AN UPDATE ON THE 2004 PRE-FEASIBILITY STUDY FOR A FIXED LINK BETWEEN LABRADOR AND THE ISLAND OF NEWFOUNDLAND

MARCH 2018

THE HARRIS CENTRE
Memorial University

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March 27, 2018

Mr. Ted Lomond
Deputy Minister of Tourism, Culture, Industry & Innovation
Government of Newfoundland and Labrador
P.O. Box 8700
St. John's, NL
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Dear Mr. Lomond:

An Update on the 2004 Pre-Feasibility Study for a Fixed Link Between Labrador and the Island of Newfoundland

On behalf of the Leslie Harris Centre of Regional Policy and Development, I am pleased to submit the final report of a study on a possible Fixed Link between Labrador and the Island of Newfoundland.

This study was intended as a follow-up to a study originally undertaken by the Harris Centre back in 2004. The purpose of this current new study is, first, to determine to what extent new geological research, innovations in tunneling technology, changes in labour costs, inflation or other factors may have an impact (positive or negative) on the original cost and time estimates. Secondly, the study aims to measure some possible impacts on the economy of the province overall and on those regions of the province that would be most affected by a change in traffic patterns.

The report is in four parts. The first consists of a 6-page executive summary of the entire study. The second consists of the detailed engineering and geotechnical study undertaken by Hatch, and runs to 397 pages, including eight appendices. The third part consists of the potential socio-economic impacts of a fixed link the Labrador Straits region and on Western Newfoundland undertaken by RAnLab, and runs to 27 pages. The final section consists of the terms of reference for the study, which runs to 20 pages.

Thank you for entrusting this project to the Harris Centre.

Sincerely,

Michael Clair

Michael Clair, MBA
Associate Director (Public Policy)

An Update on the 2004 Pre-Feasibility Study for a Fixed Link Between Labrador and the Island of Newfoundland (2018)

Executive Summary

A Pre-Feasibility Study undertaken in 2004 by Hatch Mott MacDonald examined five different options for a fixed transportation link between Labrador and the Island of Newfoundland:

- An 18-km long suspension bridge.
- A combination of two 2-km long suspension bridges linked by three causeways.
- An immersed tube tunnel, consisting of prefabricated modules that are laid in a trench dug into the seabed.
- A tunnel excavated using drill and blast techniques.
- A tunnel excavated by a Tunnel Boring Machine (TBM).

The first three options were dismissed due to high construction costs and/or construction and operating risks. For the latter two options (the tunnels excavated in rock), the study investigated a road scenario (where vehicles are driven across individually) and a train option (where vehicles cross aboard a shuttle train). Both options included a single tunnel with a single-lane and a single-track respectively, and alternating traffic in each direction. A summary of the 2004 findings is provided in the following two tables. The financial information is provided in 2004 dollars.

Comparison of Fixed Link Road Options (2004 Pre-Feasibility Study)

Option	Construction Cost ($M-2004)	Annual Operating Cost ($M-2004)	Risk Level	Project Duration (years)
TBM Bored Tunnel[1)]	1,559	6.8	Moderate	12.2
Drill & Blast Tunnel	1,800	6.8	High	17.8
Immersed Tube Tunnel	4,810	6.8	High	14.7
Bridge	4,227	16.9	Extreme	15
Causeway / Bridge	10,123	4.3	High	18

1) TBM Bored Road Tunnel with 11 m inner diameter and 20 km length

Comparison of Fixed Link Rail Options (2004 Pre-Feasibility Study)

Option	Construction Cost ($M-2004)	Annual Operating Cost ($M-2004)	Risk Level	Project Duration (years)
TBM Bored Tunnel[1)]	1,144	7.64	Moderate	12.5
Drill & Blast Tunnel	2,272	7.64	High	23.8
Immersed Tube Tunnel	3,814	7.64	High	15

1) TBM Bored Rail Tunnel with 7.5 m inner diameter and 26.3 km length

The 2004 study concluded that the most viable option was an underground tunnel excavated by a Tunnel Boring Machine, with vehicles being transported on an electric shuttle train. The total development cost, including interest during construction and escalation, was estimated to be $1.144 billion in 2004 dollars. The project was estimated to take 12½ years to complete.

Hatch Mott MacDonald has now split into two separate firms, Hatch and Mott MacDonald, with the former having the expertise in tunneling technology in Canada. To build upon the existing expertise, Hatch was retained as the engineering consultant for the current project to revise the 2004 Pre-Feasibility Study.

Hatch reviewed the geotechnical data that was available from various investigations carried out by others for Nalcor Energy between 2009 and 2012. Hatch also reviewed the HDD feasibility study and the conceptual design of a cable tunnel, prepared by Hatch Mott MacDonald that had been generated during the planning for the Strait of Belle Isle crossing of the hydroelectric cables from Muskrat Falls. As well, Hatch looked at advances in tunneling technology, and at tunnels constructed or under construction since 2004 in Turkey, Switzerland, Norway, Germany-Denmark, Korea and the United States.

Based on the review of assumptions and background information used in the Pre-Feasibility Study in 2004 and the new information available, a rail tunnel excavated by a single TBM is still considered the most technically and economically attractive option for a fixed transportation link between Labrador and Newfoundland.[1]

A pressurized-face TBM is the best option to address the challenges of tunnelling through the different geological formations that will be encountered under the Strait of Belle Isle, comprising various rock types, varying from hard gneiss to weak shale. A pressurized-face TBM would also be capable of excavating through fault zones characterized by fractured rock and increased water inflows, as well as addressing high hydrostatic pressures that have to be expected at the estimated tunnel depth of 130 m below sea level.

The study was premised on the completion of Highway 138 on the Québec Lower North Shore and on all the Strait of Belle Isle traffic being diverted to the Fixed Link (i.e., abandonment of the Strait of Belle Isle ferry service). The analysis was further premised on the retention of the Gulf Ferry Service; it would be left to the market to determine which route to use to enter or leave Newfoundland (i.e., the Gulf Ferry Service or the Strait of Belle Isle Fixed Link). Currently, 60% of the traffic to the Island of Newfoundland is from Québec and points west; this percentage was therefore used to estimate the amount of traffic that might divert from the Gulf Ferry service to the Fixed Link in order to determine the capacity of the tunnel.

The study takes a long-term view of traffic volumes: starting from current levels, traffic volumes are projected 42 years into the future (including 12 years for planning, design and construction) with an estimated growth rate of 2.5% per year. Even at this rate of growth, this represents a relatively low projected traffic volume over the 42-year life of the project, for which a single tunnel would provide sufficient capacity.

Hatch updated the cost estimates for the construction phase and the ongoing annual operations. Two single-bore options were considered: a larger-diameter road tunnel with a single lane, and a smaller-diameter single-track rail tunnel for an electric shuttle train (like the Channel Tunnel between England and France, where cars and trucks cross aboard a train)[2]. The train option would consist of three trains: one loading vehicles at one end, the second in transit through the tunnel, and a third unloading at the other end.

The estimated capital cost for the larger road tunnel is $2.065 billion and for the smaller train tunnel $1.675 billion (see the table next page). These estimates are based on a single TBM working 7 days a week during the construction phase.

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1 An option using two TBMs (one starting at each end, and meeting in the middle) is considered later in the report. While this would lead to a shorter construction period, it would also result in a higher construction cost.

2 The larger tunnel diameter for the road option is required to accommodate an emergency passing lane and ventilation units in the tunnel to deal with vehicle exhaust fumes. An electric train would have no such requirements and could, therefore, operate in a smaller-diameter tunnel.

Comparison of Single-Bore Fixed Link Road and Rail Options (2004 vs 2017)

Option	Tunnel Dimensions	Construction Costs[1]		Annual Operating Cost		Project Duration (years)	
		$M-2004	$M-2017	$M-2004	$M-2017	2004	2017
Road option	11 m Ø 21 km Length	1,559	2,065	6.8	7.7	12.2	14.0
Rail option	7.6 m Ø 30 km Length	1,144	1,675	7.6	8.7	12.5	15.5

[1] A more detailed assessment of the topography at the Labrador portal would likely enable a reduction in the rail tunnel length and an associated reduction in cost.

The 2017 capital costs are at a Class 4 level, meaning that the accuracy range for the estimates can vary from a low of -15% to -30%, to a high of +20% to +50%. For this study, a contingency of 40% has been added to the construction cost estimate.

A single-bore tunnel option means that traffic would only go in one direction at a time. Vehicles at either end would wait their turn to cross. For the road option, a travel speed of 80 km/h was assumed, resulting in a crossing time of approximately 20 minutes. It is estimated that the longest wait on shore would be about 60 minutes. The train was assumed to travel at 100 km/h and also take about 20 minutes to cross (the rail option requires a longer tunnel to account for a reduced slope at the exit ramps). The longest wait for the train option would be 60 minutes which would comprise 40 min for wait and loading of vehicles at one tunnel end and up to 20 minutes for extended unloading of vehicles at the opposite end.

In order to provide a more complete evaluation of the economic and financial options, the report looks at construction using 1 TBM and one using 2 TBMs.

The operating costs for the rail and road options over their operating periods are as follows:

Comparison of Operating Costs ($ millions)

	1 TBM	2 TBMs
Number of years of operation	*30*	*33*
Operating costs – rail option	261	287
Operating costs – road option	229	252
Difference	32	35

The 2017 construction schedules for both the road and the rail options are longer than the 2004 schedules. The increased project duration is the result of the increased lengths of the tunnel exit ramps, which in turn are caused by the assumed greater depth below the sea bed of the tunnel, resulting in longer excavation times. The greater depth was assumed based on the available geotechnical information on ground conditions underneath the Strait and the associated risks during the tunnel excavation. As in 2004, the 2017 schedules include 3 years of planning (additional studies, field investigations, environmental assessment, etc.) and 2 years of detailed design, for a total of 5 years prior to start of construction.

Assuming that:

- 60% of the Gulf Ferry traffic decides to reroute to the Fixed Link;

- The Strait of Belle Isle Ferry service is abandoned and the annual subsidy reinvested into the Fixed Link; and
- The toll charged is equivalent to what is currently charged by the Strait of Belle Isle Ferry service;

the economic indicators are as shown in the table:

Economic Indicators

	Rail Option		Road Option	
	1 TBM	2 TBMs	1 TBM	2 TBMs
Net Present Value (NPV) of Cash Flows ($ millions)	-593	-674	-829	-928
Internal Rate of Return (IRR) (%)	-0.16	-0.34	-0.79	-0.56
Benefit/Cost Ratio (BCR)	1.03	1.08	0.84	0.88

The Net Present Value for each option is negative (ranging from -$593 million to -$928 million[3]). All IRRs are negative, rendering this indicator not useful for this economic evaluation. The Benefit Cost Ratio (the ratio of summed benefits to summed costs) is slightly above 1 for the rail option and slightly below 1 for the road option, which are both reasonable levels for public infrastructure. The NPV and BCR suggest that project justification, if pursued, would likely have to depend on public benefits that are external to this study.

Proceeding with the project will therefore require access to public funding. Various financing scenarios involving grants or contributions were considered to identify financial conditions under which the project could proceed. (To create a more robust projection, the table below assumes two scenarios: one where 60% of the Gulf Ferry service is rerouted to the Fixed Link and another where only 40% is redirected.) The main finding is that a total contribution in the order of $1.37 billion to $2.10 billion would be required for the project to provide a return of 8%. This is still below the private finance threshold considered currently applicable, except perhaps for long-term debt; however, it illustrates the level of public support that is required for advancing the project.

Project Costs in Current $, IRRs and Suggested Grants Required

	Rail Option		Road Option	
	1 TBM	2 TBMs	1 TBM	2 TBMs
Total cost ($Current) (millions)	2,188	2,213	2,632	2,657
Interest during construction (millions)	578	398	692	451
Total to finance (millions)	2,767	2,611	3,324	3,107
Assuming that 60% of the Gulf Ferry traffic is diverted to the Fixed Link				
Internal rate of return (IRR) (%)	+1.97	+2.20	+1.04	+1.28
Grant required for an 8% IRR (millions)	1,370	1,430	1,820	1,880
Assuming that 40% of the Gulf Ferry traffic is diverted to the Fixed Link				
Internal rate of return (IRR) (%)	+0.41	+0.62	+0.44	+0.19
Grant required for an 8% IRR (millions)	1,595	1,655	2,041	2,104
	Lowest			Highest

Proceeding with this project as a Public-Private partnership (P3) appears feasible. It seems worthwhile to evaluate the potential of a Design-Build-Finance-Operate-Maintain (DBFOM) approach on the condition that the Federal and Provincial governments are willing to pay for the majority of the initial capital cost and they allow a private operator to charge tolls. The tolls would pay for the operating costs and for part of the capital costs.

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3 The Net Present Value is based on a discount rate of 10% (a real social discount rate of 7.5% plus 2.5% annual inflation), the rate recommended by the Federal Treasury Board.

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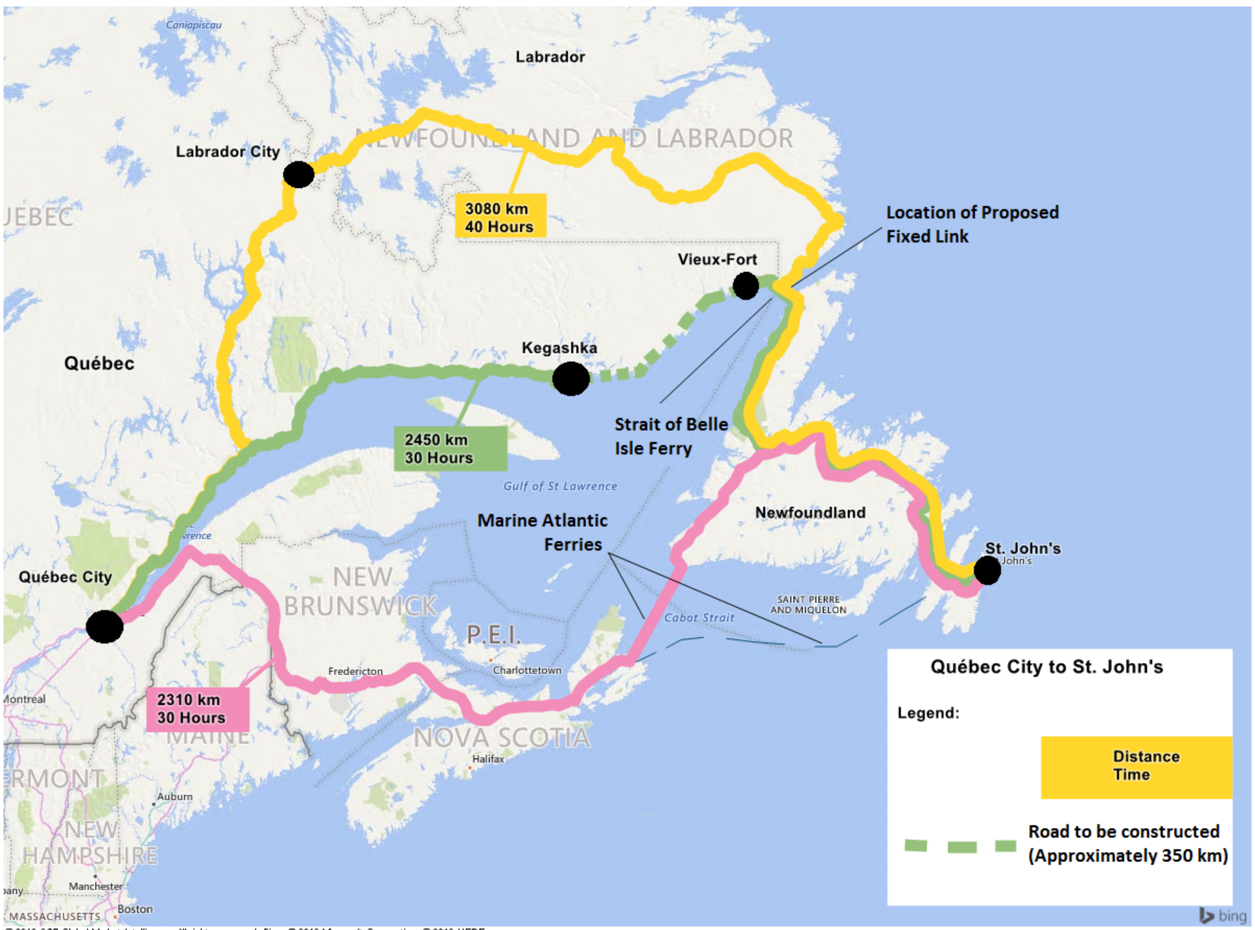
The socio-economic portion of the study was undertaken by the Harris Centre's Regional Analytics Lab (RAnLab), that uses advanced econometric models to estimate the impact of changes on the province's economy.

As with the Hatch study, the RAnLab study was premised on the fact that 60% of the traffic to the Island of Newfoundland is from Quebec and points west, and that the entirety of this traffic would reroute to the Fixed Link. The driving distance from Montreal to Deer Lake is longer by only about 120 km if travelling via the Fixed Link than via the Gulf Ferry service. When factors associated with "long-haul trips" (rest periods, time waiting on the ferry wharf and sailing time) are accounted for, the travel time for the Fixed Link route is on average 4.9 hours less than the road travel and Gulf Ferry crossing combined. (The map below is from the 2004 Hatch report and is included to provide a visual reference to the reader.)



The RAnLab study looks at two potential impacts on the province. The first asks whether rerouting traffic to the Fixed Link would affect the cost of imports and/or the competitiveness of exports. It does this by taking commercial trucking as a proxy for the economic impact on the province as a whole. The model looks at four possible options: whether a truck travels to the Gulf ferry or to the Fixed Link (including the impact of mandatory rest stops), and whether the fee structure used is similar to the current Gulf ferry service or that of the Confederation Bridge to Prince Edward Island. (At 13 km, the Confederation Bridge is closer in scale to the proposed Strait of Belle Isle crossing, at approximately 30 km, vs. 180 km for the Gulf Ferry service.)

The Gulf ferry crossing costs nearly 10 times the toll on the Confederation Bridge, a reflection of the relative distances travelled. However, given that the ferry crossing constitutes a rest period for the driver, there are additional costs related to mandatory rests or to switching drivers for the option of driving to the Fixed Link via Highway 138.

Assuming that costs (or savings) are passed on to the consumer, there is a slight saving to residents of the Island if commercial traffic from Central Canada and points west uses the Fixed Link. The saving is higher if the trucker only has to pay the Confederation Bridge rate (a saving of $13.1 million) rather than the Gulf ferry rate (a saving of $3.2 million). Dividing the savings by the population of the Island, each Newfoundlander saves about $27 per year if truckers pay the Confederation Bridge rate and $7 if truckers pay the Gulf ferry rate.

The RAnLab study goes on to examine the intra-provincial changes that might be expected if 60% of the traffic is redirected from the Gulf ferry service to the Fixed Link. The study estimates that some economic activity will migrate from Southwestern Newfoundland to the Labrador Straits and the Northern Peninsula. (The Bay St. George and Bay of Islands regions would remain relatively unchanged. There would be no anticipated impacts east of Deer Lake.) It is estimated that Southwestern Newfoundland will lose between $1.9 million and $2.9 million worth of economic activity (direct and induced), resulting in a loss of between 40 and 83 full-time jobs. The lost jobs would be primarily in the travel and tourism sector: food and beverage, accommodations, and service stations; these would account for between 25 and 57 of the jobs. This economic activity and related jobs would migrate northwards.

The RAnLab study does not look at any socio-economic impacts during the construction phase, should the Fixed Link be constructed; this was outside the scope of the study. The findings related to intra-provincial transfers are only valid for the first year of the existence of the Fixed Link; future economic impacts are complicated by difficulties in estimating the induced impact of traffic in subsequent years.

HATCH

The Leslie Harris Centre of Regional Policy and Development
Fixed Link between Labrador and Newfoundland

Update of 2004 Pre-Feasibility Study – FINAL REPORT

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1. Introduction

Hatch was retained by the Leslie Harris Centre of Regional Policy and Development (the Harris Centre), on behalf of the Government of Newfoundland and Labrador, to provide a revision of the Newfoundland and Labrador Fixed Link Pre-Feasibility Study which was prepared in 2004 by Hatch Mott MacDonald (HMM) [1]. The purpose of the current work is to update the previous study of fixed link infrastructure concepts with recent information and new data that was collected over the last years as well as with experience gained from the most recent similar fixed link projects worldwide.

The goal of the 2017 study is to determine to what extent new geotechnical and geophysical investigations and advancements in tunnelling technology as well as factors such as traffic forecasting, labour costs or inflation impact the previous assumptions and recommendations. As part of the current study, the Harris Centre is investigating the potential impact of a fixed link on the economy of the province.

1.1 Background

In 2004, HMM (now Hatch) carried out a Pre-Feasibility Study of options for a fixed transportation link between Labrador and Newfoundland across the Strait of Belle Isle with the objective to investigate economic and technical implications and the viability of a fixed link between the mainland of Labrador and the island of Newfoundland. The findings of the study were presented in HMM's final report 'Fixed Link between Labrador and Newfoundland Pre-Feasibility Study', dated November 2004 (refer to [1] and [2]).

Over the past 13 years, information pertaining to the surface and subsurface conditions along the proposed Strait of Belle Isle fixed link alignment was collected during a series of geotechnical and geophysical investigations, which were carried out for the Strait of Belle Isle High Voltage Direct Current (HVDC) cable crossing as part of Nalcor Energy's Lower Churchill Project (Nalcor Energy provided permission to Hatch to use this information in the current study). In addition, technological advances and experience was gained from other fixed link projects that were carried out worldwide, such as the Busan-Geoje Link in South Korea or the Gotthard Base Tunnel in Switzerland.

1.2 Understanding of the Work and Assumptions for this Study

The intent of this study is to update the background information and validate the assumptions applied in the 2004 Pre-Feasibility Study of Strait of Belle Isle fixed link alternatives. The main items included in the scope of work comprise the following (refer to Hatch's proposal dated March 06, 2017):

- Update of study background information based on new information available.
- Validation of previous assumptions made for the 2004 Pre-Feasibility Study.
- Update of experience gained from recent fixed link projects and technological advances worldwide.

- Update of comparison of fixed link alternatives and validation of previous recommendations for the preferred option.
- Update of cost estimate and schedule for the preferred option.
- A review of the financing considerations using public-private-partnerships (P3) is presented for a fixed link project in 2017.
- An update of the economic and financial analysis presented in the 2004 was added by addendum.

The updated fixed link recommendations are based on data review, revision of information and assumptions contained in the 2004 study, and discussions with the Harris Centre, thereby focussing on changes since 2004 that could impact the fixed link. Information or assessments contained in the 2004 Pre-Feasibility Study are recapped in the updated study only where deemed required for the understanding of the context or if considered to be otherwise relevant.

1.3 Study Approach

The following approach was used to carry out this updated study:

- A review of available information on worldwide fixed link projects that were carried out since 2004 or that are currently under construction or in planning or design phase was conducted. The review focussed on relevant projects and technological advances and innovations that can be related to the proposed Strait of Belle Isle fixed link. Project challenges, lessons learned and technological experience gained from these projects were evaluated and considered for the assessment of the Strait of Belle Isle fixed link options.
- A review of new background information was carried out, related to geotechnical, geological and environmental information, survey data, regulatory requirements as well as traffic volume data for the Gulf Ferries and the Strait of Belle Isle Ferry that was provided by the Harris Centre. Relevant changes to previous data used for the 2004 study were identified and the implications for the Strait of Belle Isle fixed link were defined.
- Previous assumptions included in the 2004 study regarding the utilization of the fixed link, the anticipated ridership and the design criteria were reviewed and updated where required based on the new information available and on discussions with the Harris Centre.
- The assessment of the Strait of Belle Isle fixed link options and the recommendations for the preferred option were reviewed and updated based on the updated information and assumptions.
- Cost estimate and schedule for construction were updated for the preferred option to reflect current market realities and to account for the recent technological advances.
- The economic and financial analysis included in the 2004 study was revised and updated.

- Financing considerations using P3 were reviewed and updated to reflect current trends in terms of delivery methods for major projects in North America.

2. Project Description and Location

The study area for the proposed fixed link is the Strait of Belle Isle, located between Newfoundland and Labrador (see **Figure 2-1**).

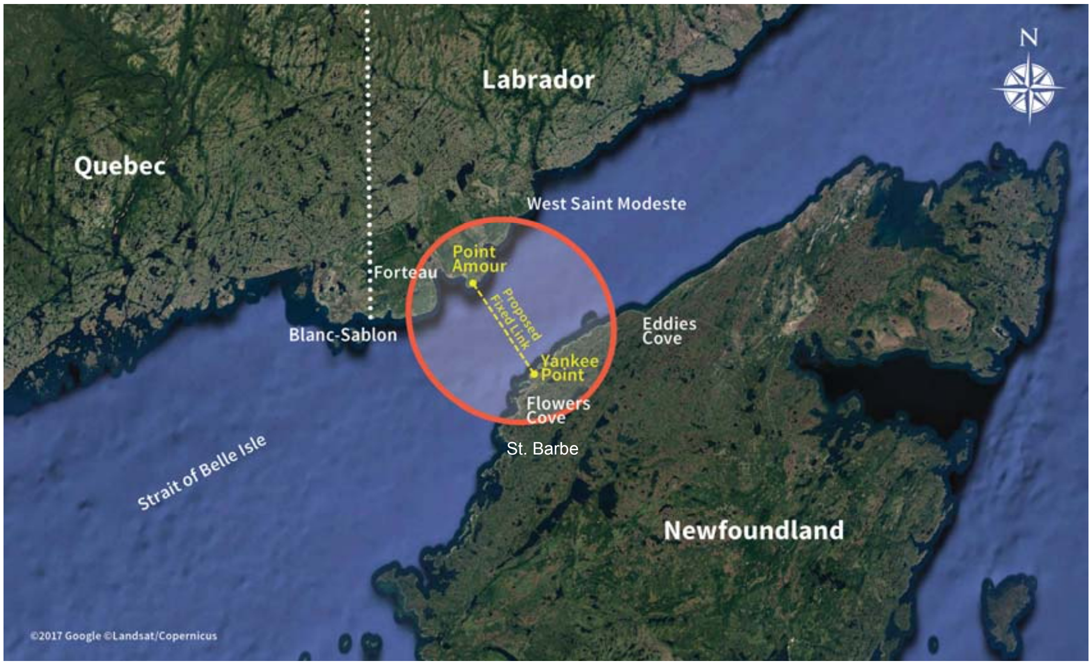


Figure 2-1: Proposed Project Location

Currently, the mainland of Labrador and the isle of Newfoundland are connected by ferry between Blanc-Sablon in Québec and St. Barbe in Newfoundland. Although the ferry connection is in operation throughout the year, it is subject to weather and ice conditions in the Strait of Belle Isle and interruptions during the winter months are common. The proposed fixed link project investigates a transportation link between Newfoundland and Labrador that would provide a permanent connection for vehicles between the isle and the mainland independently from weather and ice conditions.

The proposed fixed link is assumed to be located between Point Amour in Labrador (approximately 30 km east of Blanc-Sablon) and Yankee Point in Newfoundland (approximately 25 km north of St. Barbe), at the narrowest point of the Strait. The width across the Strait at this location is approximately 18 km. The water depth varies between shallower waters of approximately 25 m close to the Newfoundland shore and depths up to approximately 110 m towards the middle of the Strait and locally close to the Labrador shore.

The project location provides various challenges that impact the fixed link project. The great water depth, harsh environmental conditions, sea ice that covers the waters of the Strait for up to seven months each year and icebergs that float through the Strait, typically between the months of December to June, all have to be considered for any fixed link solution installed above surface, such as bridges or immersed tube tunnels. As a further constraint, marine traffic has to be maintained during construction and operation of surface fixed links. These factors will also impact pre-construction ground investigations that would need to be carried out for potential subsurface fixed links such as bored tunnels. The complex geology underneath the Strait that includes fault zones and variable rock conditions will have to be considered for any subsurface construction.

Furthermore, Nalcor Energy's HVDC subsea cable that was installed in recent years on the sea bottom across the Strait of Belle Isle would have to be taken into account for the construction of all proposed subsurface fixed links at this location as well as for potential ground investigations carried out in the Strait.

3. Overview of 2004 Pre-Feasibility Study

Within the Pre-Feasibility Study carried out in 2004 [1], three basic fixed link concepts were investigated for the Strait of Belle Isle crossing. For each of these concepts, it was assumed that the crossing would be between Point Amour (Labrador) and Yankee Point (Newfoundland) which is the shortest distance between the two shores. The fixed link concepts included:

1. Bridge
2. Causeway with bridges
3. Tunnel, including:
    i) Immersed Tube Tunnel (ITT)
    ii) Bored tunnel
    iii) Drill & blast tunnel

The assessment indicated that the projected traffic could be accommodated by a two lane above ground facility or with appropriate capacity by a single lane tunnel operated periodically in each direction for use by road vehicles or by roll-on/roll-off shuttle trains. All tunnel options included the integration of three high-voltage, direct current (HVDC) cables in the crossing.

3.1 Fixed Link Alternatives Considered in the 2004 Pre-Feasibility Study

Brief summaries of the fixed link concepts investigated during the 2004 study are summarized in the following sections. For more details about these options, the reader should refer to the 2004 Pre-Feasibility Study.

3.1.1 Bridge

A suspension bridge with two-kilometre spans crossing the approximately 18 km wide Strait of Belle Isle was considered the most economic bridge solution. The general concept is shown in **Figure 3-1**.

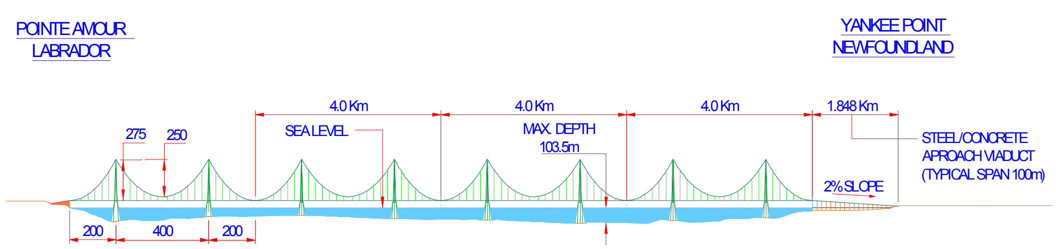


Figure 3-1: Bridge Concept (2004 Pre-Feasibility Study)

The wide spans would minimize the number of foundations to be installed in great water depth and the exposure of the structures to iceberg loadings. The bridge piers would have to be protected by berms to withstand impact from icebergs. A clearance of at least 50 m between the bridge deck and sea level was considered to accommodate marine traffic and moving icebergs. A bridge crossing of the Strait of Belle Isle was associated with very high risks related to design, construction and operation resulting from the difficult environmental conditions at the site, including the location in an iceberg zone, the foundation installation in great water depths and the harsh weather conditions.

3.1.2 *Causeway with Bridges*

The causeway across the Strait of Belle Isle would consist of a rock berm placed on the sea floor and protected with armour stones on the outside to withstand the impact from icebergs. The general concept is shown in **Figure 3-2**.

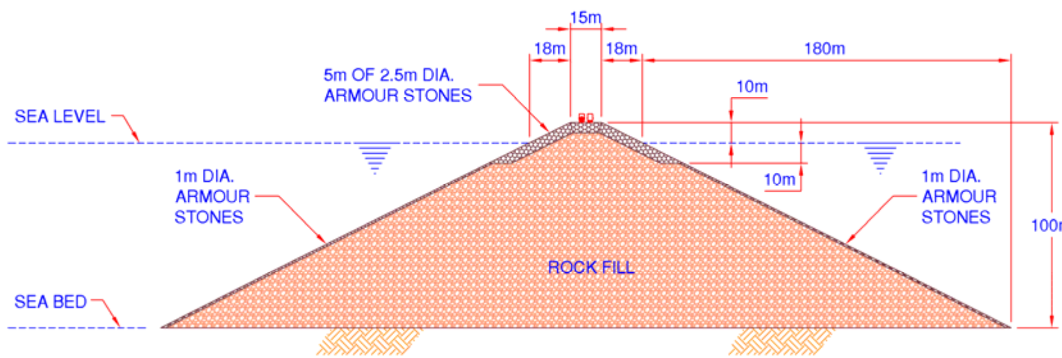


Figure 3-2: Causeway with Bridges Concept (2004 Pre-Feasibility Study)

To allow for marine traffic and moving icebergs, openings in the causeway would be required. For the 2004 study, it was assumed that two openings in the causeway would be needed, located at the position of the shipping lanes. Bridges would have to be integrated in the crossing to span the causeway openings. The bridge piers could be integrated into the causeway structure for protection against iceberg impact; however, foundations and anchoring of the bridges would still be challenging. The construction of a causeway across the Strait of Belle Isle was considered an ambitious undertaking and the risks associated with a causeway were considered high. A major environmental risk is the likely effect of a causeway on marine life and on the sea current regime in the area.

3.1.3 *Immersed Tube Tunnel (ITT)*

An ITT is a subsea tunnel that is installed on the sea bottom in a trench dredged into the sea floor. The ITT consists of pre-fabricated tunnel segments that are floated to their required location and sunk to their final position. The segments are connected and sealed under water, and backfilled to prevent uplift. The tunnel cross section suggested in 2004 is shown in **Figure 3-3**.

Since the ITT would be installed on the sea bed in varying water depths, there is a risk of iceberg impact on the tunnel where the depth is less than the submerged portion of the icebergs. The tunnel elements would have to be protected against iceberg impact and scour, either by burying the ITT elements below the depth of iceberg scour, or by having sufficient protection to absorb the energy of an iceberg. The risk associated with the construction of the ITT is considered high due to the depth of the water, the location of the site in an iceberg area and the harsh weather conditions.

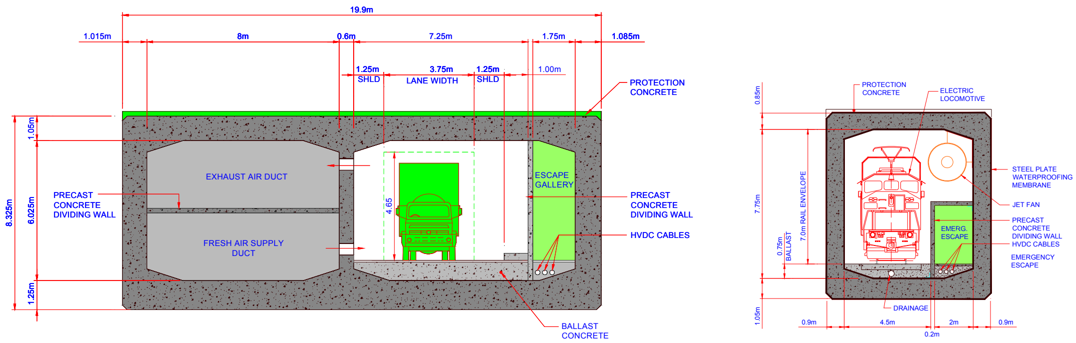


Figure 3-3: ITT Concept for Road and Rail (2004 Pre-Feasibility Study)

3.1.4 *Mined Tunnel*

Most of the risk factors associated with surface crossings of the Strait of Belle Isle (such as iceberg impact and construction in great water depth) would be eliminated with a tunnel that is constructed below the seabed. In the 2004 study, it was assumed that the tunnel would be excavated in the sedimentary rock layer below the seafloor. Water inflow into the tunnel would have to be considered, in particular in the many fault zones expected to be encountered along the alignment. A tunnel excavated in less permeable rock in greater depth of approximately 300 to 400 m below the sea bed (approximately 400 to 500 m below sea level) was considered not economically feasible. The tunnel excavation can be accomplished by either drill & blast excavation or by using a Tunnel Boring Machine (TBM).

3.1.4.1 *Bored Tunnel*

The general concept for a bored tunnel as suggested in the 2004 study is provided in **Figure 3-4**. Tunnel excavation was assumed to be carried out using a pressurized face TBM. This type of TBM is designed to apply pressure to the excavation face to support the ground and to counteract water pressure in fractures and fissures. It was assumed that the tunnel lining would be installed immediately as the tunnel is progressed to prevent water ingress. For the 2004 study, an alignment with approximately 10 m of minimum rock cover was assumed.

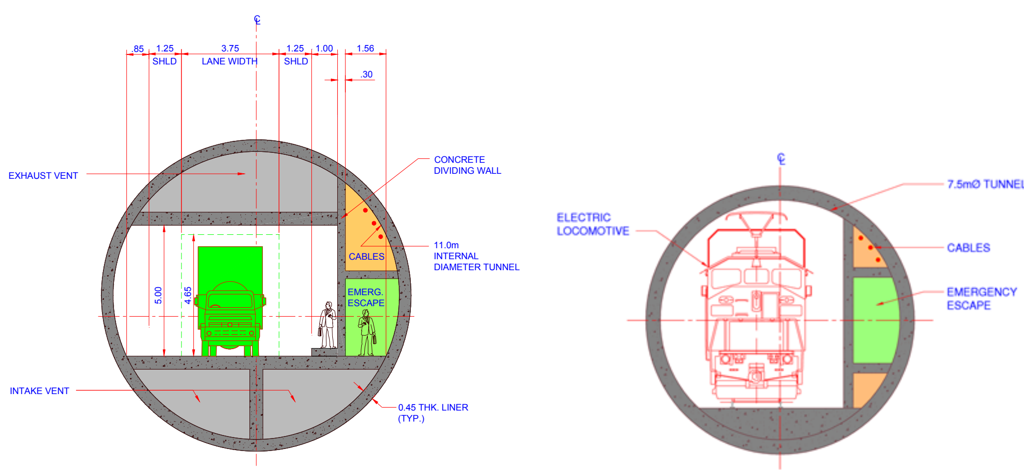


Figure 3-4: TBM Bored Tunnel Concept for Road and Rail (2004 Pre-Feasibility Study)

3.1.4.2 *Drill & Blast Tunnel*

The general concept for a tunnel excavated by drilling and blasting as suggested in the 2004 study is shown in **Figure 3-5**. A drill & blast excavation would require probe drilling and grouting ahead of the tunnel face to stabilize the rock in areas of poor rock quality and to seal water paths and reduce water ingress into the tunnel. Since grouting might not prevent water ingress entirely, a tunnel depth of approximately 60 m below the sea bed was assumed to separate the tunnel from the presumably more fractured rock in the upper rock layers closer to bedrock surface. Because of the greater depth, the drill & blast tunnels were assumed to be between 0.3 km (road tunnel) and 4.4 km (rail tunnel) longer than the respective TBM excavated tunnels.

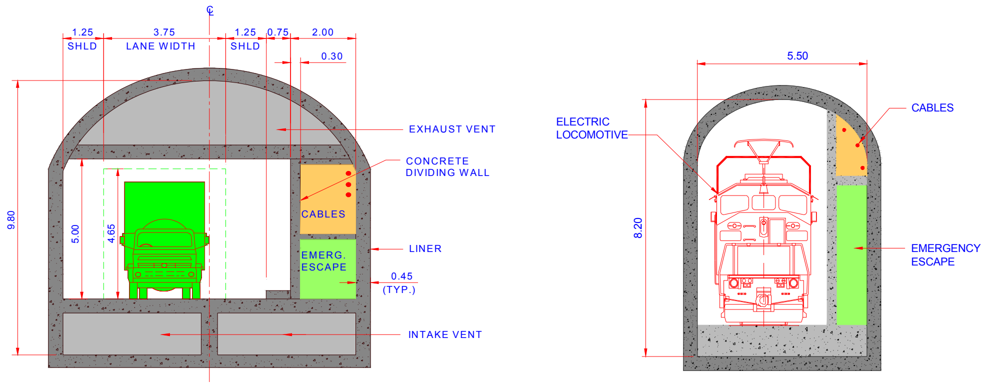


Figure 3-5: Drill & Blast Tunnel Concept for Road and Rail (2004 Pre-Feasibility Study)

3.2 Comparison of Alternatives (2004 Pre-Feasibility Study)

The comparison of the fixed link alternatives in the 2004 study was based on an assessment of the construction (short-term) risks and the operational (long-term) risks associated with each alternative.

3.2.1 *Construction Risks*

All surface fixed link options (bridge, causeway with bridges and ITT) would be exposed to construction risks related to the harsh weather and environmental conditions in the Strait of Belle Isle. Factors such as icebergs and sea ice conditions during the winter months, water depths up to 100 m, rough sea conditions and strong currents as well as the need to maintain heavy marine traffic in the navigation channel will impact the construction work and will likely prevent marine based construction during the winter period. These factors present a high level of risk that the construction would be interrupted and the schedule extended with consequent increases in cost.

For the immersed tube tunnel, the construction process is likely more sensitive to the environmental conditions due to some unprecedented aspects related to the Strait of Belle Isle project location, including depth of immersion, length of tunnel, excavation of rock at depth underwater, and substantial excavation volumes.

The mined tunnel fixed link options (TBM bored tunnel and drill & blast tunnel) are exposed to construction risks associated with subsea tunnelling at great depth. For the Strait of Belle Isle project location, these include the occurrence of faults or fractured rock requiring immediate support or pre-excavation support systems as well as ground treatment to reduce groundwater inflows. For a bored tunnel, these geotechnical risks would be reduced with the use of an appropriate TBM such as a slurry or EPB machine together with a precast concrete tunnel lining. This type of machine provides the ability to pressurize and stabilize the excavation face to address poor rock conditions and seal off the workers from exposure to the ground conditions and associated water inflows. Drill & blast tunnelling would generally require a deeper tunnel alignment to increase the tunnel separation from the seabed and reduce water ingress. Water inflow would have to be addressed by grouting; however, the risk inherent with this method is considered high due to the high water pressures that have to be expected.

3.2.2 *Operational Risks*

The bridge option as well as the causeway with bridges option are associated with a considerable risk to the operation of the facility during the winter due to snow and icing, high winds and fog as well as iceberg interactions and ship impacts. The risk of having operational interruptions in the winter months was considered high.

The operational risks are similar for all tunnel options. The major risk of service interruption is associated with breakdowns or accidents within the tunnel. For the road tunnels, this risk is addressed with a passing lane and CCTV monitoring of the tunnel. For more substantial accidents and fires, an emergency egress passage has been provided and a fire suppressor system will likely be included to protect the structure and to reduce the closure time. Since the likelihood of fires in tunnels, especially in rail tunnels is low, the risk of operational interruptions in the tunnel options was considered low.

Specific for the ITT option is the risk of iceberg impact which could lead to an outage and to substantial protection work repairs or damage to the ITT elements themselves.

3.2.3 *Summary*

The following tables provide a comparative summary of the road (**Table 3-1**) and rail (**Table 3-2**) options investigated in the 2004 study, including estimated construction costs and project duration. The details regarding costs and schedule are not repeated in this report; for details refer to 2004 Pre-Feasibility Study [1] and [2].

Table 3-1: Comparison of Fixed Link Road Options (2004 Pre-Feasibility Study)

Option	Construction Cost ($M-2004)	Annual Operating Cost ($M-2004)	Risk Level	Project Duration (years)
TBM Bored Tunnel[1)]	1,559	6.8	Moderate	12.2
Drill & Blast Tunnel	1,800	6.8	High	17.8
ITT	4,810	6.8	High	14.7
Bridge	4,227	16.9	Extreme	15
Causeway / Bridge	10,123	4.3	High	18

1) TBM Bored Road Tunnel with 11 m inner diameter and 20 km length

Table 3-2: Comparison of Fixed Link Rail Options (2004 Pre-Feasibility Study)

Option	Construction Cost ($M-2004)	Annual Operating Cost ($M-2004)	Risk Level	Project Duration (years)
TBM Bored Tunnel[1)]	1,144	7.64	Moderate	12.5
Drill & Blast Tunnel	2,272	7.64	High	23.8
ITT	3,814	7.64	High	15

1) TBM Bored Rail Tunnel with 7.5 m inner diameter and 26.3 km length

3.3 Preferred Alternative (2004 Pre-Feasibility Study)

Based on the technical assessment and on the comparison of costs, risks and schedule, a TBM bored rail tunnel was considered the preferred alternative in the 2004 study.

4. Review of Recent Fixed Link Projects

As part of this study, a review of recent fixed link projects that were constructed since 2004 or that are currently under construction or in planning was carried out. Although various fixed link tunnel projects were realized over the past years, the focus of the review was on tunnel projects that are relevant to the proposed Strait of Belle Isle fixed link. The findings are summarized in the following sections. Experience from projects constructed up to 2004 are included in the previous Pre-Feasibility Study (refer to [1]).

4.1 Istanbul Strait Tunnel (Eurasia Tunnel)

The Istanbul Strait Tunnel project (Eurasia Tunnel) includes a 5.4 km long tunnel section that crosses underneath the Bosphorus Strait and connects the Asian and European sides of Istanbul. The tunnel section comprises an approximately 3.4 km long subsea tunnel excavated by TBM, a 1 km long drill & blast twin-tunnel on the Asian side as well as sections of cut-and-cover tunnel. The tunnel alignment and simplified geological profile are shown in **Figure 4-1** and **Figure 4-2**.

Figure 4-1: Eurasia Tunnel Location in Turkey
(https://www.newcivilengineer.com/world-view/under-pressure-eurasia-tunnel/10001844.article)

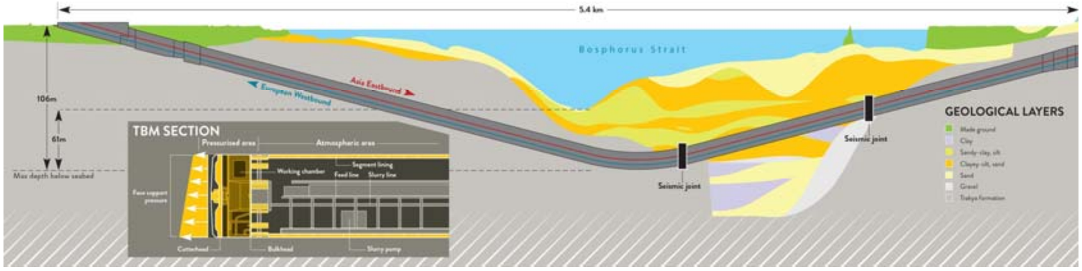


Figure 4-2: Simplified Geological Profile along Eurasia Tunnel Alignment
(https://www.newcivilengineer.com/world-view/under-pressure-eurasia-tunnel/10001844.article)

The TBM tunnel, housing a stacked roadway for light vehicles only with two lanes in each direction (see **Figure 4-3**, left), was excavated with a 13.7 m diameter Mixed Shield TBM mostly in sedimentary rock; however, a significant section of the tunnel passes through soft alluvial deposits including sand and clay. Due to the depth of the tunnel alignment of up to 106 m below the water level, high hydraulic pressures of up to approximately 12 bar at the deepest point of the tunnel alignment were considered. The Mixed Shield TBM was specifically designed to address the various ground conditions including zones of heavily fractured rock as a result of tectonic events as well as mixed and soft ground conditions and to withstand the high hydraulic pressures. The 12.0 m diameter tunnel liner that was installed behind the machine consists of 600 mm thick precast concrete segments.

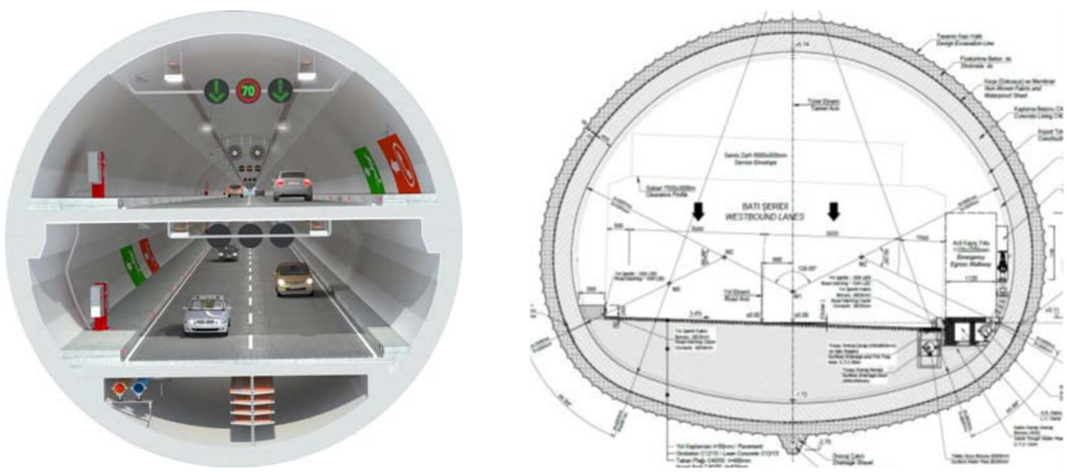


Figure 4-3: Eurasia Tunnel Cross Sections: TBM (left), Drill & Blast (right)
(https://www.newcivilengineer.com/world-view/under-pressure-eurasia-tunnel/10001844.article); (Istanbul Strait Road Tube Crossing: Challenges, Risk and Mitigation Strategies, N. Munfah et al.)

To address poor ground conditions and high hydrostatic pressure, the drill & blast twin tunnels were excavated with a curvilinear cross section (see **Figure 4-3**, right) using the sequential excavation method including pre-support consisting of a continuous pipe umbrella support (forepoling). The initial support comprised lattice girders, rock bolts and shotcrete to address the poor ground conditions. 400 mm reinforced concrete over a waterproof membrane system was installed as the final liner in this tunnel section.

The project was executed under a Design-Build-Finance-Operate-Maintain (DBFOM) contract in a public-private-partnership delivery method. The tunnel opened in 2016 for an anticipated daily capacity of 100,000 light vehicles. The tunnel is open 24 hrs per day; the current toll for a one-way passage through the tunnel is approximately $5.50 (16.60 TL) per car and $8.30 (24.90 TL) per minibus (https://www.avrasyatuneli.com/en/). All other vehicles such as trucks, tractor trailers, motorcycles, busses, etc. are prohibited in the tunnel, A height and weight limit is in effect and the transport of hazardous materials is prohibited.

Challenges of the project included the large excavation diameter, the difficult geology that included full face rock sections, full face soft ground and mixed face transition zones, the high hydrostatic pressure and the susceptibility to seismic activity. The Mixed Shield TBM was capable of managing the ground challenges as well as the high water pressures that were encountered at the deepest point of the tunnel, which coincided with mixed face conditions. Cutterhead maintenance under the encountered high face pressure conditions required the machine to be equipped for saturation hyperbaric inspections. However, a non-exposure maintenance procedure was incorporated that included a remote monitoring system which allowed monitoring of the cutterhead conditions, disc cutter wear etc. using sensors and cameras installed at the cutterhead. Tool maintenance systems allowed the replacement of cutter tools under atmospheric conditions from inside the cutterhead spokes without exposure to the pressurized conditions.

4.2 Follo Tunnel

The Follo Tunnel is a rail tunnel project that is currently under construction in Norway. The 20 km long twin tunnels will provide a transportation link for high-speed passenger trains (with speeds up to 250 km/h) as well as for freight trains between Oslo Central Station and the new station in the city of Ski. The project location is shown in **Figure 4-4.**

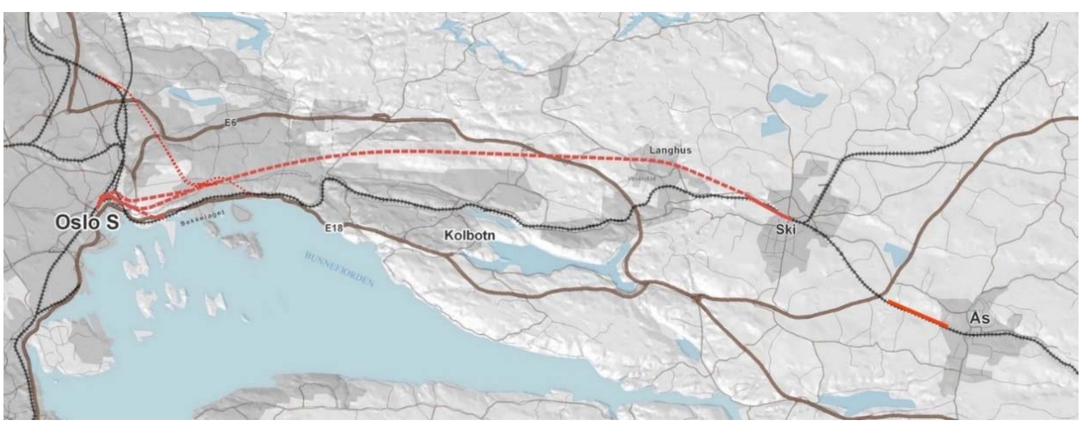


Figure 4-4: Follo Tunnel Location in Norway
(http://www.northsouthraillink.org/follo-line-oslo/)

The majority of the tunnel length (18.5 km) will be excavated by TBM, using four double-shield hard rock TBMs with a 10 m diameter that are designed for abrasive and strong rock. Starting from a launch area at mid-point of the alignment, two machines advance north towards Oslo and two machines south towards Ski, each excavating an approximately 9 km long section of the tunnels. Pre-cast concrete elements will be installed as final tunnel liner behind the machines. Cross-passages between the two tunnels will be installed every 500 m along the alignment to provide escape routes. At the north end of the tunnel towards Oslo, where the new tunnels had to be excavated close to existing tunnels and sensitive installations, a 1.5 km long tunnel section was excavated by drill & split or drill & blast. The tunnel is Norway's first long twin tube rail tunnel and one of the first tunnels in Norway excavated by TBM. A tunnel cross section is shown in **Figure 4-5**.

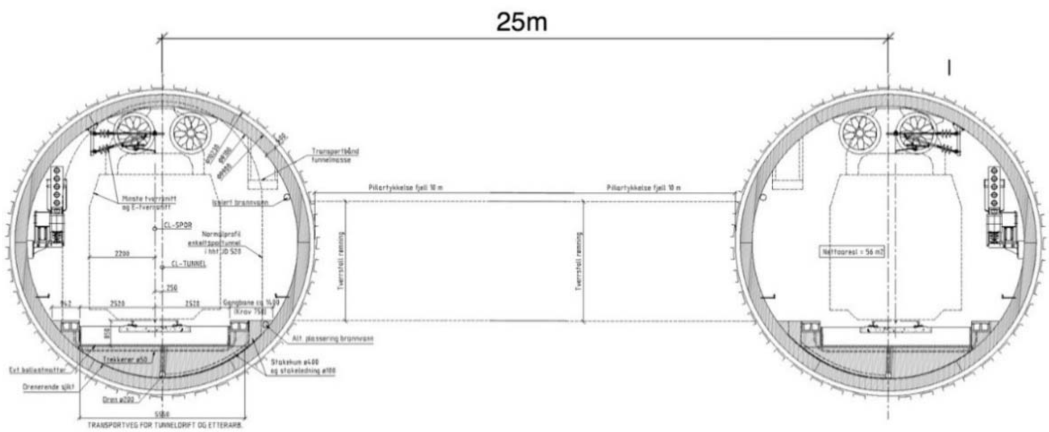


Figure 4-5: Cross Section of the Follo Tunnel Twin Tubes
(http://www.northsouthraillink.org/follo-line-oslo/)

Available information on the timeline for planning and design indicates that the preliminary work for the tunnel commenced in 2008/2009 and final design started in 2012. Main construction work began in 2015 and TBM excavation started in September 2016. Beginning November 2017, 50% of the TBM tunnels were completed. It is expected that the TBMs will reach Oslo in the Summer of 2018. The scheduled construction time for the TBM tunnel excavation is 2 years with TBM advance rates anticipated to be between 12 m and 15 m per day. Project completion is scheduled for December 2021. As of early November 2017, all four machines were on schedule and no major difficulties were experienced so far.

4.3 Gotthard Base Tunnel

As part of the Alp Transit Project, the Gotthard Base Tunnel is a railway tunnel with two single track tubes that cross under the Alps in Switzerland and provide a high-speed rail link between southern and northern Europe. The tunnel alignment is shown in **Figure 4-6**. Both tunnel tubes have a length of approximately 57 km (total tunnelled length of 114 km) and were constructed at depths up to 2,450 m below ground surface. The tunnel opened in 2016.

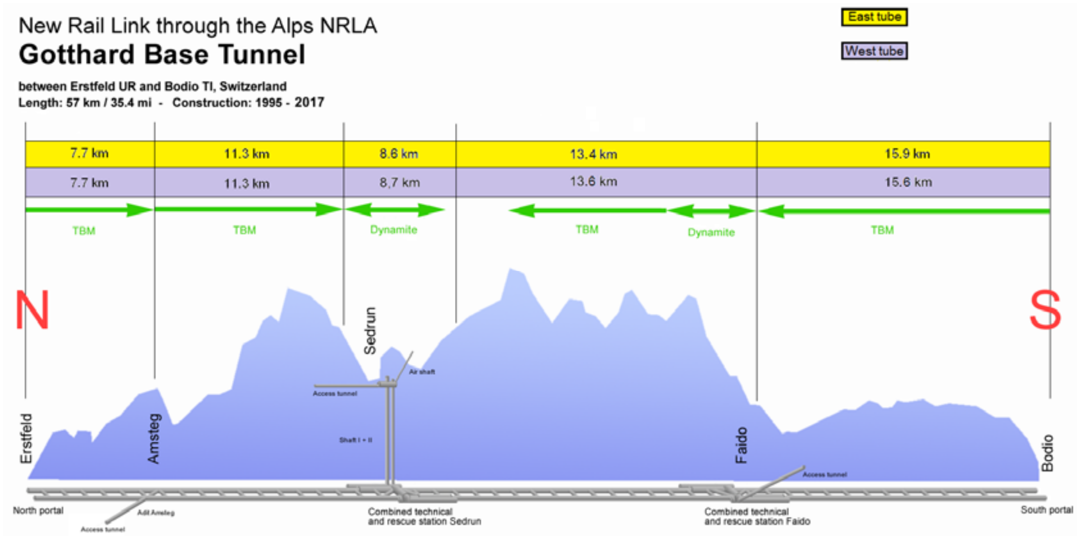


Figure 4-6: Profile along Gotthard Base Tunnel in Switzerland
(https://en.wikipedia.org/wiki/Gotthard_Base_Tunnel)

The tunnel tubes were excavated mainly by four open face gripper TBMs with diameters between 8.8 m and 9.6 m (**Figure 4-7**). The average advance rates were approximately 10 to 14 m per work day with maximum performance up to 40 m per work day. The lengths of the individual sections excavated by TBM varied between 7 and 14 km.

Approximately 20% of the entire tunnel length as well as several access tunnels and cross passages were excavated by conventional drill & blast methods with excavation diameters between 8.8 m and 13.1 m and average advance rates of 1 m to 4.5 m per work day, depending on rock conditions. The maximum advance rate was 11.5 m per work day. Drill & blast excavation was chosen for tunnel sections that were expected to be in rather weak rock and that required a controlled approach of the expected unstable fault zones and prevention of uncontrolled water inflow.

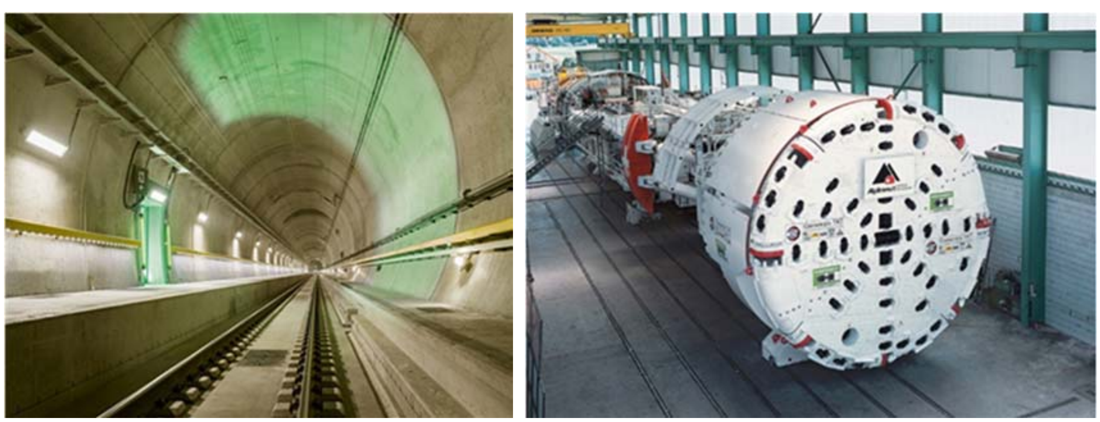


Figure 4-7: Gotthard Base Tunnel after Completion (left) and Gripper TBM (right)
(http://www.littlegatepublishing.com/tag/gotthard-base-tunnel/ and
https://tunneltalk.com/Gotthard-TBM-safely-across-the-Piora-Mulda2.php)

The rock support used to stabilize the excavated tunnel walls and crowns comprised typically rock bolts and shotcrete. In areas where large radial displacements were experienced, a yielding support including steel arches was used. In zones of loose, fractured rock, auxiliary measures including a pipe screen umbrella with extensive pre-excavation grouting were applied.

Lessons learned during TBM excavation were mostly related to difficult geological conditions. These included zones of soft ground that were too soft for the gripper TBM as well as areas of poor rock quality. An unexpected zone of unconsolidated rock resulted in the TBM being stuck due to the sudden inflow of loosened rock mixed with water into the TBM’s cutterhead. To improve the stability of the rock ahead of the cutterhead, a cement/bentonite mixture was injected into the unconsolidated rock. In addition, a bypass gallery had to be advanced from the parallel tunnel tube to free the TBM cutterhead from in front.

Challenges at the intermediate station in Sedrun were caused by difficult geological conditions including an extensive fault zone consisting of steeply inclined sequences of soft and hard rock in which radial deformations up to 700 mm occurred. Large overbreak and a yielding tunnel lining that included steel arches were used to address the rock deformations.

Challenges resulted also from the high pressure due to the high rock overburden above the tunnel. To prevent extreme deformations of the tunnel, a new tunnel support concept of flexible steel arches was developed that allowed deformation of the ground around the over-excavated tunnel opening without damage to the final tunnel liner.

A further challenge was the management of the 28.2 million tons of excavated rock material that had to be processed for use as aggregate for concrete or for embankments, etc. Approximately 0.2 million tons were classified as hazardous waste.

4.4 Eiksund Tunnel

The Eiksund Tunnel in Norway is part of a fixed link project including three tunnels and a bridge between the Norwegian mainland and Hareidlandet Island (**Figure 4-8**). The 7.8 km long single tube road tunnel (**Figure 4-9**) has a width of 10 m and accommodates three traffic lanes, allowing for a crawler lane on each exit gradient to address slower traffic on the steep exit grades of up to 9.6%. The Eiksund Tunnel passes under the Vartdalsfjorden and is to date the world’s deepest sub-sea rock tunnel with a depth of 287 m below sea level at the deepest point.

The tunnel was excavated in Precambrian gneiss with a minimum rock cover of approximately 50 m using traditional drill & blast technique and supported by rock bolts and shotcrete. The tunnel final lining system consist of reinforced patented fabric and steel arches. During construction, probe drilling from the tunnel face and pre-excavation grouting was used to control groundwater inflows and improve the ground conditions ahead of the excavation face.

Figure 4-8: Eiksund Tunnel Location in Norway
(https://www.roadtraffic-technology.com/projects/eiksund/)

Figure 4-9: Eiksund Tunnel after Completion
(http://www.panoramio.com/user/80930)

Opened in 2008, the projected usage was 1000 vehicles per day (vpd). However, due to ease of access actual traffic increased rapidly to 2200 vpd. The toll for a one-way passage was approximately $13 (76 NOK) per car and $40 (228 NOK) per truck. After six years in operation, the tunnel was fully financed and became toll free in 2014, resulting in a traffic increase to 2880 vpd (2014), half of which were trucks.

The Eiksund Tunnel is a typical example for tunnel constructions in Norway. The lessons learned from this project are that traditional drill & blast tunnels in deep undersea conditions are feasible and that significant water inflows can be addressed with appropriate probe drilling and pre-excavation grouting. Attention had to be paid to the issue of corrosion of the rock support and the tunnel liner as well as damage to electrical and other equipment installed in the tunnel due to salt water seepage into the tunnel. These problems would also need to be addressed in a drill & blast tunnel at the Strait of Belle Isle due to the expected high sea water inflow into the tunnel through the faults underneath the Strait. By choosing steep grades of up to 9.6%, the lengths of the Eiksund tunnel entrance/exit ramps were reduced.

4.5 Ceneri Base Tunnel

The Ceneri Base Tunnel was constructed as part of the Alp Transit Project in Switzerland (**Figure 4-10**). The tunnel consists of two single track tubes, each with a length of 15.4 km, that were excavated by drilling and blasting; excavation was completed between 2007 and early 2016. The rock overburden above the tunnels has a thickness between approximately 10 m and up to approximately 900 m. The tunnel tubes have cross-sections between 62 m^2 and 87 m^2 (approximately 8.7 m excavated width); a total bulked volume of 3.5 million m^3 rock was excavated.

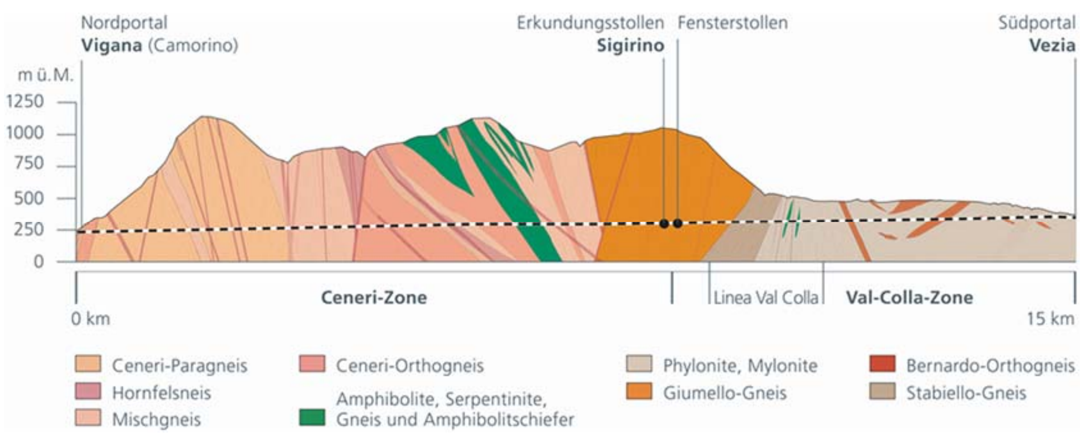


Figure 4-10: Geological Profile along Ceneri Base Tunnel in Switzerland
(https://www.alptransit-portal.ch/en/events/ereignis/construction-of-the-ceneri-tunnel/)

The tunnel was excavated through varying geological conditions and fault zones. Rock support and excavation shape were adjusted depending on the conditions. In areas located in stable rock formations a flat tunnel invert with a few short radial rock bolts and a thin shotcrete lining were required. Sections with intermediate fault zones were advanced using curved inverts, steel ribs in the crown, rock bolts in the tunnel walls and thick shotcrete lining. In areas located in the most severe fault zones the tunnel was excavated with a circular invert and supported with steel ribs in the crown and invert, with many long rock bolts and a thick shotcrete lining.

The lesson learned from the Ceneri Tunnel project is that drill & blast methods can be used for long tunnel excavations and these allow for flexibility regarding tunnel size, shape and support installation to address varying ground conditions and size requirements.

4.6 Busan-Geoje Link

The Busan-Geoje fixed link in South Korea connects the City of Busan on the south coast with the island of Geoje (**Figure 4-11**). The dual two-lane road link has a total length of 8.2 km and consists of a 3.2 km long ITT along with two cable-stayed bridges (total of 3.6 km) and short rock tunnels excavated on two islands along the alignment.

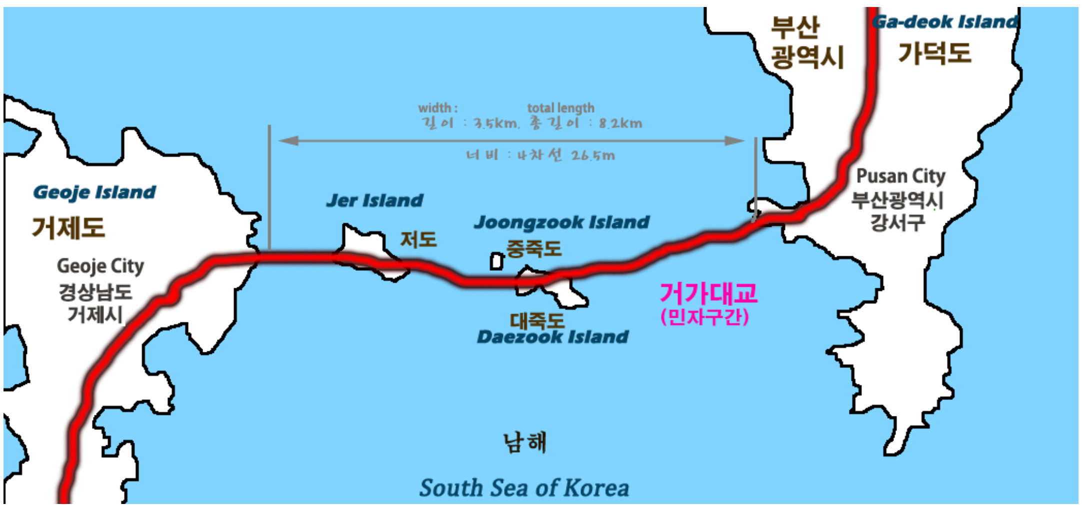


Figure 4-11: Busan-Geoje Fixed Link Location in South Korea
(https://en.wikipedia.org/wiki/Busan%E2%80%93Geoje_Fixed_Link)

The immersed tunnel consists of 18 segments with an average length of 180 m. Crossing the strait at a depth of up to 48 m below mean sea level, the Busan-Geoje ITT was the world's deepest immersed vehicle tunnel when it opened in 2010, becoming the second deepest with the opening of the Marmaray rail tunnel (see section 4.7) in 2013.

Furthermore, two cable-stayed bridges are included in the Busan-Geoje fixed link (**Figure 4-12**). The main two pylon cable-stayed bridge has a 475 m central span and 230 m side spans; the pylons have a height of 156 m with 52 m of navigational clearance; the smaller three pylon cable-stayed bridge has two central spans of 230 m and 106 m side spans with pylons of 102 m height and 36 m clearance. Pre-cast caisson foundations were placed at water depths of 30 m.

Figure 4-12: Busan-Geoje Fixed Link Bridges
(http://www.ipernity.com/doc/303473/41396014)

Lessons learned from this project are that ITT constructions at greater water depths (>50 m) and in challenging environmental conditions are becoming more feasible. Project challenges included the extreme weather conditions along the strait such as typhoons and huge swell waves which can create fluctuating pressure around the immersed tunnel with hydrostatic pressure of 65 m. In addition, the region's high seismicity had to be addressed in the design of the tunnel element joints. To improve the soil conditions below the immersed tunnel, a mixture of ground replacement, sand compaction piles and cement deep mixing was used to stabilize the soil down to 65 m below sea level.

Innovations on the project included an External Positioning System (EPS) comprising two hydraulic sea-legs that can grip an immersed tunnel segment and 'walk' across the sea floor which allowed the operator to position the segment to an accuracy of a few millimetres. Steel bulkheads instead of concrete bulkheads were used to seal the tunnel segments which allowed for significant time savings during removal of the bulkheads.

4.7 Marmaray Tunnel

The Marmaray link is a rail transportation project in Turkey connecting Asia and Europe below the Bosphorus Strait (**Figure 4-13**).

The project includes 13.6 km of tunnel sections including a 1.4 km long ITT (see **Figure 4-14**). The two-tube rail tunnel was installed in water depths of up to 58 m below sea level, which to date makes the Marmaray ITT the world's deepest immersed tunnel. Project challenges included the high seismicity in the area.

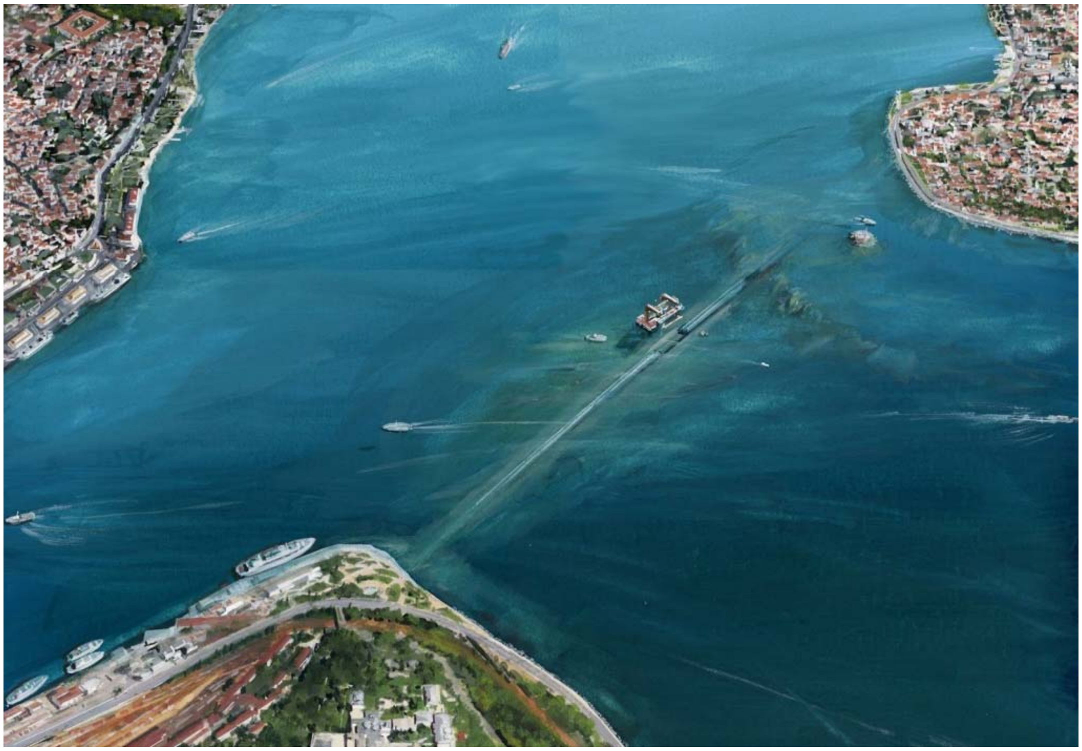


Figure 4-13: Marmaray ITT Location at the Bosphorus Strait in Turkey
(http://howtoistanbul.com/en/opening-of-the-marmaray-project-on-the-republics-90th-anniversary/10398)

As shown in **Figure 4-14**, the immersed tunnel consists of 11 prefabricated segments with lengths ranging between 100 m and 135 m. Due to the proximity of the project site to an active fault, the tunnel segments and the joints between the segments were designed and built to withstand high magnitude earthquakes.

The construction time for the ITT was approximately 4.5 years (2004 to 2008); archeological discoveries caused multiple project delays. The rail link was opened in 2013.

Lessons learned from this project are that ITT construction in difficult environments, including great water depths and high seismicity, are becoming technically feasible; however, they require costly construction measures. The chances that the new tunnel will be impacted by a 7.0 earthquake within the next 30 years were estimated to be 77%. The measures to address seismic impact included compaction grouting of the silty soil below the ITT down to 24 m below the sea bed to prevent liquefaction of the soil. In addition, each tunnel segment was designed to deform and the joints between rock tunnels and ITT were sealed with massive rubber and steel gaskets allowing the structure to shift without breaking. Floodgates at both ITT ends were installed to isolate the ITT section and prevent flooding of the rock tunnels during a major earthquake event.

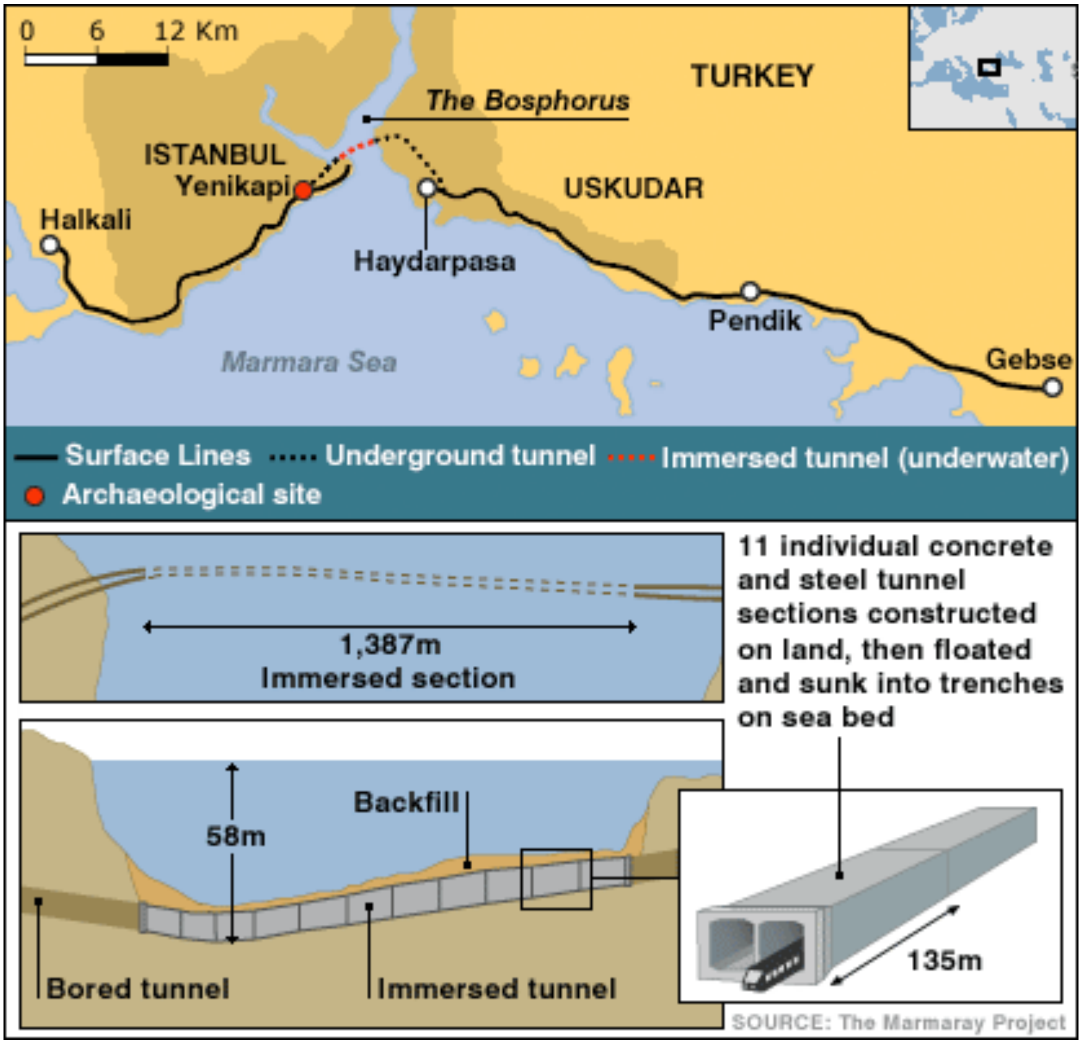


Figure 4-14: Marmaray ITT Fixed Link Construction Concept
(http://news.bbc.co.uk/2/hi/europe/4949862.stm)

Other issues that had to be addressed during construction of the ITT included environmental issues (such as impact of dredge spill on fish migration through the Bosphorus Strait, noise impact on marine life and disposal of large amounts of contaminated material dredged from the sea floor for the ITT trench), archeological discoveries including numerous structures and artefacts, and the dense marine navigation in the Bosphorus Strait.

The tunnel costs increased due to several years of delays, largely related to archeological findings during excavation that required construction to stop for extended periods of time.

4.8 Fehmarnbelt Tunnel

The Fehmarnbelt fixed link (**Figure 4-15**) between Denmark and Germany is part of the highway and rail system connecting Denmark, Sweden and Germany. Construction start is currently scheduled for 2017 with anticipated completion of the project in 2026. The link will be constructed as an 18 km long ITT between the Danish island of Lolland and the German island of Fehmarn and will be the world's longest ITT.

Figure 4-15: Fehmarnbelt ITT Location between Denmark and Germany
(https://spfaust.wordpress.com/2011/02/02/the-significance-of-another-big-tunnel/)

The tunnel will be constructed using the same method as was used for the construction of the Øresund tunnel between Denmark and Sweden that was completed in 2000 (refer to 2004 Pre-Feasibility Study [1]) and will comprise a four-lane motorway and two electrified rail tracks (**Figure 4-16**). The roadway will allow a travel speed of 110 km/h while electric trains will be able to travel at 200 km/h, reducing the travel time between Denmark and Germany to 10 min by car and 7 minutes by train.

The immersed tunnel will consist of 79 standard elements, each with a length of 217 m, and 10 special elements with an additional lower floor for machinery. These special elements will be installed every 2 km along the alignment and allow for easier maintenance of the individual tunnel sections once the tunnel is under operation. Each element has a width of 42 m and comprises two tubes for the roadways as well as two tubes for the rail tracks. The tunnel elements will be installed in a 10 to 15 m deep trench with a maximum depth of 40 m below sea level.

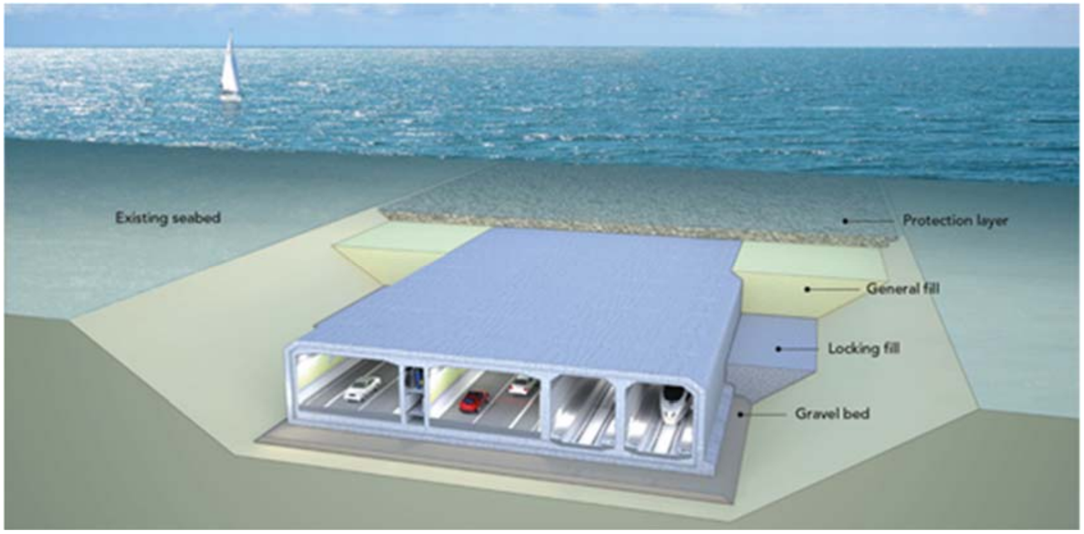


Figure 4-16: Fehmarnbelt ITT Construction Concept
(http://www.israscan.com/transport/)

Although comparable in length with the Strait of Belle Isle fixed link, the water depth in the Fehmarn Strait is significantly lower and the environment less hostile compared to the conditions in the Strait of Belle Isle.

4.9 Other Fixed Link Projects

Currently under construction is the approximately 5.6 km long ITT that is part of the Hong Kong-Zhuhai-Macau Fixed Link project. The immersed tunnel comprises 33 elements installed in water depth of approximately 40 m.

Also under construction is the 36 km long Sheikh Jaber Al-Ahmad Al-Sabah Causeway which spans across Kuwait Bay between Kuwait City and the Subiyah area. The project includes the construction of a 27 km long low-level bridge across the bay, a main bridge with a span of 200 m, an elevated road, and a 5 km approach road onshore in Subiyah. The causeway crosses two artificial islands on its route. The project comprises over 1500 piles that are installed up to 72 m into the loose clay seabed in water depth between approximately 5 and 23 m. The bridges will be between 9 and 23 m above sea level.

Currently in the pre-construction stage is the Rogaland Fixed Link project in Norway (**Figure 4-17**). The proposed 27 km long Rogfast twin tube tunnel with an inner width of 8.5 m is planned to be excavated by traditional drill & blast technique at a record maximum depth below sea level of up to 390 m. The Ryfast tunnel system (**Figure 4-17**), which is currently under construction in Norway, is an approximately 20 km long subsea twin-tube tunnel system (including the Ryfylke Tunnel with 14.3 km and the Hundvåg Tunnel (completed) with 5.5 km) with two lanes per tube that is also excavated by drill & blast. The inner tunnel diameter of the Ryfast tunnels are approximately 8.5 m and 9.5 m respectively. These road tunnels will reach a maximum depth of up to 290 m (Ryfylke) and 95 m (Hundvåg) below sea level. Financing of the Ryfast tunnels will be mostly by toll income.

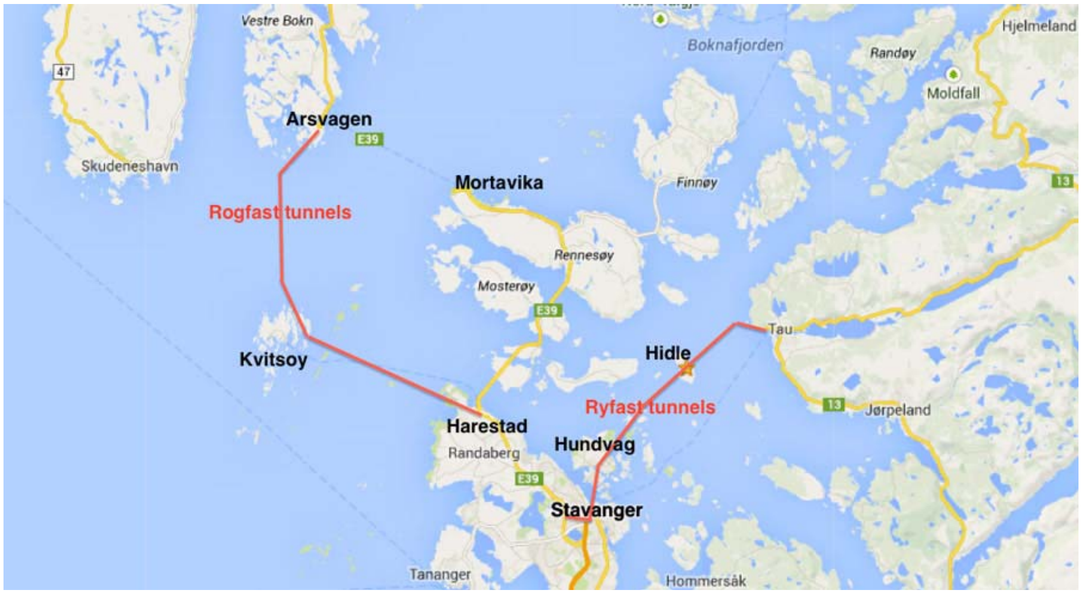


Figure 4-17: Rogfast Tunnels and Ryfast Tunnels in Norway
(https://www.tunneltalk.com/Norway-16Oct2013-World-record-subsea-Rogfast-highway-tunnel-moves-towards-final-design.php)

4.10 Experience from Recent Relevant Fixed Link Projects and Implications for Strait of Belle Isle Fixed Link

In the following **Table 4-1** the relevant recent fixed link projects are summarized:

Table 4-1: Summary of Recent Fixed Links

Fixed Link	Eurasia Tunnel	Follo Tunnel	Gotthard Base Tunnel	Eiksund Tunnel	Ryfast Tunnels	Ceneri Base Tunnel	Busan-Geoje Link	Marmaray Tunnel	Fehmarnbelt Link
Type	Rock Tunnel	Rock Tunnel	Rock Tunnel	Rock Tunnel	Rock Tunnels	Rock Tunnel	ITT, Cable-Stayed Bridges	ITT	ITT
Excavation Method	TBM, partly Drill & Blast and cut and cover	TBM; partly Drill & Blast	TBM; partly Drill & Blast	Drill & Blast	Drill & Blast	Drill & Blast	n/a	n/a	n/a
Crossing Length	5.4 km (3.4 km TBM; 1 km Drill & Blast)	Two tubes with 20 km each (18.5 km TBM; 1.5 km Drill & Blast/Split)	Two tubes with 57 km each	7.8 km	Two tubes with 14.3 km each (Ryfylke) and 5.5 km each (Hundvåg)	Two tubes with 15.4 km each	3.2 km ITT (total fixed link 8.2 km)	1.4 km ITT (total fixed link 13.6 km)	18 km
Excavation Cross Section	13.7 m Ø	10 m Ø	8.8 / 9.6 m Ø; up to 13.1 m for Drill & Blast	10 m width	Approx. 8.5 m and 9.5 m width	Approx. 8.7 m width (typ)	n/a	n/a	n/a
TBM Type	Mixed Shield	Double Shield	Open Face Gripper	n/a	n/a	n/a	n/a	n/a	n/a
Max Depth Below Sea Level	106 m	n/a	n/a	287 m	290 m and 95 m	n/a	48 m	58 m	40 m
Ground Cover	Variable	Variable	Up to 2450 m	50 m minimum	50 m minimum	Few m to 900m maximum	n/a	n/a	n/a
Road	✓	--	--	✓	✓	--	✓	--	✓
Rail	--	✓	✓	--	--	✓	--	✓	✓
Status	In use since 2016	Under construction	In use since 2016	In use since 2008	Under construction	Excavation completed in 2016; opening planned in 2019	In use since 2010	In use since 2013	Pre-construction (opening planned in 2026)
Vehicles per day (vpd)	100,000[2)]	n/a	n/a	2,880 (in 2014)	8,000 and 25,000 by 2035[2)]	n/a	[1)]	n/a	9,500[2)]
Cost CAN$ (2017)[3)]	1.5 Billion	[1)]	16.5 Billion	105 Million	780 Million[2)]	3.25 Billion[2)]	1.1 Billion	5 Billion	13 Billion[2)]

1) Information not available
2) Forecast/Estimate
3) Approximate cost estimates based on cost information available online

4.10.1 TBM Tunnels

There have been significant technological advances in mechanized tunnelling using TBMs over the recent years to successfully extend the use of TBMs to a wider range of ground conditions, improve safety and achieve higher advance rates. The challenge of mixed ground conditions has been addressed with technological developments such as the dual mode machines that can be adjusted to varying ground conditions.

The construction of a 4.8 km long intake tunnel at Lake Mead in the United States is an example of the successful use of a dual mode tunnelling machine. The rock in the project area contained alternating layers of hard rock and conglomerates as well as fault zones and required a hard rock TBM that could be converted rapidly from an open-face machine to a slurry machine with a closed pressurised face that could withstand hydrostatic pressures of up to 17 bar. During tunnelling, actual pressures of 15 bar were encountered. Successful sub-sea tunnel excavation under high hydrostatic pressures of 12 bar using a Mixed Shield TBM was also achieved at the Eurasia tunnel. A further significant advancement for safe TBM tunnelling is the remote cutterhead monitoring and replacement system that was implemented at the Eurasia Tunnel. This system monitored the cutterhead and tool conditions using sensors and cameras installed at the cutterhead. Replacement of cutter tools could be carried out from inside the cutterhead without the need of human exposure to pressurized conditions in front of the cutterhead.

To date, the longest and deepest rail tunnel is the Gotthard Base Tunnel with a total length of 57 km per tunnel tube, of which individual sections of 7 to 14 km length were excavated by TBM. The ground cover above the tunnel varies between approximately 500 m and 2,450 m. The excavation with an open face TBM and subsequently installed rock support (mostly rock bolts and shotcrete; steel arches and pre-grouting in difficult rock conditions) managed various challenges including difficult ground conditions, large fault zones, high pressure from the overlying rock cover and rock deformations of up to 0.7 m. Average advance rates (excluding downtime) between 12 and 18 m per work day were achieved in the Gotthard Base Tunnel, with maximum performances of up to 56 m within 24 hrs. The advance rates of the TBM currently excavating the Ryfast Tunnel are on average approximately 12 m to 15 m per day.

4.10.2 Drill & Blast Tunnels

Drill & blast tunnels (such as the Eiksund Tunnel) have continued to be implemented successfully in deep sub-sea conditions at depth of currently up to 287 m below sea level under high hydrostatic pressures. Many of these tunnels have great lengths such as the 20 km long Ryfast tunnels that are currently under construction. Measures such as probe drilling and pre-excavation grouting to control groundwater inflows and improve the stability of the surrounding rock have been in use successfully for many years and the rock support and reinforcement technology has developed to better address the issue of corrosion caused by aggressive environments such as exposure to sea water.

The proposed Rogfast Tunnel as part of the Rogaland Fixed Link project in Norway is planned to be excavated by traditional drill & blast technique. The tunnel will set a new record for the longest and deepest drill & blast sub-sea tunnel with a length of 27 km and a maximum depth of 390 m below sea level.

Drill & blast methods have also been used successfully for long tunnels with great rock cover, such as the Ceneri Base Tunnel, as well as in challenging rock conditions, as encountered on the up to approximately 8 km long sections of the Gotthard Base Tunnel. Average advance rates in favourable rock conditions between 3 m and 4.5 m per work day were achieved in the Gotthard Base Tunnel, with maximum performances of up to 11.5 m within 24 hrs. Average advance rates in unfavourable conditions were approximately 1 m per work day.

4.10.3 Immersed Tube Tunnel (ITT)

The technology for ITT installations at greater depths and in challenging environments has developed over the past years. However, to date, no ITT has been constructed in water depths greater than approximately 60 m which is still significantly shallower compared with the over 100 m water depth at the Strait of Belle Isle.

The longest ITT to date is the approximately 5.6 km long immersed tunnel that is installed approximately 40 m below the water level as part of the Hong Kong-Zhuhai-Macau Fixed Link project. This length is still significantly shorter than the Strait of Belle Isle crossing with its minimum length of approximately 20 km. The Fehmarnbelt ITT with a comparable length of 19 km is yet to be built; however, it has to be noted that experience that will arise from the construction of the Fehmarnbelt ITT will be related to a significantly shallower water depth and a less hostile environment at the project location.

No ITT project to date has been executed in an area known for iceberg movements and had to be designed to withstand iceberg pitting and scour. Hence, no relevant experience from previous projects can be related to the Strait of Belle Isle Fixed Link. The risk associated with the construction of an ITT Fixed Link across the Strait of Belle Isle is still considered significant.

A detailed assessment and cost estimate for the ITT option was provided in the Pre-Feasibility Study in 2004 [1] and [2]. Overall, the scheme for the construction of an ITT fixed link remains the same as described in the 2004 study. However, due to the recent installation of the HVDC cable crossing on the sea floor between Forteau Point (Labrador) and Shoal Cove (Newfoundland), the dredging of a trench for the ITT installation on the bottom of the Strait between Point Amour and Yankee Point would interfere with the cable crossing and, hence, the alignment of the ITT would have to be changed. Since the Strait has its narrowest width between Point Amour and Yankee Point, a relocated alignment would inevitably result in a longer tunnel crossing, causing significantly higher costs. In addition, an alignment further east would place the ITT into shallower waters and would increase the risk for iceberg impacts.

Difficulties during trenching of the sea floor for the installation of the tunnel tubes will arise from the lack of overburden and the various steep bedrock scarps and offsets of up to 30 m height that are located across the Strait and trend perpendicular to the proposed alignment.

Since an ITT fixed link is not considered the preferred option for the Strait of Belle Isle, no further update of the previous assessment has been carried out for this study.

4.11 Outlook

A new technology currently under investigation for passenger and freight transportation is the Hyperloop, a mode of transportation that involves a sealed tube system in which travelling would be possible without friction or air resistance. Several potential above-ground routes as well as tunneled routes, for example a 500 km long connection between Stockholm and Helsinki passing under the Baltic Sea, have been proposed or are presently in an early stage of pre-feasibility studying, mostly for mid-range distances of some hundreds of kilometers. However, so far, no Hyperloop route has been implemented. Currently, the technology focusses on fast and energy efficient mass transportation, which is not the primary focus for the Strait of Belle Isle Fixed Link. However, going forward, the ongoing development of the Hyperloop concept could in the future provide a feasible transportation mode also for shorter, less frequented routes.

