DECEMBER 2023
NOVA SCOTIA DEPARTMENT OF PUBLIC WORKS

SEAL ISLAND BRIDGE BENEFIT-COST ANALYSIS

FINAL REPORT

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FINAL REPORT

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EXECUTIVE SUMMARY

The Seal Island Bridge (herein referred to as "the bridge") is located along Highway 105 in Victoria County, Cape Breton, Nova Scotia and serves as a major transportation and shipping link. The through-arch truss bridge is approximately 750 m long, and it was opened to traffic in 1961. While it is still in serviceable condition, the bridge has a history of structural complications and operational difficulties. Previous phases of Seal Island Bridge Benefit-Cost Analysis Project included inspections and a structural analysis with the goal to provide the Nova Scotia Department of Public Works (NSDPW) with recommendations on required actions to achieve a minimum service life extension of 15 years. The engineering for this work is ongoing and construction for the localized rehabilitations will start in the near future.

To determine a sustainable long-term path forward for the crossing, NSDPW assigned COWI and Stantec Consulting Ltd (herein referred to as "the Team") the task of identifying feasible long-term full-scale rehabilitation options as well as options that involve the replacement of the existing bridge. The assignment, known as a benefit-cost analysis (BCA), also includes ranking the identified feasible options according to the preferences and evaluation criteria established by the Team in consultation with NSDPW.

To develop the options, the Team considered multiple technical considerations, the most significant ones being presented in Table 1.

Table 1. BCA technical considerations for development of options

Marine traffic	Traffic
Community and stakeholders	Highway design
Hydrology	Highway lighting
Environment	Structural
Aesthetics	Vessel collision
Active transportation	Constructability and site considerations

The Team developed 11 feasible options, three rehabilitation options and eight replacement options, that are presented in Table 2. In addition to assessing the performance of each of options according to the technical considerations presented in Table 1, an estimate of probable costs was developed for each option based on the Team’s experience and recent project data.

Table 2. Options considered for BCA

Rehabilitation Options	Service Life
Through-arch truss (existing alignment)	+25 years
Through-arch truss (existing alignment)	+50 years
Through-arch truss (improved existing alignment)	+50 years
Replacement Options	**Service Life**
Concrete box girder (improved existing alignment)	+100 years
Steel box girder (improved existing alignment)	+100 years
Network arch (improved existing alignment)	+100 years
Cable-stayed (improved existing alignment)	+100 years
Concrete box girder (north of existing alignment)	+100 years
Cable-stayed (north of existing alignment)	+100 years
Concrete box girder (south of existing alignment)	+100 years
Cable stayed (south of existing alignment)	+100 years

To rank the 11 options, the Team developed a methodology intended to provide an objective and quantitative comparison. The methodology assesses an extensive list of evaluation criteria and features, organized into five predefined categories: cost, features, risks, opportunities, and social implications. The importance of each evaluation criterion was established using pairwise comparisons and identified that, the following five design criteria were the most important to NSDPW:

1. designs should enhance and protect the public safety, both during operation and construction;
2. designs should maintain or exceed the existing navigational clearance of the waterway;
3. designs should use of modern bridge design methods and materials;
4. designs should optimize lifecycle and maintenance costs;
5. designs should provide a service life beyond 50 years.

The two highest ranked options, shown in Figure 1 and Figure 2, were a new concrete box girder bridge and a steel network arch bridge. Both options would be built adjacent to the existing bridge and maximize re-use of the existing alignment. After construction of either new bridge, the existing bridge would be decommissioned. Both options include two widened roadway lanes, accommodation for active transportation and an improved approach roadway alignment. Land acquisition would likely be required, primarily on the west approach.

If a replacement option is ultimately selected, the Team estimates that the replacement will take at least ten years to complete – approximately five years for planning, consultation, and environmental permitting followed by five years of construction.

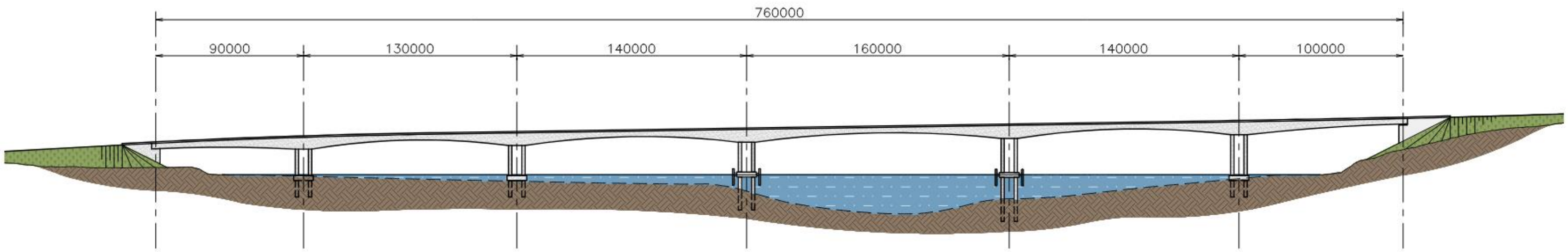

Figure 1. Highest ranked option: a concrete box girder bridge adjacent to existing crossing alignment (Option 2A, looking north)

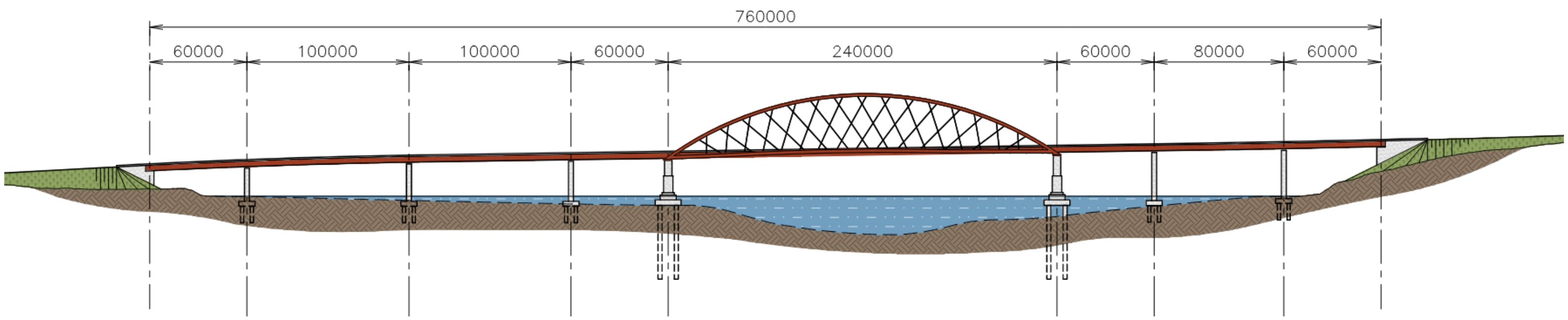

Figure 2. Second highest ranked option: a steel network arch bridge adjacent to existing crossing alignment (Option 2C, looking north)

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1 Introduction

Seal Island Bridge (herein referred to as "the bridge") is located along Highway 105 in Victoria County, Cape Breton, Nova Scotia and serves as a major transportation and shipping link. The through-arch truss bridge was opened to traffic in 1961 (construction started in 1960) and is approximately 750 m long. The structure has undergone various maintenance and rehabilitation works since 1990, including a deck replacement, recoating, and various truss reinforcements. The bridge is shown in Figure 3 and Figure 4. For the existing bridge naming convention, refer to Appendix A.

Figure 3: Seal Island Bridge north face

Figure 4: Seal Island Bridge at deck level

At over 60 years in service, the bridge is near the end of its expected design life and showing structural and operational difficulties such as a failed truss diagonal, cracked floor beams, steel material property complexities, wind-induced vibrations, and restricted access due to narrow deck geometry.

To determine a sustainable long-term path forward for this crossing, potential bridge rehabilitation and replacement options for the Seal Island Bridge were identified, developed and compared in a benefit-cost analysis (BCA). As a part of the study, evaluation criteria were established by the Team in consultation with Nova Scotia Department of Public Works (NSDPW) and to directly compare the developed options. Then, the options were ranked to provide a recommendation for the future of the Seal Island Bridge crossing.

1.1 Project Team

NSDPW engaged COWI North America Ltd (COWI) and Stantec Consulting Ltd. (Stantec) (herein referred to as "the Team") to assist in determining a recommended path forward for the crossing. As the Prime Consultant, COWI provided overall project management and coordination for the assignment, and the Team performed a benefit-cost analysis of each option under consideration. Possible long-term rehabilitation and replacement options were developed, and a detailed evaluation was completed to determine the best options of either rehabilitating the existing bridge to extend its service life or to maintain the bridge for 15 years and replace it with a new bridge.

1.2 Objectives

The intent of this report is to provide NSDPW with an understanding of their options for the future of the existing Seal Island Bridge crossing and, through a detailed evaluation, provide a recommended path forward. Specifically, the objectives of this report are:

- Determine NSDPW’s desired characteristics for the crossing.
- Identify the importance of each desired characteristic.
- Develop suitable and feasible bridge rehabilitation and replacement options for NSDPW’s consideration.
- Evaluate each option using the technical knowledge and professional experience of the Team’s specialists.
- Assess the significant issues, advantages, and disadvantages of the two highest ranked options.
- Recommend a path forward for the replacement or rehabilitation of the existing crossing for NSDPW’s consideration.

2 Project Background

Since its opening in 1961, the bridge has undergone various rehabilitations including expansion bearing replacements (1985) and a complete deck replacement and truss reinforcing program (late 1990s and into the early 2000s). Between 2003 and 2016, basic maintenance of the structure was undertaken while the bridge effectively performed without significant issues. In November 2016, a steel diagonal member in the northwest quadrant of the main arch span truss was observed to be fractured and was replaced on an emergency basis.

In 2018/2019, Harbourside Engineering Consultants performed a detailed inspection [1] that included a thorough visual inspection of the structure and limited non-destructive examination (NDE). The visual inspection indicated an abundance of tack welds, many of which were cracked, along with other defects that were identified as actions for NSDPW to address or to investigate further.

As a part of the current project, the Team performed a full structural assessment of the existing bridge superstructure and substructure [2]. As a result of the assessment, recommendations were made to allow the existing structure remain operational until 2037. However, it is recognized that the bridge is nearing the end of its expected design life. Therefore, NSDPW has retained the Team to perform a benefit-cost analysis to assess different options for the future of this crossing. Known shortcomings to be overcome for the existing structure are presented below.

2.1 Challenges with Existing Crossing

This section summarizes the key challenges associated with extending the life of the existing bridge crossing and provides some context for the need for the benefit-cost analysis performed by the Team.

- The existing bridge has a narrow two-lane deck that requires single lane closures to perform inspections, maintenance, or rehabilitation.

- The existing bridge does not have dedicated active transportation (AT) lanes.

- The existing roadway, descending Kelly's Mountain on the west approach, is not a desirable alignment as it contains substandard horizontal and vertical characteristics and multiple posted speed limits. There is a history of accidents and consistent anecdotal near misses located at the Kelly's Mountain Switchback.

- The existing roadway lighting on the bridge is provided only along the north side of the bridge. The lighting design details are not known, but as the most recent Transportation Association of Canada (TAC) lighting standards were released in 2006, it is unlikely that the existing lighting meets the current standards. Additionally, there are new design standards that consider the effect of lighting on migratory birds and their food sources, which was likely not considered for the original lighting design.

- There are known cracks on steel superstructure components of the structure [3]. These typically initiate at tack welds located at truss nodes in all spans. Some of the observed cracks have propagated into the parent material.

- The existing superstructure steel has poor weldability, low fracture toughness, ductility, and yield strength [4].

- The existing substructure is deteriorating due to highly permeable concrete (increased freeze-thaw deterioration) combined with Alkali Aggregate Reactivity (AAR) resulting in map cracking, spalling, and efflorescence throughout [5].

- The condition of the existing foundations and soil conditions are not well known.

- There are various structural elements with demand-to-capacity ratios (D/Cs) exceeding 1.0 that require attention [2].

- The as-built documentation of the bridge has negligible information on the steel connections and limited geotechnical information.

- It is likely that the structure was not designed for ship impact which was not a typical design consideration for bridges of its age (circa 1960s).

- Sea level rise associated with climate change coupled with wind and wave action during extreme weather events results in the risk of potential overtopping and corresponding erosion of the existing approach causeway in the future.

3 Desired Features

Through discussions with NSDPW and their subject matter specialists, our Team outlined key features for incorporation into the rehabilitation or new crossing designs, where feasible. These features represent NSDPW's desires for the final product of the crossing and Bridge but are not required design criteria. The potential for a new design to accommodate these features is significantly higher than a rehabilitation and therefore not all options in this study incorporate all the desired features. NSDPW's preferred features are presented in Table 3.

Table 3: NSDPW's desired features

Category	Description
Wider Traffic Lanes (min. 2 Lanes)	Where possible, options should consider a deck with adequate width to accommodate two-way traffic during maintenance and inspection activities on the deck. However, only two painted lanes of traffic are required.
Active transportation lanes	Where possible, options should include AT lanes to accommodate flexibility of a shared use path in the future or maintenance vehicle access.
Clearance of navigational channel	All options must maintain existing navigational clearances at a minimum.
Use of existing highway infrastructure	Where possible, the existing roadway infrastructure should be re-used and/or improved.
NSDPW owns required land	To minimize the impacts to the community and the environment during construction and over the lifespan of the structure, options where NSDPW owns more of the land needed are considered as more favourable.
Service life beyond 50 years	NSDPW would like to ensure that the service life from the time of this report is extended at least 50 years, preferably 100 years.
Utility/service accommodations	Where possible, NSDPW would like to take advantage of a rehabilitated or new crossing to be able to accommodate utility and service distribution lines from service providers.

4 Crossing Options

In consultation with NSDPW, the Team reviewed the background information, held a brainstorming session with NSDPW and developed an assessment model to evaluate potential rehabilitation and replacement options.

The Team developed 11 rehabilitation/replacement options. The options were developed to the preliminary stage and include the bridge type, main span length, roadway alignment, and key features. Each option was evaluated on the maximum period of 100 years such that any 25- and 50-year options were combined with the highest rated rehabilitation/replacement option (only applicable for Options 1A through 1C). The option details are provided below and include particulars on the service life, geometry considerations, and rehabilitation requirements.

