REV.	0



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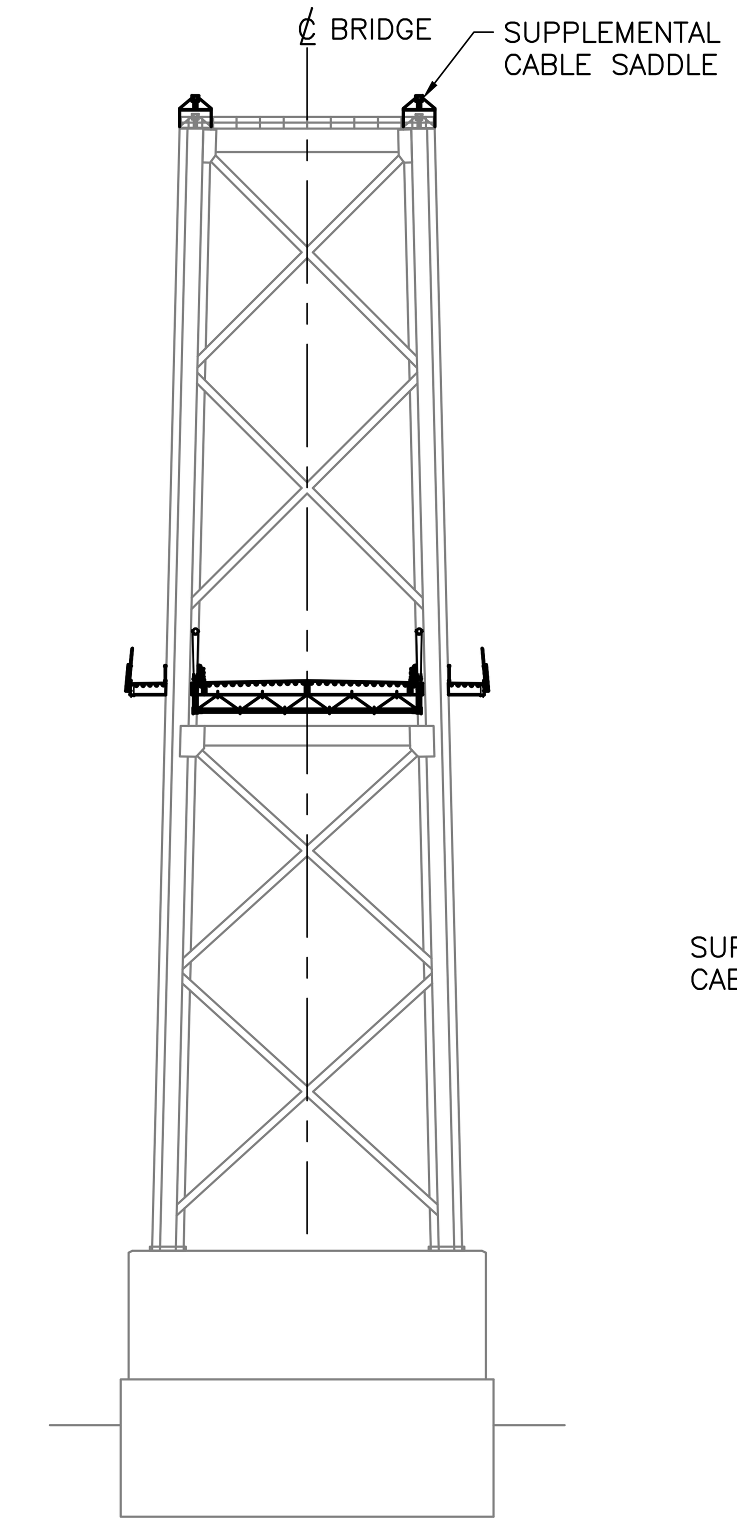