The developing technology of Automated Vehicles (AV) and Connected Vehicles (CV) will lead to new requirements for road and tunnel infrastructures. CVs are equipped with devices that allow the connection with other devices inside the vehicle or with devices, networks or services outside the vehicle, including, for example, other vehicles or infrastructures. Connected car features can have different functions such as safety, navigation or infotainment. Most newer generation vehicles possess some form of connection which is typically used to assist the driver to enhance safety and navigation. AVs, however, are defined as self-driving or driverless vehicles that detect their surrounding environment using artificial intelligence, sensors and global positioning systems and that make their own decisions about how to act rather than being controlled by a driver. In Canada as well as in many other countries, the technology of self-driving vehicles is currently in a stage of testing and does not yet serve the mass market. However, as the technology advances, self-driving vehicles are likely to become more and more frequent on the roads, resulting in the requirements for road and tunnel infrastructures to be equipped with the necessary technology to serve these vehicles.

It should be noted that large scale adoption of electrically powered vehicles would significantly reduce the ventilation requirements for road tunnels during normal operations.

5. Summary of Relevant Investigations and Studies since 2004

Several investigations, including offshore and onshore field investigations as well as desktop studies, have been performed in the vicinity of the project area since 2004. Most of these were related to the HVDC cable crossing of the Strait of Belle Isle as part of Nalcor Energy's Lower Churchill Project. Available information from these investigations were used to update the assumptions and background information used in 2004. **Figure 5-1** and Figure A1 in Appendix A provide an overview of the borehole locations drilled during previous geotechnical investigations.

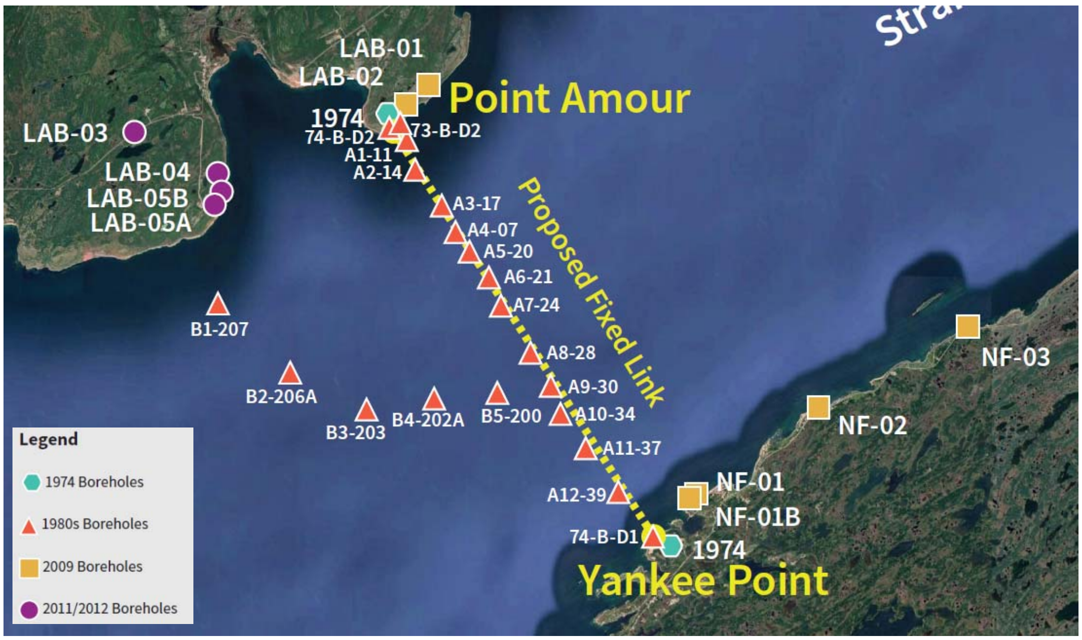


Figure 5-1: Borehole Locations near the Fixed Link Project Location

5.1 Onshore Field Investigations

2009 Geotechnical Investigation: The geotechnical investigation carried out by SNC-Lavalin (SNC) in 2009 comprised six inclined boreholes, drilled from shore into the basement rocks underneath the Strait of Belle Isle, to investigate the subsurface conditions for a potential HVDC cable tunnel across the Strait [10] to [13]. Two holes were drilled on the Labrador side of the Strait (borehole lengths of 540 m and 170 m); four holes were advanced on the Newfoundland side (borehole lengths of 71 m, 890 m, 955 m and 146 m). Packer tests were carried out in all holes to investigate the permeability of the rock. In addition to the drilling, seven test pits were excavated at Point Amour to determine the overburden thickness and bedrock surface elevation. The SNC-Lavalin borehole data was supplemented by an evaluation of the rock conditions by Landsvirkjun Power/Mannvit Engineering (Landsvirkjun) [9].

2011/2012 Geotechnical Investigation: The geotechnical investigation carried out by AMEC in 2011 and 2012 included drilling of four boreholes at Forteau Point on the Labrador side of the Strait of Belle Isle [19]. In addition to the drilling, 42 test pits were excavated at Forteau Point to determine the composition of the overburden material for future construction work.

2011/2012 HDD Pilot Bore Investigation: A horizontal directional drilling (HDD) pilot bore investigation was carried out by Hatch in 2011 and 2012 near Shoal Cove, Newfoundland, comprising a 251 mm diameter inclined pilot hole drilled approximately 1,558 m from the shore into the bedrock below the Strait of Belle Isle and subsequent reaming of the upper 326 m of the pilot bore to a diameter of 610 mm (refer to [21]).

5.2 Offshore Field Investigations

2007 Geophysical Survey: A high resolution acoustic survey was carried out by Fugro Jacques Geosurveys Inc. (Fugro) to characterize bathymetric and seafloor conditions along potential cable routes across the Strait of Belle Isle [4].

2009 Geophysical Survey: A 2D seismic survey was carried out by Fugro to define sub-surface bedrock structures along a possible subsea cable tunnel route [15].

2011 Geophysical Investigation: A geophysical survey was carried out by Fugro including nearshore and offshore geophysical surveys and general visual inspections of the proposed HDD exit location at Forteau Point, Labrador [20].

5.3 Desktop Studies

2008 Data Compilation Study: Fugro prepared a compilation of existing geophysical and environmental data relevant to a proposed seabed HVDC power transmission corridor across the Strait of Belle Isle [3]. The purpose of the study was to characterize physical and environmental conditions in the Strait that could affect the proposed subsea cable installations, and to identify potential human and environmental constraints to cable route design and planning.

2009 Desktop Study of Bedrock Conditions: Fugro prepared a study describing the current geological knowledge in support of a continuous bedrock micro-tunnel crossing of the Strait of Belle Isle, using the information from drilling campaigns at Point Amour and Yankee Point in 1973 and 1974, and from the1981 drilling campaign executed by Beaver Dredging Company Ltd. [8].

2010 Conceptual Design for Cable Crossing: A conceptual design report was prepared by Hatch Mott MacDonald for the Strait of Belle Isle cable conduit option [17].

2010 Feasibility Study for HDD Cable Crossing: A feasibility study was carried out by Hatch for the installation of onshore cable conduits using horizontal directional drilling (HDD) [18].

6. Physical Environment at the Strait of Belle Isle

Since the preparation of the previous Pre-Feasibility Study in 2004, new information regarding the project site environment has been collected. Updates on the data included in the 2004 study are provided in the following sections. Information provided in the 2004 study is repeated only where it was deemed required for the understanding in context with the new information.

6.1 Climate Data

Long-term data for Climate Normals and Averages was available from the Government of Canada, Environment and Natural Resources [30] for the time period between 1981 and 2010, collected at the weather stations at Flower's Cove (Newfoundland) and Lourdes-de-Blanc-Sablon (Québec) as the nearest stations to the project site. The relevant data for these stations is listed in **Table 6-1**. The long-term data from the Blanc-Sablon station including the most recent data up to 2014 shows that most of the monthly extreme high temperatures occurred in recent years, whereas the occurrence of monthly extreme low temperatures has become less likely, indicating that overall the temperatures show a rising trend. Only few occasions with temperatures below -30°C occurred. This is consistent with the observed tendency of reduced sea ice cover in the Strait of Belle Isle in the recent years (refer to Section **6.3**).

Overall, the changes noted in the climate data in comparison to the data available in 2004 are not expected to have a significant impact on the proposed fixed link options.

Table 6-1: Summary of Long-Term Climate Data (1981 to 2010)

		Flower's Cove (Newfoundland)	Lourdes-de-Blanc-Sablon (Québec)
Air Temperature			
Daily Maximum Temperature in Aug [°C]		17.3[2)]	16.6[3)]
Daily Minimum Temperature in Feb [°C]		-15.8[2)]	-16.5[3)]
Daily Average Temperature in Feb [°C]		-11.4[2)]	-12[3)]
Extreme Minimum Temperature [°C]	In February[2)]	-34[2)] (Feb 04, 1995)	-34.1[3)] (Feb 08, 1994)
	In March[2)]	-31[2)] (March 08, 1990)	-32.5[3)] (March 10, 1986)
Precipitation			
Average Total Precipitation per Year [mm]		1039.0[2)]	1021.7[2)]
Extreme Daily Rainfall [mm]		74[2)] (Jun 08, 1995)	88[2)] (Oct 02, 2010)
Extreme Daily Snowfall [cm]		36[2)] (Jan 25, 1982)	41.8[2)] (March 15, 2001)
Wind			
Average Wind Speed per Year [km/h]		Not available	19.6[4)]
Predominant Wind Direction		Not available	W in winter, SW in summer
Maximum Hourly Wind Speed [km/h]		Not available	111 (March 17, 1987, NE)
Maximum Wind Gust Speed [km/h]		Not available	141 (Jan 12, 1987)
Freezing Degree Days (FDD)			
FDD Below 0°C		1148.3[1)]	1424.7[1)]

1) Cumulative Freezing Degree Days (FDD) for at least 15 years of record.
2) For at least 15 years of record.
3) For at least 20 years of record.
4) World Meteorological Organization (WMO) "3 and 5 rule" (i.e. no more than 3 consecutive years and no more than 5 total missing years for either temperature or precipitation).

An updated version of the National Building Code of Canada (NBC) [22] became effective in 2015. The Code provides climate design data for selected locations. On the Newfoundland side of the Strait, the location closest to the project area is St. Anthony; on the Labrador side, the nearby location listed in the Code is Harrington Harbour in Québec. The most relevant climate design data for these locations is summarized in **Table 6-2**. The recent version of the NBC used an annual probability of exceedance of 1 in 50 years instead of the previously used 1 in 100 years in the version in effect in 2004.

Table 6-2: Climate Design Data, National Building Code of Canada (2015)

		St. Anthony (Newfoundland)	Harrington Harbour (Québec)
Minimum Design Air Temperature (January) [°C]	1%[1)]	-27	-29
	2.5%[1)]	-25	-27
One Day Rain [mm] [2)]		86	96
Annual Total Precipitation [mm] [3)]		1280	1150
Snow Load [kPa] [2)]		6.1	4.9
Hourly Wind Pressures [kPa] [2)]		0.87	0.72

1) The 1% and 2.5% values represent percentiles of the cumulative frequency distribution of hourly temperatures and correspond to January temperatures that are colder for 8 and 19 hours, respectively, on average over the long term.
2) Probability of exceedance of 1 in 50 in any one year.
3) Precipitation observations for the 30-year period from 1961 to 1990.

No additional studies regarding icing that were carried out since the 2004 Pre-Feasibility Study were found by Hatch.

6.2 Oceanography

Recent bathymetry data was collected by Fugro in 2007 as part of the subsea cable route survey for the HVDC cable crossing (refer to [4]). The focus of the survey was on the proposed cable route; however, the survey also covered the area of the proposed Strait of Belle Isle fixed link crossing. The bathymetric information for the project area is shown in **Figure 6-1**. The data indicates a wide area of deep water in the mid-portion of the Strait (Central Trough) as well as deep water close to the Labrador shore, with water depths up to 115 m. These deep-water areas are divided by an area of shallower waters (Bank) with water depths less than 75 m. Shallower waters occur also along the shore of Newfoundland. **Figure 6-1** provides the surveyed water depths in the various zones of the Strait of Belle Isle. (Note that the cable route shown in **Figure 6-1** does not present the final location of the cable crossing.)

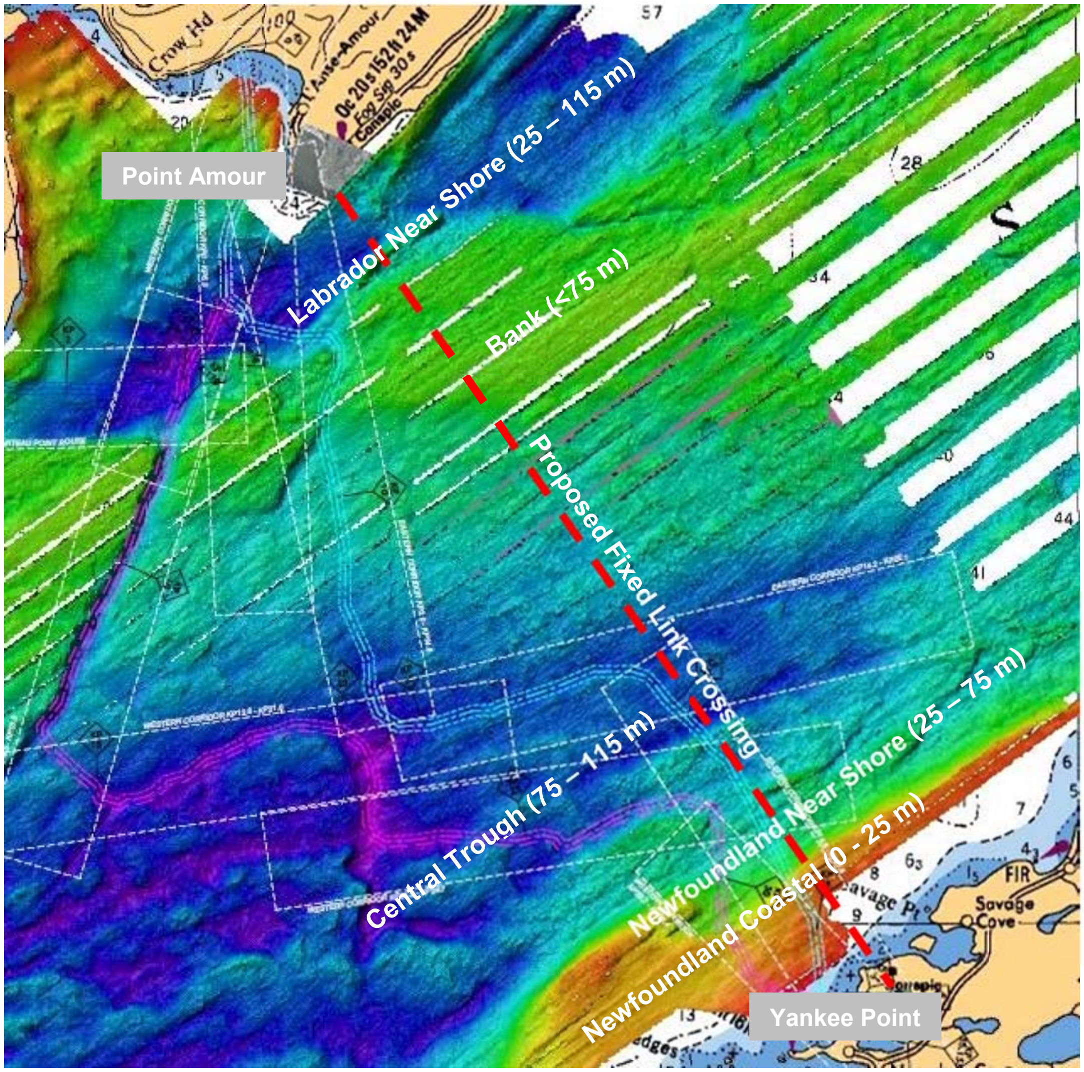


Figure 6-1: Bathymetry Data at Strait of Belle Isle (modified from [4] and [7])

No relevant new information regarding waves and currents in the Strait of Belle Isle became available since the Pre-Feasibility Study in 2004.

6.3 Sea Ice

Statistical data regarding sea ice in the Strait of Belle Isle (Government of Canada, Environment and Climate Change, https://www.ec.gc.ca/glaces-ice ice [29]) provides information about sea ice conditions over the past 30 years. The data for the years 1981 to 2010 indicates that the sea ice cover in the Strait of Belle Isle can last until the end of July and can form as early as mid December. The ice coverage can vary significantly from year to year; however, in general, from 1980/81 to 1994/95, the condition of the sea ice cover were above normal conditions while the condition between 1995/96 and 2009/10 were below normal. The least amount of ice for the period 1981 to 2010 occurred in the winter of 2009/10. However, sea ice conditions vary and extreme conditions with thick sea ice cover have occurred in recent years, such as in 2017.

Figure 6-2 illustrates the minimum (2010) and maximum (1993) extent of ice cover in the Newfoundland and Labrador area encountered on March 1st during the time period from 1981 to 2010.

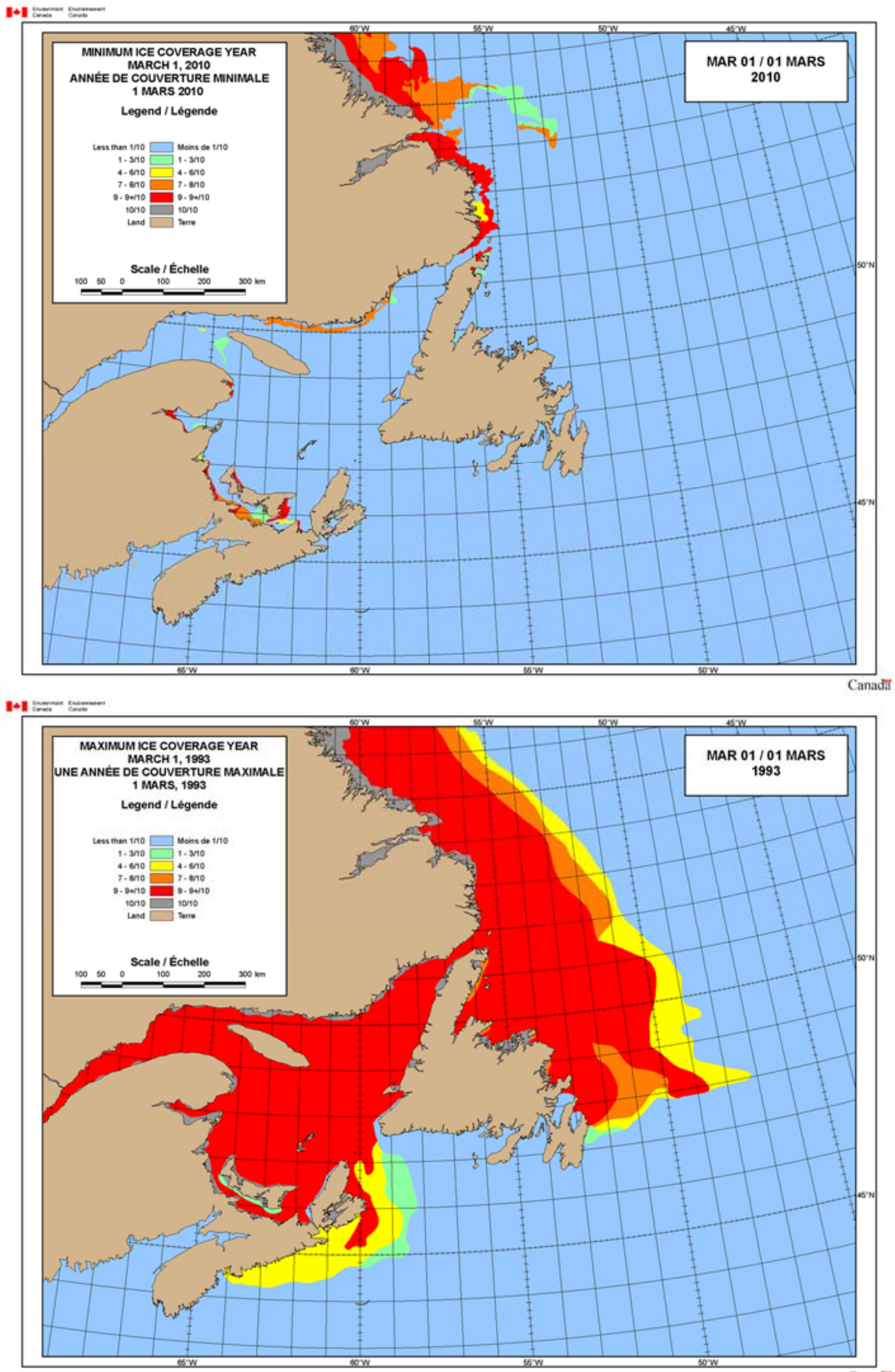


Figure 6-2: Minimum (top) and Maximum (bottom) Ice Cover on March 01 (for the time period between 1981 and 2010) [29]

6.4 Icebergs and Iceberg Scour

Recent information regarding iceberg scour is presented in the investigation report by Fugro [4] pertaining to the subsea cable route survey carried out in 2007. The investigation was commissioned by Nalcor Energy to investigate two proposed subsea HVDC corridors across the Strait of Belle Isle. During this investigation, numerous intersecting iceberg scours were noted on the seafloor in larger water depths (below about 100 m with a transition zone starting at about 80 m depth). These scours were interpreted as having occurred in the past, possibly thousands of years ago. Using the 2007 data, Fugro also interpreted numerous northeast-southwest striking boulder- and cobble-rich berms in water depth greater than 80 m, which were previously understood as glacial Ribbed Moraines, as relict iceberg scours. The absence of these old scour marks in shallower water led to the interpretation that in the past, iceberg scours were confined to greater depths due to different environmental conditions at that time.

In their survey report from 2010 [14], Fugro noted that the seabed in the deep Central Trough has an overall rough texture that was shaped by iceberg grounding and scouring. Iceberg scours were interpreted to align with the dominant currents in the Strait and with the bedrock structure; it was assumed that the bedrock topography could have steered scouring ice keels.

Recent iceberg scour marks were observed by Fugro in water depths up to 77 m on the Labrador side and up to 69 m on the Newfoundland side [4]. **Figure 6-3** shows examples of apparently fresh iceberg scour marks offshore from Forteau Point, Labrador.

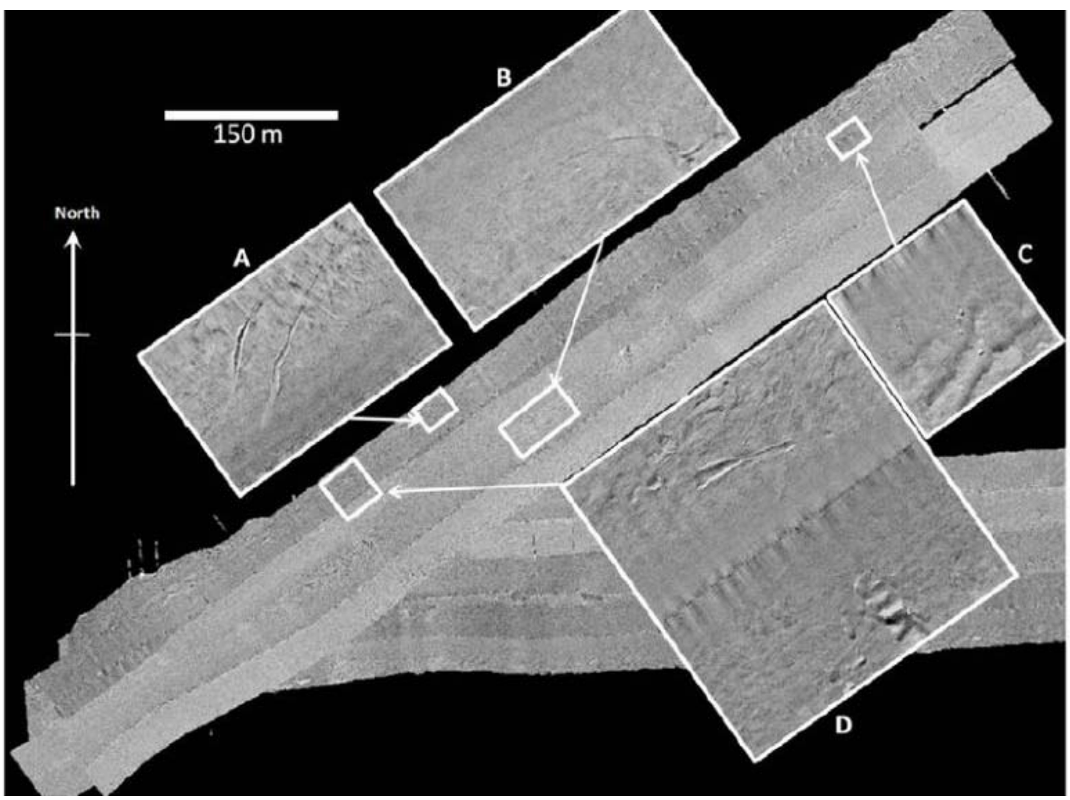


Figure 6-3: Examples of Recent Iceberg Scours near Forteau Point [4]

The depth of these features was typically less than 0.75 m. The longest recent scour mark was noted to be 350 m. Recent scour marks are typically oriented approximately parallel to the Strait. No fresh scour marks were observed in deeper water during the 2007 investigation, which led to the conclusion that icebergs with larger drafts are prevented from entering the Strait of Belle Isle, presumably due to the shoal located east of the project area with water depth up to approximately 75 m.

In the past years, HVDC cable crossing was installed across the Strait between Forteau Point in Labrador and Shoal Cove in Newfoundland as part of the Lower Churchill Project. The cable crossing project included a cable installation in underground conduits onshore and an offshore placement of the cable on the seafloor where the cable was covered with a rock berm for protection against impacts from icebergs and fishery. **Figure 6-4** shows the general cable crossing layout.

Figure 6-4: Location of HVDC Cable Crossing across the Strait of Belle Isle
(www.muskratfalls.nalcorenergy.com [27])

For the exit elevations of the cable conduits and for the required cover of the subsea cables, shielding of the cable crossing route against iceberg scour due to the shallower waters upstream of the project area was considered. Exit elevations for the cable conduits of 70 m below water level on the Newfoundland side and 80 m below water level on the Labrador side were chosen, considering a shielding water depth of 60 m (**Figure 6-5**).

It is assumed that the exit elevations and the height of the rock coverage of the subsea cable were chosen based on the risk assessment carried out by C-Core, as summarized in C-Core's 2007 report regarding ice scour risk (included in the Data Compilation Study by Fugro [3]). In their 2007 risk assessment for various cable crossings, C-Core evaluated shielding effects for the proposed cable routes and considered areas that are shielded from iceberg impact. **Figure 6-6** illustrates the sheltered areas along the proposed routes.

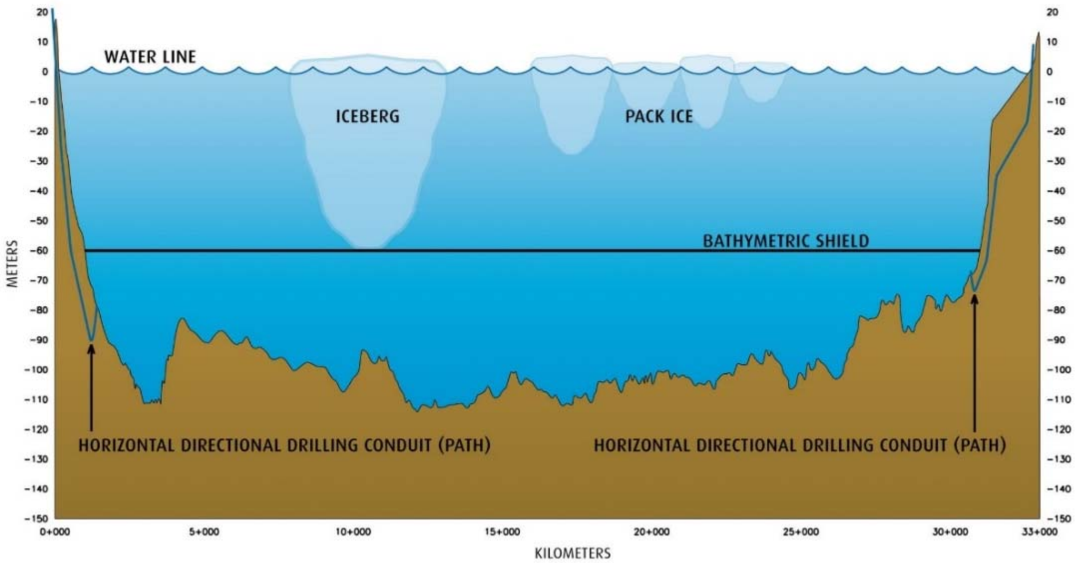


Figure 6-5: HVDC Cable Conduit Exit Depths
(www.muskratfalls.nalcorenergy.com [27])

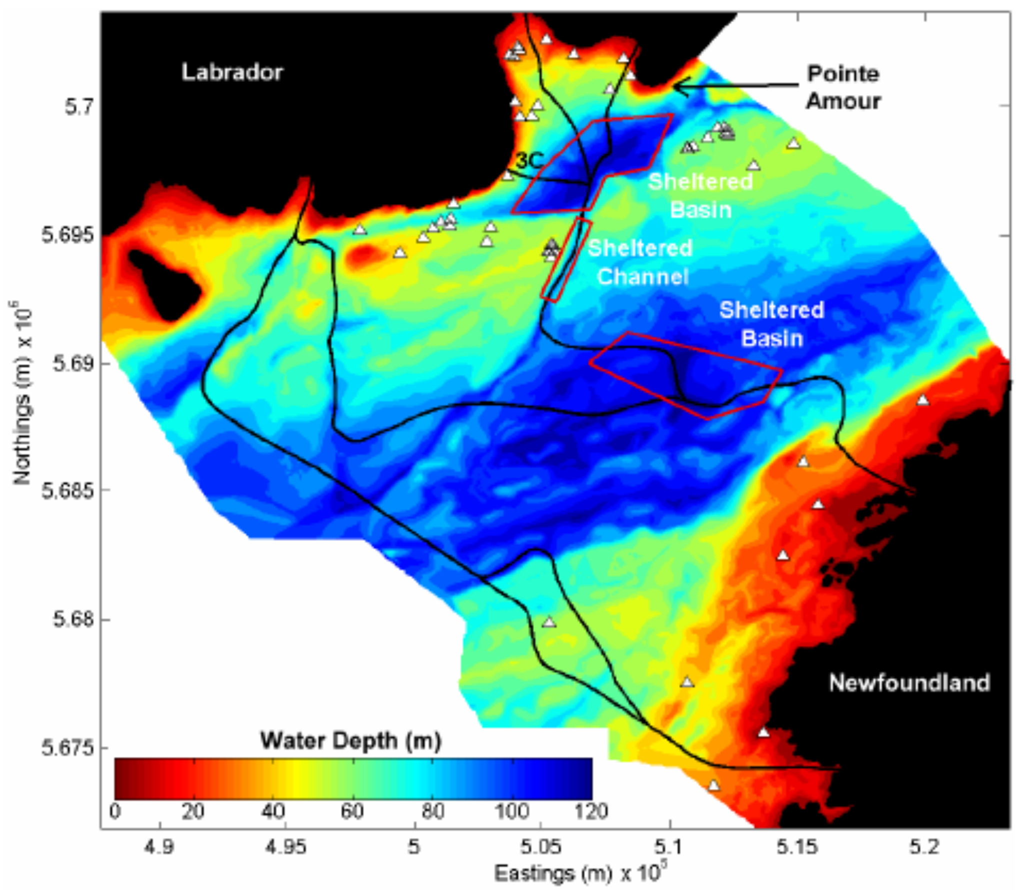


Figure 6-6: Potential Cable Routes and Sheltered Areas (C-Core 2007, included in [3])

No additional information regarding numbers, travel routes or grounding locations of icebergs drifting into the Strait of Belle Isle was available for this study update. However, some news articles from past years indicate that in some years a higher than normal number of icebergs drift into the Strait, such as in 2013 with reportedly 'three to four times more [icebergs] than in the previous five years' (http://globalnews.ca/news/701657/watch-up-close-look-at-icebergs-off-newfoundland/) or in 2017 when by April the amount of icebergs reached a number usually reported over the entire ice season (http://www.citynews.ca/2017/04/28/iceberg-dead-ahead-record-673-icebergs-counted-off-newfoundland/).

6.5 Geology

The bedrock and surficial geology was described in the 2004 Pre-Feasibility Study [1]. Based on the 2004 study by HMM and additional recent studies, such as the study by Fugro [8], a brief overview of the geological setting in the general project area is presented below; the discussion follows largely the geological overview presented in [17].

6.5.1 General Geological Setting at the Strait of Belle Isle

The general geology at the Strait of Belle Isle has been described in the 2004 Pre-Feasibility Study [1] and since 2004 in numerous reports related to the investigations and studies for the Strait of Belle Isle HVDC cable crossing as part of the Lower Churchill Project. A brief general overview is provided below; for a detailed description, the reader is referred to the previous study as well as the report 'Descriptive Overview of Regional Bedrock Geology' [8], prepared by Fugro Jacques Geosurveys Inc. for the HVDC cable crossing project.

The bedrock at the Strait of Belle Isle between Point Amour (Labrador) and Yankee Point (Newfoundland) comprises a vertical succession of sedimentary rock of Cambrian age overlying much older gneisses of Precambrian age (basement rock). The general project area and a geological cross section presented in **Figure 6-7** and **Figure 6-8** (modified from [22]) provide a general overview of the interpreted bedrock stratigraphy underneath the Strait of Belle Isle, showing the Precambrian basement rock (AHn) underlying the gently east to southeast dipping sedimentary rocks. (Note that the Eddies Cove Formation shown in **Figure 6-8** was renamed to the Port-au-Port Group which includes the Formations Petit Jardin, March Point and Berry Head [21]. These formation names were used in the recent geotechnical investigations; however, the Berry Head Formation does not exist in the project area).

The Precambrian basement rocks in the area of the Strait of Belle Isle belong to the Grenville Province and consist of a complex of metamorphic and granitic rocks. On the Newfoundland side, the complex consists of schists and gneisses, cut by several granitic and gabbroic intrusives and by numerous steeply dipping diabase dykes striking north-easterly. On the Labrador side, the complex consists of granite and granodiorite intrusives. Near the project site, the upper basement rocks are deeply eroded and weathered gneisses.

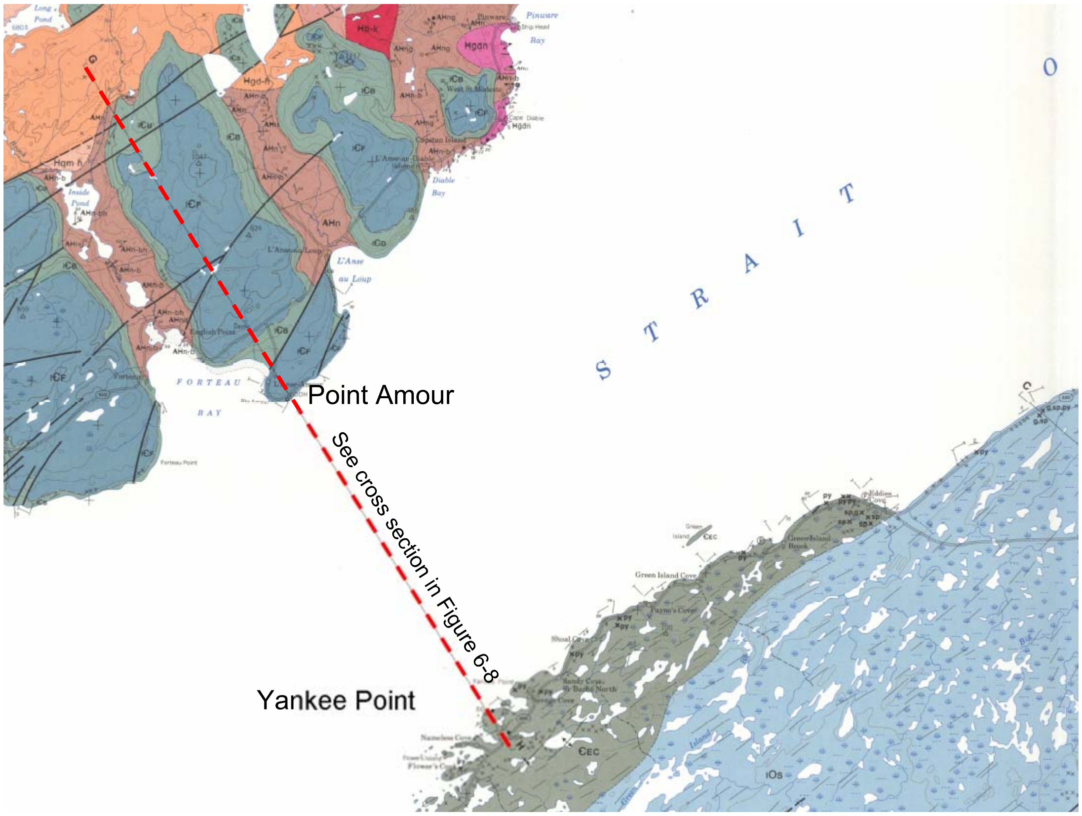


Figure 6-7: Geological Plan View of the Project Area (modified after [22])

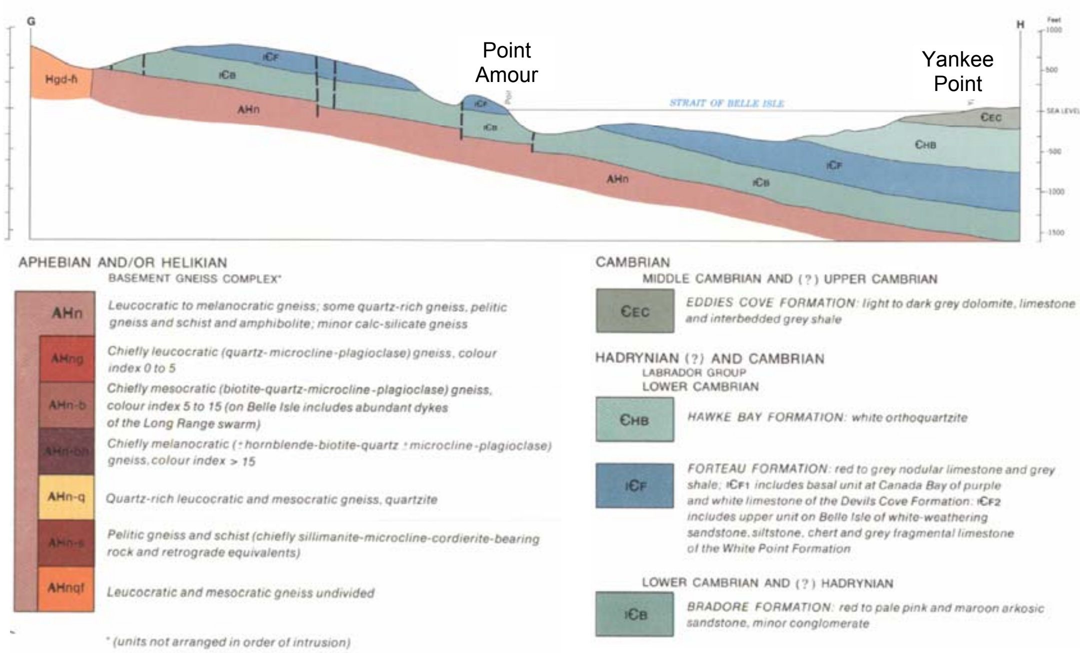


Figure 6-8: Geological Cross Section between Point Amour (A) and Yankee Point (B) (modified after [22])

The sedimentary rock layers overlying the Precambrian basement rock are nearly flat-lying or gently dipping east to southeast and are mainly composed of sandstones, dolomite, limestone and shale. The contact between the sedimentary rock and the Precambrian rock strata is an angular unconformity that occurs approximately 95 m below the Labrador shoreline and approximately 460 m below the Newfoundland shoreline. The contact dips gently southerly but is frequently offset vertically by extensive faulting occurring in the Strait.

Geophysical offshore investigations and visual observations on shore indicate extensive faulting in the sedimentary rock strata and in the Precambrian basement rock. The predominant fault set strikes approximately parallel with the direction of the Strait from north-east to south-west and has vertical offsets in the order of 10 to 40 m which are typical for normal (downwards slip) or reverse (thrust or upwards slip) faults. Less prominent faulting occurs at right angles to the predominant faults. Joint sets generally follow the fault pattern.

A seismic profile across the Strait of Belle Isle between Point Amour and Yankee Point showing the approximate formation boundaries as well as mapped faults is presented in **Figure 6-9**.

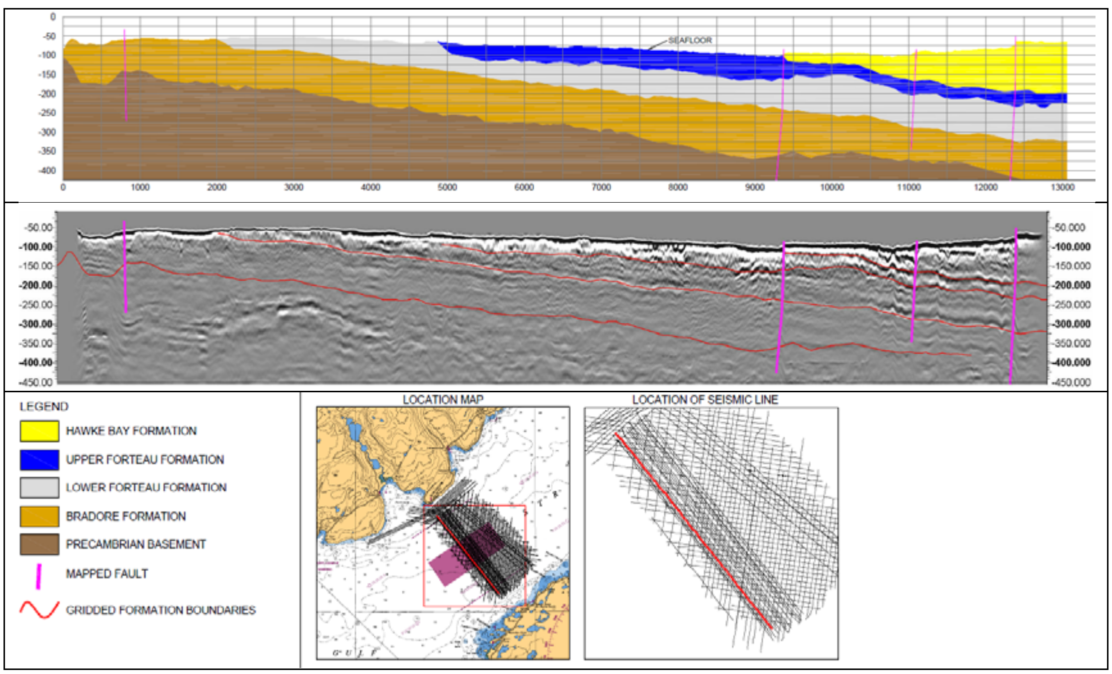


Figure 6-9: Seismic Profile across the Strait of Belle Isle (modified after [15])

The seafloor topography is dominated by the underlying bedrock structure and is gently dipping towards east and southeast. Features such as bedrock outcrops, ridges and channels are frequent and glacial till, erratics and striations are common. The overburden on the seabed is typically shallow and composed mostly of uniformly distributed sand, gravel, cobbles and boulders. In many places, a more recent deposition of a thin layer of shells and shell fragments overlies the soil and bedrock.

6.5.2 Seabed Surface Stratigraphy

An understanding of the surficial geology is needed for an assessment of the immersed tube tunnel concept as well as for the nearshore and offshore excavations for the tunnel approaches. Based on the information presented by Fugro in 2008 [4], prominent seafloor structures identified during recent geophysical surveys included bedrock channels and scarps, moraine ridges and iceberg scour. **Figure 6-10** provides an overview of these features along the route between Point Amour and Yankee Point.

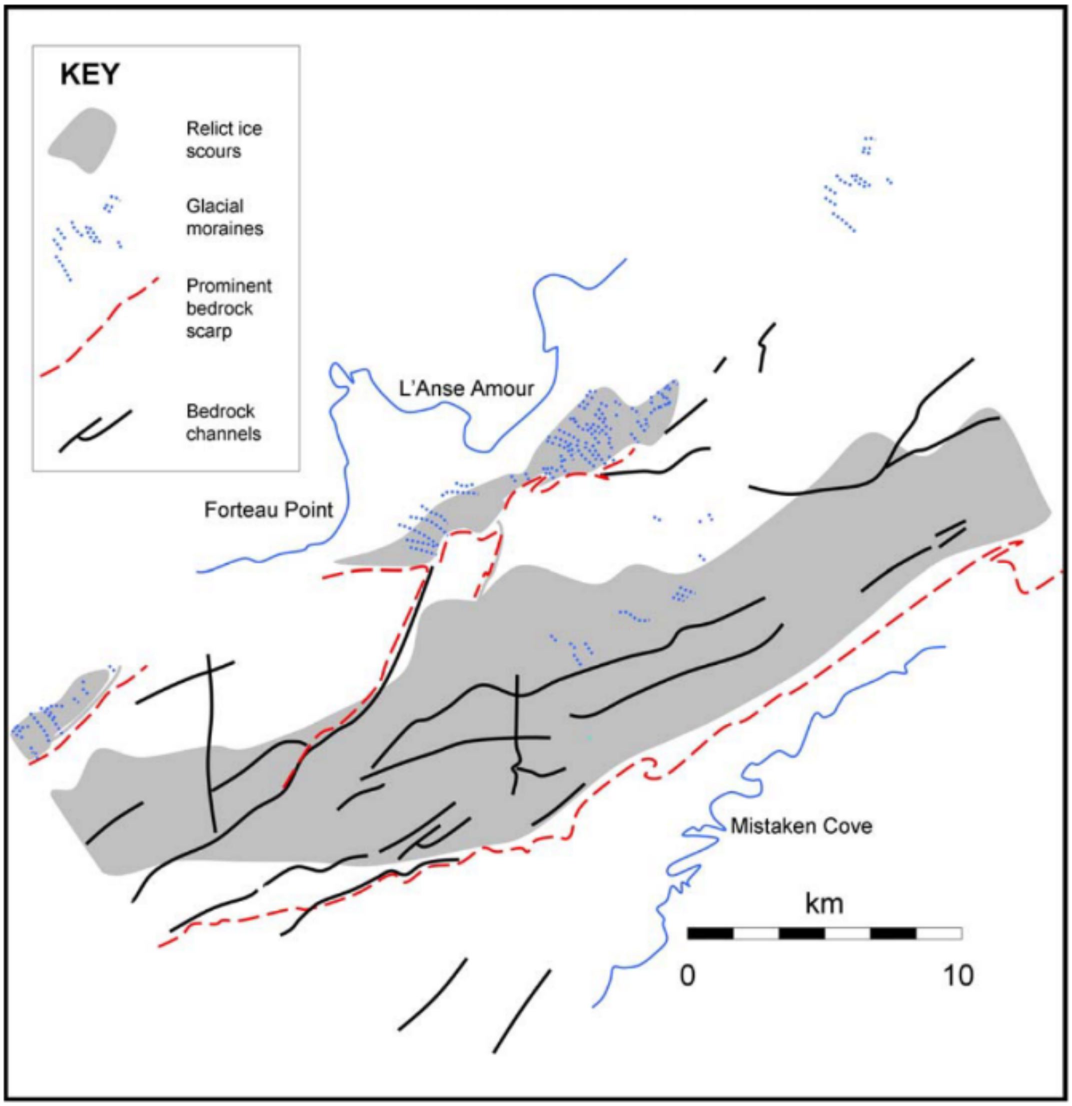


Figure 6-10: Prominent Sea Floor Features in the Strait of Belle Isle [4]

Bedrock Channels and Scarps: A network of bedrock channels was observed on the sea floor which trend approximately northeast-southwest parallel to the Strait [4]. The vertical relief of the channels varied up to 30 m; the channel width ranged from 200 to 500 m. Prominent bedrock scarps were noted off the coastlines on both sides of the Strait, marking the transitions on the Labrador side from the deep near shore water to the offshore bank and on the Newfoundland side from the deep water of the Central Trough to the near shore area.

Iceberg Scour: Iceberg scour and pitting marks were observed across the Strait; however, scours in greater water depths (below approximately 100 m) were all interpreted as relict. Modern iceberg scour marks were identified only in water depths above 77 m. Iceberg scour occurrence is discussed in greater detail in Section 6.4 above.

Glacial Moraines: Various groups of ridge-like features were identified on the bedrock surface [4] that were interpreted as glacial moraines (accumulations of dirt and rocks that have fallen onto the glacier surface or have been pushed along by the glacier as it moves). The spacing between the ridges is typically approximately 250 m; their length was measured up to 750 m with a trend approximately northwest-southeast, almost perpendicular to the relict iceberg scour marks. The ridge crests were noted to be cut by relict iceberg scours, indicating that the ridges are of older age than the scours. Based on the acoustic signals during the geophysical investigation, the ridges appear to comprise massive, compacted sediments. Based on the data from 2007, some features in greater water depth previously interpreted as ribbed moraines were identified to be iceberg scour berms [4].

Seafloor Mounds: Irregular mounds with relief less than 1 m and ranging in width between 10 and 50 m and in length from 50 to 175 m were identified on the sea floor; these mounds were interpreted as concentrations of cobbles and boulders [20].

Sea Floor Sediment: Based on the survey of various cable crossing routes carried out in 2007, Fugro described the seafloor in the survey region in general as a gravelly to bouldery lag deposit with overlying sand ribbons that trend northeast to southwest [4]. The thickness of the overburden on the tunnel route between Point Amour and Yankee Point was investigated in previous investigations, as reported in [8], and ranged from 2 to 4 m, with some areas of exposed bedrock. A maximum thickness of 12 m was noted in isolated areas. **Figure 6-11** shows the overburden thickness and composition identified from drillholes advanced across the Strait in the 1980s. The locations of these drillholes are shown in **Figure 5-1**.

The 2007 survey by Fugro confirmed that most of the sea floor is covered by a thin sediment layer of 1 to 3 m thickness. Areas directly along the proposed Point Amour – Yankee Point fixed link route revealed a typical overburden thickness of less than 1 m, with some areas of 2 to 2.5 m thickness. An isolated area of 4 to 4.5 m thick sediment was noted.

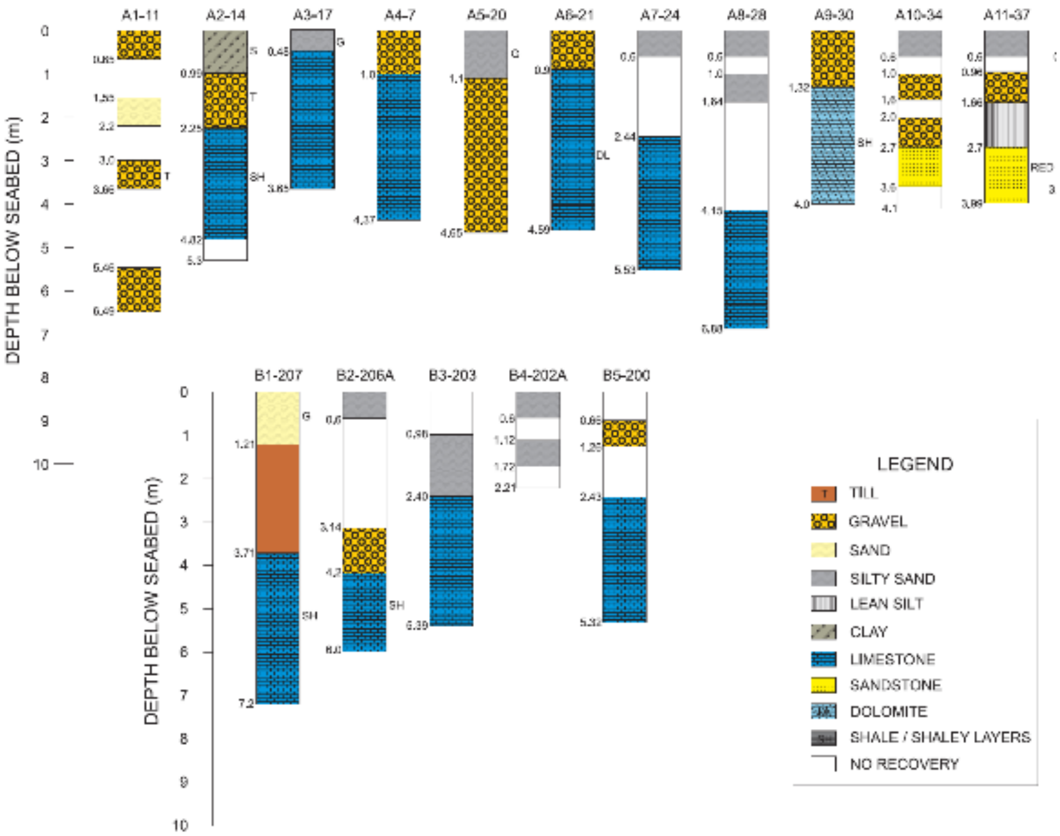


Figure 6-11: Overburden Thickness on Sea Floor identified during 1980s Investigation (included in [4])

6.5.3 *Bedrock Stratigraphy*

The rock units that are relevant for the project location are the gneisses that form the upper part of the Precambrian basement rock and the overlying formations of Cambrian age. These are described from oldest to youngest in the following.

The Precambrian basement complex comprises mafic and felsic intrusive rocks and gneisses that outcrop along the coast, with granitoid intrusions occurring further inland [8]. These rocks are described as granite or granitic gneiss [9], which typically consist of quartz, oligoclase and potassium feldspar, along with biotite, hornblende and orthopyroxene [17]. Based on the available borehole information, the depth to the top of the Precambrian rock is in the range of about 95 m to 110 m on the Labrador side and at about 460 m near the Newfoundland coast.

An unconformity (defined as a gap in the geologic record, representing a time during where no sediments were deposited or as an erosional surface between rocks of significantly different age) with minor relief of 1-2 m separates the Precambrian basement rocks from the cover rocks of the Bradore Formation [8]. The contact was found to be well defined in the 2009 boreholes. The surface of the unconformity is expected to be irregular but overall gently dipping to the south or southeast.

The Precambrian rocks are overlain by a succession of sedimentary rocks of Cambrian age. These rocks are comprised of sandstone, shale, siltstone and carbonates (limestone and dolomite) that belong to two stratigraphic groups: the Labrador Group and the Port au Port Group [17].

The Labrador Group includes the following formations (oldest to youngest):

- Bradore Formation: Dominantly sandstone, but includes minor layers of conglomerate, shale and siltstone. The Bradore Formation was deposited unconformably on the Precambrian surface. The lower section above the unconformity tends to be conglomeratic and includes arkosic sandstones, which yield to cleaner quartz sandstones higher in the formation [17]. Where observed in the available boreholes, the Bradore Formation exhibits a relatively uniform thickness of approximately 100 m along the Labrador coast and slightly thicker at 107 to 112 m along the Newfoundland coast [9]. At the Labrador shoreline and under most of the area of the Strait, the Bradore is overlain by younger sedimentary rocks; however, at the deepest seafloor location in the Strait near the Labrador shoreline, the exposed upper part of the Bradore is eroded and only a partial thickness remains (refer to Drawing H354440-SK-001 in Appendix B).
- Forteau Formation: Dominated by limestone, but includes interbedded shale and minor dolomite and sandstone in the basal part of the formation. Based on the boreholes advanced from the Newfoundland coast, the Forteau Formation is approximately 111 m to 117 m thick. At the Labrador coast, the Forteau Formation occurs at the ground surface, and only a partial thickness ranging between 7 m and 28 m was observed [17]. Formations stratigraphically higher than the Forteau Formation are not observed along the Labrador coast.
- Hawke Bay Formation: Comprised of an interlayered and interbedded mix of quarzitic sandstone, orthoquartzite, shale and dolomite. The lower part of the formation is dominantly quartzite and sandstone, but it becomes more interbedded with shale and dolomite toward the top of the formation. Where the Hawke Bay is observed in boreholes drilled along the Newfoundland Coast, it ranges in thickness from approximately 160 m to 170 m.

The Port au Port Group includes only two formations in the immediate project vicinity which are observed only along the Newfoundland coast. Both formations are dominated by carbonate rocks (limestone and dolomite). These formations are (oldest to youngest):

- March Point Formation: Described by Landsvirkjun [9] as dolomite with thin shaly partings; however, Fugro [8] describes the formation as limestone, dolomitic limestone and dolomite. In the two boreholes where the apparent full thickness of the March Point Formation was observed, the thickness ranges from approximately 31 m to 35 m.
- Petit Jardin Formation: Dominantly dolomite but includes intervals of interbedded shales. Since the Petit Jardin Formation occurs at the ground surface at the borehole locations, only a partial thickness of at maximum 28 m was observed [17].

A brief description of each formation is summarized in the following **Table 6-3**, based on the information provided by SNC in 2009 [10] and summarized by Hatch in 2013 [21]. Considering the proposed tunnel alignment, all the formations identified below will be encountered during the tunnel excavation.

Table 6-3: Bedrock Formations at the Strait of Belle Isle

Age	Group	Formation	Description
Cambrian	Port au Port	Petit Jardin	Light to dark grey dolomite, shale interbeds, shaley dolomite, minor shale, shale partings and laminations
		Marche	Medium to dark grey dolomite, shaley dolomite, shale partings
	Upper Labrador	Hawke Bay	Sandstone with shale interbeds, shale with sandstone interbeds, quartzite, orthoquartzite
		Forteau	Grey limestone, shale interbeds, limestone reef, Devils Cove Member comprising limestone and shale at base
		Bradore	Reddish brown sandstone, grey to pink arkose; unconformity at base
Precambrian	N/A	N/A	Pink to grey crystalline granitic gneiss

The bedrock stratigraphy encountered in the deep boreholes advanced in 2009 from both shores of the Strait is shown in the geological cross sections in **Figure 6-12** and **Figure 6-13** that were developed by Landsvirkjun [9] based on the results from the 2009 investigation. No borehole was drilled at Yankee Point during this investigation; however, the boreholes advanced on the opposite side of Savage Cove and at Shoal Cove indicate a reasonable correlation between the 2009 holes and the borehole carried out at Yankee Point in 1974.

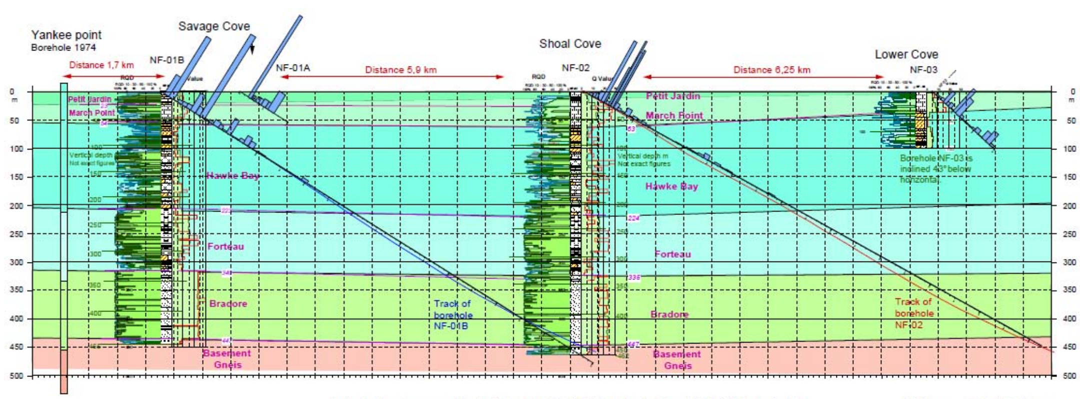


Figure 6-12: Geological Cross-Section between Yankee Point and Lower Cove (Newfoundland), modified from [9]

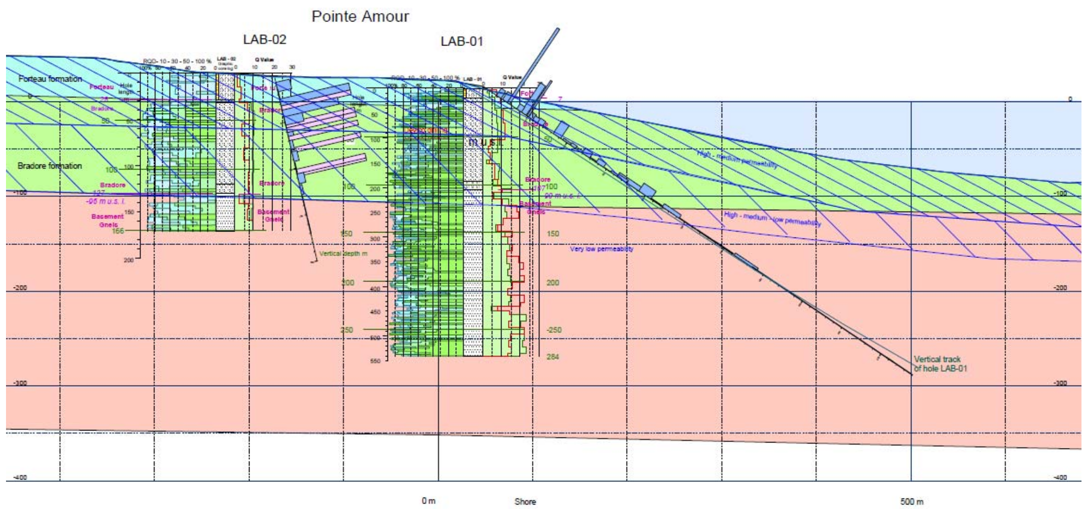


Figure 6-13: Geological Cross-Section at Point Amour (Labrador), modified from [9]

The approximate vertical thickness of each formation in the immediate project area near Yankee Point and Point Amour is summarized in **Table 6-4**, based on the borehole information from 2009. The information for Yankee Point is taken from borehole NF01B at Savage Cove; however, the formation depths identified in borehole NF02 at Shoal Cove are in general accordance with the depth found in borehole NF01B.

Table 6-4: Thickness of Bedrock Formations at Proposed Fixed Link Location

	Point Amour, Labrador[1)]		Yankee Point, Newfoundland[2)]	
Formation	**Depth from Surface (m)**	**Approximate Vertical Thickness (m)**	**Depth from Surface (m)**	**Approximate Vertical Thickness (m)**
Petit Jardin	Not existent on shore	N/A	0 to 23	23 (partial formation thickness)
Marche	Not existent on shore; outcrops offshore	N/A	23 to 54	31
Hawke Bay	Not existent on shore; outcrops offshore	N/A	54 to 223	169
Forteau	0 to 28 Exists only locally on shore	28 (partial formation thickness)	223 to 340	117
Bradore	28 to 96-127	68 to 99	340 to 447	107
Precambrian Gneiss	96-127 (surface of basement rock)	N/A	447 (surface of basement rock)	N/A

1) Borehole LAB 02 (Point Amour) [9]
2) Borehole NF 01B (Savage Cove) [9]

Updated surface contacts between the geologic formations were provided by Fugro [14] based on the 2009 survey data; AMEC [19] summarized the surface contacts at Point Amour during the investigation in 2011/2012. **Figure 6-14** shows the interpreted offshore boundaries between the different bedrock formations near surface across the Strait of Belle Isle as well as on the Labrador shore.

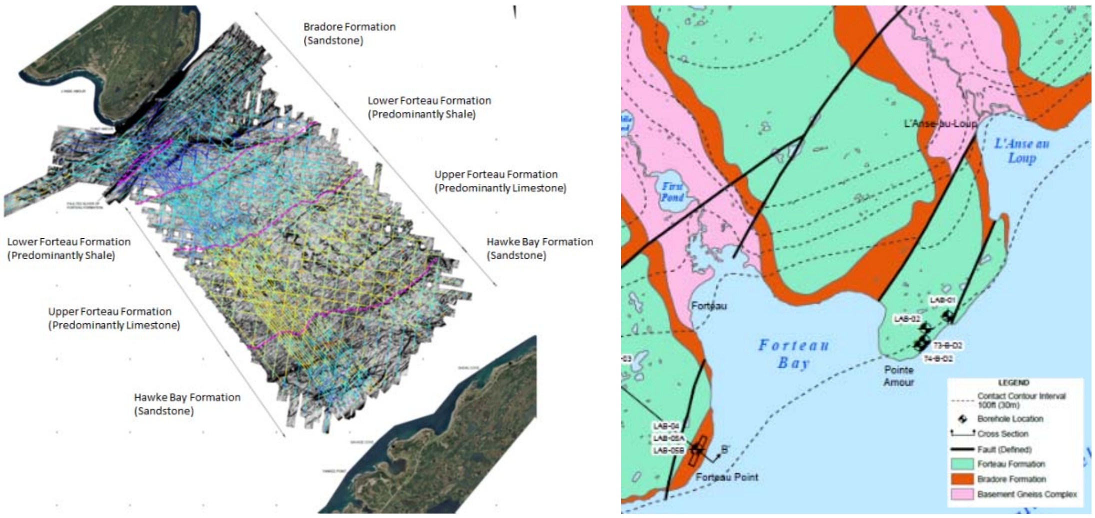


Figure 6-14: Formations Boundaries on Surface; offshore within the Strait [15] (left) and onshore at Point Amour (Labrador) [19] (right)

6.5.4 *Geological Faulting*

Recent information about geological faulting underneath the Strait of Belle Isle was provided by Fugro in the 'Descriptive Overview of Regional Bedrock Geology' based on onshore mapping and a 2007 geophysical survey [8]. **Figure 6-15** shows the inferred locations of faults and formation boundaries in the Strait of Belle Isle that were developed based on mapped onshore faults and stratigraphic boundaries and on offshore structures identified in the 2007 geophysical survey.

Further information was gained during the 2009 investigations that included a drilling investigation on both shores, as described by Landsvirkjun [9], and a geophysical offshore survey, as discussed by Fugro in [14].

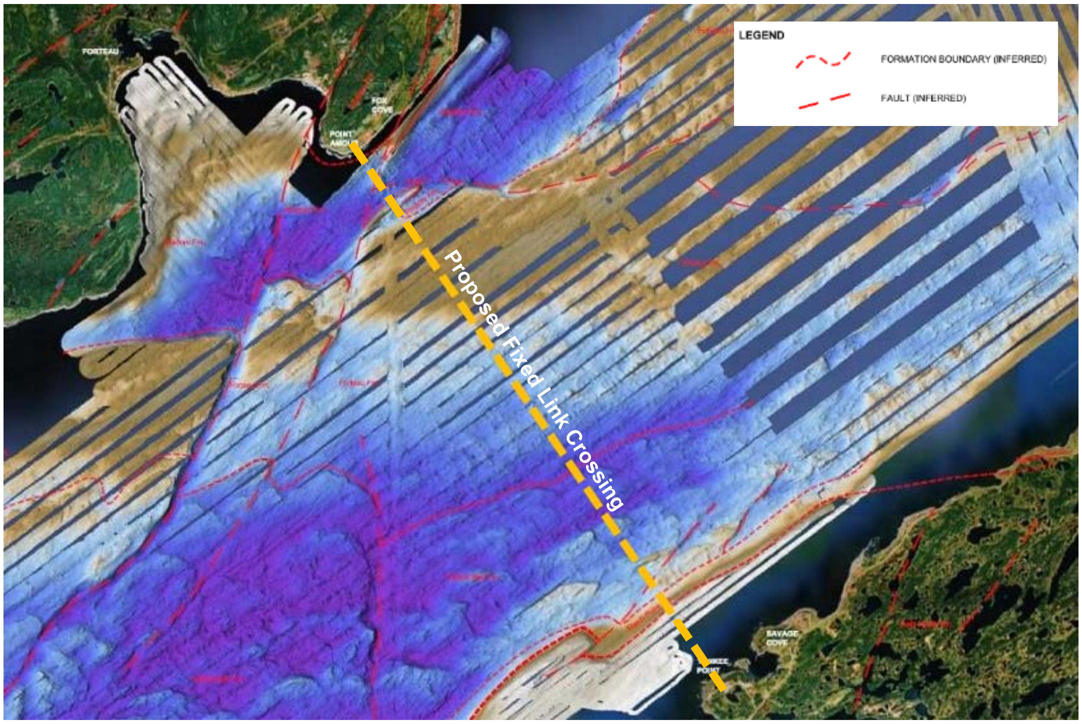


Figure 6-15: Inferred Faults, modified from [8]

Although various faults and tectonic lineaments are visible onshore (examples of faults visible on surface are shown in **Figure 6-16**), no major faults or tectonized zones were identified in the boreholes drilled during the 2009 geotechnical investigation [9]. The potential fault zones that were identified in the boreholes included relatively small areas of fractured rock or lost core.

On the Newfoundland side, some sections of lost core occurred in a borehole near Lower Cove which were identified as a potential fault zone. On the Labrador shore, a zone of jointed rock and lost core at approximately 60 m vertical depth in a borehole near Fox Cove located north-east of Point Amour (see **Figure 6-17**) was interpreted as having experienced tectonic action and associated degrading due to shearing and weathering [18].

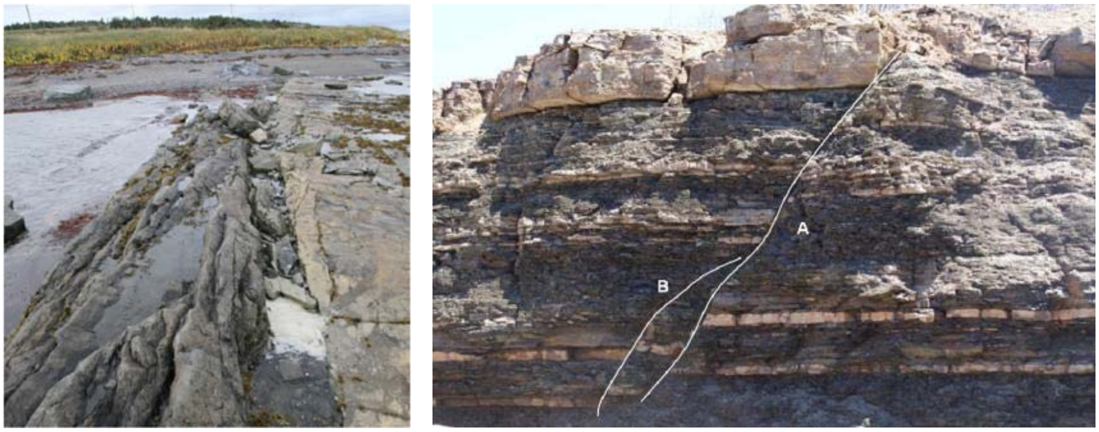


Figure 6-16: Faults visible on Surface: Tectonic Lineament near Lower Cove, NL (left) [9]; Fault Zone in Forteau Formation near L'Anse au Loup, LAB (right) [14]

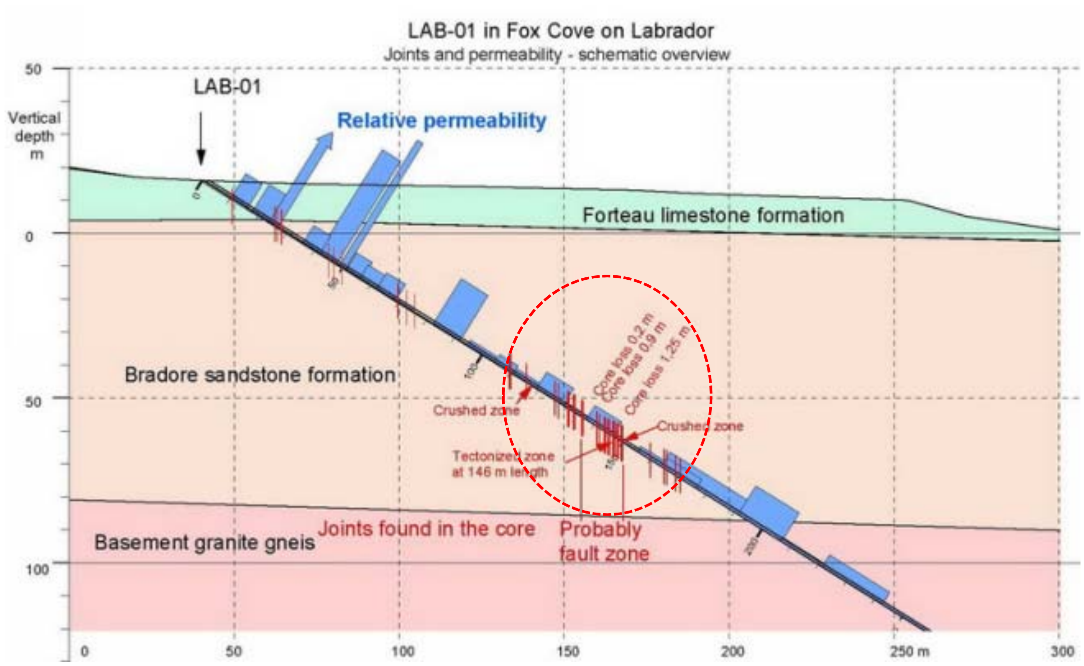


Figure 6-17: Potential Fault Zone identified in Borehole LAB-01 near Fox Cove on Labrador Shore [9]

Based on the 2009 geophysical survey results, Fugro provided a map showing interpreted bedrock outcrops and fault locations across the Strait of Belle Isle, as shown in **Figure 6-18**. The majority of the potential fault zones were identified towards both shores, mainly in the Bradore and Hawke Bay Formations. While the data provides an overview of the fault locations, it does not provide information about the width or characteristics of the material or fault gouge within the faults.

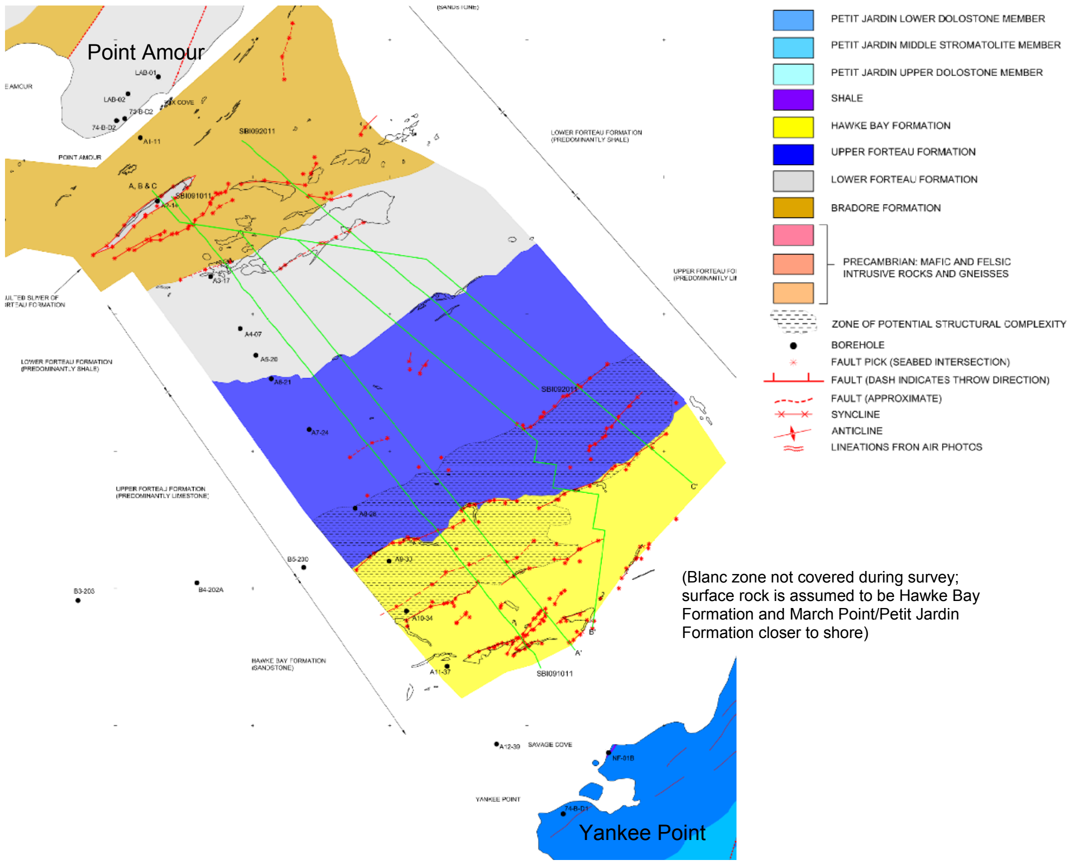


Figure 6-18: Interpreted Fault Zones across the Strait of Belle Isle, modified from [15]

6.6 Seismicity

According to recent information from Natural Resources Canada, the Strait of Belle Isle lies in a region of low risk regarding seismic hazards [31]; hence, seismic events are not considered a significant risk for the Strait of Belle Isle fixed link options. **Figure 6-19** shows the hazard rating for the project area.

Mean seismic hazard values (**Table 6-5**) were determined for the project site using the seismic hazard calculator from Natural Resources Canada. The values were provided for a 2% in 50 years probability of exceedance. Spectral (Sa(T), where T is in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s.

Table 6-5: Mean Seismic Hazard Values at Proposed Fixed Link Location

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA	PGV
0.046	0.066	0.068	0.061	0.054	0.036	0.020	0.0049	0.0022	0.038	0.044

Note: Values are for 'firm ground' (NBC 2015 Soil Class C, average Vs30 shear wave velocity 450 m/s)

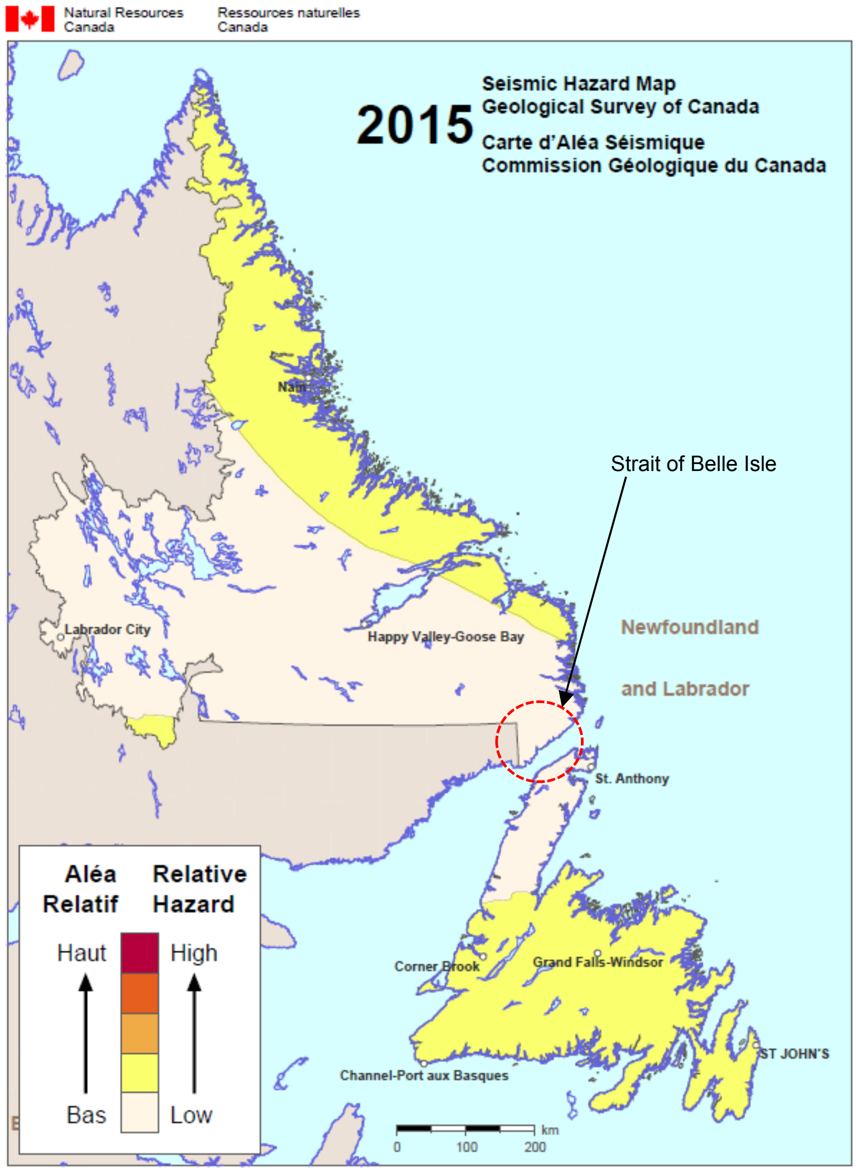


Figure 6-19: Seismic Hazard Map 2015 [31]

6.7 Geotechnical Properties

Field and laboratory testing were carried out as part of the investigations in 2009 to determine geotechnical characteristics of the rock. The results are provided in [19], [12] and [13] and are summarized in [21]. The tested rock samples are taken in the general project area and are not specific to the immediate project area; however, the results provide a general understanding on the rock properties in the project area.

6.7.1 Rock Quality

The rock quality derived from the Rock Quality Designation (RQD) index, an index used to describe the quality of rock by evaluating the length of the intact rock core retrieved from boreholes. The rock quality on both shores at the proposed project location, based on RQD values provided by Landsvirkjun [9] and SNC [10], is summarized by formation in **Table 6-6**.

The rock quality in potential fault zones that were encountered in the boreholes during the 2009 investigation was described typically as very poor to poor quality.

Table 6-6: Quality of the Rock Mass by Formation

	Point Amour, Labrador[1)]		Yankee Point, Newfoundland[2)]	
Formation	**Vertical Depth (m)**	**Rock Quality (RQD)**	**Vertical Depth (m)**	**Rock Quality (RQD)**
Petit Jardin	N/A	Not existent on Labrador shore	0 to 23	RQD 20 to 100 (very poor to excellent) Average indicates fair quality
March Point	N/A	Not existent on Labrador shore	23 to 50	RQD 50 to 98 (fair to excellent) Average indicates fair to good quality
Hawke Bay	N/A	Not existent on Labrador shore	50 to 223	RQD 0 to 100 (very poor to excellent) Average indicates fair to good quality RQD 0 to 50 (very poor or poor) mostly in upper 50 m of formation and in shale throughout the borehole.
Forteau	0 to 33	RQD 15 to 65 (very poor to fair) Average indicates poor quality	223 to 340	RQD 0 to 100 (very poor to excellent) Average indicates good quality RQD 0 to 50 (poor to very poor) mainly in lower part of formation; typically related to shale
Bradore	33 to 123	RQD 60 to 100 (fair to excellent) Average indicates good quality	340 to 447	RQD 80 to 100 (good to excellent) Average indicates excellent quality
Basement Rock	123 to 163	RQD 43 to 95 (poor to excellent) Average indicates fair to good quality Poor quality related to top portion of basement rock (contact with Bradore) (borehole advanced approx. 40 m into basement rock)	447 to approx. 477	RQD 60 to 90 (fair to excellent) Average indicates fair to good quality (borehole advanced approx. 30 m into basement rock)

1) Borehole NF 01B [9]
2) Borehole LAB 02 [9]

6.7.2 *Rock Mass Classification*

An assessment and classification of the rock mass has to be carried out to define the requirements for initial rock support during tunnel excavation, which applies in particular to Drill & Blast or mechanically excavated tunnels. Landsvirkjun [9] used the Q-System, a rating system based on various rock parameters. The chart used for the evaluation of the rock on both shores is shown in **Figure 6-20**. An overall Q range between 4 and 25 was determined for the core rock, indicating poor to good rock quality, with an average between 8 and 12, corresponding to fair quality. To account for adverse conditions such as effects of blasting and water inflow, Landsvirkjun reduced the rock quality by 50%, resulting in Q values between 2 and 12, corresponding to poor to fair quality. Based on these Q-values and assuming a tunnel diameter of 10 m (with Excavation Support Ratio (ESR) of 1.0 for major tunnels), initial rock support with shotcrete and rock bolts would be generally sufficient; however, additional support will most likely be required in areas of poor rock conditions, such as weak shale, fractured rock, fault zones, etc. Pre-excavation grouting ahead of the face will most likely be required to reduce the permeability of the rock and control water inflow into the tunnel.

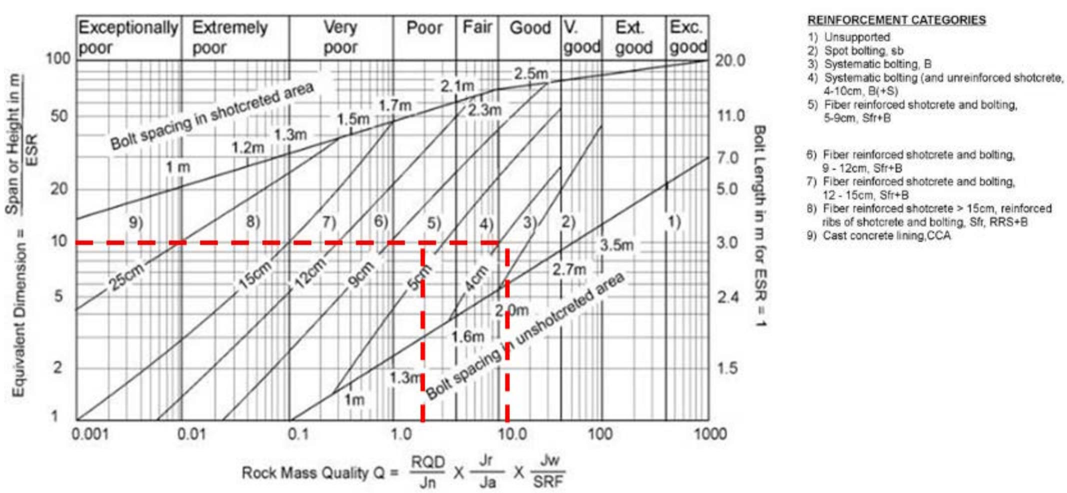


Figure 6-20: Q-System: Rock Mass Quality and Rock Support Chart

6.7.3 *Unconfined Compressive Strength (UCS)*

UCS tests were carried out on 12 sedimentary rock core samples of the Hawke, Forteau and Bradore Formations, taken on both the Labrador and Newfoundland side (refer to [12]). The results are summarized in **Table 6-7**. The intact rock strength was determined to be typically between 76 MPa and 178 MPa, indicating strong to very strong rock. Three results showed low values between 1.9 MPa (Hawke Bay Formation) and 16.3 MPa (Forteau Formation), indicating very weak to weak rock. The rock type of the sample was not provided; however, low strength results are assumed to be related to rock samples containing a plane of weakness or larger amounts of shale. This assumption is supported by the results of further strength testing (Point Load Tests) that typically indicate reduced strengths for shale or shale containing samples.

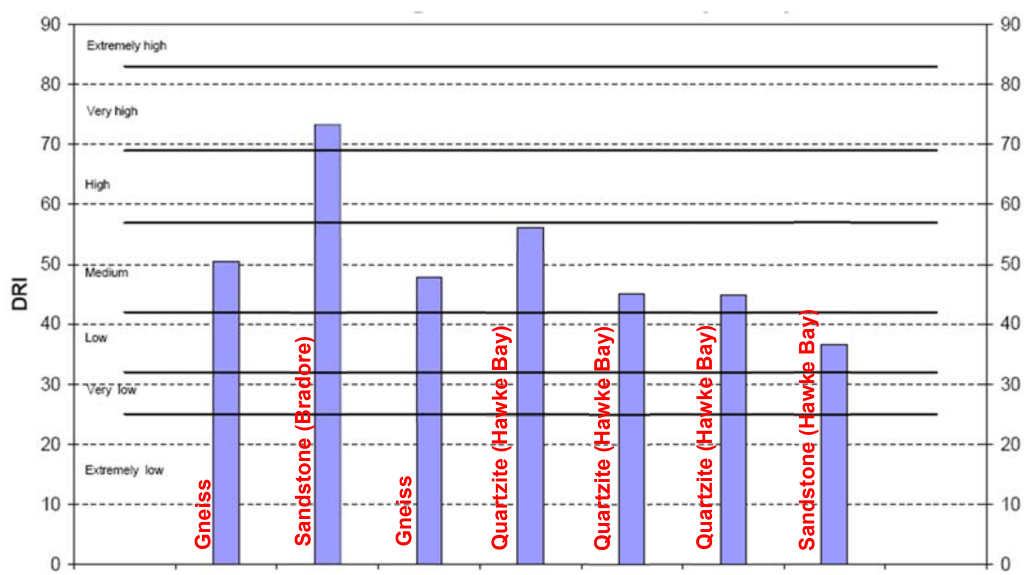
Table 6-7: Unconfined Compressive Strength of the Intact Rock by Formation

	Newfoundland		Labrador	
Formation	**UCS (MPa)**	**Depth (m)**	**UCS (MPa)**	**Depth (m)**
Hawke Bay	1.9 171 178	281.6 – 281.8 155.1 – 156.0 403.4 – 403.8	--	--
Forteau	5.5 142 16.3	458.4 – 459.1 461.4 – 462.1 514.7 – 515.6	148	17.5 – 17.95
Bradore	108	785.7 – 786.5	138 125 76 103	36.8 – 37.4 50.3 – 51.05 46.1 – 46.5 60.4 – 61.0

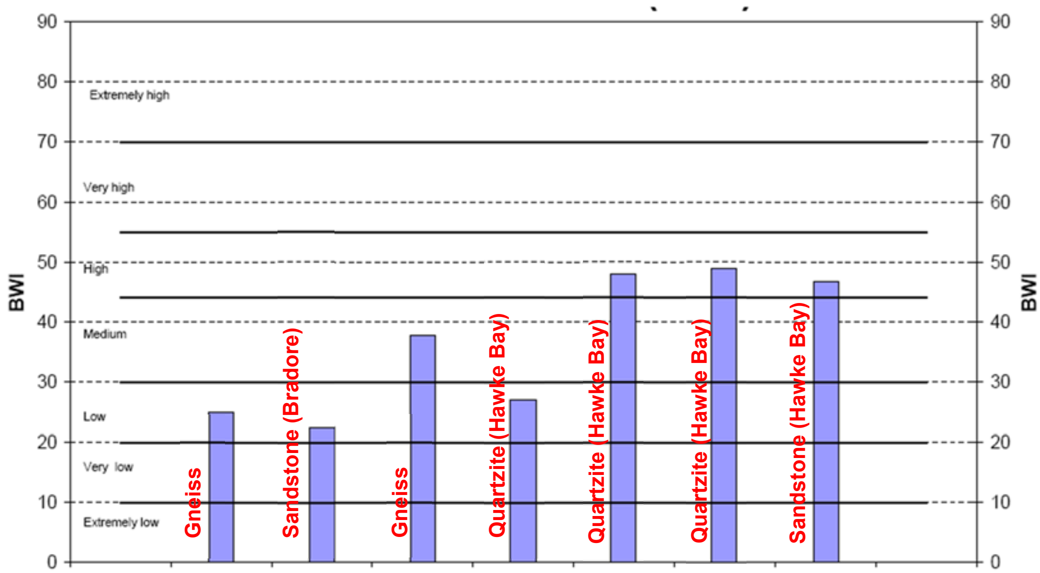
6.7.4 *Drillability Properties*

Laboratory tests to determine drillability properties of the rock (including Drilling Rate Index DRI, Bit Wear Index BWI and Cutter Life Index CLI) were carried out on seven rock core samples, including samples of gneiss, sandstone and quartzite (refer to [12]). The test results indicate the following:

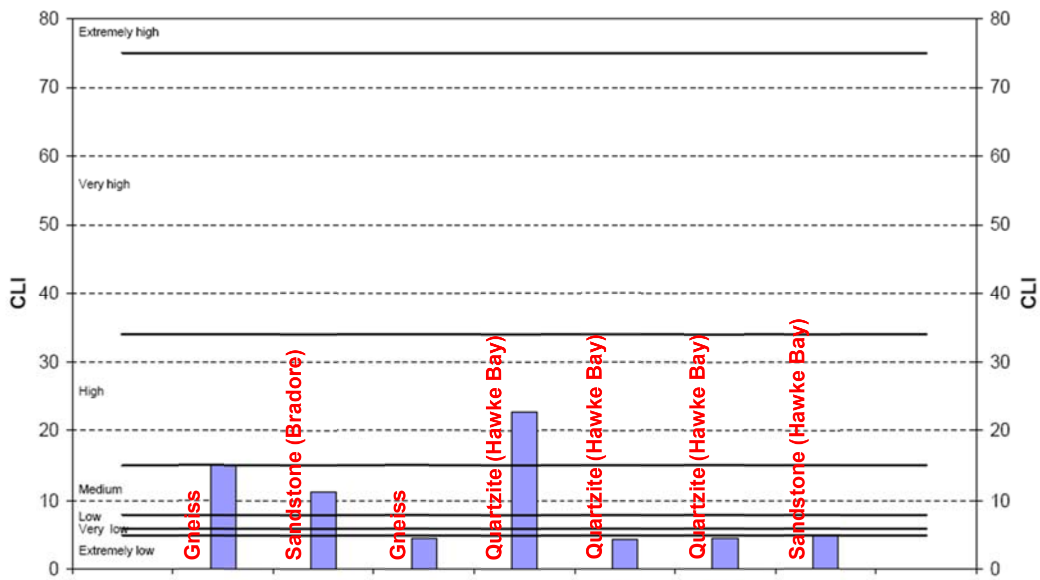
- The DRI values for the rock samples were low (sandstone, Hawke Bay Formation) to very high (sandstone, Bradore Formation) with most samples classified as medium.



- The BWI is used to estimate the lifetime of drill bits. The values for the rock samples varied uniformly; three were classified as low and three as high. The value for one sample was medium (basement gneiss).



- CLI expresses the lifetime of TBM disc cutter steel rings. Four samples showed extremely low or very low values. Three sample were classified as medium to high (quartzite, Hawke Bay Formation).



6.7.5 *Abrasiveness*

The abrasiveness of the rock is an important factor to evaluate the expected TBM disc cutter wear and influences the choice of the appropriate cutters. Laboratory tests to determine the abrasiveness (Cerchar Abrasivity Index) of the rock were carried out on eight sedimentary rock core samples, including dolomite, sandstone and quartzite from the Petit Jardin, March Point and Hawke Bay Formations. The test results indicate abrasivity indices ranging between abrasive (index 1.0 - 2.0) to extremely abrasive (index 4.0 - 6.0), with the lowest abrasiveness at 1.5 (sandstone, Hawke Bay Formation) and the highest at 5.7 (quartzite, Hawke Bay Formation). The dolomite samples from the Petit Jardin and March Point Formations were abrasive to highly abrasive, corresponding to indices of 1.9 and 2.2.

6.7.6 *Time-Dependent Deformations (Swelling)*

The time-dependent behavior of the rock will influence the choice of TBM and the choice of tunnel lining. Free swell tests were carried out on six shale samples taken from the cored rock (refer to [13]). The samples were taken on the Labrador side from rock core of the Hawke Bay and Forteau Formations. The results of the preliminary laboratory investigation indicate that a strong potential for swelling in the shale under investigation exists. In summary, the results showed the following:

- The rock samples show swelling behaviour (i.e. time-dependent deformation) in all directions.
- There is no evidence of significant amounts of swelling clay minerals in the samples.
- The existence of a significant salt concentration in the rock and relatively low calcite content provide a mechanism for swelling. Two samples with high calcite content showed very little swelling.

6.7.7 *Permeability*

As part of the geotechnical investigations in 2009 and 2011/2012, hydraulic conductivity testing was carried out in boreholes on both sides of the Strait to investigate the permeability of the various rock formations. The test results from the 2009 investigation as provided in [9] are illustrated in the geological cross sections in **Figure 6-21** and **Figure 6-22**.