1A: Rehabilitation (existing bridge), 25-yr lifespan, 2 lanes (no change to existing capacity)

1B: Rehabilitation (existing bridge), 50-yr lifespan, 2 lanes (no change to existing capacity)

1C: Rehabilitation (existing bridge), 50-yr lifespan, 2 lanes (with existing alignment improvements)

2A: New bridge (concrete box girder), adjacent to the existing bridge, improved existing alignment, medium span, two lanes with widened shoulders, active transportation (AT)

2B: New bridge (steel box girder), adjacent to the existing bridge, improved existing alignment, medium span, two lanes with widened shoulders, AT

2C: New bridge (network arch), adjacent to the existing bridge, improved existing alignment, medium span, two lanes with widened shoulders, AT

2D: New bridge (cable-stayed), adjacent to the existing bridge, improved existing alignment, long span, two lanes with widened shoulders, AT

3A: New bridge (highest ranked bridge type from 2A-2C), new alignment to the north of existing structure, medium span, two lanes with widened shoulders, AT

3B: New bridge (cable-stayed), new alignment to the north of existing structure, long span, two lanes with widened shoulders, AT

4A: New bridge (highest ranked bridge type from 2A-2C), new alignment to the south of existing structure, medium span, two lanes with widened shoulders, AT

4B: New bridge (cable-stayed), new alignment to the south of existing structure, long span, two lanes with widened shoulders, AT

4.1 Key Assumptions

The Team's key assumptions, which have been developed and refined through discussions with NSDPW, are listed below:

- For new crossings, NSDPW confirmed that they prefer a roadway with adequate width to accommodate two-way traffic during maintenance and inspection activities on the deck without impacting the traffic. Although this corresponds to wider lanes, it does not represent three traffic lanes unless the traffic volume projections indicate three lanes are required.

- The Team’s original assignment was to develop rehabilitation and replacement options with a service life of 100 years. Based on the Team's field investigations [3, 5], the Team does not believe a rehabilitation service life beyond 50 years is a reasonable option for consideration. Therefore, and as discussed with NSDPW, the rehabilitation options have been reduced to 25- and 50-year service life options but will be evaluated over the maximum anticipated period of 100 years. That is, that the cost of deconstruction at end-of-service life and new structure construction will be considered.

- The Team’s assignment was to assume that the service life of the existing bridge is to have been extended to the year 2037 (15 years from the time of the structural analysis report [2]). Therefore, it is assumed that bridge replacement and rehabilitation options would be in-service as of the year 2038.

- During the early stages of this benefit-cost analysis, the following potential options were considered infeasible and removed from consideration:

  - A new crossing location at the narrowest part of the channel near New Campbellton: this crossing does not appear to be a feasible option based on the presence of a protected area to the north of the existing bridge, a graveyard near the probable landing site, a wetland near the probable landing site and highway alignments appearing to require slopes that exceed acceptable grades.

  - A rehabilitation design with AT lane(s): a preliminary assessment showed that this option was not structurally feasible due to the anticipated need of extensive truss reinforcements to accommodate the additional load.

5 Evaluation

The Team developed a multi-criteria assessment model to evaluate the rehabilitation and replacement options for the bridge. The evaluation was performed in four main stages:

Stage 1: Develop the evaluation criteria and corresponding “importance” of each (refer to Section 5.1 and Section 5.2).

Stage 2: Assess each option with respect to the project’s technical considerations (refer to Section 5.3) and estimate the costs of each option (Appendix R).

Stage 3: Rate each option with respect to the evaluation criteria based on the results of technical assessments from Stage 2 (refer to Section 5.4).

Stage 4: Rank the options using the final weighted ratings (results presented in Section 7).

5.1 Evaluation Criteria

Based on previous experience, the Team presented NSDPW with the categories used for the evaluation, presented in Table 4.

Table 4. Evaluation categories

ID	Category	Description
1.1	Life-Cycle Cost	The Life-cycle cost comprises the construction, maintenance demolition of the existing bridge and building relocation costs.
1.2	Features	NSDPW's key features for the rehabilitated or replacement structure.
1.3	Risk	Events that could negatively impact public safety, project cost or schedule
1.4	Opportunity	Potential to improve public safety, include added features or possible future benefits.
1.5	Social Implications	Impacts to the community and the environment during construction and over the lifespan of the structure.

Through discussion and collaboration, NSDPW provided the Team with the feedback necessary to develop the criteria with which to assess the categories presented above. The criteria used to assess the bridge options are presented below.

5.1.1 Life-Cycle Cost

Costs for each option were based upon recent and indicative projects in North America and are considered a reasonable assumption with this study's level of detail. The overall cost was broken down into the categories as shown in Table 5.

Table 5. Category 1: Life-cycle costs criteria

ID	Cost Item	Description
1.1	Direct construction cost	The cost to construct and deconstruct the bridge
1.2	Owner's cost for construction	The cost to design, prepare for, and manage the works
1.3	Road re-alignment cost	The cost to widen or realign roads
1.4	Relocation of existing infrastructure	The cost to relocate ancillary or adjacent infrastructure
1.5	Lifecycle and maintenance cost	The cost to maintain the bridge, assuming a 0% discount rate

However, one challenge is that 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 land acquisition costs, if required.

Not all options have the same design life. Based on discussions between the Team and NSDPW, it was decided that the rehabilitation options have either a 25- or 50-year design life, while new options have a 100-year design life. To make the cost comparison between options as fair as possible, it was agreed with NSDPW that all options will be evaluated based on 100 years of service. That is, the evaluation for a scenario with a 50-year design life includes the cost of demolition of the existing crossing and new construction of the replacement crossing after 50 years (as required).

Maintenance and operation 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 R.

5.1.2 Features

NSDPW provided input on key features that are to be considered and incorporated (if reasonable) into the rehabilitated or new structure options. Each option incorporates as many as the key features as possible, but not all, and not all key features are practical for each option. The features considered in the evaluation assessments are presented in Table 6.

Table 6. Category 2: Features description

ID	Cost Item	Description
2.1	Wider Traffic Lanes (min. 2 Lanes)	Where possible, options should consider a deck with adequate width to accommodate two-way traffic during maintenance and inspection activities on the deck. However, only two painted lanes of traffic are required.
2.2	Active transportation lanes	Where possible, options should include AT lanes to accommodate flexibility of a shared use path in the future or maintenance vehicle access.

ID	Cost Item	Description
2.3	Clearance of navigational channel	All options must maintain existing navigational clearances at a minimum.
2.4	Use of existing highway infrastructure	Where possible, the existing roadway infrastructure should be re-used and/or improved.
2.5	NSDPW owns required land	To minimize the impacts to the community and the environment during construction and over the lifespan of the structure, options where NSDPW owns more of the land needed are considered as more favourable.
2.6	Service life beyond 50 years	NSDPW would like to ensure that the service life of the crossing from the time of this report is extended by over 50 years, preferably 100 years.
2.7	Utility/service accommodations	Where possible, NSDPW would like to take advantage of a rehabilitated or new crossing to be able to accommodate utility and service distribution lines from service providers.

5.1.3 Risks

Each project has inherent risks. For this study, risk was assumed to be factors that could occur and negatively impact project cost or schedule, while understanding the project would incorporate all pertinent risk 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 new bridge options. Some risks go beyond initial construction, such operational issues during the service life. The risks considered in the evaluation assessments are presented in Table 7.

Table 7. Category 3: Risks description

ID	Risk	Description
3.1	Impact to trade corridors during construction	Likelihood of unplanned interruptions impacting the trade corridors (vehicular traffic, marine channel, etc.) during construction
3.2	Impact to trade corridors in-service	Likelihood of unplanned interruptions impacting the trade corridors (vehicular traffic, marine channel, etc.) with the crossing after it is in-service
3.3	Constructability / complexity of erection sequence	Increased level of effort and expertise necessary to ensure construction continues as planned, including the likelihood of requiring specialist personnel, equipment, materials or procedures which would increase cost and possibly extend schedule
3.4	Climate Change	Likelihood of changes to hydraulic requirements under bridge, environmental loading (i.e., wind, temperature, ice, seismic) or navigational clearance during the bridge service life.
3.5	Geotechnical	Likelihood of discovering negative geotechnical conditions during design/construction, which would lead to further cost and delays

ID	Risk	Description
3.6	Approvals and permitting	Likelihood of a design scenario to be denied Regulatory Approval, due to social, environmental impacts, or archeological findings, and possibility of the permitting process delaying design and construction, extending the schedule (e.g., presence of endangered species)
3.7	Operational issues during service life	Likelihood of major maintenance being required during the life of the bridge due to the type of bridge selected
3.8	Land acquisition	Likelihood of increased capital cost and schedule delays resulting from acquisition negotiations

5.1.4 Opportunities

Each project has the potential to provide opportunities that would otherwise be unobtainable. Opportunities are understood as factors that have the potential to improve the project, generally through added features or possible future benefits. The potential opportunities considered during the evaluation assessments are presented in Table 8.

Table 8. Category 4: Opportunities description

ID	Opportunity	Description
4.1	Public safety	Ability to improve public safety and fully bring structure and roadway up to current safety codes, standards, and accepted best practices for current construction
4.2	Use of modern bridge design / methods and materials	Ability to optimize materials and minimize maintenance
4.3	Environmental gains	Potential to use sustainable practices and to exceed environmental goals during and post construction
4.4	Local content within construction industry	Potential that the selected option is within skillset of local construction/fabrication industry allowing them to be competitive in its design and construction
4.5	Technological gains	Ability to improve knowledge base of local engineers, update NSDPW's structural inventory, utilization of emerging technologies, and potential to implement a structural health monitoring system

5.1.5 Social Implications

This evaluation category focuses on the impacts to the community and the environment. NSDPW is aware of the effect replacing or rehabilitating the Seal Island Bridge will have on the community, both during construction and over the lifespan of the structure. The social implications considered during the evaluation assessments are presented in Table 9.

Table 9. Category 5: Social implications description

ID	Social Implication	Description
5.1	Public perception	How the public are likely to perceive each option; public acceptance
5.2	Effects on nearby communities	General effect on quality of life in the surrounding neighborhoods, including noise and traffic disruptions, as well as impacts on local businesses
5.3	Mi'kmaq perception	How the Mi'kmaq of Nova Scotia are likely to perceive each option.
5.4	Stakeholder impact	The effect (interruptions, access, property ownership, noise, landscape changes, etc.) of the project on stakeholder groups
5.5	Architectural and aesthetics	Lasting effect of the physical structure, including the sentimental value of the existing truss bridge aesthetics.

5.2 Category and Criteria Weighting

To determine the weighting (or "importance") of each category and criteria, a series of pairwise analyses were performed. Pairwise comparisons determine preference between seemingly independent variables (decision criteria) when making complex decisions. To perform the comparison, criteria are directly compared in pairs to determine their overall importance in the final decision. For additional information on pairwise comparisons, refer to Appendix B.

For this analysis, a two-level Pairwise comparison was performed. First, the overall categories (refer to Table 4) were compared and then the individual criteria within each category (refer to Table 5 through Table 9) were compared.

In April 2022, COWI hosted a pairwise analysis and comparison workshop with NSDPW with two objectives: describe the pairwise analysis approach to NSDPW and to facilitate NSDPW's comparisons of the categories and criteria as the ultimate "decision-maker". To provide background on the pairwise comparison procedure, the category-level comparison procedure is presented below as an example.

5.2.1 Pairwise Comparison Example – Categories

Each category was directly compared to each other category using the ranking system presented in Table 10. Using this ranking system, NSDPW ranked category vs. category based on their perceived importance.

Table 10. Pairwise analysis comparison ranking system

Rank	Description
1	Much less important than other option
2	Less important than other option
3	Same importance as other option
4	More important than other option
5	Much more important than other option

The detailed results for the overall and individual category pairwise comparison rankings are presented in Appendix C; an excerpt of the rankings for the overall categories is shown in Figure 5. For clarity, Figure 5 can be interpreted using the following examples:

- Cost vs. Features rates as a "2", which is interpreted as "Cost is less important than Features"
- Features vs Risk rates as a "3", which is interpreted as "Features is the same importance as Risk"
- Social Implications vs Cost rates as a "4", which is interpreted as "Social Implications are more important than Cost"

The sum of all rankings is 60 (6 points per comparison, 10 total comparisons) and the sum of each category divided by the total points is the categories weight (or importance) in %.

Category Comparisons

		vs. Cost	vs. Features	vs. Risk	vs. Opportunity	vs. Social Implications	Ranking
Cost	The Life-cycle cost comprises the construction, maintenance demolition of the existing bridge and building relocation costs.		2	2	2	2	13%
Features	NSPW's key features for the rehabilitated or replacement structure designs.	4		3	4	4	25%
Risk	Events that could negatively affect project cost or schedule	4	3		3	4	23%
Opportunity	Potential to improve public safety, include added features or possible future benefits.	4	2	3		5	23%
Social Implications	Impacts to the community and the environment during construction and over the lifespan of the structure.	4	2	2	1		15%
							100%

Figure 5: Excerpt of pairwise analysis comparison (showing overall categories only)

5.2.2 Results of Pairwise Analysis

After performing the pairwise analysis for the categories, the same procedure was completed for the individual criteria within each category (refer to Appendix C for the details on each pairwise comparison). Then, the overall weight of each criterion was taken as the product of its weight and the weight of its category. The weights (or importances) of the criteria are presented below in Table 11.

Table 11. Category and criteria weighting

Category	Cat. Weight	Criterion	Criterion Weight	Overall Weight	Rank (/30)
Costs	**13%**	Direct construction cost	17%	2.2%	24
		Owner's cost for construction	17%	2.2%	25
		Road re-alignment cost	17%	2.2%	26
		Relocation of existing infrastructure	17%	2.2%	27
		Lifecycle and maintenance cost	33%	4.4%	4
Features	**25%**	Wider Traffic Lanes (min. 2 Lanes)	16%	4.0%	8
		Active transportation lanes	17%	4.2%	6
		Clearance of navigational channel	24%	6.0%	2
		Use of existing highway infrastructure	10%	2.6%	21
		NSPW owns required land	11%	2.8%	18
		Service life beyond 50 years	17%	4.4%	5
		Utility/service accommodations	5%	1.2%	30
Risks	**23%**	Impact to trade corridors during construction	6%	1.4%	29
		Impact to trade corridors in-service	17%	3.9%	9
		Constructability / complexity of erection sequence	11%	2.6%	20
		Climate Change	17%	3.9%	10
		Geotechnical	13%	3.1%	16
		Approvals, permitting and consultation	13%	2.9%	17
		Operational issues during service life	17%	4.0%	7
		Land acquisition	7%	1.5%	28
Opportunities	**23%**	Public safety	32%	7.4%	1
		Use of modern bridge design methods and materials	22%	5.1%	3
		Environmental gains	15%	3.5%	14
		Local content within construction industry	17%	3.9%	11
		Technological gains	15%	3.5%	15
Social Implications	**15%**	Public perception	17%	2.5%	22
		Effects on nearby communities	25%	3.8%	12
		Mi'kmaq perception	15%	2.3%	23
		Stakeholder impact	25%	3.8%	13
		Architectural and aesthetics	18%	2.8%	19

5.3 Assessments

The Team's specialists assessed each option with respect to the project's technical considerations presented in Table 12 and the evaluation criteria presented in the preceding sections. For the sake of brevity, the details of each assessment are presented in the appendices.