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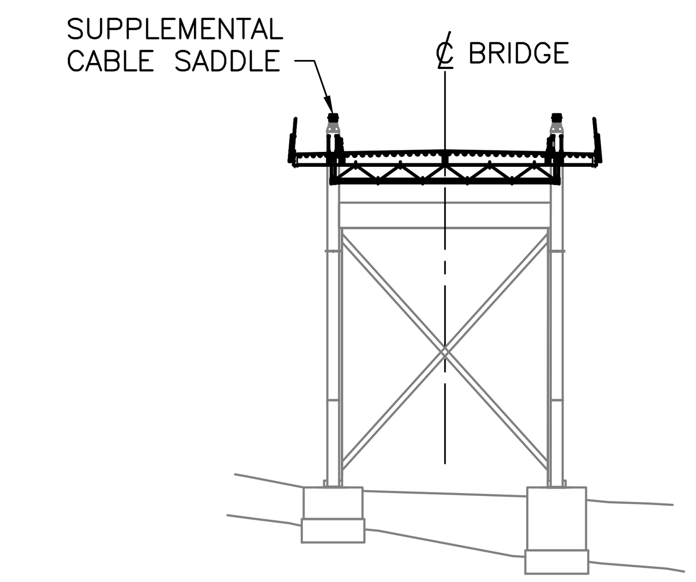

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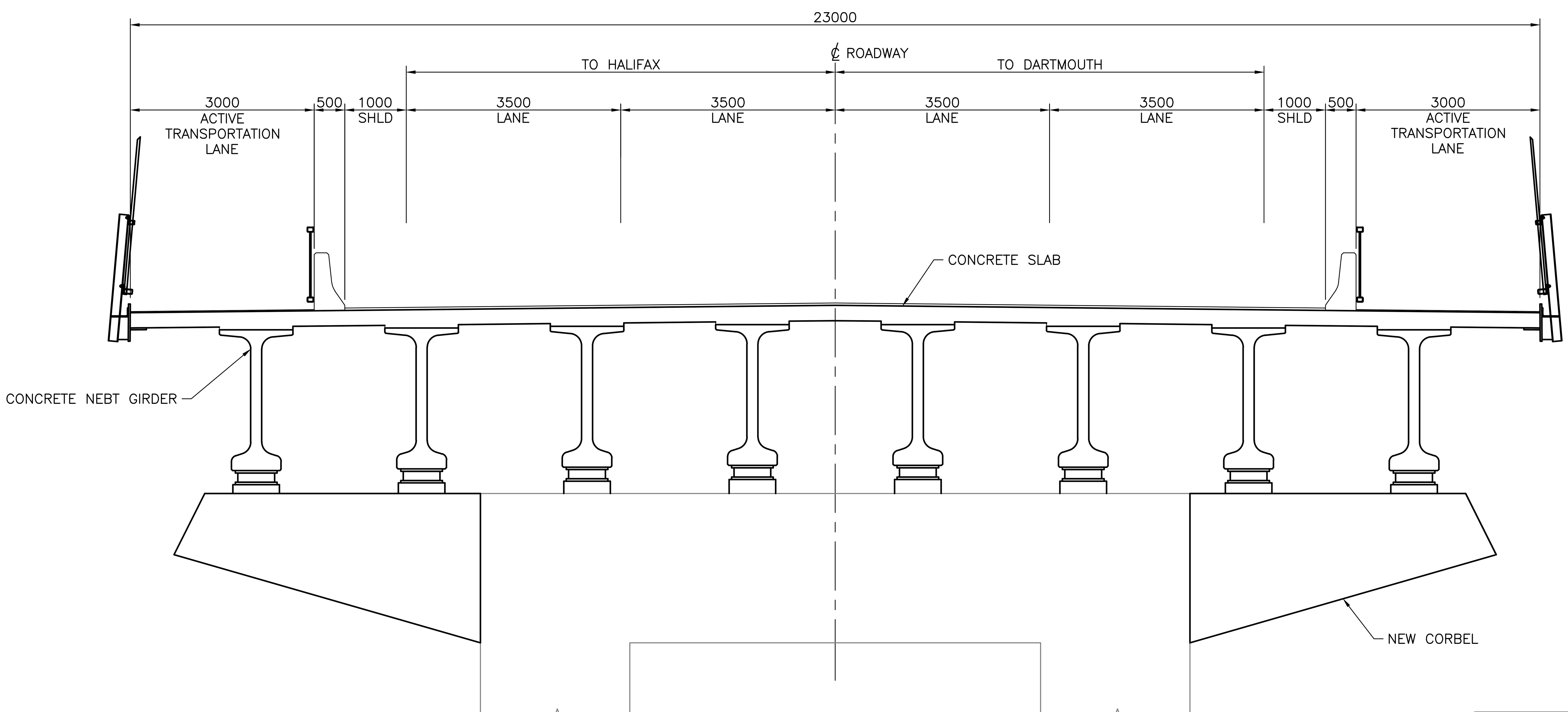