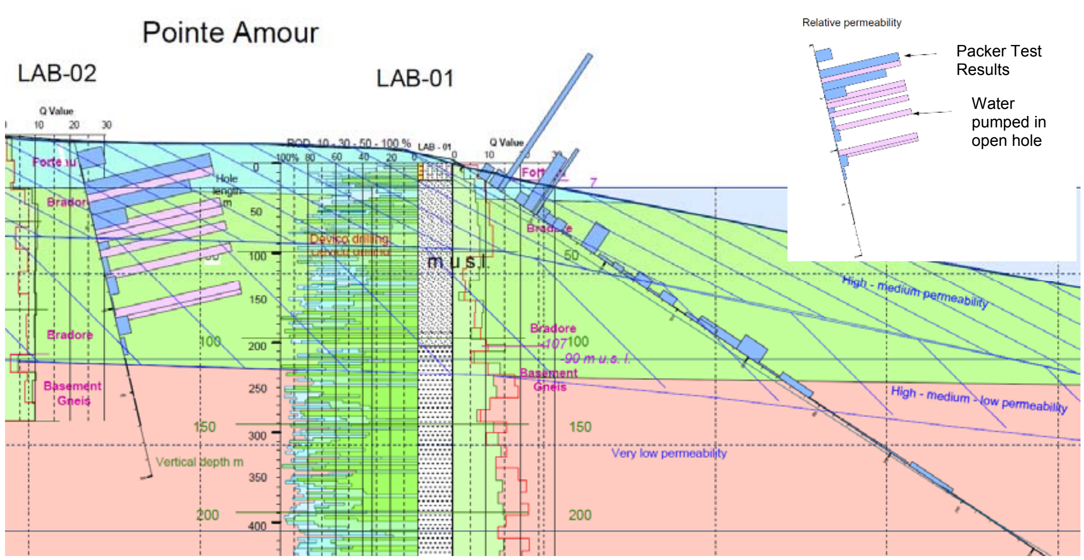


Figure 6-21: Permeability Test Results – Point Amour [9]

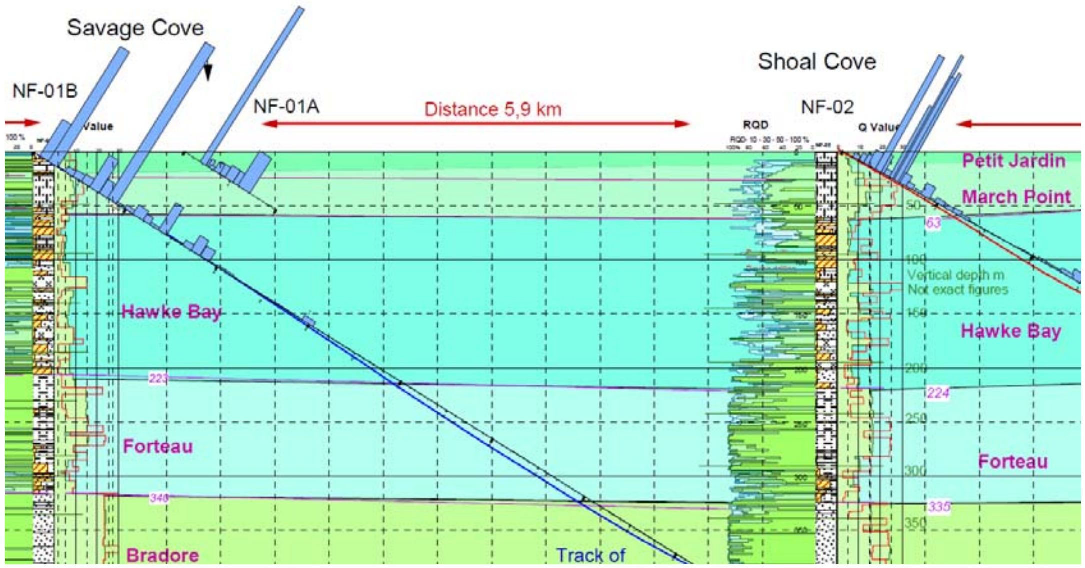


Figure 6-22: Permeability Test Results – near Yankee Point [9]

The test results were analyzed by Landsvirkjun [9] and reviewed and summarized by HMM [17]. Based on the analysis, three zones of varying rock mass permeability were identified, related to ranges of depth below the ground surface. The zone from ground surface to approximately 50 m depth was identified as the zone with high permeability. The zone ranging in depth approximately from 50 m to 100 m was found to have typically a medium permeability. The permeability of the rock in depths greater than approximately 100 m was identified as medium to low. It was found that the permeability decreases rapidly with depth and was identified generally as very low or impermeable below depths of 150 m [9]. The ranges of permeability associated with the three zones was summarized by HMM [17], as shown in **Table 6-8**.

Table 6-8: Summary of Rock Mass Permeability by Range of Depth (after [17])

Depth below Ground Surface (m)	K (m/s)*			
	10^{-8}	10^{-7}	10^{-6}	10^{-5}
0 to 50	1%	22%	57%	2%
50 to 100	18%	48%	34%	0%
> 100	41%	48%	11%	0%
Fault	0%	0%	50%	50%

* K values are presented as order of magnitude ranges based on the packer test results provided in [9] as Lugeon values

Although the permeability ranges associated with the three zones overlap, it was found that the permeability of the rock mass decreases with increasing depth. Considering that the rock formations dip towards the Newfoundland shore and that some formations, such as the Forteau and Bradore Formation, occur near surface on the Labrador shore as well as in greater depth on the Newfoundland shore, it can be concluded that the zones of varying permeability are related to depth below surface rather that to the rock formations.

Fault zones that occur throughout all rock formations underneath the Strait of Belle Isle typically comprise zones of more intensely fractured rock and as a result tend to have a higher permeability than the surrounding rock mass.

Permeability tests were also carried out in 2011/2012 in boreholes on the Labrador side of the Strait [19]. The tests were carried out in the Bradore Formation in depths of approximately 20 to 80 m below the ground surface. The test results indicated hydraulic conductivity values between $5x10^{-8}$ and $2x10^{-6}$ m/sec, corresponding to a very low to moderate permeability. The results of tests at the contact between Bradore Formation and basement rock suggest a mean hydraulic conductivity of $2x10^{-7}$ m/s, corresponding to low permeability of the rock mass.

7. Design Criteria and Construction Considerations for a Tunnel Fixed Link

7.1 Environmental Design Considerations

Based on the data provided above, the updated design criteria associated with the environmental parameters of the study area are summarized in the following **Table 7-1**.

Table 7-1: Environmental Design Considerations

Climate		
Minimum design air temperature		-30°C
Maximum hourly wind speed		100 km/h
Maximum gust wind speed		148 km/h
Design hourly wind pressure		0.87 kPa
Atmospheric Icing		11.5 cm with 115 km/h wind gust
Ground snow loading		6.1 kPa
Freezing Degree Days Below 0°C		1323
Oceanography		
Currents	at 15 m depth	3.6 m/sec
	at 50 m depth	2.5 m/sec
Maximum Wave Height (100-year return period)		10 m
Sea Ice		
Uniform ice floe thickness		0.6 m
Ice compressive strength (uniform ice)		2 MPa
Icebergs		
Mass		1 million tonnes
Speed		1 m/sec
Ice strength		5 MPa
Scour depth (1000-year return period)		5.5 m

7.2 Alignment Location and Depth

The investigated fixed link alignment between Yankee Point and Point Amour would cross the HVDC cable crossings that were installed in HDD tunnels on shore and covered with a rock berm on the sea floor between Forteau Point, Labrador (approximately 7 km west of Point Amour) and Shoal Cove, Labrador (approximately 5.5 km east of Yankee Point). The cable location and the proposed fixed link alignment are shown in **Figure 7-1**. Considering a subsurface fixed link (TBM or drill & blast tunnel), the proposed tunnel alignment would not affect the existing cable crossing. The tunnel portal locations as well as the onshore portion of the tunnel would be in a distance larger than 5 km away from the HDD cable conduits on shore and the HDD exits under water and no interference between the new tunnel and the existing structures are expected.

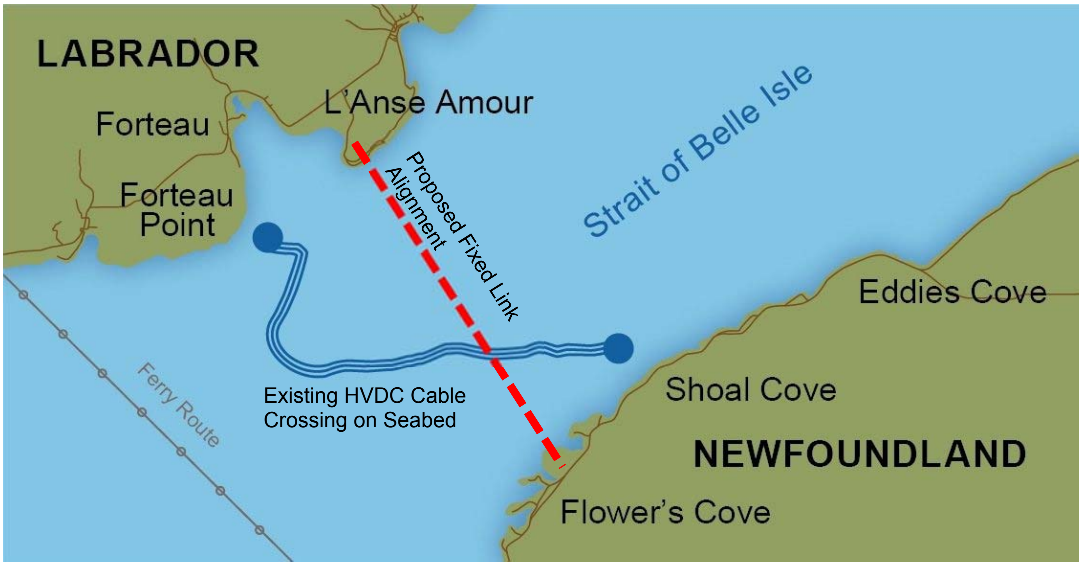


Figure 7-1: Subsea Cable crossing Fixed Link Alignment

Considering surface fixed link options, including bridge, causeway with bridges and ITT, these options would be impacted by the existing HVDC cable crossing. The installation of bridge foundations would have to consider the location of the cable conduits on the sea floor; however, considering the wide span of 2 km between the individual foundations, the cable crossing is not expected to prevent the installation of bridge foundations. The construction of a causeway would have to either consider the load impact from the rock berm on the existing cable conduits or strategically place the causeway openings spanned with bridges above the cable conduits. The installation of an ITT in a trench on the sea floor would be impacted by the existing cable crossing since dredging of a trench would not be feasible at the intersection with the surface cable conduit. ITT construction would require an alignment change to prevent an alignment crossing. This would involve either moving the entire ITT alignment or replacing the entry locations on either the Labrador side or the Newfoundland side. All alignment changes would result in an increased length of the ITT fixed link.

The required depth of the tunnel alignment below ground surface depends on the geotechnical conditions underneath the Strait as well as the excavation method. The poor ground conditions that are expected locally due to fault zones and the likelihood of highly permeable rock in the upper 50 m of rock must be considered when defining the required depth.

Information available from sub-sea tunnels excavated in Norway between 1980 and 2009 using drill & blast methods indicate that typical rock covers ranged between 20 and 50 m. Experience from the Oslofjord sub-sea tunnel (completed in 2000) with low rock covers and poor ground conditions, which required extensive rock reinforcement including ground freezing operations, led to the requirement of greater rock covers. Based on the sub-sea tunneling practices in Norway as described in [25] and assuming a maximum water depth of 110 m in the Strait of Belle Isle, a rock cover of at least 50 m should be considered for a tunnel excavation using drilling and blasting. This cover thickness would avoid the area of highest permeability on the upper 50 m of rock. A bored tunnel typically requires less coverage than a drill & blast tunnel. Considering the current knowledge of the ground conditions and to prevent critical situations in the tunnel due to rockfalls and water inflow, a rock cover of approximately two tunnel diameters is recommended for the tunnel excavation using a TBM. However, alignment depths can be adjusted when more information about the subsurface conditions become available from recommended future investigations in the Strait.

An alignment depth of approximately 130 m below sea level would have to be considered, based on the assumed deepest water in the Central Trough of approximately 110 m. However, the inflow rates at this elevation should still be expected to be significant and measures must be in place during excavation to address high water inflows. Hydraulic pressures of up to at least 13 bar should be taken into account for the selection of the tunnelling machine at this depth, assuming that the tunnel will be connected to the water body in the Strait due to fault zones and/or open joints.

Assuming that the up to 100 m of high to medium permeable ground encountered in the boreholes on shore also exist below the Strait, the avoidance of the entire high to medium permeability zone would result in a tunnel depth of approximately 200 m below sea level.

The depth of the alignment influences the length of the tunnel. A deeper alignment would be accompanied by a significant increase in tunnel length due to the extended access ramps and, consequently, by increased construction costs. Considering drill & blast excavation, however, parts of these costs will likely be offset by the reduced risk of encountering poor ground and high water inflow and hence reduced mitigation efforts.

A geological profile across the Strait of Belle Isle is provided in **Figure 7-2** and on Drawing 1 in Appendix B that shows the suggested TBM tunnel alignment at an approximate depth of 22 m (two tunnel diameters, based on the TBM road tunnel diameter) below the seabed. It has to be noted that the currently available information about the permeability of the rock mass is restricted to the immediate shore area. Additional investigations would be required to verify the rock mass permeability below the Strait prior to defining the most suitable tunnel alignment depth of the Strait of Belle Isle Fixed Link. However, the assumption that full hydrostatic pressure occurs at the TBM excavation face reduces the sensitivity to the permeability of the rock mass.

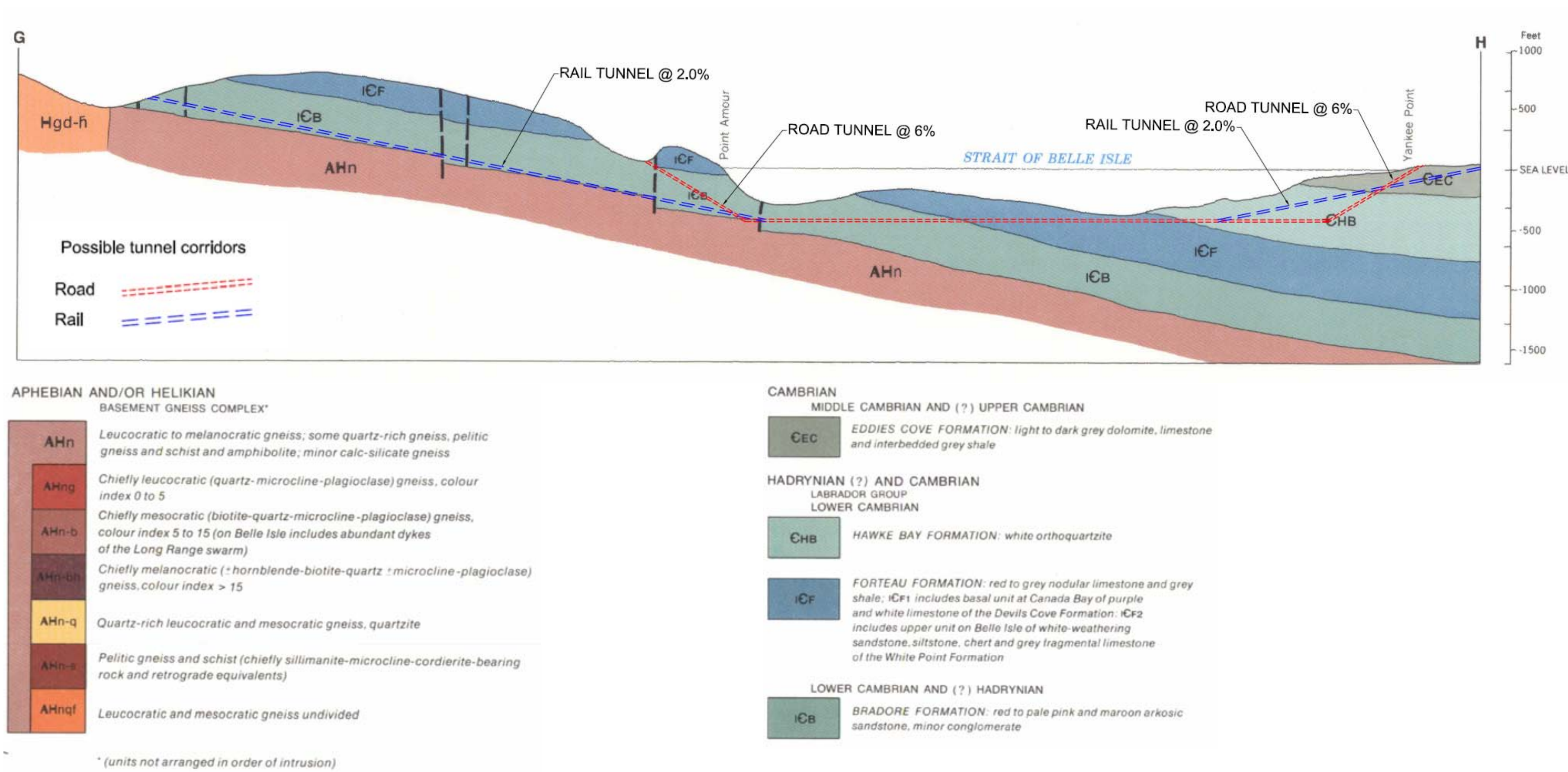


Figure 7-2: Profile across the Strait of Belle Isle with proposed Tunnel Alignment

Due to the increased depth of the tunnel alignment, the exit ramps for both the rail and the road tunnel will increase in length. The exit grades of the proposed rail tunnel were slightly modified to 2% (slightly steeper than the 1.66% suggested in the 2004 study) to reduce the length of the exit ramps but still be feasible for modern electric shuttle trains. The exit grades for the road tunnel were set to 6% (in agreement with the 2004 study).

On the Labrador side, the length of the rail tunnel exit ramp extends significantly depending on the surface elevations, as can be seen in **Figure 7-2**. However, the ramp, as shown, extends along a tunnel with a straight horizontal alignment. The design of a curved ramp that follows a more favorable surface profile will most likely allow a significant reduction in length. Steeper exit grades for the rail tunnel to further shorten the ramps could be achieved by custom made rail shuttle locomotives.

7.3 Tunnel Usage

In the 2004 Pre-Feasibility Study, the tunnel cross-sections included space for the integration of three HVDC cables. The cables were assumed to run through the tunnel for electricity transfer from Labrador to Newfoundland as part of the Nalcor Energy Lower Churchill project and would provide a means of additional revenue. In the past years, these cables have been installed in cable conduits across the Strait; however, the tunnel cross sections still provide space that could be utilized for utilities should the need arise during the design stage.

7.4 Capacity Requirements

The principal factors in determining the spatial requirements of a tunnel including the required number of traffic lanes or tracks are the projected traffic volumes as well as the requirements for emergency egress and tunnel ventilation.

7.4.1 Projected Traffic Volumes

Traffic projections for the Strait of Belle Isle fixed link are based on the recent traffic volume data for the existing Strait of Belle Isle Ferry between Blanc-Sablon and St. Barbe and the traffic volume data for the existing Gulf Ferries providing services between North Sydney and Port aux Basques as well as between North Sydney and Argentia.

Based on discussions with the Harris Centre and the Government, similar traffic growth assumptions as in 2004 were made to estimate the projected traffic volumes for the Strait of Belle Isle Fixed Link; it was assumed that all traffic currently using the Strait of Belle Isle Ferry would be transferred to the new fixed link and that up to 60% of the current Gulf Ferry traffic can be diverted to the new Strait of Belle Isle Fixed Link.

7.4.1.1 Current Strait of Belle Isle Ferry Traffic Volume

Traffic volume data was provided to Hatch by the Government of Newfoundland and Labrador and was available for the years from 2000 to 2016, each annual data set for the months from May to October. The data is divided into the categories passenger vehicles and commercial vehicles. It is assumed that the number of tour busses using the Strait of Belle Isle Ferry is included in the commercial vehicles numbers; separate tour bus counts were carried out only until 2007. Traffic numbers are provided as Twenty-foot Equivalent Units (TEU). Based on information provided by the Government of Newfoundland and Labrador, the vehicle types associated with the TEUs are as shown in **Table 7-2**.

Table 7-2: Vehicle Types and associated Twenty-foot Equivalent Units (TEU)

Vehicle	TEUs
Automobile	1
Motorcycle	0.5
Commercial Vehicles up to 6 m (20ft)	1
Commercial Vehicles over 6 m (20ft)	2
RVs up to 6m (20 ft)	1
RVs over 6m (20 ft)	1.5
Bus	2
Tractor Trailer	4

Figure 7-3 illustrates the ferry usage development over the past 17 years. Except from some years of declining ferry usage, the traffic numbers have increased continuously over the past years.

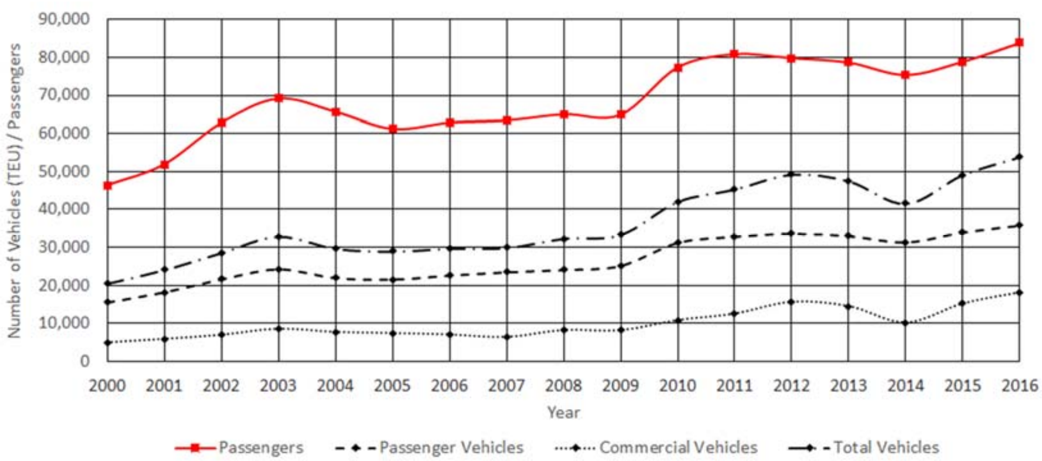


Figure 7-3: Strait of Belle Isle Ferry Usage - Private and Commercial Traffic

The data was further analyzed regarding total numbers of vehicles and percentage of traffic growth since 2004 (**Table 7-3**). Overall, there has been an increase in vehicle crossings of approximately 81% since 2004; the average annual growth was 5.5%. The largest annual growth occurred in 2010 with 26%; the most considerable negative growth of -12.5% was noted in 2014. Commercial vehicles account for 33% of the total traffic and represent the area of most significant growth.

Table 7-3: Strait of Belle Isle Ferry Usage - Blanc-Sablon/St. Barbe

	2004 (May to October)	2016 (May to October)	Growth since 2004[1)]
Passengers	65,623	83,815	27.7%
Passenger Vehicles (TEU)	21,986	35,798	62.8%
Commercial Vehicles (TEU)	7,715.5	18,079	134.3%
TOTAL Vehicles (TEU)	**29,701.5**	**53,877**	**81.4%**

1) Green indicating traffic increase; red indicating traffic decrease.

Most vehicles used the ferry during the tourist season in the months of July and August. Considering the maximum amount of 8,173 passenger vehicles (TEUs) and 3,615 commercial vehicles (TEUs) that used the ferry in August 2016 and assuming an even distribution over the entire month, the daily use of the ferry included 380 vehicles (TEUs).

7.4.1.2 Current Gulf Ferry Traffic Volume

Traffic volume data for the Gulf ferries was provided to Hatch by the Government of Newfoundland and Labrador.

7.4.1.2.1 Private Traffic Data

Traffic volume data for private vehicles was available for the ferry route North Sydney - Port aux Basques as well as the route North Sydney - Argentia for the years from 1999 to 2016. The data is divided into different ridership categories, including automobiles, trailers, campers, busses and motorcycles/bicycles. Total traffic numbers were provided as Passenger Related Vehicles (PRV) units. To allow a comparison with the Strait of Belle Isle Ferry traffic data, the PRV units were converted into TEUs using the following conversions which were chosen in accordance with the conversions provided by the Government of Newfoundland and Labrador for the Strait of Belle Isle Ferry.

- Automobile: 1 PRV = 1 TEU
- Trailer (assumed to be travel trailer): 1 PRV = 2 TEU
- Camper: 1 PRV = 1.5 TEU
- Busses: 1 PRV = 2 TEU
- Motorcycles/Bicycles: 1 PRV = 0.5 TEU

Figure 7-4 illustrates the development of the ferry usage by private traffic over the past 18 years. Except for some years of increasing ferry usage, the total traffic numbers have decreased continuously over the past years.

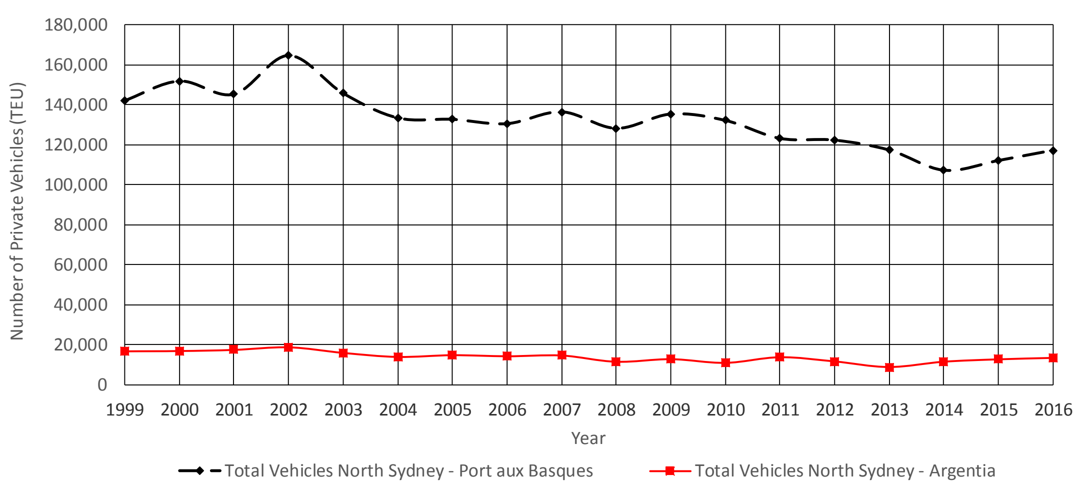


Figure 7-4: Gulf Ferry Usage - Private Traffic

The data was further analyzed for both ferry routes regarding total numbers of vehicles and percentage of traffic growth since 2004 (**Table 7-4** and **Table 7-5**).

North Sydney - Port aux Basques: Although the private traffic numbers for trailers, campers and motorcycles/bicycles have increased since 2004, an overall reduction of the ferry usage of 12.2% (including both directions) was noted due to the reduced demand for automobile and bus transfers; the average annual decline was approximately 1%. However, it should be noted that in more recent years the traffic numbers have slightly increased for all traveler categories. Overall, slightly more traffic is entering Newfoundland on this route than exiting.

Table 7-4: Gulf Ferry Usage - North Sydney/Port aux Basques - Private Traffic

	2004	2016	Growth since 2004[1)]
Passengers	386,078	299121	-22.5%
Automobiles[2)]	109,818	91,293	-16.9%
Trailers[2)]	16,134	17,588	9.0%
Campers[2)]	4,965	5,733	15.5%
Busses[2)]	1,082	670	-38.1%
Motorcycles/Bicycles[2)]	1,377	1,852	34.5%
TOTAL Vehicles[2)]	**133,376**	**117,136**	**-12.2%**

1) Green indicating traffic increase; red indicating traffic decrease.
2) Values have been converted from PRV to TEU considering the assumptions stated above.

North Sydney - Argentia: On this ferry route, private traffic numbers for automobiles, trailers and campers have decreased since 2004; only the demand for bus and motorcycle/bicycle transfers have increased over the past years. The overall ferry usage by private traffic has decreased by 3.7% with an average annual decline of 1.1% (including both directions). In more recent years, the private traffic volume has increased for all traveler categories. Overall, slightly more traffic is exiting Newfoundland on this route than entering. Compared to the ferry route North Sydney - Port aux Basques, the route North Sydney – Argentia is significantly less travelled with only approximately 10% of all vehicles.

Table 7-5: Gulf Ferry Usage - North Sydney/Argentia - Private Traffic

	2004	2016	Growth since 2004[1)]
Passengers	33,393	29407	-11.9%
Automobiles[2)]	9,620	9,299	-3.3%
Trailers[2)]	2,046	1,804	-11.8%
Campers[2)]	1,596	1,325	-17.0%
Busses[2)]	144	154	6.9%
Motorcycles/Bicycles[2)]	506	812	60.6%
TOTAL Vehicles[2)]	**13,912**	**13,394**	**-3.7%**

1) Green indicating traffic increase; red indicating traffic decrease.
2) Values have been converted from PRV to TEU considering the assumptions stated above.

Most vehicles used the Gulf Ferries during the months of July and August. Considering the maximum amount of 24,798 private vehicles (TEUs) on the North Sydney – Port aux Basques route and 4,772 private vehicles (TEUs) on the North Sydney – Argentia route that used the ferry in August 2016 and assuming an even distribution over the entire month, the daily use of the ferries included 954 (29,570/31) private vehicles (TEUs). Assuming a 60% diversion towards the Strait of Belle Isle, 572 private vehicles should be considered using the new fixed link per day in addition to the traffic currently using the Strait of Belle Isle Ferry.

7.4.1.2.2 Commercial Traffic Data

Commercial traffic data was available as traffic entering and exiting the province for the years 1989 to 2016. The data set was cumulative for both Gulf Ferries and no differentiation between different types of commercial vehicles was made. No indication of the traffic unit used was given; it was assumed that the data is in CRV (Commercial Related Vehicles) units which were converted into TEUs considering the following assumptions:

- 40% of all traffic are tractor trailers: 1 CRV = 4 TEU
- 60% of all traffic are commercial vehicles over 6 m length: 1 CRV = 2 TEU

Figure 7-5 illustrates the development of the ferry usage by commercial traffic over the past 27 years. Although the overall total traffic numbers have increased over the past years, some years of decreasing ferry usage were observed, in particular in more recent years (2012 to 2015).

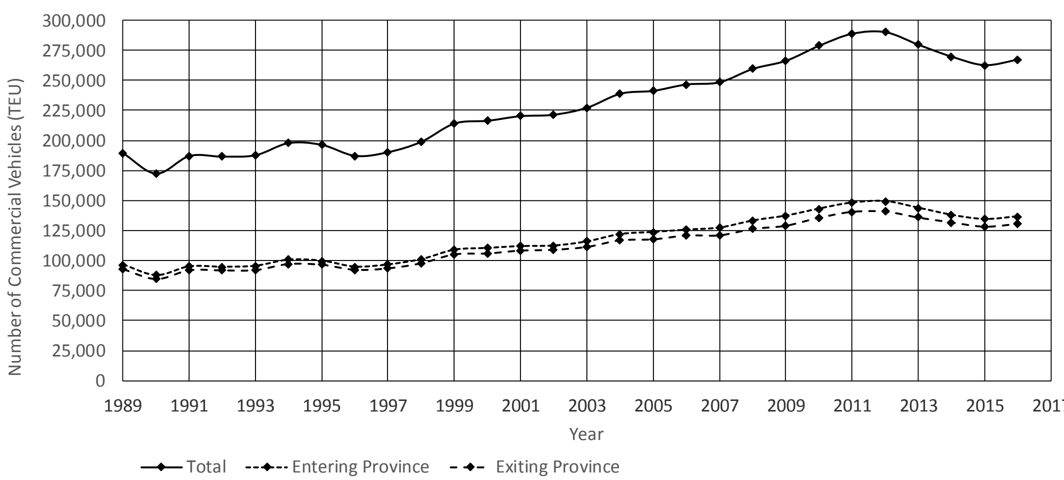


Figure 7-5: Gulf Ferry Usage - Commercial Traffic

The data was further analyzed regarding total numbers of vehicles and percentage of traffic growth since 2004 (**Table 7-6**). Overall the commercial traffic increased by 11.9 % since 2004, with a slightly larger number of vehicles leaving the province compared to the vehicles entering the province.

Table 7-6: Gulf Ferry Usage - Commercial Traffic

	2004	2016	Growth since 2004[1)]
Entering Province[2)]	116,992	130,609	11.6%
Leaving Province[2)]	121,887	136,665	12.1%
TOTAL Vehicles[2)]	**238,879**	**267,274**	**11.9%**

1) Green indicating traffic increase; red indicating traffic decrease.
2) Values have been converted from CRV to TEU considering the assumptions stated above.

Considering the maximum amount of 24,604 commercial vehicles (TEUs) that used the Gulf Ferries in August 2016 and assuming an even distribution over the entire month, the daily use of the ferries included 794 (24,604/31) commercial vehicles (TEUs). Assuming a 60% diversion towards the Strait of Belle Isle, 476 commercial vehicles (TEUs) should be considered using the new fixed link per day in addition to the private vehicles and the traffic currently using the Strait of Belle Isle Ferry.

7.4.1.3 *Projected Fixed Link Traffic Volume*

The traffic forecast was undertaken for the 30 years following the construction of the fixed link. Assuming a project duration of 12 years, the projection includes 42 years from today. An annual traffic growth of 2.5% was assumed. The resulting traffic volumes are shown in **Table 7-7**.

Table 7-7: Traffic Projection for Strait of Belle Isle Fixed Link

	Volume Year 1	Volume Year 42[3)]
Strait of Belle Isle Ferry per Day (TEU)	380	1046
60% Diversion from Gulf Ferries per Day – private traffic (TEU)[1)]	572	1574
60% Diversion from Gulf Ferries per Day – commercial traffic (TEU)[2)]	476	1310
TOTAL per Day (including both directions)[1)]	1428	3930

1) Traffic volume for the Gulf Ferries were converted from PRV units to TEU (see 7.4.1.2.1).
2) Traffic volume for the Gulf Ferries were converted from CRV (assumed) units to TEU (see 7.4.1.2.2).
3) Assumed increase of 2.5% per year

7.4.2 *Fixed Link Required Capacity*

As in 2004, the fixed link capacity requirements were assessed in terms of peak hour volume that allows safe traffic conditions and the following assumptions were applied:

- Peak periods occur over a 5-hour window per day.
- 50% of the average daily traffic volume occurs during the peak period.

With a total daily volume of 3930 vehicles per day, approximately 393 vehicles should be accommodated during a peak design hour (50% of 3930, divided by 5 hrs), including both directions, or 197 vehicles per hour per direction, which is below the assumed theoretical capacity of 1,200 PCU (Passenger Car Units) per hour per direction for two-lane undivided Canadian highways.

However, for the fixed link road tunnel, the capacity will be determined partly by the traffic composition as well as the speed and geometric conditions of the tunnel. Since the tunnel is to be designed for both passenger and commercial vehicles, the critical sections will be exit sections that include long uphill gradients for exiting vehicles. The profile for the tunnel includes exit sections that have a vertical gradient of 6% over lengths of more than 2 km. With heavy trucks using the fixed link, these vehicles will slow down considerably climbing out of the tunnel. At a travel speed of 50 km/h as assumed in the 2004 study, trucks will slow to approximately 27 km/h by the time they exit the tunnel. To reduce the delay to other vehicles and raise the level of service, an overall operating speed of up to 80 km/h should be permitted. Consideration could be given to adding a truck climbing lane in each of the exit sections; however, the implementation of a climbing lane would require a larger TBM diameter or a tunnel excavation using drill & blast.

Based on the updated peak traffic, a one-lane tunnel with alternating single direction operation is still appropriate to safely manage the projected traffic subject to modifying the permitted travel speed.

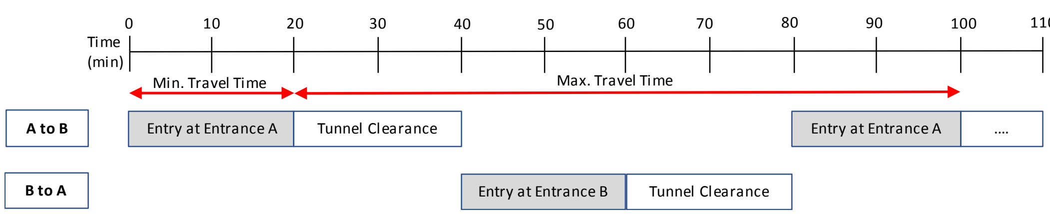
7.4.3 *Tunnel Operation and Crossing Times*

Two tunnel options, a single lane tunnel for individual vehicle traffic as well as a single-track tunnel for an electric shuttle train, were considered for the assessment of the tunnel operation and the potential crossing times.

7.4.3.1 *Single-Lane Vehicle Tunnel*

A single-lane tunnel with an emergency lane would be operated alternating in both directions with an assumed design operating speed of 80km/h. The advantage of using a higher speed in the tunnel (as opposed to the operating speed of 50 km/h as assumed in the 2004 study) is that it permits a shorter crossing time, shorter opening frequencies and higher level of service as the speed on the exit sections behind trucks would be approximately 42 km/h in lieu of approximately 27 km/h in the 50 km/h case.

The average travel time through the tunnel at a maximum operating speed of 80 km/h would be approximately 17 minutes (at an average speed of 72 km/h after adjusting for the effects of trucks slowing down at the exit sections). The operation scenario illustrated in **Figure 7-6** with a 20-minute operation phase could be considered. Operating hours for the road tunnel were assumed to be 7 days per week, 24 hours per day.



Note: A and B indicating the two tunnel entrances; 'A to B' indicating the travel direction.

Figure 7-6: Single-Lane Vehicle Operation

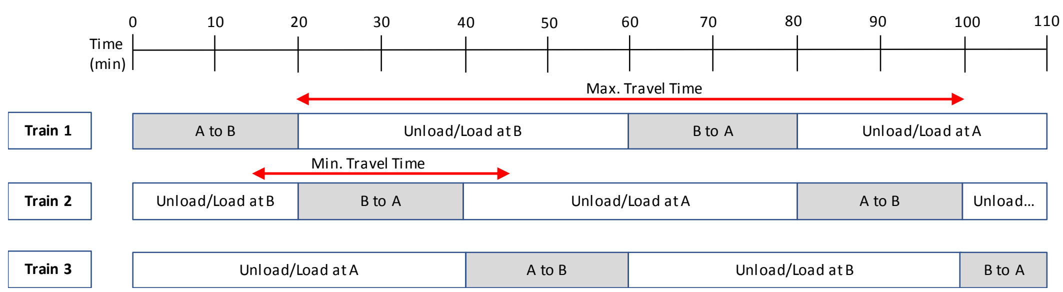
Entry into the tunnel would be alternating from both sides, allowing for a window of 20 minutes to enter the tunnel at one entrance and another 20 minutes of clearance time before entry from the opposite entrance will commence. This would result in an 80 minutes schedule of entering the tunnel on each side.

The minimum crossing time for a vehicle arriving at a tunnel entrance during entry time would include 20 minutes of travel time through the tunnel. The maximum crossing time (waiting time plus travel time) of 80 minutes would occur for a vehicle arriving at a tunnel entrance just after the entry is closed. In this event, the crossing time would include 60 minutes of waiting time and 20 minutes of travel time.

During each 20-minute period on average approximately 66 vehicles will arrive at each portal (based on the peak amount of 197 vehicles per hour per direction arriving at the portal on each end of the tunnel). Considering that during a maximum waiting time of 60 minutes approximately 197 vehicles arrive at one tunnel entrance, the maximum number of vehicles that travel through the tunnel within the entry window of 20 minutes is 263 vehicles (197 vehicles accumulated during the waiting time plus 66 vehicles that arrive during the 20-minute entry time). This volume is equivalent to an hourly directional volume of 789 vehicles, which is below the theoretical capacity of 1,200 vehicles per hour as noted above.

7.4.3.2 *Single-Track Rail Shuttle Tunnel*

A single-track rail tunnel would also be operated alternating in both directions with an assumed design operating speed of 100 km/h. The operation scenario illustrated in **Figure 7-7** could be considered.



Note: A and B indicating the two tunnel entrances; ‘A to B’ indicating the travel direction.

Figure 7-7: Single-Track Shuttle Train Operation

Entry into the tunnel would be alternating from both sides, allowing for a window of approximately 20 minutes to travel through the tunnel, after which time a train will enter the tunnel from the opposite entrance. This would result in a 40-minute schedule of entering the tunnel on each side. A minimum of three shuttle trains would be required to accomplish this schedule, considering that at all times one train is travelling through the tunnel (as shown in **Figure 7-7**). While the first train (Train 1) enters the tunnel from one side (Entrance A), a second train (Train 2) loads vehicles on the opposite side (Entrance B). Train 2 starts travelling through the tunnel from Entrance B towards Entrance A as soon as Train 1 arrives at Entrance B. At the same time, a third train (Train 3) loads vehicles at Entrance A and gets ready to pass through the tunnel as soon as Train 2 arrives at Entrance A.

The minimum crossing time for a vehicle arriving at a tunnel entrance shortly before departure of the shuttle train would include assumed 5 minutes of loading, 20 minutes of travel time through the tunnel and further assumed 5 minutes for unloading. The maximum crossing time of 80 minutes would occur for a vehicle arriving at a tunnel entrance just after the shuttle train has left. In this event, the crossing time would include a maximum of 40 minutes of waiting and loading time, 20 minutes of travel time and further 20 minutes for unloading.

The rail tunnel option assumed operating hours of 7 days per week, 12 hours per day. The shuttle train configuration would have to allow for the maximum number of vehicles that are to be transported through the tunnel within the window of 20 minutes. Based on the peak amount of 197 vehicles per hour and direction, approximately 130 vehicles will arrive at one tunnel entrance during a maximum waiting time of 40 minutes, for which a 22-car train with six vehicles per car and sufficient seating capacity for passengers would be sufficient.

7.5 Clearance Requirements

7.5.1 Road Tunnel

The traffic analysis discussed above indicates that a single-lane tunnel operated in a cycle with flow in one direction followed by flow in the opposite direction will satisfy the projected traffic demands. There are no specific vertical and lateral clearance standards for single-lane uni-directional tunnels, and in North America, general standards for clearances in tunnels are not well established. The following documents were, therefore, referenced to obtain guidance on appropriate clearance standards for the road tunnel option:

- PIARC: World Road Association "Cross Section Geometry in Unidirectional Road Tunnels"
- AASHTO Standard Specification for Bridges, Section 2.5 Highway Clearance for Tunnels
- Geometric Design Guide for Canadian Roads, Part 1, Transportation Association of Canada

Using the guidelines within these documents and Hatch's experience on similar highway tunnel projects, the parameters shown in **Table 7-8** were adopted for the development of highway tunnel cross-sections.

Table 7-8: Design Parameters – Road Tunnel Option

Design Element	Desirable Criteria
Tunnel Design Speed	80 km/h
Maximum Truck Width	2.6 m
Maximum Truck Height	4.2 m
Lane Width	3.75 m
Vertical Clearance from Vehicle Running Surface	4.65 m
Shoulder Width	1.5 m
Off-Roadway Distance (without Walkway)	2.25 m (0.75 m + 1.5 m)
Off-Roadway Distance (with Walkway)	2.50 m (1.0 m + 1.5 m)

This configuration permits vehicles to pass a truck or other vehicle that has broken down within the tunnel as shown in **Figure 7-8**.

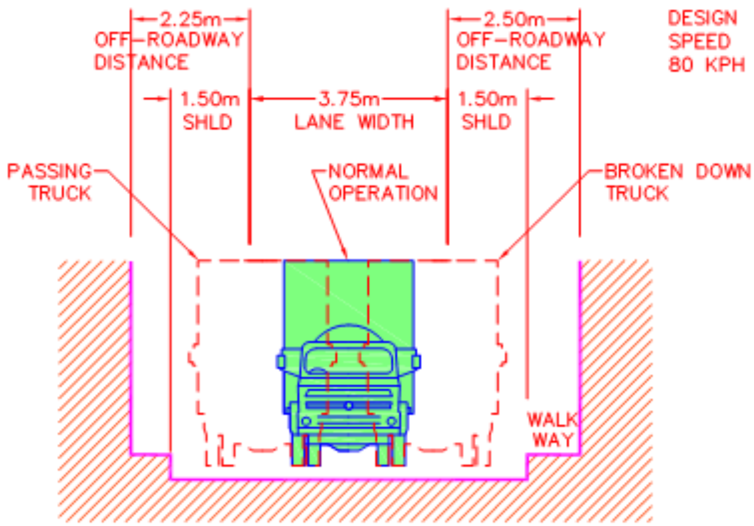


Figure 7-8: Road Tunnel Clearance Details

For higher speed applications, it is important to provide a barrier system that will redirect an errant vehicle back onto the roadway. Typically, this is done with the use of concrete barriers (Jersey barriers) delineating the edges of the shoulders. With the dimensions shown above, there is sufficient room to incorporate two 0.4 m wide barriers adjacent to the tunnel walls and a 1.0 m wide walkway on one side of the roadway.

7.5.2 Rail Tunnel

Roll-on/roll-off (RORO) tunnels are very rare globally; there are currently two operational tunnels that resemble the Strait of Belle Isle Fixed Link Project: the Channel Tunnel (completed 1994) connecting England to France and the Vereina Tunnel in Switzerland (completed 1999). The tunnel size requirements that were established in the 2004 study assumed that a shuttle railcar similar to that used for the Channel Tunnel and an associated tunnel clearance envelope are appropriate for the fixed link. These dimensions are still reasonable assumptions. **Figure 7-9** shows the required dynamic clearance envelope for such a vehicle.

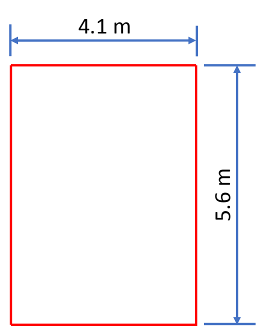


Figure 7-9: Dynamic Clearance Envelope for Shuttle Railcar

Locomotives, cars, and equipment would need to be custom designed for a project of this size and type which would require design effort and consultation with train manufacturers prior to determining the final tunnel dimensions.

7.6 Ventilation

7.6.1 Code and Standards

When developing a tunnel ventilation system, applicable codes and standards provide guidelines and recommendations to govern the design. However, it should be noted that most international standards and guidance documents are typically generic and not tailored to specific tunnel scenarios and being generic, they must cater for a wide range of alternative designs. Therefore, it is often appropriate to introduce some level of performance based design to ensure that a suitable system is provided. This approach then considers emergency ventilation in context and within a fully integrated safety strategy for the complete tunnel. For the tunnels subject of this study, National Fire Protection Agency codes NFPA502 and NFPA130 are applicable standards.

7.6.2 Ventilation Design Consideration

Standards and guidance would recommend that a mechanical ventilation system (ranging from a non-ducted longitudinal ventilation system, to a fully ducted transverse ventilation system) should be incorporated for a road or rail tunnel of an equivalent length to the Strait of Belle Isle Fixed Link. The type of system would mainly depend on the type of tunnel (uni-directional or bi-directional) and the expected traffic capacity (i.e. non-congested or congested traffic in the case of road). In the case of a road tunnel, compared with similar fixed link projects, the traffic data for the Strait of Belle Isle Fixed Link indicates a relatively low number of vehicles. It is, therefore, expected that under normal operation, congestion inside the tunnel can be prevented, even during peak hours. On this basis, the use of a longitudinal ventilation system for smoke control is proposed in the conceptual design.

A longitudinal ventilation approach would also eliminate the need for a ventilation island at mid-tunnel, an undesirable structure for shipping through the Strait. A longitudinal ventilation design supported by ventilation plants at the portals only could thus reduce both capital and running costs and environmental impacts. **Figure 7-10** shows a typical example of a longitudinal ventilation system in a road tunnel using jet fans.

For road tunnels, the most probable fire hazards will arise from the vehicles using the tunnel, the materials from which they are manufactured and the materials they are transporting. Another potential source of fire hazard comes from failures of equipment in the road tunnels or any plant and equipment room which, although fire separated from the tunnel, may still impact the operation.

Figure 7-10: Example of Jet Fans installed in a Road Tunnel

The conceptual design of the ventilation system has incorporated fan redundancy requirements to account for the potential of a fan failure during an emergency.

7.6.2.1 Road Tunnels

Road tunnels pose specific challenges in terms of ventilation and fire safety design. While diluting the traffic exhaust pollutants to acceptable international limits remains the purpose of any ventilation design, the issue of light extinction and visibility through diesel smoke can be more significant in tunnels with a high proportion of diesel engines or commercial trucks. In normal operation, the average speed of traffic usually provides adequate piston effect to ventilate a tunnel longitudinally through the portals, without operating any fans. In peak hours, when low-speed congested traffic is expected, the aerodynamic drag of vehicles drops while the journey time and hence the pollution rate per vehicle increases. The tunnel ventilation system shall be able to cater for this critical scenario.

Finally, the case of fire emergency has to be considered, with the ventilation system capable of either removing smoke through duct-work (transverse ventilation) or providing critical velocity to prevent smoke back-layering (longitudinal ventilation). In many tunnels, it is this last design criterion of tenability for fire emergencies that drives the fan capacity and overall system cost. Although longitudinal design is the most cost-effective method (typically a fraction of the cost of fully transverse), it has obvious limitations with tunnel length and in a fire emergency, where one side of the fire has to be sacrificed as smoke downstream of the fire makes that portion of tunnel untenable. Because of their smaller space demand and lower cost, the use of jet fans has become considered the choice among many recent tunnel ventilation designers for longer tunnels, other variants combining jet fans with intermittent vent shafts have been used. In the case of the Strait of Belle Isle Fixed Link, having an intermittent vent shaft is not considered a feasible solution.

In the event of a fire in the road tunnel, it is assumed that the traffic in front of the fire will continue to drive through the tunnel and will be travelling faster than the flowing smoke layer. The traffic behind the fire will stop and the occupants of these vehicles will commence the evacuation upstream of the fire (as illustrated in **Figure 7-11**). The occupants will be notified via the signage and the alarm system to evacuate into the designated evacuation path. Cross passages into the evacuation path could be spaced at intervals of 200 m, less than recommendations in international guidance, providing an increased level of life safety.

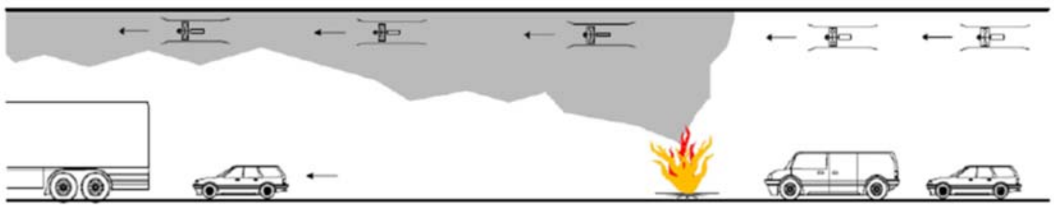


Figure 7-11: Ventilation of Road Tunnel in the Event of Fire using Jet Fans

For the proposed Strait of Belle Isle Fixed Link tunnel, the use of a ducted ventilation system significantly increases the cross-sectional area and perhaps necessitates the need for a ventilation island in the middle of the tunnel. Preliminary concept calculation has indicated that the required ventilation duct would be in the order of up to 45 m^2 to overcome the pressure differences associated with ducting hot gases. This duct area could be reduced by the introduction of a ventilation island in the middle of the tunnel, thereby only requiring hot gases to be ducted a maximum of 10 km. This would have the benefit of providing additional space for ventilation fan stations. However, introducing an island in the middle would have the recognisable drawback of increasing the risk for ship collisions and environmental consequences. A ducted system however has a number of other implications for the tunnel design over and above the longitudinal system. These include a reduced reliability and an increased risk to life safety due to more single points of failure, e.g. extract fan failure or fire damper failure, both of which have the potential to impact on the effectiveness system wide. Furthermore, there are increased maintenance requirements, an increased construction time and increased costs.

7.6.2.2 Rail Tunnels

In accordance with current practice for most railway tunnels, a train on fire should make all attempts to leave the tunnel and this practice will be initiated across the Strait of Belle Isle Fixed Link. Considering the block sections and timetabling discussed above, the low rail traffic volumes in the operating period indicate that it is unlikely that more than one train will be present in the tunnel at any one time. For both road and rail tunnels based on past experiences of tunnel fires and the predictive traffic volumes and composition, it is possible to identify relevant fire hazards.

For the rail tunnel, the potential source of fire hazard comes from failures of equipment in the tunnel or any plant and equipment room which, although fire separated from the tunnel, may still impact the operation.

7.6.3 Emergency Egress

Typically, in tunnel fires the critical areas for life safety are within the vicinity of the fire and in the order of a few hundred metres away, particularly downstream of the fire. At that distance, away from the fire, visibility is likely to be lost; however, smoke temperatures will be reduced (especially with the inclusion of a suppression system) and toxicity often reduced to tenable conditions because of dilution. Within the Strait of Belle Isle Fixed Link road tunnel, exits are proposed every 200 m for self rescue. With a single-lane tunnel, emergency exits can only be provided by a passageway that is fire-separated from the vehicular space. For the rail tunnel, emergency egress will be via the walkway to a rescue vehicle that will be dispatched from the upstream (ventilation-wise) end of the tunnel.

7.6.4 Fire Suppression System

Fire suppression systems have been installed for many years in many long road tunnels in Japan and, during the last 20 years, in all road tunnels in Australia. Recently, following the major fires in the Mont Blanc, Tauern, Gotthard and Frejus tunnels in Europe, the World Road Association (PIARC) and the National Fire Protection Association (NFPA) have both revised their recommendations concerning suppression systems to much more positive consideration, but clearly state that such systems should only be installed as a part of an overall safety approach.

The trend for railway tunnels is less defined as there are limited known rail tunnels internationally incorporating a suppression system. This may be for a number of reasons including that rail fires are less frequent than road tunnel fires and, that in the event of a fire, trains are designed to drive out of the tunnel and thereby further reduce the incidents of rolling stock fires in tunnels. On this basis, the cost/benefit of the suppression system may not be perceived to be significant enough to warrant the initial investment. However, the shuttle vehicles will be equipped with self contained fire suppression systems.

In both road and rail tunnels with fire suppression installed, the immediate effect will be to limit the fire size and control the fire growth. Fires occurring in vehicles may sometimes not be directly affected by a suppression system if the fire is shielded by the vehicle. In these instances, the suppression system is controlling the fire rather than suppressing or extinguishing the fire. By controlling the fire, the development of a catastrophic fire can be avoided and the tunnel structure protected, minimizing damage and repair time. If the fire is controlled, the chances of a successful evacuation will increase while aiding the emergency services' ability to control the situation. Another aspect is that by minimizing the frequency of development of a catastrophic fire, the risk to life safety can be drastically reduced and, furthermore, the downtime as a result of a fire can be minimized. In the context of the overall risk assessment for the Strait of Belle Isle Fixed Link tunnel, these two aspects assist in ensuring that the risk level to tunnel users, operational revenue and reputation is as low as reasonably practicable. For this reason, a deluge suppression system is recommended to be considered for installation in both the road and rail tubes of the Strait of Belle Isle Fixed Link provided issues related to low ambient temperatures can be resolved.

7.6.5 Ventilation Strategy

The use of a longitudinal ventilation system for smoke control is the basis for the conceptual design of the Strait of Belle Isle Fixed Link. This longitudinal ventilation approach is cost effective and eliminates the need for a ventilation island at mid-tunnel. For this design, jet fans will be placed along the tunnel as shown in **Figure 7-12**. A typical jet fan is shown in **Figure 7-13** below. During normal operation, both road and rail tunnels are self-ventilated as a result of generated piston effects with moving cars/ trucks or trains. At later stages of design for the option of road tunnel, in case generated piston effect was determined not be sufficient to bring the level of contaminants down to an acceptable level, some of the jet fans could be in operation to exhaust contaminate through portals.

In the event of emergency for road tunnel option, the traffic in front of the fire will continue to drive through the tunnel. The traffic behind the fire will stop and the occupants of these vehicles will commence the evacuation upstream of the fire. Jet fans will be in operation to direct the smoke opposite to the direction of evacuation. For rail tunnel in a similar pattern, smoke will be directed to the opposite direction of evacuation. In both tunnel options, a protected egress path within the tunnel has been allocated for safe evacuation of passengers.

With 21 km length of Strait of Belle Isle Fixed Link, four jet fans are proposed to be installed at every 500 m interval (**Figure 7-12**). This will translate to about 168 fans in the tunnel.

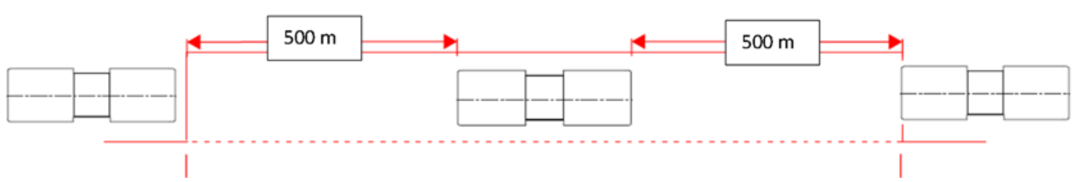


Figure 7-12: Longitudinal Cross Section Along Proposed Ventilation Arrangement

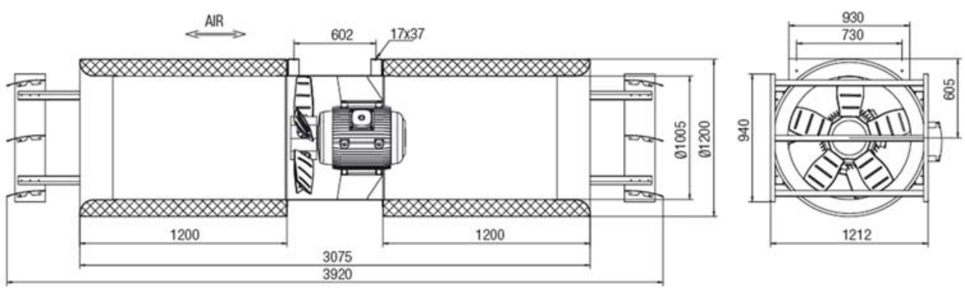


Figure 7-13: Typical Jet Fan

7.7 Tunnel Services

There are a number of tunnel services that will impact the tunnel spatial arrangements, schedule and costs. Dedicated services shall be serving both, the travelled portion of the tunnel and the emergency egress space.

For the rail tunnel, a separate consideration is required for traction power provisions within the tunnel, including catenary integrity, grounding conditions within the tunnel and traction power reliability.

7.7.1 Road Tunnel

7.7.1.1 Tunnel Communications Services

Fire detection is particularly important for road tunnels. Due to the tunnel length, video surveillance based fire detection is recommended as a part of the overall tunnel surveillance strategies. Thermal cameras located at strategic locations within the tunnel and connected to the main backbone should be installed for early warning of a fire within the tunnel so that traffic in and out of the tunnel could be properly managed. The entire tunnel should be under the surveillance so that all tunnel conditions for safety, traffic control and tunnel operations are fully observed.

A dedicated tunnel control centre should act as the main communications node. Responsibility for the centre includes safety, traffic control and tool collection. A backup control centre should be planned at the other tunnel end.

All tunnel services, such as ventilation, road conditions monitoring, power and lighting controls, drainage pumps, etc., should also be remotely controlled.

As per NFPA-502, emergency call stations must be located at strategic locations within the tunnel. Typically, such emergency nodes include an emergency telephone, blue light for identification and fire-extinguisher. Such emergency stations are placed within the tunnel at regular distances (typically 250 m apart).

Tunnel signage are placed at strategic locations within the tunnel for both emergencies as well as traffic announcements. Both static and dynamic signage are used along the tunnel clearly identifying tunnel stationing, access to closest escape route, status of traffic flow, etc. Tunnel portals require additional signage to ensure safe passage and constant supervision of the traffic flows, which is specifically important for a single-lane tunnel with alternating travel directions.

Significant communications requirements for tunnel operations will be served by a dedicated backbone, redundant optical cables that run along the entire tunnel length.

7.7.1.2 Tunnel Electrical Services

Utility power provisions for the tunnel are assumed to be available at both tunnel portals. Otherwise, additional large in-situ backup generation power needs to be provided. Due to the tunnel length, medium voltage power distribution within the tunnel is required. As the result, intermediate power stepdown transformers would be required within the tunnel, as illustrated in **Figure 7-14**. Placements of those stepdown transformers within the tunnel would require accessible space, fire-protection, alarming and fire-fighting facilities.

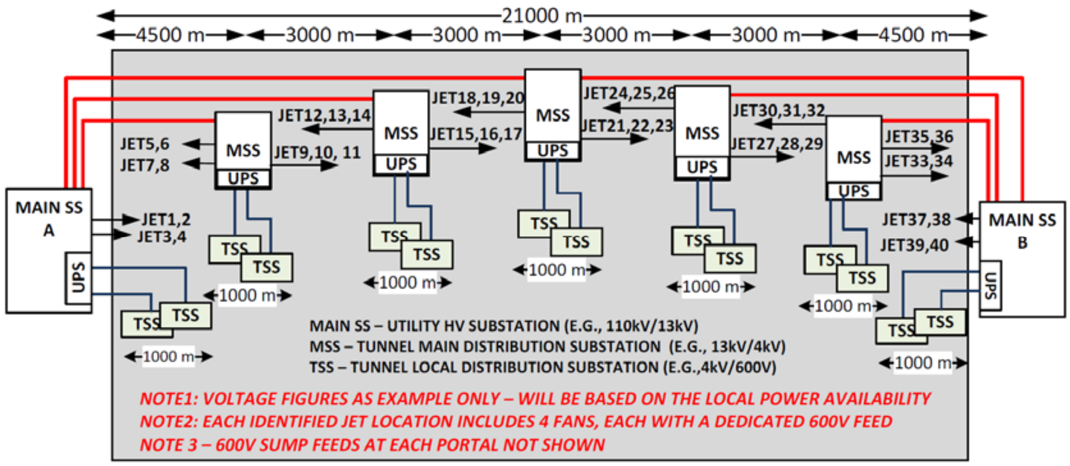


Figure 7-14: Power Distribution for Road Tunnel Services (illustration only)

Tunnel electrical services considered life safety for tunnel lighting, communications and tunnel smoke ventilation. Tunnel power distribution for emergency services is based on a 600V AC distribution infrastructure along the entire tunnel length, designed and placed to ensure continuous power services. Tunnel electrical infrastructure is designed to ensure a minimum 2-hr fire rating for all emergency services.

All tunnel lighting is designated as emergency, LED based lighting that ensures durability, low consumption and low maintainability requirements. Tunnel lighting is rated at 600V AC to optimize overall power requirements and coverage. Tunnel lighting is designed so that any single fault will not impact the minimal lighting conditions within both traffic and emergency escape tunnels. Additionally, emergency power at 120V AC, typically required for communications needs, is obtain by the local 600/120V AC mini-substations strategically located within the tunnel (**Figure 7-15**).

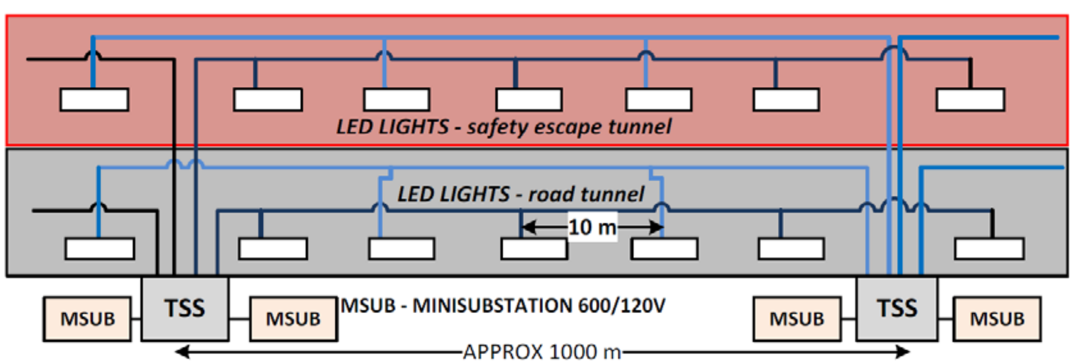


Figure 7-15: Road Tunnel Power Distribution - Typical Section

Additional (normal) power should be provided for other tunnel services like fans, receptacles, sumps, traffic lane lights and portal lights. Preliminary tunnel power load estimates for both emergency and normal power are provided in the following **Table 7-9** and **Table 7-10**.

Table 7-9: Road Tunnel Emergency Power Requirements

Essential Services (emergency power)	Total Load kVA (estim.)	Quantity	Comment
Emergency lights one every 10 m for the main tunnel; 64W per light fixture	240	21 x 100	Section length approximated. Total tunnel length 21 km. Each light 1.73*64=111 VA
Emergency lights one every 10 m per 1000 m emergency tunnel section; 32W per light fixture	120	21 x 100	Section length approximated. Total tunnel length 21 km. Each light 1.73*32=55 VA.
Emergency Blue Stations – four per 1000 m tunnel section (approx. 250 m apart	370	21 x 4	Each Blue Station with telephone, repeater, camera and networking switches (2.5kW each = 4.3 kVA).
Portal Infrastructure	40	2	Portal light, info boards, security
Total	**770 kVA**		

NOTE: Electrical losses are considered in the above rounded total load numbers.

Table 7-10: Road Tunnel Normal Power Requirements

Other Services (normal power)	Total Load (estim.)	Quantity	Comment
Tunnel ventilation (redundant feeds)	3,600 kVA	21 x 2 x 4	4 jet fans per 500 m. 90 kVA each
Tunnel sumps	120 kVA	2	One at each portal end; 60 kVA each
Traffic lane tunnel lights	250 kVA	21 x 200	2 x 100 LED (32W) per 1000 m (one above each lane)
Total	**3,970 kVA**		

NOTE: Electrical losses are considered in the above rounded total load numbers.

7.7.2 Rail Tunnel

7.7.2.1 Tunnel Communications Services

Fire detection is less of an issue for rail tunnels compared to road tunnels. Fire detection is recommended for areas with potential fire hazards, e.g., electrical substations and the major electrical components. A standard in-situ fire/smoke detection is recommended. Places of interest within the tunnel, such as main communications and electrical nodes, should be under surveillance. Moreover, all rail cars should be under surveillance with on-line video streams available within the control centre.

A dedicated tunnel control centre should act as the main communications node. Responsibility for the centre includes safety and security for all rail and tunnel operations. A backup control centre should be planned at the other tunnel end.

All tunnel services such as ventilation, tunnel conditions monitoring, power and lighting controls, drainage pumps, etc. should be remotely controlled.

As per NFPA-130, emergency call stations must be located at strategic locations within the tunnel. Typically, such emergency nodes include an emergency telephone and blue light. The emergency stations are placed within the tunnel at maximum distances of 240 m apart.

Tunnel signage are placed at strategic locations within the tunnel for information during emergency situations but also for general information during normal maintenance activities.

Significant communications requirements for tunnel operations will be served by a dedicated backbone, with redundant optical cables, that runs along the entire tunnel length.

7.7.2.2 Tunnel Electrical Services

Utility power provisions for the tunnel are assumed to be available at both tunnel portals. Otherwise, additional large in-situ backup generation power needs to be provided. Due to the tunnel length, medium voltage power distribution within the tunnel is required. As the result, intermediate power stepdown transformers would be required within the tunnel, as illustrated in **Figure 7-16**. Placements of those stepdown transformers within the tunnel would require accessible space, fire-protection, alarming and fire-fighting facilities.

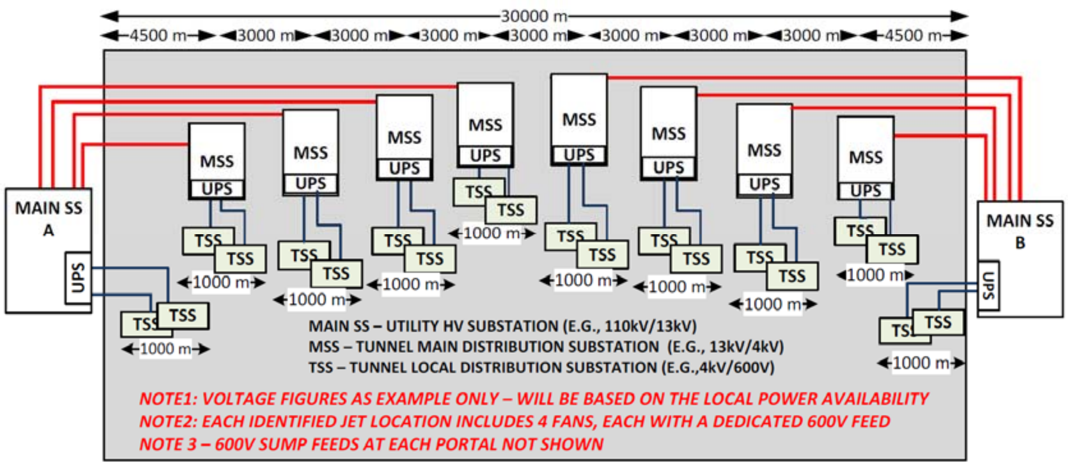


Figure 7-16: Power Distribution for Rail Tunnel Services (illustration only)

Tunnel electrical services considered life safety; for tunnel lighting, communications and tunnel smoke ventilations. Tunnel power distribution for emergency services is based on a 600V AC distribution infrastructure along the entire tunnel length, designed and placed to ensure continuous power services. Tunnel electrical infrastructure is designed to ensure a minimum 2-hr fire rating for all emergency services.

All tunnel lighting is designated as emergency. LED based lighting that ensures durability, low consumption and low maintainability requirements. Tunnel lighting is rated at 600V AC to optimize overall power requirements and coverage. Tunnel lighting is designed so that any single fault will not impact the minimal lighting conditions within both traffic and emergency escape tunnels. Additionally, emergency power at 120V AC, typically required for communications needs, is obtain by the local 600/120V AC mini-substations strategically located within the tunnel (**Figure 7-17**).

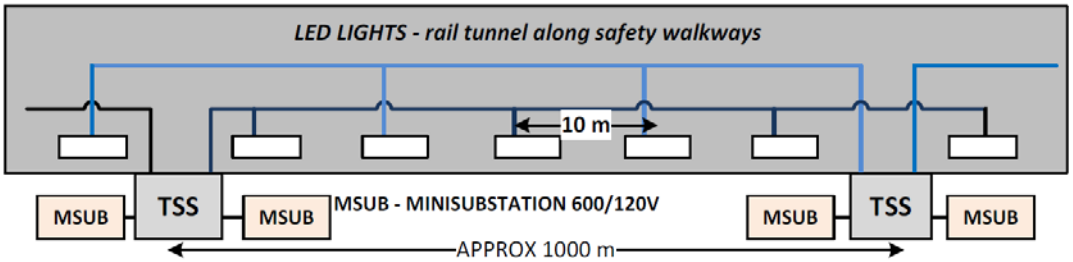


Figure 7-17: Rail Tunnel Lighting – Typical Section

All tunnel communications power shall be on emergency services. Additional (normal) power shall be provided for other tunnel services e.g., receptacles, sumps and portal lights. Preliminary tunnel power load estimates for both emergency and normal power are provided in the following **Table 7-11** and **Table 7-12.**

Table 7-11: Rail Tunnel Emergency Power Requirements

Essential Services	Total Load (estm.)	Quantity	Comment
Emergency lights one every 10 m for the main tunnel; 64W per light fixture	350 kVA	30 x 100	Section length approximated. Total tunnel length 30 km. Each light 1.73*64=111 VA.
Emergency Blue Stations – four per 1000 m tunnel section (approx. 250 m apart	550 kVA	30 x 4	Each Blue Station with telephone, repeater, camera and networking switches (2.5kW each = 4.3 kVA)
Total	**900 kVA**		

NOTE: Electrical losses are considered in the above rounded total load numbers.

Table 7-12: Rail Tunnel Normal Power Requirements

Other Services	Total Load (estm.)	Quantity	Comment
Tunnel ventilation (redundant feeds)	1400 kVA	2 x 2	Push-Pull fan operation, 1 backup fan at each portal.
Portal Infrastructure	40 kVA	2	Portal light, info boards, security.
Tunnel sumps	120 kVA	2	One at each portal end; 60 kVA each.
Total	**1,560 kVA**		

NOTE: Electrical losses are considered in the above rounded total load numbers.

7.7.2.3 Traction Power

Traction power is assumed to be supplied to the train cars at 25kV AC single phase. Sources for traction power would be from each end of the tunnel at the portal area and will be from dedicated traction power substations (TPSS). Power utilities in the Province of Newfoundland and Labrador would need to be consulted and accept potential de-balance that could be caused by the project as the train will run on a single phase 25kV AC.

Traction power substations will be sized to accommodate the proposed 3MW train propulsion system. This will consider train traction power and auxiliary loads as well as system losses for delivering the power to point of use as the train travels along the track alignment. Under normal operating conditions, each TPSS would feed half of the tunnel (AC systems are typically sectionalized) but the system will be designed to be able to feed the whole tunnel under a contingency condition from a single TPSS. This would allow getting the train out of the tunnel if one of the TPSS fails.

Overhead contact rail would provide a compact design from a space and ampacity prospective. The 25kV overhead insulators must abide by clearance limits from live to grounded components. All mounting hardware and other associated equipment will need to be grounded as per the Canadian Electrical Code requirements throughout the tunnel. Isolation switches for the overhead rail system to be placed at intervals within the tunnel to accommodate isolation and grounding of the overhead rail for maintenance purposes. Track and OCS maintenance is assumed to take place outside of the normally scheduled operational times of the trains.

At the midpoint of the tunnel (**Figure 7-18**), three high voltage (HV) cabinets (one for each HV connection to the OCS and one to house the remotely operable HV breaker or current interruptible switch) will be placed to allow for an isolation point between two different power sources, one from each tunnel end. Space within the tunnel for the HV equipment and related auxiliary cabinets would be required at this location (e.g., step down transformer, UPS system, controls, communication, etc.).

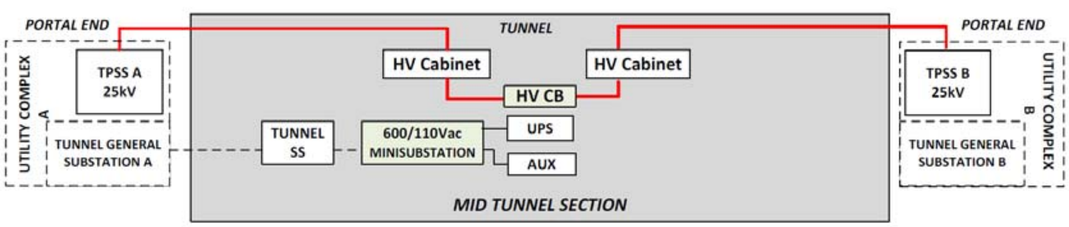


Figure 7-18: Rail Tunnel Traction Power – Typical Mid Tunnel Section

The midpoint isolation breaker and supply breakers from the TPSS provide an integrated protection scheme for transfer trip of the breakers under abnormal condition detection along a section of the line.

Return path for the power supplied to the trains will be by the rail system. Rails on the AC system will be grounded for safety reasons. All wayside equipment will also be grounded. DC stray current is minimal for an AC systems and cathodic corrosion will be minimal, but should be reviewed as part of the due diligence for the project.

7.7.3 TBM Construction Power Requirements

If the tunnel will be excavated by two TBMs, each working from the opposite tunnel sides, two construction camps with all facilities are required near each portal. An initial estimate is to have temporary (construction) power means of 4 MVA at each launch shaft for a TBM, plus 2 MVA for temporary tunnel ventilation and lighting and the construction site needs.

7.8 Rescue Strategy

Due to difference in tunnels construction and operations, separate rescue strategies apply to the road and rail tunnel options.

7.8.1 Road Tunnel

Considering that rescue efforts would apply to the entire tunnel, an emergency space separated from the travelled portion of the tunnel will be available along the entire tunnel length. Access into the emergency escape route will be provided every 250 m; fully identified, easy accessible and with public announcements and security cameras to support evacuations.

The emergency escape space will have its own lighting, communication and ventilation infrastructures to ensure passenger safety and access.

The key emergency features are traffic controls to minimise the number of vehicles remaining within the tunnel in case of an emergency. Traffic flow planning and supervision will require increased traffic controls, lane signalling and surveillance. Therefore, in addition to a single lane normal transit through the tunnel and strict speed controls, the tunnel layout will enable emergency vehicle passage even if traffics stops within the tunnel.

7.8.2 Rail Tunnel

The evacuation strategy for the rail tunnel option considers that only a single train will be present within the tunnel at any time and that the number of passengers per train will be strictly controlled. Protocols for shuttle train inspections before trains enter the tunnel have to be regular and completed for each tunnel run. Each train car must be equipped with its own fire detection and suppression systems.

An electrical train within the tunnel will follow a predetermined emergency strategy. Priority will remain to get the train out of the tunnel in case of emergencies. Any emergency train stop within the tunnel will be followed by a catenary system disconnection prior to evacuation efforts.

Communication infrastructure between the control centre and the train drivers is of utmost importance; redundancy and additional protective measures will be required to ensure such communications systems are available.

Rescue vehicles will be available at each tunnel portal and will be sized to evacuate all passengers in a single attempt. A separate emergency space along the tunnel will not be required considering this rescue approach.

7.9 Tunnel Dimensions

The dimensions of the tunnel cross-sections were defined based on the requirements for clearance, ventilation, emergency egress and other services as discussed above.

7.9.1 Road Tunnel

As in 2004, a tunnel cross section with an inner tunnel diameter of 11 m is suitable to accommodate the required widths of the traffic lane including passing lane and the emergency space. The proposed cross-section is shown in **Figure 7-19**. The area above the travelled lane, that was previously designated as exhaust ventilation space, can accommodate the proposed jet fan ventilation system. Room for required utilities, cables etc. as well as for potential future utilities is available above the emergency space.

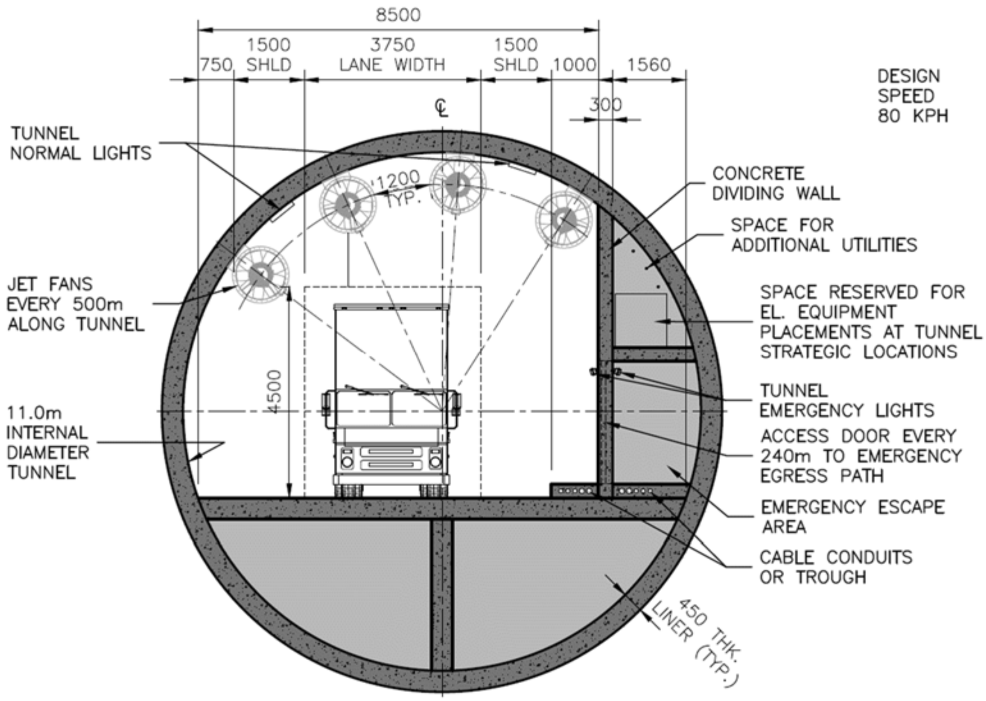
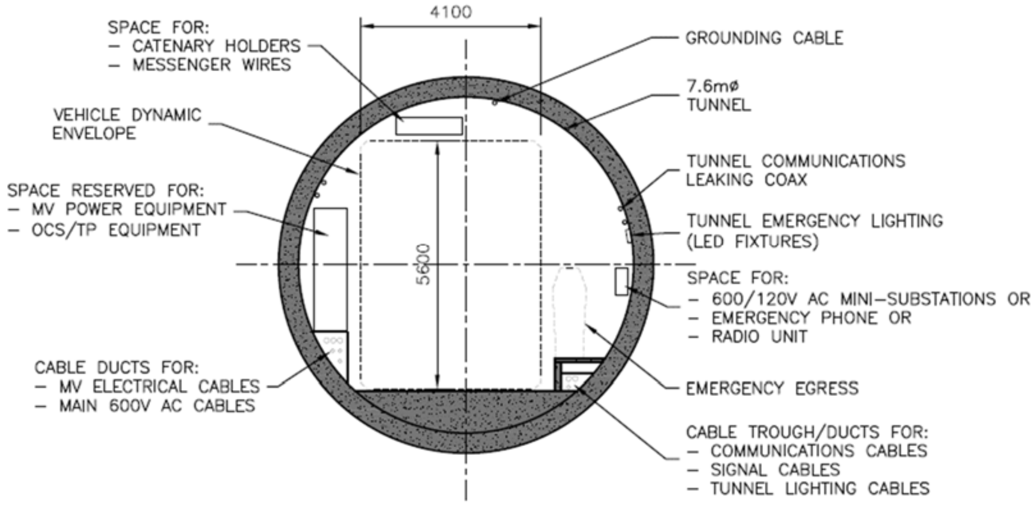


Figure 7-19: Proposed Cross-Section – Road Tunnel

7.9.2 Rail Tunnel

For the rail tunnel, as in 2004 a tunnel cross section with an inner tunnel diameter of 7.6 m is suitable to accommodate the required widths and height of the single-track shuttle train including the catenary system. The proposed cross-section is shown in **Figure 7-20**. For emergency egress, with only one train in the tunnel, the tunnel would be available for egress. Passengers would exit the shuttle train and egress along the walkway towards the exiting direction of the tunnel to the rescue vehicle.



Note: To ensure minimal lighting and communications within the tunnel during emergencies, MV power equipment and associated cables shall be fire protected or implemented with full redundancy.

Figure 7-20: Proposed Cross-Section – Rail Tunnel

7.9.3 Tunnel Approaches, Road Connections and Terminus Facilities

The concept for the tunnel approaches on both shores including road connections and terminus facilities was discussed in the 2004 study. The general layout of these approaches with their entailed portal and terminus structures as well as the new roads required to connect the tunnel with the existing road system on both sides of the Strait as described in the 2004 study is still considered valid. A more detailed study of the approaches would be required at a later stage of the project.

7.10 Excavation Methods

The excavation method for the tunnel excavation across the Strait of Belle Isle has to be appropriate for the ground conditions and must be capable of addressing the various challenges that might be encountered on shore and underneath the Strait.

In very general terms, the geology for the Strait crossing is typified by more permeable sedimentary rock overlying less permeable gneiss. Considering that a tunnel excavation in the less permeable gneiss would result in a significantly longer tunnel alignment at great depth and, hence, significantly higher costs, it is assumed that the tunnel will be excavated in sedimentary rock of varying quality, from strong, good quality rock to highly fractured and weak rock. Challenges that have to be expected during tunnelling under the Strait include the following:

- Varying ground conditions including very strong, stable rock to weak, unstable rock, requiring different means of rock support and/or reinforcement.
- Locally poor ground conditions with highly fractured, unstable rock, related to fault zones or areas of weak shale.

- High water inflow into the tunnel through fractures in the rock mass, related to fault zones or other areas of poor ground conditions.
- High hydrostatic pressure of up to approximately 13 bar if faults or vertical fractures connect the tunnel to the water body of the Strait of Belle Isle (considering a tunnel elevation of 130 m below water level; actual pressure will depend on tunnel depth).
- Time-dependent rock deformations that might occur following the excavation, including squeezing and swelling of the rock.

7.10.1 Drill & Blast Excavation

Drill & blast excavation methods involve the controlled use of explosives. The method requires several steps involving multiple machines, resulting in a higher cycling time and typically in a slower advancement rate. Drilling equipment varies from handheld jackhammers and jack legs to large mobile jumbos and gantries, depending on the size of the tunnel heading. The typical drill & blast excavation scheme is shown in **Figure 7-21**. Typically, drill & blast techniques are more suitable for tunnels with larger diameter or with multiple access points, which allow development of multiple faces at once, resulting in higher operational efficiency.

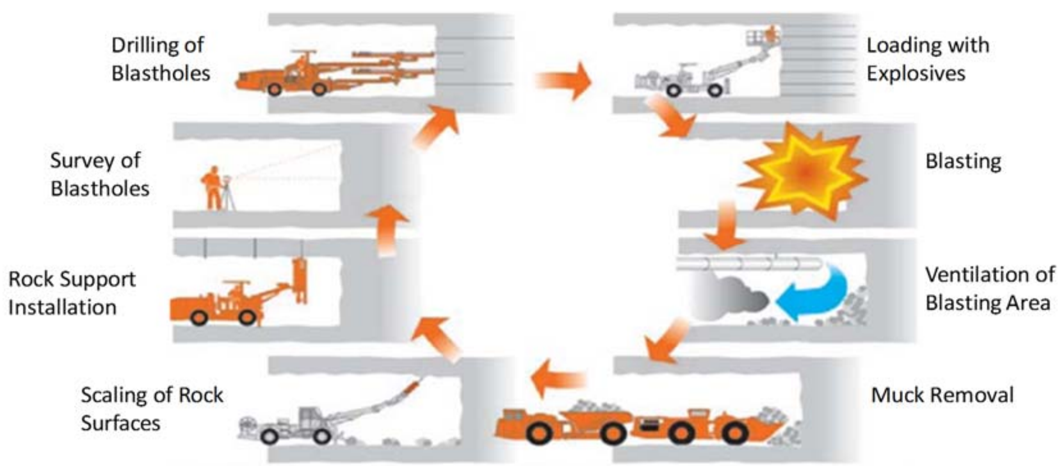


Figure 7-21: Typical Drill & Blast Excavation Scheme

The general advantage of drill & blast excavation is its flexibility regarding excavation size and ground support. In changing or difficult ground conditions such as faults or squeezing ground, the support as well as the excavation diameter can be adjusted to the requirements based on the encountered conditions. The advance rate for drill & blast excavations depends on the rock support required; minimal support installation in stable ground results in greater advance rates.

Drill & blast excavation is suitable for all rock types. Problems are typically related to over-excavation in areas of fractured rock or due to poor blasting operations as well as to the evacuation of gases from explosives after blasting. Issues such as noise or vibration due to the use of explosives do not apply to the Strait of Belle Isle excavation.

7.10.2 Mechanical Excavation (Roadheader)

Mechanical excavation includes the use of mechanical cutting equipment such as a roadheader (see **Figure 7-22**). A roadheader is a specialized mechanical equipment for the excavation of rock that uses a rotating cutting head system installed at the end of a hydraulic boom. The cutting head comprises typically two rotary cutters that are equipped with 5 to 6 rows of cutting bits which, by their rotation, cut and excavate rock. The roadheader moves on tracks. The energy required for rock excavation is supplied by an electrical power supply while the movements of the machine can be done either by a diesel engine or by an electric motor. Roadheaders are very flexible and mobile and can excavate various sizes and shapes of openings.

Removal of the excavated rock can be carried out with trucks or a conveyor belt. A typical roadheader excavation approach is shown in **Figure 7-23**.

Figure 7-22: Roadheader

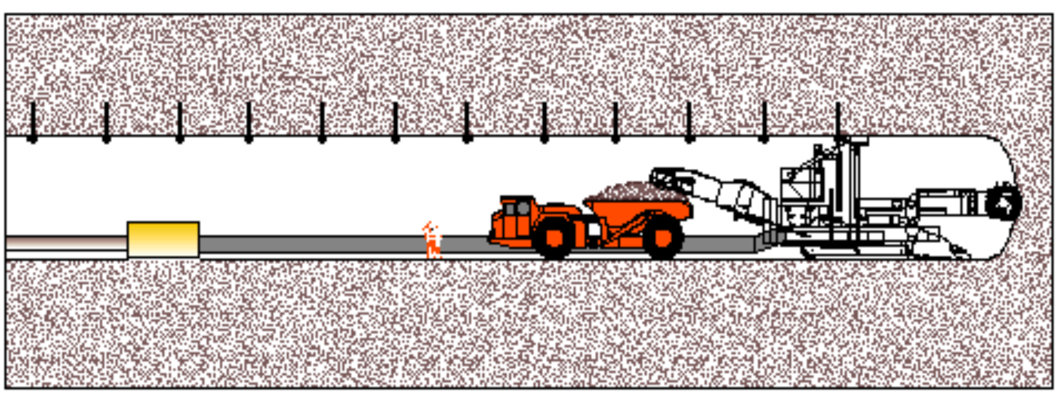


Figure 7-23: Typical Roadheader Excavation Scheme

The effective use of a roadheader depends largely on the rock type that is to be excavated and the characteristics of the rock mass. Highly abrasive rock types such as sandstone and gneiss with a high content of quartz are typically not suitable for the use of a roadheader due to the abrasiveness of the quartz. A further factor of influence is the strength of the rock; an unconfined compressive strength of 140 MPa is typically considered the upper range for efficiency.

Progress rates are typically influenced by the structural features of the rock mass. A rock that contains discontinuities such as bedding planes and joints which create a blocky rock mass is favorable for the use of a roadheader since the discontinuities provide natural breaking planes in the rock; the roadheader pulls the fractured rock apart rather than cutting through it. Fault zones, water inflow and the requirements for rock support will further impact the efficiency of the roadheader. Overall, progress rates are generally slower compared to TBM excavations.

Issues such as dust from the rock breakage have to be addressed with a proper ventilation system in the tunnel during excavation. A water spraying system can reduce dust.

7.10.3 Tunnel Boring Machine (TBM)

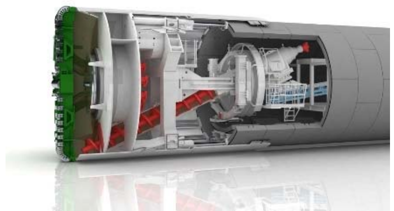
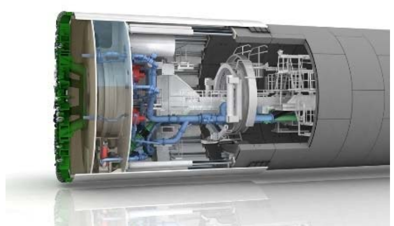
TBMs are available in a range of different machines; the selection of the appropriate machine for a tunnelling project should consider the geotechnical and hydrogeological conditions of the project site. A comparison of the most common machines and their typical applications is provided in **Table 7-13** below (images taken from Herrenknecht [28]). Hybrid (dual or multi-mode) machines that combine the advantages of individual TBMs are available to suit mixed or unpredictable ground conditions. These machines were developed to operate in both open and closed mode to address heterogeneous ground conditions but also withstand high hydrostatic pressures. As discussed above, this type of TBM was successfully used for projects under water pressures of up to 17 bar.

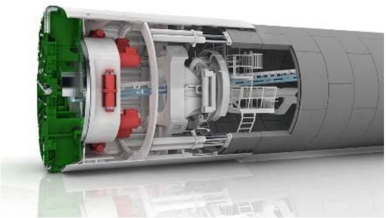
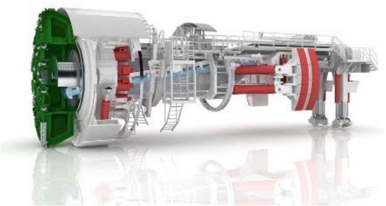
The general advantages of the use of a TBM are the limited disturbance to the surrounding ground and the production of smooth tunnel walls. Consideration must be given to the effects of cutter wear associated with plucking thinly bedded rock from the excavation face and with the abrasivity of the quartz rich gneiss and sandstone formations.

Based on the comparison in **Table 7-13** and pending further geotechnical investigation prior to construction of a tunnel fixed link at the Strait of Belle Isle, the use of a pressurized face machine, for example a Mixshield TBM, is currently considered the most suitable solution.

Mixshield machines are suitable for the expected difficult ground conditions varying between strong rock and potentially weak faults zones with high water inflow, under which condition the machine would operate in closed mode with pressurized face. Considering the tunnel elevation of approximately 130 m below sea level, the machine has to be capable of sustaining the corresponding hydrostatic pressure of 13 bars. Recent projects such as the Eurasia Tunnel project as well as the Lake Mead Tunnel have shown that Mixshield TBMs have the capabilities to address these pressures.

Table 7-13: Overview of Common Tunnel Boring Machines (TBMs)

Earth Pressure Balance (EPB) Machine • Typically used in soft cohesive ground with low permeability; for all excavation diameters. • Special solutions available for use in heterogenous or unstable ground and increased water pressure. • Excavation under controlled positive face support pressure using soil paste. • Excavated material entering the excavation chamber is turned into paste and used as tunnel face support; controlled pressure conditions in the excavation chamber prevent uncontrolled soil inflow and settlements/heave. • Soil enhancement possible with injections of soil conditioning material into the surrounding ground. • Tunnel lining/rock support consists of pre-cast concrete segments installed behind the machine. • Machine advances with the use of hydraulic cylinders that push the machine forward from the previously installed concrete liner ring.	
Slurry Machine • Typically used in all ground conditions, including complex ground and high permeability; typically for small to medium excavation diameters (microtunnelling) • Excavation under controlled positive face support pressure using slurry suspension. • Hydraulic tunnel face support to control difficult geology and high water pressure; controlled pressure conditions in the excavation chamber stabilize the tunnel face, prevent uncontrolled soil inflow and settlements/heave. Hydraulic pressures of up to 17 bar have been addressed in recent projects. • Tunnel lining/rock support consists of pre-cast concrete segments installed behind the machine. • Machine advances with the use of hydraulic cylinders that push the machine forward from the previously installed concrete liner ring.	
Mixshield Machine • Typically used in heterogenous ground conditions with high permeability and high water pressure; for all excavation diameters. • Excavation under controlled positive face support pressure using slurry suspension and pressurized air cushion. • Hydraulic tunnel face support to control difficult geology and high water pressure; controlled pressure conditions in the excavation chamber stabilize the tunnel face, prevent uncontrolled soil inflow and settlements/heave. • Tunnel lining/rock support consists of pre-cast concrete segments installed behind the machine. • Machine advances with the use of hydraulic cylinders that push the machine forward from the previously installed concrete liner ring.	

Single Shield Machine • Typically used in soft to hard rock or stable, non-groundwater bearing soil; for all excavation diameters. Shielded and sealed machine not usable in high water pressure conditions. • Excavation under atmospheric pressure. • Machine can be protected against jamming in the rock, for example in squeezing rock, if design accounts for an excavation diameter larger than shield skin diameter. • Can be equipped for use in rock with high water inflow; an injection system allows drilling and grouting of the rock ahead of the excavated face to control water inflow. • Shielding provides great safety for workers and machine and provides improved support of weak ground until initial support can be installed. • Tunnel lining/rock support consists typically of pre-cast concrete segments installed behind the machine. • Machine advances with the use of hydraulic cylinders that push the machine forward from the previously installed concrete liner ring.	
Open Face (Main Beam) Machine • Typically used in hard, stable rock with medium to high rock strength; suited for short faulted zones; for all excavation diameters. Usable in high water pressure conditions. • Excavation under atmospheric pressure. • Low potential of getting stuck in squeezing or swelling ground. • No segmental lining; excavated rock walls are unsupported; in fractured rock, immediate rock support can be installed behind the machine. • Flexible for installation of optional or additional rock support/reinforcement elements, thus minimizing ground displacements and stabilization requirements. • Can be equipped for probing and grouting ahead of the tunnel face if required in poor rock conditions or high water inflow • Tunnel lining/support with rock anchors, ring beams, shotcrete, etc. and/or subsequent concrete liner. • Machine advances with the use of hydraulic cylinders that push the machine forward from grippers that push against the excavated tunnel walls. • Tunnelling progress depends on the time for installation of rock support. High advance rates in good quality rock masses. • Roof shield above the unit behind the cutterhead provides protection for workers and machine against breaking rock.	

8. Updated Assessment of Preferred Fixed Link Option

The updated assessment focusses on the preferred option identified in the 2004 study to evaluate if the previous assessment is still valid or if the preferred option should be revised. Based on economic and technical considerations, the preferred option as defined in the 2004 study was a single-track rail tunnel excavated by TBM. Alternatively, a single-lane road tunnel excavated by TBM could be considered.