Table 12. Project technical considerations

Technical Consideration	Appendix Section
Marine Traffic	Appendix F
Community and Stakeholders	Appendix G
Hydrology	Appendix H
Environment	Appendix I
Aesthetics	Appendix J
Active Transportation	Appendix K
Traffic	Appendix L
Highway Design	Appendix M
Highway Lighting	Appendix N
Structural	Appendix O
Vessel Collision	Appendix P
Constructability and Site Considerations	Appendix Q

5.4 Criteria Ratings

The results of the specialists’ assessments were used to rate each option with respect to each evaluation criterion. After the ratings were decided, the results were multiplied by the criteria weights from the pairwise analysis. In this section, the criteria ratings for each option are presented.

Each of the 11 options are defined in Section 4 and illustrated with conceptual sketches in summary sheets later in this report (Section 6).

5.4.1 Category 1: Life-Cycle Costs

Life-cycle costs comprise the direct construction cost, owner's cost for construction, road re-alignment cost, relocation of existing infrastructure cost (if applicable), and the life-cycle and maintenance costs. Each option is evaluated over the anticipated service life of 100 years. That is, that the cost of deconstruction at end-of-service life and new structure construction will be considered, where applicable. Estimated costs for each option were based upon recent and indicative projects in North America and are considered a reasonable assumption for this study's level of details.

The inputs for this category were the estimated costs in million of dollars (CAD). For each criterion, the costs were weighted by assigning the highest cost with the lowest rating (0), the lowest cost with the highest rating (100), and costs between the highest and lowest with a rating determined using a linear interpolation. This is a simplification that the Team deemed appropriate for this BCA considering that there are no zero-cost options that would heavily skew this approach. The numerical values were then multiplied by their pairwise percentage, summed vertically, and then multiplied by the maximum total points to represent the final weighted score. Final scores for Category 1 are shown in Table 13.

Table 13. Category 1: Life cycle costs scoring results

COSTS IN MILLIONS OF DOLLARS (CAD)													
	Category 1. LIFE-CYCLE COST		**Rehabilitate**			**New Bridge - Existing Location**				**New Bridge - North**		**New Bridge - South**	
	MAX TOTAL POINTS: 13	**Pairwise %**	**1A**	**1B**	**1C**	**2A**	**2B**	**2C**	**2D**	**3A**	**3B**	**4A**	**4B**
1.1	Direct construction cost	17	202	205	208	149	181	137	160	310	412	248	322
1.2	Owner's cost for construction	17	59	60	61	44	53	40	47	90	120	72	94
1.3	Road re-alignment cost	17	11	11	11	11	11	11	11	8	8	21	21
1.4	Relocation of existing infrastructure	17	0	0	0	0	0	0	0	0	0	0	0
1.5	Lifecycle and maintenance cost	33	104	144	144	64	131	129	102	128	250	80	132
	Total Cost (Rounded to nearest 10 Million CAD)	-	**380**	**420**	**430**	**270**	**380**	**320**	**320**	**540**	**790**	**430**	**570**

	Category 1. LIFE-CYCLE COST		**Rehabilitate**			**New Bridge - Existing Location**				**New Bridge - North**		**New Bridge - South**	
	MAX TOTAL POINTS: 13	**Pairwise %**	**1A**	**1B**	**1C**	**2A**	**2B**	**2C**	**2D**	**3A**	**3B**	**4A**	**4B**
1.1	Direct construction cost	17	**76**	**75**	**74**	**96**	**84**	**100**	**92**	**37**	**0**	**60**	**33**
1.2	Owner's cost for construction	17	**76**	**75**	**74**	**95**	**84**	**100**	**91**	**38**	**0**	**60**	**33**
1.3	Road re-alignment cost	17	**77**	**77**	**77**	**77**	**77**	**77**	**77**	**100**	**100**	**0**	**0**
1.4	Relocation of existing infrastructure	17	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
1.5	Lifecycle and maintenance cost	33	**78**	**57**	**57**	**100**	**64**	**65**	**80**	**66**	**0**	**91**	**63**
	SCORE	-	**10.8**	**9.8**	**9.8**	**12.6**	**10.5**	**11.3**	**11.5**	**9.0**	**4.4**	**8.9**	**6.5**

5.4.2 Category 2: Features

Inputs for this category were either *Yes* (numerical value of 1) or *No* (numerical value of 0) to indicate whether a feature is present or not present, respectively. The numerical values were then multiplied by their pairwise percentage, summed vertically, and then multiplied by the maximum total points to represent the final weighted score. Final scores for Category 2 are shown in Table 14.

Table 14. Category 2: Features scoring results

	Category 2. FEATURES		**Rehabilitate**			**New Bridge - Existing Location**				**New Bridge - North**		**New Bridge - South**	
	MAX TOTAL POINTS: 25.0	**Pairwise %**	**1A**	**1B**	**1C**	**2A**	**2B**	**2C**	**2D**	**3A**	**3B**	**4A**	**4B**
2.1	Wider Traffic Lanes (min. 2 Lanes)	16	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.2	Active transportation lanes	17	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.3	Clearance of navigational channel	24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.4	Use of existing highway infrastructure	10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
2.5	NSDPW owns required land	11	Yes	Yes	No	No	No	No	No	No	No	No	No
2.6	Service life beyond 50 years	17	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.7	Utility/service accommodations	5	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	SCORE		**11.3**	**11.3**	**8.5**	**22.2**	**22.2**	**22.2**	**22.2**	**19.6**	**19.6**	**19.6**	**19.6**

5.4.3 Category 3: Risks

Risks have *Low*, *Moderate* or *High* severity based on the potential consequences of the event and are assigned a value of 1, 0.5 or 0, respectively, where *Low* risks produce a more favourable result. Each risk was evaluated for each option and assigned a likelihood of occurrence of *Low*, *Moderate* or *High*. The numerical values were then multiplied by their pairwise percentage, summed vertically, and then multiplied by the maximum total points to represent the final weighted score. Final scores for Category 3 are shown in Table 15.

Table 15. Category 3: Risks scoring results

	Category 3. RISKS		Rehabilitate			New Bridge - Existing Location				New Bridge - North		New Bridge - South	
	MAX TOTAL POINTS 23.3	Pairwise %	1A	1B	1C	2A	2B	2C	2D	3A	3B	4A	4B
			Probability of Occurrence										
3.1	Impact to trade corridors during construction	6	High	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low
3.2	Impact to trade corridors in-service	17	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low	Low	Low	Low
3.3	Constructability / complexity of erection sequence	11	Low	Low	Low	Moderate	Moderate	Moderate	High	Moderate	High	Moderate	High
3.4	Climate Change	17	High	High	High	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low
3.5	Geotechnical	13	Moderate	Moderate	Moderate	High	High	High	High	High	High	High	High
3.6	Approvals, permitting and consultation	13	Low	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
3.7	Operational issues during service life	17	High	High	Moderate	Low	Low	Low	Low	Low	Low	Low	Low
3.8	Land acquisition	7	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	High	High
		SCORE	10.6	10.6	12.5	14.1	14.1	14.1	12.8	16.0	14.7	16.0	14.7

5.4.4 Category 4: Opportunities

Opportunities have *Low*, *Moderate* or *High* benefit based on the potential consequences of the event and are assigned a value of 0, 0.5 or 1 respectively, where *High* rated opportunities produce a more favourable result. Each risk was evaluated for each option and assigned a likelihood of occurrence of *Low*, *Moderate* or *High*. The numerical values were then multiplied by their pairwise percentage, summed vertically, and then multiplied by the maximum total points to represent the final weighted score. Final scores for Category 4 are shown in Table 16.

Table 16. Category 4: Opportunities scoring results

	Category 4. OPPORTUNITIES		Rehabilitate			New Bridge - Existing Location				New Bridge - North		New Bridge - South	
	MAX TOTAL POINTS 23.3	Pairwise %	1A	1B	1C	2A	2B	2C	2D	3A	3B	4A	4B
			Probability of Occurrence										
4.1	Public safety	32	Low	Low	Low	High	High	High	High	High	High	High	High
4.2	Use of modern bridge design / methods and materials	22	Low	Low	Low	High	High	High	High	High	High	High	High
4.3	Environmental gains	15	Low	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
4.4	Local content within construction industry	17	High	High	High	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate	Low
4.5	Technological gains	15	Moderate	Moderate	Moderate	High	High	High	High	High	High	High	High
		SCORE	5.6	5.6	5.6	19.6	19.6	19.6	17.7	19.6	17.7	19.6	17.7

5.4.5 Category 5: Social Implications

Social Implications have *Worse*, *Neutral* or *Better* assignment based on the impact or perception of their influence on each option such and are assigned a value of 0, 0.5 or 1 respectively, where *Better* rated social implications produce a more favourable result. The numerical values were then multiplied by their pairwise percentage, summed vertically, and then multiplied by the maximum total points to represent the final weighted score. Final scores for Category 5 are shown in Table 17.

Note that "public perception" and Mi'kmaq perception" were rated as "neutral" for all options to reflect that without dedicated engagement sessions with those specific groups, it would be extremely difficult and potentially reckless to assume the favourability of an option over any other.

Table 17. Category 5: Social implications scoring results

	Category 5. SOCIAL IMPLICATIONS		Rehabilitate			New Bridge - Existing Location				New Bridge - North		New Bridge - South	
	MAX TOTAL POINTS 15.0	Pairwise %	1A	1B	1C	2A	2B	2C	2D	3A	3B	4A	4B
5.1	Public perception	17	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
5.2	Effects on nearby communities	25	Neutral	Neutral	Neutral	Better	Better	Better	Better	Worse	Worse	Worse	Worse
5.3	Mi'kmaq perception	15	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
5.4	Stakeholder impact	25	Better	Better	Neutral	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse
5.5	Architectural and aesthetics	18	Neutral	Neutral	Neutral	Better	Better	Better	Better	Better	Better	Better	Better
		SCORE	9.4	9.4	7.5	8.9	8.9	8.9	8.9	5.1	5.1	5.1	5.1

6 Summary Sheets

Table 18 shows a summary of the crossing types, alignments, intended service life and costs.

Table 18. Summary of crossing types

No.	Bridge Type	Alignment [1]	Service Life	Estimated Probable Total Cost [2]
1A	Through-Arch Truss *Rehabilitation*	Existing	25 years	$380,000,000
1B	Through-Arch Truss *Rehabilitation*	Existing	50 years	$420,000,000
1C	Through-Arch Truss *Rehabilitation*	Existing + *Improved Hairpin*	50 years	$430,000,000
2A	Concrete Box Girder *New*	Existing + *Improved Hairpin*	100 years	$270,000,000
2B	Steel Box Girder *New*	Existing + *Improved Hairpin*	100 years	$380,000,000
2C	Network Arch *New*	Existing + *Improved Hairpin*	100 years	$320,000,000
2D	Cable-Stayed *New*	Existing + *Improved Hairpin*	100 years	$320,000,000
3A	Concrete Box Girder *New*	New *North of Existing*	100 years	$540,000,000
3B	Cable-Stayed *New*	New *North of Existing*	100 years	$790,000,000
4A	Concrete Box Girder *New*	New *South of Existing*	100 years	$430,000,000
4B	Cable-Stayed *New*	New *South of Existing*	100 years	$570,000,000

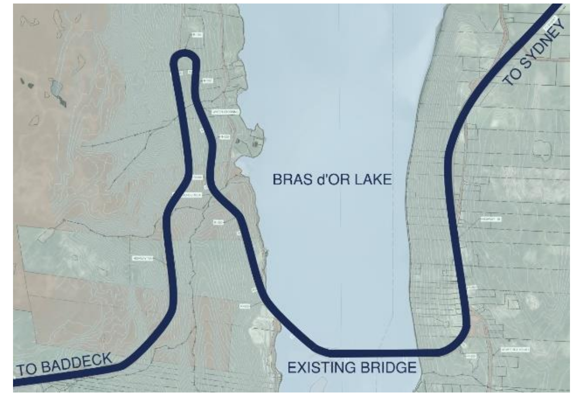
[1] Reference to "existing" is referring to the existing alignment. Options 1C and 2A through 2D are assumed to re-use part of the existing alignment with improvements to the existing hairpin; Options 3A/3B and 4A/4B are to the north and south of the existing alignment, respectively.
[2] Reflects the estimated probable total project cost rounded to the nearest $10M CAD in 2023 dollars. Refer to Appendix R for further details on the limitations on the estimate. Costs are intended to be sufficient in detail for comparison purposes only to complete this BCA – these costs should not be used for budgeting purposes.