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0	ISSUED FOR REPORT	JEMC	EER	2020 MAY 22

CLIENT
Halifax Harbour Bridges

PROJECT
A. MURRAY MACKAY BRIDGE
FEASIBILITY STUDY – REHABILITATE OR REPLACE

TITLE
OPTION 1B
REHABILITATE AND ADD TWO AT LANES
GENERAL ARRANGEMENT – 2

COWI

DRAWN	KECH/JEMC	DESIGNED	JGPR
CHECKED	–	CHECKED	–
SCALE	AS SHOWN	APPROVED	EER
DATE	2020 MAY 22	REVIEWED	–

DRAWING No. A102894–S–002 REV. 0

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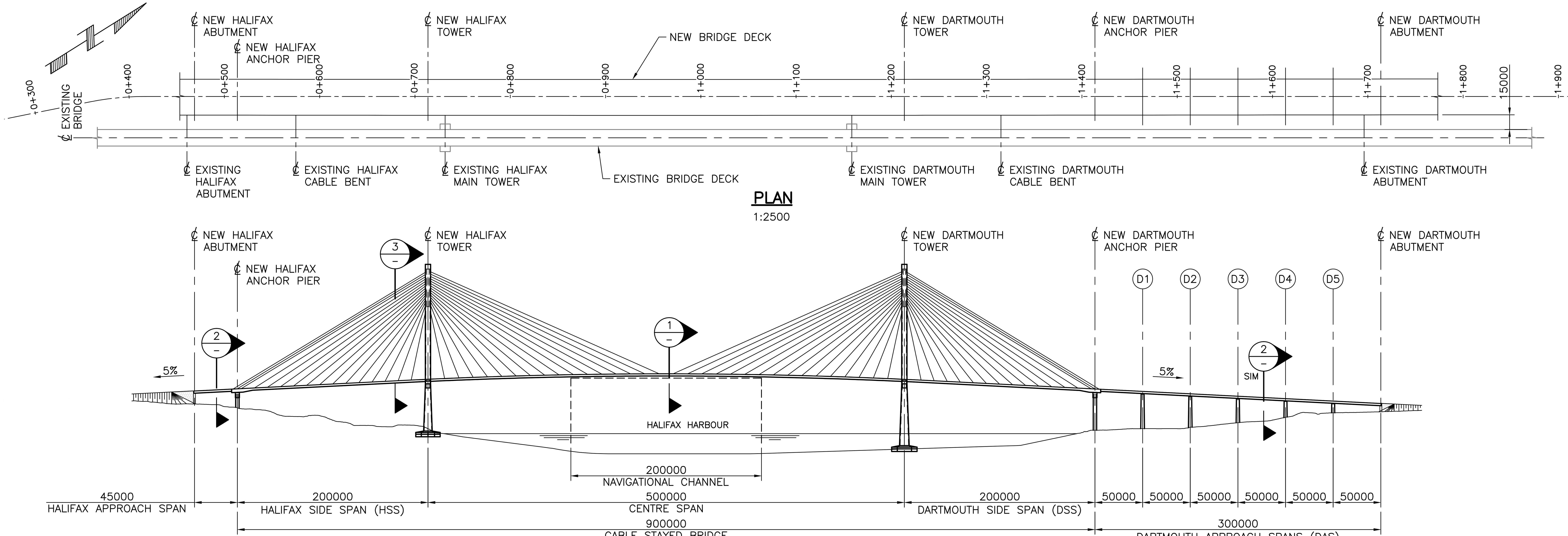