8.1 Updated Risk Assessment

As in 2004, construction risks and operational risks were considered for the risk assessment of the fixed link options. The main hazards that contribute to the risks associated with the Strait of Belle Isle fixed link options emerge from the difficult environment at the project location. The hazards include deep water, icebergs and sea ice, marine traffic, long winter season, snow and ice, high winds and fog but also the difficult ground conditions. Other hazards that relate to the operation of the fixed links include events such as accidents, vehicle breakdown and fire. The risks associated with these hazards result from the probability that a hazard occurs and the potential consequences. For this study, only a high-level risk assessment was undertaken. A detailed risk assessment should be conducted for the preferred option at a later project stage.

8.1.1 Construction Risks

TBM technology has continued to advance in the past years to address challenging ground conditions and high hydrostatic pressures and, compared to 2004, the general risk associated with TBM excavations has decreased due to experience gained from numerous large tunnel projects. However, certain risks related to the geotechnical conditions, including locally poor ground conditions, high water pressures and increased water inflows, remain and need to be addressed during tunnelling.

The use of an open face machine allows the installation of rock support adjusted to the specific requirements for individual tunnel sections. The machine also allows probing and grouting ahead of the tunnel face to address unstable ground and control water inflow.

The recent advances in the development of dual mode TBMs has led to machines that are capable to operate under high hydrostatic pressures of up to 17 bar which is higher than the pressures expected for tunneling underneath the Strait of Belle Isle. A TBM designed to operate in different modes, such as a mixshield machine to address unstable ground and high water inflow/pressure combined with a hard rock TBM (as was used for deep tunneling under Lake Mead with water pressure up to 17 bar), can reduce the risk associated with the water inflow and unstable ground while also enabling the excavation of competent hard rock. The use of a dual mode machine would require the installation of a segmental concrete lining.

Construction risks also include that the machine can get stuck due to time-dependent rock deformations (such as squeezing or swelling ground) or due to mechanical problems. A potentially required recovery of the TBM through a shaft drilled from ground surface would not be possible at the Strait of Belle Isle.

Construction risks associated with drill & blast tunnel excavation relate mainly to the geotechnical conditions, including the expected faults zones with poor, fractured rock and high water inflows. A tunnel alignment at 50 m depth below the seabed would reduce the potential inflows due to the expected decrease of rock permeability in greater depths. However, a lower alignment also increases the hydrostatic pressure in the tunnel if faults extend to the seabed. Significant water inflow can be controlled only by grout injections into the surrounding rock; poor rock conditions must be addressed with appropriate support measures.

Considering that the impact of the excavation on the surrounding ground is high with drill & blast techniques, a deeper alignment would also allow for a greater rock cover above the tunnel to mitigate the risk associated with reduced crown thickness due to overbreak and rockfall from the tunnel roof. However, a deeper alignment also increases the length of the tunnel and hence the construction costs.

Mechanical tunnel excavation using a roadheader would need to address the same risks associated with geotechnical conditions as drill & blast tunnels. However, the impact of a roadheader excavation on the surrounding rock is significantly less that with drill & blast operations.

8.2 Updated Cost Estimate

8.2.1 Capital Costs Estimate

As in 2004, the 2017 updated estimate for the construction costs of a TBM bored tunnel was carried out using the Hatch tunnel estimating database (TED 2001). This database contains up-to-date information on labour and equipment requirements and advance rates from similar TBM bored tunnelling projects which were used in the development of a contractor style estimate. Where applicable, labour rates for Newfoundland were used. The costs include the connecting roads on each side of the Strait (but not the costs for a new highway along the north shore of the Gulf of St. Lawrence nor any upgrade of Highway 430), and the marshalling areas.

To allow a comparison of the costs, the 2017 construction cost estimates include the same assumptions as in 2004. In summary, the principal assumptions used in preparation of the estimates comprise the following:

- Earth pressure balance or mixshield type TBM, for the one TBM option, used to mine the tunnel starting from the Newfoundland side of the Strait or, for the two TBM option, one machine would launch from Newfoundland and one machine would launch from Labrador.
- Bolted precast concrete linings installed behind the TBM as it advances. The concrete elements were assumed to be manufactured in the Province of Newfoundland and Labrador.
- Labour conditions and wages as outlined in the collective agreement between the Construction Labour Relations Association of Newfoundland and Labrador Inc (CLRA)

and LIUNA, Local 1208, Construction, Rock and Tunnel and General Workers Union, June 2017.

- TBM advance rates of 14 m per day and 17.7 m per day where rock conditions are good, for highway and railway tunnels respectively.
- TBM advance rates of 5.4 m per day and 7.1 m per day in faulted zones which are assumed to occur over a 1400 m length of the tunnel alignment, for highway and railway tunnels respectively.
- 8-week long learning curve at commencement of tunnelling where advance rates are 50% of those achieved when the crews are experienced.
- 40% contingency applied to civil elements of the work.
- 20% contingency applied to mechanical and electrical elements of the work.
- 15% contractor's overheads and profit applied to the estimate.
- 17% applied to the overall estimate for design, construction management, and owner's costs.
- $20 to $23 million for feasibility study and environmental assessment.

The construction costs for the single bore road tunnel (1 TBM) option is estimated to be $2,064 million and the costs for the single bore rail tunnel (1 TBM) is estimated to be $1,675 million, both in in 2017 dollars. A detailed cost breakdown of both estimates is provided in Appendix C.

The construction costs for the rail tunnel option include estimates for three shuttle trains.

Camp cost and duration are not included in the estimated costs above and should be considered in the more detail phase.

8.2.2 Operating & Maintenance Costs (O&M Costs)

At a pre-feasibility study level, the O&M costs will be similar for all three tunnel concepts (single road tunnel, twin road tunnels, and single rail tunnel).

8.2.2.1 Road Tunnel

As in 2004, the updated O&M expenditures associated with the operation of a road tunnel can be categorized as follows:

- Management and operation of the tunnel control building.
- Traffic supervision costs. Closed circuit television would be used for monitoring of the tunnels, with full time monitoring taking place at the surface within the tunnel control building (costs doubled for twin tunnels).
- Emergency truck costs. Required for the removal of broken down vehicles from the tunnel, and for carrying emergency fire fighting equipment. One emergency truck will be required at each portal, and these should be stationed close to the portals but away from

the traffic flow. Fully trained operators and an assistant will be required for each truck on a 24-hour basis (same costs for single tunnel and for twin tunnels).

- Energy costs associated with the operation of the control centre, tunnel vehicles, tunnel ventilation equipment, and drainage pumps (costs doubled for twin tunnels).
- Electrical maintenance costs associated with the inspection and maintenance of the power distribution system (includes switchgear, transformers, wiring, and cabling), tunnel lighting, communication and signal systems (costs doubled for twin tunnels). A platform truck is required for maintenance of the tunnel lighting system (same cost for single tunnel and for twin tunnels).
- Mechanical maintenance costs associated with the inspection and maintenance of the tunnel ventilation system, emergency diesel generators, and drainage pumps (costs doubled for twin tunnels).
- Structure maintenance costs associated with the inspection, cleaning, and maintenance of the roadway, drainage sumps, and tunnel structure. A street cleaner vehicle is required for cleaning of the roadway, and a washing truck for frequent cleaning of the tunnel walls and soffit (costs doubled for twin tunnels).

Estimated operating and maintenance costs for the single road tunnel option are $7.7 million per annum and for the twin road tunnel option $12.1 million per annum, both in 2017 dollars. Appendix D1 provides a breakdown of these costs.

8.2.2.2 *Rail Tunnel*

As in 2004, the updated O&M expenditures associated with the operation of a rail tunnel can be categorized as follows:

- Emergency rescue vehicles cost: (Rail Tunnel) Required for rescue of passengers during an emergency event. One rail mounted diesel powered rescue vehicle will be required at each portal. Fully trained operators will be required for each rescue vehicle on a 12-hour daily basis (same costs for single tunnel and for twin tunnels). Energy costs associated with the operation of tunnel lighting, equipment, and drainage pumps. Most of these costs will be for the supply of electrical power and would, therefore, vary with fluctuations in market costs for electricity.
- Electrical maintenance costs associated with the inspection and maintenance of the power distribution system (includes switchgear, transformers, wiring, and cabling), tunnel lighting, communication and signal systems.
- Mechanical maintenance costs associated with the inspection and maintenance of the tunnel ventilation system, emergency diesel generators, and drainage pumps.
- Structure maintenance costs associated with the inspection, cleaning and maintenance of the permanent way, drainage sumps, and tunnel structure.
- Staffing costs associated with loading vehicles on to the shuttle, three staff per shoreline.

Estimated operating costs for the rail tunnel alone are $1.0 million per annum in 2017 dollars. The estimated operating costs for the train shuttle are $7.7 million for a total of $8.7 million per annum in 2017 dollars. A breakdown of these costs is provided in Appendix D2.

8.2.3 *Contingency*

For tunnelling projects, typical contingencies at a pre-feasibility stage range from 40% to 75%. The selection of contingency level is particularly related to the existence or lack of geotechnical investigation. Typically, at this stage no investigation has taken place. For this project, a contingency of 40% has been chosen for the tunnel (civil) costs based on the availability of much improved geotechnical information due to the geotechnical investigations and surveys that have taken place for the Nalcor Energy project. In addition, the use of a TBM reduces the sensitivity to unpredicted ground conditions and it is, therefore, justifiable that the lower end of the range of contingency levels is used.

8.3 Cost Estimate Classification

The cost estimate prepared for the Conceptual Design Submittal is a Class 4 estimate as defined by the Association for the Advancement of Cost Engineering (AACE) [26]. As shown in **Figure 8-1**, an AACE Class 4 estimate is considered accurate to +30% to -20% based on:

- Level of Project Definition – Conceptual Design
- Methodology
- Preparation Effort

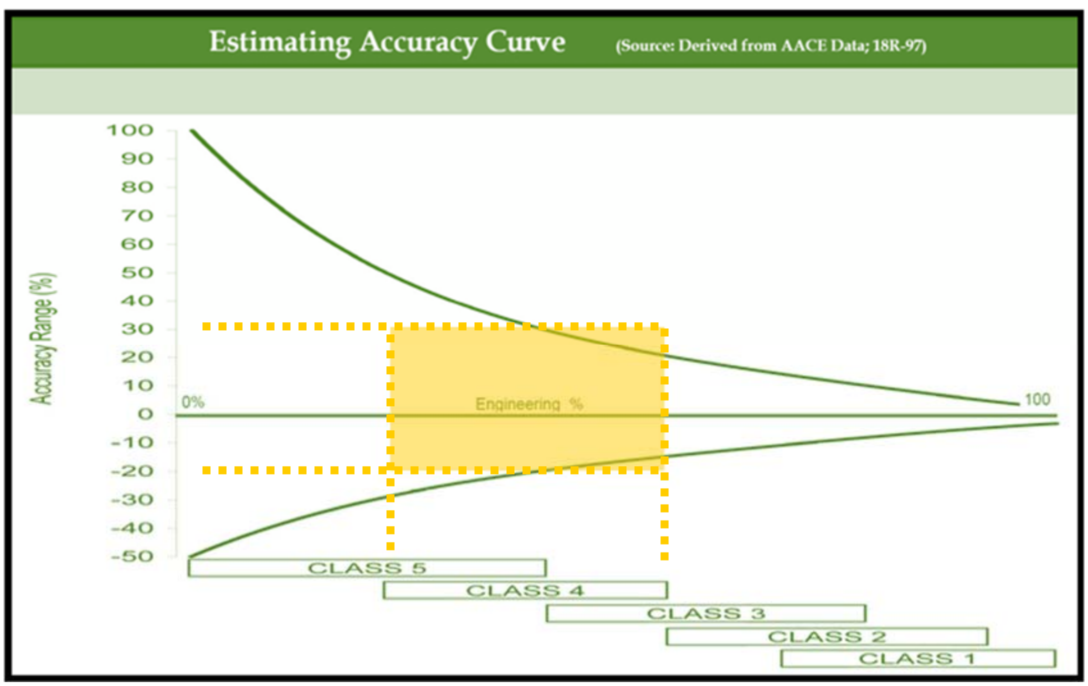


Figure 8-1: Estimate Accuracy

Figure 8-2 provides the cost estimate accuracy matrix that includes details regarding the specific characteristics of the classification levels such as maturity level of a project, purpose of cost estimate and associated accuracy ranges.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low(L), and high(H) ranges[a]
Class 5	0% to 2%	Conceptual planning	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Screening options	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Funding authorization	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Project control	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Fixed price bid check estimate	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of technology, availability of applicable reference cost data and many other risks affect the range markedly. The +/- values represent typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Figure 8-2: Cost Estimate Classification Matrix [26]

8.3.1 Markups

General contractor profit was applied at 15% based on industry averages for tunnel construction.

Indirect costs are generally inclusive of items such as supervision, survey, vehicles, quality assurance, insurance, safety, site office expenses, ablutions and miscellaneous costs. The calculated indirect costs for the project are equivalent to 12% of the direct costs.

Estimate contingency was applied to the aggregate of direct costs, indirect costs, and profit at 15% per AACE Class 4 standards based on the estimate level of effort and design percent completion.

8.3.2 Escalation Rate

Tunnel Work: Labour rates were not escalated from effective wages 2017 to the anticipated construction midpoint, 2024.

Surface Work: Unit costs were applied per the following:

- ENR September 2017 index value basis: 10823
- A final escalation of the unit costs will be performed for the final 100% estimate based on published cost data available closer to the time of bid.

8.3.3 Cost Resources

Cost data was obtained from the following resources and utilized where appropriate based on the estimate methodology for individual cost components:

- Tunnel & Shafts:
  - Hatch Proprietary Software - Tunnel Estimating Database (TED)
  - Historical project data
  - Vendor Materials / Equipment Quotations
  - Newfoundland and Labrador 2017 Prevailing Wages
- Surface Work:
  - R.S. Means
  - Historical Bid Data
  - Vendor Quotes on Equipment and Materials where appropriate

8.4 Updated Construction Schedule

A major factor in the schedule for a TBM bored tunnelling operation is the procurement of the TBM and manufacture and supply of precast concrete lining rings in advance of commencement of tunnelling operations. Experience on other major projects has demonstrated that TBM procurement / manufacture can typically take up to 15 months, and such a period has been assumed for the scheduling of the tunnel options.

The updated schedule for construction of the single road tunnel option comprises 14 years, including assumed 3 years for planning activities and 2 years for tunnel design. This schedule assumes that the tunnelling work would be undertaken by a single TBM operating from the Newfoundland side.

The schedule for construction of the railway option was assumed to be similar to that for the road tunnel with an additional 11 months because of the greater tunnelling length due to the flatter exit ramp grades. Using a single TBM results in an overall construction schedule of 15 years.

The updated schedules are shown in **Figure 8-3** and **Figure 8-4** below for the single bore road and rail tunnel option, both assuming the use of one TBM. The schedules for all road and rail tunnel options included in this report are provided in Appendix E.

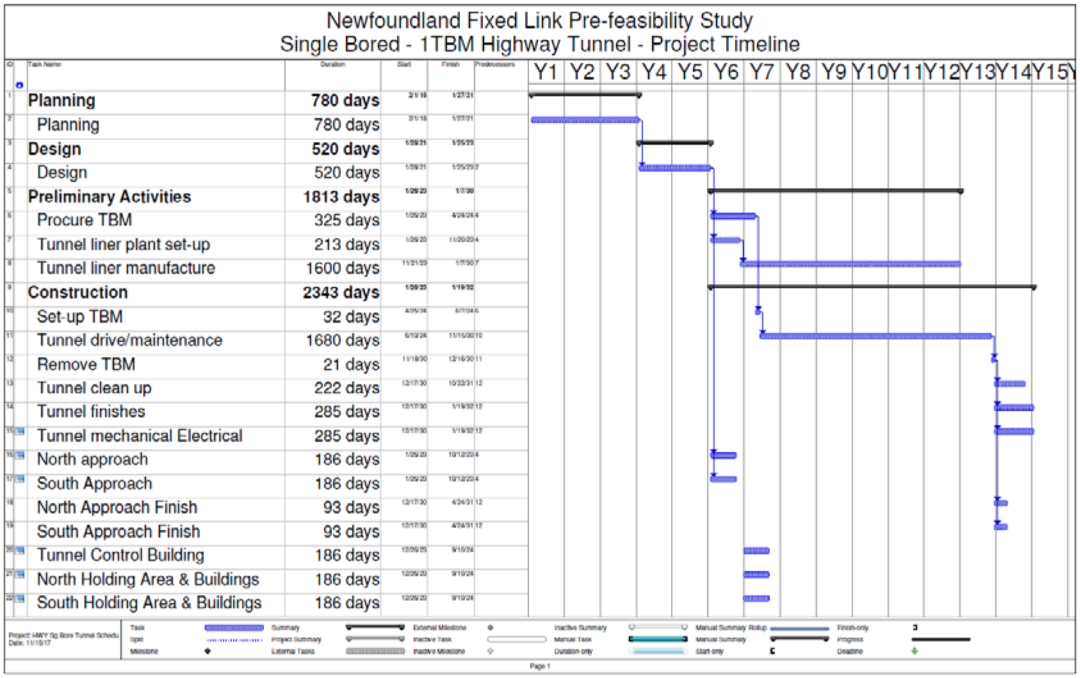


Figure 8-3: Project Schedule for TBM bored Road Tunnel (1 TBM)

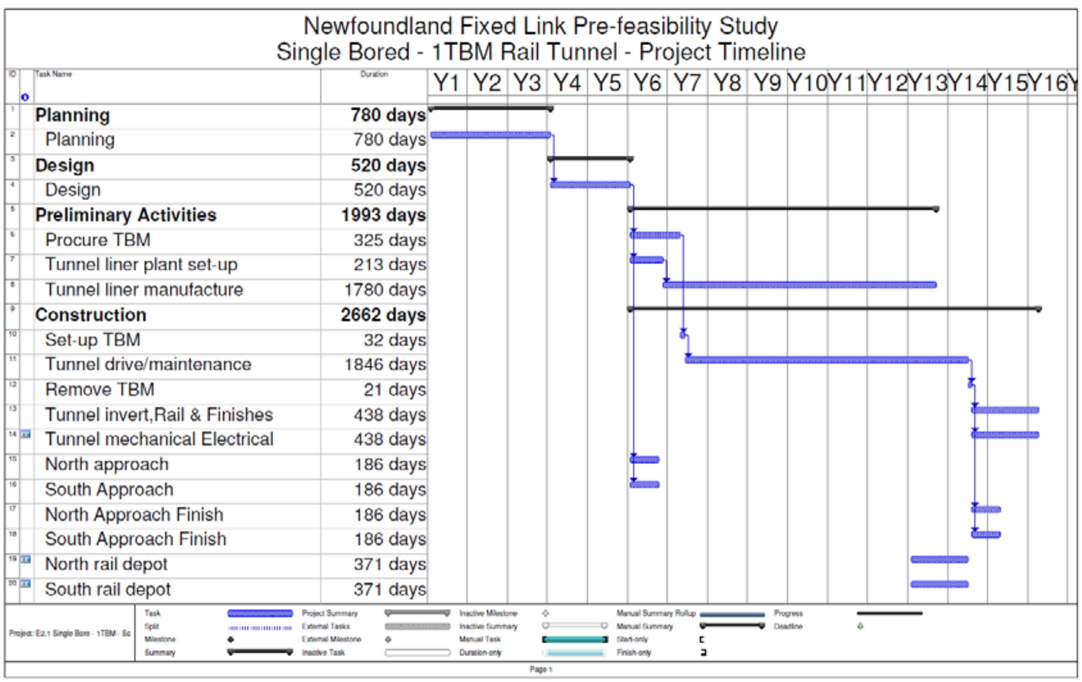


Figure 8-4: Project Schedule for TBM bored Rail Tunnel (1 TBM)

8.5 Cost and Schedule Comparison

In the following **Table 8-1** and **Table 8-2** the 2004 and 2017 costs and schedules are summarized for comparison. As in 2004, the 2017 schedule comprises 3 years of planning and 2 years of detailed design for a total of 5 years prior to start of construction. For all options, the three years of planning were allowed for additional studies, field investigations, environmental assessment and other planning activities. Costs and schedule details for all road and rail options are provided in the Appendices C, D and E.

Table 8-1: Comparison of Fixed Link Road Options

Option	Tunnel Dimensions	Construction Costs		Annual Operating Cost		Project Duration (years)	
		$M-2004	$M-2017	$M-2004	$M-2017	2004	2017
TBM Single Bore Tunnel 1 TBM (7days/week)	11 m Ø 21 km Length	1,559	2,064	6.8	7.7	12.2	14
TBM Single Bore Tunnel 2 TBM (7days/week)	11 m Ø 21 km Length	N/A	2,162	N/A	7.7	N/A	10.8
TBM Twin Bore Tunnel 1 TBM per Bore	11 m Ø 21 km Length (each bore)	N/A	3,967	N/A	12.1	N/A	14

Table 8-2: Comparison of Fixed Link Rail Options

Option	Tunnel Dimensions	Construction Costs		Annual Operating Cost		Project Duration (years)	
		$M-2004	$M-2017	$M-2004	$M-2017	2004	2017
TBM Single Bore Tunnel 1 TBM (7days/week)	7.6 m Ø 30 km Length	1,144	1,675	7.6	8.7	12.5	15.5
TBM Single Bore Tunnel 2 TBM (7days/week)	7.6 m Ø 30 km Length	1,184	1,764	7.6	8.7	10.7	12

The graph in **Figure 8-5** illustrates the capital costs for the various options reviewed in this study in comparison with the capital cost estimates from the 2004 study.

Based on the Construction Cost Index published by the Engineering News Record (ENR), a ratio of 1.54 applies when comparing costs in 2017 to costs in 2004. Comparing the cost for the rail tunnel of $1,144M in 2004 and $1,675M in 2017 results in a ratio of 1.46, which is similar to the ENR ratio.

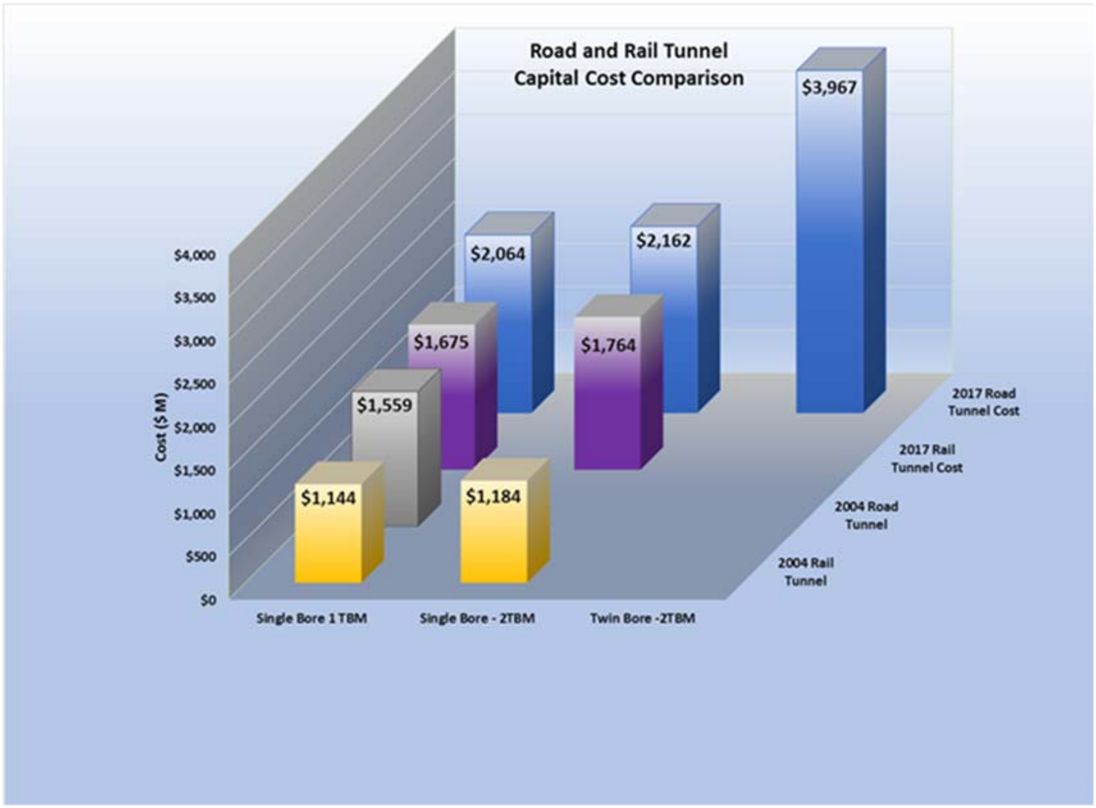


Figure 8-5: Capital Costs Comparison

The increased project duration time compared to the 2004 schedule for both the road and the rail tunnel is the result of the increased lengths of the tunnel exit ramps which are caused by the greater depth below the sea bed of the tunnel, resulting in longer excavation times. For the road tunnel, a total alignment length of 21 km was assumed; the rail tunnel was assumed to have a total length of 30 km. A refinement of the recommended tunnel depth below sea bed and a detailed study of the most suitable alignment location of the tunnel exit ramps at a later project stage will impact the tunnel costs as well as the schedule. For the purpose of this study update, the exit ramps were assumed to be in line with the tunnel which resulted in long ramps due to the surface topography at the shores. An adjustment of the tunnel exit ramps to follow a more suitable topography will most likely reduce the ramp lengths are hence the tunnelling schedule.

8.6 Recommended Option

Based on the assessment of capacity requirements, construction and operational risks as well as the updated construction and operational cost estimates and construction schedules, a single-track rail tunnel excavated with a TBM is still considered the most suitable option to address the transportation requirements at the Strait of Belle Isle.

9. Regulatory Requirements and Environmental Implications

Regulatory requirements and environmental implications and the required process of obtaining approval for a fixed link tunnel project were discussed in the Pre-Feasibility Study in 2004 and a list of the applicable legislation, standards and permits on federal, provincial and municipal level was provided (refer to 2004 Pre-Feasibility Study [1]). A complete assessment of the requirements and implications would be undertaken as the project moves forward.

Potential environmental implications related to the construction of a tunnel under the Strait of Belle Isle would have to be addressed in an Environmental Assessment. Compared to surface fixed link alternatives, no to very little impact on the environment in the Strait of Belle Isle is associated with the construction of a subsurface fixed link. Potential impact of the tunnel construction on marine life could be related to noise and vibrations during construction.

An impact of the tunnel construction and operation on the environment is expected on the onshore portions of the tunnel, including the areas for tunnel approaches, tunnel portals, parking spaces and amenities for travellers during waiting times, marshalling areas, etc. This impact would be significantly larger for a rail tunnel than a road tunnel due to the required terminal facilities, loading areas, etc.

In addition, the required construction of roadways to connect the tunnel approaches with the highway system should be considered. Implications concern, for example:

- Impact of emissions during construction such as noise, dust and exhaust fumes on workers, wild life and vegetation.
- Transport and disposal of excavated material.
- Impact of land use for required surface construction on existing vegetation or animal habitats or on potential rare species or archaeological sites.

The impact of the changing environmental conditions on the fixed link, which include in particular the observed tendency of less sea ice coverage across the Strait of Belle Isle over past years but also the tendency for a larger number of icebergs floating through the Strait as noted in past years, affect mostly surface options. The subsurface tunnel options would not be affected by changing ice and iceberg conditions in the Strait.

10. Ferry Service across the Strait of Belle Isle

As requested by the client, an update of the upgraded Strait of Belle Isle ferry crossing was carried out to account for an anticipated increased need for passenger transportation across the Strait as an alternative to a fixed link implementation.

10.1 Existing Ferry Service

The existing ferry service across the Strait of Belle Isle between Blanc-Sablon (QC) and St. Barbe (NL) is currently provided by Labrador Marine Inc. The ferry service includes passengers and vehicles only and is maintained with the MS Apollo, a Ro-Ro/Passenger ship that is certified for 85 vehicles and 240 passengers.

The ferry service between Blanc-Sablon and St. Barbe is currently provided year-round with reduced services during the winter months. An alternative route between Blanc-Sablon and Corner Brook (NL) is used in the event that St. Barbe becomes inaccessible due to ice conditions.

The current schedule (**Table 10-1**) provides 38 one-way crossings per week during the summer months from mid June to mid September (19 crossings each from Blanc-Sablon and from St. Barbe). The fall and spring schedule of 28 one-way crossings per week (14 crossings in each direction) applies from mid September to early January and from late April to mid June. The winter schedule includes 14 one-way crossings per week (7 in each direction) between early January and late April. Dangerous goods transports are carried out once per week from spring to fall; passenger numbers are limited on crossings that carry dangerous goods. In total, the 2017 schedule includes approximately 1374 one-way crossings (687 in each direction).

The crossing time for the 36 km long route between Blanc-Sablon and St. Barbe is 1 hour 45 minutes. The crossing time for the alternative winter route between Blanc-Sablon and Corner Brook is 12 hours (for 302 km).

Table 10-1: Strait of Belle Isle Ferry Crossings (2017 Schedule)

	Winter	Spring	Summer	Fall
Crossings (one-way)	15 weeks; Jan 8 - Apr 22	8 weeks; Apr 23 - Jun 18	12.5 weeks; Jun 19 - Sep 13	16.5 weeks; Sep 14 - Jan 7
Per Week:	14 7 per direction	28 14 per direction	38 19 per direction	28 14 per direction
Per Day:	2 1 per direction	3 to 5 1 to 3 per direction	5 to 7 2 to 4 per direction	3 to 5 1 to 3 per direction

10.2 Upgraded Ferry Service

Options to upgrade the existing ferry services include:

- Increased numbers of crossings per day using the existing vessel. This option requires longer operating hours per day.

- Increased numbers of passengers per crossing. This option requires a larger ship with a greater capacity for transporting passengers and vehicles.
- Increased numbers of crossings per day and reduced waiting time using two vessels. This option requires the acquisition of a second vessel.
- Crossings during winter months to provide year-round services. This option is already implemented with one daily return crossing between January and April. An alternative route is provided between Blanc-Sablon and Corner Brook during adverse ice conditions in St. Barbe harbor. However, the winter crossings are impacted by the sea ice conditions which can lead to a temporary suspension of the ferry service. This was experienced for example in March 2015 when the ferry was trapped in ice for 10 days in the St. Barbe harbor; in April 2017, the ferry remained docked in Blanc-Sablon due to extreme sea ice conditions in the Strait.

Assuming ferry services with a single vessel with scheduled sailings at 5 hour intervals in each direction and start of services at 6am during the summer season and at 8am from fall to spring, an upgraded schedule as summarized in **Table 10-2** was developed. The total number of crossings would increase from 1374 (2017 schedule) to 1789 one-way crossings (increase of 30%). A traveler would experience crossing times between approximately 2 hours (1 hour 45 min travel time plus time to disembark) and 7 hours if the traveler misses a sailing.

Table 10-2: Upgraded Ferry Schedule (One Vessel)

	Winter	Spring	Summer	Fall
Crossings (one-way)	15 weeks Jan 8 - Apr 22	8 weeks; Apr 23 - Jun 18	13 weeks; Jun 19 - Sep 13	16 weeks; Sep 14 - Jan 7
Per Week:				
2017 Schedule	14	28	38	28
Upgraded Schedule	21	35	49	35
Per Day:				
2017 Schedule	2	3 to 5	5 to 7	3 to 5
Upgraded Schedule	3	5	7	5

Assuming ferry services with two vessels with scheduled sailings at 2.5 hour intervals in each direction and similar service hours as above, the total number of one-way crossings would increase from 1374 (2017 schedule) to 3578 (increase of 60%). Crossing times would be between approximately 2 hours (1 hour 45 min for the travel plus time to disembark) and 4.5 hours if the traveler misses a particular sailing.

Note that the upgraded ferry schedule does not account for actual arrival times and vehicle types arriving at a certain time. This information was not provided to Hatch. A more detailed study of vehicle arrivals and types would be required to evaluate required capacities throughout the day and year.

11. Economic Analysis - Rail Tunnel Option

This section sets out the economic and business case analysis. Two traffic cases are described, both for a tunnel option with a railway shuttle:

- The Base Case with 40% diversion of traffic from the Gulf Ferries.
- The Higher Traffic Case with 60% diversion of traffic from the Gulf Ferries.

The assumed diversion percentages were provided by the Harris Centre.

Combined with these two traffic cases, two construction cases are addressed:

- Construction by one TBM operated from the Newfoundland side of the Strait, resulting in a construction period of 10 years.
- Construction by two TBMs, one operated from the Newfoundland side and one operated from the Labrador side of the Strait, resulting in a construction period of 7 years.

For both construction cases, the planning and design period is assumed to be 5 years. The operating period for the one TBM option is 30 years; the operating period for the option using two TBMs is 33 years. This results in economic life cycles of 45 years which were studied for both construction cases.

11.1 Traffic Prediction

The traffic predictions are based on the following assumptions:

1. All present traffic using the Strait of Belle Isle Ferry will divert to the new Fixed Link facility.
2. Present traffic for the peak operating period for 2016 is presented in the following **Table 11-1**.

Table 11-1: Present Traffic on Belle Isle Ferry

Strait of Belle Isle Ferry	2016 (May to October)
Passengers	83,815
Passenger Vehicles (TEU)	35,798
Commercial Vehicles (TEU)	18,079

3. A one-time surge of traffic of 30% for the opening year has been assumed to reflect the all-year round operation of the new facility and the increased frequency of service.
4. Traffic diversion from the Gulf Ferries has been analyzed based on 40% and 60% diversion rates from the present traffic.
5. The present traffic for the Gulf Ferries is based on the following **Table 11-2** that summarizes the private and commercial traffic data presented in **Table 7-4**, **Table 7-5** and **Table 7-6** (refer to Section **7.4**).

Table 11-2: Present Traffic on Gulf Ferries

Gulf Ferries	2016
Passengers	328,528
Passenger Vehicles (TEU)	130,530
Commercial Vehicles (TEU)	267,274

6. Growth factors have been applied to the traffic data as follows:
   - Strait of Belle Isle Ferry – all traffic +2.5% per annum
   - Gulf Ferries – passengers -1.0% per annum
   - Gulf Ferries – passenger vehicles -1.0% per annum
   - Gulf Ferries – commercial vehicles +1.6% per annum

Based on these assumptions, the resulting traffic predictions for the first year of operation (Year 16 for 1 TBM and Year 13 for 2 TBMs) for the investigated diversion rates and construction alternatives are presented in **Table 11-3**.

Table 11-3: Predicted Traffic for First Operating Year of Fixed Link

	1 TBM		2 TBMs	
Diversion Rate	40%	60%	40%	60%
Passengers	276,567	331,953	268,120	325,201
Passenger Vehicles	114,824	136,830	111,115	133,795
Commercial Vehicles	175,788	245,802	166,723	233,481

11.2 Tolls and Revenue Forecasts

It has been assumed that the tolls for the Fixed Link will align with the tolls for the existing Strait of Belle Isle Ferry. Blended rates have been developed for passengers, passenger vehicles, and commercial vehicles, based on the distribution of ferry user types and related tolls for the existing Strait of Belle Isle Ferry traffic. The resulting toll rates divided by ferry user types are presented in 2017 dollars in **Table 11-4**. The rate development as well as sensitivity tests addressing toll rates at 150% and 200% of the present ferry rates are shown in detail in Appendix F,

Table 11-4: Blended Toll Rates for the Fixed Link

	Tolls ($2017)
Passengers	$11.30
Passenger Vehicles	$47.66
Commercial Vehicles	$120.75

Revenue forecasts for each operating year have been developed by multiplying the annual traffic by the appropriate toll value. These revenue forecasts have been developed for each proposed diversion rate and construction case. The revenues and costs are presented in **Table 11-5**.

Table 11-5: Total Revenues and Costs[1)]

	Diversion Rate	1 TBM	2 TBM
Total Revenue	40%	1,309	1,433
Total Revenue	60%	1,754	1,926
Operating Costs		261	287
Net Revenue (less Operating Costs)	40%	1,048	146
Net Revenue (less Operating Costs)	60%	1,493	1,638
Total Subsidy (30 years)		240	264
Net Revenue with Subsidy Saving	40%	1,288	1,410
Net Revenue with Subsidy Saving	60%	1,733	1,902
Total Capital Cost		1,675	1,764

1) Costs are in $(2017) millions

The operating costs have been used with a constant yearly amount, with replacements of equipment covered by annual depreciation amounts based on the normal life of the specific equipment. The capital costs have been distributed over the planning, design and construction periods based on experience from other projects of this scale.

The present government annual subsidy provided for the Strait of Belle Isle Ferry has been assumed to be $8.0 million based on inflating the value provided in 2004. This subsidy would be saved on the opening of the Fixed Link and has been either not included or included in the analysis to present the effect of this saving. It should be noted that this saving would likely be exceeded by the compensatory subsidy increase that would be required on the Gulf Ferries due to the loss of the diverted traffic.

11.3 Economic Evaluation

All costs and revenues provided in this section are expressed in terms of Constant Canadian dollars valued at 2017. Inflation projections and conversions into current dollar values, or nominal currency, are considered in the financial evaluation in Section 12.

Three indicators of economic value are employed: Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit Cost Ratio (BCR). The applications of these indicators are described as follows:

- NPV is calculated using a real social discount rate of 7.5%, which is the recommended rate of the Federal Treasury Board assuming annual inflation at 2.5% over the project time horizon (i.e. 10% nominal). The net cash flow for each year (positive or negative) is discounted to reflect the equivalent value in 2017, and all the years are summed to one total NPV.
- IRR is calculated internally, before cash flows are discounted; it is the effective discount rate that would produce a null NPV.

- BCR is calculated using the same cash flow inputs as the NPV, except that activities which are meant to produce benefits are separated and summed independently from those that are meant to cause cost; the ratio of the summed benefits to the summed costs is the BCR. Values greater than one are desirable and suggest economic justification. Values less than unity are undesirable; however, they are not necessarily conclusive in themselves, without considering external factors (such as benefits to the overall provincial economy, encouragement of local investments, diversification of industry, encouragement of tourism, etc.) that are not quantified in the analysis.

The results of the economic analyses for the rail tunnel option are presented in **Table 11-6**.

Table 11-6: Economic Indicators

	1 TBM				2 TBMs			
Subsidy	**Not included**		**Included**		**Not included**		**Included**	
Diversion Rate	**40%**	**60%**	**40%**	**60%**	**40%**	**60%**	**40%**	**60%**
Net Present Value (NPV) of Cash Flows ($ millions)	-677	-625	-645	-593	-780	-715	-739	-674
Internal Rate of Return (IRR) (%)	-2.05	-0.52	-1.18	-0.16	-1.83	-0.33	-0.99	-0.34
Benefit/Cost Ratio (BCR)	0.63	0.89	0.77	1.03	0.65	0.93	0.80	1.08

The following observations apply to the analysis results shown in **Table 11-6**:

- NPVs are all negative, which places the investigated alternatives in the realm of the public sector because quantifiable benefits are insufficient to sustain viability.
- All IRRs are negative, rendering this indicator not useful for this economic evaluation.
- BCRs are mostly less than unity, but at reasonable levels for public infrastructure, suggesting that project justification would likely have to depend on factors that are external to this study.

12. Financial Analysis - Rail Tunnel Option

12.1 Selection of Key Target Parameters

Based on the preceding discussion, the following key parameters are selected for use in the financial analysis:

The long-term inflation rate of 2.5%, and nominal and real social discount rates of 10% and 7.5% respectively have been introduced and employed in the economic analysis reported previously.

For the purpose of examining debt financing, the rate employed for the base case is 8% real (10.5% nominal), to be applied in amortization calculations over the operating life of 30 years, and including a risk premium because of the nature of the project. Short-term debt to finance construction work is estimated to be 5%.

If the project were to involve equity participation, then an acceptable long-term equity return would be 22.5% pre-tax. This is based on after-tax return on equity of 13.5% (high end, with risk premium), assuming an effective corporate tax rate of 40%. If a project were to be financed 25% with equity, then the blended target rate of return would be 13.5%. If the debt rate were to be reduced by 2%, then the blended target rate of return would drop to 12%.

At the pre-feasibility stage of the project, these parameters are considered in line with the risk and reward expectations of prospective investors. However, internal rates of return below 12% are not likely to attract private capital without significant external favorable considerations.

The project in its entirety will most likely not reach this target rate of return. However, this aspect should be considered in respect of a strategy that would segment the costs and risks to privatize a portion of the project. For example, if the project were to be built with public financing, then the operation could be submitted to tender or some other competitive process to franchise it for pecuniary considerations. The pricing for this would be influenced by the target returns from operations.

12.2 Financial Analysis Results

For the financial analysis, the constant dollar estimates for project costs and revenues were translated into nominal values. In carrying out this conversion, the cost of financing during construction is determined by calculating interest on current year costs plus previous year payments plus interest accumulated in prior years. The project costs translated into current dollars, representing the total cost of the project, are shown in **Table 12-1** for both the longer and shorter construction periods.

Table 12-1: Project Costs in Current $, IRRs and Suggested Grants Required

	1 TBM	2 TBMs
Total Cost ($2017) (millions)	1,675	1,764
Total Cost ($Current) (millions)	2,188	2,213
Interest during Construction (millions)	578	398
Total to Finance (millions)	2,767	2,611
Internal Rate of Return (40%)	+0.41%	+0.62%
Internal Rate of Return (60%)	+1.97%	+2.20%
Grant required for 8.0% IRR (40%)(millions)	1,595	1,655
Grant required for 8.0% IRR (60%)(millions)	1,370	1,430

The analysis results show that the total project costs (Total to Finance) are approximately 50% to 65% higher than the Total Costs ($2017) because of inflation and interest expense – $2.6 billion versus $1.8 billion (for 2 TBMs) or $2.8 billion versus $1.7 billion (for 1 TBM). The advantage of a faster construction phase is apparent; a slight cost disadvantage in constant dollar terms becomes an advantage in real world conditions. The difference in the total costs to finance is worth $156 million.

The total amount to finance is $2,767 million (for 1 TBM), or $2,611 million (for 2 TBMs). Incorporating the post operation cash flows, the Internal Rate of Return ranges from 0.41% to 2.2%. These values remain consistent with the conclusion of the economic analysis, that the project is not bankable on its own merits. Proceeding with the project will, hence, require access to free capital made available to suit purposes other than the gain of investment.

Various financing scenarios involving grants or contributions were considered to identify financial conditions under which the project could proceed. The main finding is that a total contribution in the order of $1.5 billion, or more, would be required for the project to be self-sufficient. For example, to provide a return of 8%, grants ranging from $1.370 billion to $1.655 billion would be required. This is still below the private finance threshold considered currently applicable, except perhaps for long-term debt; however, it illustrates the level of public support that is required for advancing the project. It is of interest that the 2 TBMs option has a lower financed construction cost and a longer revenue generating period but still requires a higher grant. This is the result of the proponent being relieved of much of the financing burden under a grant scenario since the construction cost is almost completely funded by the grant. Therefore, the construction financing advantage presented by the 2 TBMs option is negated when a grant is used to cover most of the construction costs as they occur. Hence, the 1 TBM option requires a smaller grant due to its lower overall costs in a mostly finance cost relieved environment.

The public sector involvement is considered the fundamental pre-condition for advancing the project beyond the present pre-feasibility stage. Once the level of support is decided, the models developed for this project can be employed to explore more financing variations and to examine potential revenue and cost relationships.

13. Economic Analysis - Road Tunnel Option

This section sets out the economic and business case analysis for the road tunnel option. Two traffic cases are described:

- The Base Case with 40% diversion of traffic from the Gulf Ferries.
- The Higher Traffic Case with 60% diversion of traffic from the Gulf Ferries.

The assumed diversion percentages were provided by the Harris Centre.

Combined with these two traffic cases, two construction cases are addressed:

- Construction by one TBM operated from the Newfoundland side of the Strait, resulting in a construction period of 9 years.
- Construction by two TBMs, one operated from the Newfoundland side and one operated from the Labrador side of the Strait, resulting in a construction period of 6 years.

For both construction cases, the planning and design period is assumed to be 5 years. The operating period for the one TBM option is 30 years; the operating period for the option using two TBMs is 33 years. This results in economic life cycles of 44 years which were studied for both construction cases.

13.1 Traffic Prediction

The traffic predictions are identical for the road and rail tunnel options (refer to Section 11.1).

13.2 Tolls and Revenue Forecasts

It has been assumed that the tolls for the Fixed Link will align with the tolls for the existing Strait of Belle Isle Ferry. Blended rates have been developed for passengers, passenger vehicles, and commercial vehicles, based on the distribution of ferry user types and related tolls for the existing Strait of Belle Isle Ferry traffic. The resulting toll rates divided by ferry user types are presented in 2017 dollars in **Table 13-1.** The rate development as well as sensitivity tests addressing toll rates at 150% and 200% of the present ferry rates are shown in detail in Appendix G.

Table 13-1: Blended Toll Rates for the Fixed Link

	Tolls ($2017)
Passengers	$11.30
Passenger Vehicles	$47.66
Commercial Vehicles	$120.75

Revenue forecasts for each operating year have been developed by multiplying the annual traffic by the appropriate toll value. These revenue forecasts have been developed for each proposed diversion rate and construction case. The revenues and costs are presented in **Table 13-2.**

Table 13-2: Total Revenues and Costs[1)]

	Diversion Rate	1 TBM	2 TBM
Total Revenue	40%	1,289	1,411
Total Revenue	60%	1,728	1,898
Operating Costs		229	252
Net Revenue (less Operating Costs)	40%	1,059	1,159
Net Revenue (less Operating Costs)	60%	1,499	1,646
Total Subsidy (30 years)		240	264
Net Revenue with Subsidy Saving	40%	1,299	1,423
Net Revenue with Subsidy Saving	60%	1,739	1,910
Total Capital Cost		2,064	2,164

1) Costs are in $(2017) millions

The operating costs have been used with a constant yearly amount, with replacements of equipment covered by annual depreciation amounts based on the normal life of the specific equipment. The capital costs have been distributed over the planning, design and construction periods based on experience from other projects of this scale.

The present government annual subsidy provided for the Strait of Belle Isle Ferry has been assumed to be $8.0 million, based on inflating the value provided in 2004. This subsidy would be saved on the opening of the Fixed Link and has been either not included or included in the analysis to present the effect of this saving. It should be noted that this saving would likely be exceeded by the compensatory subsidy increase that would be required on the Gulf Ferries due to the loss of the diverted traffic.

13.3 Economic Evaluation

All costs and revenues provided in this section are expressed in terms of Constant Canadian dollars valued at 2017. Inflation projections and conversions into current dollar values, or nominal currency, are considered in the financial evaluation in Section 14.

As for the rail tunnel option, three indicators of economic value are employed: Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit Cost Ratio (BCR). The applications of these indicators are described as follows:

- NPV is calculated using a real social discount rate of 7.5%, which is the recommended rate of the Federal Treasury Board assuming annual inflation at 2.5% over the project time horizon (i.e. 10% nominal). The net cash flow for each year (positive or negative) is discounted to reflect the equivalent value in 2017, and all the years are summed to one total NPV.
- IRR is calculated internally, before cash flows are discounted; it is the effective discount rate that would produce a null NPV.

- BCR is calculated using the same cash flow inputs as the NPV, except that activities which are meant to produce benefits are separated and summed independently from those that are meant to cause cost; the ratio of the summed benefits to the summed costs is the BCR. Values greater than one are desirable and suggest economic justification. Values less than unity are undesirable; however, they are not necessarily conclusive in themselves, without considering external factors (such as benefits to the overall provincial economy, encouragement of local investments, diversification of industry, encouragement of tourism, etc.) that are not quantified in the analysis.

The results of the economic analyses for the road tunnel option are presented in **Table 13-3**.

Table 13-3: Economic Indicators

	1 TBM				2 TBMs			
Subsidy	**Not included**		**Included**		**Not included**		**Included**	
Diversion Rate	**40%**	**60%**	**40%**	**60%**	**40%**	**60%**	**40%**	**60%**
Net Present Value (NPV) of Cash Flows ($ millions)	-919	-863	-884	-829	-1,041	-972	-997	-928
Internal Rate of Return (IRR) (%)	-2.88	-1.43	-2.06	-0.79	-2.63	-1.2	-1.83	-0.56
Benefit/Cost Ratio (BCR)	0.51	0.73	0.63	0.84	0.54	0.76	0.66	0.88

The following observations apply to the analysis results shown in **Table 13-3**:

- NPVs are all negative, which places the investigated alternatives in the realm of the public sector because quantifiable benefits are insufficient to sustain viability.
- All IRRs are negative, rendering this indicator not useful for this economic evaluation.
- BCRs are mostly less than unity, but at reasonable levels for public infrastructure, suggesting that project justification would likely have to depend on factors that are external to this study.

14. Financial Analysis - Road Tunnel Option

14.1 Selection of Key Target Parameters

The selection of the key target parameters is described in Section 12.1. These parameters are identical for the road and rail tunnel options.

14.2 Financial Analysis Results

For the financial analysis, the constant dollar estimates for project costs and revenues were translated into nominal values. In carrying out this conversion, the cost of financing during construction is determined by calculating interest on current year costs plus previous year payments plus interest accumulated in prior years. The project costs translated into current dollars, representing the total cost of the project, are shown in **Table 14-1** for both the longer and shorter construction periods.

Table 14-1: Project Costs in Current $, IRRs and Suggested Grants Required

	1 TBM	2 TBMs
Total Cost ($2017) (millions)	2,064	2,162
Total Cost ($Current) (millions)	2,632	2,657
Interest during Construction (millions)	692	451
Total to Finance (millions)	3,324	3,107
Internal Rate of Return (40%)	+0.44%	+0.19%
Internal Rate of Return (60%)	+1.04%	+1.28%
Grant required for 8.0% IRR (40%)(millions)	2,041	2,104
Grant required for 8.0% IRR (60%)(millions)	1,820	1,880

The analysis results show that the total project costs (Total to Finance) are approximately 60% to 67% higher than the Total Costs ($2017) because of inflation and interest expense – $3.1 billion versus $2.2 billion (for 2 TBMs) or $3.3 billion versus $2.1 billion (for 1 TBM). The advantage of a faster construction phase is apparent; a slight cost disadvantage in constant dollar terms becomes an advantage in real world conditions. The difference in the total costs to finance is worth $217 million.

The total amount to finance is $3,324 million (for 1 TBM), or $3,107 million (for 2 TBMs). Incorporating the post operation cash flows, the Internal Rate of Return ranges from 0.44%% to 1.28%. These values remain consistent with the conclusion of the economic analysis, that the project is not bankable on its own merits. Proceeding with the project will, hence, require access to free capital made available to suit purposes other than the gain of investment.

Various financing scenarios involving grants or contributions were considered to identify financial conditions under which the project could proceed. The main finding is that a total contribution in the order of $2 billion, or more, would be required for the project to be self-sufficient. For example, to provide a return of 8%, grants ranging from $1.820 billion to $2.104 billion would be required. This is still below the private finance threshold considered currently applicable, except perhaps for long-term debt; however, it illustrates the level of public support that is required for advancing the project. It is of interest that the 2 TBMs option has a lower financed construction cost and a longer revenue generating period but still requires a higher grant. This is the result of the proponent being relieved of much of the financing burden under a grant scenario since the construction cost is almost completely funded by the grant. Therefore, the construction financing advantage presented by the 2 TBMs option is negated when a grant is used to cover most of the construction costs as they occur. Hence, the 1 TBM option requires a smaller grant due to its lower overall costs in a mostly finance cost relieved environment.

The public sector involvement is considered the fundamental pre-condition for advancing the project beyond the present pre-feasibility stage. Once the level of support is decided, the models developed for this project can be employed to explore more financing variations and to examine potential revenue and cost relationships.

15. Financing Considerations using Public-Private-Partnership

The government of Newfoundland is operating deficits, and is facing rising costs associated with the maintenance of its existing infrastructure assets. Notwithstanding this, the province has a tremendous need for new infrastructure to enable economic growth.

Given this context, it is worth considering the potential to deliver the "Fixed Link" project via a Public-Private Partnership (P3).

P3s deliver several real, tangible benefits. The single most important way that they do this is by enabling the risks most associated with cost and schedule overruns (i.e. construction and maintenance) to be transferred from government to private sector partners who are better able to manage them. While government pays a cost premium to private financiers to achieve this risk transfer, the predictability of cost it creates is valuable.

P3 structures entail a non-traditional approach to government procurement. Traditional government procurements seek to encourage many competitive bids to deliver a 100% defined output. By contrast, the best P3 procurement processes are focused on outcomes/performance indicators that government hopes to realize from a given infrastructure project. A much smaller number of pre-qualified consortia (involving talented designers, builders, financiers, and maintainers) are then invited to propose how they would achieve these desired outcomes. When done right, government ensures that responses are sufficiently similar to allow for comparison, but still leaves lots of room for innovation.

P3 structures also have fiscal profiles that are beneficial to government. Rather than paying capital costs as they arise, these structures allow government to recognize costs over a longer period. In almost all cases, substantial completion payments (which represent a considerable portion of the total capital costs) are only paid once a government is satisfied that assets have been built to the pre-agreed standard. Similarly, ongoing "availability payments" are only made when the asset has achieved pre-agreed performance standards.

The following **Table 15-1** shows various types of P3 structures and the risk transfer which (ideally) is achieved through their usage.

It is worth noting that, for those models that do not involve private ownership and operation of infrastructure (i.e. DB, DBF, DBFM), there is a robust community of investors that has proven more than willing to participate in Canada. Since the inception of Infrastructure Ontario, close to $3 billion worth of provincial infrastructure has been financed via a P3. Half of this money has come from investment funds, 31% from insurance companies, 12% from banks, and 7% from pension funds. The federal government, in the form of P3 Canada, has also been willing to invest in these types of projects.

Table 15-1: Risk Transfer to Private Sector by P3 Structure

P3 Procurement Type	Design Risk	Construction Risk	Financial Risk	Maintenance Risk	Operating Risk	Traffic & Revenue Risk
Design-Build (DB)	✓	✓				
Design-Build-Finance (DBF)	✓	✓	✓			
Design-Build-Finance-Maintain (DBFM)	✓	✓	✓	✓		
Design-Build-Finance-Operate-Maintain (DBFOM)	✓	✓	✓	✓	✓	
Design-Build-Finance-Operate-Maintain (DBFOM) + Toll Concession	✓	✓	✓	✓	✓	✓

Design-Build: The winning concession bids a fixed fee from which they must deliver the infrastructure asset based on a generally pre-determined schedule. The single concession is tasked with completing the design and construction for the project, and also takes on all associated risks with doing so. Sponsors take on the financing, operating and maintenance of the asset once completed. This type of development is more prevalent in pure private sector projects, but is increasingly gaining prominence in public sector procurements.

Design-Build-Finance: Under DBF contracts the winning concession takes on the additional responsibility of financing the project for the sponsor. Depending on the structure of the deal, the Sponsor can make periodic payments to the concession at specified completion points (milestone payments), payment once the project has been delivered (substantial completion payments), or some combination of both. Since the concession takes on additional financing responsibility, there is an impetus for them to deliver the project in a time conscious manner.

Design-Build-Finance-Maintain: The winning concession of this type of contract assumes maintenance responsibilities for the useful life of asset, or for some other unspecified period. Maintenance contracts are most effective for Government if they are well set up to manage the concession over the life of the maintenance contract. This includes being able to set delivery, service and quality thresholds.

Design-Build-Finance-Operate-Maintain: The winning concession takes the on the additional responsibility to operate the asset. Generally this component is added when the concession is able to provide a breakthrough service through cost, scale and technological efficiencies. Both maintenance and operating components provide concessions incentive to deliver assets of the highest design and construction quality given the long-term cost associated with maintaining and operating.

The Strait of Belle Isle Fixed Link project has characteristics very similar to other large DBFM public-private partnerships (as we will demonstrate through case studies below).

A different set of considerations arises when government is looking for the private sector to operate and maintain infrastructure assets. Under DBFOM delivery models, projects are either partly or wholly financed by debt repaid with project revenues. If future revenues by themselves are insufficient to raise all capital needed, projects are often supplemented by public sector grants or in-kind (e.g., right-of-way) contributions. In most cases, private partners will be required to make equity investments. For this reason, DBFOM concessions are often attractive to public transportation agencies, as they can provide access to new sources of financing, transfer long-term life-cycle performance risk to the private sector, and deliver similar schedule and cost-efficiency benefits as DB and DBOM procurements.

Private investors are typically looking for three things when deciding where to invest their infrastructure allocations:

A) Cash flow certainty. They want to know that the contract they are signing with government and the regulatory regime they will face will guarantee a reasonably predictable return on their investment.

B) A positive track record of performance. The private sector prefers dealing in assets and services that have known risk profiles, that will allow them to better predict a likely return under various scenarios.

C) A sizable equity investment. They want to be able to deploy large tranches of capital.

Based on their typical preferences, if we were to visually plot various types of investors against these three dimensions, the result might look like shown in **Figure 15-1**:

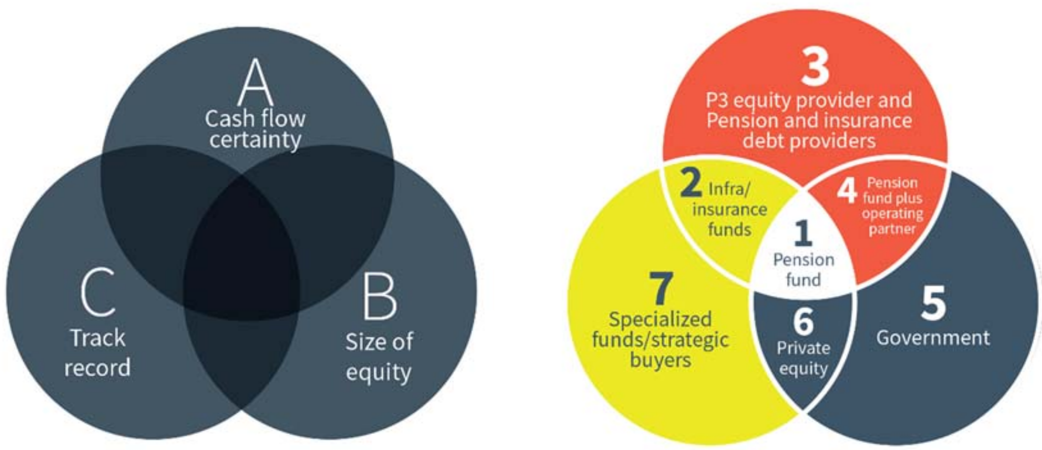


Figure 15-1: What the private sector looks for in projects to finance (left) and the kind of investment options that typically exist (right)

Many government projects fall squarely into the bottom right-hand space of this figure – Area 5 – Government. These projects require large sums of money, often have uncertain risks related to ridership volumes, revenues, operating costs, and regulatory regimes. Investors often participate in these projects on an equity basis when governments promise to retain responsibility for these various risks.

It is worth evaluating the potential to deliver the Strait of Belle Isle Fixed Link project via a DBFOM approach (with an associated tolling concession) provided:

1) The government is receptive to tolling both passenger and freight traffic;

2) The federal and provincial governments are willing to pay for the majority of the initial capital costs (N.B. most toll roads and tunnels make an operating profit, but this toll revenue rarely pays for the initial capital costs); and,

3) Projected tolling revenue is likely to enable the private consortium to achieve a sufficient return on their investment.

Should these conditions be met, numerous large institutional investors would be extremely interested in participating to the project. Pension plans, insurance companies, infrastructure funds, and sovereign wealth investors have billions to spend annually on these types of projects, and often struggle to spend their full allocation.

Given recent announcements, the federal government could also play a role in this approach. It could either ear-mark some monies from the planned $187 billion in infrastructure grants for the project, or the project could be delivered via the Canadian Infrastructure Bank (CIB). The premise of the CIB is that there are countless infrastructure projects, each of which has the potential to enhance Canadian productivity while delivering returns to investors. But these projects, being risky (per the above) require some first loss capital to convince investors to proceed. To this end, Ottawa has set aside $35 billion to invest in these projects. If project risks are realized – Ottawa is the first investor who suffers a loss. If the project yields revenue, the CIB achieves a return similar to other investors.

P3s: Impressive International Record

It has been over 20 years since countries such as Australia, United States and the United Kingdom began to use P3s as a regular method of procurement for public infrastructure projects. While the UK pioneered the P3 concept in the early 1990s, Canada is now widely acknowledged to be the key source of international best practice – the model and inspiration for emerging P3 programs around the globe. Especially since the onset of the financial crisis, the Canadian market has emerged as one of the world's most consistently productive – a market characterized by a strong pipeline, efficient procurement, vigorous competition in supply, and a supportive political environment.

In these countries, dozens of transportation projects are now in a mature phase of operation or under construction. As empirical experience has accumulated, there is clear evidence about specific advantages of the P3 model in terms of reducing the risks and enhancing the economic benefits associated with large-scale infrastructure and transportation investments. Experience shows that allocating risk in this way through the P3 model leads to two major benefits in project delivery: significant cost and time savings in construction; and, substantially greater focus on, and innovation to achieve, minimization of the costs infrastructure delivery across the life-cycle of the assets.

Below are some relevant examples where the P3 model has been used to successfully delivery large-scale transportation projects. It should be noted that these examples refer to P3 projects executed in densely populated areas as opposed to the rather remote area for the proposed Strait of Belle Isle Fixed Link.

Eglinton Crosstown LRT, Toronto, Ontario, Canada – DBFM ($8.25 Billion)

Project Highlights:

The Eglinton Crosstown LRT is a light rail line under construction in Toronto, Ontario. Stage 1 consists of a 19-km corridor that will include a 10-km underground portion; 25 stops and stations, linking to bus routes, three subway stations and various GO Transit lines; and a new maintenance and storage facility. An extension (east or west) to the Crosstown LRT is anticipated, but not yet planned.

Key Takeaways:

- Procurement began as a standard TTC run procurement program, but was subsequently taken over by the regional rail authority (Metrolinx). Contract is scheduled as a DBFM with TTC remaining as operator for the line for 30-years after financial close.
- Two separate tunnel construction contracts, both let ahead of the DBFM, created significant complexity. There was an entire framework created for who is responsible for what, and the hand-off of the tunnels to the ultimate DBFM contractor.
- Metrolinx vowed to hand over tunnels that had not yet been built to a DBFM contractor. The process included a series of tests to determine if the DBB-constructed tunnels were fit for hand-over to the DBFM contractor.
- Vehicles and the two tunnel contracts were purchased outside the DBFM, and were effectively DBBs.
- TTC would likely operate the extension through an expansion of their current operating contract on the original Crosstown LRT.
- TTC is a logical choice in this scenario to operate the extension for the following reasons: strong labour union would object to another independent operator; longevity and deep understanding of the City of Toronto, and the hard infrastructure of the Crosstown LRT; and, internationally recognized for their safety record.

Ottawa LRT, Ottawa, Ontario, Canada – DBFM ($2.1 Billion)

Project Highlights:

Ottawa's LRT system will be built in two stages. The first stage includes a new 12.5-km line along the existing Bus Route System (BRT) corridor and 13 stations, including three underground stations. The second stage (package one) includes adding 13-km of rail and 10 LRT stations. The future extension (Stage 2) is approved by council, and consists of a package of three extensions that will add over 39-km of rail and 23 new stations to the O-Train system by 2023.

Key Takeaways:

- In anticipation of building an extension to the Ottawa LRT, the City of Ottawa has sole sourced the operations contract for the extension (valued at $600 M) to the incumbent RTG.
- In exchange for the sole sourced contract, RTG is precluded from bidding on the DBFM contract to build and maintain the extension component of the Ottawa LRT.
- Sole sourcing operations of the extension to RTG serves a dual purpose. It helps to maintain competitive tension for the build and maintain component of the extension while also ensuring that service levels across the line are maintained through use of one operator.
- To ensure consistent service across entire system, the following components were sole sourced to RTG as part of their operating component: system design, vehicles (38 additional light rail vehicles), supply of materials, and administration.

Port of Miami Tunnel, Miami, Florida, USA – DBFOM ($1.4 Billion)

Project Highlights:

The Port of Miami Tunnel (POMT) project created a new, direct-access roadway connection from South Florida's Interstate highway network to the Port of Miami (POM). Project consisted of three integrated components: twin bored tunnels underneath the Main Shipping Channel between Dodge Island and Watson Island; widening of the existing MacArthur Causeway Bridge; and connections between the tunnel and the existing Port road network.

Key Takeaways:

- Extensive geotechnical sampling gave bidders sufficient confidence about the technical feasibility of the project which resulted in more competitive and cost-effective bids from private sector.
- Instead of receiving revenue from direct user tolls, the concessionaire will receive availability payments from FDOT throughout the duration of the contract to repay the up-front private sector financing of the design and construction of the tunnel plus the costs of operating and maintenance efforts once the facility is completed and placed into operation.
- Unique geotechnical risks associated with a tunnel of this size required risk-sharing between private developer and public sponsor with regards to potential changes in site conditions, such as unforeseen geotechnical conditions that increase project costs.
- Specific performance standards outlined by FDOT included measures of availability, service quality, and safety which helped create incentives for both timely completion of project construction and high operating and maintenance standards.
- FDOT has also included a High Traffic Payment as part of the availability payment, which compensated the concessionaire for higher maintenance costs if traffic levels greatly exceed the forecasts.
- Project highlights how availability payments can be used effectively in place of tolling when user fees are not an attractive option.

Elizabeth River Tunnels Project, Virginia, USA – DBFOM ($2.1 Billion))

Project Highlights:

Project consists of a new two-lane tunnel adjacent to the existing Midtown Tunnel under the Elizabeth River, maintenance and safety improvements to the existing Midtown and Downtown tunnels, extending the MLK from London Boulevard to Interstate 264, and interchange modifications at Brambleton Avenue and Hampton Boulevard.

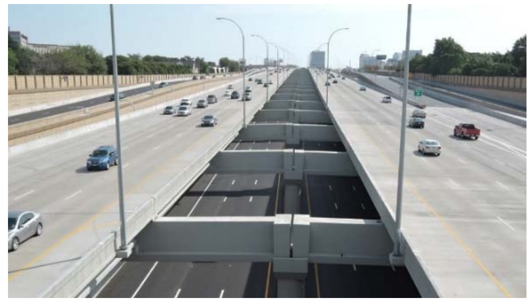
Key Takeaways:

- Fulling integrated DBFOM solution incorporated all the advantages of a DB solution and more (e.g. fixed price, date certain delivery of the asset; involvement of the O&M provider during the project development/design stage) which reduced risk of delay, leading to 6-month saving in delivering the new Midtown Tunnel.
- Project financing structure included: $637.5 million Private Activity Bonds (PABs), $441.4 million TIFIA loan, $581 million State subsidy, $251 million private equity, and $150 million toll revenue during construction.
- Delivery method enabled seamless transfer of VDOT tunnel staff into ERC operating company, as well as rollout of all-electronic tolling (AET) solution during construction in order to reduce the toll rate once the project was finally completed.
- The agreement with Virginia DOT envisions that approximately 17.5% of the $1.45-billion construction cost will be funded by tolling the existing free tunnels during the five-year construction period. The large savings on capitalized interest in the bond financing helped to reduce the starting toll from $2.89 in an earlier plan.
- Joint workshops co-chaired by each party (developer, contractor, and VDOT) helped build a high degree of respect and trust before contract was mobilized.
- High political risk related to a change in state administration during project development state was mitigated by working with both gubernatorial administrations to adapt the contract to gain public approval, while meeting the state's goals and team's business targets.
- Full scale-marketing and media relations campaign was undertaken to inform citizens about tolling procedures and fares related to the implementation of AET for the first time in Hampton Roads, Virginia.

LBJ Express, Dallas County, USA – DBFOM ($2.6 Billion)

Project Highlights:

The project involved the reconstruction of the main lanes and frontage roads along I-635, addition of six managed lanes (mostly subsurface) along I-635 from I-35E to US 75 and four managed lanes west and east of that stretch, and an addition of six elevated managed lanes along I-35E from Loop 12 to the I-35E/I-635 interchange.



Key Takeaways:

- The managed lanes are dynamically priced following a six-month introductory fixed-price schedule. HOV2+ users receive a 50 percent discount during peak operating periods.
- Funding courses include: Private Activity Bonds (PABs) - $606 million; TIFIA loan - $850 million; Equity contribution - $682 million; Toll revenues during construction - $17 million; Public funds - $490 million.
- The TIFIA loan will be repaid with project revenues, which include all income, tolls, revenues, rates, fees, charges, rentals, or other receipts derived by or related to the operation of the project.
- Innovative financing package includes PABs and TIFIA credit assistance.
- Met the project goal to not increase the width or height of the existing roadway by constructing the managed lanes as an open trench, rather than placing them in tunnels, and cantilevering the existing general-purpose lanes above them. This approach also resulted in significant cost savings.

Capital Beltway, Virginia, USA – DBFOM ($2.1 Billion)

Project Highlights:

The projected included 14 miles of two new lanes in each direction; first time introduction of High Occupancy Vehicles (HOV) lanes to the Capital Beltway and reliable transit options to the Beltway and Tysons Corner, Virginia; congestion-free network for carpools, vanpools, transit and toll-paying motorists; and construction of carpool ramps connecting I-95 with the Capital Beltway to create a seamless HOV network.

Key Takeaways:

- Innovative design significantly reduced the displacements and impacts, as well as project costs which involved the replacement of more than $260- million worth of aging infrastructure, including 50 bridges and overpasses outside of the HOT lanes.
- Dynamic tolling based on real-time traffic conditions.
- The total length of the concession is 85 years - five years of construction and 80 years of operation.
- First time a Private Activity Bond was used for HOT lanes in the U.S. and the first time combined with TIFIA financing
- The TIFIA loan holds a subordinate lien on a pledge of the project's toll revenues and interest income, after operations and maintenance expenses, certain capital expenditures, senior debt service reserve, and debt service payments to senior lenders.
- The TIFIA loan is structured with five years of capitalized interest during construction followed by five years of partially capitalized interest during ramp-up; then current interest only for 15 years followed by 15 years of interest plus principal.

16. Conclusions

16.1 Study Findings

Based on the review of assumptions and background information used in the Pre-Feasibility Study in 2004 and new information available, a review of fixed link projects that were carried out worldwide in recent years and the updated construction cost estimate, a rail tunnel excavated by TBM is still considered the most technically and economically attractive option for a fixed transportation link between Labrador and Newfoundland.

To assess the required capacity of the tunnel, it was assumed that all traffic from the current Strait of Belle Isle Ferry and 60% of the current Gulf Ferries traffic would be diverted to the new Fixed Link tunnel. Based on the traffic volume data provided to Hatch and considering a 2.5% traffic increase per year over the next 42 years (including 12 years for planning, design and construction), a design peak hour traffic volume of 197 vehicles per hour and direction was estimated for the Fixed Link. Considering this relatively low traffic volume, a single-track shuttle train with alternating operation in both directions would provide sufficient capacity to address the design traffic volume over the next 42 years. The shuttle cars would be custom made and could be designed to address the requirements regarding vehicle types using the Fixed Link.

The rail shuttle option would include a single bore tunnel with a 7.6 m inner diameter. The recommended ground cover above the tunnel is approximately 20 m, resulting in a tunnel depth of approximately 130 m below the water level in the Strait of Belle Isle. An optimization of the required tunnel depth below sea bottom will be possible based on further geotechnical investigation results at a later stage of the project.

The tunnel length was estimated to be approximately 30 km, assuming a straight tunnel alignment below the Strait of Belle Isle and on shore and considering exit ramps with 2% grades. A refinement of the tunnel length will be possible by aligning the exit ramps to the topography on both shores as part of a later project stage.

The tunnel excavation is recommended to be executed using a pressurized face TBM to address the challenges of tunnelling through the different geological formations that will be encountered at the project site comprising various rock types, varying from hard gneiss to weak shale. A pressurized face TBM would also be capable of excavating through fault zones with increased water inflows and addressing high hydrostatic pressures that have to be expected at a depth of 130 m below water level.

The construction costs for the single-track tunnel option, considering the use of one TBM, would be in the order of $1,675 million (2017) with a construction period of approximately 10 years, including approximately 7 years of TBM tunnel drive; additional 5 years would have to be considered for planning and design of the tunnel.

The construction costs for the single-lane road tunnel option, considering the use of one TBM, would be in the order of $2,064 million (2017) with a construction period of approximately 9 years, which include approximately 6.5 years of TBM tunnel drive. As for the rail tunnel, additional 5 years would have to be considered for planning and design of the tunnel.

The costs for the planning and design stage would be in the order of $20 to $23 million (2017), which would include the environmental assessment and additional geotechnical investigations at the project site. A contingency of 40% on the tunnel (civil) costs has been included in the cost estimate.

The economic assessment is based on construction and operational costs. However, the level of detail required for the conceptual design in the current stage of the project does not include costs such as camp costs. Detailed cost estimates should be evaluated in the next project stage and included in the final assessment of the most suitable solution.

Delivering the Strait of Belle Isle project under a P3 - DBFOM arrangement appears to be an appropriate financing methodology; P3 financing has been successfully used in many large-scale tunnel projects similar to the Strait of Belle Isle Fixed Link.

An upgraded Strait of Belle Isle ferry option would be a lower cost alternative to a fixed link. However, transportation services during the winter months would still be restricted due to the environmental conditions in the Strait.

16.2 Future Work

Future activities required to advance the Strait of Belle Isle Fixed Link from pre-feasibility stage to a full feasibility study were discussed in the 2004 study. These activities include in particular further geotechnical/geophysical investigations along the proposed alignment, including borehole investigations within the Strait. These investigations would be costly and technically challenging due to the water depth and the hash environment. However, they would be required to determine the ground conditions underneath the Strait and hence reduce the geotechnical risks during tunnel construction and define the most suitable tunnel alignment at depth which will have an immediate impact on the construction costs.

Considering that the planned Strait of Belle Isle Fixed Link would be serving an area with a low population density and a relatively low projected traffic volume, future work should also include an analysis of financing considerations for remote areas.

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APPENDIX A

Borehole Locations Strait of Belle Isle
(Figure 1)

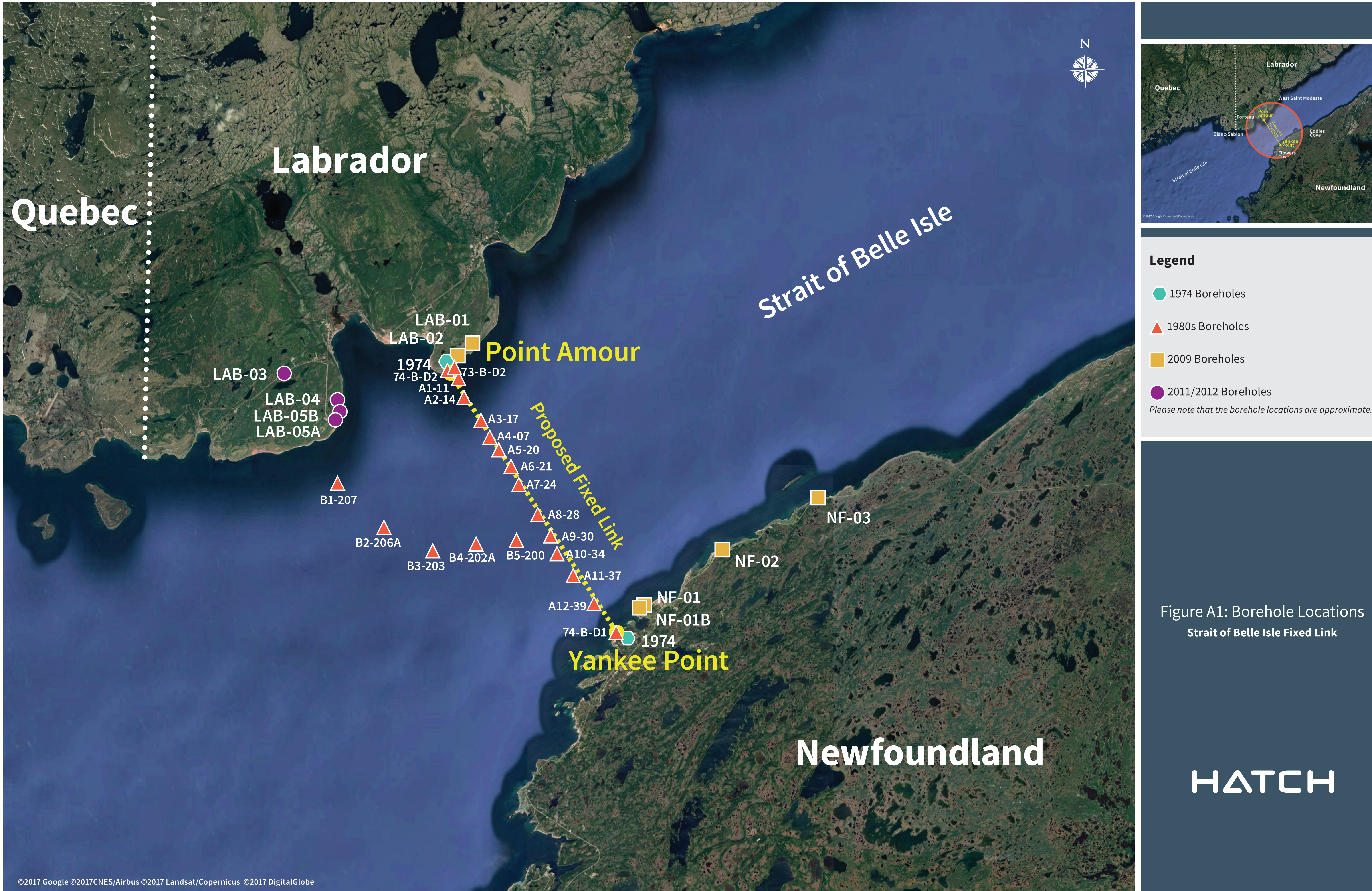


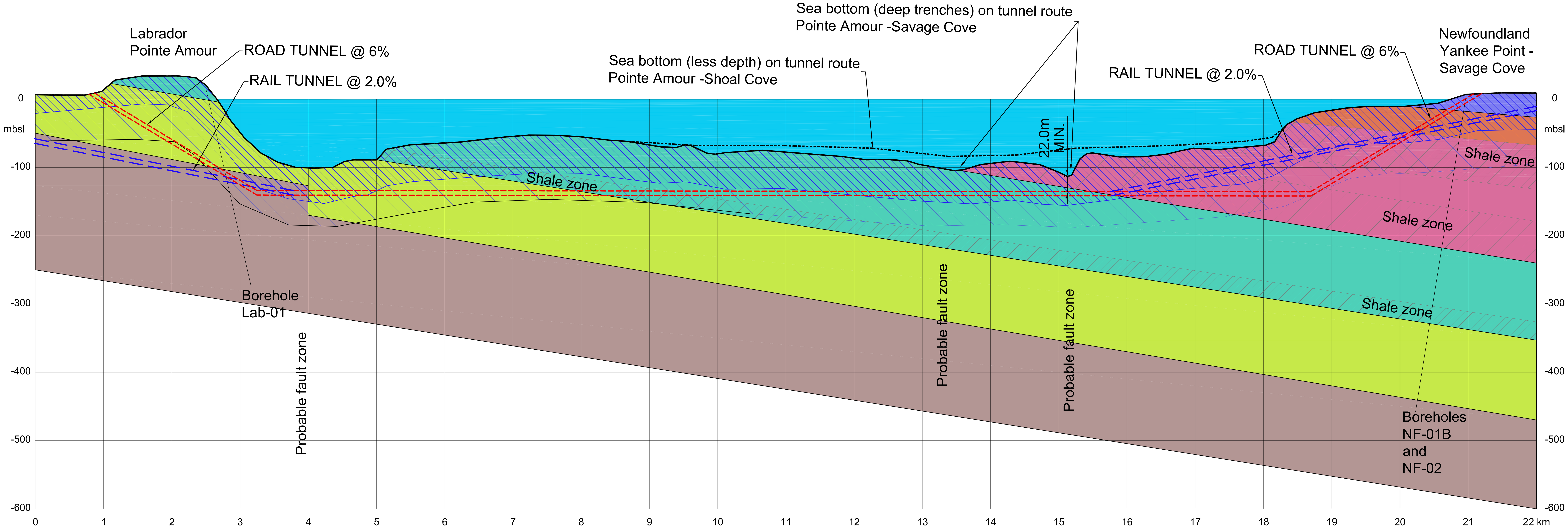
Figure A1: Borehole Locations

Strait of Belle Isle Fixed Link

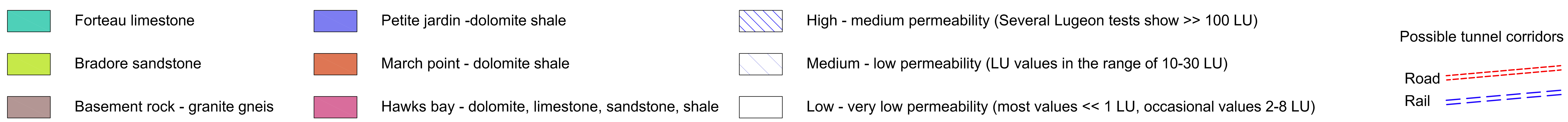
HATCH

APPENDIX B

Schematic Geological Section Strait of Belle Isle (Drawing 001)



DRAWING BASED ON DRAWING No. 5 PROVIDED IN: LANDSVIRKJUN POWER/MANNVIT ENGINEERING, 2010. LOWER CHURCHILL PROJECT, STRAIT OF BELLE ISLE, GEOTECHNICAL INVESTIGATIONS 2009, PRELIMINARY EVALUATION ON BOREHOLE DATA, REVISION 1, MARCH 2010, PREPARED FOR NALCOR ENERGY.



HATCH

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	RG		OCT2017
DESIGNER			
CHECKER	GM		OCT2017
DESIGN COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

No.	DESCRIPTION	BY	CHK'D	DATE
A	ISSUED FOR REPORT	GM		OCT2017

REVISIONS

DRAWING No.	DRAWING TITLE
-	

REFERENCE DRAWINGS

REG. PROFESSIONAL

STRAIT OF BELLE ISLE
FIXED LINK

STRAIT OF BELLE ISLE
SCHEMATIC GEOLOGICAL SECTION
POINTE AMOUR - YANKEE POINT

SCALE: OR AS NOTED

DWG. No.: H354440-SK-001

REV: A

SHEET SIZE: A1

$USERNAMES $DATES $TIMES

APPENDIX C
Construction Costs

APPENDIX C1

Road Tunnel

Appendix C1-1
Road Tunnel - Single-Bore, 1 TBM
Construction Costs

Newfoundland Fixed Link Pre-feasibility - Single Bored - 1TBM Highway Tunnel - Cost Summary		
BORED TUNNEL CONSTRUCTION COSTS		
ITEM	**UNIT**	**MAIN TUNNEL**
MOBILIZATION & DEMOBILIZATION	LS	**8,000,000**
TUNNELLING	LS	**600,306,358**
TUNNEL FINISHES	LS	**253,482,600**
NORTH APPROACH STRUCTURES	LS	**5,604,405**
SOUTH APPROACH STRUCTURES	LS	**6,979,072**
NORTH VENTILATION ADIT	LS	**11,002,540**
SOUTH VENTILATION ADIT	LS	**24,551,169**
ROAD FINISHES	LS	**4,304,750**
NORTH VEHICLE HOLDING AREA	LS	**6,960,000**
SOUTH VEHICLE HOLDING AREA	LS	**4,260,000**
TUNNEL DRAINAGE	LS	**9,554,554**
UTILITY DIVERSIONS	LS	**1,000,000**
MONITORING	LS	**1,000,000**
SUBTOTAL CIVIL		**$937,005,448**
CIVIL CONTINGENCIES		
CONTINGENCY	40%	$374,802,179
TOTAL CIVIL		**$1,311,807,628**
M&E AND FINISHING WORK		
VENTILATION EQUIPMENT	LS	$6,000,000
VENTILATION BUILDINGS x 2	LS	$2,000,000
FIRE SUPPRESSION SYSTEM	LS	$4,000,000
CONTROL CENTRE	LS	$4,000,000
SIGNALLING	LS	$0
LIGHTING	LS	$2,959,546
CCTV SYSTEM	LS	$1,115,000
GAS DETECTION	LS	$945,000
SUBSTATION, GENERATORS, UPS	LS	$4,202,000
SUBTOTAL M&E AND FINISHING		**$25,221,546**
CONTINGENCIES	20%	$5,044,309
TOTAL M&E AND FINISHING		**$30,265,855**
TOTAL CIVIL, M&E AND FINISHING		**$1,342,073,482**
ALLOWANCES		
CONTRACTOR OH	15%	$201,311,022
CONTRACTOR PROFIT	15%	$201,311,022
CONSTRUCTION TOTAL		**$1,744,695,527**
PRE-CONSTRUCTION AND SUPERVISION		
FEASIBILITY STUDY	LS	$17,000,000
ENVIRONMENTAL ASSESSMENT	LS	$6,000,000
DESIGN	5%	$87,234,776
CONSTRUCTION MANAGEMENT	10%	$174,469,553
OWNERS COSTS	2%	$34,893,911
PRE-CONSTRUCTION TOTAL		$319,598,240
GRAND TOTAL		**$2,064,293,767**

HATCH **Tunnel Estimating Database**

Detailed Cost Estimate Report

Version 2.8

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Set up	**Parent Estimate ID:**	2631
Tunnel Name:	Single Bore HWY T.	**Project Phase:**	Conceptual
Construction Activity:	Erect TBM Only	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	October 30, 2017
Estimate Definition ID:	7801	**Tunnel Characteristics ID:**	3393

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 4.5 Weeks

Total Number of Shifts 94.5

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	756.00	1.00	67,692
Tunnel miner	76.06	$/hr	756.00	2.00	115,003
Shaft bottom	75.29	$/hr	756.00	3.00	170,758
Tunnel fitter	69.92	$/hr	756.00	1.00	52,860
Tunnel electrician	84.43	$/hr	756.00	1.00	63,829
Shaft top	75.29	$/hr	756.00	1.00	56,919
Crane operator	77.86	$/hr	756.00	2.00	117,724
Surface laborer	75.22	$/hr	756.00	1.00	56,866
Equipment laborer	72.88	$/hr	756.00	1.00	55,097
				13.00	$756,748
Equipment					
Loco	8,000.00	$/wk	4.50	1.00	36,000
Muck cars & grout cars	2,900.00	$/wk	4.50	6.00	78,300
Flat cars	480.00	$/wk	4.50	2.00	4,320
Transformers & switchgear - LV	1,100.00	$/wk	4.50	1.00	4,950
Small tools	2,600.00	$/wk	4.50	1.00	11,700
Shaft crane	13,900.00	$/wk	4.50	1.00	62,550
Erection crane	10,000.00	$/wk	4.50	1.00	45,000
Compressors	1,500.00	$/wk	4.50	1.00	6,750
Generators	3,100.00	$/wk	4.50	1.00	13,950
Transformers & switchgear - HV	8,000.00	$/wk	4.50	1.00	36,000
Loaders	3,550.00	$/wk	4.50	1.00	15,975
					$315,495
Materials					
Temporary materials	3,000.00	$/wk	4.50	1.00	13,500

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Thrust frame	7,000.00	$/wk	4.50	1.00	31,500
					$45,000
			Total Estimated Cost:		$1,117,243

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Tunnel Drive	**Parent Estimate ID:**	2632
Tunnel Name:	Single Bore HWY T.	**Project Phase:**	Conceptual
Construction Activity:	TBM Tunneling	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	October 27, 2017
Estimate Definition ID:	7800	**Tunnel Characteristics ID:**	3393

Tunnel Characteristics

Tunnel Length:	21,000	m
Finished Diameter:	11	m
Initial Support Type:	Pre-cast concrete segments	
Initial Support Thickness:	0	m
Final Lining Thickness:	0.45	m
Grout Thickness:	0.125	m

Theoretical Excavation Volumes

Total Neat Excavation:	2,434,789	Cubic Metres
Initial Lining Volume:	0	Cubic Metres
Final Lining Volume:	339,928	Cubic Metres
Theoretical Grout Volume:	99,166	Cubic Metres

Normal Excavation/Support Cycle

Excavation Cycle Length:	1.5	Metres
Excavate:	28	Minutes
Erect Support:	36	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	64	Minutes

Difficult Excavation/Support Cycle

Length of Difficult Excavation:	1400	Metres
Excavate:	92	Minutes
Erect Support:	74	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	166	Minutes

Reduction Factors

Machine availability:	80	%
Back up efficiency:	55	%
Planned maintenance:	5	%
Learning curve efficiency:	40	%
Learning curve duration time:	8	Weeks

Learning Curve Rate:	5.6	m/day
Experienced Advance Rate:	14.1	m/day
Difficult Advance Rate:	5.4	m/day

TBM Skidding Through Excavation

Duration of skidding:	0	Weeks
Length of skidding:	0	Metres

Advance Rate and Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Drive Advance per Shift:	4.17	Metres
Avg. Drive Advance per Day:	12	Metres
Avg. Drive Advance per Week:	87	Metres
Duration of Tunneling (Incl. Skid):	240.05	Weeks
Total number of shifts (Incl. Skid):	5,041	

	Metres	Days
Learning Curve Drive:	316	56
Experienced Drive:	19,284	1,367
Difficult Drive:	1,400	257
Skidding Portion:	0	0

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Pit boss	89.54	$/hr	40,332.00	1.00	3,611,327
	Tunnel miner	76.06	$/hr	40,332.00	3.00	9,202,956
	Tunnel laborer	75.39	$/hr	40,332.00	4.00	12,162,518
	Loco driver	75.64	$/hr	40,332.00	4.00	12,202,850
	Shaft bottom	75.29	$/hr	40,332.00	1.00	3,036,596
	TBM operator	76.06	$/hr	40,332.00	1.00	3,067,652
	Tunnel fitter	69.92	$/hr	40,332.00	1.00	2,820,013
	Tunnel electrician	84.43	$/hr	40,332.00	1.00	3,405,231
	Shaft top	75.29	$/hr	40,332.00	2.00	6,073,193
	Crane operator	77.86	$/hr	40,332.00	1.00	3,140,250
	Surface laborer	75.22	$/hr	40,332.00	4.00	12,135,092
	Equipment laborer	72.88	$/hr	40,332.00	4.00	11,757,585
	Shift Supervisor	89.54	$/hr	40,332.00	2.00	7,222,655
					29.00	$89,837,917
Equipment						
	TBM	340,000.00	$/m2	115.94	1.00	39,419,600
	TBM optional equipment.	1,500,000.00	$/Nr	1.00	1.00	1,500,000
	Loco	8,000.00	$/wk	240.05	4.00	7,681,600
	Muck cars & grout cars	2,900.00	$/wk	240.05	56.00	38,984,120
	Flat cars	480.00	$/wk	240.05	8.00	921,792
	Person riders	480.00	$/wk	240.05	2.00	230,448
	Track	200.00	$/m	21,000.00	1.00	4,200,000
	Air pipe	46.00	$/m	21,000.00	1.00	966,000
	Water pipe	40.00	$/m	21,000.00	1.00	840,000
	Pump main	78.00	$/m	21,000.00	1.00	1,638,000
	Cabling	125.00	$/m	21,000.00	1.00	2,625,000
	Lighting	46.00	$/m	21,000.00	1.00	966,000
	Vent ducting	46.00	$/m	21,000.00	1.00	966,000
	Grout mixers	10,960.00	$/wk	240.05	1.00	2,630,948
	Grout pumps	5,250.00	$/wk	240.05	1.00	1,260,263
	Grout hoses & pipes	300.00	$/wk	240.05	2.00	144,030
	Transformers & switchgear - LV	1,100.00	$/wk	240.05	2.00	528,110
	Small tools	4,000.00	$/wk	240.05	1.00	960,200
	Shaft crane	13,900.00	$/wk	240.05	1.00	3,336,695
	Compressors	1,500.00	$/wk	240.05	1.00	360,075
	Low pressure C/A system	5,900.00	$/wk	240.05	1.00	1,416,295
	Pipework and controls	1,000.00	$/wk	240.05	2.00	480,100
	Generators	3,100.00	$/wk	240.05	1.00	744,155
	Transformers & switchgear - HV	8,000.00	$/wk	240.05	1.00	1,920,400
	Surface fans	1,200.00	$/wk	240.05	2.00	576,120
	Loaders	3,550.00	$/wk	240.05	2.00	1,704,355
	Other surface plant	4,000.00	$/wk	240.05	1.00	960,200

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Tunnel C/A system	62,000.00	$/wk	240.05	1.00	14,883,100
					$132,843,606
Consumables					
Electrical power	0.15	$/kwh	40,332.00	3,000.00	18,149,400
Gas oil	1.20	$/L	48,000.00	1.00	57,600
Lubrication materials	140.00	$/wk	240.05	1.00	33,607
TBM spares, cutters	390.00	$/m	21,000.00	1.00	8,190,000
Filters etc.	465.00	$/wk	240.05	1.00	111,623
Hydraulic oil	7.00	$/L	32,000.00	1.00	224,000
Other consumables	200.00	$/wk	240.05	1.00	48,010
Tail seal grease	200.00	$/m	21,000.00	1.00	4,200,000
					$31,014,240
Materials					
Concrete lining rings	15,661.94	$/Nr	14,000.00	1.00	219,267,194
Gaskets	170.00	$/m	21,000.00	1.00	3,570,000
Bolts	20.00	$/Nr	1,765.00	30.00	1,059,000
Grout	220.00	$/m3	99,166.00	1.00	21,816,520
Grout plugs	0.80	$/Nr	1,765.00	7.00	9,884
Packers	15.00	$/Nr	3,633.00	12.00	653,940
Temporary materials	3,000.00	$/wk	240.05	1.00	720,150
Other materials	0.00	$/t	0.00	1.00	0
					$247,096,688
Subcontracts					
Soil disposal	25.00	$/m3	2,434,789.00	1.50	91,304,588
					$91,304,588

Total Estimated Cost:	$592,097,038
Total Estimated Cost per Metre:	$28,195
Total Estimated Cost per Week:	$2,466,586
Total Estimated Cost per Shift:	$117,445

HATCH

Tunnel Estimating Database

Detailed Cost Estimate Report

Version 2.8

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	TBM Maintenance	**Parent Estimate ID:**	2633
Tunnel Name:	Single Bore HWY T.	**Project Phase:**	Conceptual
Construction Activity:	TBM Maintenance	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	October 30, 2017
Estimate Definition ID:	7802	**Tunnel Characteristics ID:**	3393

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 1 - 6 hour shifts x 1 days per week

Duration of Activity 240 Weeks

Total Number of Shifts 240

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Working foreperson	89.54	$/hr	1,440.00	1.50	193,406
Loco driver	75.64	$/hr	1,440.00	1.50	163,382
Shaft bottom	75.29	$/hr	1,440.00	1.50	162,626
TBM operator	76.06	$/hr	1,440.00	1.50	164,290
Tunnel fitter	69.92	$/hr	1,440.00	1.50	151,027
Tunnel electrician	84.43	$/hr	1,440.00	1.50	182,369
Shaft top	75.29	$/hr	1,440.00	1.50	162,626
Surface laborer	75.22	$/hr	1,440.00	1.50	162,475
				12.00	$1,342,202
Consumables					
Electrical power	0.15	$/kwh	1,440.00	600.00	129,600
Other consumables	0.00	$/wk	240.00	1.00	0
					$129,600
Materials					
Temporary materials	500.00	$/wk	240.00	1.00	120,000
					$120,000
				Total Estimated Cost:	$1,591,802

HATCH

Tunnel Estimating Database

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Tunnel Clean up	**Parent Estimate ID:**	2634
Tunnel Name:	Single Bore HWY T.	**Project Phase:**	Conceptual
Construction Activity:	Tunnel Clean Up	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	October 30, 2017
Estimate Definition ID:	7804	**Tunnel Characteristics ID:**	3393

Tunnel Characteristics

Tunnel Length:	21,000	m	
Finished Diameter:	11	m	(Circular Tunnels)
Excavated Cross Section:	0	m2	(Non-circular Tunnels)
Excavated Perimeter:	0	m	(Non-circular Tunnels)

Productivity Cycle

Section Length	30	Metres
Vent Line Removal Time	120	Minutes
Track Removal Time	60	Minutes
Temp Lighting Removal Time	60	Minutes
Clean Up Time	120	Minutes
Total Cycle Time	360	Minutes

Reduction Factors

Learning Curve Efficiency:	50	%
Back Up Efficiency:	80	%
Learning Curve Duration:	1	Weeks

Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Advance per Shift:	31.47	Metres
Avg. Advance per Week:	661	Metres
Total number of hours:	5,338	

Clean Up Productivity Data

	Average Advance		Drive Length		Drive Duration					
Learning Curve Portion:	48.0	m/day	336	Metres	21	Shifts	7	Days	1.00	Weeks
Experienced Drive Portion:	96.0	m/day	20,664	Metres	646	Shifts	215	Days	30.75	Weeks
Total:	94.5	m/day	21,000	Metres	667	Shifts	222	Days	31.75	Weeks

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Tunnel laborer	75.39	$/hr	5,338.00	6.00	2,414,591
Shaft bottom	75.29	$/hr	5,338.00	1.00	401,898
Shaft top	75.29	$/hr	5,338.00	1.00	401,898
Crane operator	77.86	$/hr	5,338.00	1.00	415,617
				9.00	$3,634,004
Equipment					
Transformers & switchgear - LV	1,100.00	$/wk	31.75	1.00	34,925

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Hoists operator	2,600.00	$/wk	31.75	1.00	82,550
Shaft crane	13,900.00	$/wk	31.75	1.00	441,325
Compressors	1,500.00	$/wk	31.75	1.00	47,625
Loaders	3,550.00	$/wk	31.75	1.00	112,713
Other surface plant	3,000.00	$/wk	31.75	1.00	95,250
Bobcat	800.00	$/wk	31.75	1.00	25,400
					$839,788

Consumables

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Electrical power	0.15	$/kwh	5,338.00	200.00	160,140
					$160,140

Total Estimated Cost:	$4,633,931
Total Estimated Cost per Metre:	$221
Total Estimated Cost per Week:	$145,951
Total Estimated Cost per Shift:	$6,945

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	TBM Removal	**Parent Estimate ID:**	2635
Tunnel Name:	Single Bore HWY T.	**Project Phase:**	Conceptual
Construction Activity:	TBM Removal	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	October 30, 2017
Estimate Definition ID:	7803	**Tunnel Characteristics ID:**	3393

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 3 Weeks

Total Number of Shifts 63

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	504.00	1.00	45,128
Tunnel miner	76.06	$/hr	504.00	3.00	115,003
Shaft bottom	75.29	$/hr	504.00	2.00	75,892
Tunnel fitter	69.92	$/hr	504.00	1.00	35,240
Tunnel electrician	84.43	$/hr	504.00	1.00	42,553
Shaft top	75.29	$/hr	504.00	2.00	75,892
Crane operator	77.86	$/hr	504.00	2.00	78,483
Surface laborer	75.22	$/hr	504.00	2.00	75,822
Equipment laborer	72.88	$/hr	504.00	1.00	36,732
				15.00	$580,744
Equipment					
Loco	8,000.00	$/wk	3.00	1.00	24,000
Muck cars & grout cars	2,900.00	$/wk	3.00	6.00	52,200
Flat cars	480.00	$/wk	3.00	4.00	5,760
Person riders	480.00	$/wk	3.00	1.00	1,440
Booster fans	1,500.00	$/wk	3.00	1.00	4,500
Transformers & switchgear - LV	1,100.00	$/wk	3.00	1.00	3,300
Other plant	2,200.00	$/wk	3.00	1.00	6,600
Hoists operator	3,000.00	$/wk	3.00	1.00	9,000
Shaft crane	13,900.00	$/wk	3.00	1.00	41,700
50T Crane	7,000.00	$/wk	3.00	1.00	21,000
TBM Crane	20,000.00	$/wk	3.00	1.00	60,000
Compressors	1,500.00	$/wk	3.00	1.00	4,500
Transformers & switchgear - HV	8,000.00	$/wk	3.00	1.00	24,000
Surface fans	1,200.00	$/wk	3.00	1.00	3,600
					$261,600

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Consumables					
Gas oil	1.20	$/L	15.00	1,000.00	18,000
Other consumables	500.00	$/wk	3.00	1.00	1,500
					$19,500
Materials					
Temporary materials	800.00	$/wk	3.00	1.00	2,400
					$2,400
General Supplies					
Small tools	700.00	$/wk	3.00	1.00	2,100
					$2,100
			Total Estimated Cost:		$866,344

Initialisation

Project: Newfoundland Fixed Link Pre-feasibility Study
Section: North Approach
Option: Bored Highway Tunnel

Date: 31-Oct-17

Calculations by:

Surface gradient	0.4	%	+ sloping same way as track/road - sloping against track/road
Track/Road Gradient	6	%	
Ground elevation at portal	100	m	
Bottom of slab elevation at portal	81.6	m	
Total length=	328.571429	m	
Total Cost=$	5.6	M	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

UNIT RATES (Sep. 2017)

Current construction index: 10823
Base index(April 2001): 6286

Materials

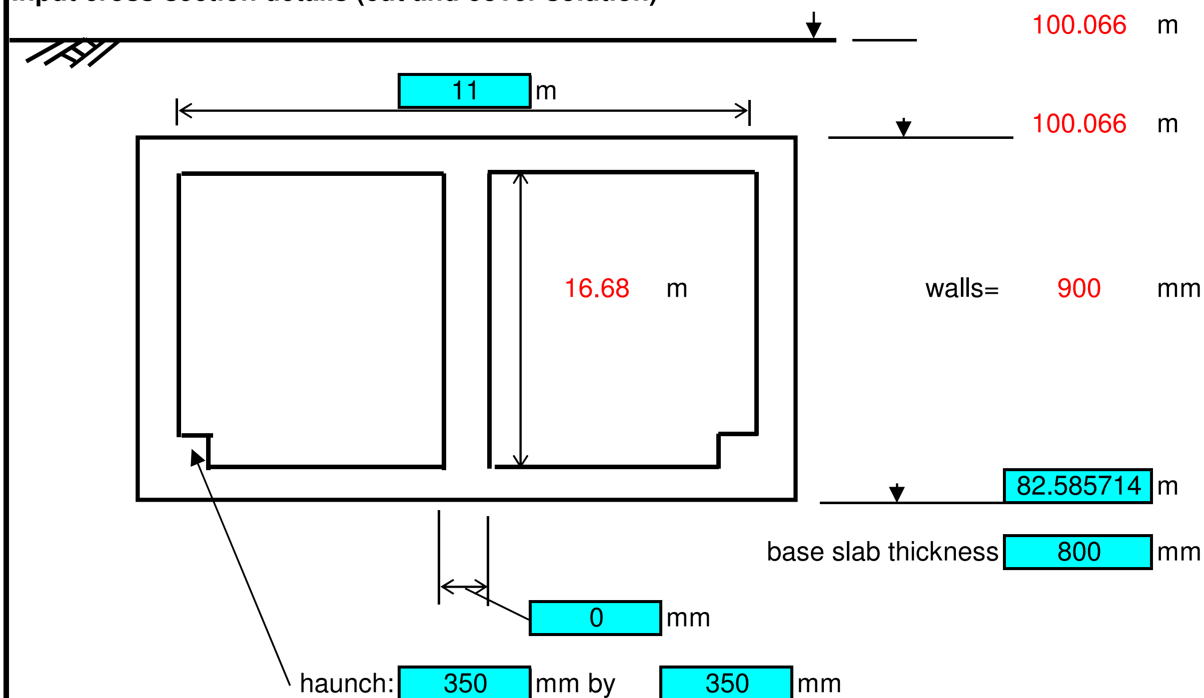
Item	unit	Rate
excavation	m3	60
concrete	m3	220
rebar	tonnes	1600
formwork/falsework	m2	241
SP&L<=4.6m deep	m2	0
4.6<SP&L<=6.7m deep	m2	0
6.7<SP&L<=10.6m deep	m2	0
10.6<SP&L<=13.7m deep	m2	0
13.7<SP&L<=16.8m deep	m2	0
16.8<SP&L<=20.0m deep	m2	0
20<SP&L<=25m deep	m2	0
backfill + compact	m3	69
surface reinstatement	m2	52

Note: Above unit rates include allowance for overheads and profit

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 32.85714 m **Section 1**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	7351.6	m3
concrete=	1331.01	m3
rebar=	159.7	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	1096.114	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	1148.7	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	420.5714	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	7351.6	60	441095.3143
concrete	m3	1331.01	220.0	292822.2
rebar	tonnes	159.7	1600	255553.92
formwork/falsework	m2	1096.114	241.0468	264214.8088
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	1148.7	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	420.5714	51.65288	21723.72529
			Total	1275409.968

Indirect costs, profit, and contingency

0 % indirect costs = $ 0

Subtotal 2 = $ 1275410

0 % profit = $ 0

Subtotal 3 = $ 1275410

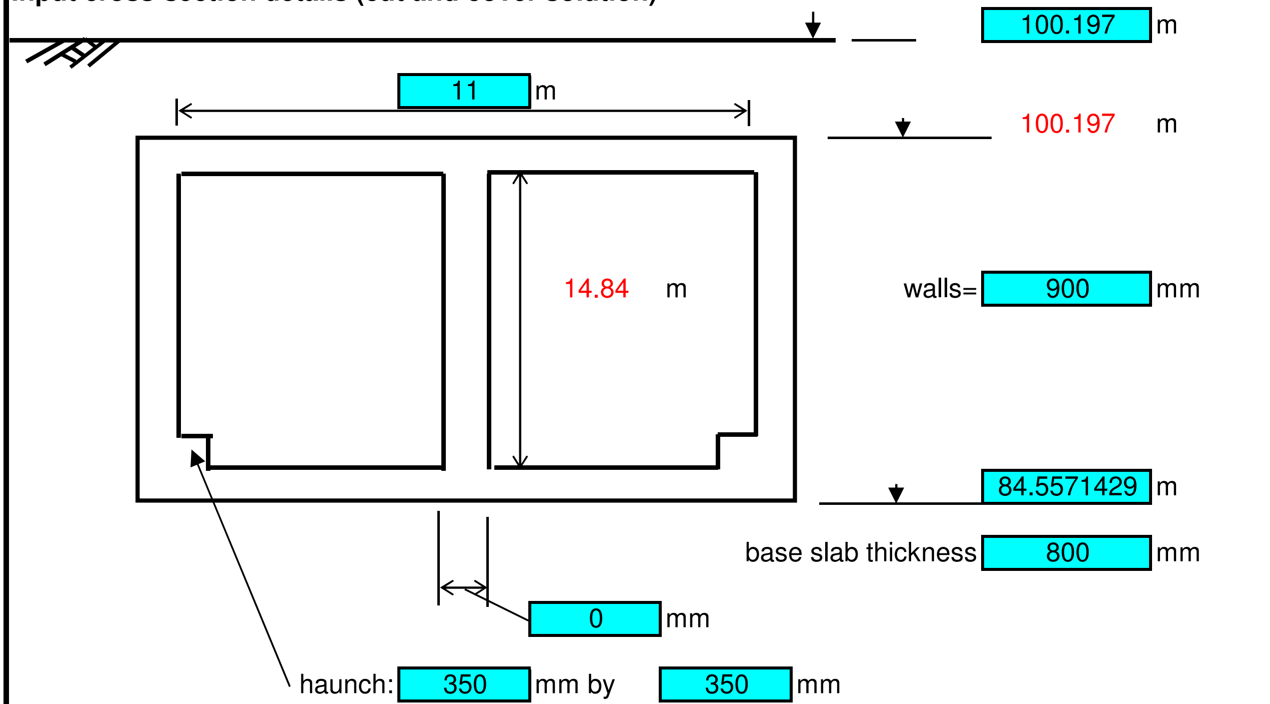
25 % contingency = $ 318852.4921

Total Cost = $ 1,594,262

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 31-Oct-17
North Approach | **Calculations by:** 0
Bored Highway Tunnel |

Section Cut and Cover
Length of section: 32.85714 m | **Section** 2

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	6577.7	m3
concrete=	1222.187	m3
rebar=	146.7	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	975.2	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	1027.8	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	420.5714	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	6577.7	60	394664.2286
concrete	m3	1222.187	220.0	268881.1714
rebar	tonnes	146.7	1600	234659.9314
formwork/falsework	m2	975.2	241.0468	235068.8107
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	1027.8	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	420.5714	51.65288	21723.72529
			Total	1154997.867

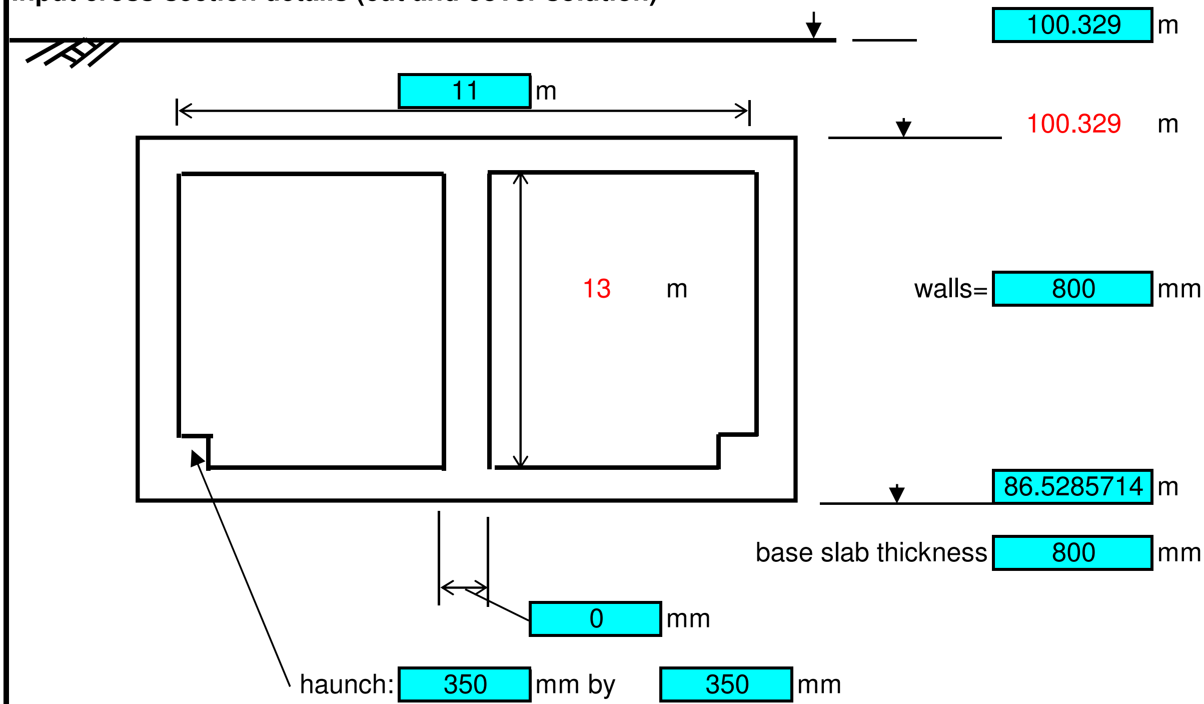
Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	1154998
0	% profit = $	0
	Subtotal 3 = $	1154998
25	% contingency = $	288749.4669
	Total Cost = $	**1,443,747**

Section Cut and Cover
Length of section: 32.85714 m

Section 3

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	5713.2	m3
concrete=	1022.679	m3
rebar=	122.7	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	854.2857	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	906.9	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	414	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	5713.2	60	342792
concrete	m3	1022.679	220.0	224989.2857
rebar	tonnes	122.7	1600	196354.2857
formwork/falsework	m2	854.2857	241.0468	205922.8126
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	906.9	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	414	51.65288	21384.29208
			Total	991442.6761

Indirect costs, profit, and contingency

0 % indirect costs = $ 0

Subtotal 2 = $ 991443

0 % profit = $ 0

Subtotal 3 = $ 991443

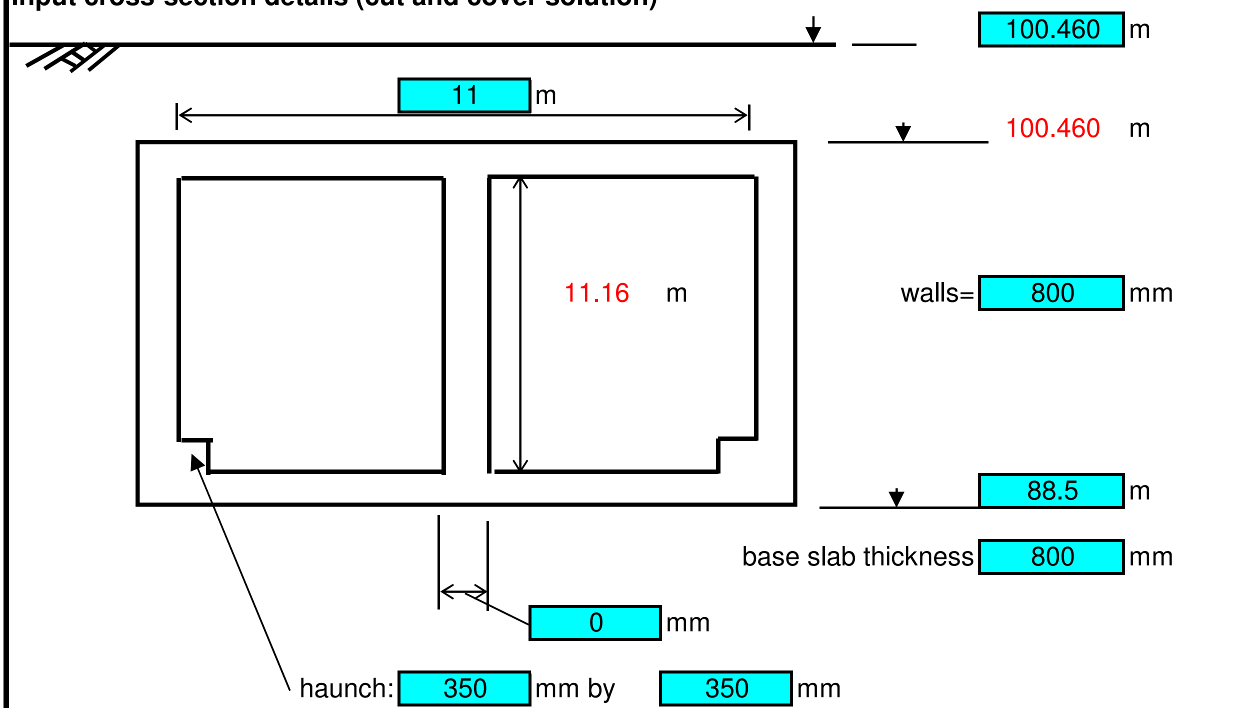
25 % contingency = $ 247860.669

Total Cost = $ 1,239,303

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 32.85714 m **Section** 4

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	4951.4	m3	
concrete=	925.9471	m3	
rebar=	111.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	733.3714	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	785.9	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	414	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	4951.4	60	297086.4
concrete	m3	925.9471	220.0	203708.3714
rebar	tonnes	111.1	1600	177781.8514
formwork/falsework	m2	733.3714	241.0468	176776.8145
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	785.9	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	414	51.65288	21384.29208
			Total	876737.7294

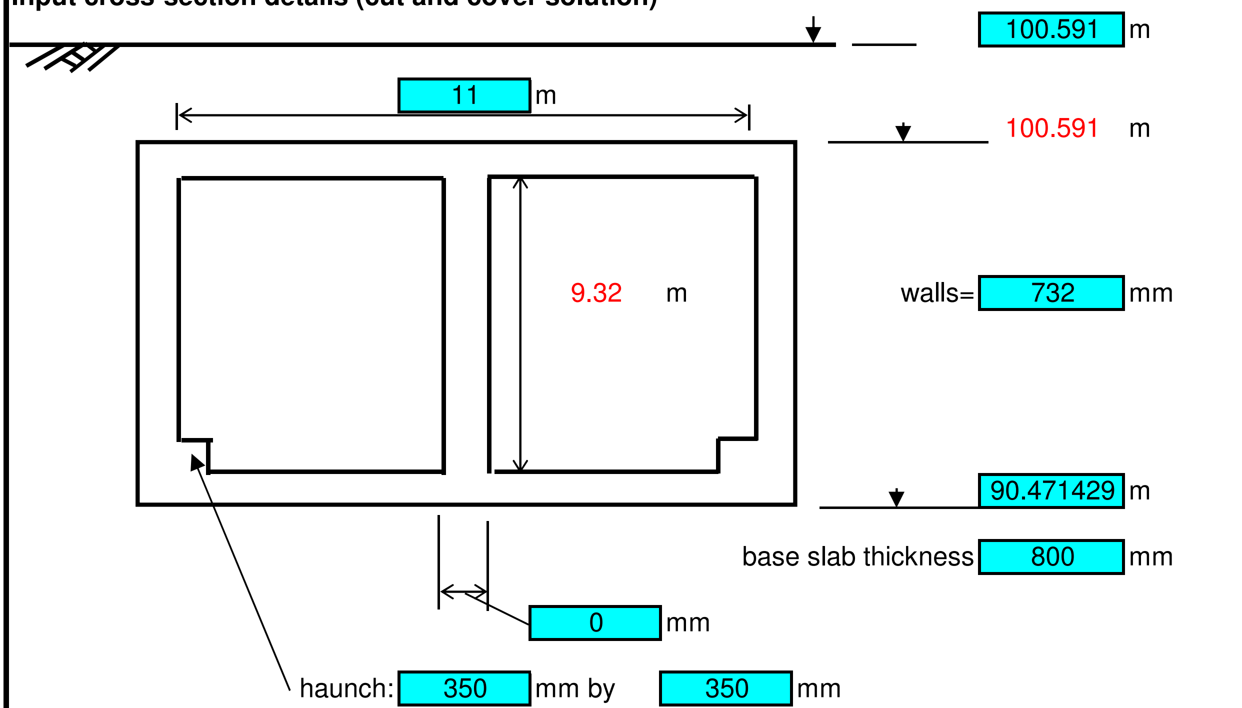
Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	876738
0	% profit = $	0
	Subtotal 3 = $	876738
25	% contingency = $	219184.4324
	Total Cost = $	**1,095,922**

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 32.85714 m **Section 5**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	4144.5	m3
concrete=	783.9938	m3
rebar=	94.1	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	612.4571	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	665.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	409.5314	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	4144.5	60	248667.4834
concrete	m3	783.9938	220.0	172478.6297
rebar	tonnes	94.1	1600	150526.8041
formwork/falsework	m2	612.4571	241.0468	147630.8164
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	665.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	409.5314	51.65288	21153.4775
			Total	740457.2112

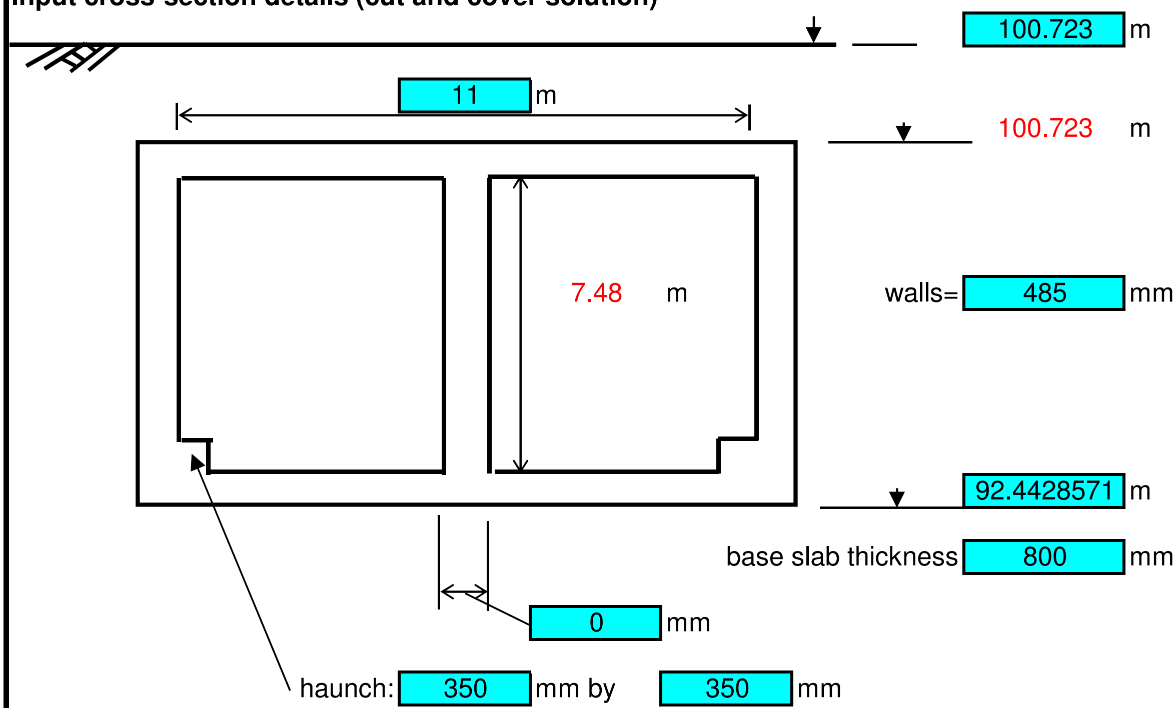
Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	740457
0	% profit = $	0
	Subtotal 3 = $	740457
25	% contingency = $	185114.3028
	Total Cost = $	**925,572**

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 32.85714 m **Section** **6**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	3256.5	m3
concrete=	561.0883	m3
rebar=	67.3	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	491.5429	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	544.1	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	393.3	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	3256.5	60	195391.44
concrete	m3	561.0883	220.0	123439.4229
rebar	tonnes	67.3	1600	107728.9509
formwork/falsework	m2	491.5429	241.0468	118484.8183
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	544.1	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	393.3	51.65288	20315.07747
			Total	565359.7095

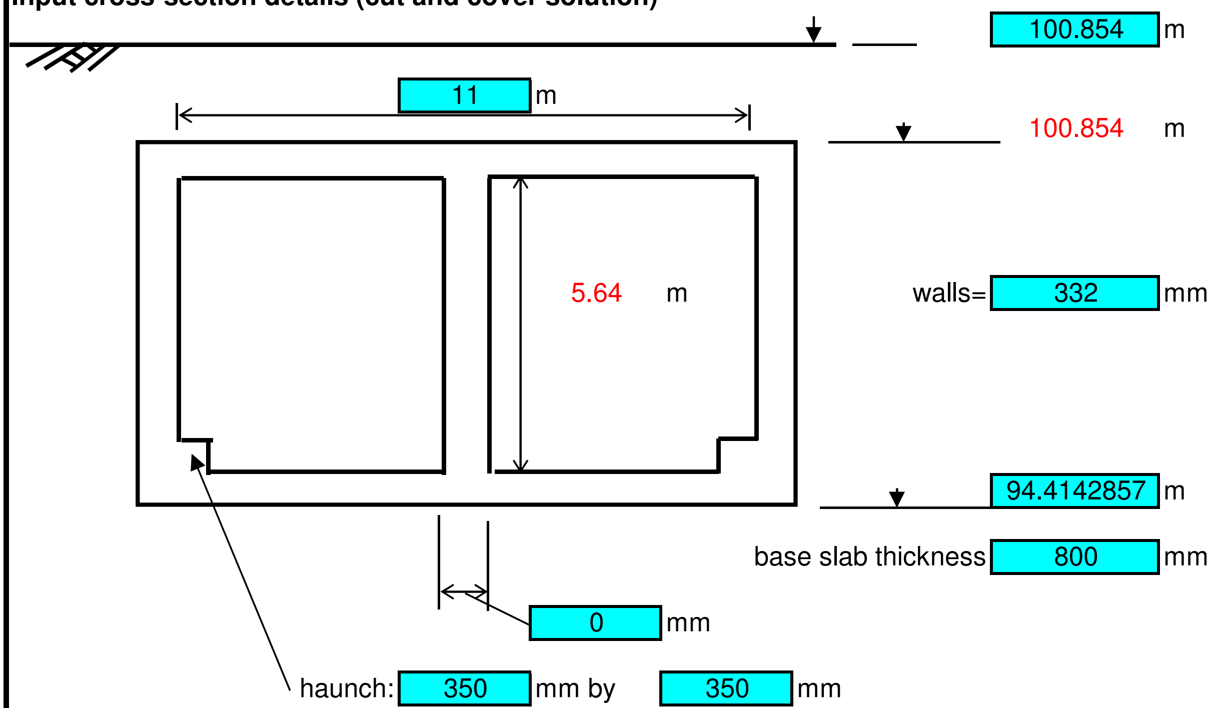
Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	565360
0	% profit = $	0
	Subtotal 3 = $	565360
25	% contingency = $	141339.9274
	Total Cost = $	**706,700**

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 31-Oct-17
North Approach | **Calculations by:** 0
Bored Highway Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 32.85714 m | **Section 7**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	2468.1	m3	
concrete=	437.6953	m3	
rebar=	52.5	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	370.6286	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	423.2	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	383.2457	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	2468.1	60	148086.144
concrete	m3	437.6953	220.0	96292.95657
rebar	tonnes	52.5	1600	84037.48937
formwork/falsework	m2	370.6286	241.0468	89338.82024
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	423.2	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	383.2457	51.65288	19795.74467
			Total	437551.1548

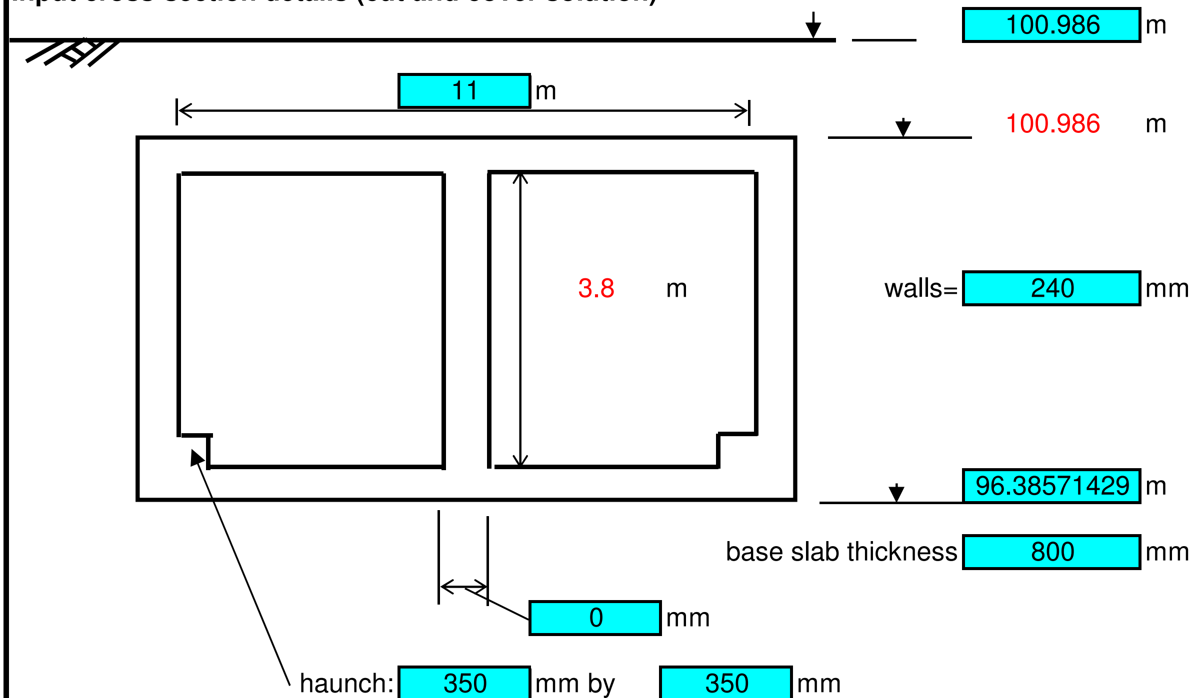
Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	437551
0	% profit = $	0
	Subtotal 3 = $	437551
25	% contingency = $	109387.7887
	Total Cost = $	**546,939**

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 32.85714 m **Section** 8

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1735.1	m3	
concrete=	369.7414	m3	
rebar=	44.4	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	249.7143	m2	
SP&L<=4.6m deep	302.3	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	377.2	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1735.1	60	104107.2
concrete	m3	369.7414	220.0	81343.11429
rebar	tonnes	44.4	1600	70990.35429
formwork/falsework	m2	249.7143	241.0468	60192.82214
SP&L<=4.6m deep	m2	302.3	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	377.2	51.65288	19483.46612
			Total	336116.9568

Indirect costs, profit, and contingency

0 % indirect costs = $ 0

Subtotal 2 = $ 336117

0 % profit = $ 0

Subtotal 3 = $ 336117

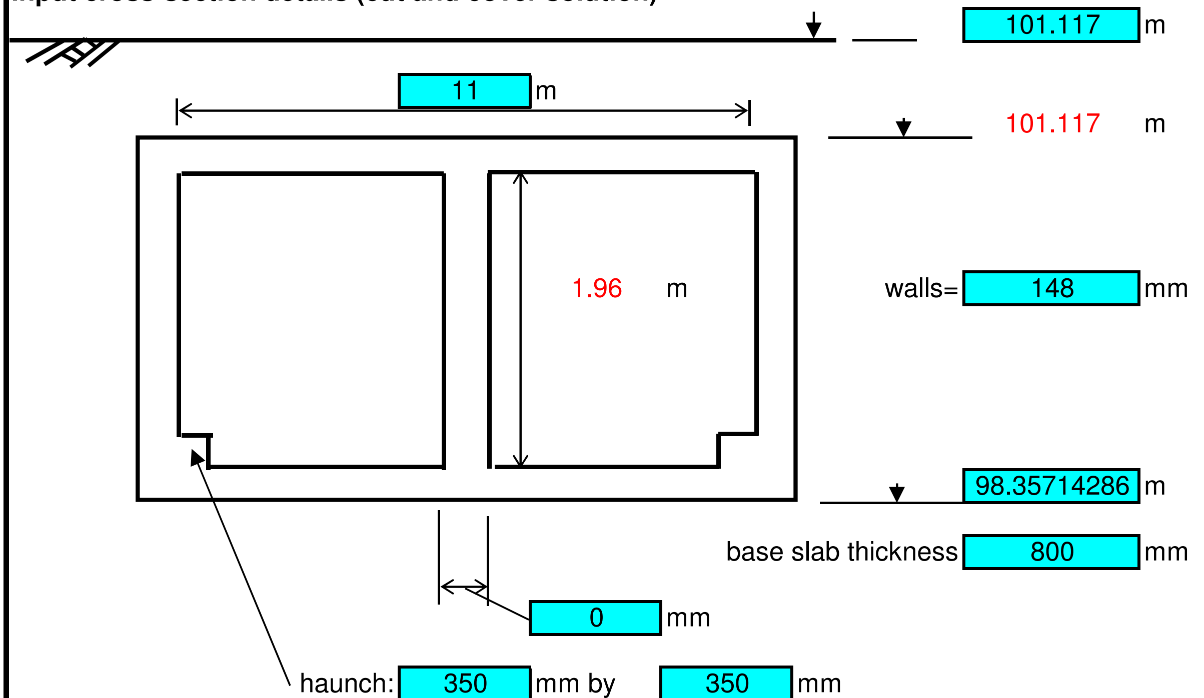
25 % contingency = $ 84029.23921

Total Cost = $ 420,146

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 31-Oct-17
North Approach | **Calculations by:** 0
Bored Highway Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 32.85714 m | **Section** 9

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1024.4	m3	
concrete=	324.0358	m3	
rebar=	38.9	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	128.8	m2	
SP&L<=4.6m deep	181.4	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	371.1543	m2	

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1024.4	60	61463.14971
concrete	m3	324.0358	220.0	71287.88229
rebar	tonnes	38.9	1600	62214.87909
formwork/falsework	m2	128.8	241.0468	31046.82405
SP&L<=4.6m deep	m2	181.4	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	371.1543	51.65288	19171.18756
			Total	245183.9227

Indirect costs, profit, and contingency

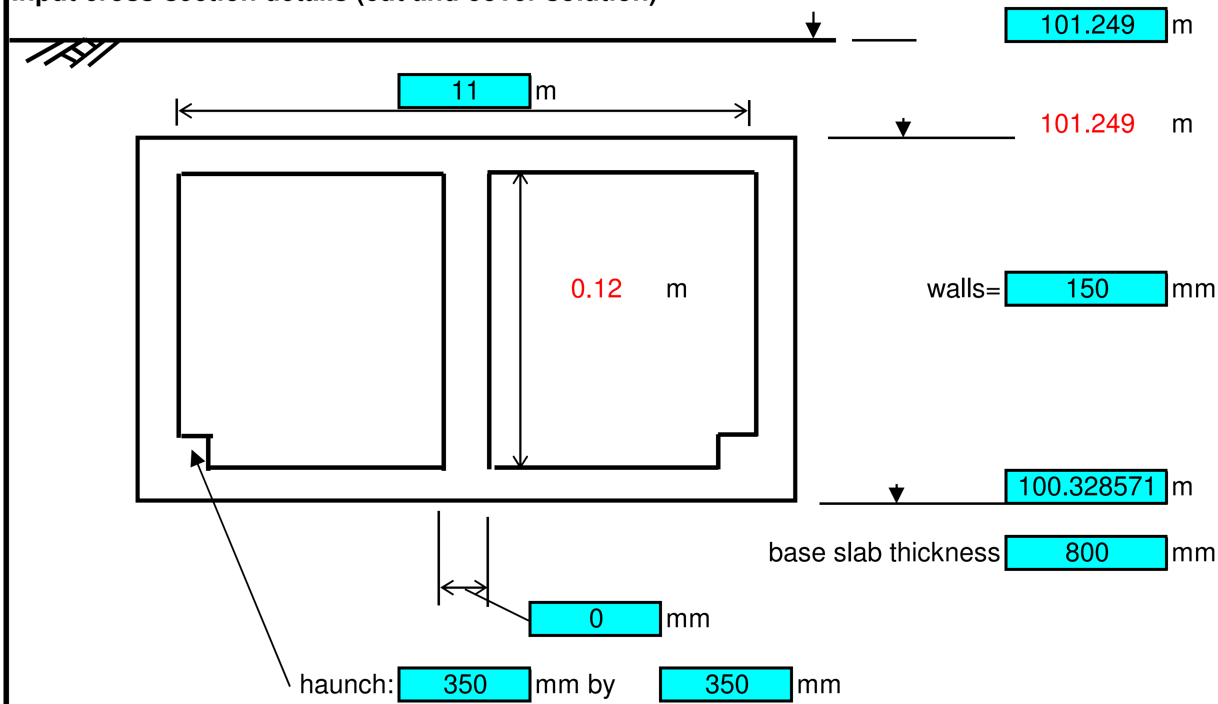
0	% indirect costs = $	0
	Subtotal 2 = $	245184
0	% profit = $	0
	Subtotal 3 = $	245184
25	% contingency = $	61295.98068
	Total Cost = $	**306,480**

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 31-Oct-17
North Approach | **Calculations by:** 0
Bored Highway Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 32.85714 m

Section 10

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	341.6	m3	
concrete=	306.2614	m3	
rebar=	36.8	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	7.885714	m2	
SP&L<=4.6m deep	60.5	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	371.2857	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	341.6	60	20494.97143
concrete	m3	306.2614	220.0	67377.51429
rebar	tonnes	36.8	1600	58802.19429
formwork/falsework	m2	7.885714	241.0468	1900.825962
SP&L<=4.6m deep	m2	60.5	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	68.87051	0
surface reinstatement	m2	371.2857	51.65288	19177.97623
			Total	167753.4822

Indirect costs, profit, and contingency

0 % indirect costs = $ 0

Subtotal 2 = $ 167753

0 % profit = $ 0

Subtotal 3 = $ 167753

25 % contingency = $ 41938.37055

Total Cost = $ 209,692

Newfoundland Fixed Link Pre-feasibility Study **Date:** 31-Oct-17
North Approach **Calculations by:** 0
Bored Highway Tunnel

Summary of Costs

Markup for adjacent 0 %

Section		Cost
1	$	1,275,410.0
2	$	1,154,997.9
3	$	991,442.7
4	$	876,737.7
5	$	740,457.2
6	$	565,359.7
7	$	437,551.2
8	$	336,117.0
9	$	245,183.9
10	$	167,753.5
Sub-total	**$**	**5,604,405**

Initialisation

Project: Newfoundland Fixed Link Pre-feasibility Study
Section: South Approach
Option: Bored Highway Tunnel

Date: 1-Nov-17

Calculations by:

Surface gradient	0.55	%	+ sloping same way as track/road - sloping against track/road
Track/Road Gradient	6	%	
Ground elevation at portal	100	m	
Bottom of slab elevation at portal	81.6	m	
Total length=	338	m	
Total Cost=$	7.0	M	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

UNIT RATES

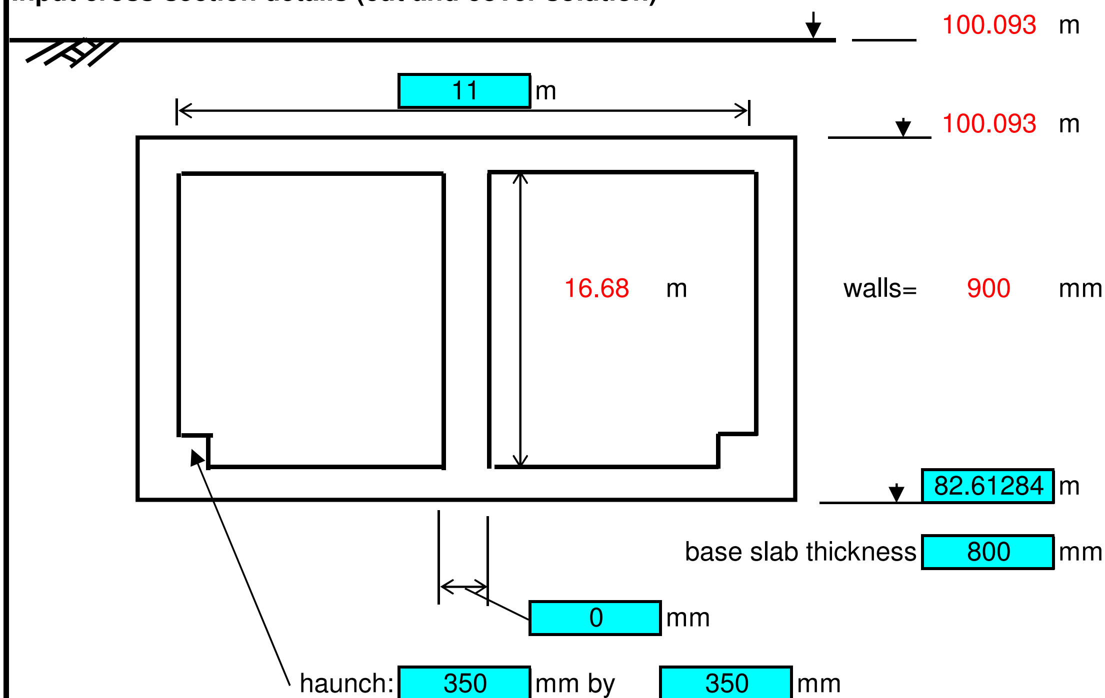
Materials

Item	unit	Rate
excavation	m3	60
concrete	m3	220
rebar	tonnes	1600
formwork/falsework	m2	241
SP&L<=4.6m deep	m2	0
4.6<SP&L<=6.7m deep	m2	0
6.7<SP&L<=10.6m deep	m2	0
10.6<SP&L<=13.7m deep	m2	0
13.7<SP&L<=16.8m deep	m2	0
16.8<SP&L<=20.0m deep	m2	0
20<SP&L<=25m deep	m2	0
backfill + compact	m3	69
surface reinstatement	m2	52

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 33.8 m **Section** **1**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	7553.9	m3	
concrete=	1367.643	m3	
rebar=	164.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1126.283	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	1180.3	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	432.1468	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

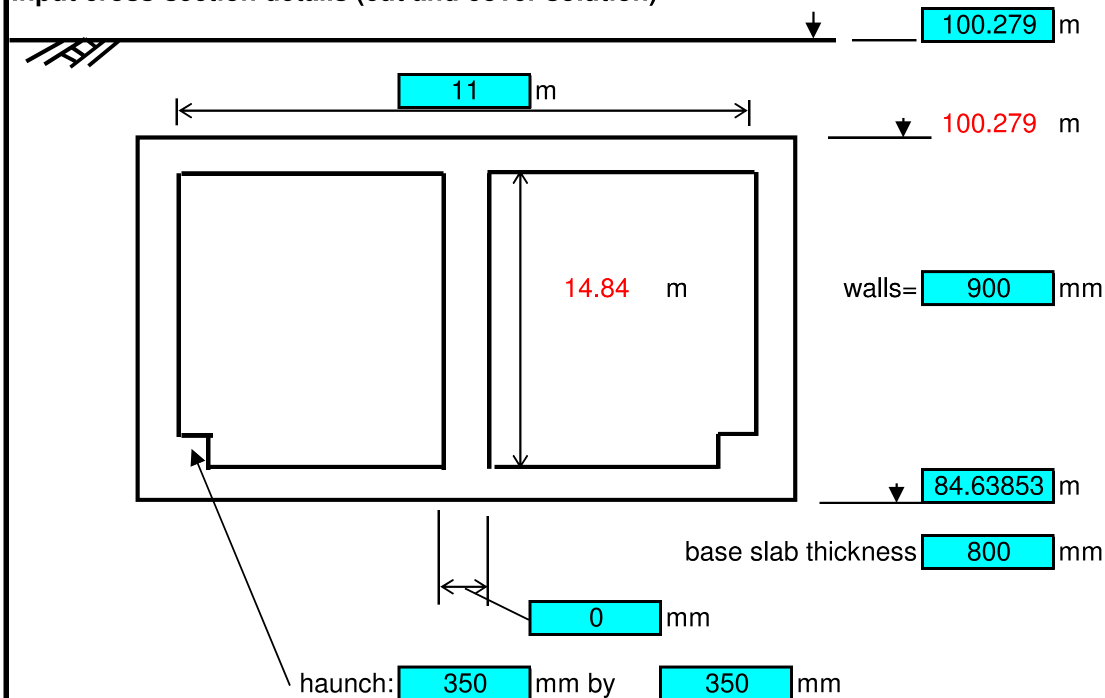
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	7553.9	60	453235.6
concrete	m3	1367.643	220.0	300881.5
rebar	tonnes	164.1	1600	262587.5
formwork/falsework	m2	1126.283	241	271434.1
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	1180.3	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	432.1468	52	22471.63
			Total	1310610

Section Cut and Cover

Length of section: 34 m **Section** 2

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	6758.8	m3
concrete=	1255.825	m3
rebar=	150.7	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	1002.04	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	1056.1	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	432.1468	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

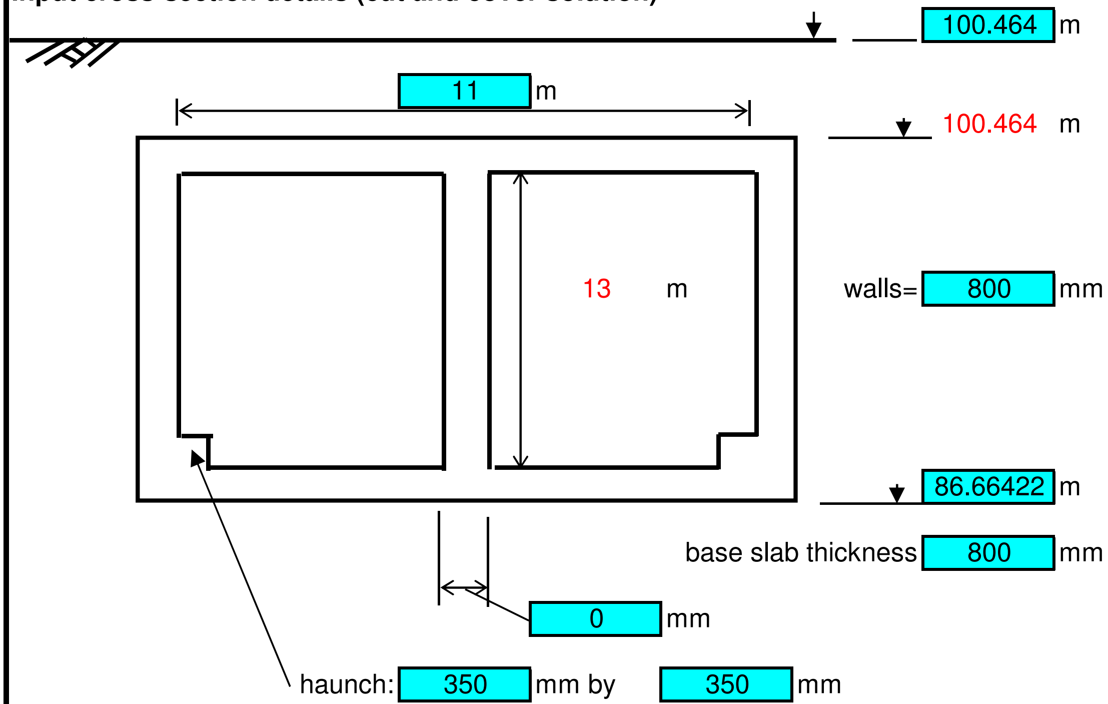
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	6758.8	60	405526.5
concrete	m3	1255.825	220.0	276281.6
rebar	tonnes	150.7	1600	241118.5
formwork/falsework	m2	1002.04	241	241491.7
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	1056.1	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	432.1468	52	22471.63
			Total	1186890

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 34 m **Section 3**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	5870.4	m3	
concrete=	1050.826	m3	
rebar=	126.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	877.7982	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	931.8	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	425.3945	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

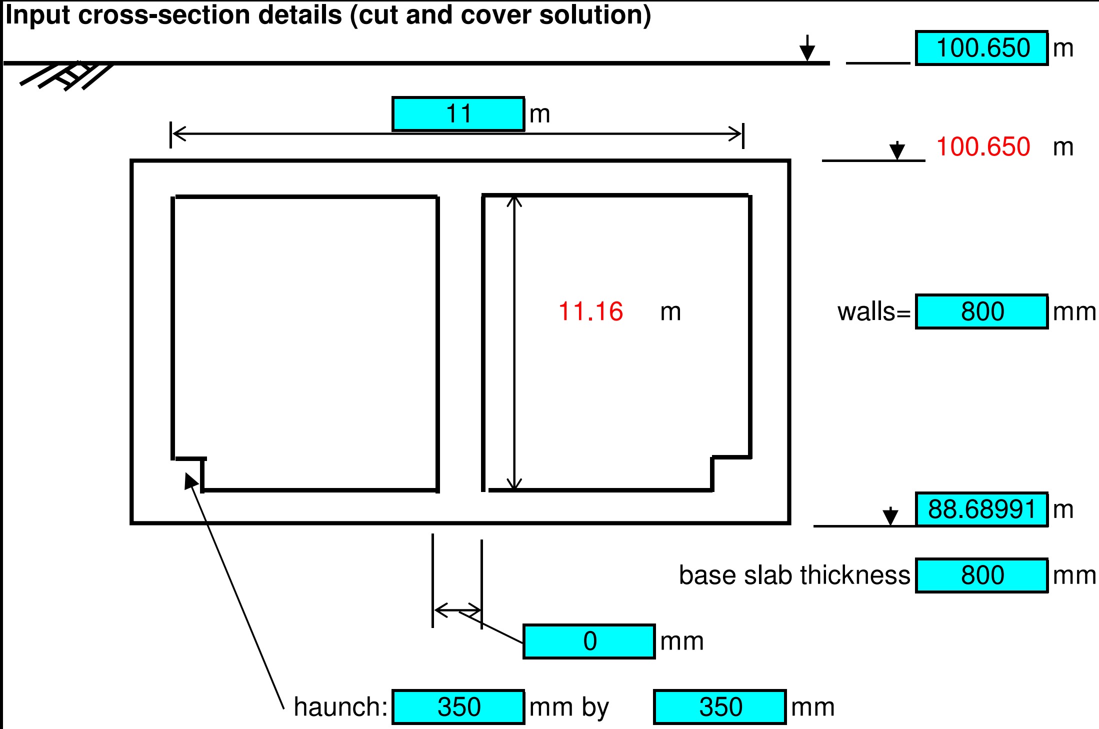
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	5870.4	60	352226.6
concrete	m3	1050.826	220.0	231181.7
rebar	tonnes	126.1	1600	201758.5
formwork/falsework	m2	877.7982	241	211549.4
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	931.8	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	425.3945	52	22120.51
			Total	1018837

Newfoundland Fixed Link Pre-feasibility Study — **Date:** 1-Nov-17
South Approach — **Calculations by:** 0
Bored Highway Tunnel — **Page 1 of 2**

Section Cut and Cover
Length of section: 33.76147 m — **Section 4**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	5087.7	m3
concrete=	951.4319	m3
rebar=	114.2	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	753.556	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	807.6	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	425.3945	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

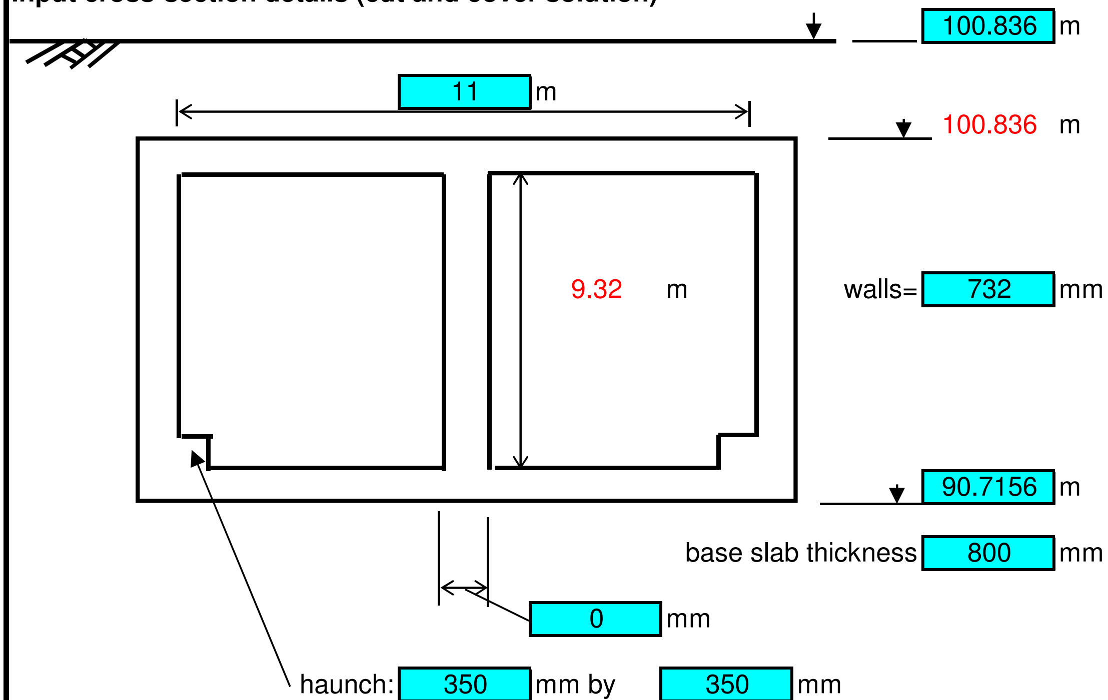
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	5087.7	60	305263.1
concrete	m3	951.4319	220.0	209315
rebar	tonnes	114.2	1600	182674.9
formwork/falsework	m2	753.556	241	181607
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	807.6	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	425.3945	52	22120.51
			Total	900980.5

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 33.76147 m **Section** 5

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	4258.5	m3	
concrete=	805.5716	m3	
rebar=	96.7	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	629.3138	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	683.3	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	420.8029	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

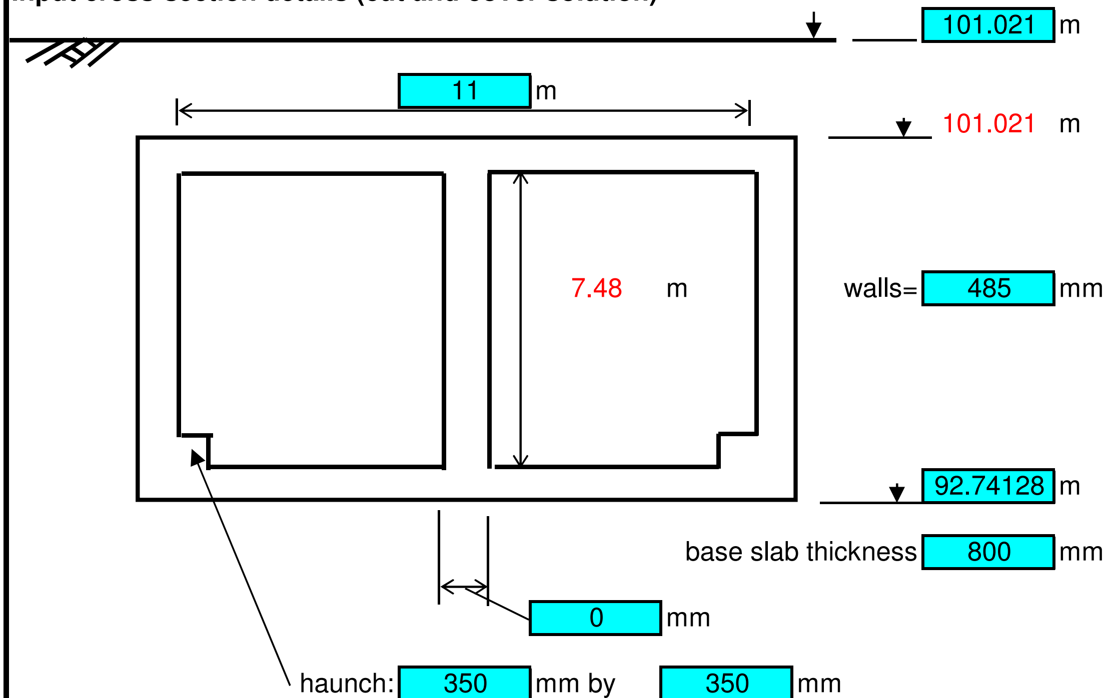
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	4258.5	60	255511.5
concrete	m3	805.5716	220.0	177225.7
rebar	tonnes	96.7	1600	154669.7
formwork/falsework	m2	629.3138	241	151664.6
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	683.3	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	420.8029	52	21881.75
			Total	760953.4

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel |

Section Cut and Cover
Length of section: 33.76147 m | **Section** 6

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	3346.2	m3
concrete=	576.5311	m3
rebar=	69.2	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	505.0716	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	559.1	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	404.1248	m2

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel

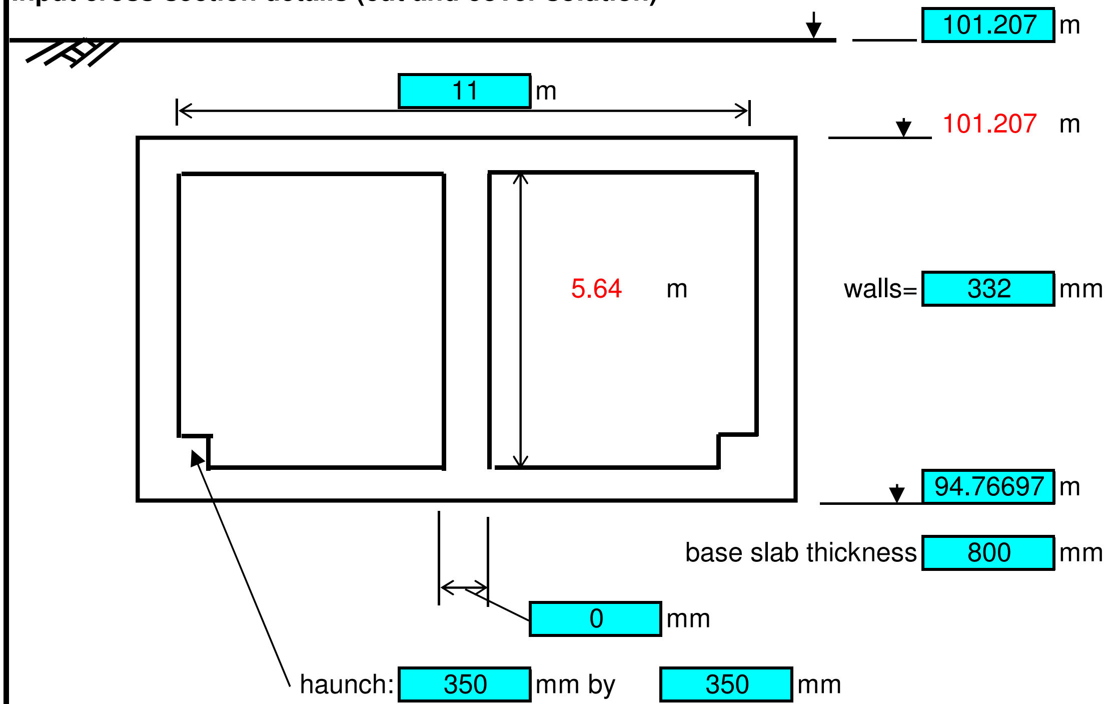
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	3346.2	60	200769.2
concrete	m3	576.5311	220.0	126836.8
rebar	tonnes	69.2	1600	110694
formwork/falsework	m2	505.0716	241	121722.2
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	559.1	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	404.1248	52	21014.49
			Total	581036.7

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 33.76147 m | **Section 7**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	2536.0	m3
concrete=	449.7419	m3
rebar=	54.0	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	380.8294	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	434.8	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	393.7938	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

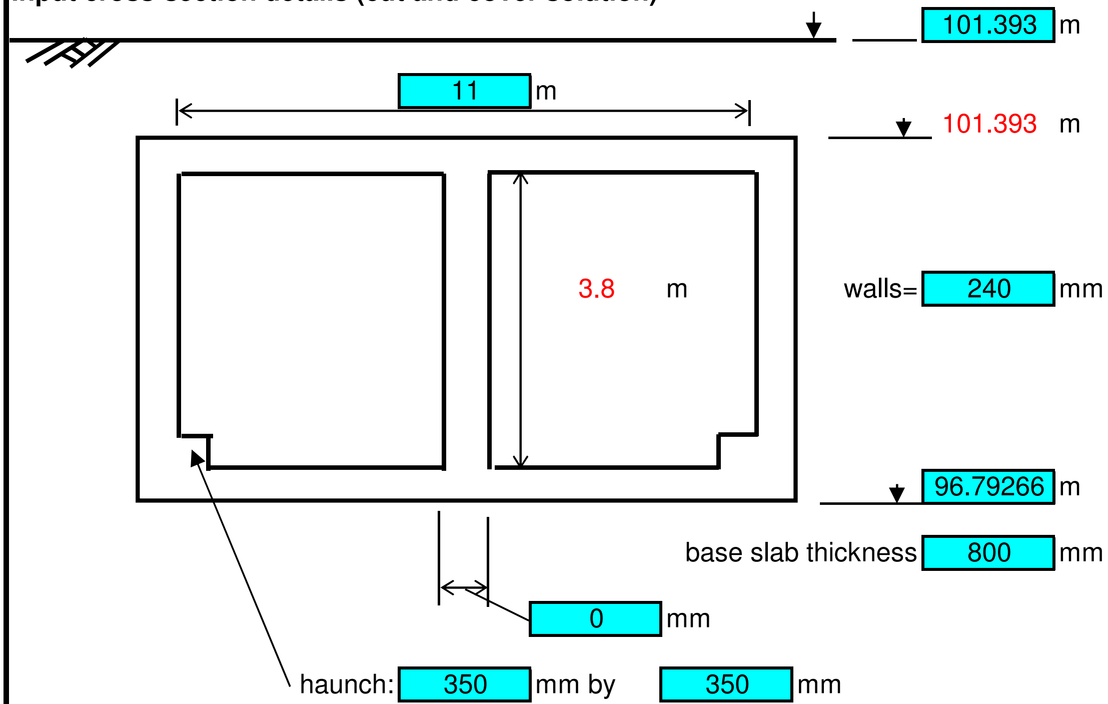
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	2536.0	60	152161.9
concrete	m3	449.7419	220.0	98943.22
rebar	tonnes	54.0	1600	86350.45
formwork/falsework	m2	380.8294	241	91779.88
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	434.8	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	393.7938	52	20477.28
			Total	449712.7

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

Section Cut and Cover
Length of section: 33.76147 m **Section** 8

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1782.9	m3
concrete=	379.9178	m3
rebar=	45.6	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	256.5872	m2
SP&L<=4.6m deep	310.6	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	387.5817	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

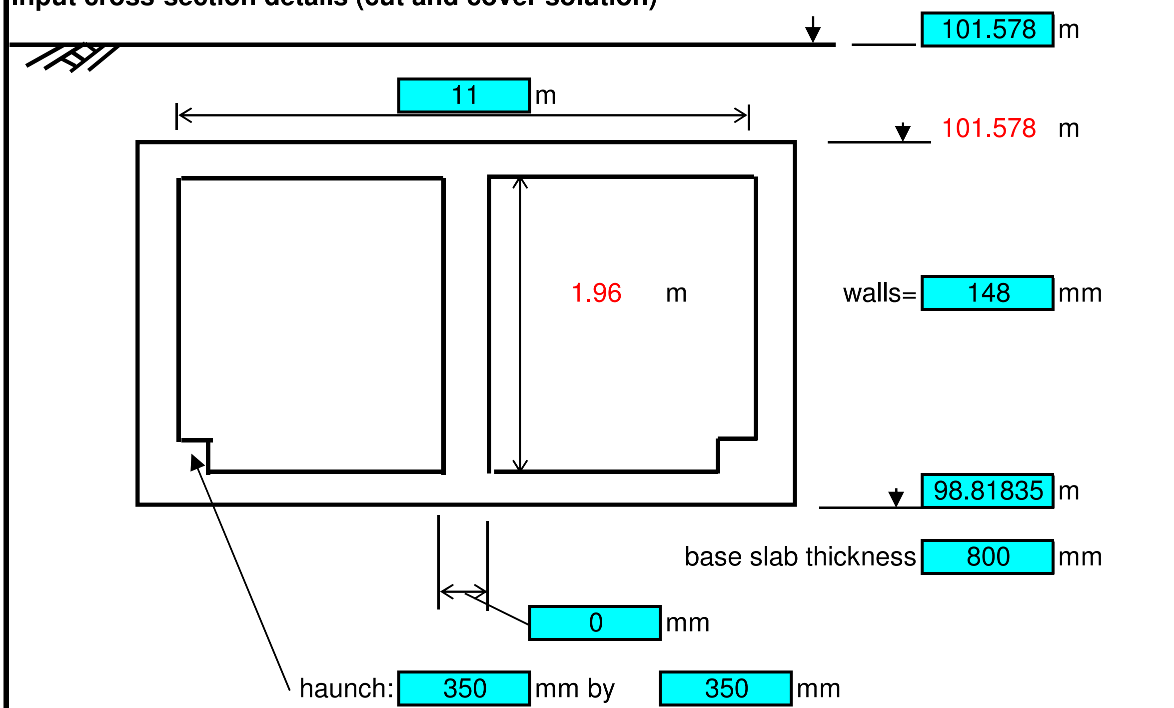
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1782.9	60	106972.5
concrete	m3	379.9178	220.0	83581.92
rebar	tonnes	45.6	1600	72944.22
formwork/falsework	m2	256.5872	241	61837.5
SP&L<=4.6m deep	m2	310.6	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	387.5817	52	20154.25
			Total	345490.4

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel |

Section Cut and Cover
Length of section: 33.76147 m **Section** 9

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1052.6	m3	
concrete=	332.9542	m3	
rebar=	40.0	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	132.345	m2	
SP&L<=4.6m deep	186.4	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	381.3695	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

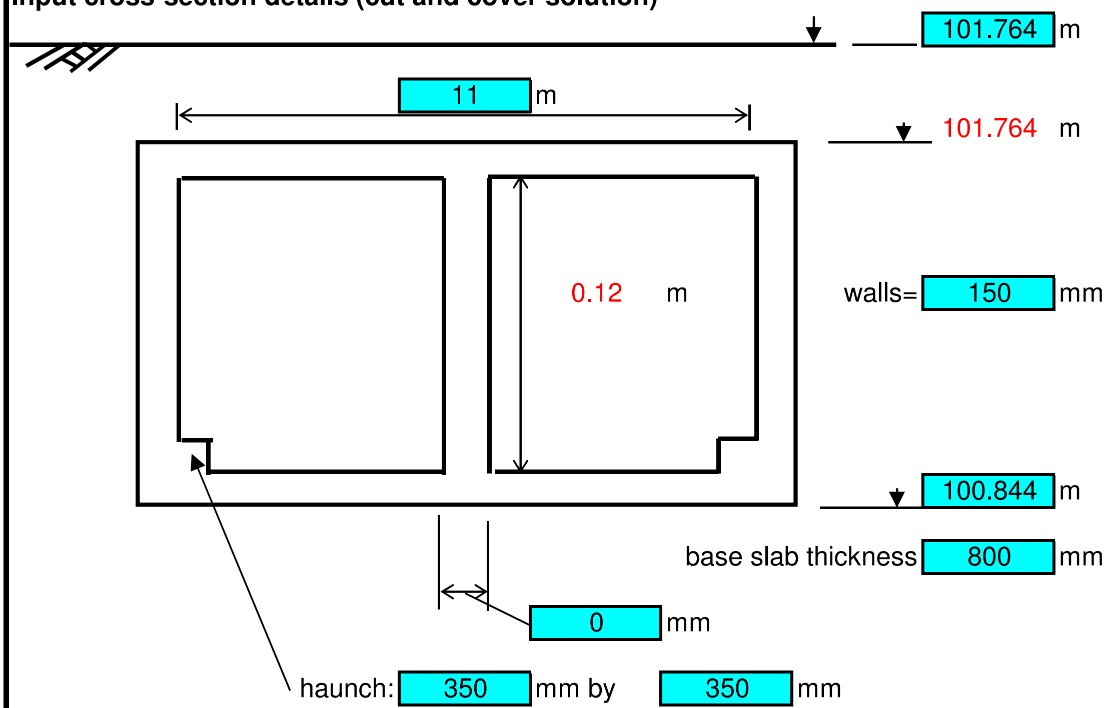
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1052.6	60	63154.8
concrete	m3	332.9542	220.0	73249.93
rebar	tonnes	40.0	1600	63927.22
formwork/falsework	m2	132.345	241	31895.13
SP&L<=4.6m deep	m2	186.4	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	381.3695	52	19831.22
			Total	252058.3

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 1-Nov-17
South Approach | **Calculations by:** 0
Bored Highway Tunnel |

Section Cut and Cover
Length of section: 33.76147 m **Section** 10

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	351.0	m3
concrete=	314.6906	m3
rebar=	37.8	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	8.102752	m2
SP&L<=4.6m deep	62.1	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	381.5046	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	351.0	60	21059.05
concrete	m3	314.6906	220.0	69231.94
rebar	tonnes	37.8	1600	60420.6
formwork/falsework	m2	8.102752	241	1952.763
SP&L<=4.6m deep	m2	62.1	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	381.5046	52	19838.24
			Total	172502.6

Newfoundland Fixed Link Pre-feasibility Study **Date:** 1-Nov-17
South Approach **Calculations by:** 0
Bored Highway Tunnel

Summary of Costs

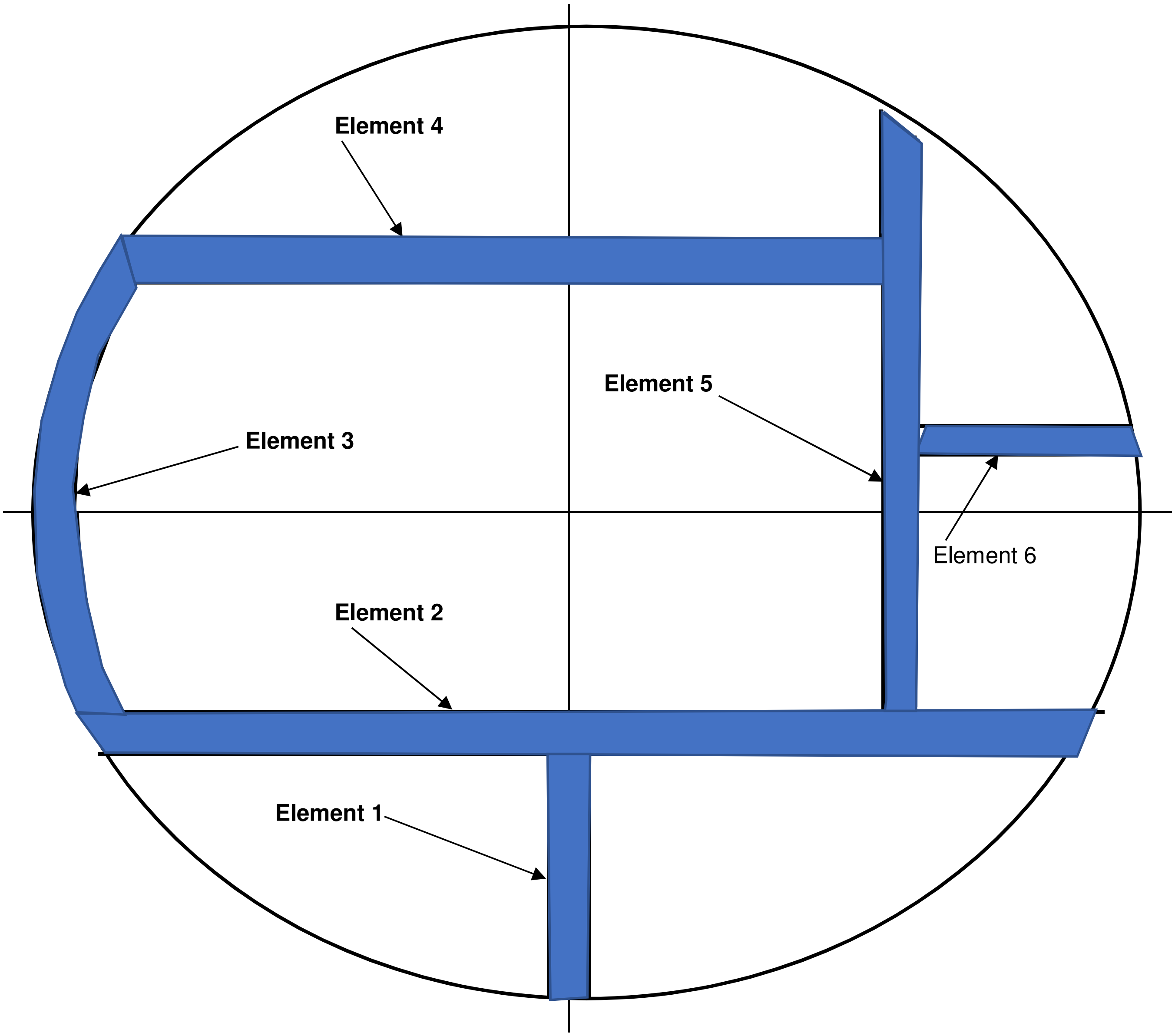
Markup for adjacent 0 %

Section		Cost
1	$	1,310,610.3
2	$	1,186,889.9
3	$	1,018,836.7
4	$	900,980.5
5	$	760,953.4
6	$	581,036.7
7	$	449,712.7
8	$	345,490.4
9	$	252,058.3
10	$	172,502.6
Sub-total	**$**	**6,979,072**

Newfoundland Fixed Link Pre-feasibility Study
Cost Estimating
Single Lane Bored Highway Tunnel
Tunnel Structural Finishes

Date: October 31, 2017
Calculation by:

Tunnel length= 21000 m



Assumed tunnel cross section

Newfoundland Fixed Link Pre-feasibility Study
Cost Estimating
Single Lane Bored Highway Tunnel
Tunnel Structural Finishes

Date: Oct. 31, 2017
Calculation by:

Quantity Take-off

Concrete

Element	Nr.	L(m)	b(m)	d(m)	Concrete Qty(m3)		Rebar Qty(m3)	
1	1	21000	0.5	2.5	26,250		3,150	
2	1	21000	9.4	0.5	98,700		11,844	
3	1	21000	0.3	4.8	30,240		3,629	
4	1	21000	7.5	0.5	78,750		9,450	
5	1	21000	0.3	6.6	41,580		4,990	
6	1	21000	2.1	0.3	13,230		1,588	
					288,750	m3	22,806	t

Formwork/falsework

Element	Nr.	L(m)	d(m)	Faces	Area(m2)	
1	1	21000	2.5	2	105000	
2	2	21000	8.5	1	178500	
3	1	21000	4.8	1	100800	
4	2	21000	7	1	147000	
5	2	21000	6.6	2	277200	
6	1	21000	2.1	1	44100	
					852600	m2

Rates

Concrete	m3	220
Formwork	m2	180
Reinforcement	t	1600

Costs

Concrete	m3	288,750	m3	at	220	=	63,525,000
Formwork	m2	852,600	m2	at	180	=	153,468,000
Reinforcement	t	22,806	t	at	1600	=	36,489,600
						$	**253,482,600**

877.8618182

Main Electrical Components for Novaroute
Single TBM Bored Highway Tunnel Option

Length of each tunnel= 21000 m   Number of tunnels= 1
Tunnel width= 11 m

Item	Component	Unit	Qty	Unit Cost	Total Cost
	Lighting				
	Threshold + transition (1st 700m)	m2	7280	315	2,293,200
	Interior (balance)	m2	223300	120.00	26,796,000
				Lighting subtotal	0
	Substations, generators, UPS				
	Substations	Ea	2	1337000	2,674,000
	Emergency generator	Ea	1	955000	955,000
	UPS (Battery system)	Ea	1	573000	573,000
				Substations, generators, UPS subtotal	4,202,000
	CCTV system				
	Cameras (every 60m)	Each	350	3100	1,085,000
	Control station	Each	1	30000	30,000
				CCTV system subtotal	1,115,000
	Provide power for gas detection, ventilation etc.				
	Power provision	m	21000	45	945,000
				Power subtotal	945,000
	Lane control system				
	Fibre optic display (every 200m)	Each	105	12500	0
				Lane control system subtotal	0

Total Electrical $	**6,262,000**

Prorating for Newfoundland - assuming *50% for single lane tunnel

for 21,000 m length of tunnel

732	m of threshold lighting costs $	661,231.22	1,260	lights
20,268	m of interior lighting costs $	1,812,524.13	3,445	lights
21,000	m of nightime circuit costs $	1,717,488.39	241	lights
4,946	lights cost $	353,702.33	to instal	
21,000	m of conduit costs	1,374,145.03		
		5,919,091.09	* 0.5	= $ **2,959,546**

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - North Vent Adit
Tunnel Final Liner Cost Estimate

Tunnel length=	600	m
Liner cross section area=	5.47	m2

Shift pattern

Shifts	Hours	Days
3	8	5

Advance rate=	30	m/day
Rebar ratio=	0.12	t/m3 of concrete
Concrete supply=$	190	/m3
Rebar supply=$	1200	/t
Initial form set-up time=	4	weeks

Durations

Number of days=	40	days
Number of hours=	960	hours
Number of weeks=	8	weeks

Labour

Crew size	15	
Average labour rate $	76	/hour

Total labour cost=$ 1,094,400

Equipment

Form $	1500000	
Weekly cost of other equipment $	25000	(see TED 2370)

Total equipment cost=$ 1,700,000

Materials

Concrete=	3279.8227	m3
Rebar=	393.57873	

Concrete cost=$	623,166
Rebar cost=$	472,294

Total material cost=$ 1,095,461

Cost Summary

Labour	1,094,400
Equipment	1,700,000
Materials	1,095,461
Total	**3,889,861**

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - North Vent Adit
Tunnel Drill and Blast Cost Estimate

Drill & blast excavation @	$	250	/m3
Tunnel length=	600	m	
Tunnel excavated diameter=	6.5	m	
Excavated volume=	19909.8	m3	
Excavation cost=$	4,977,461		

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - North Vent Adit Shaft
Tunnel Drill and Blast Cost Estimate

shaft excavated diameter=	5.5	m
depth=	100	m
shaft final diameter=	6.1	m

From graph

unlined shaft cost=$	17000	/m

Quantities

Concrete Base=	24	m3
Shotcrete=	173	m3
Rockbolts=	1728	m2
final cast in place liner=	547	m3

Direct Costs

				$ - Cost	
shaft excavation etc.	100	*	17000	1700000	
Concrete Base	24	*	150	3564	
Shotcrete	173	*	500	86394	
Rockbolts	1728	*	10	17279	
liner	547	*	600	327982	(includes steel & forms)
			Total Direct Cost=	**2135219**	

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel
TBM Bored Option - North Vent Adit

D&B Excavation	4,977,461
Liner	3,889,861
Shaft	2,135,219
	11,002,540

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - South Vent Adit
Tunnel Final Liner Cost Estimate

Tunnel length= 2000 m
Liner cross section area= 5.47 m2

Shift pattern

Shifts	Hours	Days
3	8	5

Advance rate= 30 m/day

Rebar ratio= 0.12 t/m3 of concrete

Concrete supply=$ 190 /m3

Rebar supply=$ 1200 /t

Initial form set-up time= 4 weeks

Durations

Number of days= 87 days
Number of hours= 2080 hours
Number of weeks= 17 weeks

Labour

Crew size 15
Average labour rate $ 76 /hour

Total labour cost=$ 2,371,200

Equipment

Form $ 1500000
Weekly cost of other equipment $ 25000 (see TED 2370)

Total equipment cost=$ 1,933,333

Materials

Concrete= 10932.742 m3
Rebar= 1311.9291

Concrete cost=$ 2,077,221
Rebar cost=$ 1,574,315

Total material cost=$ 3,651,536

Cost Summary

Labour	2,371,200
Equipment	1,933,333
Materials	3,651,536
Total	**7,956,069**

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - South Vent Adit
Tunnel Drill and Blast Cost Estimate

Drill & blast excavation @	$	250	/m3
Tunnel length=	2000	m	
Tunnel excavated diameter=	6.5	m	
Excavated volume=	66366.1	m3	
Excavation cost=$	16,591,536		

Newfoundland Fixed Link Pre-feasibility Study
Highway Tunnel - South Vent Adit Shaft
Tunnel Drill and Blast Cost Estimate

shaft excavated diameter=	5.5	m
depth=	0	m
shaft final diameter=	6.1	m

From graph

unlined shaft cost=$ 17000 /m

Quantities

Concrete Base=	24	m3
Shotcrete=	0	m3
Rockbolts=	0	m2
final cast in place liner=	0	m3

Direct Costs

				$ - Cost	
shaft excavation etc.	0	*	17000	0	
Concrete Base	24	*	150	3564	
Shotcrete	0	*	500	0	
Rockbolts	0	*	10	0	
liner	0	*	600	0	(includes steel & forms)
			Total Direct Cost=	**3564**	

Newfoundland Fixed Link Pre-feasibility Study
TBM Bored Highway Tunnel
TBM Bored Option - South Vent Adit

D&B Excavation	16,591,536
Liner	7,956,069
Shaft	3,564
	24,551,169

Newfoundland Fixed Link Pre-feasibility Study
Tunnel Drainage
Bored Highway Tunnel
Drainage Costs

Calculation by:
Date: Nov.1, 2017

Sump Sizing

Assume inflow to tunnel of 1 litres/m2/24hours

Tunnel length= 21000 m
Tunnel diameter= 11 m

24 hour inflow= 1995697 litres = 1996 m3
assume same again for firefighting= 1996 m3

Required sump capacity= 3991 m3

Assumed sump diameter= 6 m
Assumed number of sump structures= 2 m

Required length of each sump= 71 m

Piping

Assume 300 mm diameter steel pipe connecting each sump to the portal areas
Number of pipes= 1
Assume sumps located at 1/3 and 2/3 of tunnel length

Total length of piping= 14300 m

Rates

Sump construction-$	17795	/m of sump	
Pipe-$	400	/m of pipe	
Pipe installation labour -$	36	/m of pipe	(assume 6 person crew installing 100m/day)
Pipe installation equipment-$	20	/m of pipe	(assume $1000/day for equipment)
Pumps-$	125000	/pump	

Costs

Item	Unit	Qty	Rate	$-Cost
Sump construction	m	142	17795	2,526,890
Pipe	m	14300	400	5,720,000
Pipe installation	m	14300	36	521,664
Equipment	m	14300	20	286,000
Pumps	Nr	4	125000	500,000
			Total	**9,554,554**

Newfoundland Fixed Link Pre-feasibility Study
North Vehicle Holding Area

Area= 300 m by 600 m

Earthworks

Assume 0.5 m depth cleared over entire area

Spoil excavation and removal @ $ 30 /m3

Earthworks= 2,700,000

Surface

Assume surface @ 20 /m2

Surface= 3,600,000

Buildings etc.

Public facilities building @	80000	See CJT estimate
Site maintenance building @	220000	See CJT estimate
Fire engines @	360000	See CJT estimate

Total cost 6,960,000

Newfoundland Fixed Link Pre-feasibility Study
South Vehicle Holding Area

Area= 300 m by 600 m

Earthworks

Assume 0 m depth cleared over entire area

Spoil excavation and removal @ $ 30 /m3

Earthworks= 0

Surface

Assume surface @ 20 /m2

Surface= 3,600,000

Buildings etc.