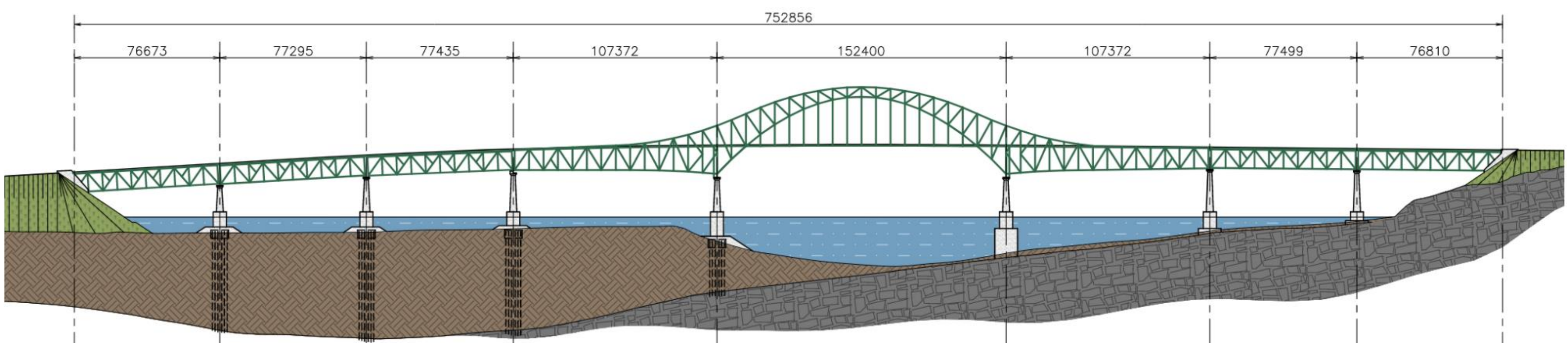
A high-level summary for each of the 11 options evaluated in this benefit-cost analysis is presented in the following pages. For each option, the following characteristics are described:

- Design features
- Alignment configuration
- Challenges
- Main span cross section and lane designations
- Rehabilitation sequence (if applicable)
- Estimated probable direct and life cycle costs over the life of the options
- Constructability and traffic impact

OPTION 1A
REHABILITATION (25 YRS)

- Simplest rehabilitation option with a limited service life
- Maintain existing alignment
- Familiar silhouette





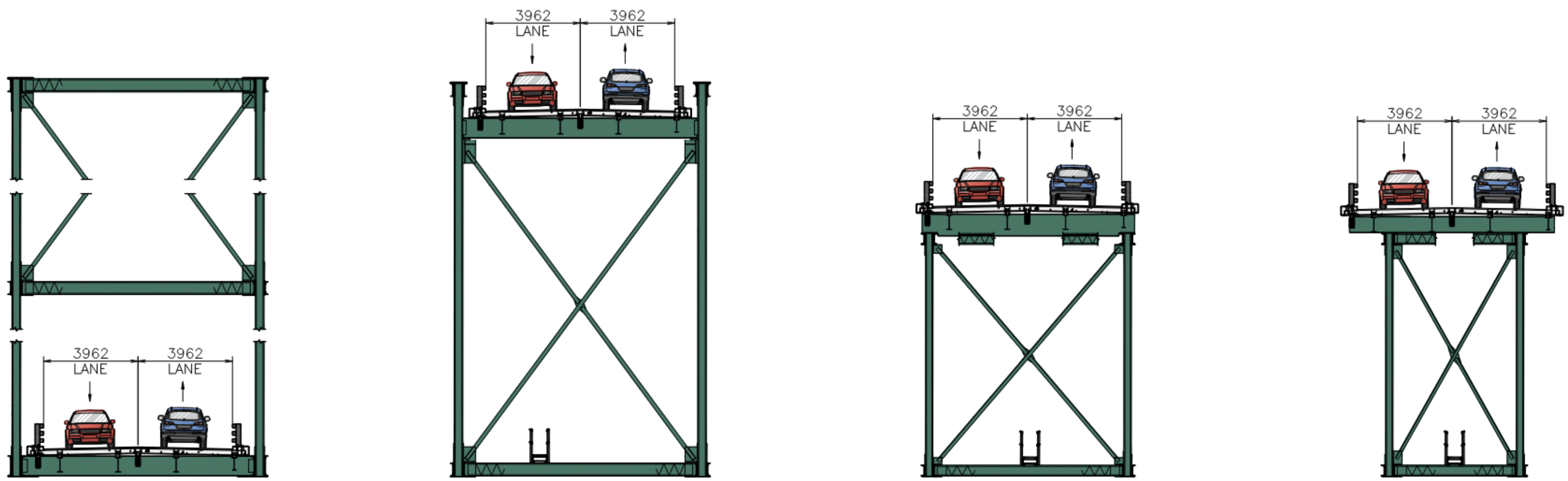
DESIGN FEATURES

- 25-year design life through rehabilitation
- Existing alignment unchanged
- Existing pier locations unchanged
- Re-use of existing roadways
- Maintain existing navigational clearances
- Familiar aesthetics and appearance
- Negligible impact on adjacent properties and land acquisition

CHALLENGES

- Limited design life; requires replacement after 25 years
- Sustains deficiencies with existing alignment
- Rehabilitation works required to superstructure and substructure
- Limited as-built information available on structure
- Crossing continues to use present lane configuration with narrow shoulders
- Significant impact to travelling public due to road closures during construction
- No accommodation for AT users

BRIDGE CROSS SECTION(S)



ANTICIPATED REHABILITATION / CONSTRUCTION SEQUENCE

Year 0-25:

- Rehabilitate superstructure and substructure
- Recoating of superstructure

Year 25-100:

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The existing bridge would be rehabilitated, resulting in numerous traffic interruptions over a multi-year period.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

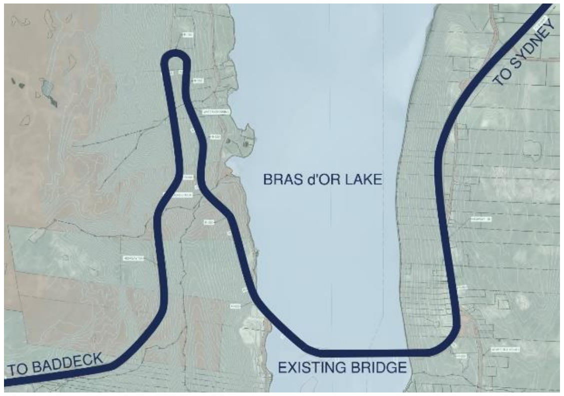
ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction†	$ 202,000,000
Owner's Cost For Construction	$ 59,000,000
Road Re-alignment Cost†	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 104,000,000
Total	**$ 380,000,000**

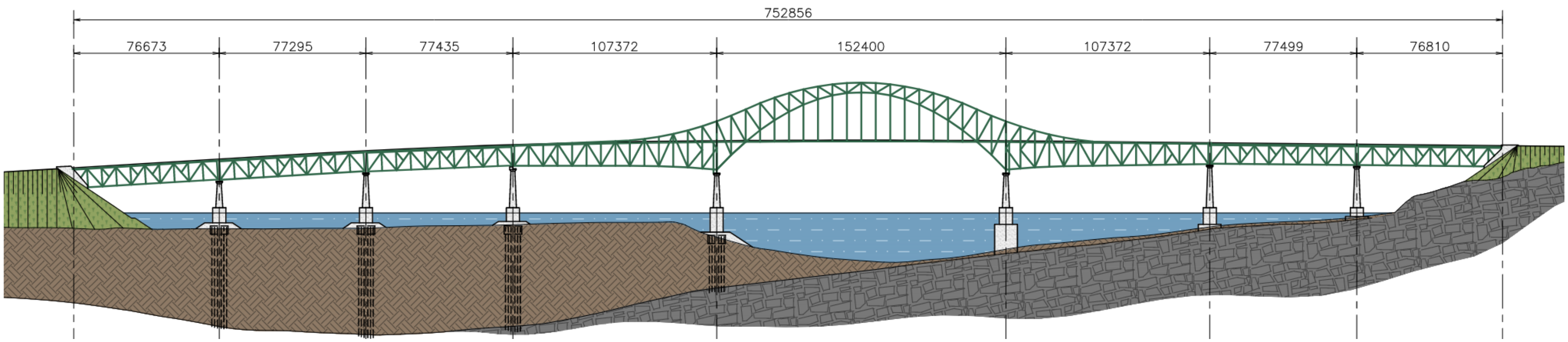
** This estimate of probable costs is presented on the basis of experience, qualifications, and best judgement. It has been prepared in accordance with acceptable principles and practices. Market trends, non-competitive bidding situations, unforeseen labour and material adjustments and the like are beyond the control of COWI and Stantec and as such we cannot warrant or guarantee that actual costs will not vary from the estimate provided.*
† Includes cost of demolition/replacement of structure at year 25.

OPTION 1B

REHABILITATION (50 YRS)

- Involved rehabilitation option with moderate service life
- Maintain existing alignment
- Familiar silhouette





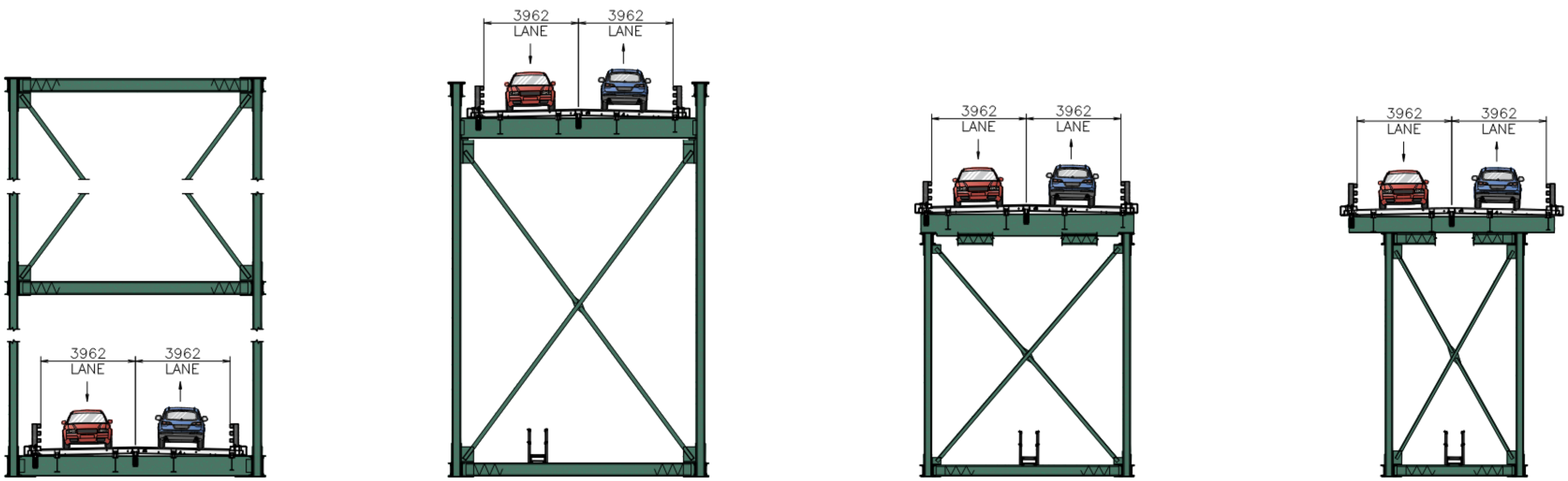
DESIGN FEATURES

- 50-year design life through rehabilitation
- Existing alignment unchanged
- Existing pier locations unchanged
- Re-use of existing roadways
- Maintain existing navigational clearances
- Familiar aesthetics and appearance
- Negligible impact on adjacent properties and land acquisition

CHALLENGES

- Limited design life; requires replacement after 50 years
- Sustains deficiencies with existing alignment
- Rehabilitation works required to superstructure and substructure
- Limited as-built information available on structure
- Crossing continues to use present lane configuration with narrow shoulders
- Significant impact to travelling public due to road closures during construction
- No accommodation for AT users

BRIDGE CROSS SECTION(S)



ANTICIPATED REHABILITATION / CONSTRUCTION SEQUENCE

Year 0-50:

- Rehabilitate superstructure and substructure
- Recoating of superstructure
- Replace bearings

Year 50-100:

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The existing bridge would be rehabilitated, resulting in numerous traffic interruptions over a multi-year period.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction†	$ 205,000,000
Owner's Cost For Construction	$ 60,000,000
Road Re-alignment Cost†	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 144,000,000
Total	**$ 420,000,000**

** This estimate of probable costs is presented on the basis of experience, qualifications, and best judgement. It has been prepared in accordance with acceptable principles and practices. Market trends, non-competitive bidding situations, unforeseen labour and material adjustments and the like are beyond the control of COWI and Stantec and as such we cannot warrant or guarantee that actual costs will not vary from the estimate provided.*

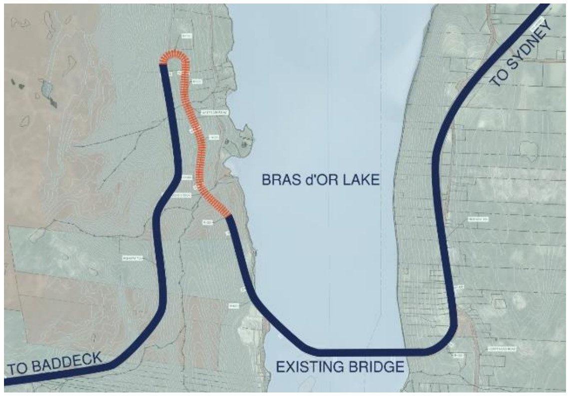
† Includes cost of demolition/replacement of structure at Year 50.

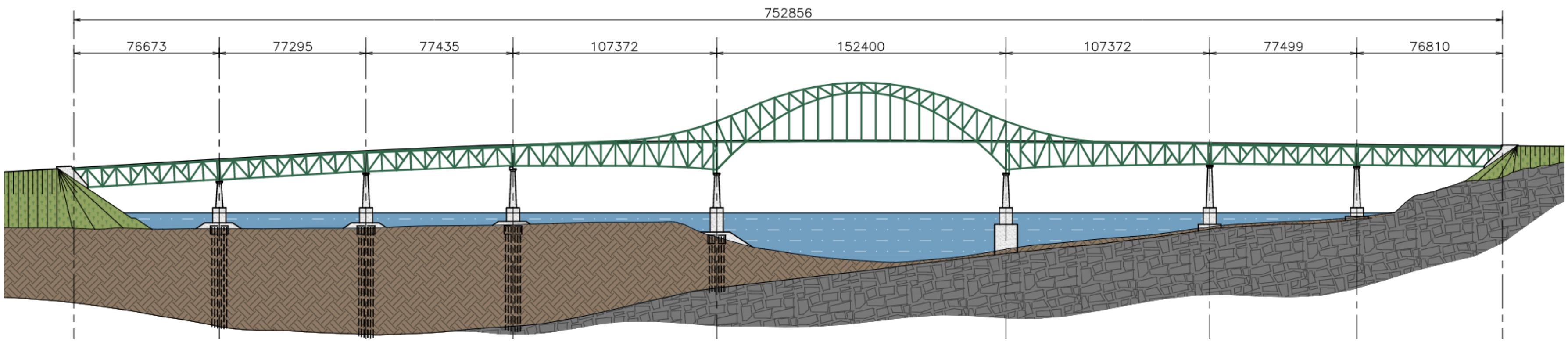
OPTION 1C

REHABILITATION (50 YRS + ALIGNMENT UPDATE)

- Involved rehabilitation option with moderate service life
- Improvements to existing alignment (west approach)
- Familiar silhouette

ACTUAL ALIGNMENT(S) TO BE ESTABLISHED AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING. NOTE THAT A REPRESENTATIVE ALIGNMENT INCLUDING AN IMPROVED HAIRPIN WAS ASSUMED TO COMPLETE THE EVALUATION.