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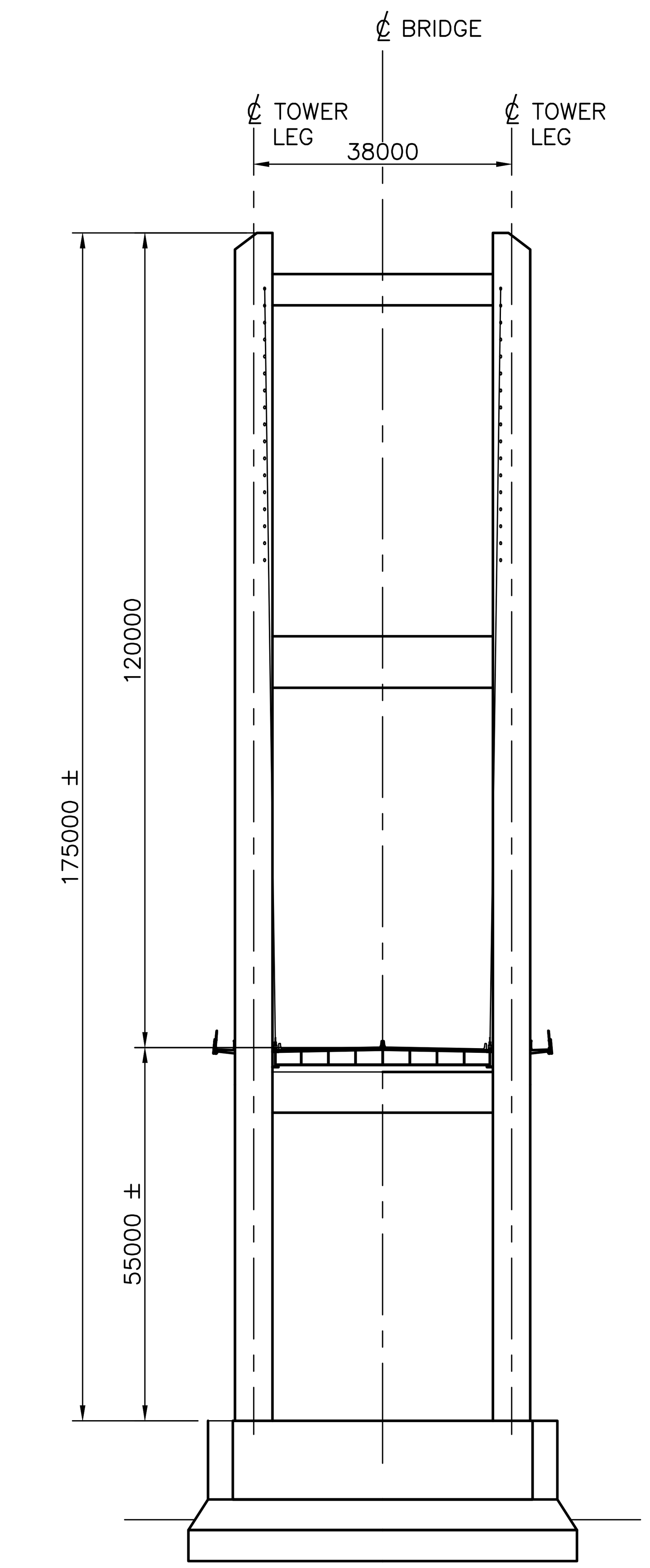