Public facilities building @	80000	See CJT estimate
Site maintenance building @	220000	See CJT estimate
Fire engines @	360000	See CJT estimate

Total cost **4,260,000**

Appendix C1-2
Road Tunnel - Single-Bore, 2 TBMs
Construction Costs

Newfoundland Fixed Link Pre-feasibility - 2 TBM 2 sides Single Bored Highway Tunnel - Cost Summary		
BORED TUNNEL CONSTRUCTION COSTS		
ITEM	**UNIT**	**MAIN TUNNEL**
MOBILIZATION & DEMOBILIZATION	LS	**8,000,000**
TUNNELLING	LS	**646,428,999**
TUNNEL FINISHES	LS	**253,482,600**
NORTH APPROACH STRUCTURES	LS	**5,604,405**
SOUTH APPROACH STRUCTURES	LS	**6,979,072**
NORTH VENTILATION ADIT	LS	**11,002,540**
SOUTH VENTILATION ADIT	LS	**24,551,169**
ROAD FINISHES	LS	**4,304,750**
NORTH VEHICLE HOLDING AREA	LS	**6,960,000**
SOUTH VEHICLE HOLDING AREA	LS	**4,260,000**
TUNNEL DRAINAGE	LS	**9,554,554**
UTILITY DIVERSIONS	LS	**1,000,000**
MONITORING	LS	**1,000,000**
SUBTOTAL CIVIL		**$983,128,090**
CIVIL CONTINGENCIES		
CONTINGENCY	40%	$393,251,236
TOTAL CIVIL		**$1,376,379,326**
M&E AND FINISHING WORK		
VENTILATION EQUIPMENT	LS	$6,000,000
VENTILATION BUILDINGS x 2	LS	$2,000,000
FIRE SUPPRESSION SYSTEM	LS	$4,000,000
CONTROL CENTRE	LS	$4,000,000
SIGNALLING	LS	$0
LIGHTING	LS	$2,959,546
CCTV SYSTEM	LS	$1,115,000
GAS DETECTION	LS	$945,000
SUBSTATION, GENERATORS, UPS	LS	$4,202,000
SUBTOTAL M&E AND FINISHING		**$25,221,546**
CONTINGENCIES	20%	$5,044,309
TOTAL M&E AND FINISHING		**$30,265,855**
TOTAL CIVIL, M&E AND FINISHING		**$1,406,645,180**
ALLOWANCES		
CONTRACTOR OH	15%	$210,996,777
CONTRACTOR PROFIT	15%	$210,996,777
CONSTRUCTION TOTAL		**$1,828,638,734**
PRE-CONSTRUCTION AND SUPERVISION		
FEASIBILITY STUDY	LS	$17,000,000
ENVIRONMENTAL ASSESSMENT	LS	$6,000,000
DESIGN	5%	$91,431,937
CONSTRUCTION MANAGEMENT	10%	$182,863,873
OWNERS COSTS	2%	$36,572,775
PRE-CONSTRUCTION TOTAL		$333,868,585
GRAND TOTAL		**$2,162,507,319**

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	2TBM Set-up	**Parent Estimate ID:**	7801
Tunnel Name:	HWYTunnel 2TBMs Bore	**Project Phase:**	Conceptual
Construction Activity:	Erect TBM Only	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 02, 2017
Estimate Definition ID:	7807	**Tunnel Characteristics ID:**	3394

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 4.5 Weeks

Total Number of Shifts 94.5

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	756.00	2.00	135,384
Tunnel miner	76.06	$/hr	756.00	4.00	230,005
Shaft bottom	75.29	$/hr	756.00	6.00	341,515
Tunnel fitter	69.92	$/hr	756.00	2.00	105,719
Tunnel electrician	84.43	$/hr	756.00	2.00	127,658
Shaft top	75.29	$/hr	756.00	2.00	113,838
Crane operator	77.86	$/hr	756.00	4.00	235,449
Surface laborer	75.22	$/hr	756.00	2.00	113,733
Equipment laborer	72.88	$/hr	756.00	2.00	110,195
				26.00	$1,513,497
Equipment					
Loco	8,000.00	$/wk	4.50	2.00	72,000
Muck cars & grout cars	2,900.00	$/wk	4.50	12.00	156,600
Flat cars	480.00	$/wk	4.50	4.00	8,640
Transformers & switchgear - LV	1,100.00	$/wk	4.50	2.00	9,900
Small tools	2,600.00	$/wk	4.50	2.00	23,400
Shaft crane	13,900.00	$/wk	4.50	2.00	125,100
Erection crane	10,000.00	$/wk	4.50	2.00	90,000
Compressors	1,500.00	$/wk	4.50	2.00	13,500
Generators	3,100.00	$/wk	4.50	2.00	27,900
Transformers & switchgear - HV	8,000.00	$/wk	4.50	2.00	72,000
Loaders	3,550.00	$/wk	4.50	2.00	31,950
					$630,990
Materials					
Temporary materials	3,000.00	$/wk	4.50	2.00	27,000

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Thrust frame	7,000.00	$/wk	4.50	2.00	63,000
					$90,000
			Total Estimated Cost:		$2,234,487

HATCH

Tunnel Estimating Database

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	2 TBM HWY Tunnel	**Parent Estimate ID:**	7800
Tunnel Name:	HWYTunnel 2TBMs Bore	**Project Phase:**	Conceptual
Construction Activity:	TBM Tunneling	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 02, 2017
Estimate Definition ID:	7806	**Tunnel Characteristics ID:**	3394

Tunnel Characteristics

Tunnel Length:	10,500	m
Finished Diameter:	11	m
Initial Support Type:	Precast segmental	
Initial Support Thickness:	0	m
Final Lining Thickness:	0.45	m
Grout Thickness:	0.125	m

Theoretical Excavation Volumes

Total Neat Excavation:	1,217,395	Cubic Metres
Initial Lining Volume:	0	Cubic Metres
Final Lining Volume:	169,964	Cubic Metres
Theoretical Grout Volume:	49,583	Cubic Metres

Normal Excavation/Support Cycle

Excavation Cycle Length:	1.5	Metres
Excavate:	28	Minutes
Erect Support:	36	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	64	Minutes

Difficult Excavation/Support Cycle

Length of Difficult Excavation:	700	Metres
Excavate:	92	Minutes
Erect Support:	74	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	166	Minutes

Reduction Factors

Machine availability:	80	%
Back up efficiency:	55	%
Planned maintenance:	5	%
Learning curve efficiency:	40	%
Learning curve duration time:	8	Weeks

Learning Curve Rate:	5.6	m/day
Experienced Advance Rate:	14.1	m/day
Difficult Advance Rate:	5.4	m/day

TBM Skidding Through Excavation

Duration of skidding:	0	Weeks
Length of skidding:	0	Metres

Advance Rate and Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Drive Advance per Shift:	4.08	Metres
Avg. Drive Advance per Day:	12	Metres
Avg. Drive Advance per Week:	86	Metres
Duration of Tunneling (Incl. Skid):	122.42	Weeks
Total number of shifts (Incl. Skid):	2,571	

	Metres	Days
Learning Curve Drive:	316	56
Experienced Drive:	9,484	672
Difficult Drive:	700	129
Skidding Portion:	0	0

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Pit boss	89.54	$/hr	20,571.00	1.00	1,841,927
	Working foreperson	89.54	$/hr	20,571.00	2.00	3,683,855
	Tunnel miner	76.06	$/hr	20,571.00	3.00	4,693,891
	Tunnel laborer	75.39	$/hr	20,571.00	4.00	6,203,391
	Loco driver	75.64	$/hr	20,571.00	4.00	6,223,962
	Shaft bottom	75.29	$/hr	20,571.00	1.00	1,548,791
	TBM operator	76.06	$/hr	20,571.00	1.00	1,564,630
	Tunnel fitter	69.92	$/hr	20,571.00	1.00	1,438,324
	Tunnel electrician	84.43	$/hr	20,571.00	1.00	1,736,810
	Shaft top	75.29	$/hr	20,571.00	2.00	3,097,581
	Crane operator	77.86	$/hr	20,571.00	1.00	1,601,658
	Surface laborer	75.22	$/hr	20,571.00	4.00	6,189,402
	Equipment laborer	72.88	$/hr	20,571.00	4.00	5,996,858
					29.00	$45,821,080
Equipment						
	TBM	340,000.00	$/m2	115.94	1.00	39,419,600
	TBM optional equipment.	1,500,000.00	$/Nr	1.00	1.00	1,500,000
	Loco	8,000.00	$/wk	122.42	4.00	3,917,440
	Muck cars & grout cars	2,900.00	$/wk	122.42	56.00	19,881,008
	Flat cars	480.00	$/wk	122.42	8.00	470,093
	Person riders	480.00	$/wk	122.42	2.00	117,523
	Track	200.00	$/m	10,500.00	1.00	2,100,000
	Air pipe	46.00	$/m	10,500.00	1.00	483,000
	Water pipe	40.00	$/m	10,500.00	1.00	420,000
	Pump main	78.00	$/m	10,500.00	1.00	819,000
	Cabling	125.00	$/m	10,500.00	1.00	1,312,500
	Lighting	46.00	$/m	10,500.00	1.00	483,000
	Vent ducting	46.00	$/m	10,500.00	1.00	483,000
	Grout mixers	10,960.00	$/wk	122.42	1.00	1,341,723
	Grout pumps	5,250.00	$/wk	122.42	1.00	642,705
	Grout hoses & pipes	300.00	$/wk	122.42	2.00	73,452
	Transformers & switchgear - LV	1,100.00	$/wk	122.42	2.00	269,324
	Small tools	4,000.00	$/wk	122.42	1.00	489,680
	Shaft crane	13,900.00	$/wk	122.42	1.00	1,701,638
	Compressors	1,500.00	$/wk	122.42	1.00	183,630
	Low pressure C/A system	5,900.00	$/wk	122.42	1.00	722,278
	Pipework and controls	1,000.00	$/wk	122.42	2.00	244,840
	Generators	3,100.00	$/wk	122.42	1.00	379,502
	Transformers & switchgear - HV	8,000.00	$/wk	122.42	1.00	979,360
	Surface fans	1,200.00	$/wk	122.42	2.00	293,808
	Loaders	3,550.00	$/wk	122.42	2.00	869,182
	Other surface plant	4,000.00	$/wk	122.42	1.00	489,680

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Tunnel C/A system	62,000.00	$/wk	122.42	1.00	7,590,040
					$87,677,006
Consumables					
Electrical power	0.15	$/kwh	20,571.00	3,000.00	9,256,950
Gas oil	1.20	$/L	48,000.00	1.00	57,600
Lubrication materials	140.00	$/wk	122.42	1.00	17,139
TBM spares, cutters	390.00	$/m	10,500.00	1.00	4,095,000
Filters etc.	465.00	$/wk	122.42	1.00	56,925
Hydraulic oil	7.00	$/L	32,000.00	1.00	224,000
Other consumables	200.00	$/wk	122.42	1.00	24,484
Tail seal grease	200.00	$/m	10,500.00	1.00	2,100,000
					$15,832,098
Materials					
Concrete lining rings	15,661.94	$/Nr	7,000.00	1.00	109,633,597
Gaskets	170.00	$/m	10,500.00	1.00	1,785,000
Bolts	20.00	$/Nr	883.00	30.00	529,800
Grout	220.00	$/m3	49,583.00	1.00	10,908,260
Grout plugs	0.80	$/Nr	883.00	7.00	4,945
Packers	15.00	$/Nr	1,817.00	12.00	327,060
Temporary materials	3,000.00	$/wk	122.42	1.00	367,260
					$123,555,922
Subcontracts					
Soil disposal	25.00	$/m3	1,217,395.00	1.50	45,652,313
					$45,652,313

Total Estimated Cost:	$318,538,418
Total Estimated Cost per Metre:	$30,337
Total Estimated Cost per Week:	$2,601,936
Total Estimated Cost per Shift:	$123,878

Tunnel Estimating Database

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	2TBM Maintenance	**Parent Estimate ID:**	7802
Tunnel Name:	HWYTunnel 2TBMs Bore	**Project Phase:**	Conceptual
Construction Activity:	TBM Maintenance	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 02, 2017
Estimate Definition ID:	7808	**Tunnel Characteristics ID:**	3394

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 1 - 6 hour shifts x 1 days per week

Duration of Activity 122 Weeks

Total Number of Shifts 122

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Working foreperson	89.54	$/hr	732.00	2.00	131,087
	Loco driver	75.64	$/hr	732.00	2.00	110,737
	Shaft bottom	75.29	$/hr	732.00	2.00	110,225
	TBM operator	76.06	$/hr	732.00	2.00	111,352
	Tunnel fitter	69.92	$/hr	732.00	2.00	102,363
	Tunnel electrician	84.43	$/hr	732.00	2.00	123,606
	Shaft top	75.29	$/hr	732.00	2.00	110,225
	Surface laborer	75.22	$/hr	732.00	2.00	110,122
					16.00	$909,715
Consumables						
	Electrical power	0.15	$/kwh	732.00	600.00	65,880
						$65,880
Materials						
	Temporary materials	500.00	$/wk	122.00	2.00	122,000
						$122,000

Total Estimated Cost: $1,097,595

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	2TBM Removal	**Parent Estimate ID:**	7803
Tunnel Name:	HWYTunnel 2TBMs Bore	**Project Phase:**	Conceptual
Construction Activity:	TBM Removal	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 02, 2017
Estimate Definition ID:	7809	**Tunnel Characteristics ID:**	3394

Tunnel Characteristics

Finished Diameter: 11 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 3 Weeks

Total Number of Shifts 63

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	504.00	2.00	90,256
Tunnel miner	76.06	$/hr	504.00	6.00	230,005
Shaft bottom	75.29	$/hr	504.00	4.00	151,785
Tunnel fitter	69.92	$/hr	504.00	2.00	70,479
Tunnel electrician	84.43	$/hr	504.00	2.00	85,105
Shaft top	75.29	$/hr	504.00	4.00	151,785
Crane operator	77.86	$/hr	504.00	4.00	156,966
Surface laborer	75.22	$/hr	504.00	4.00	151,644
Equipment laborer	72.88	$/hr	504.00	2.00	73,463
				30.00	$1,161,488
Equipment					
Loco	8,000.00	$/wk	3.00	2.00	48,000
Muck cars & grout cars	2,900.00	$/wk	3.00	12.00	104,400
Flat cars	480.00	$/wk	3.00	8.00	11,520
Person riders	480.00	$/wk	3.00	2.00	2,880
Booster fans	1,500.00	$/wk	3.00	2.00	9,000
Transformers & switchgear - LV	1,100.00	$/wk	3.00	2.00	6,600
Other plant	2,200.00	$/wk	3.00	2.00	13,200
Hoists operator	3,000.00	$/wk	3.00	2.00	18,000
Shaft crane	13,900.00	$/wk	3.00	2.00	83,400
50T Crane	7,000.00	$/wk	3.00	2.00	42,000
TBM Crane	20,000.00	$/wk	3.00	2.00	120,000
Compressors	1,500.00	$/wk	3.00	2.00	9,000
Transformers & switchgear - HV	8,000.00	$/wk	3.00	2.00	48,000
Surface fans	1,200.00	$/wk	3.00	2.00	7,200
					$523,200

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Consumables					
Gas oil	1.20	$/L	15.00	2,000.00	36,000
Other consumables	500.00	$/wk	3.00	2.00	3,000
					$39,000
Materials					
Temporary materials	800.00	$/wk	3.00	2.00	4,800
					$4,800
General Supplies					
Small tools	700.00	$/wk	3.00	2.00	4,200
					$4,200

Total Estimated Cost: $1,732,688

Appendix C1-3
Road Tunnel - Twin-Bore
Construction Costs

Newfoundland Fixed Link Pre-feasibility - Twin TBM Bored Highway Tunnel - Cost Summary		
BORED TUNNEL CONSTRUCTION COSTS		
ITEM	**UNIT**	**MAIN TUNNEL**
MOBILIZATION & DEMOBILIZATION	LS	**8,000,000**
TUNNELLING	LS	**1,200,612,716**
TUNNEL FINISHES	LS	**506,965,200**
NORTH APPROACH STRUCTURES	LS	**11,208,810**
SOUTH APPROACH STRUCTURES	LS	**13,958,143**
NORTH VENTILATION ADIT	LS	**11,002,540**
SOUTH VENTILATION ADIT	LS	**24,551,169**
ROAD FINISHES	LS	**4,304,750**
NORTH VEHICLE HOLDING AREA	LS	**6,960,000**
SOUTH VEHICLE HOLDING AREA	LS	**4,260,000**
TUNNEL DRAINAGE	LS	**18,472,164**
UTILITY DIVERSIONS	LS	**1,200,000**
MONITORING	LS	**1,200,000**
SUBTOTAL CIVIL		**$1,812,695,493**
CIVIL CONTINGENCIES		
CONTINGENCY	40%	$725,078,197
TOTAL CIVIL		**$2,537,773,690**
M&E AND FINISHING WORK		
VENTILATION EQUIPMENT	LS	$12,000,000
VENTILATION BUILDINGS x 2	LS	$4,000,000
FIRE SUPPRESSION SYSTEM	LS	$8,000,000
CONTROL CENTRE	LS	$8,000,000
SIGNALLING	LS	$0
LIGHTING	LS	$5,571,934
CCTV SYSTEM	LS	$2,230,000
GAS DETECTION	LS	$1,890,000
SUBSTATION, GENERATORS, UPS	LS	$4,202,000
SUBTOTAL M&E AND FINISHING		**$45,893,934**
CONTINGENCIES	20%	$9,178,787
TOTAL M&E AND FINISHING		**$55,072,721**
TOTAL CIVIL, M&E AND FINISHING		**$2,592,846,411**
ALLOWANCES		
CONTRACTOR OH	15%	$388,926,962
CONTRACTOR PROFIT	15%	$388,926,962
CONSTRUCTION TOTAL		**$3,371,000,000**
PRE-CONSTRUCTION AND SUPERVISION		
FEASIBILITY STUDY	LS	$17,000,000
ENVIRONMENTAL ASSESSMENT	LS	$6,000,000
DESIGN	5%	$168,550,000
CONSTRUCTION MANAGEMENT	10%	$337,100,000
OWNERS COSTS	2%	$67,420,000
PRE-CONSTRUCTION TOTAL		$596,070,000
GRAND TOTAL		**$3,967,070,000**

APPENDIX C2

Rail Tunnel

Appendix C2-1
Rail Tunnel - Single-Bore, 1 TBM
Construction Costs

Newfoundland Fixed Link Pre-feasibility - Single Bored -1TBM Railway Tunnel - Cost Summary		
BORED TUNNEL CONSTRUCTION COSTS		
ITEM	**UNIT**	**MAIN TUNNEL**
MOBILIZATION & DEMOBILIZATION	LS	**8,000,000**
TUNNELLING	LS	**565,272,196**
TUNNEL FINISHES	LS	**105,382,800**
NORTH APPROACH STRUCTURES	LS	**9,144,099**
SOUTH APPROACH STRUCTURES	LS	**9,583,984**
RAIL TRACK	LS	**13,923,100**
TUNNEL DRAINAGE	LS	**11,307,454**
UTILITY DIVERSIONS	LS	**1,000,000**
MONITORING	LS	**1,000,000**
SUBTOTAL CIVIL		**$724,613,633**
CIVIL CONTINGENCIES		
CONTINGENCY	40%	$289,845,453
TOTAL CIVIL		**$1,014,459,087**
M&E, ROLLING STOCK, RAIL HARDWARE AND FINISHING WORK		
ROLLING STOCK, TERMINALS, OCS, ETC	LS	$48,773,000
VENTILATION EQUIPMENT	LS	$3,000,000
VENTILATION SHAFTS AND BUILDINGS x 2	LS	$0
FIRE SUPPRESSION SYSTEM	LS	$2,000,000
CONTROL CENTRE	LS	$1,000,000
SIGNALLING	LS	$1,000,000
LIGHTING	LS	$1,000,000
CCTV SYSTEM	LS	$0
GAS DETECTION	LS	$900,000
SUBSTATION, GENERATORS, UPS	LS	$2,000,000
SUBTOTAL M&E AND FINISHING		**$59,673,000**
CONTINGENCIES	20%	$11,934,600
TOTAL M&E AND FINISHING		**$71,607,600**
TOTAL CIVIL, M&E AND FINISHING		**$1,086,066,687**
ALLOWANCES		
CONTRACTOR OH	15%	$162,910,003
CONTRACTOR PROFIT	15%	$162,910,003
CONSTRUCTION TOTAL		**$1,411,886,693**
PRE-CONSTRUCTION AND SUPERVISION		
FEASIBILITY STUDY	LS	$17,000,000
ENVIRONMENTAL ASSESSMENT	LS	$6,000,000
DESIGN	5%	$70,594,335
CONSTRUCTION MANAGEMENT	10%	$141,188,669
OWNERS COSTS	2%	$28,237,734
PRE-CONSTRUCTION TOTAL		$263,020,738
GRAND TOTAL		**$1,674,907,430**

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail-Sgl.Bore Set up	**Parent Estimate ID:**	7801
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	Erect TBM Only	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7811	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Finished Diameter: 7.6 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 4.5 Weeks

Total Number of Shifts 94.5

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	756.00	1.00	67,692
Tunnel miner	76.06	$/hr	756.00	2.00	115,003
Shaft bottom	75.29	$/hr	756.00	3.00	170,758
Tunnel fitter	69.92	$/hr	756.00	1.00	52,860
Tunnel electrician	84.43	$/hr	756.00	1.00	63,829
Shaft top	75.29	$/hr	756.00	1.00	56,919
Crane operator	77.86	$/hr	756.00	2.00	117,724
Surface laborer	75.22	$/hr	756.00	1.00	56,866
Equipment laborer	72.88	$/hr	756.00	1.00	55,097
				13.00	$756,748
Equipment					
Loco	8,000.00	$/wk	4.50	1.00	36,000
Muck cars & grout cars	2,900.00	$/wk	4.50	6.00	78,300
Flat cars	480.00	$/wk	4.50	2.00	4,320
Transformers & switchgear - LV	1,100.00	$/wk	4.50	1.00	4,950
Small tools	2,600.00	$/wk	4.50	1.00	11,700
Shaft crane	13,900.00	$/wk	4.50	1.00	62,550
Erection crane	10,000.00	$/wk	4.50	1.00	45,000
Compressors	1,500.00	$/wk	4.50	1.00	6,750
Generators	3,100.00	$/wk	4.50	1.00	13,950
Transformers & switchgear - HV	8,000.00	$/wk	4.50	1.00	36,000
Loaders	3,550.00	$/wk	4.50	1.00	15,975
					$315,495
Materials					
Temporary materials	3,000.00	$/wk	4.50	1.00	13,500

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Thrust frame	7,000.00	$/wk	4.50	1.00	31,500
					$45,000
			Total Estimated Cost:		$1,117,243

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail-SinglBore Tnl	**Parent Estimate ID:**	7800
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	TBM Tunneling	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7810	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Tunnel Length:	30,000	m
Finished Diameter:	7.6	m
Initial Support Type:	Not Applicable	
Initial Support Thickness:	0	m
Final Lining Thickness:	0.35	m
Grout Thickness:	0.1	m

Theoretical Excavation Volumes

Total Neat Excavation:	1,702,349	Cubic Metres
Initial Lining Volume:	0	Cubic Metres
Final Lining Volume:	262,244	Cubic Metres
Theoretical Grout Volume:	79,168	Cubic Metres

Normal Excavation/Support Cycle

Excavation Cycle Length:	1.5	Metres
Excavate:	24	Minutes
Erect Support:	27	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	51	Minutes

Difficult Excavation/Support Cycle

Length of Difficult Excavation:	1400	Metres
Excavate:	73	Minutes
Erect Support:	54	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	127	Minutes

Reduction Factors

Machine availability:	80	%
Back up efficiency:	55	%
Planned maintenance:	5	%
Learning curve efficiency:	40	%
Learning curve duration time:	8	Weeks

Learning Curve Rate:	7.1	m/day
Experienced Advance Rate:	17.7	m/day
Difficult Advance Rate:	7.1	m/day

TBM Skidding Through Excavation

Duration of skidding:	0	Weeks
Length of skidding:	0	Metres

Advance Rate and Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Drive Advance per Shift:	5.42	Metres
Avg. Drive Advance per Day:	16	Metres
Avg. Drive Advance per Week:	114	Metres
Duration of Tunneling (Incl. Skid):	263.72	Weeks
Total number of shifts (Incl. Skid):	5,539	

	Metres	Days
Learning Curve Drive:	397	56
Experienced Drive:	28,203	1,593
Difficult Drive:	1,400	197
Skidding Portion:	0	0

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Pit boss	89.54	$/hr	44,309.00	1.00	3,967,428
	Working foreperson	89.54	$/hr	44,309.00	2.00	7,934,856
	Tunnel miner	76.06	$/hr	44,309.00	3.00	10,110,428
	Tunnel laborer	75.39	$/hr	44,309.00	4.00	13,361,822
	Loco driver	75.64	$/hr	44,309.00	4.00	13,406,131
	Shaft bottom	75.29	$/hr	44,309.00	1.00	3,336,025
	TBM operator	76.06	$/hr	44,309.00	1.00	3,370,143
	Tunnel fitter	69.92	$/hr	44,309.00	1.00	3,098,085
	Tunnel electrician	84.43	$/hr	44,309.00	1.00	3,741,009
	Shaft top	75.29	$/hr	44,309.00	2.00	6,672,049
	Crane operator	77.86	$/hr	44,309.00	1.00	3,449,899
	Surface laborer	75.22	$/hr	44,309.00	4.00	13,331,692
	Equipment laborer	72.88	$/hr	44,309.00	4.00	12,916,960
					29.00	$98,696,525
Equipment						
	TBM	340,000.00	$/m2	56.74	1.00	19,291,600
	TBM optional equipment.	1,500,000.00	$/Nr	1.00	1.00	1,500,000
	Loco	8,000.00	$/wk	263.72	5.00	10,548,800
	Muck cars & grout cars	2,900.00	$/wk	263.72	56.00	42,828,128
	Flat cars	480.00	$/wk	263.72	8.00	1,012,685
	Person riders	480.00	$/wk	263.72	2.00	253,171
	Track	200.00	$/m	30,000.00	1.00	6,000,000
	Air pipe	46.00	$/m	30,000.00	1.00	1,380,000
	Water pipe	40.00	$/m	30,000.00	1.00	1,200,000
	Pump main	78.00	$/m	30,000.00	1.00	2,340,000
	Cabling	125.00	$/m	30,000.00	1.00	3,750,000
	Lighting	46.00	$/m	30,000.00	1.00	1,380,000
	Vent ducting	46.00	$/m	30,000.00	1.00	1,380,000
	Grout mixers	10,960.00	$/wk	263.72	1.00	2,890,371
	Grout pumps	5,250.00	$/wk	263.72	1.00	1,384,530
	Grout hoses & pipes	300.00	$/wk	263.72	2.00	158,232
	Transformers & switchgear - LV	1,100.00	$/wk	263.72	2.00	580,184
	Small tools	4,000.00	$/wk	263.72	1.00	1,054,880
	Shaft crane	13,900.00	$/wk	263.72	1.00	3,665,708
	Compressors	1,500.00	$/wk	263.72	1.00	395,580
	Low pressure C/A system	5,900.00	$/wk	263.72	1.00	1,555,948
	Pipework and controls	1,000.00	$/wk	263.72	2.00	527,440
	Generators	3,100.00	$/wk	263.72	1.00	817,532
	Transformers & switchgear - HV	8,000.00	$/wk	263.72	1.00	2,109,760
	Surface fans	1,200.00	$/wk	263.72	2.00	632,928
	Loaders	3,550.00	$/wk	263.72	2.00	1,872,412
	Other surface plant	4,000.00	$/wk	263.72	1.00	1,054,880

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Tunnel C/A system	62,000.00	$/wk	263.72	1.00	16,350,640
					$127,915,409

Consumables

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Electrical power	0.15	$/kwh	44,309.00	3,000.00	19,939,050
Gas oil	1.20	$/L	48,000.00	1.00	57,600
Lubrication materials	140.00	$/wk	263.72	1.00	36,921
TBM spares, cutters	390.00	$/m	30,000.00	1.00	11,700,000
Filters etc.	465.00	$/wk	263.72	1.00	122,630
Hydraulic oil	7.00	$/L	32,000.00	1.00	224,000
Other consumables	200.00	$/wk	263.72	1.00	52,744
Tail seal grease	200.00	$/m	30,000.00	1.00	6,000,000
					$38,132,945

Materials

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Concrete lining rings	10,066.82	$/Nr	20,000.00	1.00	201,336,364
Gaskets	170.00	$/m	30,000.00	1.00	5,100,000
Bolts	20.00	$/Nr	1,765.00	30.00	1,059,000
Grout	220.00	$/m3	79,168.00	1.00	17,416,960
Grout plugs	0.80	$/Nr	1,765.00	7.00	9,884
Packers	15.00	$/Nr	3,633.00	12.00	653,940
Temporary materials	3,000.00	$/wk	263.72	1.00	791,160
Other materials	0.00	$/t	0.00	1.00	0
					$226,367,308

Subcontracts

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Soil disposal	25.00	$/m3	1,702,349.00	1.50	63,838,088
					$63,838,088

Total Estimated Cost:	$554,950,274
Total Estimated Cost per Metre:	$18,498
Total Estimated Cost per Week:	$2,104,336
Total Estimated Cost per Shift:	$100,197

Tunnel Estimating Database

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail-SglB.-TBM Maint	**Parent Estimate ID:**	7802
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	TBM Maintenance	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7812	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Finished Diameter: 7.6 m

Activity Details

Shift Arrangement 1 - 6 hour shifts x 1 days per week

Duration of Activity 264 Weeks

Total Number of Shifts 264

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Working foreperson	89.54	$/hr	1,584.00	1.50	212,747
Loco driver	75.64	$/hr	1,584.00	1.50	179,721
Shaft bottom	75.29	$/hr	1,584.00	1.50	178,889
TBM operator	76.06	$/hr	1,584.00	1.50	180,719
Tunnel fitter	69.92	$/hr	1,584.00	1.50	166,130
Tunnel electrician	84.43	$/hr	1,584.00	1.50	200,606
Shaft top	75.29	$/hr	1,584.00	1.50	178,889
Surface laborer	75.22	$/hr	1,584.00	1.50	178,723
				12.00	$1,476,423
Consumables					
Electrical power	0.15	$/kwh	1,584.00	600.00	142,560
Other consumables	0.00	$/wk	264.00	1.00	0
					$142,560
Materials					
Temporary materials	500.00	$/wk	264.00	1.00	132,000
					$132,000

Total Estimated Cost: $1,750,983

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail-SglBoreTnlCl up	**Parent Estimate ID:**	7804
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	Tunnel Clean Up	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7814	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Tunnel Length:	30,000	m	
Finished Diameter:	7.6	m	(Circular Tunnels)
Excavated Cross Section:	0	m2	(Non-circular Tunnels)
Excavated Perimeter:	0	m	(Non-circular Tunnels)

Productivity Cycle

Section Length	30	Metres
Vent Line Removal Time	120	Minutes
Track Removal Time	60	Minutes
Temp Lighting Removal Time	60	Minutes
Clean Up Time	120	Minutes
Total Cycle Time	360	Minutes

Reduction Factors

Learning Curve Efficiency:	50	%
Back Up Efficiency:	80	%
Learning Curve Duration:	1	Weeks

Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Advance per Shift:	31.63	Metres
Avg. Advance per Week:	665	Metres
Total number of hours:	7,588	

Clean Up Productivity Data

	Average Advance		Drive Length		Drive Duration					
Learning Curve Portion:	48.0	m/day	336	Metres	21	Shifts	7	Days	1.00	Weeks
Experienced Drive Portion:	96.0	m/day	29,664	Metres	927	Shifts	309	Days	44.14	Weeks
Total:	94.9	m/day	30,000	Metres	949	Shifts	316	Days	45.14	Weeks

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Tunnel laborer	75.39	$/hr	7,588.00	6.00	3,432,356
Shaft bottom	75.29	$/hr	7,588.00	1.00	571,301
Shaft top	75.29	$/hr	7,588.00	1.00	571,301
Crane operator	77.86	$/hr	7,588.00	1.00	590,802
				9.00	$5,165,759
Equipment					
Transformers & switchgear - LV	1,100.00	$/wk	45.14	1.00	49,654

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Hoists operator	2,600.00	$/wk	45.14	1.00	117,364
Shaft crane	13,900.00	$/wk	45.14	1.00	627,446
Compressors	1,500.00	$/wk	45.14	1.00	67,710
Loaders	3,550.00	$/wk	45.14	1.00	160,247
Other surface plant	3,000.00	$/wk	45.14	1.00	135,420
Bobcat	800.00	$/wk	45.14	1.00	36,112
					$1,193,953

Consumables

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Electrical power	0.15	$/kwh	7,588.00	200.00	227,640
					$227,640

Total Estimated Cost:	$6,587,352
Total Estimated Cost per Metre:	$220
Total Estimated Cost per Week:	$145,922
Total Estimated Cost per Shift:	$6,945

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail-Sgl.B-TBM Remv.	**Parent Estimate ID:**	7803
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	TBM Removal	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7813	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Finished Diameter: 7.6 m

Activity Details

Shift Arrangement 3 - 8 hour shifts x 7 days per week

Duration of Activity 3 Weeks

Total Number of Shifts 63

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor					
Pit boss	89.54	$/hr	504.00	1.00	45,128
Tunnel miner	76.06	$/hr	504.00	3.00	115,003
Shaft bottom	75.29	$/hr	504.00	2.00	75,892
Tunnel fitter	69.92	$/hr	504.00	1.00	35,240
Tunnel electrician	84.43	$/hr	504.00	1.00	42,553
Shaft top	75.29	$/hr	504.00	2.00	75,892
Crane operator	77.86	$/hr	504.00	2.00	78,483
Surface laborer	75.22	$/hr	504.00	2.00	75,822
Equipment laborer	72.88	$/hr	504.00	1.00	36,732
				15.00	$580,744
Equipment					
Loco	8,000.00	$/wk	3.00	1.00	24,000
Muck cars & grout cars	2,900.00	$/wk	3.00	6.00	52,200
Flat cars	480.00	$/wk	3.00	4.00	5,760
Person riders	480.00	$/wk	3.00	1.00	1,440
Booster fans	1,500.00	$/wk	3.00	1.00	4,500
Transformers & switchgear - LV	1,100.00	$/wk	3.00	1.00	3,300
Other plant	2,200.00	$/wk	3.00	1.00	6,600
Hoists operator	3,000.00	$/wk	3.00	1.00	9,000
Shaft crane	13,900.00	$/wk	3.00	1.00	41,700
50T Crane	7,000.00	$/wk	3.00	1.00	21,000
TBM Crane	20,000.00	$/wk	3.00	1.00	60,000
Compressors	1,500.00	$/wk	3.00	1.00	4,500
Transformers & switchgear - HV	8,000.00	$/wk	3.00	1.00	24,000
Surface fans	1,200.00	$/wk	3.00	1.00	3,600
					$261,600

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Consumables					
Gas oil	1.20	$/L	15.00	1,000.00	18,000
Other consumables	500.00	$/wk	3.00	1.00	1,500
					$19,500
Materials					
Temporary materials	800.00	$/wk	3.00	1.00	2,400
					$2,400
General Supplies					
Small tools	700.00	$/wk	3.00	1.00	2,100
					$2,100
			Total Estimated Cost:		$866,344

HATCH — Tunnel Estimating Database

Detailed Cost Estimate Report

Version 2.8

Project:	NFLink	**Project Number:**	213789
Estimate Description:	Rail-SgB-Prec.Lining	**Parent Estimate ID:**	7805
Tunnel Name:	Rail-Single BoreT	**Project Phase:**	Conceptual
Construction Activity:	Precast Linings	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 06, 2017
Estimate Definition ID:	7815	**Tunnel Characteristics ID:**	3395

Tunnel Characteristics

Tunnel Length:	30,000	m
Finished Diameter:	7.6	m
Final Lining Thickness:	0.35	m

Assumptions

A) Duration

	Maximum	Minimum	
TBM Fabrication Time	19	15	Months
TBM Erection Time	3	2	Months
Tunneling Time	50	80	Months
Total	**72**	**97**	Months
Facility Setup Time	6	5	Months
Learning Curve/Shakedown Time	1	1	Months
Concrete Strength Gain Time	1	1	Months
Available Manufacturing Time	**64**	**90**	Months

B) Production

Allowance for Damage	2	%
Ring Length	1.5	m
Number of Rings Required	20,400	
Production Rate Required	56.7	Rings/Week
Actual Production Rate Achieved	60	Rings/Week

Investment on plant, equipment and moulds $5,000,000

Initial Shakedown Time	4	Weeks
Production Time	340.0	Weeks

	Shakedown Crew	Production / QC Crew
Shifts per Day	1	2
Hours per Shift	12	12
Days per Week	5	5

Number of Rings per Truck	1	
Concrete	13.11	m3/ring
Reinforcing Steel	120	kg/m3
Dunnage Assumption	50	% of total required storage

C) Overheads

	$/Month	Months	Cost
Project Manager Rate	7,000	93	651,000
Plant Manager Rate	5,000	91	455,000
Quality Manager Rate	5,000	89	445,000
Secretary Rate	2,000	93	186,000
Office Building Cost			150,000
Office Equipment and Supplies Cost			0
Finance Assume $	1,000,000	93	465,000
Financing @	6 %		
Head Office Support @	1 %		1,788,921

Total Overhead Cost $4,140,921

Profit Margin 10 %

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Shakedown crew	25.00	$/hr	240.00	30.00	180,000
	Production & QC crew	32.00	$/hr	40,800.00	30.00	39,168,000
					60.00	$39,348,000
Consumables						
	Power	0.06	$/kwh	41,040.00	1,020.00	2,511,648
	Heating	0.11	$/m2/wk	344.00	10,600.00	401,104
	Steam curing	0.54	$/m2/wk	344.00	2,000.00	371,520
	Fuel	0.50	$/L	344.00	3,000.00	516,000
	Water	0.05	$/L	267,489.00	100.00	1,337,445
						$5,137,717
Materials						
	Concrete	180.00	$/m3	13.11	20,400.00	48,139,920
	Rebar	1.50	$/kg	1,573.00	20,400.00	48,133,800
	Grout nozzles	3.00	$/Nr	20,400.00	12.00	734,400
	Lifting socket	10.00	$/Nr	20,400.00	12.00	2,448,000
	Bolt inserts	5.00	$/Nr	20,400.00	12.00	1,224,000
	Gaskets	100.00	$/Nr	20,400.00	12.00	24,480,000
	Dunnage	2.50	$/m	18.00	10,200.00	459,000
	Site preparation	10.00	$/m2	12.45	3,400.00	423,300
						$126,042,420

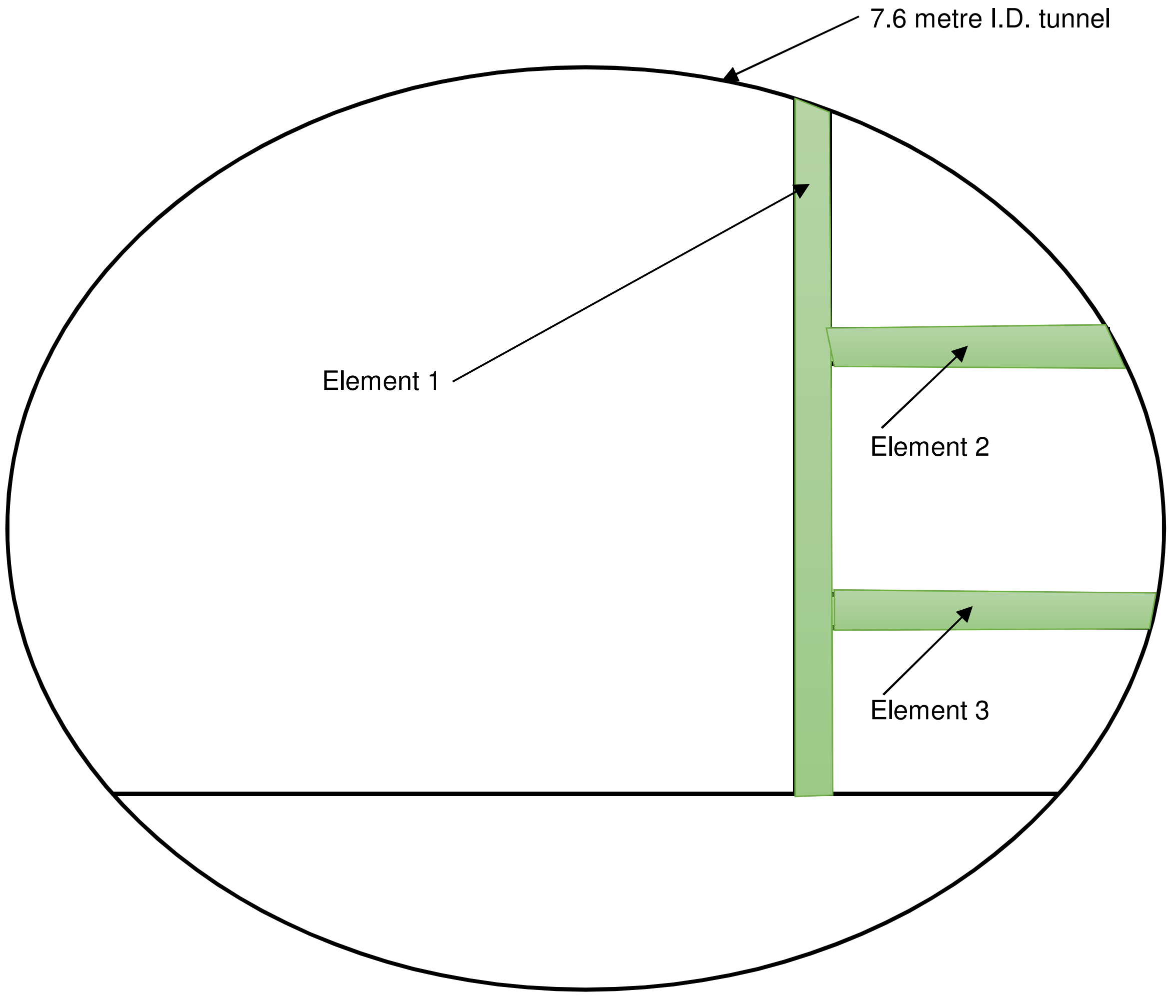
Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Subcontracts					
Delivery	80.00	$/hr	2.00	20,400.00	3,264,000
Testing	100,000.00	$/Nr	1.00	1.00	100,000
					$3,364,000

Subtotal:	$173,892,137
Investment on Plant:	$5,000,000
Total Overhead Cost:	$4,140,921
Subtotal:	$183,033,058
Profit:	$18,303,306
Total Precast Lining Cost:	**$201,336,364**
Total Cost per Cubic Metre:	**$753**
Total Cost per Ring:	**$9,869**

Newfoundland Fixed Link Pre-feasibility Study
Cost Estimating
Single Bored Railway Tunnel
Tunnel Structural Finishes

Date: Nov. 07, 2017
Calculation by:

Tunnel length= 30000 m



Assumed tunnel cross section

Newfoundland Fixed Link Pre-feasibility Study	
Cost Estimating	**Date:** Nov. 07, 2017
Single Bored Railway Tunnel	**Calculation by:**
Tunnel Structural Finishes	

Quantity Take-off

Concrete

Element	**Nr.**	**L(m)**	**b(m)**	**d(m)**	**Concrete Qty(m3)**	**Rebar Qty(m3)**
1	1	30000	0.3	5.9	53100	6372.0
2	1	30000	1.2	0.3	10800	1296.0
3	1	30000	1.2	0.3	10800	1296.0
					74700 m3	7668 t

Formwork/falsework

Element	**Nr.**	**L(m)**	**d(m)**	**Faces**	**Area(m2)**
1	1	30000	5.9	2	354000
2	1	30000	1.2	1	36000
3	1	30000	1.2	1	36000
					426000 m2

Rates

Concrete	m3	220
Formwork	m2	180
Reinforcement	t	1600

Costs

Concrete	m3	74700	m3	at	220	=	16,434,000
Formwork	m2	426000	m2	at	180	=	76,680,000
Reinforcement	t	7668	t	at	1600	=	12,268,800
						$	105,382,800

Initialisation

Project: Newfoundland Fixed Link Pre-feasibility Study
Section: North Approach
Option: Bored Rail Tunnel

Date: 7-Nov-17

Calculations by:

Surface gradient	-0.08	%	+ sloping same way as track/road - sloping against track/road
Track/Road Gradient	1.663	%	
Ground elevation at portal	100	m	
Bottom of slab elevation at portal	86.95	m	
Total length=	748.7091	m	
Total Cost=$	9.1	M	

Newfoundland Fixed Link Pre-feasibility Study | Date: 7-Nov-17
North Approach | Calculations by: 0
Bored Rail Tunnel

UNIT RATES

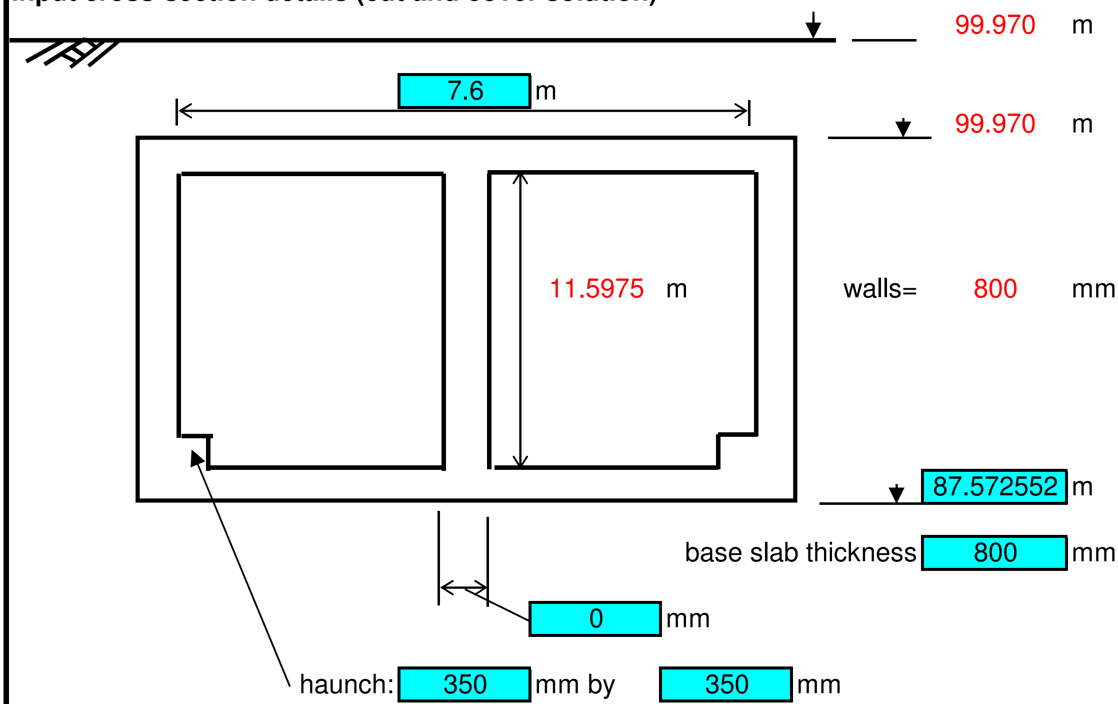
Materials

Item	unit	Rate
excavation	m3	60
concrete	m3	220
rebar	tonnes	1600
formwork/falsework	m2	241
SP&L<=4.6m deep	m2	0
4.6<SP&L<=6.7m deep	m2	0
6.7<SP&L<=10.6m deep	m2	0
10.6<SP&L<=13.7m deep	m2	0
13.7<SP&L<=16.8m deep	m2	0
16.8<SP&L<=20.0m deep	m2	0
20<SP&L<=25m deep	m2	0
backfill + compact	m3	69
surface reinstatement	m2	52

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section 1**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	8539.6	m3
concrete=	1958.698	m3
rebar=	235.0	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	1736.631	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	1856.4	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	688.8124	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

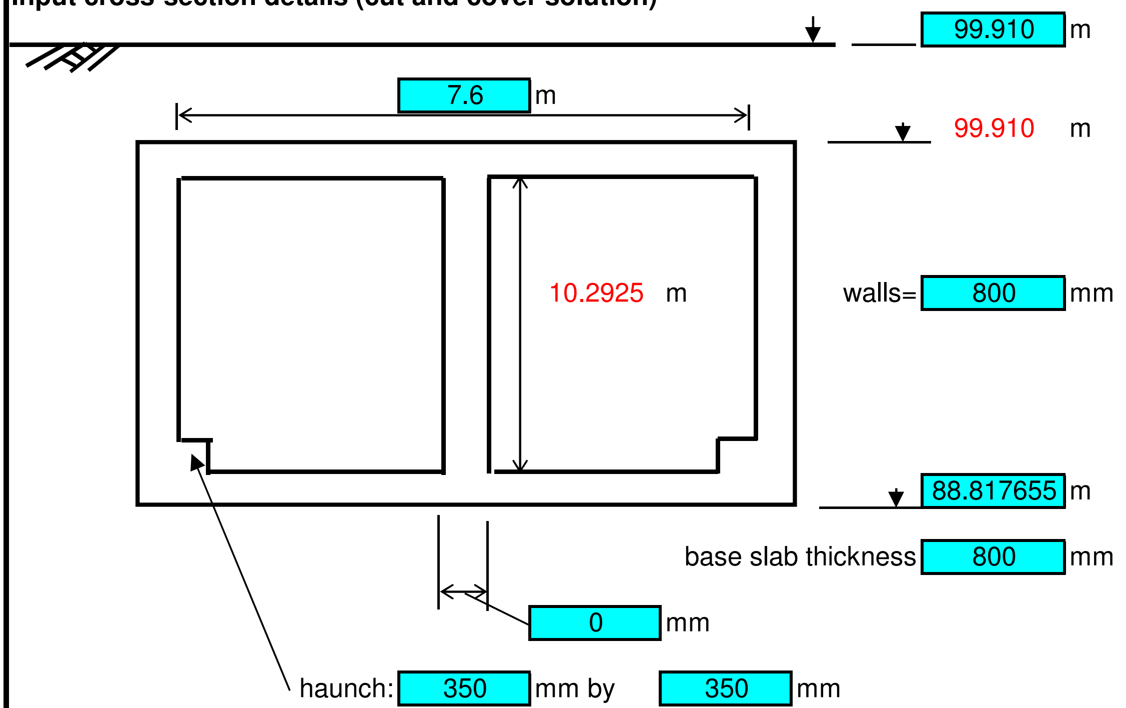
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	8539.6	60	512373.1
concrete	m3	1958.698	220.0	430913.5
rebar	tonnes	235.0	1600	376070
formwork/falsework	m2	1736.631	241	418528
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	1856.4	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	688.8124	52	35818.24
			Total	1773703

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section** 2

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	7640.7	m3	
concrete=	1802.367	m3	
rebar=	216.3	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1541.218	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	1661.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	688.8124	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	7640.7	60	458439.1
concrete	m3	1802.367	220.0	396520.8
rebar	tonnes	216.3	1600	346054.6
formwork/falsework	m2	1541.218	241	371433.5
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	1661.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	688.8124	52	35818.24
			Total	1608266

Newfoundland Fixed Link Pre-feasibility Study — **Date:** 7-Nov-17

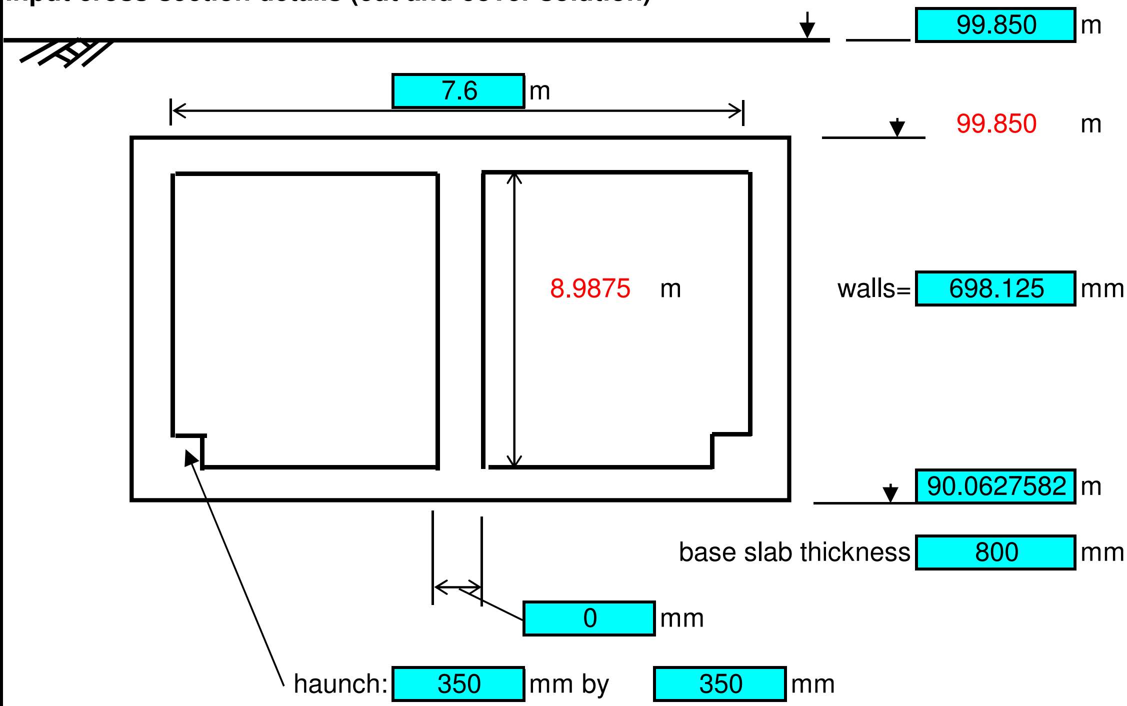
North Approach — **Calculations by:** 0

Bored Rail Tunnel

Section Cut and Cover

Length of section: 74.87091 m — **Section** 3

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	6592.4	m3
concrete=	1496.729	m3
rebar=	179.6	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	1345.805	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	1465.6	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	673.5574	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

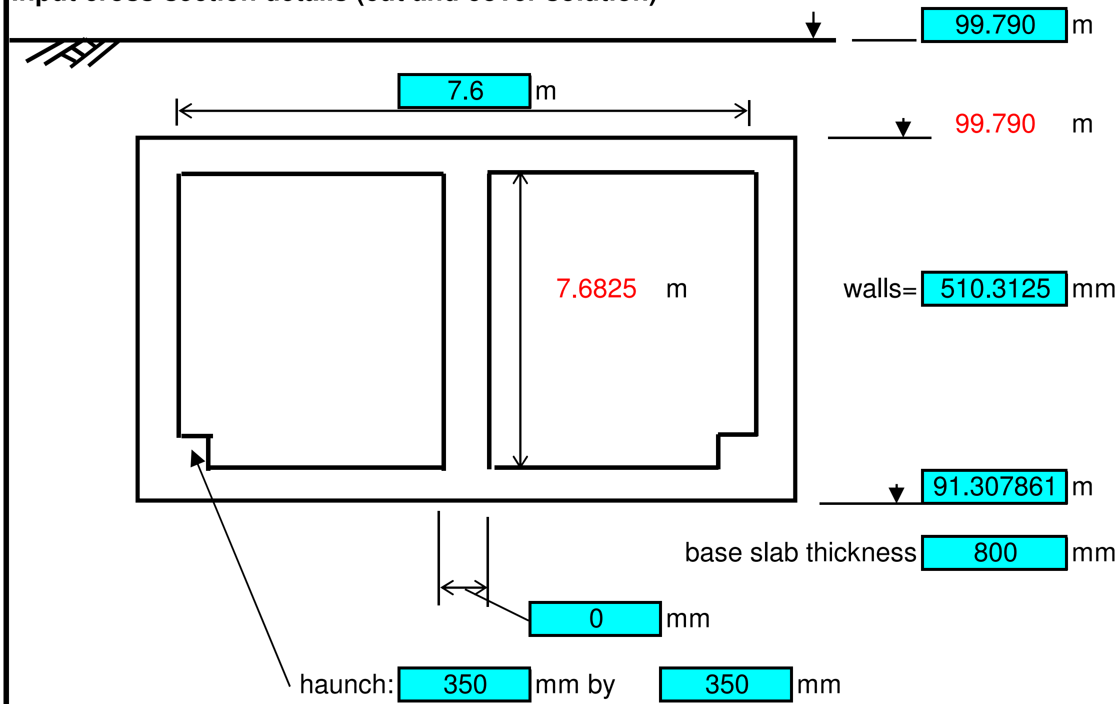
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	6592.4	60	395546.6
concrete	m3	1496.729	220.0	329280.4
rebar	tonnes	179.6	1600	287372
formwork/falsework	m2	1345.805	241	324338.9
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1465.6	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	673.5574	52	35024.99
			Total	1371563

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
North Approach | **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 74.87091 m **Section 4**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	5474.9	m3
concrete=	1121.75	m3
rebar=	134.6	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	1150.392	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	1270.2	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	645.4341	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

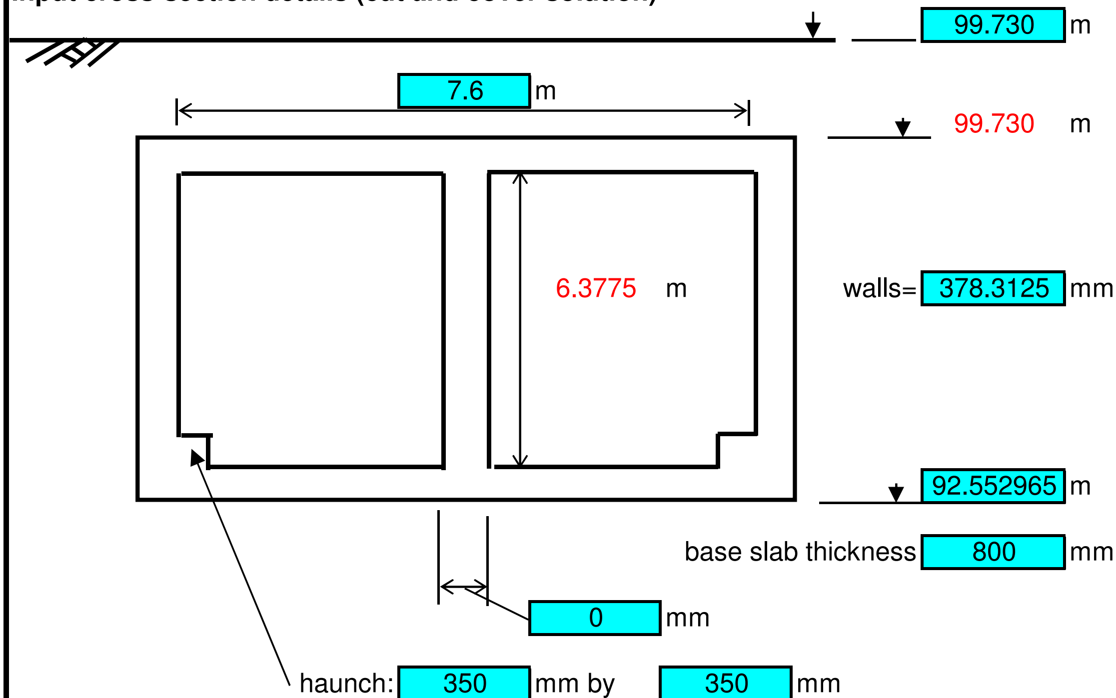
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	5474.9	60	328493.7
concrete	m3	1121.75	220.0	246785
rebar	tonnes	134.6	1600	215376
formwork/falsework	m2	1150.392	241	277244.4
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1270.2	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	645.4341	52	33562.57
			Total	1101462

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section** **5**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	4490.7	m3
concrete=	880.1582	m3
rebar=	105.6	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	954.9785	m2
SP&L<=4.6m deep	0.0	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	1074.8	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	625.6681	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

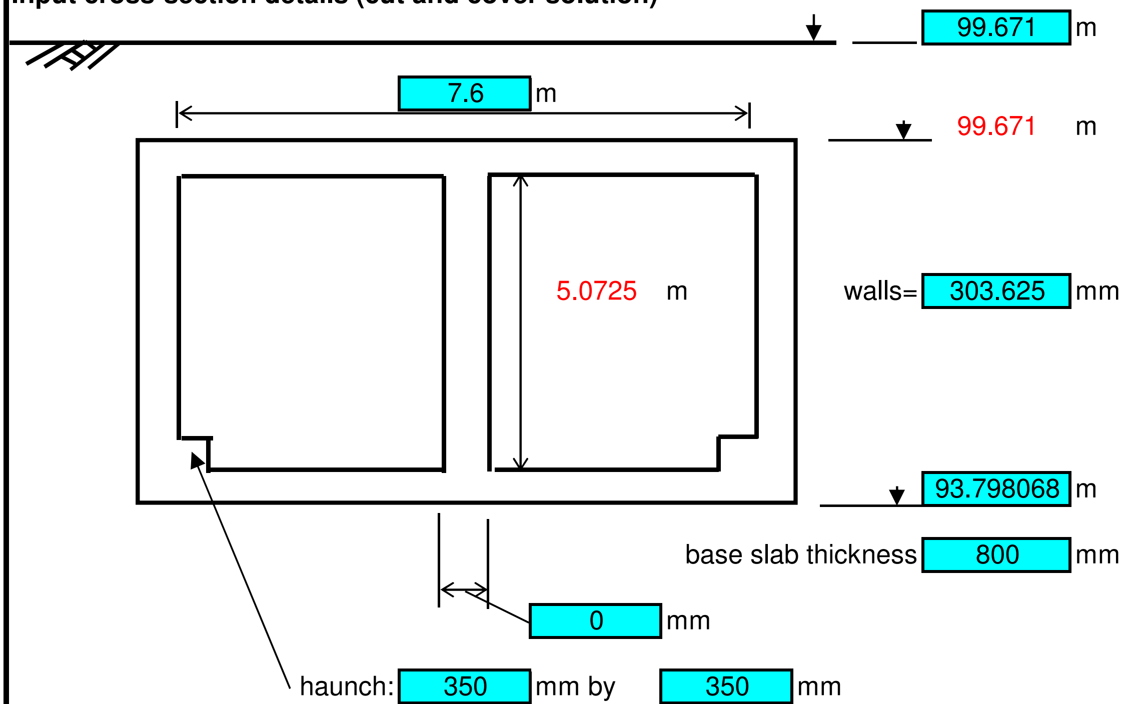
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	4490.7	60	269444
concrete	m3	880.1582	220.0	193634.8
rebar	tonnes	105.6	1600	168990.4
formwork/falsework	m2	954.9785	241	230149.8
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1074.8	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	625.6681	52	32534.74
			Total	894753.7

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 74.87091 m **Section** 6

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	3608.6	m3	
concrete=	740.5539	m3	
rebar=	88.9	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	759.5654	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	879.4	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	614.4843	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

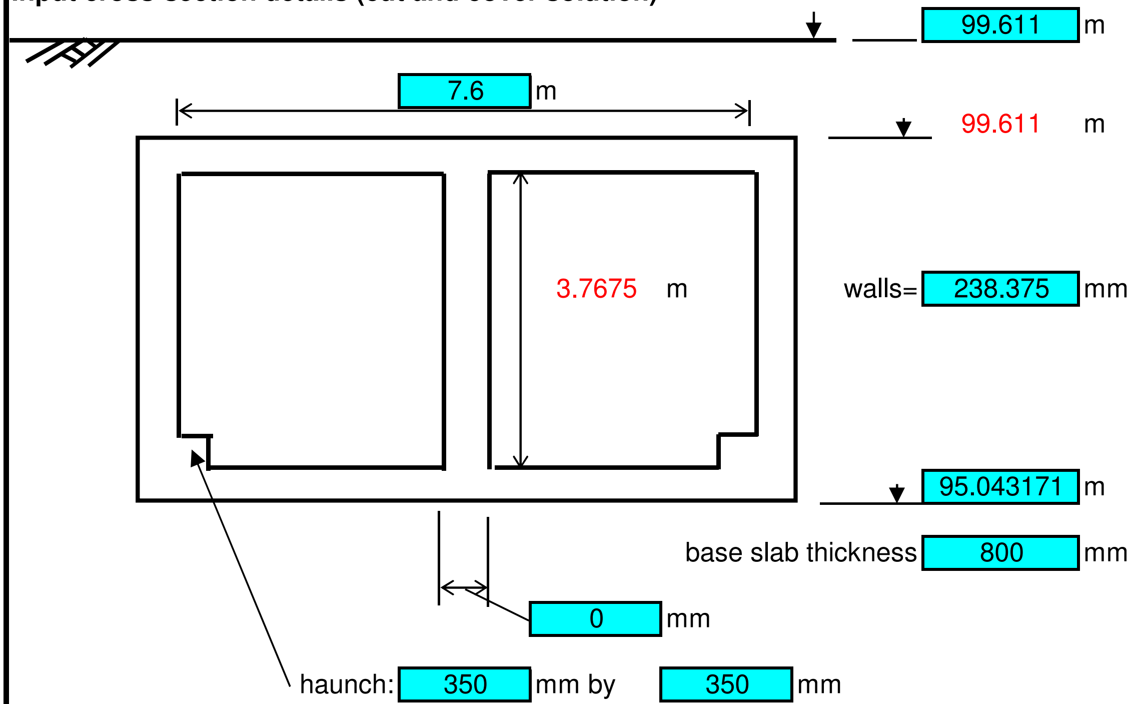
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	3608.6	60	216513.5
concrete	m3	740.5539	220.0	162921.8
rebar	tonnes	88.9	1600	142186.3
formwork/falsework	m2	759.5654	241	183055.3
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	879.4	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	614.4843	52	31953.18
			Total	736630.2

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
North Approach | **Calculations by:** 0
Bored Rail Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section** 7

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	2762.0	m3	
concrete=	636.5941	m3	
rebar=	76.4	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	564.1523	m2	
SP&L<=4.6m deep	683.9	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	604.7136	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

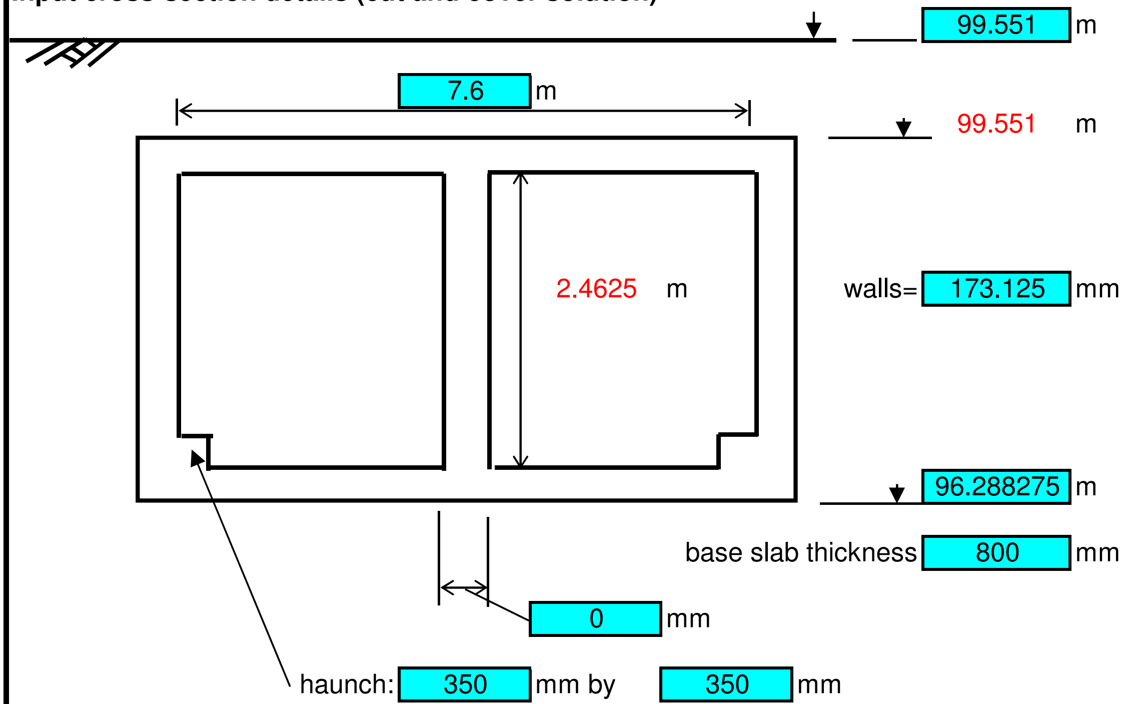
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	2762.0	60	165721.8
concrete	m3	636.5941	220.0	140050.7
rebar	tonnes	76.4	1600	122226.1
formwork/falsework	m2	564.1523	241	135960.7
SP&L<=4.6m deep	m2	683.9	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	604.7136	52	31445.11
			Total	595404.4

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 74.87091 m **Section** 8

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1941.0	m3	
concrete=	558.1357	m3	
rebar=	67.0	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	368.7392	m2	
SP&L<=4.6m deep	488.5	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	594.943	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

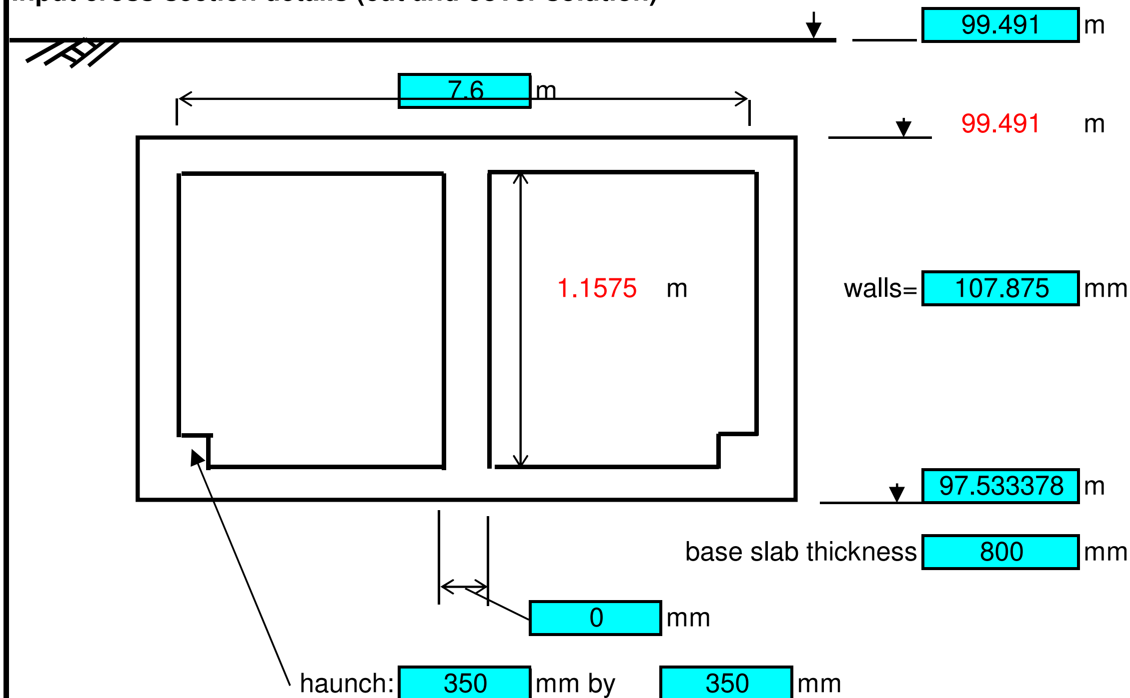
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1941.0	60	116460.1
concrete	m3	558.1357	220.0	122789.9
rebar	tonnes	67.0	1600	107162.1
formwork/falsework	m2	368.7392	241	88866.16
SP&L<=4.6m deep	m2	488.5	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	594.943	52	30937.04
			Total	466215.2

Newfoundland Fixed Link Pre-feasibility Study	**Date:**	7-Nov-17
North Approach	**Calculations by:**	0
Bored Rail Tunnel		**Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section 9**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1145.5	m3	
concrete=	505.1788	m3	
rebar=	60.6	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	173.3262	m2	
SP&L<=4.6m deep	293.1	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	585.1723	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

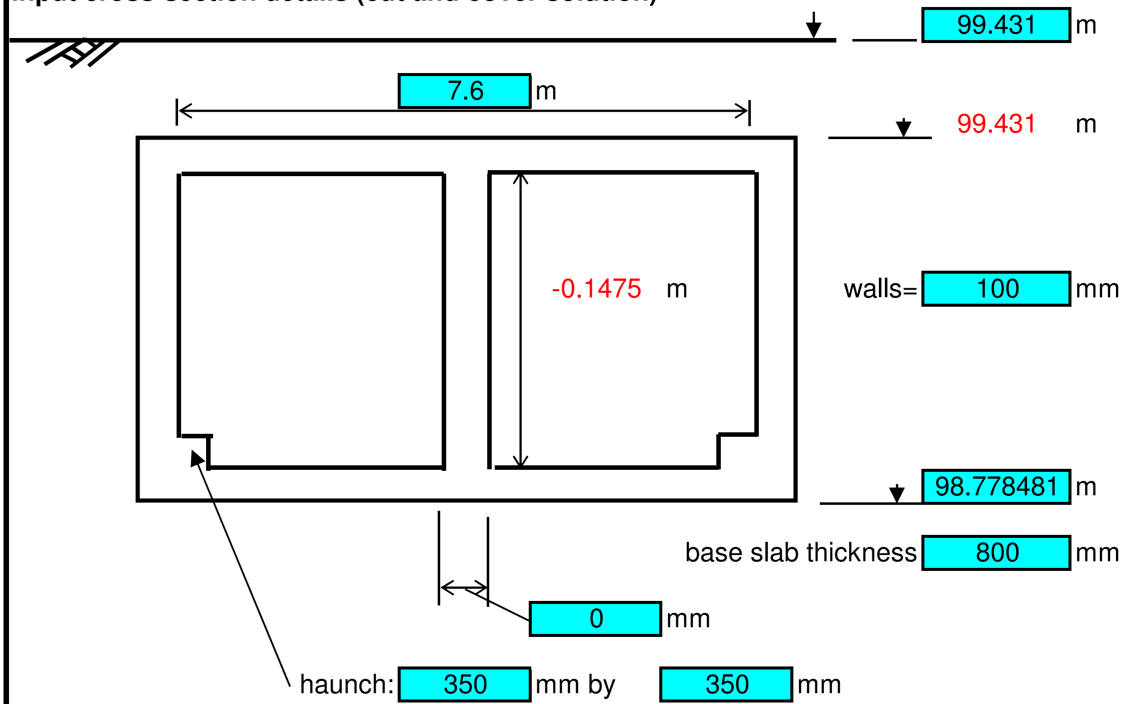
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1145.5	60	68728.49
concrete	m3	505.1788	220.0	111139.3
rebar	tonnes	60.6	1600	96994.33
formwork/falsework	m2	173.3262	241	41771.6
SP&L<=4.6m deep	m2	293.1	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	585.1723	52	30428.96
			Total	349062.7

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 74.87091 m **Section** **10**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	381.1	m3	
concrete=	483.3292	m3	
rebar=	58.0	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	-22.0869	m2	
SP&L<=4.6m deep	97.7	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	583.9931	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

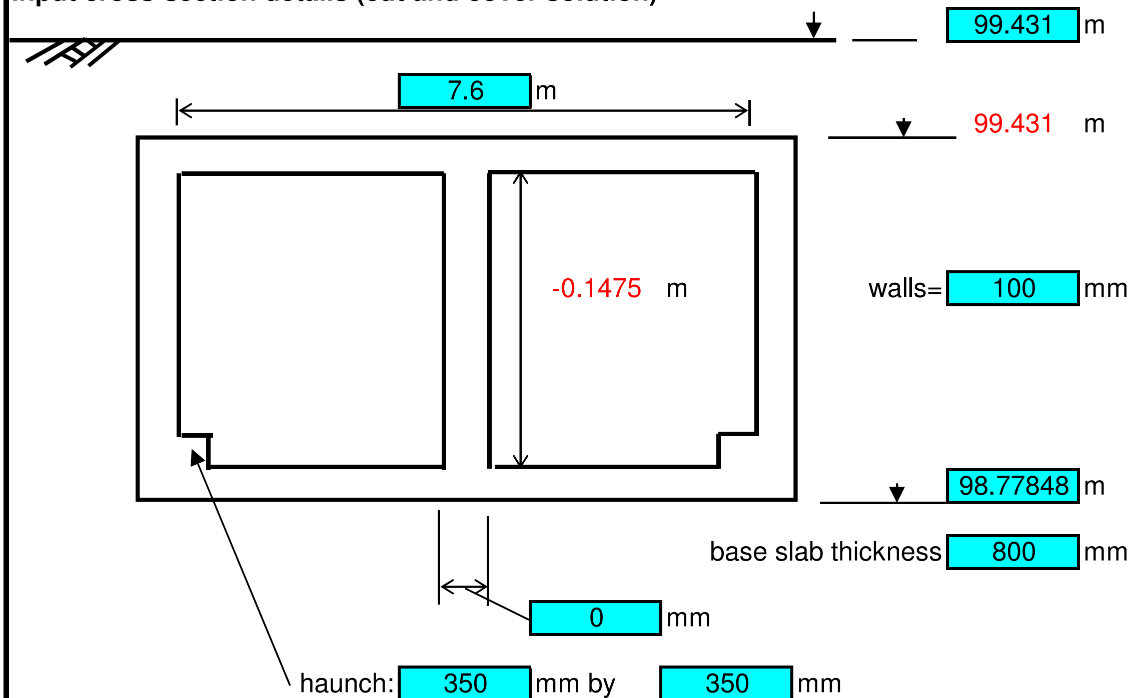
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	381.1	60	22863.33
concrete	m3	483.3292	220.0	106332.4
rebar	tonnes	58.0	1600	92799.2
formwork/falsework	m2	-22.0869	241	-5322.95
SP&L<=4.6m deep	m2	97.7	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	583.9931	52	30367.64
			Total	247039.6

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 74.87091 m **Section** 10

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	381.1	m3	
concrete=	483.3292	m3	
rebar=	58.0	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	-22.0869	m2	
SP&L<=4.6m deep	97.7	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	583.9931	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3			2554583.7
concrete	m3			2240368.7
rebar	tonnes			1955230.9
formwork/falsework	m2			2066025.4
SP&L<=4.6m deep	m2			0
4.6<SP&L<=6.7m deep	m2			0
6.7<SP&L<=10.6m deep	m2			0
10.6<SP&L<=13.7m deep	m2			0
13.7<SP&L<=16.8m deep	m2			0
16.8<SP&L<=20.0m deep	m2			0
20<SP&L<=25m deep	m2			0
backfill	m3			0
surface reinstatement	m2			327890.72
			Total	9144099.4

Indirect costs, profit, and contingency

0 % indirect costs = $ 0

Subtotal 2 = $ 9144099

0 % profit = $ 0

Subtotal 3 = $ 9144099

25 % contingency = $ 2286024.9

Total Cost = $ 11430124

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
North Approach **Calculations by:** 0
Bored Rail Tunnel

Summary of Costs

Markup for adjacent 0 %

Section		Cost
1	$	1,773,703
2	$	1,608,266
3	$	1,371,563
4	$	1,101,462
5	$	894,754
6	$	736,630
7	$	595,404
8	$	466,215
9	$	349,063
10	$	247,040
Sub-total	**$**	**9,144,099**

Initialisation

Project: Newfoundland Fixed Link Pre-feasibility Study
Section: South Approach
Option: Bored Rail Tunnel

Date: 7-Nov-17

Calculations by:

Surface gradient	0	%	+ sloping same way as track/road - sloping against track/road
Track/Road Gradient	1.663	%	
Ground elevation at portal	100	m	
Bottom of slab elevation at portal	86.95	m	
Total length=	784.7264	m	
Total Cost=$	9.6	M	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

UNIT RATES

Materials

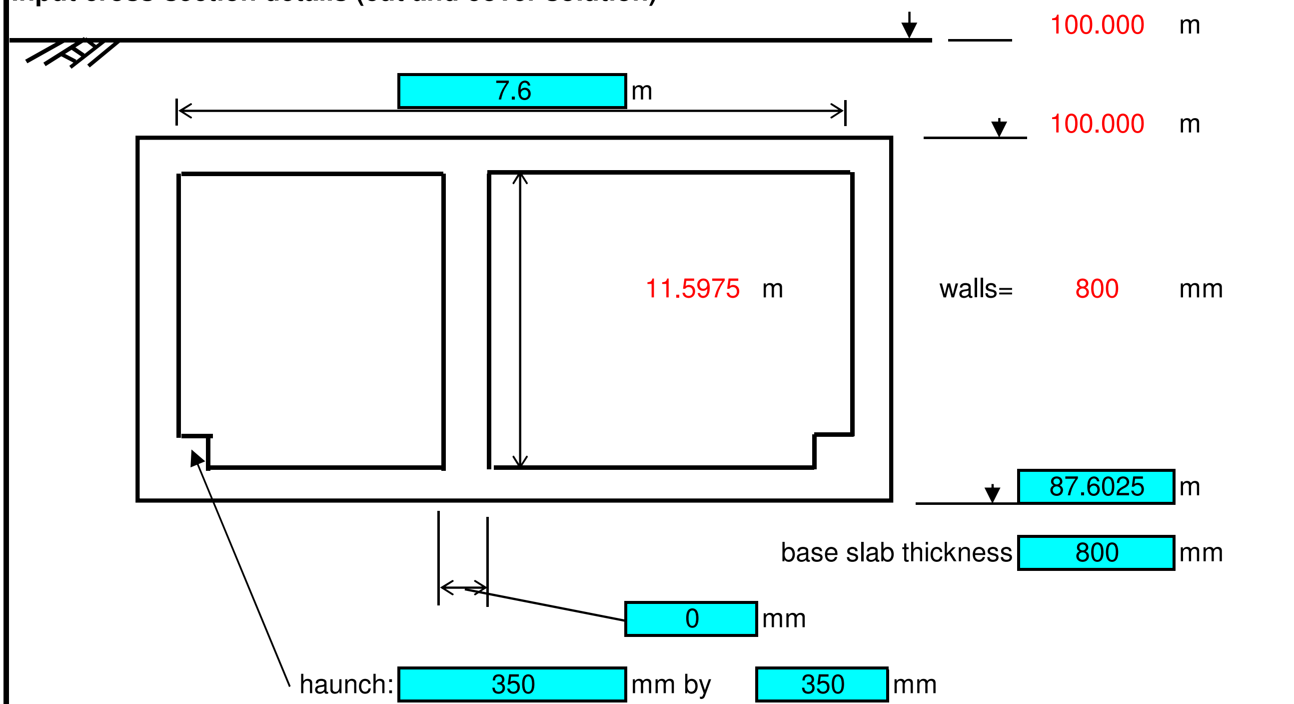
Item	unit	Rate
excavation	m3	60
concrete	m3	220
rebar	tonnes	1600
formwork/falsework	m2	241
SP&L<=4.6m deep	m2	0
4.6<SP&L<=6.7m deep	m2	0
6.7<SP&L<=10.6m deep	m2	0
10.6<SP&L<=13.7m deep	m2	0
13.7<SP&L<=16.8m deep	m2	0
16.8<SP&L<=20.0m deep	m2	0
20<SP&L<=25m deep	m2	0
backfill + compact	m3	69
surface reinstatement	m2	52

Newfoundland Fixed Link Pre-feasibility Study	**Date:** 7-Nov-17
South Approach	**Calculations by:** 0
Bored Rail Tunnel	

Section Cut and Cover

Length of section: 78.47264 m **Section 1**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	8950.4	m3	
concrete=	2052.92273	m3	
rebar=	246.4	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1820.17288	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	1945.7	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	721.9482862	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

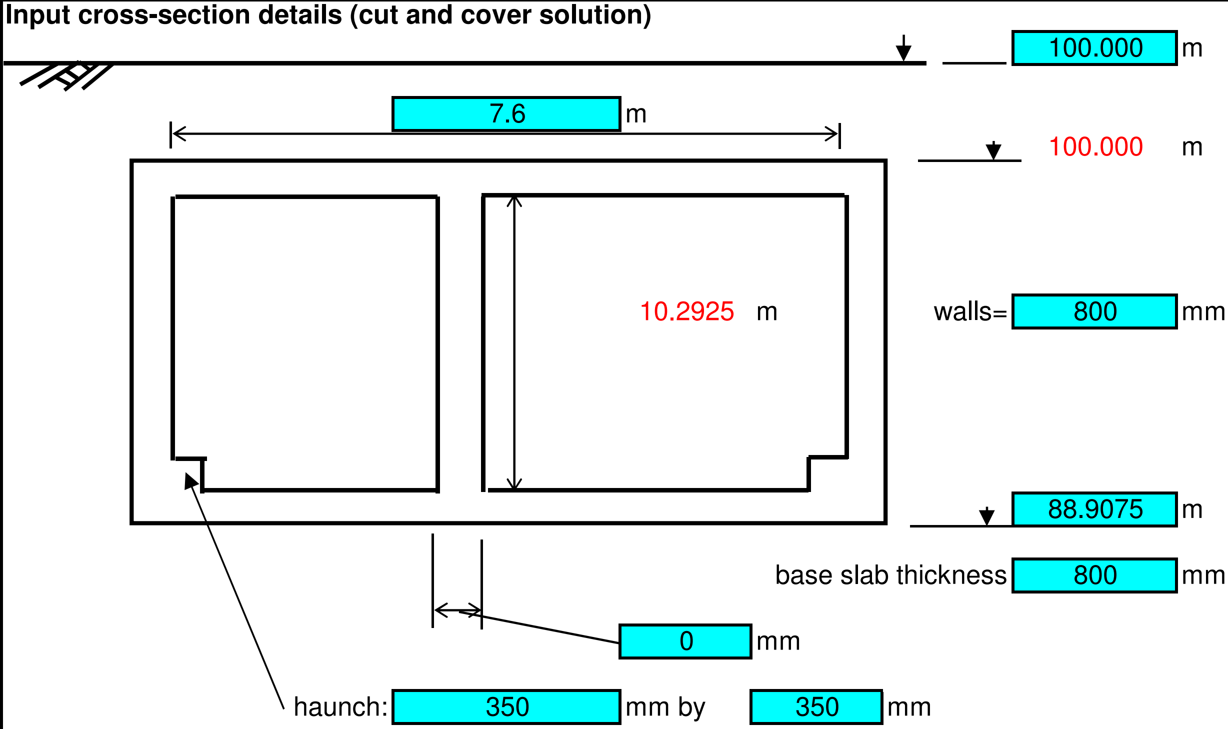
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	8950.4	60	537021.2
concrete	m3	2052.923	220.0	451643
rebar	tonnes	246.4	1600	394161.2
formwork/falsework	m2	1820.173	241	438661.7
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	1945.7	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	721.9483	52	37541.31
			Total	1859028

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** 2

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	8008.2	m3	
concrete=	1889.071858	m3	
rebar=	226.7	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1615.35929	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	1740.9	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	721.9482862	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

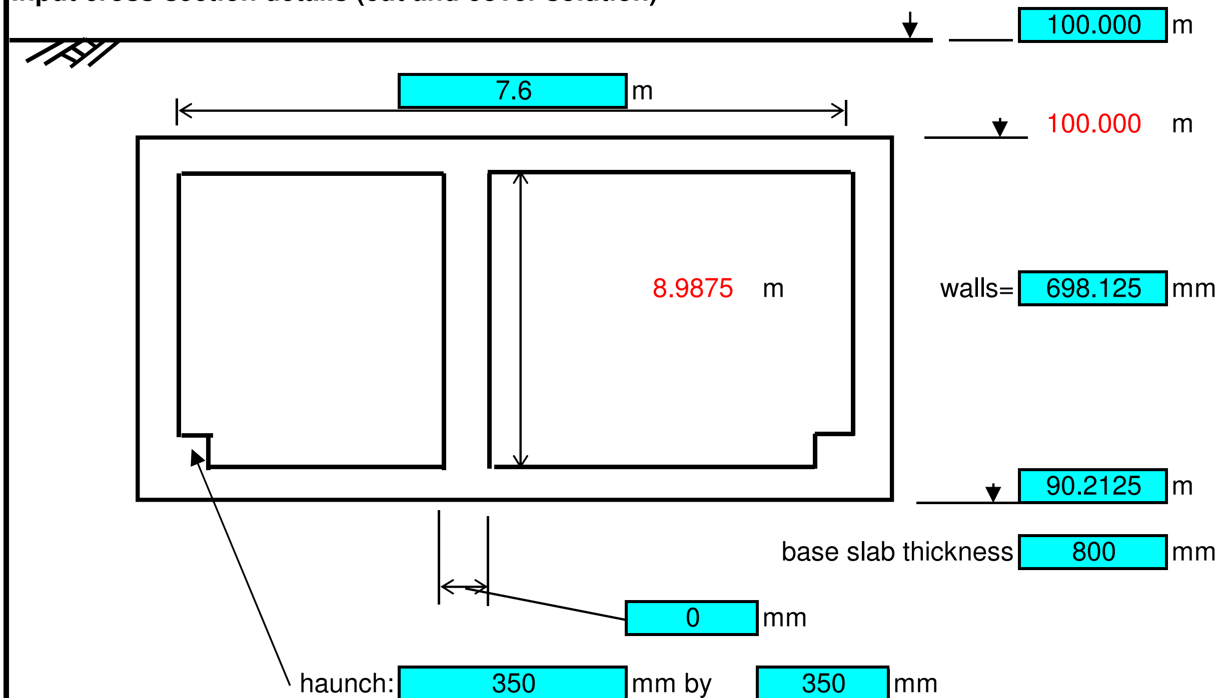
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	8008.2	60	480492.7
concrete	m3	1889.072	220.0	415595.8
rebar	tonnes	226.7	1600	362701.8
formwork/falsework	m2	1615.359	241	389301.6
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	1740.9	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	721.9483	52	37541.31
			Total	1685633

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
South Approach | **Calculations by:** 0
Bored Rail Tunnel |

Section Cut and Cover
Length of section: 78.47264 m **Section** 3

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	6909.6	m3	
concrete=	1568.730603	m3	
rebar=	188.2	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1410.545701	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	1536.1	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	705.9594859	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

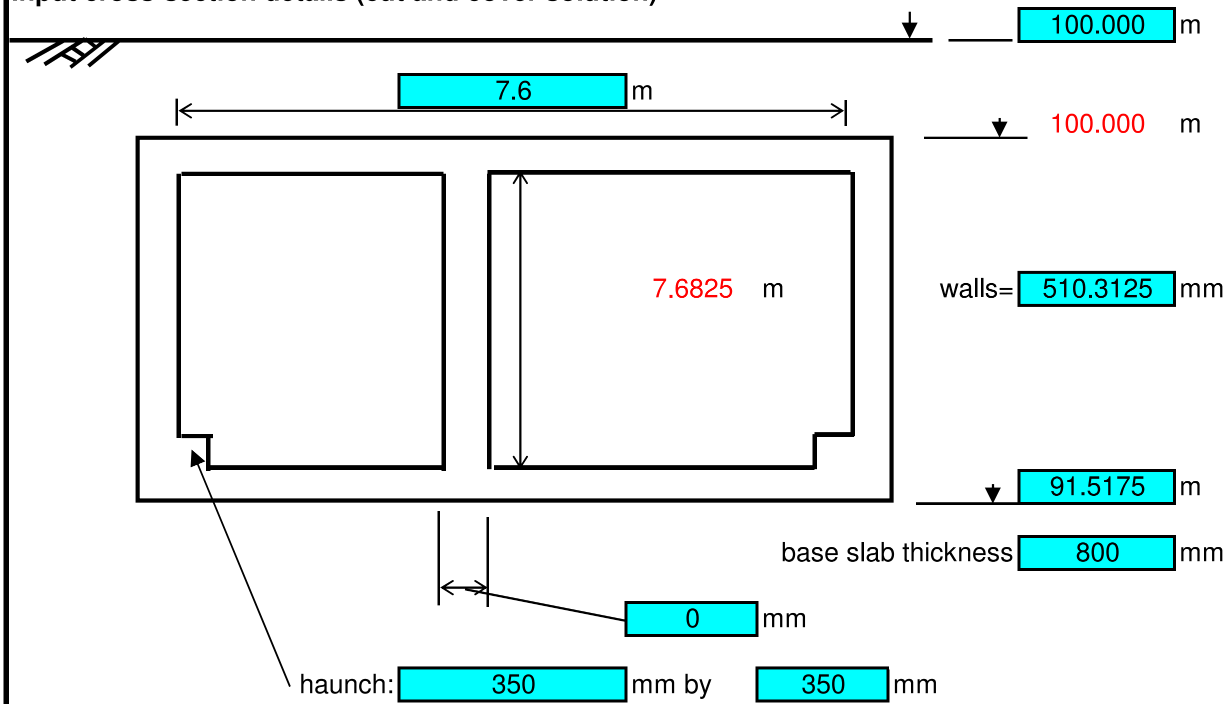
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	6909.6	60	414574.7
concrete	m3	1568.731	220.0	345120.7
rebar	tonnes	188.2	1600	301196.3
formwork/falsework	m2	1410.546	241	339941.5
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1536.1	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	705.9595	52	36709.89
			Total	1437543

Newfoundland Fixed Link Pre-feasibility Study	Date:	7-Nov-17
South Approach	Calculations by:	0
Bored Rail Tunnel		Page 1 of 2

Section Cut and Cover
Length of section: 78.47264 m **Section** **4**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	5738.3	m3	
concrete=	1175.712525	m3	
rebar=	141.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1205.732111	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	1331.3	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	676.4832005	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

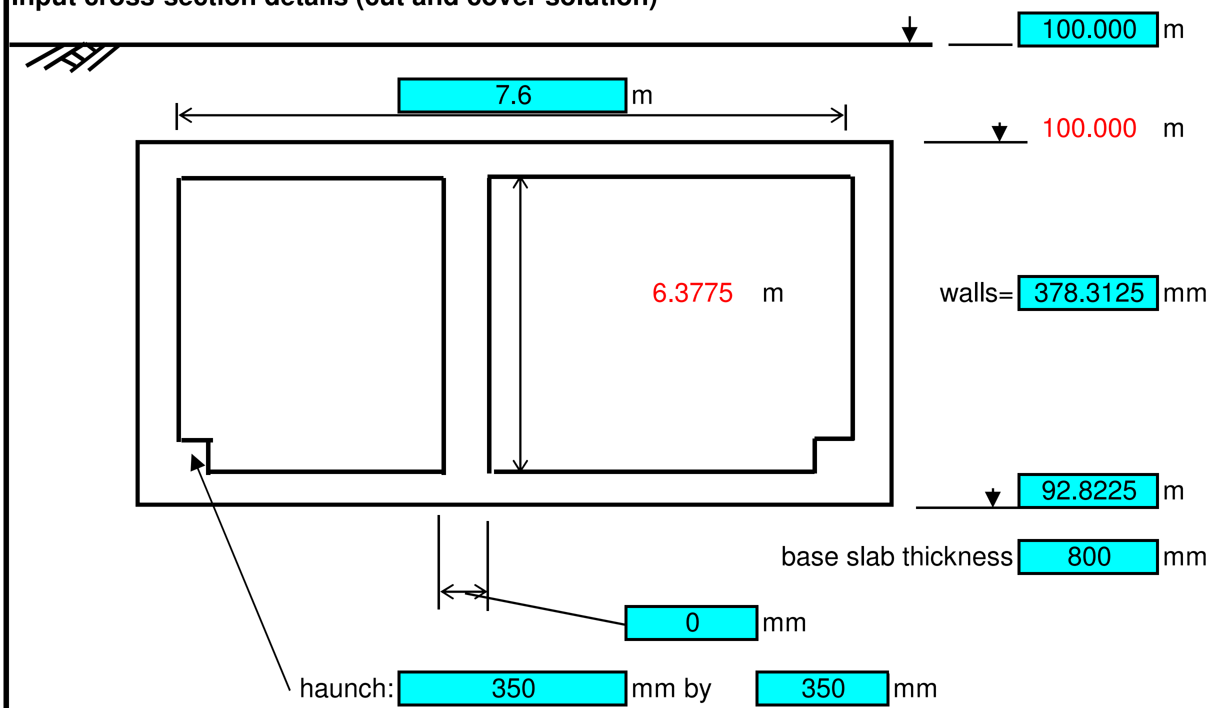
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	5738.3	60	344296.1
concrete	m3	1175.713	220.0	258656.8
rebar	tonnes	141.1	1600	225736.8
formwork/falsework	m2	1205.732	241	290581.4
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1331.3	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	676.4832	52	35177.13
			Total	1154448

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
South Approach | **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** 5

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	4706.8	m3	
concrete=	922.4989235	m3	
rebar=	110.7	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	1000.918521	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	1126.5	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	655.7664236	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

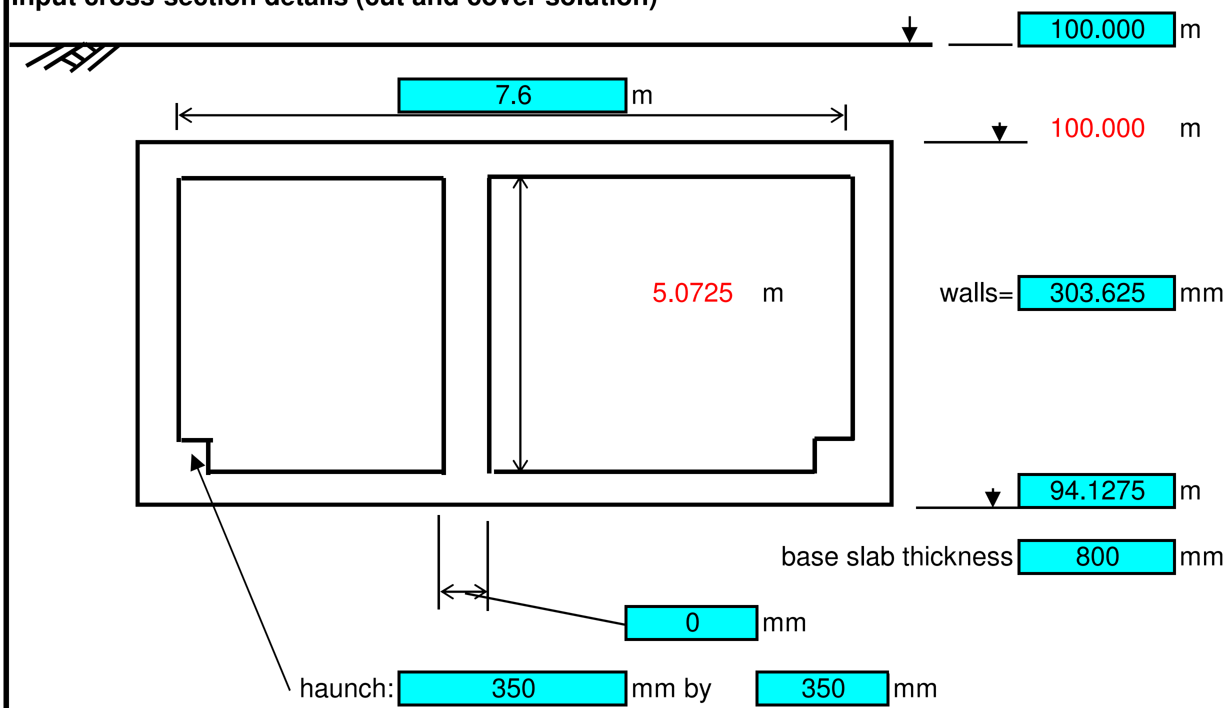
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	4706.8	60	282405.8
concrete	m3	922.4989	220.0	202949.8
rebar	tonnes	110.7	1600	177119.8
formwork/falsework	m2	1000.919	241	241221.4
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	1126.5	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	655.7664	52	34099.85
			Total	937796.6

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
South Approach | **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** 6

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	3782.2	m3	
concrete=	776.1788148	m3	
rebar=	93.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	796.1049308	m2	
SP&L<=4.6m deep	0.0	m2	
4.6<SP&L<=6.7m deep	921.7	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	644.0445731	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

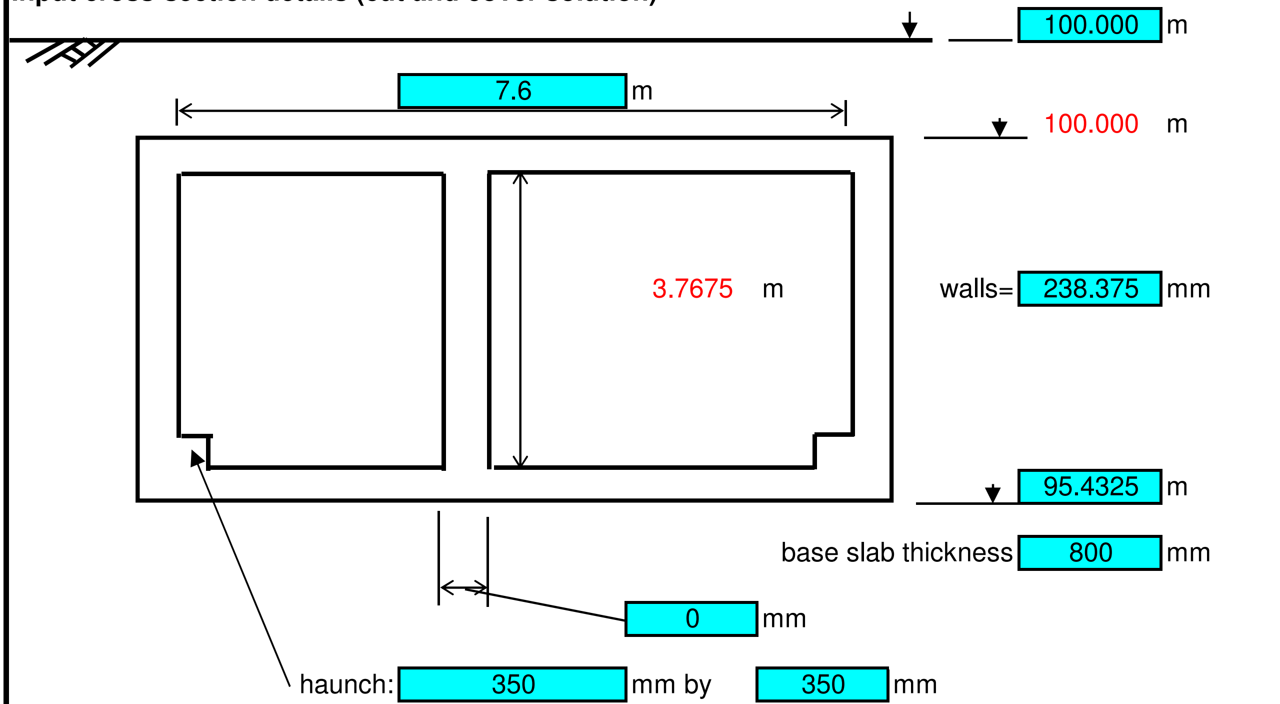
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	3782.2	60	226929.1
concrete	m3	776.1788	220.0	170759.3
rebar	tonnes	93.1	1600	149026.3
formwork/falsework	m2	796.1049	241	191861.3
SP&L<=4.6m deep	m2	0.0	0	0
4.6<SP&L<=6.7m deep	m2	921.7	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	644.0446	52	33490.32
			Total	772066.4

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** **7**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	2894.9	m3	
concrete=	667.217985	m3	
rebar=	80.1	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	591.291341	m2	
SP&L<=4.6m deep	716.8	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	633.8038936	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

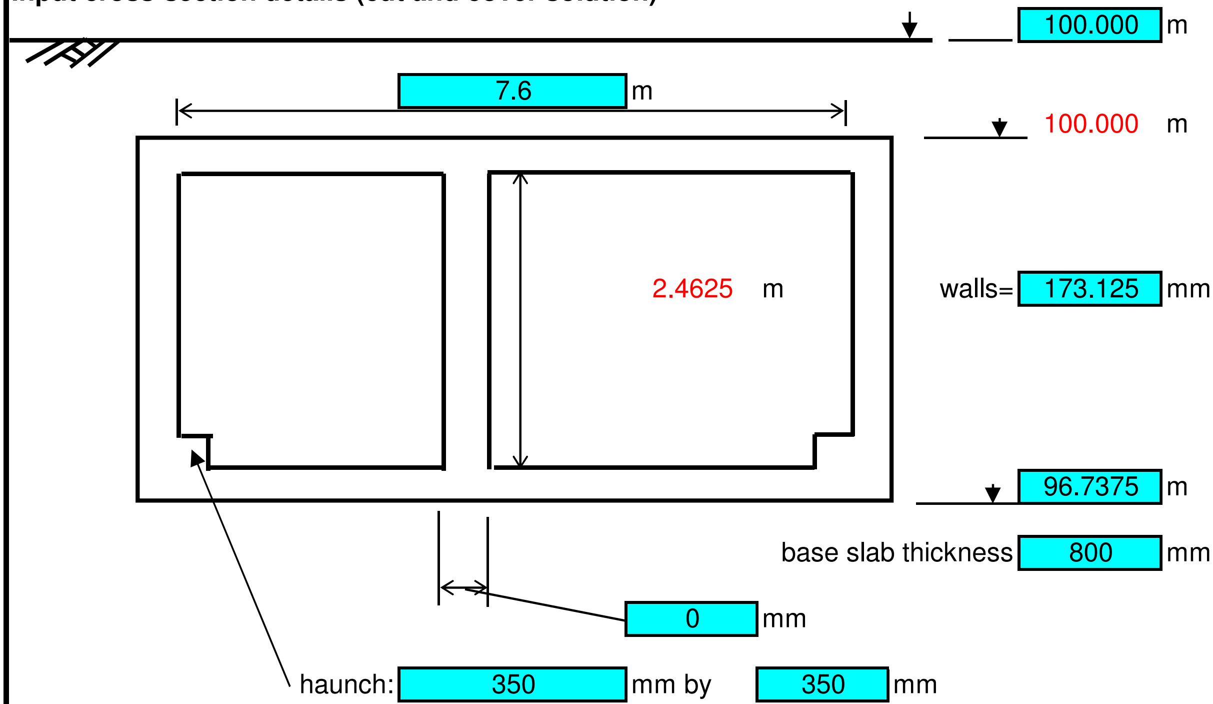
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	2894.9	60	173694
concrete	m3	667.218	220.0	146788
rebar	tonnes	80.1	1600	128105.9
formwork/falsework	m2	591.2913	241	142501.2
SP&L<=4.6m deep	m2	716.8	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	633.8039	52	32957.8
			Total	624046.8

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
South Approach | **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** 8

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	2034.4	m3	
concrete=	584.9853287	m3	
rebar=	70.2	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	386.4777511	m2	
SP&L<=4.6m deep	512.0	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	623.5632141	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