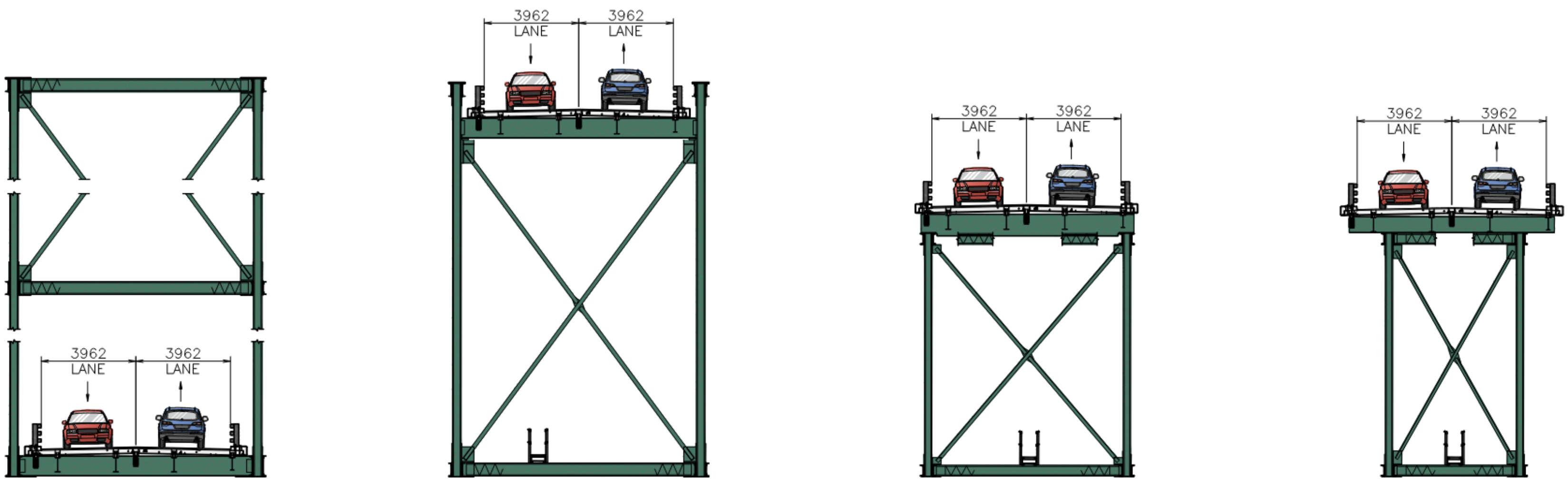
DESIGN FEATURES

- 50-year design life through rehabilitation
- Improvements to existing alignment (west approach)
- Existing pier locations unchanged
- Re-use of existing roadways
- Maintain existing navigational clearances
- Familiar aesthetics and appearance
- NSDPW owns land on re-used portions of existing alignment

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Limited design life; requires replacement after 50 years
- Rehabilitation works required to superstructure and substructure
- Limited as-built information available on structure
- Crossing continues to use present lane configuration with narrow shoulders
- Significant impact to travelling public due to road closures during construction
- No accommodation for AT users

BRIDGE CROSS SECTION(S)



ANTICIPATED REHABILITATION / CONSTRUCTION SEQUENCE

<u>Year 0-50:</u>

- Construct alignment improvements
- Rehabilitate superstructure and substructure
- Recoating of superstructure
- Replace bearings

<u>Year 50-100:</u>

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The existing bridge would be rehabilitated, resulting in numerous traffic interruptions over a multi-year period.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction[†]	$ 208,000,000
Owner's Cost For Construction	$ 61,000,000
Road Re-alignment Cost[†]	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 144,000,000
Total	**$ 430,000,000**

** This estimate of probable costs is presented on the basis of experience, qualifications, and best judgement. It has been prepared in accordance with acceptable principles and practices. Market trends, non-competitive bidding situations, unforeseen labour and material adjustments and the like are beyond the control of COWI and Stantec and as such we cannot warrant or guarantee that actual costs will not vary from the estimate provided.*

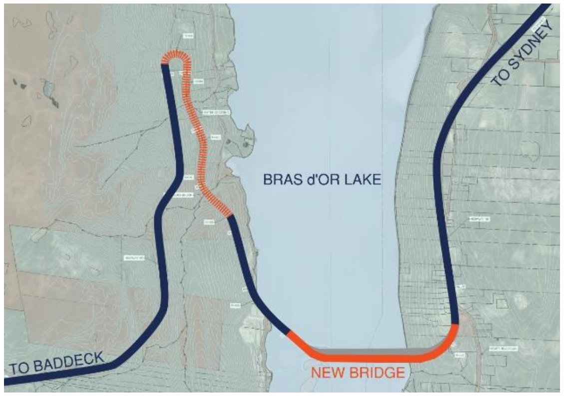
† Includes cost of demolition/replacement of structure at Year 50.

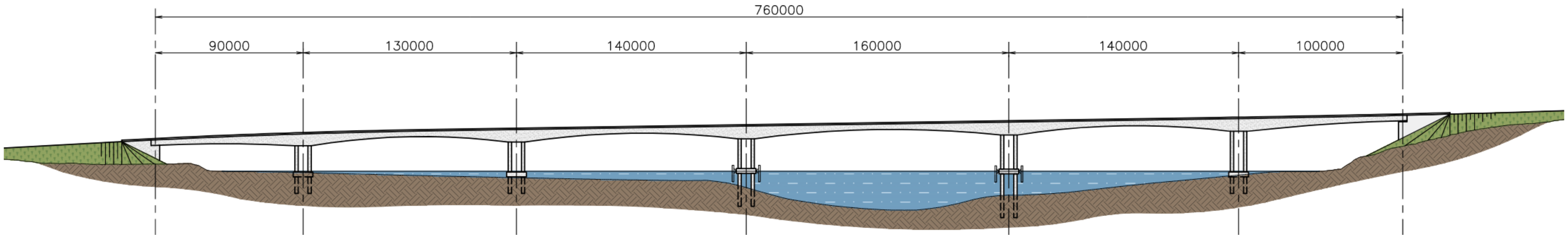
OPTION 2A

REPLACEMENT | MEDIUM SPAN | CONCRETE BOX

- Replacement bridge; medium span; two widened lanes; AT
- Improvements to existing alignment; crossing adjacent to existing
- New silhouette

ACTUAL ALIGNMENT(S) TO BE ESTABLISHED AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING. NOTE THAT A REPRESENTATIVE ALIGNMENT INCLUDING AN IMPROVED HAIRPIN WAS ASSUMED TO COMPLETE THE EVALUATION.





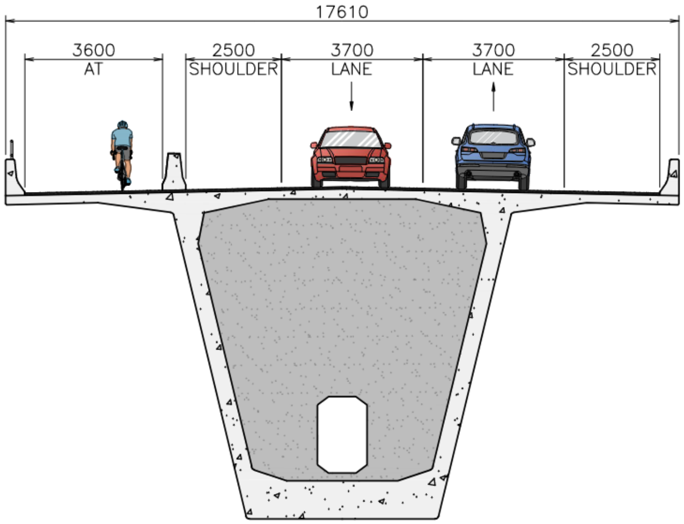
DESIGN FEATURES

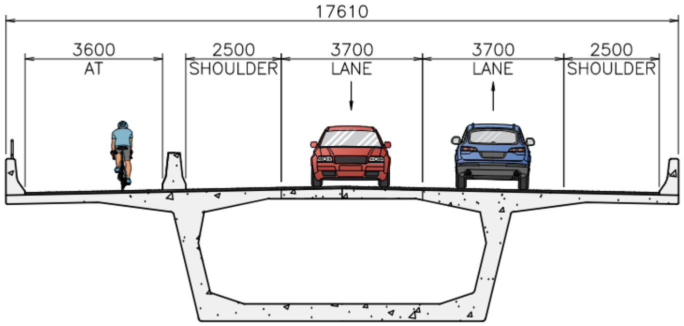
- 100-year design life
- Improvements to existing alignment
- Pier locations optimized for navigation channel and span lengths
- Significant re-use of existing roadways
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- NSDPW owns land on re-used portions of existing alignment
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Durable performance of concrete

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Proximity to existing structure results in challenges during construction
- Hairpin on west approach is improved, but remains
- Piers in water near navigation channel will require ship impact protection
- Bridge type is not common within Atlantic Canada; likely requires outside construction expertise

BRIDGE CROSS SECTION(S)





ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built adjacent to the existing bridge with a new alignment re-using components of the existing resulting in some traffic interruptions.

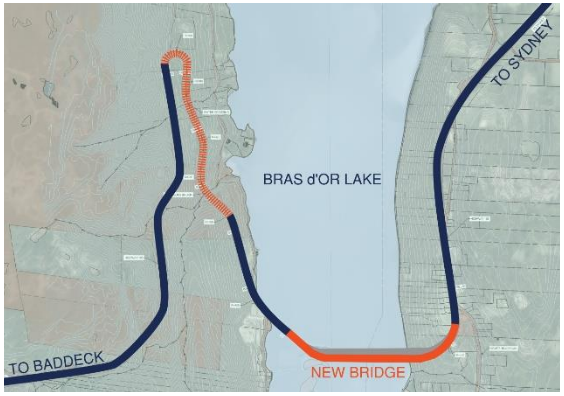
ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 149,000,000
Owner's Cost For Construction	$ 44,000,000
Road Re-alignment Cost	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 64,000,000
Total	**$ 270,000,000**

** This estimate of probable costs is presented on the basis of experience, qualifications, and best judgement. It has been prepared in accordance with acceptable principles and practices. Market trends, non-competitive bidding situations, unforeseen labour and material adjustments and the like are beyond the control of COWI and Stantec and as such we cannot warrant or guarantee that actual costs will not vary from the estimate provided.*

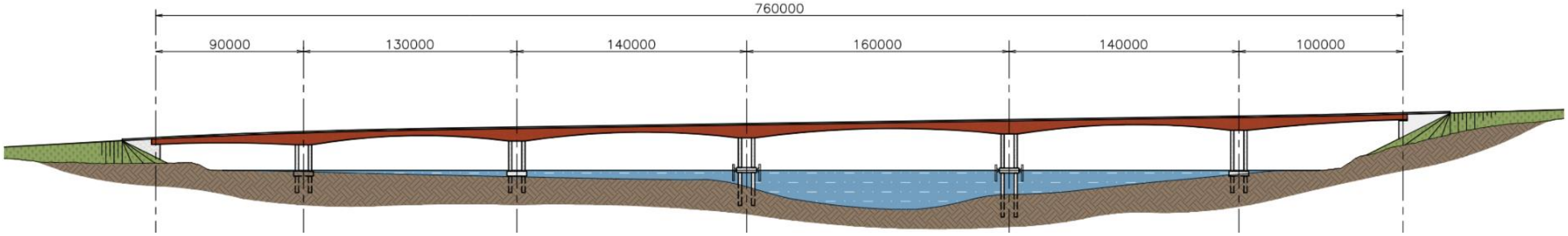
ACTUAL ALIGNMENT(S) TO BE ESTABLISHED AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING. NOTE THAT A REPRESENTATIVE ALIGNMENT INCLUDING AN IMPROVED HAIRPIN WAS ASSUMED TO COMPLETE THE EVALUATION.



OPTION 2B

REPLACEMENT | MEDIUM SPAN | STEEL BOX

- Replacement bridge; medium span; two widened lanes; AT
- Improvements to existing alignment; crossing adjacent to existing
- New silhouette



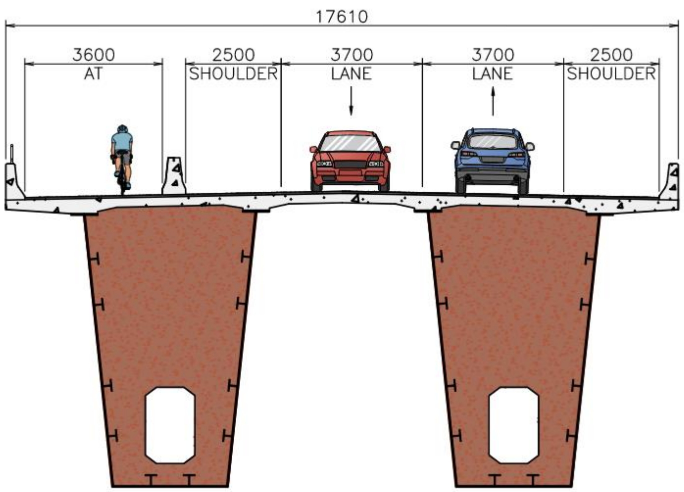
DESIGN FEATURES

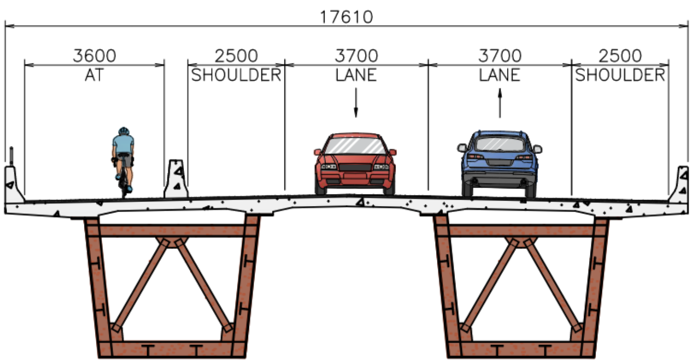
- 100-year design life
- Improvements to existing alignment
- Pier locations optimized for navigation channel and span lengths
- Significant re-use of existing roadways
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- NSDPW owns land on re-used portions of existing alignment
- AT lanes
- Widened lanes accommodate future maintenance without lane closures

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Proximity to existing structure results in challenges during construction
- Hairpin on west approach is improved, but remains
- Piers in water near navigation channel will require ship impact protection
- Bridge type is common within Atlantic Canada but requires outside construction expertise
- Steel typically requires more maintenance than concrete

BRIDGE CROSS SECTION(S)





ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built adjacent to the existing bridge with a new alignment re-using components of the existing resulting in some traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 181,000,000
Owner's Cost For Construction	$ 53,000,000
Road Re-alignment Cost	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 131,000,000
Cost	**$ 380,000,000**

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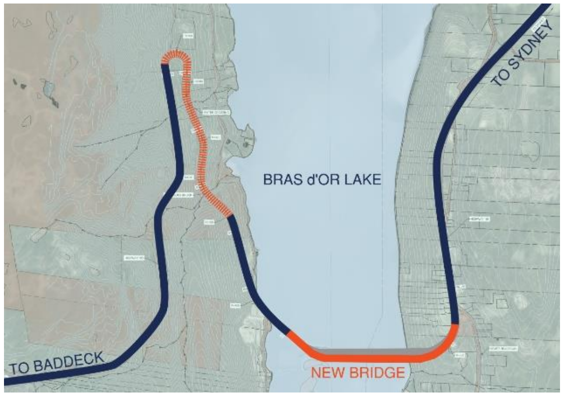
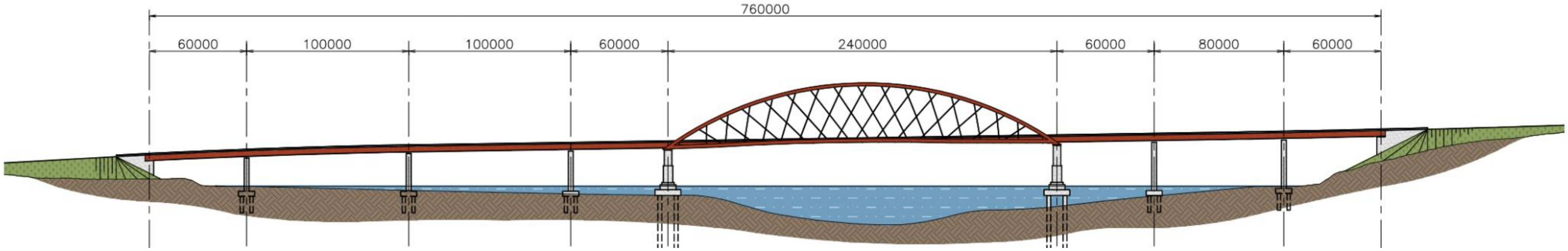
ACTUAL ALIGNMENT(S) TO BE ESTABLISHED AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING. NOTE THAT A REPRESENTATIVE ALIGNMENT INCLUDING AN IMPROVED HAIRPIN WAS ASSUMED TO COMPLETE THE EVALUATION.