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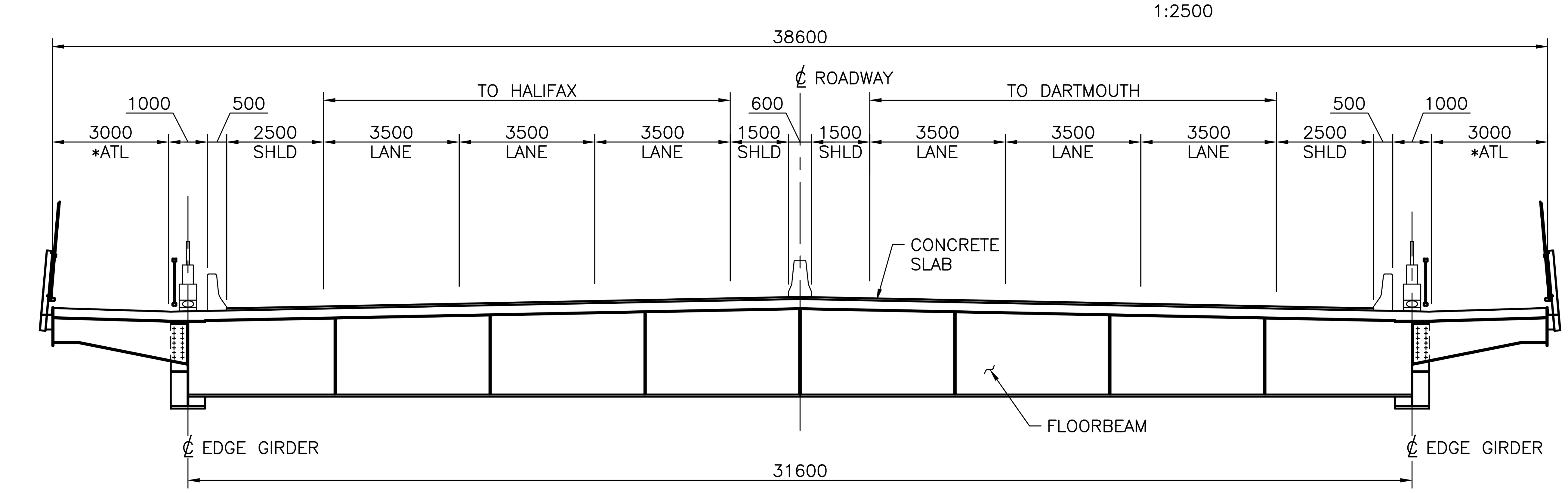

SECTION 1
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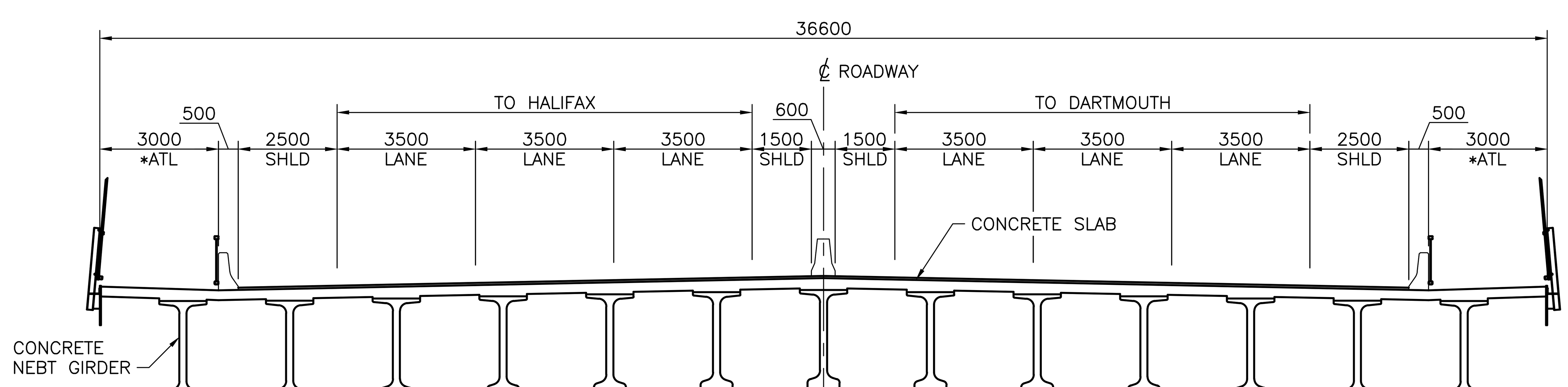
* ACTIVE TRANSPORTATION LANE



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* ACTIVE TRANSPORTATION LANE

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0	ISSUED FOR REPORT	JEMC	EER	2020 MAY 22

CLIENT: Halifax Harbour Bridges

PROJECT: A. MURRAY MACKAY BRIDGE
FEASIBILITY STUDY – REHABILITATE OR REPLACE

TITLE: OPTION 2A
NEW 6 LANE 500m CABLE–STAYED BRIDGE
GENERAL ARRANGEMENT

COWI

DRAWN	KECH/JEMC	DESIGNED	JGPR
CHECKED	–	CHECKED	–
SCALE	AS SHOWN	APPROVED	EER
DATE	2020 MAY 22	REVIEWED	–
DRAWING No.	A102894–S–003	REV.	0

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