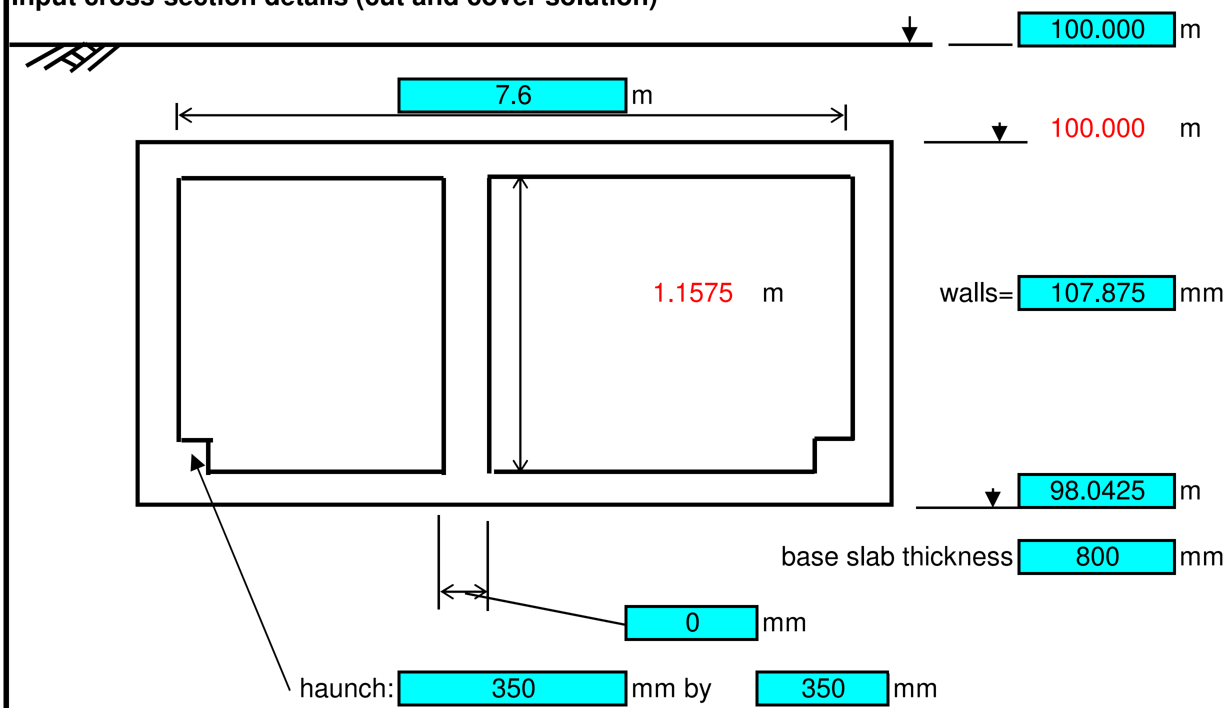
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	2034.4	60	122062.5
concrete	m3	584.9853	220.0	128696.8
rebar	tonnes	70.2	1600	112317.2
formwork/falsework	m2	386.4778	241	93141.14
SP&L<=4.6m deep	m2	512.0	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	623.5632	52	32425.29
			Total	488642.9

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

Section Cut and Cover
Length of section: 78.47264 m **Section** 9

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	1200.6	m3
concrete=	529.4808458	m3
rebar=	63.5	tonnes (assume 0.12t/m3 of concrete)
formwork/falsework=	181.6641612	m2
SP&L<=4.6m deep	307.2	m2
4.6<SP&L<=6.7m deep	0.0	m2
6.7<SP&L<=10.6m deep	0.0	m2
10.6<SP&L<=13.7m deep	0.0	m2
13.7<SP&L<=16.8m deep	0.0	m2
16.8<SP&L<=20.0m deep	0.0	m2
20<SP&L<=25m deep	0.0	m2
backfill=	0	m3
surface reinstatement=	613.3225346	m2

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

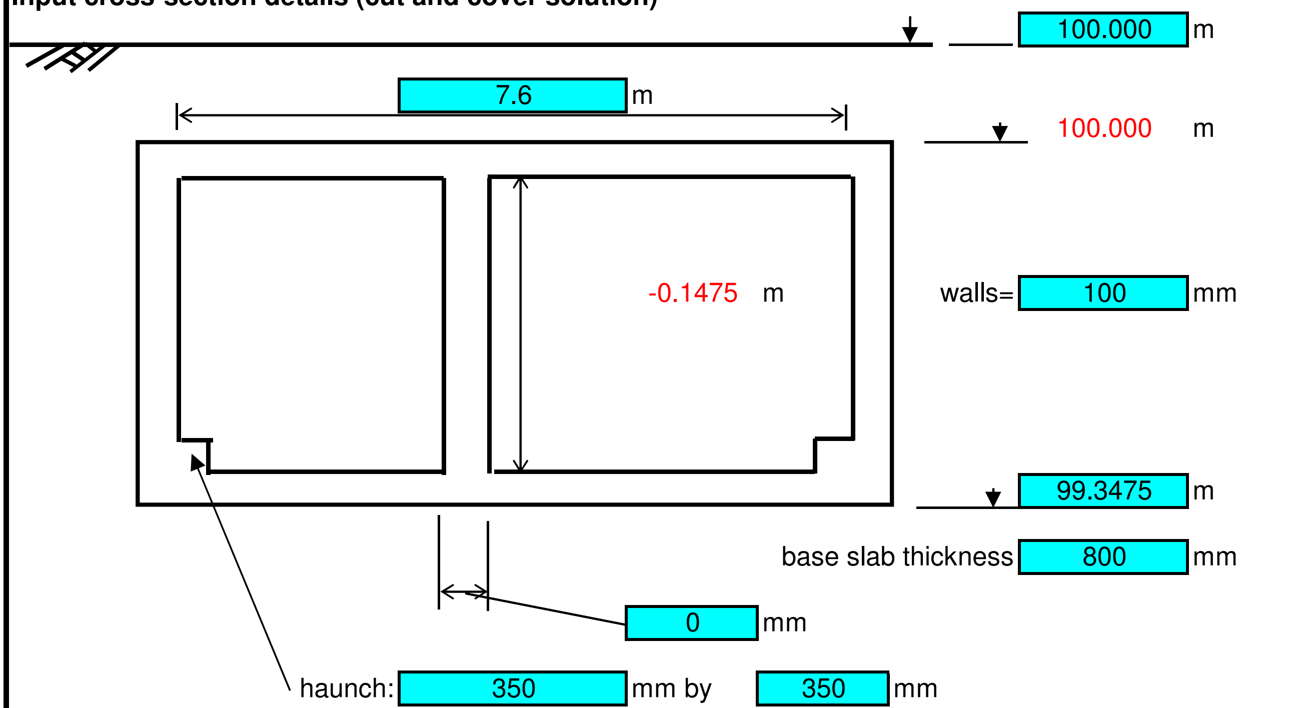
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	1200.6	60	72034.73
concrete	m3	529.4808	220.0	116485.8
rebar	tonnes	63.5	1600	101660.3
formwork/falsework	m2	181.6642	241	43781.06
SP&L<=4.6m deep	m2	307.2	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	613.3225	52	31892.77
			Total	365854.7

Newfoundland Fixed Link Pre-feasibility Study | **Date:** 7-Nov-17
South Approach | **Calculations by:** 0
Bored Rail Tunnel | **Page 1 of 2**

Section Cut and Cover
Length of section: 78.47264 m **Section** **10**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	399.4	m3	
concrete=	506.5801263	m3	
rebar=	60.8	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	-23.14942874	m2	
SP&L<=4.6m deep	102.4	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	612.0865905	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

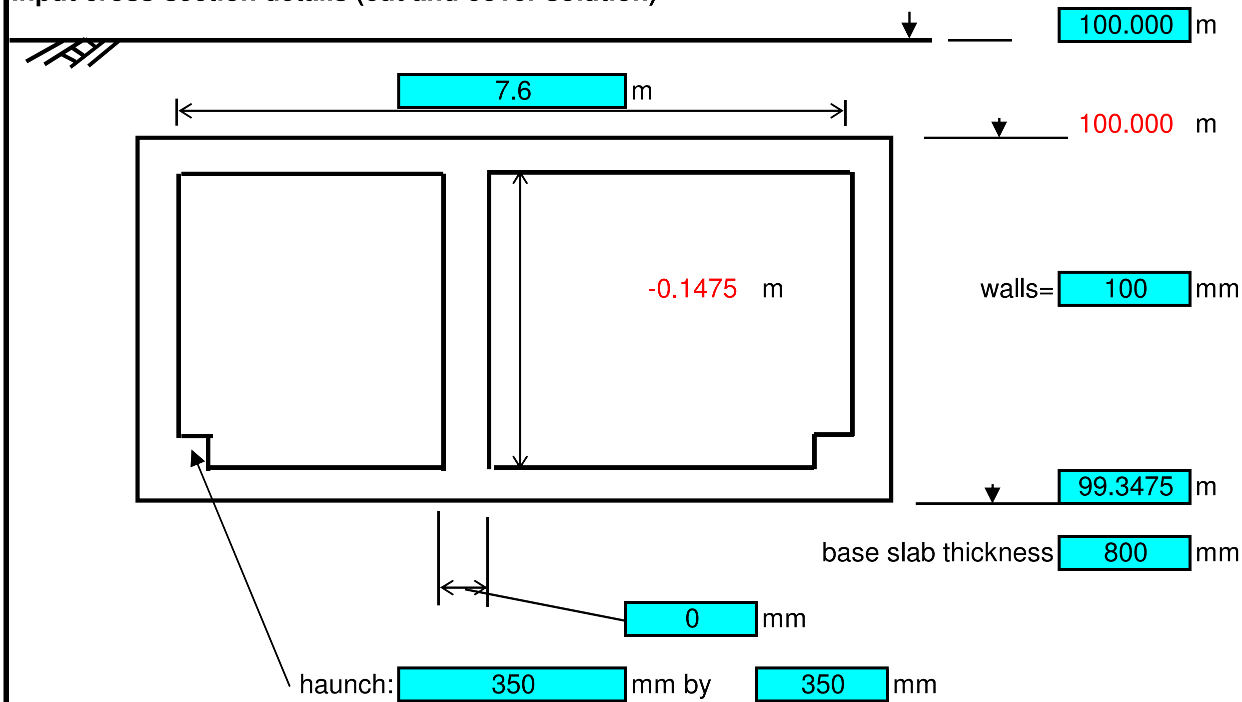
Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	399.4	60	23963.19
concrete	m3	506.5801	220.0	111447.6
rebar	tonnes	60.8	1600	97263.38
formwork/falsework	m2	-23.1494	241	-5579.01
SP&L<=4.6m deep	m2	102.4	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	612.0866	52	31828.5
			Total	258923.7

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel **Page 1 of 2**

Section Cut and Cover
Length of section: 78.47264 m **Section 10**

Input cross-section details (cut and cover solution)



Calculated Quantities

excavation=	399.4	m3	
concrete=	506.5801263	m3	
rebar=	60.8	tonnes	(assume 0.12t/m3 of concrete)
formwork/falsework=	-23.14942874	m2	
SP&L<=4.6m deep	102.4	m2	
4.6<SP&L<=6.7m deep	0.0	m2	
6.7<SP&L<=10.6m deep	0.0	m2	
10.6<SP&L<=13.7m deep	0.0	m2	
13.7<SP&L<=16.8m deep	0.0	m2	
16.8<SP&L<=20.0m deep	0.0	m2	
20<SP&L<=25m deep	0.0	m2	
backfill=	0	m3	
surface reinstatement=	612.0865905	m2	

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

Calculated costs

Item	Unit	Quantity	Rate	Cost
excavation	m3	399.4	60	2677474.041
concrete	m3	506.5801	220.0	2348143.543
rebar	tonnes	60.8	1600	2049288.91
formwork/falsework	m2	-23.1494	241	2165413.259
SP&L<=4.6m deep	m2	102.4	0	0
4.6<SP&L<=6.7m deep	m2	0.0	0	0
6.7<SP&L<=10.6m deep	m2	0.0	0	0
10.6<SP&L<=13.7m deep	m2	0.0	0	0
13.7<SP&L<=16.8m deep	m2	0.0	0	0
16.8<SP&L<=20.0m deep	m2	0.0	0	0
20<SP&L<=25m deep	m2	0.0	0	0
backfill	m3	0	69	0
surface reinstatement	m2	612.0866	52	343664.1774
			Total	9583983.93

Indirect costs, profit, and contingency

0	% indirect costs = $	0
	Subtotal 2 = $	9583984
0	% profit = $	0
	Subtotal 3 = $	9583984
25	% contingency = $	2395995.983
	Total Cost = $	**11979980**

Newfoundland Fixed Link Pre-feasibility Study **Date:** 7-Nov-17
South Approach **Calculations by:** 0
Bored Rail Tunnel

Summary of Costs

Markup for adjacent 0 %

Section		Cost
1	$	1,859,028
2	$	1,685,633
3	$	1,437,543
4	$	1,154,448
5	$	937,797
6	$	772,066
7	$	624,047
8	$	488,643
9	$	365,855
10	$	258,924
Sub-total	**$**	**9,583,984**

Newfoundland Fixed Link Pre-feasibility Study
Tunnel Drainage
Bored Railway Tunnel
Drainage Costs

Calculation by:
Date: Nov. 07, 2017

Sump Sizing

Assume inflow to tunnel of 1 litres/m2/24hours

Tunnel length= 30000 m
Tunnel diameter= 7.6 m

24 hour inflow= 1360938 litres = 1361 m3
assume same again for firefighting= 1361 m3

Required sump capacity= 2722 m3

Assumed sump diameter= 6 m
Assumed number of sump structures= 2 m

Required length of each sump= 49 m

Piping

Assume 300 mm diameter steel pipe connecting each sump to the portal areas
Number of pipes= 1
Assume sumps located at 1/3 and 2/3 of tunnel length

Total length of piping= 20300 m

Rates

Sump construction-$ 17795 /m of sump
Pipe-$ 400 /m of pipe
Pipe installation labour -$ 36 /m of pipe (assume 6 person crew installing 100m/day)
Pipe installation equipment-$ 10 /m of pipe (assume $1000/day for equipment)
Pumps-$ 125000 /pump

Costs

Item	Unit	Qty	Rate	$-Cost
Sump construction	m	98	17795	1,743,910
Pipe	m	20300	400	8,120,000
Pipe installation	m	20300	36	740,544
Equipment	m	20300	10	203,000
Pumps	Nr	4	125000	500,000
			Total	**11,307,454**

Appendix C2-2
Rail Tunnel - Single-Bore, 2 TBMs
Construction Costs

Newfoundland Fixed Link Pre-feasibility - Single Bored - 2TBM Railway Tunnel - Cost Summary		
	BORED TUNNEL CONSTRUCTION COSTS	
ITEM	**UNIT**	**MAIN TUNNEL**
MOBILIZATION & DEMOBILIZATION	LS	**8,000,000**
TUNNELLING	LS	**607,237,443**
TUNNEL FINISHES	LS	**105,382,800**
NORTH APPROACH STRUCTURES	LS	**9,144,099**
SOUTH APPROACH STRUCTURES	LS	**9,583,984**
RAIL TRACK	LS	**13,923,100**
TUNNEL DRAINAGE	LS	**11,307,454**
UTILITY DIVERSIONS	LS	**1,000,000**
MONITORING	LS	**1,000,000**
SUBTOTAL CIVIL		**$766,578,880**
CIVIL CONTINGENCIES		
CONTINGENCY	40%	$306,631,552
TOTAL CIVIL		**$1,073,210,432**
	M&E, ROLLING STOCK, RAIL HARDWARE AND FINISHING WORK	
ROLLING STOCK, TERMINALS, OCS, ETC	LS	$48,773,000
VENTILATION EQUIPMENT	LS	$3,000,000
VENTILATION SHAFTS AND BUILDINGS x 2	LS	$0
FIRE SUPPRESSION SYSTEM	LS	$2,000,000
CONTROL CENTRE	LS	$1,000,000
SIGNALLING	LS	$1,000,000
LIGHTING	LS	$1,000,000
CCTV SYSTEM	LS	$0
GAS DETECTION	LS	$900,000
SUBSTATION, GENERATORS, UPS	LS	$2,000,000
SUBTOTAL M&E AND FINISHING		**$59,673,000**
CONTINGENCIES	20%	$11,934,600
TOTAL M&E AND FINISHING		**$71,607,600**
TOTAL CIVIL, M&E AND FINISHING		**$1,144,818,032**
ALLOWANCES		
CONTRACTOR OH	15%	$171,722,705
CONTRACTOR PROFIT	15%	$171,722,705
CONSTRUCTION TOTAL		**$1,488,263,442**
	PRE-CONSTRUCTION AND SUPERVISION	
FEASIBILITY STUDY	LS	$17,000,000
ENVIRONMENTAL ASSESSMENT	LS	$6,000,000
DESIGN	5%	$74,413,172
CONSTRUCTION MANAGEMENT	10%	$148,826,344
OWNERS COSTS	2%	$29,765,269
PRE-CONSTRUCTION TOTAL		$276,004,785
GRAND TOTAL		**$1,764,268,227**

HATCH

Tunnel Estimating Database

Version 2.8

Detailed Cost Estimate Report

Project:	Newfoundland Fixed Link Pre-feasibility Study	**Project Number:**	213789
Estimate Description:	Rail T.2sidesDrv	**Parent Estimate ID:**	7810
Tunnel Name:	Rail Tunnel-2Sides	**Project Phase:**	Conceptual
Construction Activity:	TBM Tunneling	**Geology Type:**	Not Applicable
Tunnel Technique:	EPB TBM - Precast segmental	**Estimate Date:**	November 08, 2017
Estimate Definition ID:	7816	**Tunnel Characteristics ID:**	3396

Tunnel Characteristics

Tunnel Length:	15,000	m
Finished Diameter:	7.6	m
Initial Support Type:	Not Applicable	
Initial Support Thickness:	0	m
Final Lining Thickness:	0.35	m
Grout Thickness:	0.1	m

Theoretical Excavation Volumes

Total Neat Excavation:	851,175	Cubic Metres
Initial Lining Volume:	0	Cubic Metres
Final Lining Volume:	131,122	Cubic Metres
Theoretical Grout Volume:	39,584	Cubic Metres

Normal Excavation/Support Cycle

Excavation Cycle Length:	1.5	Metres
Excavate:	24	Minutes
Erect Support:	27	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	51	Minutes

Difficult Excavation/Support Cycle

Length of Difficult Excavation:	1400	Metres
Excavate:	73	Minutes
Erect Support:	54	Minutes
Extend Services:	0	Minutes
Total Cycle Time:	127	Minutes

Reduction Factors

Machine availability:	80	%
Back up efficiency:	55	%
Planned maintenance:	5	%
Learning curve efficiency:	40	%
Learning curve duration time:	8	Weeks

Learning Curve Rate:	7.1	m/day
Experienced Advance Rate:	17.7	m/day
Difficult Advance Rate:	7.1	m/day

TBM Skidding Through Excavation

Duration of skidding:	0	Weeks
Length of skidding:	0	Metres

Advance Rate and Shift Details

Shift Arrangement:	3 - 8 hour shifts x 7 days per week	
Avg. Drive Advance per Shift:	5.01	Metres
Avg. Drive Advance per Day:	15	Metres
Avg. Drive Advance per Week:	105	Metres
Duration of Tunneling (Incl. Skid):	142.68	Weeks
Total number of shifts (Incl. Skid):	2,997	

	Metres	Days
Learning Curve Drive:	397	56
Experienced Drive:	13,203	746
Difficult Drive:	1,400	197
Skidding Portion:	0	0

	Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Labor						
	Pit boss	89.54	$/hr	23,974.00	1.00	2,146,632
	Working foreperson	89.54	$/hr	23,974.00	2.00	4,293,264
	Tunnel miner	76.06	$/hr	23,974.00	3.00	5,470,387
	Tunnel laborer	75.39	$/hr	23,974.00	4.00	7,229,599
	Loco driver	75.64	$/hr	23,974.00	4.00	7,253,573
	Shaft bottom	75.29	$/hr	23,974.00	1.00	1,805,002
	TBM operator	76.06	$/hr	23,974.00	1.00	1,823,462
	Tunnel fitter	69.92	$/hr	23,974.00	1.00	1,676,262
	Tunnel electrician	84.43	$/hr	23,974.00	1.00	2,024,125
	Shaft top	75.29	$/hr	23,974.00	2.00	3,610,005
	Crane operator	77.86	$/hr	23,974.00	1.00	1,866,616
	Surface laborer	75.22	$/hr	23,974.00	4.00	7,213,297
	Equipment laborer	72.88	$/hr	23,974.00	4.00	6,988,900
					29.00	$53,401,126
Equipment						
	TBM	340,000.00	$/m2	56.74	1.00	19,291,600
	TBM optional equipment.	1,500,000.00	$/Nr	1.00	1.00	1,500,000
	Loco	8,000.00	$/wk	142.68	5.00	5,707,200
	Muck cars & grout cars	2,900.00	$/wk	142.68	56.00	23,171,232
	Flat cars	480.00	$/wk	142.68	8.00	547,891
	Person riders	480.00	$/wk	142.68	2.00	136,973
	Track	200.00	$/m	15,000.00	1.00	3,000,000
	Air pipe	46.00	$/m	15,000.00	1.00	690,000
	Water pipe	40.00	$/m	15,000.00	1.00	600,000
	Pump main	78.00	$/m	15,000.00	1.00	1,170,000
	Cabling	125.00	$/m	15,000.00	1.00	1,875,000
	Lighting	46.00	$/m	15,000.00	1.00	690,000
	Vent ducting	46.00	$/m	15,000.00	1.00	690,000
	Grout mixers	10,960.00	$/wk	142.68	1.00	1,563,773
	Grout pumps	5,250.00	$/wk	142.68	1.00	749,070
	Grout hoses & pipes	300.00	$/wk	142.68	2.00	85,608
	Transformers & switchgear - LV	1,100.00	$/wk	142.68	2.00	313,896
	Small tools	4,000.00	$/wk	142.68	1.00	570,720
	Shaft crane	13,900.00	$/wk	142.68	1.00	1,983,252
	Compressors	1,500.00	$/wk	142.68	1.00	214,020
	Low pressure C/A system	5,900.00	$/wk	142.68	1.00	841,812
	Pipework and controls	1,000.00	$/wk	142.68	2.00	285,360
	Generators	3,100.00	$/wk	142.68	1.00	442,308
	Transformers & switchgear - HV	8,000.00	$/wk	142.68	1.00	1,141,440
	Surface fans	1,200.00	$/wk	142.68	2.00	342,432
	Loaders	3,550.00	$/wk	142.68	2.00	1,013,028
	Other surface plant	4,000.00	$/wk	142.68	1.00	570,720

Resource Name	Unit Rate	UOM	Unit Quantity	Resource Quantity	Total
Tunnel C/A system	62,000.00	$/wk	142.68	1.00	8,846,160
					$78,033,495
Consumables					
Electrical power	0.15	$/kwh	23,974.00	3,000.00	10,788,300
Gas oil	1.20	$/L	48,000.00	1.00	57,600
Lubrication materials	140.00	$/wk	142.68	1.00	19,975
TBM spares, cutters	390.00	$/m	15,000.00	1.00	5,850,000
Filters etc.	465.00	$/wk	142.68	1.00	66,346
Hydraulic oil	7.00	$/L	32,000.00	1.00	224,000
Other consumables	200.00	$/wk	142.68	1.00	28,536
Tail seal grease	200.00	$/m	15,000.00	1.00	3,000,000
					$20,034,757
Materials					
Concrete lining rings	10,066.82	$/Nr	10,000.00	1.00	100,668,182
Gaskets	170.00	$/m	15,000.00	1.00	2,550,000
Bolts	20.00	$/Nr	1,765.00	30.00	1,059,000
Grout	220.00	$/m3	39,584.00	1.00	8,708,480
Grout plugs	0.80	$/Nr	1,765.00	7.00	9,884
Packers	15.00	$/Nr	3,633.00	12.00	653,940
Temporary materials	3,000.00	$/wk	142.68	1.00	428,040
Other materials	0.00	$/t	0.00	1.00	0
					$114,077,526
Subcontracts					
Soil disposal	25.00	$/m3	851,175.00	1.50	31,919,063
					$31,919,063

Total Estimated Cost:	$297,465,967
Total Estimated Cost per Metre:	$19,831
Total Estimated Cost per Week:	$2,084,902
Total Estimated Cost per Shift:	$99,264

Estimate Definition ID: 7816

Estimated by: ____________

Checked by: ____________

APPENDIX D

Operating and Maintenance Costs

APPENDIX D1

Road Tunnel

Appendix D1-1

Road Tunnel - Single Bore
Operating and Maintenance Costs

Estimate of annual operating costs

A. Management and operation of tunnel control building

1. Manager (Assume 1 individual in full time management position)

Manager	2080	hrs/yr @	120	$/hr=	$	249600	/yr

2. Office assistants (assume 2 full time office assistants)

Office staff	4160	hrs/yr @	70	$/hr=	$	291200	/yr

3. Cleaners (assume 2 full time cleaners 5 days per week)

Cleaners	4160	hrs/yr @	50	$/hr=	$	208000	/yr
				Sub-total A - $		748800	/yr

B. Traffic Supervision Costs

1. Closed circuit TV system cost= $	1,115,000						
	written-off over	40	years = $			27875	/yr

2. Monitoring staff (assume full time monitoring by 2 persons 24 hours per day

CCTV personnel	17472	hrs/yr @	60	$/hr=	$	1048320	/yr
				Sub-total B - $		1076195	/yr

C. Emergency Truck Costs

1. Assume 1 truck and each replaced every 15 years

Emergency truck costs= $	70000						
	written-off over	15	years = $			4666.7	/yr

2. Truck operators (assume 2 persons for each truck 24 hours per day)

Truck operators	34944	hrs/yr @	68	$/hr=	$	2376192	/yr

3. Truck maintenance and fuel

				Allow $		20000	/yr
				Sub-total C - $		2,400,858.7	/yr

Estimate of annual operating costs

D. Energy Costs

2.7 kilometre long twin bore Eisenhower Highway Tunnel on I70 in Colorado has annual electricity bill of $840,000

Assume energy costs largely governed by tunnel length

For	21	km long tunnel	Lane factor=	0.25
		Energy cost - $	816666.67	
		Sub-total D - $	816667	/yr

Total Operating Cost - $ $ 5,042,520 /yr

Estimate of annual maintenance costs

A. Electrical Maintenance Costs

1. Labour (Assume equivalent of 1 electrician present at all times)

Electrician 1	8736	hrs/yr @	84	$/hr=	$	733824	/yr

2. Materials/replacement of equipment (assume electrical equipment replaced once every 40 years)

Electrical equipment cost= $	7035000	(sub-station, generators, etc.)		
written-off over	40	years = $	175875	/yr
Fire suppression equipment cost= $	4000000			
written-off over	40	years = $	100000	/yr
Signalling equipment cost= $	0			
written-off over	40	years = $	0	/yr
Gas detection equipment cost= $	945000			
written-off over	40	years = $	23625	/yr

3. Platform truck for replacing lights etc.

Platform truck= $	60000			
written-off over	15	years = $	4000.00	/yr

4. Platform truck maintenance and fuel

Allow $	5000	/yr
Sub-total A - $	1042324	/yr

B. Mechanical Maintenance Costs

1. Labour (Assume equivalent of 1 mechanic/maintenance technician present at all times)

Mechanic	8736	hrs/yr @	70	$/hr=	$	611520	/yr

2. Materials/replacement of equipment (assume mechanical equipment replaced every 40 years)

Ventilation equipment cost= $	6000000			
written-off over	40	years = $	150000	/yr

3. Van for use by the mechanical/electrical maintenance staff (assume 1 no.)

Maintenance van= $	25000			
written-off over	8	years = $	3125	/yr

Estimate of annual maintenance costs

B. Mechanical Maintenance Costs contd.

4. Van maintenance and fuel

Allow $ 5000 /yr

Sub-total B - $ 769645 /yr

C. Structure Maintenance Costs

1. Inspection (assume 3 persons inspection crew for 5 weeks once every 4 years)

Senior engineer	50	hrs/yr @	150	$/hr=	$	7500	/yr
Engineer 1	50	hrs/yr @	120	$/hr=	$	6000	/yr
Engineer 2	50	hrs/yr @	120	$/hr=	$	6000	/yr

2. Tunnel cleaning and maintenance (assume 4 persons crew on single shift basis throughout year)

Labourers	11648	hrs/yr @	65	$/hr=	$	757120	/yr

3. Street cleaner vehicle

Street cleaner vehicle= $ 65000
written-off over 15 years = $ 4333.3 /yr

4. Street cleaner vehicle maintenance and fuel

Allow $ 5000 /yr

5. Washer truck

Washing truck= $ 40000
written-off over 15 years = $ 2666.7 /yr

6. Washer truck maintenance and fuel

Allow $ 5000 /yr

Sub-total C - $ 793620 /yr

Total Maintenance Cost - $ $ 2,605,589 /yr

Appendix D1-2

Road Tunnel - Twin Bore
Operating and Maintenance Costs

Estimate of annual operating costs

A. Management and operation of tunnel control building

1. Manager (Assume 1 individual in full time management position)

Manager	2080	hrs/yr @	120	$/hr=	$	249600	/yr

2. Office assistants (assume 2 full time office assistants)

Office staff	4160	hrs/yr @	70	$/hr=	$	291200	/yr

3. Cleaners (assume 2 full time cleaners 5 days per week)

Cleaners	4160	hrs/yr @	50	$/hr=	$	208000	/yr
				Sub-total A - $		748800	/yr

B. Traffic Supervision Costs

1. Closed circuit TV system cost= $ 2230000
written-off over 40 years = $ 55750 /yr

2. Monitoring staff (assume full time monitoring by 2 persons 24 hours per day

CCTV personnel	34944	hrs/yr @	60	$/hr=	$	2096640	/yr
				Sub-total B - $		2152390	/yr

C. Emergency Truck Costs

1. Assume 1 truck and each replaced every 15 years

Emergency truck costs= $ 70000
written-off over 15 years = $ 4666.7 /yr

2. Truck operators (assume 2 persons for each truck 24 hours per day)

Truck operators	34944	hrs/yr @	68	$/hr=	$	2376192	/yr

3. Truck maintenance and fuel

Allow $ 20000 /yr

Sub-total C - $ 2,400,858.7 /yr

Estimate of annual operating costs

D. Energy Costs

2.7 kilometre long twin bore Eisenhower Highway Tunnel on I70 in Colorado has annual electricity bill of $840,000

Assume energy costs largely governed by tunnel length

For	42	km long tunnel	Lane factor=	0.25
		Energy cost - $	1633333.333	
		Sub-total D - $	1633333	/yr

Total Operating Cost - $ $ 6,935,382 /yr

TBM Bored Highway Tunnel

Estimate of annual maintenance costs

A. Electrical Maintenance Costs

1. Labour (Assume equivalent of 1 electrician present at all times)

Electrician 1	17472	hrs/yr @	84	$/hr=	$	1467648	/yr

2. Materials/replacement of equipment (assume electrical equipment replaced once every 40 years)

Electrical equipment cost= $	14070000		(sub-station, generators, etc.)		
written-off over		40	years = $	351750	/yr
Fire suppression equipment cost= $	8000000				
written-off over		40	years = $	200000	/yr
Signalling equipment cost= $	0				
written-off over		40	years = $	0	/yr
Gas detection equipment cost= $	1890000				
written-off over		40	years = $	47250	/yr

3. Platform truck for replacing lights etc.

Platform truck= $	60000				
written-off over		15	years = $	4000.00	/yr

4. Platform truck maintenance and fuel

Allow $	5000	/yr
Sub-total A - $	2075648	/yr

B. Mechanical Maintenance Costs

1. Labour (Assume equivalent of 1 mechanic/maintenance technician present at all times)

Mechanic	17472	hrs/yr @	70	$/hr=	$	1223040	/yr

2. Materials/replacement of equipment (assume mechanical equipment replaced every 40 years)

Ventilation equipment cost= $	12000000				
written-off over		40	years = $	300000	/yr

3. Van for use by the mechanical/electrical maintenance staff (assume 1 no.)

Maintenance van= $	25000				
written-off over		8	years = $	3125	/yr

Estimate of annual maintenance costs

B. Mechanical Maintenance Costs contd.

4. Van maintenance and fuel

Allow $ 5000 /yr

Sub-total B - $ 1531165 /yr

C. Structure Maintenance Costs

1. Inspection (assume 3 persons inspection crew for 5 weeks once every 4 years)

Senior engineer	100	hrs/yr @	150	$/hr=	$	15000	/yr
Engineer 1	100	hrs/yr @	120	$/hr=	$	12000	/yr
Engineer 2	100	hrs/yr @	120	$/hr=	$	12000	/yr

2. Tunnel cleaning and maintenance (assume 4 persons crew on single shift basis throughout year)

Labourers	23296	hrs/yr @	65	$/hr=	$	1514240	/yr

3. Street cleaner vehicle

Street cleaner vehicle= $ 65000
written-off over 15 years = $ 4333.3 /yr

4. Street cleaner vehicle maintenance and fuel

Allow $ 5000 /yr

5. Washer truck

Washing truck= $ 40000
written-off over 15 years = $ 2666.7 /yr

6. Washer truck maintenance and fuel

Allow $ 5000 /yr

Sub-total C - $ 1570240 /yr

Total Maintenance Cost - $ $ 5,177,053 /yr

APPENDIX D2

Rail Tunnel – Single Bore
Operating and Maintenance Costs

Rail Tunnel

Estimation of annual operating and maintenance costs

A. Energy Costs

1. Tunnel lighting	3000000	kWh/yr @	0.1	$/kWh=	$	300000	/yr
2. Ventilation fans	400000	kWh/yr @	0.1	$/kWh=	$	40000	/yr
3. Sump pumps	20000	kWh/yr @	0.1	$/kWh=	$	2000	/yr
				Sub-total A -	$	**342,000**	/yr

B. Electrical Maintenance Costs

1. Labour (Assume 1 electricians for 5 days per week throughout year)

Electrician 1	2080	hrs/yr @	84	$/hr=	$	174720	/yr

2. Materials/replacement of equipment (assume electrical equipment replaced once every 40 years)

Electrical equipment cost=	$ 1000000					
	written-off over	40	years =	$	25000	/yr
			Sub-total B -	$	**199,720**	/yr

C. Mechanical Maintenance Costs

1. Labour (Assume 1 mechanic/maintenance technician for 5 days per week throughout year)

Mechanic	2080	hrs/yr @	70	$/hr=	$	145600	/yr

2. Materials/replacement of equipment (assume mechanical equipment replaced every 40 years)

Ventilation system cost=	$ 1000000					
	written-off over	40	years =	$	25000	/yr
Emergency generators=	$ 500000					
	written-off over	40	years =	$	12500	/yr
Drainage pumps cost=	$ 200000					
	written-off over	40	years =	$	5000	/yr
			Sub-total C -	$	**188,100**	/yr

contd.

Estimation of annual operating costs

D. Structure Maintenance Costs

1. Inspection (assume 3 person inspection crew for 10 weeks once every 4 years)

Senior engineer	100	hrs/yr @	150	$/hr=	$	15000	/yr
Engineer 1	100	hrs/yr @	120	$/hr=	$	12000	/yr
Engineer 2	100	hrs/yr @	120	$/hr=	$	12000	/yr

2. Tunnel Cleaning (Assume 4 person crew for 13 weeks once a year)

Labourers	2080	hrs/yr @	65	$/hr=	$	135200	/yr

3. Sump clean-up (Assume 2 person crew for 2 days twice a year)

Labourers	64	hrs/yr @	65	$/hr=	$	4160	/yr

4. Structure maintenance (Assume 4 person crew for 13 weeks once a year)

Labourers	2080	hrs/yr @	65	$/hr=	$	135200	/yr

5. Permanent Way Inspection (Assume 2 persons inspect track 3 times per week)

Labourers	312	hrs/yr @	65	$/hr=	$	20280	/yr

6. Permanent way maintenance (Assume 4 person crew for 12 weeks once a year)

Labourers	1920	hrs/yr @	65	$/hr=	$	124800	/yr
				Sub-total D -	$	280280	/yr

Total estimated maintenance cost=$ 1,010,100 /yr

Newfoundland Fixed Link
Rail System - Estimation of Annual Operating Cost

Item **Annual Cost**

Assumptions:

Facility operates 12 hours/day. 7 days/week 50% of this time the facility is fully staffed with toll collectors the remainder of the time only I toll booth is operating on each side.

A	**Salaried Staff**	Mult.	Unit	Rate	
	Tunnel Manager	1.4	Year	100,000	140,000
	Tunnel Operator	1.4	Year	100,000	140,000
	Apprentice Operator	1.4	Year	60,000	84,000
	Site Maintenance Mgr	1.4	Year	50,000	70,000
B	**Hourly Staff**	Quant	Unit	Rate	
	Toll collector-(2FT.4PT, 1PT Spare)	7,000	h	50	350,000
	Site Labour	4,000	h	75	300,000
	Electricians	6,000	h	84	504,000
	Mechanics	6,000	h	70	420,000
	Train Drivers	8,000	h	90	720,000
	Loading supervisor	4,000	h	75	300,000
	Labourers	20,000	h	65	1,300,000
C	**Subcontracted Work**	Quant	Unit	Rate	
	Locomotive maintenance	1	LS	120,000	120,000
	Rolling Stock maintenance	1	LS	25,000	25,000
	Facility cleaning	52	w	250	13,000
	Landscaping	52	w	500	26,000
	Building maintenance	1	LS	10,000	10,000
D	**Power**	Quant	Unit	Rate	
		8922	MWh	60	535,320
E	**Equipment Depreciation (strait-line)**	Life	Unit	Cap.Cost	
	Locomotive (20years)	20	Year	13,750,000	687,500
	Rolling Stock (20years)	20	Year	10,128,421	506,421
	Buildings	30	Year	2,912,000	97,067
	Roads	30	Year	1,250,000	41,667
	Trackwork	25	Year	3,130,000	125,200
	OCS system	15	Year	9,298,814	619,921
	Signal system	15	Year	6,592,000	439,467
	Train loading system	12	Year	500,000	41,667
	Heavy vehicles	12	Year	560,000	46,667
	Light trucks	7	Year	220,000	31,429
	Total Annual Operating Cost of Shuttle Train				**7,694,324**

APPENDIX E

Schedules

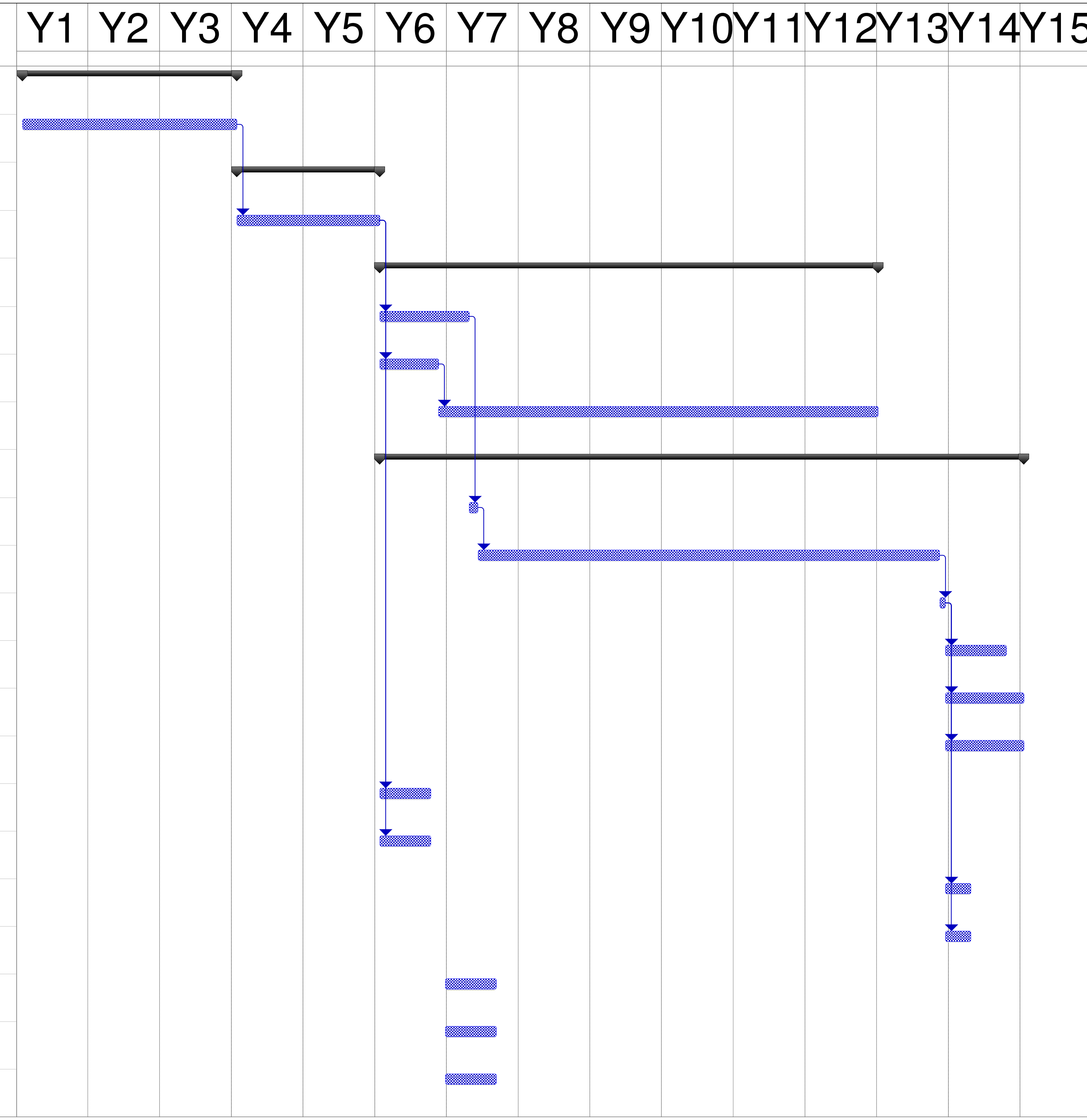
APPENDIX E1

Road Tunnel

Appendix E1-1
Single Bore 1 TBM - Schedule

Newfoundland Fixed Link Pre-feasibility Study
Single Bored - 1TBM Highway Tunnel - Project Timeline

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Planning**	**780 days**	**2/1/18**	**1/27/21**	
2	Planning	780 days	2/1/18	1/27/21	
3	**Design**	**520 days**	**1/28/21**	**1/25/23**	
4	Design	520 days	1/28/21	1/25/23	2
5	**Preliminary Activities**	**1813 days**	**1/26/23**	**1/7/30**	
6	Procure TBM	325 days	1/26/23	4/24/24	4
7	Tunnel liner plant set-up	213 days	1/26/23	11/20/23	4
8	Tunnel liner manufacture	1600 days	11/21/23	1/7/30	7
9	**Construction**	**2343 days**	**1/26/23**	**1/19/32**	
10	Set-up TBM	32 days	4/25/24	6/7/24	6
11	Tunnel drive/maintenance	1680 days	6/10/24	11/15/30	10
12	Remove TBM	21 days	11/18/30	12/16/30	11
13	Tunnel clean up	222 days	12/17/30	10/22/31	12
14	Tunnel finishes	285 days	12/17/30	1/19/32	12
15	Tunnel mechanical Electrical	285 days	12/17/30	1/19/32	12
16	North approach	186 days	1/26/23	10/12/23	4
17	South Approach	186 days	1/26/23	10/12/23	4
18	North Approach Finish	93 days	12/17/30	4/24/31	12
19	South Approach Finish	93 days	12/17/30	4/24/31	12
20	Tunnel Control Building	186 days	12/26/23	9/10/24	
21	North Holding Area & Buildings	186 days	12/26/23	9/10/24	
22	South Holding Area & Buildings	186 days	12/26/23	9/10/24	



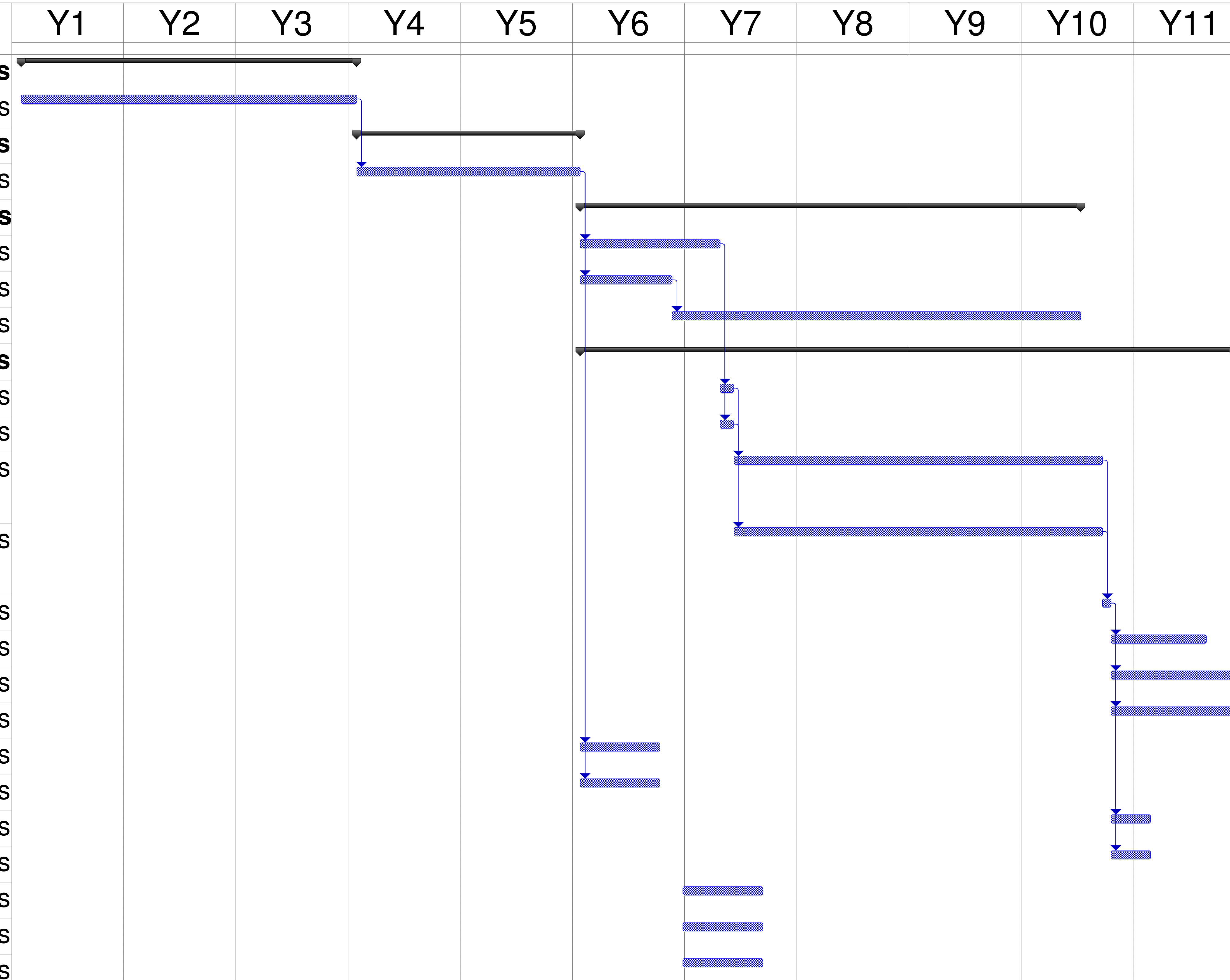
Project: HWY Sg.Bore Tunnel Schedu
Date: 11/15/17

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Progress
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Deadline

Appendix E1-2
Single Bore 2 TBM - Schedule

Newfoundland Fixed Link Pre-feasibility Study
Single Bored - 2TBM Highway Tunnel - Project Timeline

ID	Task Name	Duration
1	**Planning**	**780 days**
2	Planning	780 days
3	**Design**	**520 days**
4	Design	520 days
5	**Preliminary Activities**	**1163 days**
6	Procure TBM 1 and 2	325 days
7	Tunnel liner plant set-up	213 days
8	Tunnel liner manufacture	950 days
9	**Construction**	**1519 days**
10	Set-up TBM Newfoundland	32 days
11	Set-up TBM Labrador	32 days
12	Tunnel drive/maintenance from Newfoundland	857 days
13	Tunnel drive/maintenance from Labrador	857 days
14	Remove TBM 1 and 2	20 days
15	Tunnel clean up	222 days
16	Tunnel finishes	285 days
17	Tunnel mechanical Electrical	285 days
18	North approach	186 days
19	South Approach	186 days
20	North Approach Finish	93 days
21	South Approach Finish	93 days
22	Tunnel Control Building	186 days
23	North Holding Area & Buildings	186 days
24	South Holding Area & Buildings	186 days



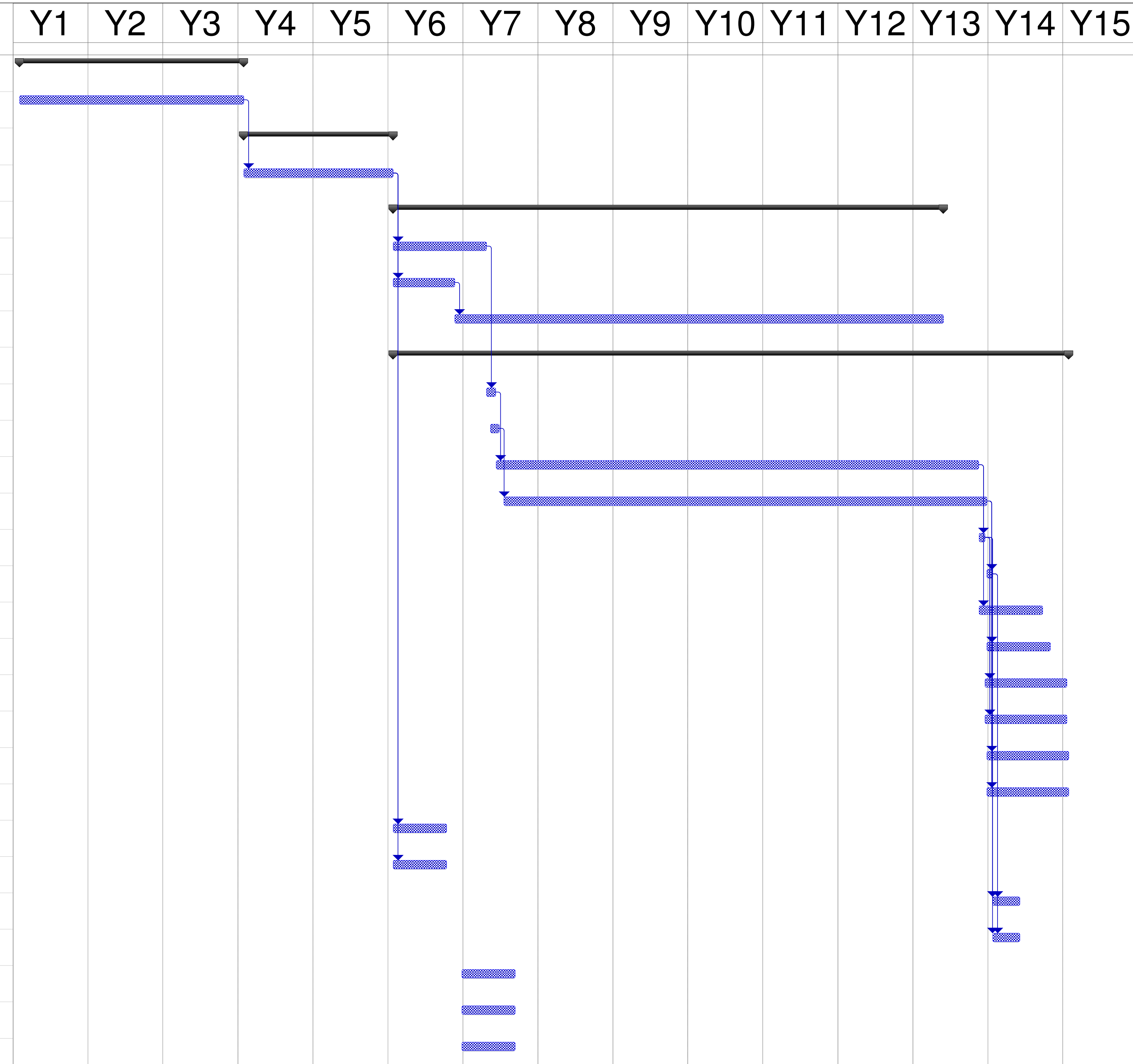
Project: HWY Sg.Bore Tunnel Schedu
Date: 11/15/17

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Progress
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Deadline

Appendix E1-3
Twin Bore 2 TBM - Schedule

Newfoundland Fixed Link Pre-feasibility Study
Twin Bored - 2TBM Highway Tunnel - Project Timeline

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Planning**	**780 days**	**2/1/18**	**1/27/21**	
2	Planning	780 days	2/1/18	1/27/21	
3	**Design**	**520 days**	**1/28/21**	**1/25/23**	
4	Design	520 days	1/28/21	1/25/23	2
5	**Preliminary Activities**	**1913 days**	**1/26/23**	**5/27/30**	
6	Procure TBM	325 days	1/26/23	4/24/24	4
7	Tunnel liner plant set-up	213 days	1/26/23	11/20/23	4
8	Tunnel liner manufacture	1700 days	11/21/23	5/27/30	7
9	**Construction**	**2350 days**	**1/26/23**	**1/28/32**	
10	Set-up TBM 1	32 days	4/25/24	6/7/24	6
11	Set-up TBM 2	32 days	5/13/24	6/25/24	
12	Tunnel drive 1/maintenance	1680 days	6/10/24	11/15/30	10
13	Tunnel drive 2/maintenance	1680 days	7/18/24	12/25/30	11
14	Remove TBM 1	21 days	11/18/30	12/16/30	12
15	Remove TBM 2	21 days	12/26/30	1/23/31	13
16	Tunnel clean up 1	222 days	11/18/30	9/23/31	12
17	Tunnel clean up 2	222 days	12/26/30	10/31/31	13
18	Tunnel finishes 1	285 days	12/17/30	1/19/32	14
19	Tunnel finishes 2	285 days	12/17/30	1/19/32	14
20	Tunnel mechanical Electrical 1	285 days	12/26/30	1/28/32	13
21	Tunnel mechanical Electrical 2	285 days	12/26/30	1/28/32	13
22	North approach	186 days	1/26/23	10/12/23	4
23	South Approach	186 days	1/26/23	10/12/23	4
24	North Approach Finish	93 days	1/24/31	6/3/31	15,14
25	South Approach Finish	93 days	1/24/31	6/3/31	15,14
26	Tunnel Control Building	186 days	12/26/23	9/10/24	
27	North Holding Area & Buildings	186 days	12/26/23	9/10/24	
28	South Holding Area & Buildings	186 days	12/26/23	9/10/24	



Project: HWY Sg.Bore Tunnel Schedu
Date: 11/15/17

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Progress | Deadline

APPENDIX E2

Rail Tunnel

Appendix E2-1
Single Bore 1 TBM - Schedule

Newfoundland Fixed Link Pre-feasibility Study
Single Bored - 1TBM Rail Tunnel - Project Timeline

ID	Task Name	Duration
1	**Planning**	**780 days**
2	Planning	780 days
3	**Design**	**520 days**
4	Design	520 days
5	**Preliminary Activities**	**1993 days**
6	Procure TBM	325 days
7	Tunnel liner plant set-up	213 days
8	Tunnel liner manufacture	1780 days
9	**Construction**	**2662 days**
10	Set-up TBM	32 days
11	Tunnel drive/maintenance	1846 days
12	Remove TBM	21 days
13	Tunnel invert,Rail & Finishes	438 days
14	Tunnel mechanical Electrical	438 days
15	North approach	186 days
16	South Approach	186 days
17	North Approach Finish	186 days
18	South Approach Finish	186 days
19	North rail depot	371 days
20	South rail depot	371 days

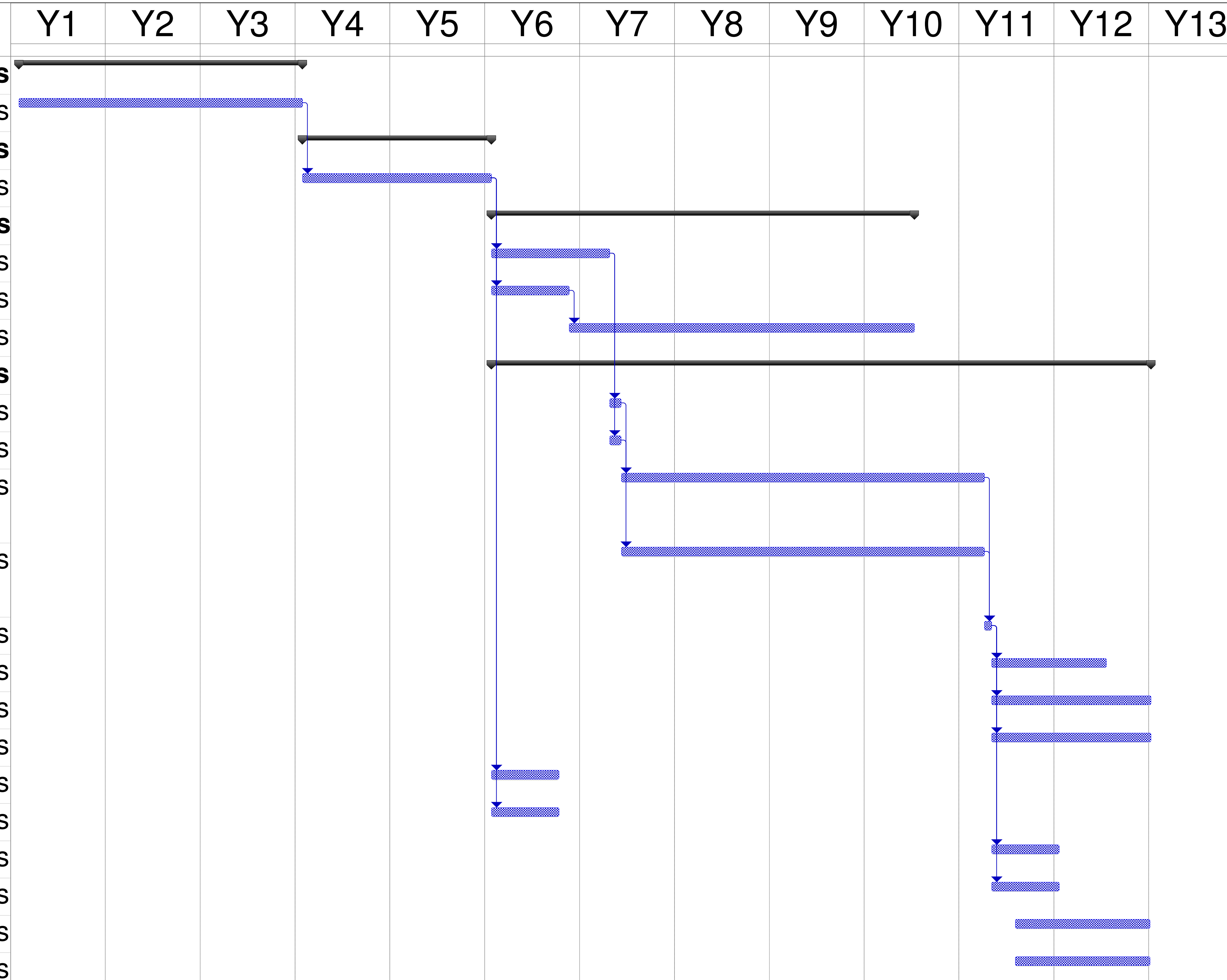
Project: E2.1 Single Bore - 1TBM - Sc

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Progress
Split	External Tasks	Inactive Summary	Manual Summary	Deadline
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Appendix E2-2
Single Bore 2 TBM - Schedule

Newfoundland Fixed Link Pre-feasibility Study
Single Bored - 2TBM Rail Tunnel - Project Timeline

ID	Task Name	Duration
1	**Planning**	**780 days**
2	Planning	780 days
3	**Design**	**520 days**
4	Design	520 days
5	**Preliminary Activities**	**1163 days**
6	Procure TBM 1 and 2	325 days
7	Tunnel liner plant set-up	213 days
8	Tunnel liner manufacture	950 days
9	**Construction**	**1814 days**
10	Set-up TBM Newfoundland	32 days
11	Set-up TBM Labrador	32 days
12	Tunnel drive/maintenance from Newfoundland	999 days
13	Tunnel drive/maintenance from Labrador	999 days
14	Remove TBM 1 and 2	20 days
15	Tunnel clean up	316 days
16	Tunnel invert, Rail & Finishes	438 days
17	Tunnel mechanical Electrical	438 days
18	North Approach	186 days
19	South Approach	186 days
20	North Approach Finish	186 days
21	South Approach Finish	186 days
22	North rail depot	371 days
23	South rail depot	371 days



Project: E2.2 Single Bore - 2TBM - Sc
Date: 11/16/17

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Progress | Deadline

APPENDIX F

Economic and Financial Analysis – Rail Tunnel

APPENDIX F1

Rail Tunnel, 1 TBM
Economic and Financial Analysis

Appendix F1-1
Rail Tunnel, 1 TBM, 100% Tolls

Economic Analysis - Option 1 TBM 100% Tolls - Rail Tunnel

		Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction
				-1	0	1	2	3	4	5	6
Traffic											
	Existing Belle Isle Ferry			May - October							
		Passengers	7,264,069	83815	85910	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	3,102,537	35798	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%										
		Passengers	1,679,732	0	0	0	0	0	0	0	0
		Passenger Vehicles	717,426	0	0	0	0	0	0	0	0
		Commercial Vehicles	362,320	0	0	0	0	0	0	0	0
	Existing Gulf Ferries										
		Passengers	5,108,158	328528	325243	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	2,029,562	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	5,257,283	267274	271550	275895	280310	284794	289351	293981	298684
	Diversion from Gulf Ferries (40%)										
		Passengers	4,863,198	0	0	0	0	0	0	0	0
		Passenger Vehicles	1,932,235	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,147,535	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)										
		Passengers	7,294,797	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,898,352	0	0	0	0	0	0	0	0
		Commercial Vehicles	9,221,302	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)										
		Passengers	12,142,036	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,041,080	0	0	0	0	0	0	0	0
		Commercial Vehicles	7,717,589	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)										
		Passengers	14,573,635	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,007,197	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,791,357	0	0	0	0	0	0	0	0
Revenue											
	Total Revenue for Fixed Link (40%)										
		Passengers	137,205,011	0	0	0	0	0	0	0	0
		Passenger Vehicles	240,232,664	0	0	0	0	0	0	0	0
		Commercial Vehicles	931,898,918	0	0	0	0	0	0	0	0
		Total	**1,309,336,593**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)										
		Passengers	164,682,079	0	0	0	0	0	0	0	0
		Passenger Vehicles	286,272,989	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,303,056,336	0	0	0	0	0	0	0	0
		Total	**1,754,011,404**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link										
		Operating Cost	261,132,720	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link										
		Net Revenue (40%)	1,048,203,873	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,492,878,684	0	0	0	0	0	0	0	0
		Net Present Value(40%)	118,545,917								
		Net Present Value(60%)	170,605,924								
		Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving										
		Net Revenue (40%)	1,288,203,873	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,732,878,684	0	0	0	0	0	0	0	0
		Net Present Value(40%)	150,477,991	0	0	0	0	0	0	0	0
		Net Present Value(60%)	202,537,998	0	0	0	0	0	0	0	0
	Total Capital Cost										
		Net Cost ($2017)	1,674,907,430			**17000000**	**3000000**	**3000000**	**35297167**	**35297167**	**103393670**
		Net Present Value ($2017)	795,191,025			**15813953**	**2595998**	**2414882**	**26430537**	**24586546**	**66995120**
Economic Analysis											
	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(676,645,108)								
		NPV Cash Flows ($2017) (60%)	(624,585,101)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(626,703,558)			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(40%)	-2.04%								
		Benefit/Cost Ratio(40%)	0.63								
		Fixed Link Cash Flow (60%)	(182,028,746)			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(60%)	-0.52%								
		Benefit/Cost Ratio(60%)	0.89								
Economic Analysis											
	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(644,713,034)								
		NPV Cash Flows ($2017) (60%)	(592,653,028)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(386,703,558)			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(40%)	-1.18%								
		Benefit/Cost Ratio(40%)	0.77								
		Fixed Link Cash Flow (60%)	57,971,254			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(60%)	0.16%								
		Benefit/Cost Ratio(60%)	1.03								

Financial Analysis - Option 1 TBM 100% Tolls - Rail Tunnel

		Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction
				-1	0	1	2	3	4	5	6
Financing During Construction	**40% Diversion Case**	Project Cost ($2017)				-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		Nominal Value				-17425000	-3151875	-3230672	-38961468	-39935505	-119904959
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**			-17425000	-21012500	-25215000	-65356451	-107585742	-231871600
		Interest During Construction	**(578,132,766)**			-435625	-971828	-1179983	-2293786	-4380899	-8595956
		Project Cost ($2017)	**(2,188,402,857)**								
	60% Diversion Case	Project Cost ($2017)				-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		Nominal Value				-17425000	-3151875	-3230672	-38961468	-39935504.64	-119904959
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**			-17425000	-21012500	-25215000	-65356451	-107585742	-231871600
		Interest During Construction	**(578,132,766)**			-435625	-971828	-1179983	-2293786	-4380899	-8595956
		Project Cost ($2017)	**(2,188,402,857)**								
Financing Base Case	**40% Diversion Case**										
	Project Cost	Pre operations cost	2,188,402,857								
		Interest during Construction	578,132,766								
	Total Amount to Finance		**2,766,535,623**								
		Annual Debt Amortization (CRF)	**$ (305,780,981)**								
		Net Cash Flow									
		IRR excluding IDC	**0.41%**								
	60% Diversion Case										
	Project Cost	Pre operations cost	2,188,402,857								
		Interest during Construction	578,132,766								
	Total Amount to Finance		**2,766,535,623**								
		Annual Debt Amortization (CRF)	**$ (305,780,981)**								
		Net Cash Flow									
		IRR excluding IDC	**1.97%**								
Subsidised Financing	**40% Diversion Case**	Project Spending	2188402857			17425000	3151875	3230672	38961468	39935505	119904959
		Grant Award	1595000000			17425000	3151875	3230672	38961468	39935505	119904959
		Cost less Grant	593402857			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**632,767,312**			0	0	0	0	0	0
		Interest During Construction	**39,364,455**			0	0	0	0	0	0
		Project Cost ($2017)	**593,402,857**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0
	60% Diversion Case	Project Spending	2188402857			17425000	3151875	3230672	38961468	39935505	119904959
		Grant Award	1370000000			17425000	3151875	3230672	38961468	39935505	119904959
		Cost less Grant	818402857			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**892,476,665**			0	0	0	0	0	0
		Interest During Construction	**74,073,808**			0	0	0	0	0	0
		Project Cost ($2017)	**818,402,857**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0

Variables - Option 1 TBM 100% Tolls - Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,595	$1,370	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$11.30	$11.30	
Per passenger vehicle	$47.66	$47.66	
Per commercial vehicle	$120.75	$120.75	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix F1-2
Rail Tunnel, 1 TBM, 150% Tolls

Economic Analysis - Option 1 TBM 150% Tolls - Rail Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Traffic	Existing Belle Isle Ferry	Passengers	7,264,069	May - October 83615	85919	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	3,102,537	35790	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%	Passengers	1,679,732	0	0	0	0	0	0	0	0
		Passenger Vehicles	717,426	0	0	0	0	0	0	0	0
		Commercial Vehicles	362,320	0	0	0	0	0	0	0	0
	Existing Gulf Ferries	Passengers	5,108,158	328528	325243	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	2,029,562	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	5,257,283	267274	273550	275895	280310	284759	289351	293981	298684
	Diversion from Gulf Ferries (40%)	Passengers	4,863,198	0	0	0	0	0	0	0	0
		Passenger Vehicles	1,932,235	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,147,335	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)	Passengers	7,294,797	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,898,352	0	0	0	0	0	0	0	0
		Commercial Vehicles	9,221,302	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)	Passengers	12,142,036	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,041,080	0	0	0	0	0	0	0	0
		Commercial Vehicles	7,717,589	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)	Passengers	14,573,635	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,007,197	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,791,357	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)	Passengers	205,807,516	0	0	0	0	0	0	0	0
		Passenger Vehicles	360,348,996	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,397,848,377	0	0	0	0	0	0	0	0
		Total	**1,964,004,889**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)	Passengers	247,023,119	0	0	0	0	0	0	0	0
		Passenger Vehicles	429,409,483	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,954,584,504	0	0	0	0	0	0	0	0
		Total	**2,631,017,106**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	261,132,720	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	1,702,872,169	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,369,884,386	0	0	0	0	0	0	0	0
		Net Present Value(40%)	195,190,771								
		Net Present Value(60%)	273,280,780								
		Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	1,942,872,169	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,609,884,386	0	0	0	0	0	0	0	0
		Net Present Value(40%)	227,122,844	0	0	0	0	0	0	0	0
		Net Present Value(60%)	305,212,854	0	0	0	0	0	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	1,674,907,430			**17000000**	**3000000**	**3000000**	**35297167**	**35297167**	**103393670**
		Net Present Value ($2017)	795,191,025			**15813953**	**2595998**	**2414882**	**26430537**	**24586546**	**66995120**
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(600,000,255)								
		NPV Cash Flows ($2017) (60%)	(521,910,245)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	27,964,739			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(40%)	0.08%								
		Benefit/Cost Ratio(40%)	1.02								
		Fixed Link Cash Flow (60%)	694,976,956			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(60%)	1.64%								
		Benefit/Cost Ratio(60%)	1.41								
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(568,068,181)								
		NPV Cash Flows ($2017) (60%)	(489,978,171)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	267,964,739			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(40%)	0.69%								
		Benefit/Cost Ratio(40%)	1.16								
		Fixed Link Cash Flow (60%)	934,976,956			-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		IRR(60%)	2.14%								
		Benefit/Cost Ratio(60%)	1.56								

Financial Analysis - Option 1 TBM 150% Tolls - Rail Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Financing During Construction	40% Diversion Case	Project Cost ($2017)				-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		Nominal Value				-17425000	-3151875	-3230672	-38961468	-39935505	-119904959
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**			-17425000	-21012500	-25215000	-65356451	-107585742	-231871600
		Interest During Construction	**(578,132,766)**			-435625	-971828	-1179983	-2293786	-4380899	-8595956
		Project Cost ($2017)	**(2,188,402,857)**								
	60% Diversion Case	Project Cost ($2017)				-17000000	-3000000	-3000000	-35297167	-35297167	-103393670
		Nominal Value				-17425000	-3151875	-3230672	-38961468	-39935504.64	-119904959
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**			-17425000	-21012500	-25215000	-65356451	-107585742	-231871600
		Interest During Construction	**(578,132,766)**			-435625	-971828	-1179983	-2293786	-4380899	-8595956
		Project Cost ($2017)	**(2,188,402,857)**								
Financing Base Case	40% Diversion Case / Project Cost	Pre operations cost	2,188,402,857								
		Interest during Construction	578,132,766								
	Total Amount to Finance		**2,766,535,623**								
		Annual Debt Amortization (CRF)	$ **(305,780,981)**								
		Net Cash Flow									
		IRR excluding IDC	**2.58%**								
	60% Diversion Case / Project Cost	Pre operations cost	2,188,402,857								
		Interest during Construction	578,132,766								
	Total Amount to Finance		**2,766,535,623**								
		Annual Debt Amortization (CRF)	$ **(305,780,981)**								
		Net Cash Flow									
		IRR excluding IDC	**4.18%**								
Subsidised Financing	40% Diversion Case	Project Spending	2188402857			17425000	3151875	3230672	38961468	39935505	119904959
		Grant Award	1279000000			17425000	3151875	3230672	38961468	39935505	119904959
		Cost less Grant	909402857			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**1,002,934,709**			0	0	0	0	0	0
		Interest During Construction	**93,531,852**			0	0	0	0	0	0
		Project Cost ($2017)	**909,402,857**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0
	60% Diversion Case	Project Spending	2188402857			17425000	3151875	3230672	38961468	39935505	119904959
		Grant Award	1010000000			17425000	3151875	3230672	38961468	39935505	119904959
		Cost less Grant	1178402857			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**1,355,052,981**			0	0	0	0	0	0
		Interest During Construction	**176,650,124**			0	0	0	0	0	0
		Project Cost ($2017)	**1,178,402,857**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0

Variables - Option 1 TBM 150% Tolls - Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,279	$1,010	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$16.95	$16.95	
Per passenger vehicle	$71.48	$71.48	
Per commercial vehicle	$181.13	$181.13	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel Surcharge**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix F1-3
Rail Tunnel, 1 TBM, 200% Tolls

Economic Analysis - Option 1 TBM 200% Tolls - Rail Tunnel

Columns: 2016 = −1, 2017 = 0; Phase 1 - Planning Approval = years 1–3; Phase 2 - Design = years 4–5; Phase 3 - Construction = years 6–15; Phase 4 - Operation = years 16–45.

Section	Item	Totals	-1 (2016)	0 (2017)	1	2	3	4	5
Traffic									
Existing Belle Isle Ferry			May - October						
	Passengers	7,264,069	83815	85910	88058	90260	92516	94829	97200
	Passenger Vehicles	3,102,537	35798	36693	37610	38551	39514	40502	41515
	Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966
One Time Surge 30%	Passengers	1,679,732	0	0	0	0	0	0	0
	Passenger Vehicles	717,426	0	0	0	0	0	0	0
	Commercial Vehicles	362,320	0	0	0	0	0	0	0
Existing Gulf Ferries	Passengers	5,108,158	328528	325243	321990	318770	315583	312427	309303
	Passenger Vehicles	2,029,562	130530	129225	127932	126653	125387	124133	122891
	Commercial Vehicles	5,257,283	267274	271550	275895	280310	284794	289351	293981
Diversion from Gulf Ferries (40%)	Passengers	4,863,198	0	0	0	0	0	0	0
	Passenger Vehicles	1,932,235	0	0	0	0	0	0	0
	Commercial Vehicles	6,147,535	0	0	0	0	0	0	0
Diversion from Gulf Ferries (60%)	Passengers	7,294,797	0	0	0	0	0	0	0
	Passenger Vehicles	2,898,352	0	0	0	0	0	0	0
	Commercial Vehicles	9,221,302	0	0	0	0	0	0	0
Total Traffic for Fixed Link (40%)	Passengers	12,142,036	0	0	0	0	0	0	0
	Passenger Vehicles	5,041,080	0	0	0	0	0	0	0
	Commercial Vehicles	7,717,589	0	0	0	0	0	0	0
Total Traffic for Fixed Link (60%)	Passengers	14,573,635	0	0	0	0	0	0	0
	Passenger Vehicles	6,007,197	0	0	0	0	0	0	0
	Commercial Vehicles	10,791,357	0	0	0	0	0	0	0
Revenue									
Total Revenue for Fixed Link (40%)	Passengers	274,410,021	0	0	0	0	0	0	0
	Passenger Vehicles	480,465,329	0	0	0	0	0	0	0
	Commercial Vehicles	1,863,797,836	0	0	0	0	0	0	0
	Total	**2,618,673,185**	0	0	0	0	0	0	0
Total Revenue for Fixed Link (60%)	Passengers	329,364,158	0	0	0	0	0	0	0
	Passenger Vehicles	572,545,978	0	0	0	0	0	0	0
	Commercial Vehicles	2,606,112,671	0	0	0	0	0	0	0
	Total	**3,508,022,808**	0	0	0	0	0	0	0
Total Operating Costs for Fixed Link	Operating Cost	261,132,720	0	0	0	0	0	0	0
Total Net Revenue for Fixed Link	Net Revenue (40%)	2,357,540,465	0	0	0	0	0	0	0
	Net Revenue (60%)	3,246,890,088	0	0	0	0	0	0	0
	Net Present Value(40%)	271,835,624							
	Net Present Value(60%)	375,955,636							
	Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0
Total Net Revenue including subsidy saving	Net Revenue (40%)	2,597,540,465	0	0	0	0	0	0	0
	Net Revenue (60%)	3,486,890,088	0	0	0	0	0	0	0
	Net Present Value(40%)	303,767,698	0	0	0	0	0	0	0
	Net Present Value(60%)	407,887,710	0	0	0	0	0	0	0
Total Capital Cost	Total Cost ($2017)	1,674,907,430			**17000000**	**3000000**	**3000000**	**35297167**	**35297167**
	Net Present Value ($2017)	795,191,025			**15813953**	**2595998**	**2414882**	**26430537**	**24586546**
Economic Analysis									
Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(523,335,401)							
	NPV Cash Flows ($2017) (60%)	(419,235,389)							
Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	682,633,035			-17000000	-3000000	-3000000	-35297167	-35297167
	IRR(40%)	1.62%							
	Benefit/Cost Ratio(40%)	1.41							
	Fixed Link Cash Flow (60%)	1,571,982,658			-17000000	-3000000	-3000000	-35297167	-35297167
	IRR(60%)	3.24%							
	Benefit/Cost Ratio(60%)	1.94							
Economic Analysis									
Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(491,423,328)							
	NPV Cash Flows ($2017) (60%)	(387,303,315)							
Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	922,633,035			-17000000	-3000000	-3000000	-35297167	-35297167
	IRR(40%)	2.11%							
	Benefit/Cost Ratio(40%)	1.55							
	Fixed Link Cash Flow (60%)	1,811,982,658			-17000000	-3000000	-3000000	-35297167	-35297167
	IRR(60%)	3.64%							
	Benefit/Cost Ratio(60%)	2.08							

Phase 3 - Construction (years 6–15):

Item	6	7	8	9	10	11	12	13	14	15
Belle Isle Ferry – Passengers	99630	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Belle Isle Ferry – Passenger Vehicles	42553	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Belle Isle Ferry – Commercial Vehicles	21490	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Surge 30% – Passengers	0	0	0	0	0	0	0	0	0	0
Surge 30% – Passenger Vehicles	0	0	0	0	0	0	0	0	0	0
Surge 30% – Commercial Vehicles	0	0	0	0	0	0	0	0	0	0
Gulf Ferries – Passengers	306210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gulf Ferries – Passenger Vehicles	121662	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gulf Ferries – Commercial Vehicles	298684	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion 40% / Diversion 60% / Total Traffic 40% / Total Traffic 60% (all rows)	0	0	0	0	0	0	0	0	0	0
Revenue 40% / 60% (all rows), Operating Cost, Net Revenue 40% / 60%, Ferry Subsidy Saving, Net Revenue incl. subsidy 40% / 60%, NPV incl. subsidy 40% / 60%	0	0	0	0	0	0	0	0	0	0
Total Cost ($2017)	**103393670**	**118164194**	**147705243**	**147705243**	**147705243**	**147705243**	**147705243**	**147705243**	**284114264**	**189409509**
Net Present Value ($2017)	**66995120**	**71224047**	**82818660**	**77040614**	**71665687**	**66665755**	**62014656**	**57688052**	**103222539**	**64013978**
Fixed Link Cash Flow (40%)	-103393670	-118164194	-147705243	-147705243	-147705243	-147705243	-147705243	-147705243	-284114264	-189409509
Fixed Link Cash Flow (60%)	-103393670	-118164194	-147705243	-147705243	-147705243	-147705243	-147705243	-147705243	-284114264	-189409509
Fixed Link Cash Flow (40%) incl. subsidy	-103393670	-118164194	-147705243	-147705243	-147705243	-147705243	-147705243	-147705243	-284114264	-189409509
Fixed Link Cash Flow (60%) incl. subsidy	-103393670	-118164194	-147705243	-147705243	-147705243	-147705243	-147705243	-147705243	-284114264	-189409509

Phase 4 - Operation (years 16–30):

Item	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Belle Isle Ferry, Surge 30%, Gulf Ferries, Diversion 40% (all rows), Diversion 60% Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion 60% – Passenger Vehicles	66018	67668	69360	71094	72871	74693	76560	78474	80436	82447	84508	86621	88786	91006	93281
Diversion 60% – Commercial Vehicles	210040	215290	220673	226190	231844	237640	243581	249671	255913	262311	268868	275590	282480	289542	296780
Total Traffic 40% – Passengers	276567	283481	290568	297832	305278	312910	320733	328751	336970	345394	354029	362880	371952	381251	390782
Total Traffic 40% – Passenger Vehicles	114824	117695	120637	123653	126744	129913	133161	136490	139902	143399	146984	150659	154425	158286	162243
Total Traffic 40% – Commercial Vehicles	175788	180183	184688	189305	194038	198889	203861	208957	214181	219536	225024	230650	236416	242326	248385
Total Traffic 60% – Passengers	331953	340252	348758	357477	366414	375574	384964	394588	404453	414564	424928	435551	446440	457601	469041
Total Traffic 60% – Passenger Vehicles	136830	140251	143757	147351	151034	154810	158681	162648	166714	170882	175154	179533	184021	188621	193337
Total Traffic 60% – Commercial Vehicles	245802	251947	258245	264701	271319	278102	285055	292181	299485	306973	314647	322513	330576	338840	347311
Revenue 40% – Passengers	6250413	6406673	6566840	6731011	6899286	7071768	7248563	7429777	7615521	7805909	8001057	8201083	8406110	8616263	8831670
Revenue 40% – Passenger Vehicles	10943867	11217463	11497900	11785347	12079981	12381981	12691530	13008818	13334039	13667390	14009075	14359301	14718284	15086241	15463397
Revenue 40% – Commercial Vehicles	42452918	43514240	44602096	45717149	46860078	48031580	49232369	50463178	51724758	53017877	54343324	55701907	57094454	58521816	59984861
Revenue 40% – Total	59647197.02	61138377	62666836	64233507	65839345	67485329	69172462	70901773	72674318	74491176	76353455	78262291	80218849	82224320	84279928
Revenue 60% – Passengers	7502138	7689692	7881934	8078983	8280957	8487981	8700181	8917685	9140627	9369143	9603372	9843456	10089542	10341781	10600325
Revenue 60% – Passenger Vehicles	13041247	13367278	13701460	14043996	14395096	14754973	15123848	15501944	15889493	16286730	16693898	17111246	17539027	17977502	18426940
Revenue 60% – Commercial Vehicles	59361098	60845126	62366254	63925410	65523545	67161634	68840675	70561692	72325734	74133877	75987224	77886905	79834077	81829929	83875678
Revenue 60% – Total	79904483.21	81902095	83949648	86048389	88199599	90404589	92664703	94981321	97355854	99789750	102284494	104841606	107462646	110149213	112902943
Operating Cost	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424
Net Revenue (40%)	50942773	52433953	53962412	55529083	57134921	58780905	60468038	62197349	63969894	65786752	67649031	69557867	71514425	73519896	75575504
Net Revenue (60%)	71200059	73197671	75245224	77343965	79495175	81700165	83960279	86276897	88651430	91085326	93580070	96137182	98758222	101444789	104198519
Net Present Value(40%)	16015745	15334468	14680438	14052697	13450312	12872370	12317985	11786292	11276452	10787650	10319093	9870013	9439666	9027332	8632312
Net Present Value(60%)	22384373	21406880	20470412	19573370	18714209	17891435	17103605	16349325	15627252	14936086	14274579	13641523	13035757	12456163	11901662
Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Net Revenue incl. subsidy (40%)	58942773	60433953	61962412	63529083	65134921	66780905	68468038	70197349	71969894	73786752	75649031	77557867	79514425	81519896	83575504
Net Revenue incl. subsidy (60%)	79200059	81197671	83245224	85343965	87495175	89700165	91960279	94276897	96651430	99085326	101580070	104137182	106758222	109444789	112198519
Net Present Value incl. subsidy (40%)	18530841	17674092	16856832	16077250	15333617	14624282	13947670	13302278	12686672	12099482	11539402	11005184	10495640	10009633	9546080
Net Present Value incl. subsidy (60%)	24899469	23746504	22646806	21597923	20597514	19643347	18733291	17865312	17037471	16247919	15494888	14776694	14091731	13438464	12815430
Fixed Link Cash Flow (40%)	50942773.02	52433953	53962412	55529083	57134921	58780905	60468038	62197349	63969894	65786752	67649031	69557867	71514425	73519896	75575504
Fixed Link Cash Flow (60%)	71200059.21	73197671	75245224	77343965	79495175	81700165	83960279	86276897	88651430	91085326	93580070	96137182	98758222	101444789	104198519
Fixed Link Cash Flow (40%) incl. subsidy	58942773	60433953	61962412	63529083	65134921	66780905	68468038	70197349	71969894	73786752	75649031	77557867	79514425	81519896	83575504
Fixed Link Cash Flow (60%) incl. subsidy	79200059	81197671	83245224	85343965	87495175	89700165	91960279	94276897	96651430	99085326	101580070	104137182	106758222	109444789	112198519

Phase 4 - Operation (years 31–45):

Item	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Belle Isle Ferry, Surge 30%, Gulf Ferries, Diversion 40% (all rows), Diversion 60% Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion 60% – Passenger Vehicles	95613	98004	100454	102965	105539	108178	110882	113654	116495	119408	122393	125453	128589	131804	135099
Diversion 60% – Commercial Vehicles	304200	311805	319600	327590	335780	344174	352779	361598	370638	379904	389402	399137	409115	419343	429826
Total Traffic 40% – Passengers	400551	410565	420829	431350	442134	453187	464517	476130	488033	500234	512740	525558	538697	552165	565969
Total Traffic 40% – Passenger Vehicles	166299	170457	174718	179086	183563	188152	192856	197678	202619	207685	212877	218199	223654	229245	234976
Total Traffic 40% – Commercial Vehicles	254594	260959	267483	274170	281024	288050	295251	302632	310198	317953	325902	334050	342401	350961	359735
Total Traffic 60% – Passengers	480767	492786	505106	517733	530677	543944	557542	571481	585768	600412	615422	630808	646578	662743	679311
Total Traffic 60% – Passenger Vehicles	198170	203125	208203	213408	218743	224212	229817	235562	241451	247488	253675	260017	266517	273180	280009
Total Traffic 60% – Commercial Vehicles	355994	364894	374016	383367	392951	402775	412844	423165	433744	444588	455703	467095	478772	490742	503010
Revenue 40% – Passengers	9052462	9278773	9510742	9748511	9992224	10242029	10498080	10760532	11029545	11305284	11587916	11877614	12174554	12478918	12790891
Revenue 40% – Passenger Vehicles	15849982	16246232	16652387	17068697	17495414	17932800	18381120	18840648	19311664	19794456	20289317	20796550	21316464	21849375	22395610
Revenue 40% – Commercial Vehicles	61484483	63021595	64597135	66212063	67867364	69564049	71303150	73085729	74912872	76785694	78705336	80672969	82689793	84757038	86875964
Revenue 40% – Total	86386926	88546599	90760264	93029271	95355003	97738878	100182350	102686908	105254081	107885433	110582569	113347133	116180811	119085332	122062465
Revenue 60% – Passengers	10865333	11136967	11415391	11700776	11993295	12293127	12600456	12915467	13238354	13569313	13908545	14256259	14612665	14977982	15352432
Revenue 60% – Passenger Vehicles	18887614	19359804	19843799	20339894	20848391	21369601	21903841	22451437	23012723	23588041	24177742	24782186	25401740	26036784	26687703
Revenue 60% – Commercial Vehicles	85972570	88121884	90324931	92583054	94897631	97270071	99701823	102194369	104749228	107367959	110052158	112803462	115623548	118514137	121476990
Revenue 60% – Total	115725517	118618654	121584121	124623724	127739317	130932800	134206120	137561273	141000305	144525312	148138445	151841906	155637954	159528903	163517125
Operating Cost	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424	8704424
Net Revenue (40%)	77682502	79842175	82055840	84324847	86650579	89034454	91477926	93982484	96549657	99181009	101878145	104642709	107476387	110380908	113358041
Net Revenue (60%)	107021093	109914230	112879697	115919300	119034893	122228376	125501696	128856849	132295881	135820888	139434021	143137482	146933530	150824479	154812701
Net Present Value(40%)	8253931	7891535	7544495	7212200	6894063	6589514	6298007	6019013	5752023	5496547	5252112	5018264	4794564	4580591	4375941
Net Present Value(60%)	11371218	10863833	10378546	9914435	9470612	9046224	8640451	8252506	7881633	7527105	7188226	6864326	6554762	6258920	5976208
Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Net Revenue incl. subsidy (40%)	85682502	87842175	90055840	92324847	94650579	97034454	99477926	101982484	104549657	107181009	109878145	112642709	115476387	118380908	121358041
Net Revenue incl. subsidy (60%)	115021093	117914230	120879697	123919300	127034893	130228376	133501696	136856849	140295881	143820888	147434021	151137482	154933530	158824479	162812701
Net Present Value incl. subsidy (40%)	9103948	8682249	8280042	7896430	7530556	7181601	6848785	6531365	6228630	5939902	5664535	5401913	5151447	4912576	4684763
Net Present Value incl. subsidy (60%)	12221235	11654546	11114093	10598665	10107105	9638310	9191229	8764858	8358240	7970460	7600649	7247975	6911645	6590904	6285031
Fixed Link Cash Flow (40%)	77682502	79842175	82055840	84324847	86650579	89034454	91477926	93982484	96549657	99181009	101878145	104642709	107476387	110380908	113358041
Fixed Link Cash Flow (60%)	107021093	109914230	112879697	115919300	119034893	122228376	125501696	128856849	132295881	135820888	139434021	143137482	146933530	150824479	154812701
Fixed Link Cash Flow (40%) incl. subsidy	85682502	87842175	90055840	92324847	94650579	97034454	99477926	101982484	104549657	107181009	109878145	112642709	115476387	118380908	121358041
Fixed Link Cash Flow (60%) incl. subsidy	115021093	117914230	120879697	123919300	127034893	130228376	133501696	136856849	140295881	143820888	147434021	151137482	154933530	158824479	162812701

Financial Analysis - Option 1 TBM 200% Tolls - Rail Tunnel

Section	Case	Item	Totals	1	2	3	4	5
Financing During Construction	**40% Diversion Case**	Project Cost ($2017)		-17000000	-3000000	-3000000	-35297167	-35297167
		Nominal Value		-17425000	-3151875	-3230672	-38961468	-39935505
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**	-17425000	-21012500	-25215000	-65356451	-107585742
		Interest During Construction	**(578,132,766)**	-435625	-971828	-1179983	-2293786	-4380899
		Project Cost ($2017)	**(2,188,402,857)**					
	60% Diversion Case	Project Cost ($2017)		-17000000	-3000000	-3000000	-35297167	-35297167
		Nominal Value		-17425000	-3151875	-3230672	-38961468	-39935504.64
	Cummulative Construction Cost	**Comprised of:**	**(2,766,535,623)**	-17425000	-21012500	-25215000	-65356451	-107585742
		Interest During Construction	**(578,132,766)**	-435625	-971828	-1179983	-2293786	-4380899
		Project Cost ($2017)	**(2,188,402,857)**					
Financing Base Case	**40% Diversion Case**	Pre operations cost (Project Cost)	2,188,402,857					
		Interest during Construction	578,132,766					
		Total Amount to Finance	**2,766,535,623**					
		Annual Debt Amortization (CRF)	$ **(305,780,981)**					
		Net Cash Flow						
		IRR excluding IDC	**4.16%**					
	60% Diversion Case	Pre operations cost (Project Cost)	2,188,402,857					
		Interest during Construction	578,132,766					
		Total Amount to Finance	**2,766,535,623**					
		Annual Debt Amortization (CRF)	$ **(305,780,981)**					
		Net Cash Flow						
		IRR excluding IDC	**5.82%**					
Subsidized Financing	**40% Diversion Case**	Project Spending	2188402857	17425000	3151875	3230672	38961468	39935505
		Grant Award	1015000000	17425000	3151875	3230672	38961468	39935505
	Total Amount to Finance	Cost less Grant	1173402857	0	0	0	0	0
		Comprised of:	**1,348,208,701**	0	0	0	0	0
		Interest During Construction	**174,805,845**	0	0	0	0	0
		Project Cost ($2017)	**1,173,402,857**					
		Internal Rate of Return (IRR)	**8.0%**	0	0	0	0	0
	60% Diversion Case	Project Spending	2188402857	17425000	3151875	3230672	38961468	39935505
		Grant Award	725000000	17425000	3151875	3230672	38961468	39935505
	Total Amount to Finance	Cost less Grant	1463402857	0	0	0	0	0
		Comprised of:	**1,765,120,231**	0	0	0	0	0
		Interest During Construction	**301,717,375**	0	0	0	0	0
		Project Cost ($2017)	**1,463,402,857**					
		Internal Rate of Return (IRR)	**8.0%**	0	0	0	0	0

Phase 3 - Construction (years 6–15):

Item	6	7	8	9	10	11	12	13	14	15
40% / 60% – Project Cost ($2017)	-103393670	-118164194	-147705243	-147705243	-147705243	-147705243	-147705243	-147705243	-284114264	-189409509
40% / 60% – Nominal Value	-119904959	-140460095	-179964496	-184463609	-189075199	-193802079	-198647131	-203613309	-401446017.1	-274321445
40% / 60% – Comprised of	-231871600	-380927650	-576427027	-785212874	-1008937126	-1248459181	-1504684219	-1778565561	-2263849523	-2641327294
40% / 60% – Interest During Construction	-8595956	-15534880	-24322239	-34649053	-45719976	-57577907	-70268033	-83837945	-103156326	-125208329
Subsidized 40% – Project Spending	119904959	140460095	179964496	184463609	189075199	193802079	198647131	203613309	401446017	274321445
Subsidized 40% – Grant Award	119904959	140460095	179964496	184463609	189075199	98427124	0	0	0	0
Subsidized 40% – Cost less Grant	0	0	0	0	0	95374955	198647131	203613309	401446017	274321445
Subsidized 40% – Comprised of	0	0	0	0	0	95374955	296406459	512317896	942007090	1266906766
Subsidized 40% – Interest During Construction	0	0	0	0	0	2384373.872	12298127.92	28243176.77	50578231	81301935
Subsidized 40% – IRR	0	0	0	0	0	-97759329	-210945259	-231856486	-452024248	-355623380
Subsidized 60% – Project Spending	119904959	140460095	179964496	184463609	189075199	193802079	198647131	203613309	401446017	274321445
Subsidized 60% – Grant Award	119904959	140460095	179964496	181965931	0	0	0	0	0	0
Subsidized 60% – Cost less Grant	0	0	0	2497677	189075199	193802079	198647131	203613309	401446017	274321445
Subsidized 60% – Comprised of	0	0	0	2497677	191635318	390356286	608590034	847915239	1302774233	1654731445
Subsidized 60% – Interest During Construction	0	0	0	62441.93518	4918888.919	19586617.49	35711896.01	53412977.47	77635767	110388786
Subsidized 60% – IRR	0	0	0	-2560119	-193994088	-213388696	-234359027	-257026286	-479081784	-384710231

Phase 4 - Operation (years 16–30):

Item	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
40% – Project Cost ($2017)	50942773	52433953	53962412	55529083	57134921	58780905	60468038	62197349	63969894	65786752	67649031	69557867	71514425	73519896	75575504
40% – Nominal Value	75624833	79784460	84162947	88771579	93622221	98727341	104100044	109754107	115704007	121964960	128552960	135484815	142778193	150451659	158524727
60% – Project Cost ($2017)	71200059	73197671	75245224	77343965	79495175	81700165	83960279	86276897	88651430	91085326	93580070	96137182	98758222	101444789	104198519
60% – Nominal Value	105696888	111378913	117356869	123645944	130262100	137222114	144543615	152245134	160346142	168867103	177829524	187256005	197170299	207597366	218563435
Base 40% – Annual Debt Amortization (CRF)	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981
Base 40% – Net Cash Flow	-230156149	-225996521	-221618035	-217009402	-212158761	-207053641	-201680937	-196026874	-190076975	-183816022	-177228022	-170296166	-163002789	-155329323	-147256255
Base 60% – Annual Debt Amortization (CRF)	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981
Base 60% – Net Cash Flow	-200084093	-194402068	-188424112	-182135038	-175518881	-168558868	-161237366	-153535848	-145434840	-136913879	-127951458	-118524976	-108610682	-98183616	-87217546
Subsidized 40% – IRR	75624833	79784460	84162947	88771579	93622221	98727341	104100044	109754107	115704007	121964960	128552960	135484815	142778193	150451659	158524727
Subsidized 60% – IRR	105696888	111378913	117356869	123645944	130262100	137222114	144543615	152245134	160346142	168867103	177829524	187256005	197170299	207597366	218563435

Phase 4 - Operation (years 31–45):