OPTION 2C

REPLACEMENT | MEDIUM SPAN | NETWORK ARCH

- Replacement bridge; medium span; two widened lanes; AT
- Improvements to existing alignment; crossing adjacent to existing
- New silhouette



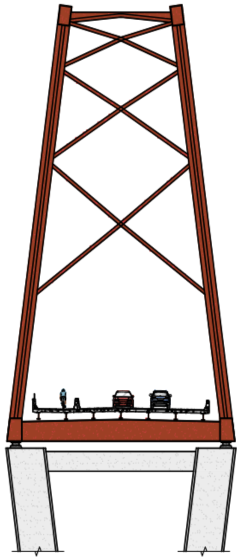
DESIGN FEATURES

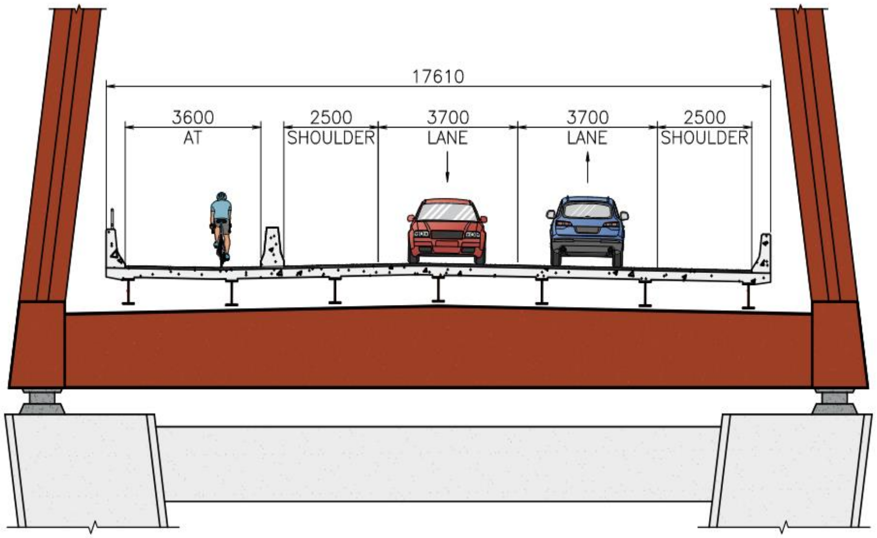
- 100-year design life
- Improvements to existing alignment
- Pier locations optimized for navigation channel and span lengths
- Significant re-use of existing roadways
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- NSDPW owns land on re-used portions of existing alignment
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Signature bridge aspects; modern style

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Proximity to existing structure results in challenges during construction
- Hairpin on west approach is improved, but remains
- Piers in water near navigation channel will require ship impact protection
- Bridge type would be a first in Atlantic Canada; limited construction knowledge locally
- Steel typically requires more maintenance than concrete

BRIDGE CROSS SECTION(S)





ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built adjacent to the existing bridge with a new alignment re-using components of the existing resulting in some traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 137,000,000
Owner's Cost For Construction	$ 40,000,000
Road Re-alignment Cost	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 129,000,000
Total	**$ 320,000,000**

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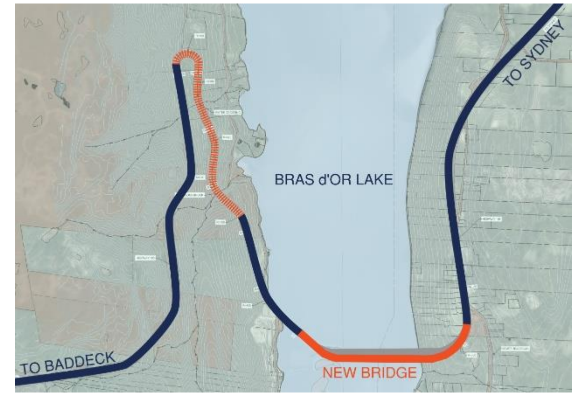
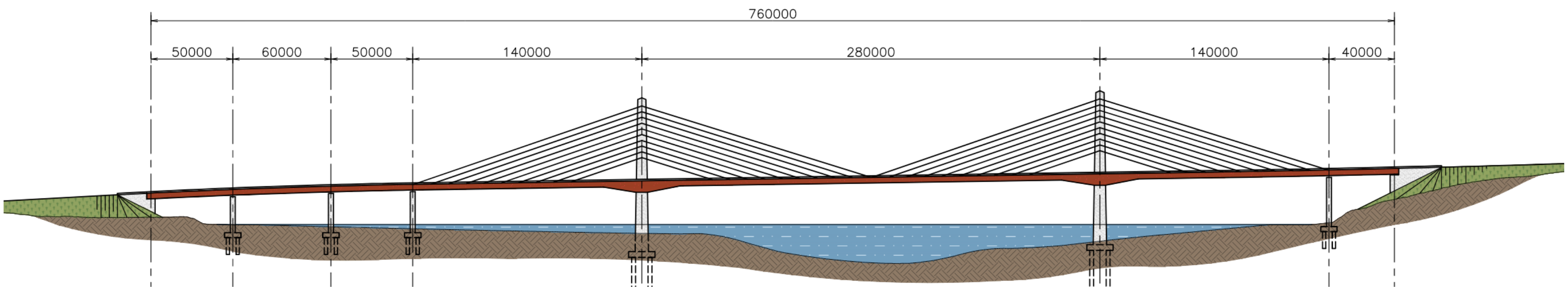
ACTUAL ALIGNMENT(S) TO BE ESTABLISHED AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING. NOTE THAT A REPRESENTATIVE ALIGNMENT INCLUDING AN IMPROVED HAIRPIN WAS ASSUMED TO COMPLETE THE EVALUATION.



OPTION 2D

REPLACEMENT | LONG SPAN | CABLE-STAYED

- Replacement bridge; long span; two widened lanes; AT
- Improvements to existing alignment; crossing adjacent to existing
- New silhouette



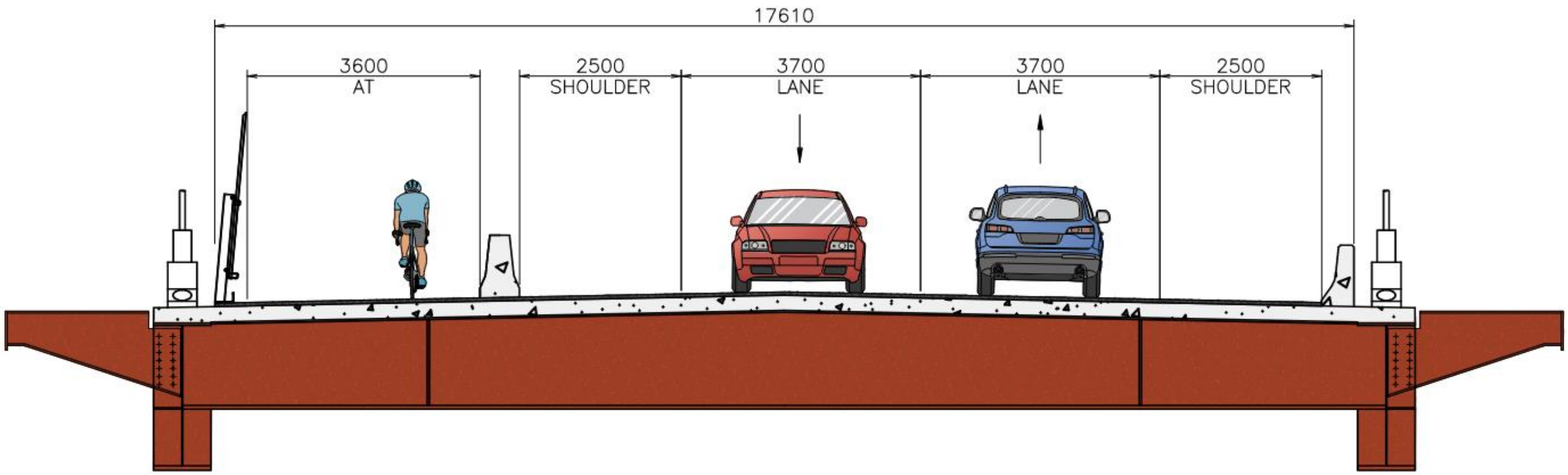
DESIGN FEATURES

- 100-year design life
- Improvements to existing alignment
- Pier locations optimized for navigation channel and span lengths
- Significant re-use of existing roadways
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- NSDPW owns land on re-used portions of existing alignment
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Signature bridge aspect; modern style

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Proximity to existing structure results in challenges during construction
- Hairpin on west approach is improved, but remains
- Piers in water near navigation channel will require ship impact protection
- Bridge type would be a first in Atlantic Canada; limited construction knowledge locally
- Unique maintenance needs; ice can fall from cables

BRIDGE CROSS SECTION(S)



ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built adjacent to the existing bridge with a new alignment re-using components of the existing resulting in some traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 160,000,000
Owner's Cost For Construction	$ 47,000,000
Road Re-alignment Cost	$ 11,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 102,000,000
Total	**$ 320,000,000**

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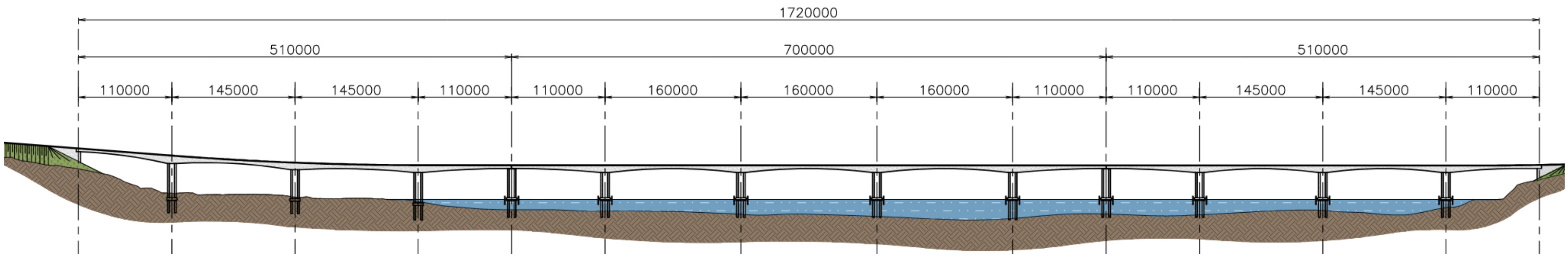
OPTION 3A

REPLACEMENT TO NORTH | MEDIUM SPAN | CONCRETE BOX

CONCEPTUAL ALIGNMENT(S) USED FOR EVALUATION PURPOSES ONLY. ACTUAL ALIGNMENT(S) TO BE ESTABLISHED IN THE FUTURE AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING.

- Replacement bridge; medium span; two widened lanes; AT
- New alignment to north of existing; minimal turns
- New silhouette



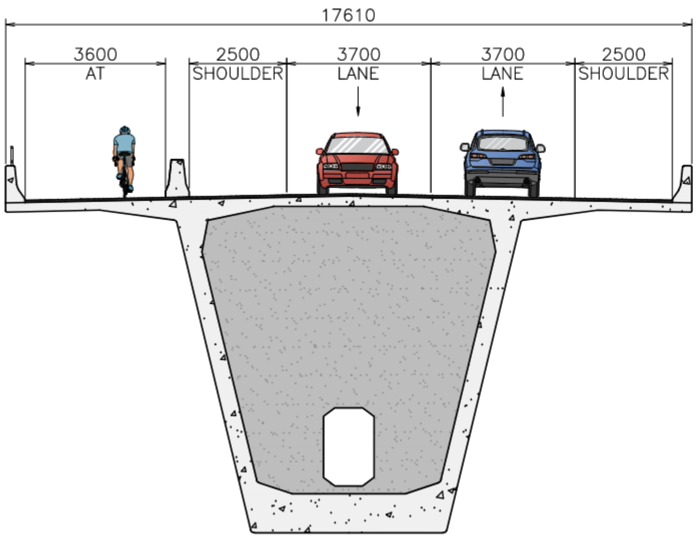
DESIGN FEATURES

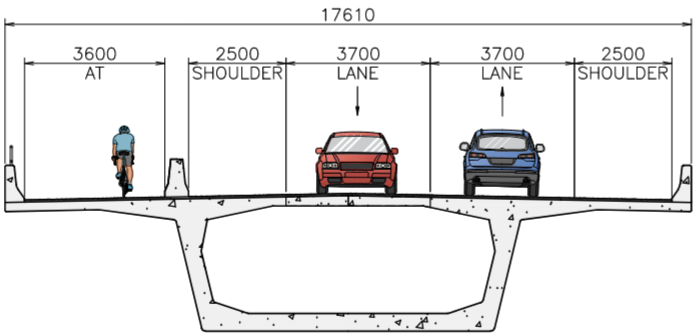
- 100-year design life
- New alignment north of existing
- Pier locations optimized for navigation channel and span lengths
- Alignment with minimal turns and hairpin removed but steeper grade (~7%)
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Durable performance of concrete

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Long crossing resulting in higher up-front capital costs
- Multiple piers in water (10-20 m depth)
- Piers in water near navigation channel will require ship impact protection
- Bridge type is not common within Atlantic Canada; likely requires outside construction expertise
- Significant total length; requires multiple expansion joints

BRIDGE CROSS SECTION(S)





ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built in a new location that is nearby but not adjacent to the existing structure resulting in limited traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 310,000,000
Owner's Cost For Construction	$ 90,000,000
Road Re-alignment Cost	$ 8,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 128,000,000
Total	**$ 540,000,000**

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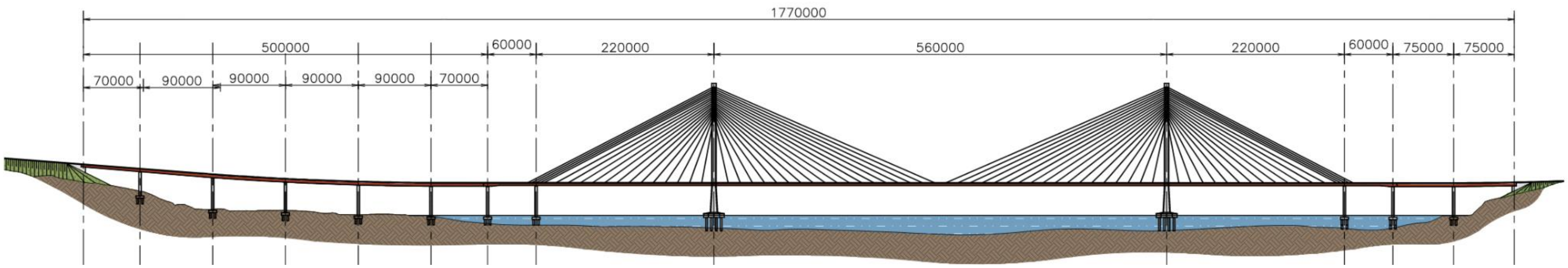
CONCEPTUAL ALIGNMENT(S) USED FOR EVALUATION PURPOSES ONLY. ACTUAL ALIGNMENT(S) TO BE ESTABLISHED IN THE FUTURE AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING.

OPTION 3B

REPLACEMENT TO NORTH | LONG SPAN | CABLE-STAYED

- Replacement bridge; long span; two widened lanes; AT
- New alignment to north of existing; minimal turns
- New silhouette



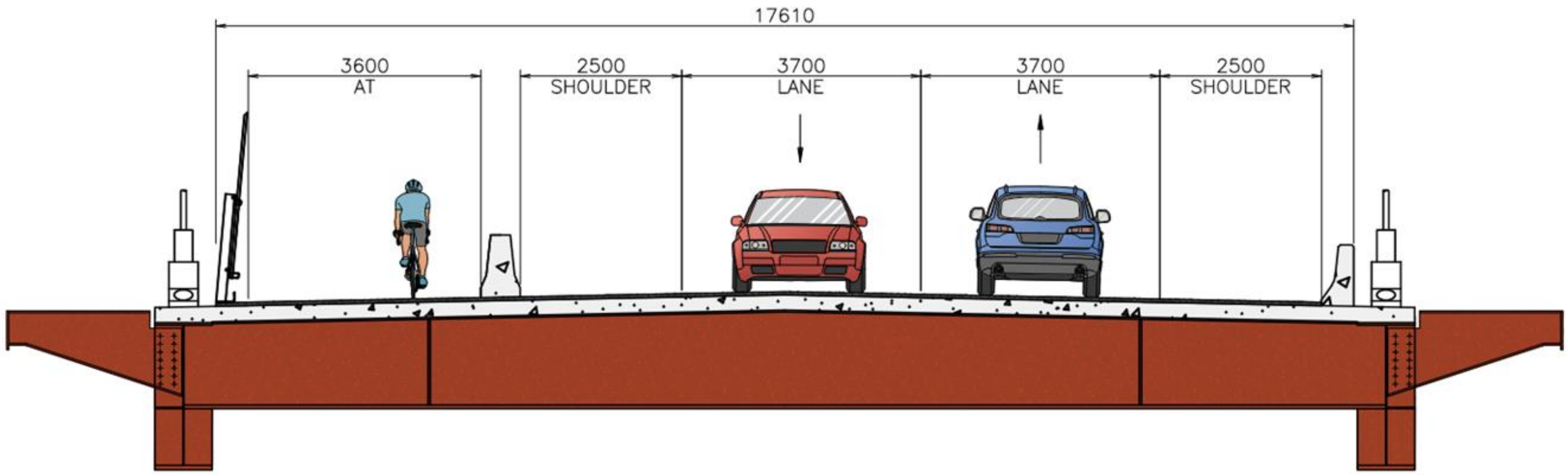
DESIGN FEATURES

- 100-year design life
- New alignment north of existing
- Pier locations optimized for navigation channel and span lengths
- Alignment with minimal turns and hairpin removed but steeper grade (~7%)
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Signature bridge aspect; modern style

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Long crossing resulting in higher up-front capital costs
- Multiple piers in water (10-20 m depth)
- Piers in water near navigation channel will require ship impact protection
- Bridge type would be a first in Atlantic Canada; limited construction knowledge locally
- Significant total length; requires multiple expansion joints
- Unique maintenance needs; ice can fall from cables

BRIDGE CROSS SECTION(S)



ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built in a new location that is nearby but not adjacent to the existing structure resulting in limited traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 412,000,000
Owner's Cost For Construction	$ 120,000,000
Road Re-alignment Cost	$ 8,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 250,000,000
Total	**$ 790,000,000**

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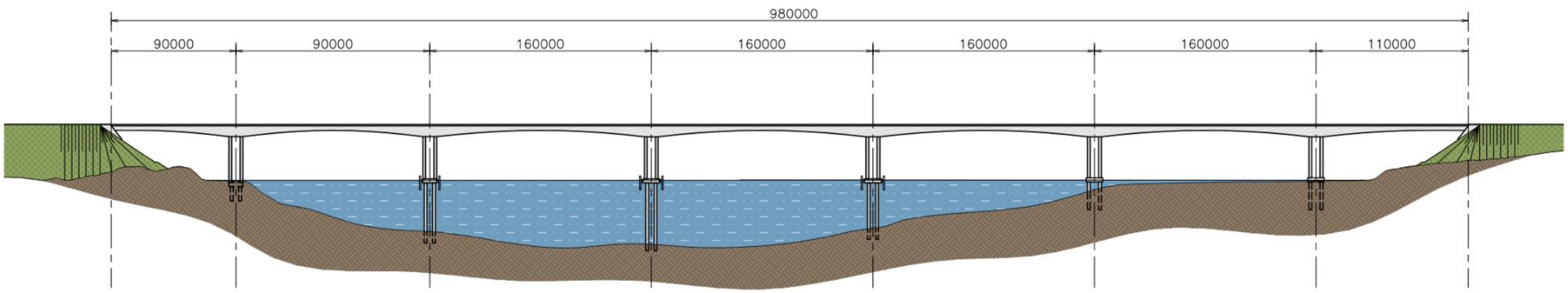
OPTION 4A

REPLACEMENT TO SOUTH | MEDIUM SPAN | CONCRETE BOX

- Replacement bridge; medium span; two widened lanes; AT
- New alignment to south of existing
- New silhouette

CONCEPTUAL ALIGNMENT(S) USED FOR EVALUATION PURPOSES ONLY. ACTUAL ALIGNMENT(S) TO BE ESTABLISHED IN THE FUTURE AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING.



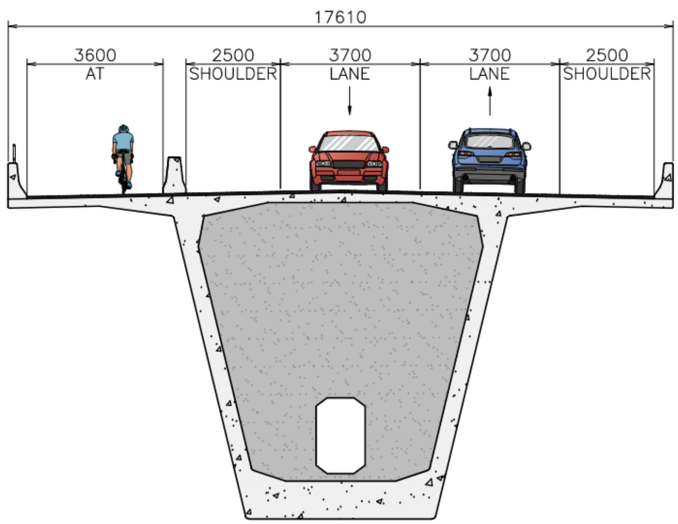
DESIGN FEATURES

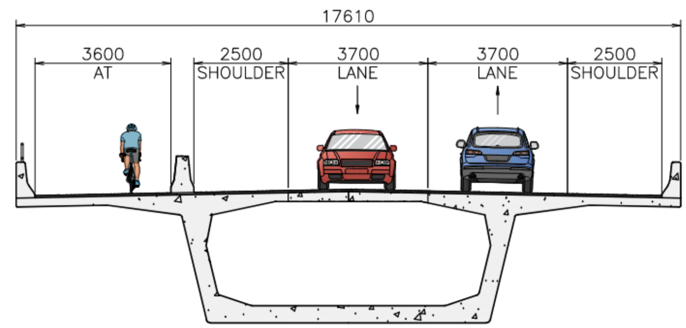
- 100-year design life
- New alignment south of existing
- Pier locations optimized for navigation channel and span lengths
- Alignment with moderate turns to replace hairpin but steeper grade (~8%)
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Durable performance of concrete

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Multiple piers in deep water (20-40 m depth)
- Piers in water near navigation channel will require ship impact protection
- Bridge type is not common within Atlantic Canada; likely requires outside construction expertise
- Significant marine construction work in deep water

BRIDGE CROSS SECTION(S)





ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built in a new location that is nearby but not adjacent to the existing structure resulting in limited traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 248,000,000
Owner’s Cost For Construction	$ 72,000,000
Road Re-alignment Cost	$ 21,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 80,000,000
Total	**$ 430,000,000**

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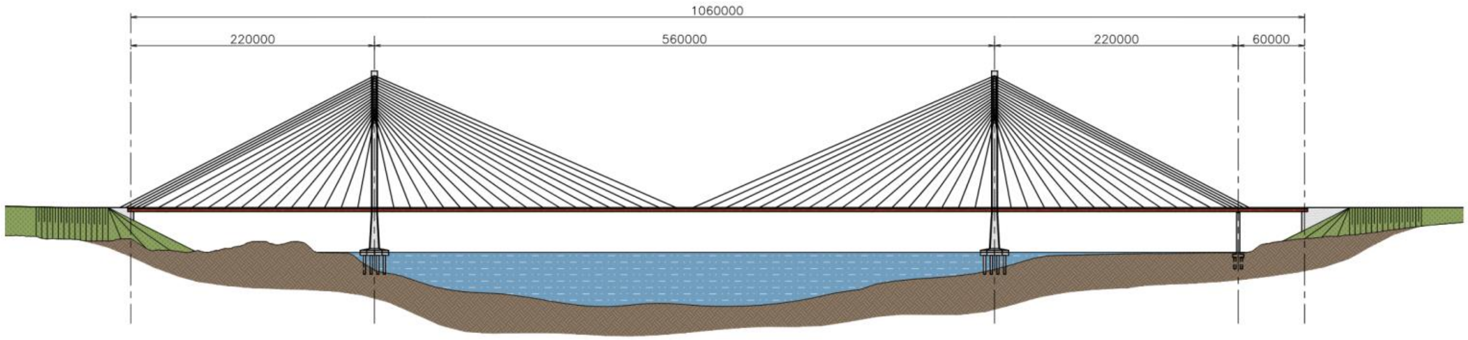
CONCEPTUAL ALIGNMENT(S) USED FOR EVALUATION PURPOSES ONLY. ACTUAL ALIGNMENT(S) TO BE ESTABLISHED IN THE FUTURE AS PART OF THE SCOPING AND DESIGN PHASES OF THE REPLACEMENT CROSSING.

OPTION 4B

REPLACEMENT TO SOUTH | LONG SPAN | CABLE-STAYED

- Replacement bridge; long span; two widened lanes; AT
- New alignment to north of existing; minimal turns
- New silhouette



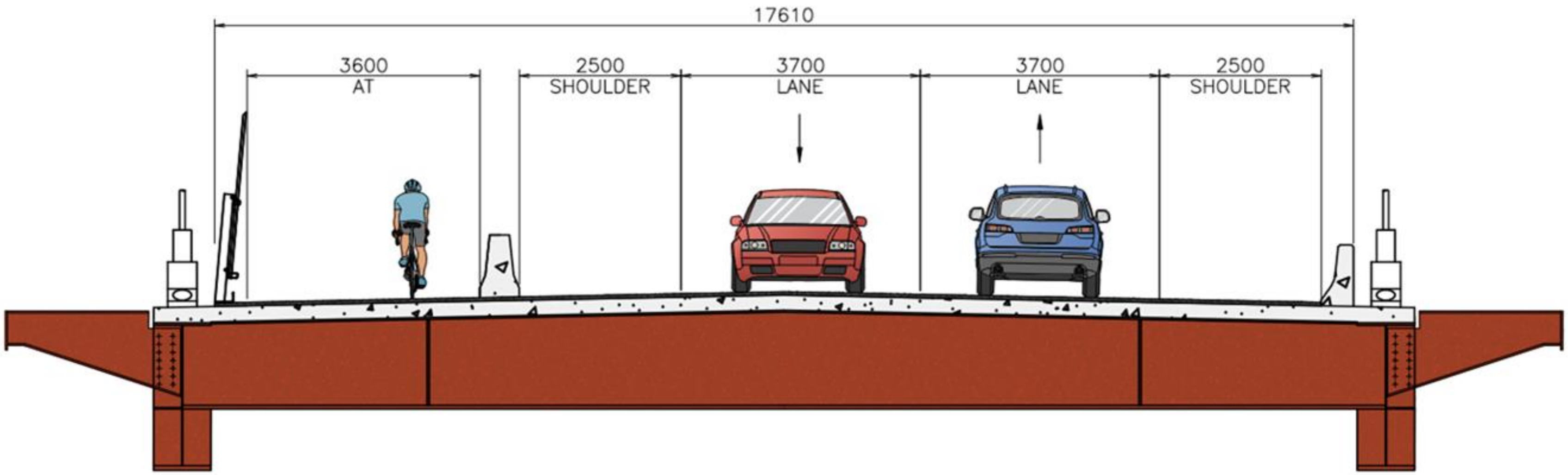
DESIGN FEATURES

- 100-year design life
- New alignment south of existing
- Pier locations located out of deep water; pier quantity minimized
- Alignment with moderate turns to replace hairpin but steeper grade (~8%)
- Maintain or exceed existing navigational clearances
- Opportunity for a new aesthetic (appearance)
- AT lanes
- Widened lanes accommodate future maintenance without lane closures
- Signature bridge aspect; modern style

CHALLENGES

- Acquisition of impacted lands will require discussions with stakeholders and community groups
- Bridge type would be a first in Atlantic Canada; limited construction knowledge locally
- Unique maintenance needs; ice can fall from cables

BRIDGE CROSS SECTION(S)



ANTICIPATED CONSTRUCTION SEQUENCE

- Construct new roadway alignment and new bridge crossing
- Re-route traffic from existing to new alignment
- Decommission existing bridge

CONSTRUCTABILITY AND TRAFFIC IMPACT

The new crossing would be built in a new location that is nearby but not adjacent to the existing structure resulting in limited traffic interruptions.

ENVIRONMENTAL AND/OR PERMITTING

Various environment studies, investigations, and environmental permits and approvals required.

ESTIMATED PROBABLE TOTAL COST*	$ (CAD)
Direct Construction	$ 322,000,000
Owner's Cost For Construction	$ 94,000,000
Road Re-alignment Cost	$ 21,000,000
Relocation of Existing Infrastructure	$ 0
Lifecycle and Maintenance	$ 132,000,000
Total	**$ 570,000,000**

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7 Evaluation Results and Recommendations

Based on the results of the evaluations, the two highest rated options are:

- Option 2A – Medium Span – Concrete Box Adjacent to Existing Bridge

- Option 2C – Medium Span – Steel Network Arch Adjacent to Existing Bridge

The following sections describe in further detail the highest scoring rehabilitation and replacement bridge options along with relevant mitigation techniques for addressing the described risks identified in Section 5.1.3.

7.1 Highest Ranked Option: Option 2A Medium Span Concrete Box Adjacent to Existing Bridge

The highest scoring option is Option 2A, which is a new concrete box girder bridge adjacent to the existing bridge with an improved existing roadway alignment (see Figure 6). It is a medium span structure with two traffic lanes with widened shoulders and an AT lane. This is an approximately 760 m long structure with a 180 m long main span located south of the existing structure. This option presents a crossing with the lowest estimated probable total cost while also providing the necessary key features, mitigates road re-work, while providing lower anticipated maintenance costs.

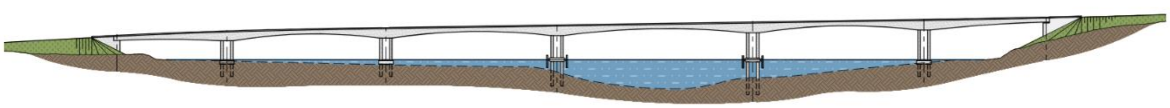

Figure 6. Highest ranked option - a new concrete box girder bridge (looking north)

Some major constraints for this option are:

- acquisition of land would require discussions with stakeholders and community groups;
- proximity to the existing structure could result in challenges during some phases of construction and demolition (of the existing bridge);
- although the hairpin has been improved, the speed limit of highway would remain limited to 70 km/h at the hairpin but would be 90 km/h elsewhere;
- piers in the water near the navigation channel would require ship impact protection; and
- the bridge type is not common in Atlantic Canada and would likely require outside construction expertise.

While these constraints are inherent to this option, associated risks can be mitigated through the design and planning phases of the replacement crossing project. The following sections list the possible mitigation measures for the risks identified in this report (see Section 5.1.3).

Impact to Trade Corridors During Construction

It is expected that the existing roadway and bridge crossing would remain in-service to support vehicular traffic during the construction of the replacement bridge. Traffic interruptions would likely be limited to partial or full roadway closures during the interfacing between new and existing alignments.

Although the marine traffic is currently comprised primarily of pleasure crafts, there will be some disruptions during the construction of the bridge piers near the navigational channel and during critical erection steps. The demolition of the existing bridge and construction of the new bridge is anticipated to require barges in the water, as well as overhead work and temporarily reduced navigational clearances during critical construction steps. Early coordination with local, provincial, and federal stakeholders is recommended to best understand the various parameters that would need to be accommodated during construction.

Impact to Trade Corridors In-Service

Once the new bridge is in service, it is expected that there would be significantly fewer traffic interruptions caused by accidents and maintenance work as the wider roadway of the new bridge would be able to accommodate two-way traffic during these occasions.

Constructability / Complexity of Erection Sequence

Cast-in-place concrete segmental box girder bridges can be designed to incorporate constructability considerations. Some examples of design elements that can be incorporated to improve constructability are:

- incorporating precast cofferboxes supported by drilled shafts would remove the need for temporary footing formwork and would significantly reduce the construction duration of the footings;
- using twin pier columns would provide stability for segmental cantilevers during out-of-balance stages of construction and would eliminate risk of cracking of the pier columns typically associated with longer span cantilevers;
- using integral connections between the piers and deck system would remove requirement for large disc bearings; and
- jacking apart the cantilevers of the main span would mitigate the effects of permanent longitudinal deformations of the superstructure and reduce force effects in the substructure (note that jacking does typically extend construction schedules by a number of weeks).

The bridge type for the concrete segmental box girder is relatively common in many places in North America and all the constructability solutions discussed above are performed on nearly all bridges of this type and span length.

Climate Change

The climate change risk assessment presented in Appendix I identified the climate risks for Option 2A at a broad system-level based on Representative Concentration Pathway (RCP) 8.5 emission scenario. In the assessment, a discussion of the potential climate impacts on each of the infrastructure components was provided. The identified climate risks associated with Option

2A were all ranked as low in the assessment. Once the final design is selected, it is recommended to climate risks identified in this assessment be reviewed to develop adaptation and resilience measures to minimize the climate impacts on the project infrastructure components.

Geotechnical

There is little information on geotechnical information at the location of the existing bridge. To mitigate project risks, primarily related to scheduled delay, it would be imperative to proactively plan for geotechnical investigations. Early in the project, a firm specializing in geotechnical engineering should be consulted to determine the level of investigation required.

Approvals and Permitting

The environmental regulatory process for this option is likely to include, but not necessarily limited to, the following:

- Transport Canada Approval under the Navigation Protection Act;
- DFO Serious Harm Authorization/Off setting compensation under the Fisheries Act;
- Federal Environmental Effects Determination (complete before Federal Permits are issued)
- Nova Scotia Department of Natural Resources and Renewables (NSDNRR) – Beaches/Crown Lands Act Approval;
- Nova Scotia Department Communities, Culture, Tourism and Heritage (NSDCCTH) - Archaeological sign-off under The Special Places Protection Act; and
- Provincial Watercourse Alteration Permit and other provincial permits

In addition to the likely requirements listed above, major regulatory tasks for this process are likely to include, but not necessarily limited to, the following:

- Regulatory, Public, and Stakeholder Consultation program;
- Indigenous Engagement Program;
- Field Surveys – Avian Survey; Fish Habitat survey, land-based and marine;
- Archaeological surveys;
- Project Description preparation;
- Navigation Protection Act Approval Submission Process;
- Federal Authorities Review Process.

Note that, based on the preliminary assessment presented in Appendix I, the project is not anticipated to trigger Provincial Environmental Assessment (EA).

This regulatory process would likely take two to three years to complete. Depending on the procurement method, this process could occur in parallel to the preliminary and detailed design programs. 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 should assemble and process applications as early as possible.

Operational Issues During Service Life

Current construction methods and materials for cast-in-place segmental bridges would provide a structure that would be expected to last 100 years without major rehabilitation work with the exception of sacrificial components such as bearings, wearing surface, etc.

One benefit of this design is that none of the superstructure is in the “splash zone” which means that it is not directly exposed to roadway salts/spray.

Due to design’s wide deck and roadway, inspection activities should have a minor impact on the vehicular traffic as the deck would be able to accommodate two lanes during maintenance and inspection activities.

Land Acquisition

NSDPW does not own all the anticipated land required to improve the existing alignment, specifically between the Highway 105 hairpin turn and the tie-in with the roadway near the west end of the crossing. The actual alignment would be established in the future as part of the design phase of the replacement crossing. Landowners in this area may be impacted and the project would likely require targeted discussions with these landowners in the spirit of collaboration and engagement to determine the acquisition cost estimates and project implications.

7.2 2nd Highest Ranked Option: Option 2C Medium Span Network Arch Adjacent to Existing Bridge

The second highest scoring option is Option 2C, which is a new steel network arch bridge adjacent to the existing bridge with an improved existing roadway alignment (see Figure 7). It is a medium span structure with two traffic lanes with widened shoulders and an AT lane. This is an approximately 760 m long structure with a 240 m long main span located south of the existing structure. This option presents a crossing with one of the lower estimated probable total cost while also providing the necessary key features, a signature bridge unlike any other in Nova Scotia, mitigates road re-work, while providing lower anticipated maintenance costs.

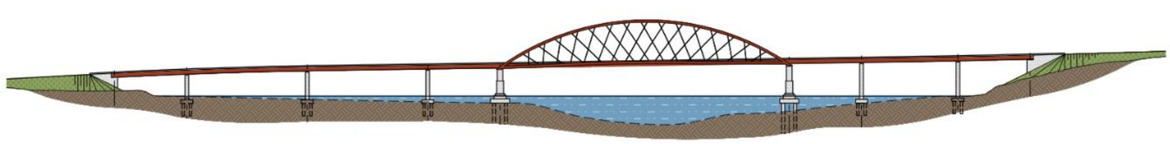

Figure 7. Second highest ranked option - a new network arch bridge (looking north)

Some major constraints for this option are:

- acquisition of land would require discussions with stakeholders and community groups;
- proximity to existing structure could result in challenges during some phases of construction and demolition (of the existing bridge);

- although the hairpin has been improved, the speed limit of highway would remain limited to 70 km/h at the hairpin but would be 90 km/h elsewhere;
- piers in the water near the navigation channel would require ship impact protection; and
- the bridge type is not common in Atlantic Canada and would require outside construction expertise.

While these constraints are inherent to this option, associated risks can be mitigated through the design and planning phases of the replacement crossing project. The following sections list the possible mitigation measures for the risks identified in this report (see Section 5.1.3).

Impact to Trade Corridors During Construction

Considering Option 2C is the same alignment as Option 2A with a similar pier arrangement, the risks and mitigation measures are virtually the same. Refer to Section 7.1 "Impact to Trade Corridors During Construction" for more details.

Impact to Trade Corridors In-Service

Considering Option 2C is the same alignment and bridge deck width of Option 2A, the risks and mitigation measures are virtually the same. Refer to Section 7.1 "Impact to Trade Corridors In-Service" for more details.

Constructability / Complexity of Erection Sequence

Network Tied Arch Bridges are typically erected using one of three construction methods:

- building the arch nearby and floating the assembled arch bridge into place;
- erecting in place using temporary stay cables and temporary towers; and
- erecting in place using temporary shoring towers.

For the replacement of the Seal Island Bridge, an arch bridge could be assembled on land and floated into place. Floating-in an assembled arch bridge is typically the fastest, most economical, and safest way to erect a tied arch bridge.

For this erection method, the tied arch bridge would be fully assembled (with the exception of the concrete deck) on falsework on land. The arch assembly would be completed in a relatively controlled environment, similar to shop fabrication. The assembled bridge would be loaded onto transport barges by means of lateral sliding, self-propelled modular transporters (SPMTs) or heavy lift jacking systems.

Once on the barges, the assembled arch would be floated to final bridge location and installed on the permanent bridge piers (which would already have been constructed). The installation of the arch onto the permanent piers could be done by either jacking into place using heavy lifting equipment or lifting into place using strand jacks mounted to the new piers. Temporary bracing members are typically needed to strengthen the arch ribs during this operation, especially if the arch is being lifted at locations other than at the arch knuckle location (at the ends of the span).

This float-in procedure would require a short duration full closure of the navigation channel. For example, the Wellsburg Bridge, a tied arch bridge designed by COWI, required the navigation channel of the Ohio River to be closed to marine traffic for approximately 12 hours during placement of the arch.

Climate Change

The climate change risk assessment presented in Appendix I identified the climate risks for Option 2A at a broad system-level based on Representative Concentration Pathway (RCP) 8.5 emission scenario. In the assessment, a discussion of the potential climate impacts on each of the infrastructure components was provided. The identified climate risks associated with Option 2C were all ranked as moderate in the assessment. Once the final design is selected, it is recommended to climate risks identified in this assessment be reviewed to develop adaptation and resilience measures to minimize the climate impacts on the project infrastructure components.

Geotechnical

Considering Option 2C is the same alignment as Option 2A, the risks and mitigation measures are virtually the same. Refer to Section 7.1 "Geotechnical" for more details.

Land Acquisition

Considering Option 2C is the same alignment as Option 2A, the risks and mitigation measures are virtually the same. Refer to Section 7.1 "Approvals and Permitting" for more details.

Operational Issues During Service Life

Steel arches and steel plate girders could be shop-fabricated, assembled, coated, and shipped to site for erection. By performing most of the work in a fabrication shop, the quality control for the steel (and non-destructive testing) and corrosion protection coating can be performed in a controlled environment prior to erection. However, steel elements do require re-coating throughout the structures design life and, therefore, a regular re-coating schedule would be required for the structure.

By virtue of having most of the superstructure below the roadway (excluding the network arch), protection from roadway salts/spray is present for the majority of this structure and should improve longevity. The network arch elements would generally be protected from direct exposure to salts/spray by the concrete barriers. While only four expansion joints would be required for the design, bearings would present at each pier between the steel girder approach spans and concrete piers. Therefore, replacement of some of these sacrificial components would be required throughout the bridge service life.

Due to design’s wide deck and roadway, inspection activities should have a minor impact on the vehicular traffic as the deck would be able to accommodate two lanes during maintenance and inspection activities.

Land Acquisition

Considering Option 2C is the same alignment as Option 2A, the risks and mitigation measures are virtually the same. Refer to Section 7.1 "Land Acquisition" for more details.

8 Conclusions

To determine a sustainable long-term path forward for the Seal Island Bridge, NSDPW retained the Team to identify, develop and compare potential bridge rehabilitation and replacement options for the Seal Island Bridge in a benefit-cost analysis (BCA). This included ranking the identified options according to the preferences and evaluation criteria established by the Team in consultation with NSDPW and determine the two highest ranked options.

This report presents 11 options based on two categories of solutions: rehabilitation or replacement. In consultation with NSDPW's personnel, the Team developed an assessment model to evaluate the options for rehabilitation or replacement of the Seal Island Bridge. In a workshop with the Team, NSDPW provided the inputs for a two-level pairwise comparison to determine the weights (or importance) of each evaluation category and criteria. Using the information from the discussions with NSDPW, the Team's specialists assessed each bridge option with respect to the developed project criteria. Then, the assessment results were weighted using the pairwise comparison results to determine the overall score for each option.

The two highest rated options based on the assessment framework defined in this report are:

1. Option 2A – Medium Span – Concrete Box Adjacent to Existing Bridge

2. Option 2C – Medium Span – Steel Network Arch Adjacent to Existing Bridge

Estimated probable total costs presented in this BCA 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 would be required.

The rehabilitation options had a poor evaluation score primarily due to the inherent existing crossing challenges, including structural improvements requiring extensive traffic closures during construction, lack of key features, and the absence of cost savings over a 100-year period due to the limited service life extension of the rehabilitation.

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10 References

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