Item	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
40% – Project Cost ($2017)	77682502	79842175	82055840	84324847	86650579	89034454	91477926	93982484	96549657	99181009	101878145	104642709	107476387	110380908	113358041
40% – Nominal Value	167017905	175952748	185351905	195239184	205639602	216579453	228086367	240189383	252919017	266307341	280388056	295196580	310770132	327147826	344370765
60% – Project Cost ($2017)	107021093	109914230	112879697	115919300	119034893	122228376	125501696	128856849	132295881	135820888	139434021	143137482	146933530	150824479	154812701
60% – Nominal Value	230096073	242224248	254978400	268390520	282494225	297324841	312919490	329317183	346558912	364687756	383748979	403790149.6	424861251.3	447014808.2	470306013
Base 40% – Annual Debt Amortization (CRF)	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981
Base 40% – Net Cash Flow	-138763076	-129828234	-120429076	-110541797	-100141379	-89201529	-77694615	-65591599	-52861964	-39473641	-25392926	-10584402	4989150	21366844	38589783
Base 60% – Annual Debt Amortization (CRF)	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981	-305780981
Base 60% – Net Cash Flow	-75684908	-63556734	-50802581	-37390461	-23286756	-8456141	7138509	23536201	40777931	58906774	77967998	98009168	119080270	141233827	164525031
Subsidized 40% – IRR	167017905	175952748	185351905	195239184	205639602	216579453	228086367	240189383	252919017	266307341	280388056	295196580	310770132	327147826	344370765
Subsidized 60% – IRR	230096073	242224248	254978400	268390520	282494225	297324841	312919490	329317183	346558912	364687756	383748979	403790150	424861251	447014808	470306013

Variables - Option 1 TBM 200% Tolls - Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,015	$725	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$22.60	$22.60	
Per passenger vehicle	$95.31	$95.31	
Per commercial vehicle	$241.50	$241.50	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel Surcharge**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

APPENDIX F2

Rail Tunnel, 2 TBMs
Economic and Financial Analysis

Appendix F2-1
Rail Tunnel, 2 TBMs, 100% Tolls

Economic Analysis - Option 2 TBM 100% Tolls - Rail Tunnel

		Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Traffic	Existing Belle Isle Ferry			May - October							
		Passengers	7,264,069	83815	85910	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	3,102,537	35798	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%	Passengers	1,789,004	0	0	0	0	0	0	0	0
		Passenger Vehicles	764,097	0	0	0	0	0	0	0	0
		Commercial Vehicles	385,890	0	0	0	0	0	0	0	0
	Existing Gulf Ferries	Passengers	4,268,947	328528	325243	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	1,696,128	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	4,223,537	267274	271550	275895	280310	284794	289351	293981	298684
	Diversion from Gulf Ferries (40%)	Passengers	5,748,564	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,284,006	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,722,997	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)	Passengers	8,622,846	0	0	0	0	0	0	0	0
		Passenger Vehicles	3,426,010	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,084,495	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)	Passengers	13,500,916	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,595,093	0	0	0	0	0	0	0	0
		Commercial Vehicles	8,395,189	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)	Passengers	16,375,198	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,737,096	0	0	0	0	0	0	0	0
		Commercial Vehicles	11,756,687	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)	Passengers	152,560,353	0	0	0	0	0	0	0	0
		Passenger Vehicles	266,634,146	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,013,719,020	0	0	0	0	0	0	0	0
		Total	**1,432,913,519**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)	Passengers	185,039,740	0	0	0	0	0	0	0	0
		Passenger Vehicles	321,056,310	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,419,619,936	0	0	0	0	0	0	0	0
		Total	**1,925,715,987**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	287,245,992	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	1,145,667,527	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,638,469,995	0	0	0	0	0	0	0	0
		Net Present Value(40%)	145,078,768								
		Net Present Value(60%)	210,191,226								
		Ferry Subsidy Saving	264,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	1,409,667,527	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,902,469,995	0	0	0	0	0	0	0	0
		Net Present Value(40%)	185,745,574	0	0	0	0	0	0	0	0
		Net Present Value(60%)	250,858,032	0	0	0	0	0	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	1,764,268,227			**17000000**	**3000000**	**3000000**	**37206586**	**37206586**	**156259439**
		Net Present Value ($2017)	924,693,470			**15813953**	**2595998**	**2414882**	**27860311**	**25916569**	**101250103**
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(779,614,701)								
		NPV Cash Flows ($2017) (60%)	(714,502,243)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(618,600,699)			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		IRR(40%)	-1.83%								
		Benefit/Cost Ratio(40%)	0.65								
		Fixed Link Cash Flow (60%)	(125,798,232)			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		IRR(60%)	-0.33%								
		Benefit/Cost Ratio(60%)	0.93								
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(738,947,896)								
		NPV Cash Flows ($2017) (60%)	(673,835,438)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(354,600,699)			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		IRR(40%)	-0.99%								
		Benefit/Cost Ratio(40%)	0.80								
		Fixed Link Cash Flow (60%)	138,201,768			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		IRR(60%)	0.34%								
		Benefit/Cost Ratio(60%)	1.08								

Financial Analysis - Option 2 TBM 100% Tolls - Rail Tunnel

		Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Financing During Construction	40% Diversion	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095837	-181213043
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793
		Project Cost ($2017)	**(2,213,030,139)**								
	60% Diversion	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095836.97	-181213043
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793
		Project Cost ($2017)	**(2,213,030,139)**								
Financing Base Case	40% Diversion / Project Cost	Pre operations cost	2,213,030,139								
		Interest during Construction	397,671,099								
	Total Amount to Finance		**2,610,701,237**								
		Annual Debt Amortization (CRF)	$ **(284,677,152)**								
		Net Cash Flow									
		IRR excluding IDC	**0.62%**								
	60% Diversion / Project Cost	Pre operations cost	2,213,030,139								
		Interest during Construction	397,671,099								
	Total Amount to Finance		**2,610,701,237**								
		Annual Debt Amortization (CRF)	$ **(284,677,152)**								
		Net Cash Flow									
		IRR excluding IDC	**2.2%**								
Subsidised Financing	40% Diversion	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043
		Grant Award	1655000000			17425000	3151875	3230672	41069109	42095837	181213043
		Cost less Grant	558030139			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**594,412,322**			0	0	0	0	0	0
		Interest During Construction	**36,382,184**			0	0	0	0	0	0
		Project Cost ($2017)	**558,030,139**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0
	60% Diversion	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043
		Grant Award	1430000000			17425000	3151875	3230672	41069109	42095837	181213043
		Cost less Grant	783030139			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**844,372,090**			0	0	0	0	0	0
		Interest During Construction	**61,341,952**			0	0	0	0	0	0
		Project Cost ($2017)	**783,030,139**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0

Variables - Option 2 TBM 100% Tolls - Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,655	$1,430	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$11.30	$11.30	
Per passenger vehicle	$47.66	$47.66	
Per commercial vehicle	$120.75	$120.75	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel Surcharge**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix F2-2
Rail Tunnel, 2 TBMs, 150% Tolls

Economic Analysis - Option 2 TBM 150% Tolls - Rail Tunnel

		Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval 1	2	3	Phase 2 - Design 4	5	Phase 3 - Construction 6
Traffic	**Existing Belle Isle Ferry**			May - October							
		Passengers	7,264,069	83815	85910	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	3,102,537	35798	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%										
		Passengers	1,789,004	0	0	0	0	0	0	0	0
		Passenger Vehicles	764,097	0	0	0	0	0	0	0	0
		Commercial Vehicles	385,890	0	0	0	0	0	0	0	0
	Existing Gulf Ferries										
		Passengers	4,268,947	328528	325243	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	1,696,128	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	4,223,537	267274	271550	275895	280310	284794	289351	293981	298684
	Diversion from Gulf Ferries (40%)										
		Passengers	5,748,564	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,284,006	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,722,997	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)										
		Passengers	8,622,846	0	0	0	0	0	0	0	0
		Passenger Vehicles	3,426,010	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,084,495	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)										
		Passengers	13,500,916	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,595,093	0	0	0	0	0	0	0	0
		Commercial Vehicles	8,395,189	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)										
		Passengers	16,375,198	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,737,096	0	0	0	0	0	0	0	0
		Commercial Vehicles	11,756,687	0	0	0	0	0	0	0	0
Revenue	**Total Revenue for Fixed Link (40%)**										
		Passengers	228,840,530	0	0	0	0	0	0	0	0
		Passenger Vehicles	399,951,220	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,520,578,529	0	0	0	0	0	0	0	0
		Total	**2,149,370,279**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)										
		Passengers	277,559,610	0	0	0	0	0	0	0	0
		Passenger Vehicles	481,584,465	0	0	0	0	0	0	0	0
		Commercial Vehicles	2,129,429,905	0	0	0	0	0	0	0	0
		Total	**2,888,573,980**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link										
		Operating Cost	287,245,992	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link										
		Net Revenue (40%)	1,862,124,287	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,601,327,988	0	0	0	0	0	0	0	0
		Net Present Value(40%)	239,741,972								
		Net Present Value(60%)	337,410,659								
		Ferry Subsidy Saving	264,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving										
		Net Revenue (40%)	2,126,124,287	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,865,327,988	0	0	0	0	0	0	0	0
		Net Present Value(40%)	280,408,778	0	0	0	0	0	0	0	0
		Net Present Value(60%)	378,077,465	0	0	0	0	0	0	0	0
	Total Capital Cost										
		Net Cost ($2017)	1,764,268,227			**17000000**	**3000000**	**3000000**	**37206586**	**37206586**	**156259439**
		Net Present Value ($2017)	924,693,470			**15813953**	**2595998**	**2414882**	**27860311**	**25916569**	**101250103**
Economic Analysis	**Net Present Value of Fixed Link Cash Flows**	NPV Cash Flows ($2017) (40%)	(684,951,497)								
		NPV Cash Flows ($2017) (60%)	(587,282,810)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	97,856,060			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		IRR(40%)	0.24%								
		Benefit/Cost Ratio(40%)	1.06								
		Fixed Link Cash Flow (60%)	837,059,762			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		IRR(60%)	1.81%								
		Benefit/Cost Ratio(60%)	1.47								
Economic Analysis	**Net Present Value of Fixed Link Cash Flows (including subsidy saving)**	NPV Cash Flows ($2017) (40%)	(644,284,692)								
		NPV Cash Flows ($2017) (60%)	(546,616,005)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	361,856,060			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		IRR(40%)	0.86%								
		Benefit/Cost Ratio(40%)	1.21								
		Fixed Link Cash Flow (60%)	1,101,059,762			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		IRR(60%)	2.32%								
		Benefit/Cost Ratio(60%)	1.62								

Financial Analysis - Option 2 TBM 150% Tolls - Rail Tunnel

		Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval 1	2	3	Phase 2 - Design 4	5	Phase 3 - Construction 6
Financing During Construction	**40% Diversion**	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259439
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095837	-181213043
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793
		Project Cost ($2017)	**(2,213,030,139)**								
	60% Diversion	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095836.97	-181213043
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793
		Project Cost ($2017)	**(2,213,030,139)**								
Financing Base Case	**40% Diversion**										
	Project Cost	Pre operations cost	2,213,030,139								
		Interest during Construction	397,671,099								
	Total Amount to Finance		**2,610,701,237**								
		Annual Debt Amortization (CRF)	**$ (284,677,152)**								
		Net Cash Flow									
		IRR excluding IDC	**2.75%**								
	60% Diversion										
	Project Cost	Pre operations cost	2,213,030,139								
		Interest during Construction	397,671,099								
	Total Amount to Finance		**2,610,701,237**								
		Annual Debt Amortization (CRF)	**$ (284,677,152)**								
		Net Cash Flow									
		IRR excluding IDC	**4.4%**								
Subsidised Financing	**40% Diversion**	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043
		Grant Award	1340000000			17425000	3151875	3230672	41069109	42095837	181213043
		Cost less Grant	873030139			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**950,978,496**			0	0	0	0	0	0
		Interest During Construction	**77,948,358**			0	0	0	0	0	0
		Project Cost ($2017)	**873,030,139**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0
	60% Diversion	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043
		Grant Award	1040000000			17425000	3151875	3230672	41069109	42095837	181213043
		Cost less Grant	1173030139			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**1,307,631,038**			0	0	0	0	0	0
		Interest During Construction	**134,600,899**			0	0	0	0	0	0
		Project Cost ($2017)	**1,173,030,139**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0

Variables - Option 2 TBM 150% Tolls - Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,340	$1,040	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$16.95	$16.95	
Per passenger vehicle	$71.48	$71.48	
Per commercial vehicle	$181.13	$181.13	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel Surcharge**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix F2-3
Rail Tunnel, 2 TBMs, 200% Tolls

Economic Analysis - Option 2 TBM 200% Tolls - Rail Tunnel

		Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction						
				-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Traffic	Existing Belle Isle Ferry			May - October													
		Passengers	7,264,069	83815	85910	88058	90260	92516	94829	97200	99630	102120	104673	107290	109973	112722	115540
		Passenger Vehicles	3,102,537	35798	36693	37610	38551	39514	40502	41515	42553	43616	44707	45824	46970	48144	49348
		Commercial Vehicles	1,566,869	18079	18531	18994	19469	19956	20455	20966	21490	22028	22578	23143	23721	24314	24922
	One Time Surge 30%	Passengers	1,789,004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	764,097	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	385,890	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Existing Gulf Ferries	Passengers	4,268,947	328528	325243	321990	318770	315583	312427	309303	306210	303147	300116	297115	294144	291202	288290
		Passenger Vehicles	1,696,128	130530	129225	127932	126653	125387	124133	122891	121662	120446	119241	118049	116869	115700	114543
		Commercial Vehicles	4,223,537	267274	271550	275895	280310	284794	289351	293981	298684	303463	308319	313252	318264	323356	328530
	Diversion from Gulf Ferries (40%)	Passengers	5,748,564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,284,006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,722,997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)	Passengers	8,622,846	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	3,426,010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,084,495	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)	Passengers	13,500,916	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,595,093	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	8,395,189	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)	Passengers	16,375,198	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,737,096	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	11,756,687	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)	Passengers	305,120,706	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	533,268,293	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	2,027,438,039	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	**2,865,827,038**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)	Passengers	370,079,480	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	642,112,620	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	2,839,239,873	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	**3,851,431,974**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	287,245,992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	2,578,581,046	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	3,564,185,982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	334,405,177	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(60%)	464,630,092	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ferry Subsidy Saving	264,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	2,842,581,046	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	3,828,185,982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	375,071,982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(60%)	505,296,898	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	1,764,268,227			**17000000**	**3000000**	**3000000**	**37206586**	**37206586**	**156259439**	**156259439**	**156259439**	**312518878**	**312518878**	**375075277**	**197963705**
		Net Present Value ($2017)	924,693,470			**15813953**	**2595998**	**2414882**	**27860311**	**25916569**	**101250103**	**94186143**	**87615016**	**163004682**	**151632262**	**169287672**	**83115879**
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(590,288,293)														
		NPV Cash Flows ($2017) (60%)	(460,063,377)														
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	814,312,820			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9	-156259438.9	-156259438.9	-312518877.8	-312518877.8	-375075277.2	-197963705.1
		IRR(40%)	1.77%														
		Benefit/Cost Ratio(40%)	1.46														
		Fixed Link Cash Flow (60%)	1,799,917,755			-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9	-156259438.9	-156259438.9	-312518877.8	-312518877.8	-375075277.2	-197963705.1
		IRR(60%)	3.43%														
		Benefit/Cost Ratio(60%)	2.02														
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(549,621,488)														
		NPV Cash Flows ($2017) (60%)	(419,396,572)														
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	1,078,312,820			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439	-156259439	-156259439	-312518878	-312518878	-375075277	-197963705
		IRR(40%)	2.28%														
		Benefit/Cost Ratio(40%)	1.61														
		Fixed Link Cash Flow (60%)	2,063,917,755			-17000000	-3000000	-3000000	-37206586	-37206586	-156259439	-156259439	-156259439	-312518878	-312518878	-375075277	-197963705
		IRR(60%)	3.85%														
		Benefit/Cost Ratio(60%)	2.17														

Group	Item	Phase 4 - Operation															
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Existing Belle Isle Ferry	Passengers	118428	121389	124424	127534	130723	133991	137341	140774	144294	147901	151598	155388	159273	163255	167336	171520
	Passenger Vehicles	50582	51846	53142	54471	55833	57228	58659	60126	61629	63170	64749	66367	68027	69727	71471	73257
	Commercial Vehicles	25545	26184	26838	27509	28197	28902	29625	30365	31124	31902	32700	33517	34355	35214	36095	36997
One Time Surge 30%	Passengers	35529	36417	37327	38260	39217	40197	41202	42232	43288	44370	45480	46616	47782	48976	50201	51456
	Passenger Vehicles	15174	15554	15943	16341	16750	17169	17598	18038	18489	18951	19425	19910	20408	20918	21441	21977
	Commercial Vehicles	7664	7855	8052	8253	8459	8671	8887	9110	9337	9571	9810	10055	10307	10564	10828	11099
Existing Gulf Ferries	Passengers	285407															
	Passenger Vehicles	113397															
	Commercial Vehicles	333786															
Diversion from Gulf Ferries (40%)	Passengers	114163	117017	119942	122941	126015	129165	132394	135704	139096	142574	146138	149792	153536	157375	161309	165342
	Passenger Vehicles	45359	46493	47655	48847	50068	51319	52602	53918	55265	56647	58063	59515	61003	62528	64091	65693
	Commercial Vehicles	133515	136852	140274	143781	147375	151059	154836	158707	162675	166741	170910	175183	179562	184051	188653	193369
Diversion from Gulf Ferries (60%)	Passengers	171244	175526	179914	184411	189022	193747	198591	203556	208645	213861	219207	224687	230305	236062	241964	248013
	Passenger Vehicles	68038	69739	71483	73270	75102	76979	78904	80876	82898	84971	87095	89272	91504	93792	96137	98540
	Commercial Vehicles	200272	205279	210411	215671	221063	226589	232254	238060	244012	250112	256365	262774	269343	276077	282979	290053
Total Traffic for Fixed Link (40%)	Passengers	268120	274823	281693	288736	295954	303353	310937	318710	326678	334845	343216	351796	360591	369606	378846	388317
	Passenger Vehicles	111115	113893	116740	119659	122650	125717	128859	132081	135383	138768	142237	145793	149437	153173	157003	160928
	Commercial Vehicles	166723	170891	175164	179543	184031	188632	193348	198182	203136	208215	213420	218755	224224	229830	235576	241465
Total Traffic for Fixed Link (60%)	Passengers	325201	333331	341665	350206	358961	367935	377134	386562	396226	406132	416285	426692	437360	448294	459501	470988
	Passenger Vehicles	133795	137139	140568	144082	147684	151376	155161	159040	163016	167091	171268	175550	179939	184437	189048	193774
	Commercial Vehicles	233481	239318	245300	251433	257719	264162	270766	277535	284473	291585	298875	306347	314005	321855	329902	338149
	Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Total Net Revenue including subsidy saving	Net Revenue (40%)	56209130	57631968	59090378	60585248	62117490	63688038	65297850	66947906	68639215	70372806	72149736	73971090	75837978	77751538	79712937	81723371
	Net Revenue (60%)	75782634	77694811	79654792	81663772	83722977	85833662	87997114	90214653	92487630	94817431	97205477	99653225	102162166	104733831	107369787	110071642
	Net Present Value(40%)	21953149	20938470	19970540	19047214	18166447	17326287	16524870	15760417	15031231	14335692	13672253	13039438	12435840	11860116	11310981	10787214
	Net Present Value(60%)	29597816	28227571	26920613	25674028	24485037	23350989	22269354	21237715	20253771	19315323	18420273	17566620	16752456	15975958	15235389	14529091
Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	48209129.6	49631968	51090378	52585248	54117490	55688038	57297850	58947906	60639215	62372806	64149736	65971090	67837978	69751538	71712937	73723371
	Fixed Link Cash Flow (60%)	67782634.41	69694810.87	71654791.74	73663772.13	75722977.04	77833662.06	79997114.21	82214652.67	84487629.59	86817430.92	89205477.3	91653224.83	94162166.05	96733830.8	99369787.17	102071642.5
Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	56209130	57631968	59090378	60585248	62117490	63688038	65297850	66947906	68639215	70372806	72149736	73971090	75837978	77751538	79712937	81723371
	Fixed Link Cash Flow (60%)	75782634	77694811	79654792	81663772	83722977	85833662	87997114	90214653	92487630	94817431	97205477	99653225	102162166	104733831	107369787	110071642

Group	Item	Phase 4 - Operation																
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Total Net Revenue including subsidy saving	Net Revenue (40%)	83784066	85896278	88061296	90280439	92555061	94886548	97276322	99725841	102236597	104810123	107447986	110151797	112923202	115763893	118675601	121660101	124719215
	Net Revenue (60%)	112841044	115679681	118589283	121571626	124628527	127761851	130973508	134265456	137639703	141098307	144643375	148277070	152001607	155819258	159732350	163743269	167854462
	Net Present Value(40%)	10287645	9811161	9356699	8923245	8509829	8115530	7739464	7380792	7038712	6712458	6401300	6104541	5821517	5551593	5294165	5048656	4814514
	Net Present Value(60%)	13855482	13213052	12600363	12016040	11458774	10927314	10420468	9937098	9476120	9036498	8617245	8217419	7836121	7472495	7125723	6795025	6479657
Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	75784066	77896278	80061296	82280439	84555061	86886548	89276322	91725841	94236597	96810123	99447986	102151797	104923202	107763892.9	110675601	113660101	116719214.6
	Fixed Link Cash Flow (60%)	104841044.1	107679680.8	110589283.4	113571626.1	116628527.4	119761851.2	122973508	126265456.3	129639703.3	133098306.5	136643374.8	140277069.8	144001607.1	147819257.9	151732349.9	155743269.3	159854461.6
Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	83784066	85896278	88061296	90280439	92555061	94886548	97276322	99725841	102236597	104810123	107447986	110151797	112923202	115763893	118675601	121660101	124719215
	Fixed Link Cash Flow (60%)	112841044	115679681	118589283	121571626	124628527	127761851	130973508	134265456	137639703	141098307	144643375	148277070	152001607	155819258	159732350	163743269	167854462

Financial Analysis - Option 2 TBM 200% Tolls - Rail Tunnel

		Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction							Phase 4 - Operation
				-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Financing During Construction	40% Diversion	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259439	-156259439	-156259439	-312518878	-312518878	-375075277	-197963705	48209130
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095837	-181213043	-185743369	-190386953	-390293254	-400050585	-492131266.8	-266239175	66456818
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374	-493758535	-704189831	-1124932902	-1571472801	-2132176444	-2492721159	
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793	-20044343	-30449818	-46489314	-68572375	-94305541	-117980079	
		Project Cost ($2017)	**(2,213,030,139)**															
	60% Diversion	Project Cost ($2017)				-17000000	-3000000	-3000000	-37206586	-37206586	-156259438.9	-156259438.9	-156259438.9	-312518877.8	-312518877.8	-375075277.2	-197963705	67782634
		Nominal Value				-17425000	-3151875	-3230672	-41069109	-42095836.97	-181213043	-185743369	-190386953	-390293254	-400050585	-492131266.8	-266239175	93439110
	Cummulative Construction Cost	**Comprised of:**	**(2,610,701,237)**			-17425000	-21012500	-25215000	-67464092	-111906406	-297662374	-493758535	-704189831	-1124932902	-1571472801	-2132176444	-2492721159	
		Interest During Construction	**(397,671,099)**			-435625	-971828	-1179983	-2346477	-4542924	-10352793	-20044343	-30449818	-46489314	-68572375	-94305541	-117980079	
		Project Cost ($2017)	**(2,213,030,139)**															
Financing Base Case	40% Diversion / Project Cost	Pre operations cost	2,213,030,139															
		Interest during Construction	397,671,099															
	Total Amount to Finance		**2,610,701,237**															
		Annual Debt Amortization (CRF)	$ **(284,677,152)**															-284677152
		Net Cash Flow																-218220335
		IRR excluding IDC	**4.32%**															
	60% Diversion / Project Cost	Pre operations cost	2,213,030,139															
		Interest during Construction	397,671,099															
	Total Amount to Finance		**2,610,701,237**															
		Annual Debt Amortization (CRF)	$ **(284,677,152)**															-284677152
		Net Cash Flow																-191238042
		IRR excluding IDC	**6.0%**															
Subsidised Financing	40% Diversion	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043	185743369	190386953	390293254	400050585	492131267	266239175	
		Grant Award	1045000000			17425000	3151875	3230672	41069109	42095837	181213043	185743369	190386953	380684142	0	0	0	
		Cost less Grant	1168030139			0	0	0	0	0	0	0	0	9609112	400050585	492131267	266239175	
	Total Amount to Finance																	
		Comprised of:	**1,301,264,266**			0	0	0	0	0	0	0	0	9609112	409899925	912771157	1222861605	
		Interest During Construction	**133,234,128**			0	0	0	0	0	0	0	0	240227.7956	10739965.1	43851273	78402662	
		Project Cost ($2017)	**1,168,030,139**															
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	-9849340	-410790550	-535982540	-344641836	66456818
	60% Diversion	Project Spending	2,213,030,139			17425000	3151875	3230672	41069109	42095837	181213043	185743369	190386953	390293254	400050585	492131267	266239175	
		Grant Award	695000000			17425000	3151875	3230672	41069109	42095837	181213043	185743369	190386953	30684142	0	0	0	
		Cost less Grant	1518030139			0	0	0	0	0	0	0	0	359609112	400050585	492131267	266239175	
	Total Amount to Finance																	
		Comprised of:	**1,746,938,270**			0	0	0	0	0	0	0	0	359609112	768649925	1298427407	1637442074	
		Interest During Construction	**228,908,132**			0	0	0	0	0	0	0	0	8990228	37646215	72775492	109496197	
		Project Cost ($2017)	**1,518,030,139**															
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	-368599340	-437696800	-564906759	-375735371	93439110

Variables - Option 2 TBM 200% Tolls -Rail Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,045	$695	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 8,704,424	$ 8,704,424	
Tolls			
Per passenger	$22.60	$22.60	
Per passenger vehicle	$95.31	$95.31	
Per commercial vehicle	$241.50	$241.50	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel Surcharge**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

APPENDIX G

Economic and Financial Analysis – Road Tunnel

APPENDIX G1

Road Tunnel, 1 TBM
Economic and Financial Analysis

Appendix G1-1
Road Tunnel, 1 TBM, 100% Tolls

Economic Analysis - Option 1 TBM 100% Tolls - Road Tunnel

Section	Item	Line	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	2	3	Phase 2 - Design (4)	5	Phase 3 - Construction (6)
Traffic	Existing Belle Isle Ferry			May - October							
		Passengers	7,003,081	83815	85910	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	2,991,067	35798	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,510,573	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%										
		Passengers	1,638,763	0	0	0	0	0	0	0	0
		Passenger Vehicles	699,928	0	0	0	0	0	0	0	0
		Commercial Vehicles	353,483	0	0	0	0	0	0	0	0
	Existing Gulf Ferries										
		Passengers	4,831,228	328528	325243	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	1,919,532	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	4,907,217	267274	271550	275895	280310	284794	289351	293981	298684
	Diversion from Gulf Ferries (40%)										
		Passengers	4,912,321	0	0	0	0	0	0	0	0
		Passenger Vehicles	1,951,752	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,050,723	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)										
		Passengers	7,368,482	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,927,628	0	0	0	0	0	0	0	0
		Commercial Vehicles	9,076,085	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)										
		Passengers	12,013,627	0	0	0	0	0	0	0	0
		Passenger Vehicles	4,984,772	0	0	0	0	0	0	0	0
		Commercial Vehicles	7,582,484	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)										
		Passengers	14,469,788	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,960,648	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,607,845	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)										
		Passengers	135,753,984	0	0	0	0	0	0	0	0
		Passenger Vehicles	237,549,308	0	0	0	0	0	0	0	0
		Commercial Vehicles	915,584,918	0	0	0	0	0	0	0	0
		Total	**1,288,888,210**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)										
		Passengers	163,508,599	0	0	0	0	0	0	0	0
		Passenger Vehicles	284,054,686	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,280,897,338	0	0	0	0	0	0	0	0
		Total	**1,728,460,623**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	229,443,270	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	1,059,444,940	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,499,017,353	0	0	0	0	0	0	0	0
		Net Present Value(40%)	129,395,845								
		Net Present Value(60%)	184,718,190								
		Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	1,299,444,940	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,739,017,353	0	0	0	0	0	0	0	0
		Net Present Value(40%)	163,722,824								
		Net Present Value(60%)	219,045,169								
	Total Capital Cost	**Net Cost ($2017)**	2,064,293,767			17000000	3000000	3000000	43617388	43617388	238748988
		Net Present Value ($2017)	1,046,278,964			15813953	2595998	2414882	32660723	30382068	154700157
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(916,883,119)								
		NPV Cash Flows ($2017) (60%)	(861,560,774)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(1,004,848,827)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(40%)	-2.47%								
		Benefit/Cost Ratio(40%)	0.51								
		Fixed Link Cash Flow (60%)	(565,276,414)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(60%)	-1.42%								
		Benefit/Cost Ratio(60%)	0.73								
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(882,556,139)								
		NPV Cash Flows ($2017) (60%)	(827,233,794)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(764,848,827)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(40%)	-2.06%								
		Benefit/Cost Ratio(40%)	0.63								
		Fixed Link Cash Flow (60%)	(325,276,414)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(60%)	-0.78%								
		Benefit/Cost Ratio(60%)	0.84								

Financial Analysis - Option 1 TBM 100% Tolls - Road Tunnel

Section	Item	Line	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	2	3	Phase 2 - Design (4)	5	Phase 3 - Construction (6)
Financing During Construction	40% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071	-276875630
	Cummulative Construction Cost	**Comprised of:**	(3,323,910,841)			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431
		Interest During Construction	(692,065,393)			-444338	-991265	-1203583	-2549780	-5114632	-13525981
		Project Cost ($2017)	(2,631,845,447)								
	60% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071.01	-276875630
	Cummulative Construction Cost	**Comprised of:**	(3,323,910,841)			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431
		Interest During Construction	(692,065,393)			-444338	-991265	-1203583	-2549780	-5114632	-13525981
		Project Cost ($2017)	(2,631,845,447)								
Financing Base Case	40% Diversion Case – Project Cost	Pre operations cost	2,631,845,447								
		Interest during Construction	692,065,393								
	Total Amount to Finance		3,323,910,841								
		Annual Debt Amortization (CRF)	$ (367,386,818)								
		Net Cash Flow									
		IRR excluding IDC	-0.44%								
	60% Diversion Case – Project Cost	Pre operations cost	2,631,845,447								
		Interest during Construction	692,065,393								
	Total Amount to Finance		3,323,910,841								
		Annual Debt Amortization (CRF)	$ (367,386,818)								
		Net Cash Flow									
		IRR excluding IDC	1.04%								
Subsidised Financing	40% Diversion Case	Project Spending	2,631,845,447			17773500	3214913	3295285	48145435	49349071	276875630
		Grant Award	2,041,000,000			17773500	3214913	3295285	48145435	49349071	276875630
		Cost less Grant	590,845,447			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	628,376,376			0	0	0	0	0	0
		Interest During Construction	37,530,928			0	0	0	0	0	0
		Project Cost ($2017)	590,845,447								
		Internal Rate of Return (IRR)	8.0%			0	0	0	0	0	0
	60% Diversion Case	Project Spending	2,631,845,447			17773500	3214913	3295285	48145435	49349071	276875630
		Grant Award	1,820,000,000			17773500	3214913	3295285	48145435	49349071	276875630
		Cost less Grant	811,845,447			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	878,970,773			0	0	0	0	0	0
		Interest During Construction	67,125,325			0	0	0	0	0	0
		Project Cost ($2017)	811,845,447								
		Internal Rate of Return (IRR)	8.0%			0	0	0	0	0	0

Variables - Option 1 TBM 100% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$2,041	$1,820	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$11.30	$11.30	
Per passenger vehicle	$47.66	$47.66	
Per commercial vehicle	$120.75	$120.75	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix G1-2
Road Tunnel, 1 TBM, 150% Tolls

Economic Analysis - Option 1 TBM 150% Tolls - Road Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Traffic				May - October							
	Existing Belle Isle Ferry	Passengers	7,003,081	83815	85910	88058	90260	92516	94829	97200	99630
		Passenger Vehicles	2,991,067	35798	36693	37610	38551	39514	40502	41515	42553
		Commercial Vehicles	1,510,573	18079	18531	18994	19469	19956	20455	20966	21490
	One Time Surge 30%	Passengers	1,638,763	0	0	0	0	0	0	0	0
		Passenger Vehicles	699,928	0	0	0	0	0	0	0	0
		Commercial Vehicles	353,483	0	0	0	0	0	0	0	0
	Existing Gulf Ferries	Passengers	4,831,228	328528	325247	321990	318770	315583	312427	309303	306210
		Passenger Vehicles	1,919,532	130530	129225	127932	126653	125387	124133	122891	121662
		Commercial Vehicles	4,907,217	267274	271550	275895	280310	284794	289351	293981	298684
	Diversion from Gulf Ferries (40%)	Passengers	4,912,321	0	0	0	0	0	0	0	0
		Passenger Vehicles	1,951,752	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,050,723	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)	Passengers	7,368,482	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,927,628	0	0	0	0	0	0	0	0
		Commercial Vehicles	9,076,085	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)	Passengers	12,013,627	0	0	0	0	0	0	0	0
		Passenger Vehicles	4,984,772	0	0	0	0	0	0	0	0
		Commercial Vehicles	7,582,484	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)	Passengers	14,469,788	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,960,648	0	0	0	0	0	0	0	0
		Commercial Vehicles	10,607,845	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)	Passengers	203,630,976	0	0	0	0	0	0	0	0
		Passenger Vehicles	356,323,962	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,373,377,378	0	0	0	0	0	0	0	0
		Total	**1,933,332,316**	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)	Passengers	245,262,898	0	0	0	0	0	0	0	0
		Passenger Vehicles	426,082,030	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,921,346,006	0	0	0	0	0	0	0	0
		Total	**2,592,690,934**	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	229,443,270	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	1,703,889,046	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,363,247,664	0	0	0	0	0	0	0	0
		Net Present Value(40%)	210,502,297								
		Net Present Value(60%)	293,485,815								
		Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	1,943,889,046	0	0	0	0	0	0	0	0
		Net Revenue (60%)	2,603,247,664	0	0	0	0	0	0	0	0
		Net Present Value(40%)	244,829,277	0	0	0	0	0	0	0	0
		Net Present Value(60%)	327,812,794	0	0	0	0	0	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	2,064,293,767			**17000000**	**3000000**	**3000000**	**43617388**	**43617388**	238748988
		Net Present Value ($2017)	1,046,278,964			**15813953**	**2595998**	**2414882**	**32660723**	**30382068**	**154700157**
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(835,776,666)								
		NPV Cash Flows ($2017) (60%)	(752,793,149)								
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(360,404,722)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(40%)	-0.86%								
		Benefit/Cost Ratio(40%)	0.83								
		Fixed Link Cash Flow (60%)	298,953,897			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(60%)	0.63%								
		Benefit/Cost Ratio(60%)	1.14								
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(801,449,687)								
		NPV Cash Flows ($2017) (60%)	(718,466,170)								
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(120,404,722)			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(40%)	-0.28%								
		Benefit/Cost Ratio(40%)	0.94								
		Fixed Link Cash Flow (60%)	538,953,897			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988
		IRR(60%)	1.10%								
		Benefit/Cost Ratio(60%)	1.26								

Financial Analysis - Option 1 TBM 150% Tolls - Road Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)
Financing During Construction	40% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071	-276875630
	Cummulative Construction Cost	**Comprised of:**	**(3,323,910,841)**			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431
		Interest During Construction	**(692,065,393)**			-444338	-991265	-1203583	-2549780	-5114632	-13525981
		Project Cost ($2017)	**(2,631,845,447)**								
	60% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071.01	-276875630
	Cummulative Construction Cost	**Comprised of:**	**(3,323,910,841)**			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431
		Interest During Construction	**(692,065,393)**			-444338	-991265	-1203583	-2549780	-5114632	-13525981
		Project Cost ($2017)	**(2,631,845,447)**								
Financing Base Case	40% Diversion Case										
	Project Cost	Pre operations cost	2,631,845,447								
		Interest during Construction	692,065,393								
	Total Amount to Finance		**3,323,910,841**								
		Annual Debt Amortization (CRF)	$ **(367,386,818)**								
		Net Cash Flow									
		IRR excluding IDC	**1.61%**								
	60% Diversion Case										
	Project Cost	Pre operations cost	2,631,845,447								
		Interest during Construction	692,065,393								
	Total Amount to Finance		**3,323,910,841**								
		Annual Debt Amortization (CRF)	$ **(367,386,818)**								
		Net Cash Flow									
		IRR excluding IDC	**3.14%**								
Subsidised Financing	40% Diversion Case	Project Spending	2631845447			17773500	3214913	3295285	48145435	49349071	276875630
		Grant Award	1725000000			17773500	3214913	3295285	48145435	49349071	276875630
		Cost less Grant	906845447			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**991,499,757**			0	0	0	0	0	0
		Interest During Construction	**84,654,310**			0	0	0	0	0	0
		Project Cost ($2017)	**906,845,447**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0
	60% Diversion Case	Project Spending	2631845447			17773500	3214913	3295285	48145435	49349071	276875630
		Grant Award	1448000000			17773500	3214913	3295285	48145435	49349071	276875630
		Cost less Grant	1183845447			0	0	0	0	0	0
	Total Amount to Finance										
		Comprised of:	**1,337,449,368**			0	0	0	0	0	0
		Interest During Construction	**153,603,920**			0	0	0	0	0	0
		Project Cost ($2017)	**1,183,845,447**								
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0

Variables - Option 1 TBM 150% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,725	$1,448	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$16.95	$16.95	
Per passenger vehicle	$71.48	$71.48	
Per commercial vehicle	$181.13	$181.13	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix G1-3
Road Tunnel, 1 TBM, 200% Tolls

Economic Analysis - Option 1 TBM 200% Tolls - Road Tunnel

Section	Group	Item	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction								
		Year		-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Traffic	Existing Belle Isle Ferry (May - October)	Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Passenger Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Commercial Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	One Time Surge 30%	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Existing Gulf Ferries	Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Passenger Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Commercial Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Diversion from Gulf Ferries (40%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenue	Total Revenue for Fixed Link (40%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)	Passengers	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	3,456,921,246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	229,443,270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	2,348,333,151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	3,227,477,976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	291,608,750																
		Net Present Value(60%)	402,253,440																
		Ferry Subsidy Saving	240,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	2,588,333,151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	3,467,477,976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	325,935,729	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(60%)	436,580,419	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Capital Cost	Net Cost ($2017)	2,064,293,767			17000000	3000000	3000000	43617388	43617388	238748988	238748988	190999191	190999191	190999191	190999191	190999191	312939037	208626025
		Net Present Value ($2017)	1,046,278,964			15813953	2595998	2414882	32660723	30382068	154700157	143907123	107093673	99622021	92671648	86206184	80191799	122222090	75796645
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(754,670,214)																
		NPV Cash Flows ($2017) (60%)	(644,025,524)																
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	284,039,384			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		IRR(40%)	0.60%																
		Benefit/Cost Ratio(40%)	1.14																
		Fixed Link Cash Flow (60%)	1,163,184,209			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		IRR(60%)	2.15%																
		Benefit/Cost Ratio(60%)	1.56																
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(720,343,234)																
		NPV Cash Flows ($2017) (60%)	(609,698,545)																
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	524,039,384			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		IRR(40%)	1.07%																
		Benefit/Cost Ratio(40%)	1.25																
		Fixed Link Cash Flow (60%)	1,403,184,209			-17000000	-3000000	-3000000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		IRR(60%)	2.53%																
		Benefit/Cost Ratio(60%)	1.68																

Item (Phase 4 - Operation)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Existing Belle Isle Ferry – Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Existing Belle Isle Ferry – Passenger Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Existing Belle Isle Ferry – Commercial Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
One Time Surge 30% – Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
One Time Surge 30% – Passenger Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
One Time Surge 30% – Commercial Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Existing Gulf Ferries – Passengers	[illegible]																													
Existing Gulf Ferries – Passenger Vehicles	[illegible]																													
Existing Gulf Ferries – Commercial Vehicles	[illegible]																													
Diversion (40%) – Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion (40%) – Passenger Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion (40%) – Commercial Vehicles	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion (60%) – Passengers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversion (60%) – Passenger Vehicles	66684	68352	70060	71812	73607	75447	77334	79267	81249	83280	85362	87496	89683	91925	94223	96579	98993	101468	104005	106605	109270	112002	114802	117672	120614	123629	126720	129888	133135	136464
Diversion (60%) – Commercial Vehicles	206732	211900	217198	222628	228193	233898	239746	245739	251883	258180	264634	271250	278031	284982	292107	299409	306895	314567	322431	330492	338754	347223	355904	364801	373921	383269	392851	402672	412739	423057
Total Traffic (40%) – Passengers	273642	280483	287495	294683	302050	309601	317341	325274	333406	341741	350285	359042	368018	377219	386649	396315	406223	416379	426788	437458	448394	459604	471094	482872	494944	507317	520000	533000	546325	559983
Total Traffic (40%) – Passenger Vehicles	113541	116380	119289	122272	125328	128462	131673	134965	138339	141798	145343	148976	152700	156518	160431	164442	168553	172767	177086	181513	186051	190702	195470	200356	205365	210499	215762	221156	226685	232352
Total Traffic (40%) – Commercial Vehicles	172711	177029	181455	185991	190641	195407	200292	205299	210432	215692	221085	226612	232277	238084	244036	250137	256391	262800	269370	276105	283007	290082	297334	304768	312387	320197	328202	336407	344817	353437
Total Traffic (60%) – Passengers	329588	337827	346273	354930	363803	372898	382221	391776	401571	411610	421900	432448	443259	454340	465699	477341	489275	501507	514044	526895	540068	553569	567409	581594	596134	611037	626313	641971	658020	674471
Total Traffic (60%) – Passenger Vehicles	135770	139164	142643	146209	149864	153611	157451	161387	165422	169558	173796	178141	182595	187160	191839	196635	201551	206589	211754	217048	222474	228036	233737	239580	245570	251709	258002	264452	271063	277840
Total Traffic (60%) – Commercial Vehicles	241622	247662	253854	260200	266705	273373	280207	287212	294393	301752	309296	317029	324954	333078	341405	349940	358689	367656	376847	386269	395925	405823	415969	426368	437027	447953	459152	470631	482397	494456
Revenue (40%) – Passengers	6184311	6338919	6497392	6659826	6826322	6996980	7171905	7351202	7534982	7723357	7916441	8114352	8317211	8525141	8738269	8956726	9180644	9410160	9645414	9886550	10133714	10387056	10646733	10912901	11185724	11465367	11752001	12045801	12346946	12655620
Revenue (40%) – Passenger Vehicles	10821626	11092166	11369470	11653707	11945050	12243676	12549768	12863512	13185100	13514727	13852596	14198911	14553883	14917730	15290674	15672941	16064764	16466383	16878043	17299994	17732494	18175806	18630201	19095956	19573355	20062689	20564256	21078363	21605322	22145455
Revenue (40%) – Commercial Vehicles	41709729	42752472	43821284	44916816	46039736	47190730	48370498	49579760	50819254	52089736	53391979	54726778	56094948	57497322	58934755	60408124	61918327	63466285	65052942	66679265	68346247	70054903	71806276	73601433	75441469	77327505	79260693	81242210	83273266	85355097
Revenue (40%) – Total	58715665.21	60183557	61688146	63230349	64811108	66431386	68092170	69794475	71539337	73327820	75161016	77040041	78966042	80940193	82963698	85037790	87163735	89342828	91576399	93865809	96212454	98617766	101083210	103610290	106200547	108855561	111576950	114366374	117225533	120156171
Revenue (60%) – Passengers	7448680	7634897	7825770	8021414	8221949	8427498	8638185	8854140	9075494	9302381	9534940	9773314	10017647	10268088	10524790	10787910	11057608	11334048	11617399	11907834	12205530	12510668	12823435	13144021	13472621	13809437	14154673	14508540	14871253	15243034
Revenue (60%) – Passenger Vehicles	12940191	13263696	13595288	13935171	14283550	14640639	15006655	15381821	15766366	16160526	16564539	16978652	17403119	17838196	18284151	18741255	19209787	19690031	20182282	20686839	21204010	21734110	22277463	22834400	23405260	23990391	24590151	25204905	25835027	26480903
Revenue (60%) – Commercial Vehicles	58351639	59810430	61305690	62838333	64409291	66019523	67670011	69361762	71095806	72873201	74695031	76562407	78476467	80438379	82449338	84510571	86623336	88788919	91008642	93283858	95615955	98006353	100456512	102967925	105542123	108180676	110885193	113657323	116498756	119411225
Revenue (60%) – Total	78740510.19	80709023	82726749	84794917	86914790	89087660	91314851	93597723	95937666	98336107	100794510	103314373	105897232	108544663	111258280	114039737	116890730	119812998	122808323	125878531	129025495	132251132	135557410	138946345	142420004	145980504	149630017	153370767	157205036	161135162
Operating Cost	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109
Net Revenue (40%)	51067556	52535448	54040037	55582240	57162999	58783277	60444061	62146366	63891228	65679711	67512907	69391932	71317933	73292084	75315589	77389681	79515626	81694719	83928290	86217700	88564345	90969657	93435101	95962181	98552438	101207452	103928841	106718265	109577424	112508062
Net Revenue (60%)	71092401	73060914	75078640	77146808	79266681	81439551	83666742	85949614	88289557	90687998	93146401	95666264	98249123	100896554	103610171	106391628	109242621	112164889	115160214	118230422	121377386	124603023	127909301	131298236	134771895	138332395	141981908	145722658	149556927	153487053
Net Present Value(40%)	17259099	16516462	15804172	15121111	14466191	13838356	13236583	12659878	12107279	11577855	11070703	10584952	10119760	9674312	9247821	8839529	8448704	8074639	7716654	7374094	7046325	6732740	6432753	6145801	5871341	5608851	5357831	5117799	4888292	4668864
Net Present Value(60%)	24026816	22969401	21956975	20987737	20059950	19171941	18322094	17508854	16730721	15986253	15274059	14592804	13941200	13318010	12722045	12152161	11607260	11086286	10588225	10112102	9656984	9221973	8806208	8408863	8029144	7666291	7319577	6988301	6671793	6369412
Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Net Revenue incl. subsidy (40%)	59067556	60535448	62040037	63582240	65162999	66783277	68444061	70146366	71891228	73679711	75512907	77391932	79317933	81292084	83315589	85389681	87515626	89694719	91928290	94217700	96564345	98969657	101435101	103962181	106552438	109207452	111928841	114718265	117577424	120508062
Net Revenue incl. subsidy (60%)	79092401	81060914	83078640	85146808	87266681	89439551	91666742	93949614	96289557	98687998	101146401	103666264	106249123	108896554	111610171	114391628	117242621	120164889	123160214	126230422	129377386	132603023	135909301	139298236	142771895	146332395	149981908	153722658	157556927	161487053
Net Present Value incl. subsidy (40%)	19962827	19031558	18143796	17297505	16490744	15721661	14988495	14289563	13623266	12988075	12382535	11805262	11254931	10730285	10230122	9753297	9298721	8865353	8452202	8058324	7682818	7324827	6983531	6658153	6347947	6052206	5770255	5501449	5245175	5000848
Net Present Value incl. subsidy (60%)	26730544	25484497	24296599	23164131	22084503	21055246	20074006	19138539	18246707	17396473	16585892	15813113	15076371	14373983	13704346	13065930	12457277	11876999	11323772	10796332	10293478	9814060	9356986	8921214	8505750	8109646	7732000	7371950	7028676	6701396
Fixed Link Cash Flow (40%)	51067556.21	52535448	54040037	55582240	57162999	58783277	60444061	62146366	63891228	65679711	67512907	69391932	71317933	73292084	75315589	77389681	79515626	81694719	83928290	86217700	88564345	90969657	93435101	95962181	98552438	101207452	103928841	106718265	109577424	112508062
Fixed Link Cash Flow (60%)	71092401.19	73060914	75078640	77146808	79266681	81439551	83666742	85949614	88289557	90687998	93146401	95666264	98249123	100896554	103610171	106391628	109242621	112164889	115160214	118230422	121377386	124603023	127909301	131298236	134771895	138332395	141981908	145722658	149556927	153487053
Fixed Link Cash Flow incl. subsidy (40%)	59067556	60535448	62040037	63582240	65162999	66783277	68444061	70146366	71891228	73679711	75512907	77391932	79317933	81292084	83315589	85389681	87515626	89694719	91928290	94217700	96564345	98969657	101435101	103962181	106552438	109207452	111928841	114718265	117577424	120508062
Fixed Link Cash Flow incl. subsidy (60%)	79092401	81060914	83078640	85146808	87266681	89439551	91666742	93949614	96289557	98687998	101146401	103666264	106249123	108896554	111610171	114391628	117242621	120164889	123160214	126230422	129377386	132603023	135909301	139298236	142771895	146332395	149981908	153722658	157556927	161487053

Financial Analysis - Option 1 TBM 200% Tolls - Road Tunnel

Section	Case	Item	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction								
		Year		-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Financing During Construction	40% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071	-276875630	-283797521	-232713967	-238531816	-244495112	-250607490	-256872677	-431389918.7	-294783111.1
	Cummulative Construction Cost	Comprised of:	(3,323,910,841)			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431	-706280933	-967214009	-1248288677	-1549234927	-1871191785	-2215358864	-2751094909	-3172648018
		Interest During Construction	(692,065,393)			-444338	-991265	-1203583	-2549780	-5114632	-13525981	-28219109	-42542851	-56451138	-71349369	-87294402	-104346126	-126769997	-151262823
		Project Cost ($2017)	(2,631,845,447)																
	60% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-43617388	-43617388	-238748988	-238748988	-190999191	-190999191	-190999191	-190999191	-190999191	-312939037	-208626025
		Nominal Value				-17773500	-3214913	-3295285	-48145435	-49349071.01	-276875630	-283797521	-232713967	-238531816	-244495112	-250607490	-256872677	-431389918.7	-294783111
	Cummulative Construction Cost	Comprised of:	(3,323,910,841)			-17773500	-21432750	-25719300	-75068318	-126967169	-408957431	-706280933	-967214009	-1248288677	-1549234927	-1871191785	-2215358864	-2751094909	-3172648018
		Interest During Construction	(692,065,393)			-444338	-991265	-1203583	-2549780	-5114632	-13525981	-28219109	-42542851	-56451138	-71349369	-87294402	-104346126	-126769997	-151262823
		Project Cost ($2017)	(2,631,845,447)																
Financing Base Case	40% Diversion Case – Project Cost	Pre operations cost	2,631,845,447																
		Interest during Construction	692,065,393																
	Total Amount to Finance		3,323,910,841																
		Annual Debt Amortization (CRF)	$ (367,386,818)																
		Net Cash Flow																	
		IRR excluding IDC	3.11%																
	60% Diversion Case – Project Cost	Pre operations cost	2,631,845,447																
		Interest during Construction	692,065,393																
	Total Amount to Finance		3,323,910,841																
		Annual Debt Amortization (CRF)	$ (367,386,818)																
		Net Cash Flow																	
		IRR excluding IDC	4.70%																
Subsidised Financing	40% Diversion Case	Project Spending	2631845447			17773500	3214913	3295285	48145435	49349071	276875630	283797521	232713967	238531816	244495112	250607490	256872677	431389919	294783111
		Grant Award	1454000000			17773500	3214913	3295285	48145435	49349071	276875630	283797521	232713967	238531816	244495112	55807749	0	0	0
		Cost less Grant	1177845447			0	0	0	0	0	0	0	0	0	0	194799741	256872677	431389919	294783111
	Total Amount to Finance	Comprised of:	1,329,809,242			0	0	0	0	0	0	0	0	0	0	194799741	456542411	909329377	1250742695
		Interest During Construction	151,963,794			0	0	0	0	0	0	0	0	0	0	4869993.518	21397046.99	46630207.33	79066546.59
		Project Cost ($2017)	1,177,845,447																
		Internal Rate of Return (IRR)	8.0%			0	0	0	0	0	0	0	0	0	0	-199669734	-278269724	-478020126	-373849658
	60% Diversion Case	Project Spending	2631845447			17773500	3214913	3295285	48145435	49349071	276875630	283797521	232713967	238531816	244495112	250607490	256872677	431389919	294783111
		Grant Award	1140000000			17773500	3214913	3295285	48145435	49349071	276875630	283797521	232713967	224834677	0	0	0	0	0
		Cost less Grant	1491845447			0	0	0	0	0	0	0	0	13697139	244495112	250607490	256872677	431389919	294783111
	Total Amount to Finance	Comprised of:	1,755,706,463			0	0	0	0	0	0	0	0	13697139	258534680	516307515	799372881	1277872132	1646926157
		Interest During Construction	263,861,015			0	0	0	0	0	0	0	0	342428.4786	7165345.369	26192689.11	47109332.2	74270913.93	108780306.2
		Project Cost ($2017)	1,491,845,447																
		Internal Rate of Return (IRR)	8.0%			0	0	0	0	0	0	0	0	-14039568	-251660457	-276800179	-303982009	-505660833	-403563417

Item (Phase 4 - Operation)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
40% – Project Cost ($2017)	51067556	52535448	54040037	55582240	57162999	58783277	60444061	62146366	63891228	65679711	67512907	69391932	71317933	73292084	75315589	77389681	79515626	81694719	83928290	86217700	88564345	90969657	93435101	95962181	98552438	101207452	103928841	106718265	109577424	112508062
40% – Nominal Value	73961048	77989168	82228307	86689326	91383639	96323244	101520749	106989406	112743143	118796598	125165155	131864982	138913071	146327281	154126378	162330086	170959134	180035305	189581490	199621749	210181364	221286903	232966287	245248859	258165452	271748470	286031962	301051712	316845322	333452304
60% – Project Cost ($2017)	71092401	73060914	75078640	77146808	79266681	81439551	83666742	85949614	88289557	90687998	93146401	95666264	98249123	100896554	103610171	106391628	109242621	112164889	115160214	118230422	121377386	124603023	127909301	131298236	134771895	138332395	141981908	145722658	149556927	153487053
60% – Nominal Value	102962994	108459337	114241029	120322692	126719695	133448187	140525142	147968397	155796695	164029736	172688221	181793903	191369644	201439467	212028619	223163629	234872374	247184153	260129749	273741513	288053441	303101254	318922490	335556594	353045016	371431311.9	390761248.4	411082918.6	432446857.9	454906168.2
Base 40% – Annual Debt Amortization (CRF)	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818
Base 40% – Net Cash Flow	-293425770	-289397650	-285158511	-280697492	-276003179	-271063574	-265866069	-260397412	-254643675	-248590220	-242221663	-235521836	-228473747	-221059537	-213260440	-205056732	-196427684	-187351513	-177805328	-167765069	-157205454	-146099915	-134420531	-122137959	-109221366	-95638348	-81354856	-66335106	-50541496	-33934514
Base 60% – Annual Debt Amortization (CRF)	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818	-367386818
Base 60% – Net Cash Flow	-264423824	-258927481	-253145789	-247064126	-240667123	-233938631	-226861676	-219418421	-211590123	-203357082	-194698597	-185592915	-176017174	-165947351	-155358199	-144223189	-132514444	-120202665	-107257069	-93645305	-79333377	-64285564	-48464328	-31830224	-14341802	4044494	23374430	43696101	65060040	87519350
Subsidised 40% – Internal Rate of Return (IRR)	73961048	77989168	82228307	86689326	91383639	96323244	101520749	106989406	112743143	118796598	125165155	131864982	138913071	146327281	154126378	162330086	170959134	180035305	189581490	199621749	210181364	221286903	232966287	245248859	258165452	271748470	286031962	301051712	316845322	333452304
Subsidised 60% – Internal Rate of Return (IRR)	102962994	108459337	114241029	120322692	126719695	133448187	140525142	147968397	155796695	164029736	172688221	181793903	191369644	201439467	212028619	223163629	234872374	247184153	260129749	273741513	288053441	303101254	318922490	335556594	353045016	371431312	390761248	411082919	432446858	454906168

Variables - Option 1 TBM 200% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,454	$1,140	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$22.60	$22.60	
Per passenger vehicle	$95.31	$95.31	
Per commercial vehicle	$241.50	$241.50	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

APPENDIX G2

Road Tunnel, 2 TBMs
Economic and Financial Analysis

Appendix G2-1
Road Tunnel, 2 TBMs, 100% Tolls

Economic Analysis - Option 2 TBM 100% Tolls - Road Tunnel

Section	Item	Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction					
				-1	0	1	2	3	4	5	6	7	8	9	10	11
Traffic	**Existing Belle Isle Ferry**			May - October												
		Passengers	7,003,081	83815	85910	88058	90260	92516	94829	97200	99630	102120	104673	107290	109973	112722
		Passenger Vehicles	2,991,067	35798	36693	37610	38551	39514	40502	41515	42553	43616	44707	45824	46970	48144
		Commercial Vehicles	1,510,573	18079	18531	18994	19469	19956	20455	20966	21490	22028	22578	23143	23721	24314
	One Time Surge 30%															
		Passengers	1,745,370	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	745,460	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	376,479	0	0	0	0	0	0	0	0	0	0	0	0	0
	Existing Gulf Ferries															
		Passengers	3,983,540	328528	325243	321990	318770	315583	312427	309303	306210	303147	300116	297115	294144	291202
		Passenger Vehicles	1,582,731	130530	129225	127932	126653	125387	124133	122891	121662	120446	119241	118049	116869	115700
		Commercial Vehicles	3,889,750	267274	271550	275895	280310	284794	289351	293981	298684	303463	308319	313252	318264	323356
	Diversion from Gulf Ferries (40%)															
		Passengers	5,806,630	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	2,307,077	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	6,617,123	0	0	0	0	0	0	0	0	0	0	0	0	0
	Diversion from Gulf Ferries (60%)															
		Passengers	8,709,946	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	3,460,616	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	9,925,684	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (40%)															
		Passengers	13,369,901	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	5,537,405	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	8,248,529	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Traffic for Fixed Link (60%)															
		Passengers	16,273,216	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	6,690,944	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	11,557,091	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenue	**Total Revenue for Fixed Link (40%)**															
		Passengers	151,079,878	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	263,885,052	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	996,009,929	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	**1,410,974,860**	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Revenue for Fixed Link (60%)															
		Passengers	183,887,340	0	0	0	0	0	0	0	0	0	0	0	0	0
		Passenger Vehicles	318,856,935	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial Vehicles	1,395,518,706	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	**1,898,262,981**	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	252,387,597	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	1,158,587,263	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,645,875,384	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	158,615,929													
		Net Present Value(60%)	227,828,583													
		Ferry Subsidy Saving	264,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	1,422,587,263	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Revenue (60%)	1,909,875,384	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(40%)	202,332,745	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Present Value(60%)	271,545,399	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	2,162,507,321			**17000000**	**3000000**	**3000000**	**45715969**	**45715969**	**200400830**	**400801660**	**400801660**	**400801660**	**427241911**	**218027664**
		Net Present Value ($2017)	1,197,820,407			**15813953**	**2595998**	**2414882**	**34232141**	**31843852**	**129852026**	**241585165**	**224730386**	**209051522**	**207295181**	**98405301**
Economic Analysis	**Net Present Value of Fixed Link Cash Flows**	NPV Cash Flows ($2017) (40%)	(1,039,204,478)													
		NPV Cash Flows ($2017) (60%)	(969,991,824)													
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(1,003,920,058)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		IRR(40%)	-2.62%													
		Benefit/Cost Ratio(40%)	0.54													
		Fixed Link Cash Flow (60%)	(516,631,937)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		IRR(60%)	-1.19%													
		Benefit/Cost Ratio(60%)	0.76													
Economic Analysis	**Net Present Value of Fixed Link Cash Flows (including subsidy saving)**	NPV Cash Flows ($2017) (40%)	(995,487,662)													
		NPV Cash Flows ($2017) (60%)	(926,275,008)													
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(739,920,058)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		IRR(40%)	-1.83%													
		Benefit/Cost Ratio(40%)	0.66													
		Fixed Link Cash Flow (60%)	(252,631,937)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		IRR(60%)	-0.56%													
		Benefit/Cost Ratio(60%)	0.88													

Item	Line	Phase 4 - Operation																																
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Existing Belle Isle Ferry	Passengers	115540	118428	121389	124424	127534	130723	133991	137341	140774	144294	147901	151598	155388	159273	163255	167336	171520	175808	180203	184708	189326	194059	198910	203884	208980	214205	219560	225049	230675	236442	242353	248412	254622
	Passenger Vehicles	49340	50582	51846	53142	54471	55833	57228	58659	60126	61629	63170	64749	66367	68027	69727	71471	73257	75089	76966	78890	80862	82884	84956	87080	89257	91488	93776	96120	98523	100986	103511	106098	108751
	Commercial Vehicles	24922	25545	26184	26838	27509	28197	28902	29625	30365	31124	31902	32700	33517	34355	35214	36095	36997	37922	38870	39842	40838	41859	42905	43978	45077	46204	47359	48543	49757	51001	52276	53583	54922
One Time Surge 30%	Passengers	34662	35529	36417	37327	38260	39217	40197	41202	42232	43288	44370	45480	46616	47782	48976	50201	51456	52742	54061	55412	56798	58218	59673	61165	62694	64261	65868	67515	69202	70933	72706	74523	76387
	Passenger Vehicles	14804	15174	15554	15943	16341	16750	17169	17598	18038	18489	18951	19425	19910	20408	20918	21441	21977	22527	23090	23667	24259	24865	25487	26124	26777	27446	28133	28836	29557	30296	31053	31830	32625
	Commercial Vehicles	7477	7664	7855	8052	8253	8459	8671	8887	9110	9337	9571	9810	10055	10307	10564	10828	11099	11377	11661	11953	12251	12558	12872	13193	13523	13861	14208	14563	14927	15300	15683	16075	16477
Existing Gulf Ferries	Passengers	288290																																
	Passenger Vehicles	114543																																
	Commercial Vehicles	328530																																
Diversion from Gulf Ferries (40%)	Passengers	115316	118199	121154	124183	127287	130470	133731	137075	140501	144014	147614	151305	155087	158965	162939	167012	171187	175467	179854	184350	188959	193683	198525	203488	208575	213790	219134	224613	230228	235984	241883	247930	254129
	Passenger Vehicles	45817	46963	48137	49340	50574	51838	53134	54462	55824	57219	58650	60116	61619	63159	64738	66357	68016	69716	71459	73246	75077	76954	78877	80849	82871	84942	87066	89243	91474	93761	96105	98507	100970
	Commercial Vehicles	131412	134697	138065	141516	145054	148681	152398	156208	160113	164116	168218	172424	176734	181153	185682	190324	195082	199959	204958	210082	215335	220717	226235	231891	237688	243630	249721	255964	262363	268922	275645	282537	289600
Diversion from Gulf Ferries (60%)	Passengers	172974	177298	181731	186274	190931	195704	200597	205612	210752	216021	221422	226957	232631	238447	244408	250518	256781	263201	269781	276525	283438	290524	297787	305232	312863	320684	328701	336919	345342	353976	362825	371896	381193
	Passenger Vehicles	68726	70444	72205	74010	75860	77757	79701	81693	83736	85829	87975	90174	92428	94739	97108	99535	102024	104574	107189	109868	112615	115430	118316	121274	124306	127414	130599	133864	137211	140641	144157	147761	151455
	Commercial Vehicles	197118	202046	207097	212274	217581	223021	228596	234311	240169	246173	252328	258636	265102	271729	278522	285486	292623	299938	307437	315123	323001	331076	339353	347836	356532	365446	374582	383946	393545	403384	413468	423805	434400
Total Traffic for Fixed Link (40%)	Passengers	265518	272156	278960	285934	293082	300409	307919	315617	323508	331596	339885	348383	357092	366019	375170	384549	394163	404017	414117	424470	435082	445959	457108	468536	480249	492255	504562	517176	530105	543358	556942	570865	585137
	Passenger Vehicles	109969	112719	115537	118425	121386	124420	127531	130719	133987	137337	140770	144289	147897	151594	155384	159269	163250	167332	171515	175803	180198	184703	189320	194053	198905	203877	208974	214198	219553	225042	230668	236435	242346
	Commercial Vehicles	163811	167906	172104	176406	180816	185337	189970	194719	199587	204577	209692	214934	220307	225815	231460	237247	243178	249257	255489	261876	268423	275133	282012	289062	296289	303696	311288	319070	327047	335223	343604	352194	360999
Total Traffic for Fixed Link (60%)	Passengers	323176	331255	339537	348025	356726	365644	374785	384155	393759	403603	413693	424035	434636	445502	456639	468055	479757	491751	504044	516645	529562	542801	556371	570280	584537	599150	614129	629482	645219	661350	677884	694831	712201
	Passenger Vehicles	132878	136200	139605	143095	146672	150339	154098	157950	161899	165946	170095	174347	178706	183174	187753	192447	197258	202190	207244	212425	217736	223179	228759	234478	240340	246348	252507	258820	265290	271923	278721	285689	292831
	Commercial Vehicles	229517	235255	241136	247164	253343	259677	266169	272823	279644	286635	293801	301146	308674	316391	324301	332409	340719	349237	357968	366917	376090	385492	395130	405008	415133	425511	436149	447053	458229	469685	481427	493462	505799
Total Revenue for Fixed Link (40%)	Passengers	3000353	3075362	3152246	3231052	3311828	3394624	3479490	3566477	3655639	3747030	3840706	3936723	4035141	4136020	4239420	4345406	4454041	4565392	4679527	4796515	4916428	5039338	5165322	5294455	5426816	5562487	5701549	5844088	5990190	6139945	6293443	6450779	6612049
	Passenger Vehicles	5240594	5371609	5505899	5643547	5784635	5929251	6077482	6229419	6385155	6544784	6708403	6876113	7048016	7224217	7404822	7589943	7779691	7974184	8173538	8377877	8587324	8802007	9022057	9247608	9478798	9715768	9958663	10207629	10462820	10724390	10992500	11267313	11548995
	Commercial Vehicles	19780142	20274645	20781511	21301049	21833575	22379415	22938900	23512372	24100182	24702686	25320253	25953260	26602091	27267144	27948822	28647543	29363731	30097825	30850270	31621527	32412065	33222367	34052926	34904249	35776855	36671277	37588059	38527760	39490954	40478228	41490184	42527438	43590624
	Total	28021088.58	28721616	29439656	30175648	30930039	31703290	32495872	33308269	34140976	34994500	35869362	36766096	37685249	38627380	39593065	40582891	41597463	42637400	43703335	44795918	45915816	47063712	48240305	49446312	50682470	51949532	53248270	54579477	55943964	57342563	58776127	60245530	61751668
Total Revenue for Fixed Link (60%)	Passengers	3651889	3743186	3836766	3932685	4031002	4131777	4235072	4340948	4449472	4560709	4674727	4791595	4911385	5034169	5160023	5289024	5421250	5556781	5695700	5838093	5984045	6133646	6286988	6444162	6605266	6770398	6939658	7113149	7290978	7473252	7660084	7851586	8047876
	Passenger Vehicles	6332302	6490609	6652874	6819196	6989676	7164418	7343529	7527117	7715295	7908177	8105881	8308528	8516242	8729148	8947376	9171061	9400337	9635346	9876229	10123135	10376214	10635619	10901509	11174047	11453398	11739733	12033227	12334057	12642409	12958469	13282431	13614491	13954854
	Commercial Vehicles	27714139	28406992	29117167	29845096	30591224	31356004	32139904	32943402	33766987	34611162	35476441	36363352	37272436	38204247	39159353	40138337	41141795	42170340	43224598	44305213	45412844	46548165	47711869	48904666	50127282	51380464	52664976	53981600	55331140	56714419	58132279	59585586	61075225
	Total	37698329.47	38640788	39606807	40596978	41610902	42652200	43718505	44811467	45931754	47080048	48257049	49465475	50706061	51979562	53266753	54598421	55962382	57362467	58796528	60266441	61772102	63315430	64896366	66522873	68185947	69890595	71637860	73429807	75264527	77146140	79074794	81052664	83077955
Total Operating Costs for Fixed Link	Operating Cost	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109	7648109
Total Net Revenue for Fixed Link	Net Revenue (40%)	20372980	21073507	21791547	22527539	23281930	24055181	24847763	25660160	26492867	27346391	28221253	29117987	30037140	30979271	31944956	32934782	33949354	34989291	36055226	37147809	38267707	39415603	40592196	41798203	43034361	44301423	45600161	46931368	48295855	49694454	51128018	52597421	54103559
	Net Revenue (60%)	30050220	30992679	31958698	32948869	33963793	35004091	36070396	37163358	38283645	39431939	40608940	41815366	43051953	44319455	45618644	46950312	48315273	49714358	51148419	52618332	54124993	55669321	57252257	58874766	60537838	62242486	63989751	65780698	67616418	69498031	71426685	73403555	75429846
	Net Present Value(40%)	8553680	8230511	7917163	7615543	7319536	7035010	6759817	6495794	6236769	5988558	5748971	5517809	5294672	5079952	4872841	4673328	4481202	4296253	4118265	3947034	3782349	3624006	3471800	3325534	3185009	3050033	2920416	2795974	2676525	2561892	2451904	2346392	2245192
	Net Present Value(60%)	12616709	12104562	11611026	11135598	10677775	10237052	9812927	9404899	9012473	8635160	8272475	7923941	7589090	7267463	6958607	6662082	6377456	6104307	5842225	5590809	5349670	5118428	4896715	4684173	4480456	4285226	4098159	3918938	3747258	3582824	3425330	3274501	3130191
	Ferry Subsidy Saving	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000	8000000
Total Net Revenue including subsidy saving	Net Revenue (40%)	28372980	29073507	29791547	30527539	31281930	32055181	32847763	33660160	34492867	35346391	36221253	37117987	38037140	38979271	39944956	40934782	41949354	42989291	44055226	45147809	46267707	47415603	48592196	49798203	51034361	52301423	53600161	54931368	56295855	57694454	59128018	60597421	62103559
	Net Revenue (60%)	38050220	38992679	39958698	40948869	41963793	43004091	44070396	45163358	46283645	47431939	48608940	49815366	51051953	52319455	53618644	54950312	56315273	57714358	59148419	60618332	62124993	63669321	65252257	66874766	68537838	70242486	71989751	73780698	75616418	77498031	79426685	81403555	83429846
	Net Present Value(40%)	11912513	11355006	10823670	10317271	9834632	9374634	8936212	8518347	8120074	7740470	7378656	7033796	6705092	6391784	6093150	5808499	5537175	5278552	5032033	4797051	4573062	4359553	4156031	3962027	3777096	3600811	3432768	3272580	3119880	2974315	2835553	2703275	2577176
	Net Present Value(60%)	15975542	15229058	14517533	13839326	13192871	12576676	11989321	11429452	10895779	10387072	9902160	9439927	8999310	8579295	8178916	7797253	7433429	7086608	6755993	6440826	6140384	5853975	5580945	5320666	5072542	4836005	4610511	4395544	4190613	3995247	3809000	3631444	3462175
Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	20372979.58	21073507	21791547	22527539	23281930	24055181	24847763	25660160	26492867	27346391	28221253	29117987	30037140	30979271	31944956	32934782	33949354	34989291	36055226	37147809	38267707	39415603	40592196	41798203	43034361	44301423	45600161	46931368	48295855	49694454	51128018	52597421	54103559
	Fixed Link Cash Flow (60%)	30050220.47	30992679	31958698	32948869	33963793	35004091	36070396	37163358	38283645	39431939	40608940	41815366	43051953	44319455	45618644	46950312	48315273	49714358	51148419	52618332	54124993	55669321	57252257	58874766	60537838	62242486	63989751	65780698	67616418	69498031	71426685	73403555	75429846
Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	28372980	29073507	29791547	30527539	31281930	32055181	32847763	33660160	34492867	35346391	36221253	37117987	38037140	38979271	39944956	40934782	41949354	42989291	44055226	45147809	46267707	47415603	48592196	49798203	51034361	52301423	53600161	54931368	56295855	57694454	59128018	60597421	62103559
	Fixed Link Cash Flow (60%)	38050220	38992679	39958698	40948869	41963793	43004091	44070396	45163358	46283645	47431939	48608940	49815366	51051953	52319455	53618644	54950312	56315273	57714358	59148419	60618332	62124993	63669321	65252257	66874766	68537838	70242486	71989751	73780698	75616418	77498031	79426685	81403555	83429846

Financial Analysis - Option 2 TBM 100% Tolls - Road Tunnel

Section	Item	Year	Totals	2016	2017	Phase 1 - Planning Approval			Phase 2 - Design		Phase 3 - Construction					
				-1	0	1	2	3	4	5	6	7	8	9	10	11
Financing During Construction	**40% Diversion Case**	Project Cost ($2017)				-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		Nominal Value				-17425000	-3151875	-3230672	-50461875	-51723422	-232403523	-476427223	-488337904	-500546351	-546905766	-286071188.7
	Cummulative Construction Cost	**Comprised of:**	**(3,107,353,996)**			-17425000	-21012500	-25215000	-76856859	-131161577	-368830093	-857888733	-1377210393	-1934408816	-2565521364	-2966195977
		Interest During Construction	**(450,669,196)**			-435625	-971828	-1179983	-2581296	-5264993	-12631417	-30983756	-56652072	-84206782	-114603424	-141158019.1
		Project Cost ($2017)	**(2,656,684,801)**													
	60% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664
		Nominal Value				-17773500	-3214913	-3295285	-50461875	-51723422.22	-232403523	-476427223	-488337904	-500546351	-546905766	-286071189
	Cummulative Construction Cost	**Comprised of:**	**(3,108,133,944)**			-17773500	-21432750	-25719300	-77384758	-131715871	-369412103	-858499843	-1377852058	-1935082564	-2566228800	-2966938785
		Interest During Construction	**(450,972,993)**			-444338	-991265	-1203583	-2607691	-5292708	-12660517	-31014312	-56684155	-84240469	-114638796	-141195160
		Project Cost ($2017)	**(2,657,160,952)**													
Financing Base Case	**40% Diversion Case**															
	Project Cost	Pre operations cost	2,656,684,801													
		Interest during Construction	450,669,196													
	Total Amount to Finance		**3,107,353,996**													
		Annual Debt Amortization (CRF)	$ **(343,451,119)**													
		Net Cash Flow														
		IRR excluding IDC	**-0.19%**													
	60% Diversion Case															
	Project Cost	Pre operations cost	2,657,160,952													
		Interest during Construction	450,972,993													
	Total Amount to Finance		**3,108,133,944**													
		Annual Debt Amortization (CRF)	$ **(343,451,119)**													
		Net Cash Flow														
		IRR excluding IDC	**1.28%**													
Subsidised Financing	**40% Diversion Case**	Project Spending	2656684801			17425000	3151875	3230672	50461875	51723422	232403523	476427223	488337904	500546351	546905766	286071189
		Grant Award	2104000000			17425000	3151875	3230672	50461875	51723422	232403523	476427223	488337904	500546351	280292155	0
		Cost less Grant	552684801			0	0	0	0	0	0	0	0	0	266613612	286071189
	Total Amount to Finance															
		Comprised of:	**586,997,842**			0	0	0	0	0	0	0	0	0	266613612	559350141
		Interest During Construction	**34,313,041**			0	0	0	0	0	0	0	0	0	6665340.299	27647701.14
		Project Cost ($2017)	**552,684,801**													
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	0	-273278952	-313718890
	60% Diversion Case	Project Spending	2657160952			17773500	3214913	3295285	50461875	51723422	232403523	476427223	488337904	500546351	546905766	286071189
		Grant Award	1880000000			17773500	3214913	3295285	50461875	51723422	232403523	476427223	488337904	500546351	55816004	0
		Cost less Grant	777160952			0	0	0	0	0	0	0	0	0	491089763	286071189
	Total Amount to Finance															
		Comprised of:	**834,342,501**			0	0	0	0	0	0	0	0	0	491089763	789438196
		Interest During Construction	**57,181,549**			0	0	0	0	0	0	0	0	0	12277244.07	44904305.24
		Project Cost ($2017)	**777,160,952**													
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	0	-503367007	-330975494

Item	Line	Phase 4 - Operation																																
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Financing During Construction 40%	Project Cost ($2017)	20372980	21073507	21791547	22527539	23281930	24055181	24847763	25660160	26492867	27346391	28221253	29117987	30037140	30979271	31944956	32934782	33949354	34989291	36055226	37147809	38267707	39415603	40592196	41798203	43034361	44301423	45600161	46931368	48295855	49694454	51128018	52597421	54103559
	Nominal Value	27399393	29050062	30790886	32626593	34562156	36602802	38754030	41021619	43411647	45930502	48584903	51381912	54328954	57433837	60704766	64150369	67779717	71602344	75628273	79868042	84332726	89033968	93984009	99195713	104682603	110458895	116539530	122940213	129677453	136768601	144231893	152086499	160352566
Financing During Construction 60%	Project Cost ($2017)	30050220	30992679	31958698	32948869	33963793	35004091	36070396	37163358	38283645	39431939	40608940	41815366	43051953	44319455	45618644	46950312	48315273	49714358	51148419	52618332	54124993	55669321	57252257	58874766	60537838	62242486	63989751	65780698	67616418	69498031	71426685	73403555	75429846
	Nominal Value	40414206	42723750	45156804	47719786	50419442	53262863	56257507	59411209	62732210	66229169	69911189	73787842	77869185	82165791	86688776	91449819	96461202	101735829	107287266	113129771	119278330	125748694	132557417	139721900	147260428	155192222.5	163537482.2	172317437.1	181554398.8	191271816.6	201494334.3	212247851.5	223559587.1
Financing Base Case 40%	Annual Debt Amortization (CRF)	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119
	Net Cash Flow	-316051726	-314401057	-312660233	-310824526	-308888963	-306848316	-304697089	-302429500	-300039472	-297520617	-294866216	-292069207	-289122164	-286017282	-282746353	-279300749	-275671402	-271848775	-267822845	-263583077	-259118393	-254417150	-249467110	-244255406	-238768516	-232992224	-226911589	-220510905	-213773666	-206682518	-199219226	-191364620	-183098553
Financing Base Case 60%	Annual Debt Amortization (CRF)	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119	-343451119
	Net Cash Flow	-303036913	-300727369	-298294315	-295731333	-293031677	-290188255	-287193612	-284039909	-280718909	-277221950	-273539929	-269663277	-265581934	-261285328	-256762343	-252001299	-246989917	-241715290	-236163853	-230321348	-224172789	-217702425	-210893702	-203729219	-196190690	-188258896	-179913637	-171133682	-161896720	-152179302	-141956785	-131203267	-119891532
Subsidised Financing 40%	Internal Rate of Return (IRR)	27399393	29050062	30790886	32626593	34562156	36602802	38754030	41021619	43411647	45930502	48584903	51381912	54328954	57433837	60704766	64150369	67779717	71602344	75628273	79868042	84332726	89033968	93984009	99195713	104682603	110458895	116539530	122940213	129677453	136768601	144231893	152086499	160352566
Subsidised Financing 60%	Internal Rate of Return (IRR)	40414206	42723750	45156804	47719786	50419442	53262863	56257507	59411209	62732210	66229169	69911189	73787842	77869185	82165791	86688776	91449819	96461202	101735829	107287266	113129771	119278330	125748694	132557417	139721900	147260428	155192223	163537482	172317437	181554399	191271817	201494334	212247851	223559587

Variables - Option 2 TBM 100% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$2,104	$1,880	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$11.30	$11.30	
Per passenger vehicle	$47.66	$47.66	
Per commercial vehicle	$120.75	$120.75	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix G2-2
Road Tunnel, 2 TBMs, 150% Tolls

Economic Analysis - Option 2 TBM 150% Tolls - Road Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)	(7)	(8)	(9)	(10)	(11)	Phase 4 - Operation (12)
Traffic																	
	Existing Belle Isle Ferry			May - October													
		Passengers	7,003,081	83815	85910	88058	90260	92516	94829	97200	99630	102120	104673	107290	109973	112722	115540
		Passenger Vehicles	2,991,067	35798	36693	37610	38551	39514	40502	41515	42553	43616	44707	45824	46970	48144	49348
		Commercial Vehicles	1,510,573	18079	18531	18994	19469	19956	20455	20966	21490	22028	22578	23143	23721	24314	24922
	One Time Surge 30%																
		Passengers	1,745,370	0	0	0	0	0	0	0	0	0	0	0	0	0	34662
		Passenger Vehicles	745,460	0	0	0	0	0	0	0	0	0	0	0	0	0	14804
		Commercial Vehicles	376,479	0	0	0	0	0	0	0	0	0	0	0	0	0	7477
	Existing Gulf Ferries																
		Passengers	3,983,540	328528	325243	321990	318770	315583	312427	309303	306210	303147	300116	297115	294144	291202	288290
		Passenger Vehicles	1,582,731	130530	129225	127932	126653	125387	124133	122891	121662	120446	119241	118049	116869	115700	114543
		Commercial Vehicles	3,889,750	267274	271550	275895	280310	284794	289351	293981	298684	303463	308319	313252	318264	323356	328530
	Diversion from Gulf Ferries (40%)																
		Passengers	5,806,630	0	0	0	0	0	0	0	0	0	0	0	0	0	115316
		Passenger Vehicles	2,307,077	0	0	0	0	0	0	0	0	0	0	0	0	0	45817
		Commercial Vehicles	6,617,123	0	0	0	0	0	0	0	0	0	0	0	0	0	131412
	Diversion from Gulf Ferries (60%)																
		Passengers	8,709,946	0	0	0	0	0	0	0	0	0	0	0	0	0	172974
		Passenger Vehicles	3,460,616	0	0	0	0	0	0	0	0	0	0	0	0	0	68726
		Commercial Vehicles	9,925,684	0	0	0	0	0	0	0	0	0	0	0	0	0	197118
	Total Traffic for Fixed Link (40%)																
		Passengers	13,369,901	0	0	0	0	0	0	0	0	0	0	0	0	0	265518
		Passenger Vehicles	5,537,405	0	0	0	0	0	0	0	0	0	0	0	0	0	109969
		Commercial Vehicles	8,248,529	0	0	0	0	0	0	0	0	0	0	0	0	0	163811
	Total Traffic for Fixed Link (60%)																
		Passengers	16,273,216	0	0	0	0	0	0	0	0	0	0	0	0	0	323176
		Passenger Vehicles	6,690,944	0	0	0	0	0	0	0	0	0	0	0	0	0	132878
		Commercial Vehicles	11,557,091	0	0	0	0	0	0	0	0	0	0	0	0	0	229517
Revenue	Total Revenue for Fixed Link (40%)																
		Passengers	226,619,818	0	0	0	0	0	0	0	0	0	0	0	0	0	4500530
		Passenger Vehicles	395,827,578	0	0	0	0	0	0	0	0	0	0	0	0	0	7860891
		Commercial Vehicles	1,494,014,894	0	0	0	0	0	0	0	0	0	0	0	0	0	29670212
		Total	**2,116,462,290**	0	0	0	0	0	0	0	0	0	0	0	0	0	42031632.87
	Total Revenue for Fixed Link (60%)																
		Passengers	275,831,010	0	0	0	0	0	0	0	0	0	0	0	0	0	5477833
		Passenger Vehicles	478,285,402	0	0	0	0	0	0	0	0	0	0	0	0	0	9498452
		Commercial Vehicles	2,093,278,059	0	0	0	0	0	0	0	0	0	0	0	0	0	41571208
		Total	**2,847,394,471**	0	0	0	0	0	0	0	0	0	0	0	0	0	56547494.2
	Total Operating Costs for Fixed Link																
		Operating Cost	252,387,597	0	0	0	0	0	0	0	0	0	0	0	0	0	7648109
	Total Net Revenue for Fixed Link																
		Net Revenue (40%)	1,864,074,693	0	0	0	0	0	0	0	0	0	0	0	0	0	34383524
		Net Revenue (60%)	2,595,006,874	0	0	0	0	0	0	0	0	0	0	0	0	0	48899385
		Net Present Value(40%)	258,820,829														14436064
		Net Present Value(60%)	362,639,810														20530609
		Ferry Subsidy Saving	264,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	8000000
	Total Net Revenue including subsidy saving																
		Net Revenue (40%)	2,128,074,693	0	0	0	0	0	0	0	0	0	0	0	0	0	42383524
		Net Revenue (60%)	2,859,006,874	0	0	0	0	0	0	0	0	0	0	0	0	0	56899385
		Net Present Value(40%)	302,537,645	0	0	0	0	0	0	0	0	0	0	0	0	0	17794898
		Net Present Value(60%)	406,356,626	0	0	0	0	0	0	0	0	0	0	0	0	0	23889442
	Total Capital Cost																
		Net Cost ($2017)	2,162,507,321			**17000000**	**3000000**	**3000000**	**45715969**	**45715969**	**200400830**	**400801660**	**400801660**	**400801660**	**427241911**	**218027664**	
		Net Present Value ($2017)	1,197,820,407			**15813953**	**2595998**	**2414882**	**34232141**	**31843852**	**129852026**	**241585165**	**224730386**	**209051522**	**207295181**	**98405301**	
Economic Analysis	Net Present Value of Fixed Link Cash Flows	NPV Cash Flows ($2017) (40%)	(938,999,578)														
		NPV Cash Flows ($2017) (60%)	(835,180,597)														
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	(298,432,628)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	34383523.87
		IRR(40%)	-0.66%														
		Benefit/Cost Ratio(40%)	0.86														
		Fixed Link Cash Flow (60%)	432,499,553			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	48899385.2
		IRR(60%)	0.84%														
		Benefit/Cost Ratio(60%)	1.20														
Economic Analysis	Net Present Value of Fixed Link Cash Flows (including subsidy saving)	NPV Cash Flows ($2017) (40%)	(895,282,762)														
		NPV Cash Flows ($2017) (60%)	(791,463,781)														
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	(34,432,628)			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	42383524
		IRR(40%)	-0.07%														
		Benefit/Cost Ratio(40%)	0.98														
		Fixed Link Cash Flow (60%)	696,499,553			-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	56899385
		IRR(60%)	1.32%														
		Benefit/Cost Ratio(60%)	1.32														

Financial Analysis - Option 2 TBM 150% Tolls - Road Tunnel

Section	Item	Year	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)	(2)	(3)	Phase 2 - Design (4)	(5)	Phase 3 - Construction (6)	(7)	(8)	(9)	(10)	(11)	Phase 4 - Operation (12)
Financing During Construction	40% Diversion Case	Project Cost ($2017)				-17000000	-3000000	-3000000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	34383524
		Nominal Value				-17425000	-3151875	-3230672	-50461875	-51723422	-232403523	-476427223	-488337904	-500546351	-546905766	-286071188.7	46242017
	Cummulative Construction Cost	**Comprised of:**	**(3,107,353,996)**			-17425000	-21012500	-25215000	-76856859	-131161577	-368830093	-857888733	-1377210393	-1934408816	-2565521364	-2966195977	
		Interest During Construction	**(450,669,196)**			-435625	-971828	-1179983	-2581296	-5264993	-12631417	-30983756	-56652072	-84206782	-114603424	-141158019.1	
		Project Cost ($2017)	**(2,656,684,801)**														
	60% Diversion Case	Project Cost ($2017)				-17340000	-3060000	-3060000	-45715969	-45715969	-200400830	-400801660	-400801660	-400801660	-427241911	-218027664	48899385
		Nominal Value				-17773500	-3214913	-3295285	-50461875	-51723422.22	-232403523	-476427223	-488337904	-500546351	-546905766	-286071189	65764237
	Cummulative Construction Cost	**Comprised of:**	**(3,108,133,944)**			-17773500	-21432750	-25719300	-77384758	-131715871	-369412103	-858499843	-1377852058	-1935082564	-2566228800	-2966938785	
		Interest During Construction	**(450,972,993)**			-444338	-991265	-1203583	-2607691	-5292708	-12660517	-31014312	-56684155	-84240469	-114638796	-141195160	
		Project Cost ($2017)	**(2,657,160,952)**														
Financing Base Case	40% Diversion Case																
	Project Cost	Pre operations cost	2,656,684,801														
		Interest during Construction	450,669,196														
	Total Amount to Finance		**3,107,353,996**														
		Annual Debt Amortization (CRF)	$ **(343,451,119)**														-343451119
		Net Cash Flow															-297209102
		IRR excluding IDC	**1.83%**														
	60% Diversion Case																
	Project Cost	Pre operations cost	2,657,160,952														
		Interest during Construction	450,972,993														
	Total Amount to Finance		**3,108,133,944**														
		Annual Debt Amortization (CRF)	$ **(343,451,119)**														-343451119
		Net Cash Flow															-277686882
		IRR excluding IDC	**3.36%**														
Subsidised Financing	40% Diversion Case	Project Spending	2656684801			17425000	3151875	3230672	50461875	51723422	232403523	476427223	488337904	500546351	546905766	286071189	
		Grant Award	1785000000			17425000	3151875	3230672	50461875	51723422	232403523	476427223	488337904	461838506	0	0	
		Cost less Grant	871684801			0	0	0	0	0	0	0	0	38707845	546905766	286071189	
	Total Amount to Finance																
		Comprised of:	**941,694,808**			0	0	0	0	0	0	0	0	38707845	586581308	889300807	
		Interest During Construction	**70,010,007**			0	0	0	0	0	0	0	0	967696.1369	16648309.78	52394001.06	
		Project Cost ($2017)	**871,684,801**														
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	-39675542	-563554076	-338465190	46242017
	60% Diversion Case	Project Spending	2657160952			17773500	3214913	3295285	50461875	51723422	232403523	476427223	488337904	500546351	546905766	286071189	
		Grant Award	1495000000			17773500	3214913	3295285	50461875	51723422	232403523	476427223	488337904	171362355	0	0	
		Cost less Grant	1162160952			0	0	0	0	0	0	0	0	329183996	546905766	286071189	
	Total Amount to Finance																
		Comprised of:	**1,285,768,347**			0	0	0	0	0	0	0	0	329183996	884319363	1209369215	
		Interest During Construction	**123,607,396**			0	0	0	0	0	0	0	0	8229599.91	38978663.89	76399131.72	
		Project Cost ($2017)	**1,162,160,952**														
		Internal Rate of Return (IRR)	**8.0%**			0	0	0	0	0	0	0	0	-337413596	-585884430	-362470320	65764237

Variables - Option 2 TBM 150% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,785	$1,495	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$16.95	$16.95	
Per passenger vehicle	$71.48	$71.48	
Per commercial vehicle	$181.13	$181.13	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
Commercial Vehicle Labrador - Surge	30.0%	30.0%	
Passenger Gulf - Traditional Growth	-1.0%	-1.0%	
Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

Appendix G2-3
Road Tunnel, 2 TBMs, 200% Tolls

Economic Analysis - Option 2 TBM 200% Tolls - Road Tunnel

Section	Item	Line	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)
Traffic						
	Existing Belle Isle Ferry			May - October		
		Passengers	7,003,081	83815	85910	88058
		Passenger Vehicles	2,991,067	35798	36693	37610
		Commercial Vehicles	1,510,573	18079	18531	18994
	One Time Surge 30%					
		Passengers	1,745,370	0	0	0
		Passenger Vehicles	745,460	0	0	0
		Commercial Vehicles	376,479	0	0	0
	Existing Gulf Ferries					
		Passengers	3,983,540	328528	325243	321990
		Passenger Vehicles	1,582,731	130530	129225	127932
		Commercial Vehicles	3,889,750	267274	271550	275895
	Diversion from Gulf Ferries (40%)					
		Passengers	5,806,630	0	0	0
		Passenger Vehicles	2,307,077	0	0	0
		Commercial Vehicles	6,617,123	0	0	0
	Diversion from Gulf Ferries (60%)					
		Passengers	8,709,946	0	0	0
		Passenger Vehicles	3,460,616	0	0	0
		Commercial Vehicles	9,925,684	0	0	0
	Total Traffic for Fixed Link (40%)					
		Passengers	13,369,901	0	0	0
		Passenger Vehicles	5,537,405	0	0	0
		Commercial Vehicles	8,248,529	0	0	0
	Total Traffic for Fixed Link (60%)					
		Passengers	16,273,216	0	0	0
		Passenger Vehicles	6,690,944	0	0	0
		Commercial Vehicles	11,557,091	0	0	0
Revenue	**Total Revenue for Fixed Link (40%)**					
		Passengers	302,159,757	0	0	0
		Passenger Vehicles	527,770,104	0	0	0
		Commercial Vehicles	1,992,019,859	0	0	0
		Total	**2,821,949,720**	0	0	0
	Total Revenue for Fixed Link (60%)					
		Passengers	367,774,680	0	0	0
		Passenger Vehicles	637,713,869	0	0	0
		Commercial Vehicles	2,791,037,412	0	0	0
		Total	**3,796,525,961**	0	0	0
	Total Operating Costs for Fixed Link	Operating Cost	252,387,597	0	0	0
	Total Net Revenue for Fixed Link	Net Revenue (40%)	2,569,562,123	0	0	0
		Net Revenue (60%)	3,544,138,364	0	0	0
		Net Present Value(40%)	359,025,729			
		Net Present Value(60%)	497,451,038			
		Ferry Subsidy Saving	264,000,000	0	0	0
	Total Net Revenue including subsidy saving	Net Revenue (40%)	2,833,562,123	0	0	0
		Net Revenue (60%)	3,808,138,364	0	0	0
		Net Present Value(40%)	402,742,545	0	0	0
		Net Present Value(60%)	541,167,854	0	0	0
	Total Capital Cost	**Net Cost ($2017)**	2,162,507,321			**17000000**
		Net Present Value ($2017)	1,197,820,407			**15813953**
Economic Analysis	**Net Present Value of Fixed Link Cash Flows**	NPV Cash Flows ($2017) (40%)	(838,794,678)			
		NPV Cash Flows ($2017) (60%)	(700,369,370)			
	Benefit/Cost Ratio and IRR	Fixed Link Cash Flow (40%)	407,054,802			-17000000
		IRR(40%)	0.79%			
		Benefit/Cost Ratio(40%)	1.19			
		Fixed Link Cash Flow (60%)	1,381,631,044			-17000000
		IRR(60%)	2.37%			
		Benefit/Cost Ratio(60%)	1.64			
Economic Analysis	**Net Present Value of Fixed Link Cash Flows (including subsidy saving)**	NPV Cash Flows ($2017) (40%)	(795,077,862)			
		NPV Cash Flows ($2017) (60%)	(656,652,554)			
	Benefit/Cost Ratio and IRR (including subsidy saving)	Fixed Link Cash Flow (40%)	671,054,802			-17000000
		IRR(40%)	1.27%			
		Benefit/Cost Ratio(40%)	1.31			
		Fixed Link Cash Flow (60%)	1,645,631,044			-17000000
		IRR(60%)	2.77%			
		Benefit/Cost Ratio(60%)	1.76			

Financial Analysis - Option 2 TBM 200% Tolls - Road Tunnel

Section	Item	Line	Totals	2016 (-1)	2017 (0)	Phase 1 - Planning Approval (1)
Financing During Construction	**40% Diversion Case**	Project Cost ($2017)				-17000000
		Nominal Value				-17425000
	Cummulative Construction Cost	**Comprised of:**	**(3,107,353,996)**			-17425000
		Interest During Construction	**(450,669,196)**			-435625
		Project Cost ($2017)	**(2,656,684,801)**			
	60% Diversion Case	Project Cost ($2017)				-17340000
		Nominal Value				-17773500
	Cummulative Construction Cost	**Comprised of:**	**(3,108,133,944)**			-17773500
		Interest During Construction	**(450,972,993)**			-444338
		Project Cost ($2017)	**(2,657,160,952)**			
Financing Base Case	**40% Diversion Case**					
	Project Cost	Pre operations cost	2,656,684,801			
		Interest during Construction	450,669,196			
	Total Amount to Finance		**3,107,353,996**			
		Annual Debt Amortization (CRF)	$ **(343,451,119)**			
		Net Cash Flow				
		IRR excluding IDC	**3.31%**			
	60% Diversion Case					
	Project Cost	Pre operations cost	2,657,160,952			
		Interest during Construction	450,972,993			
	Total Amount to Finance		**3,108,133,944**			
		Annual Debt Amortization (CRF)	$ **(343,451,119)**			
		Net Cash Flow				
		IRR excluding IDC	**4.93%**			
Subsidised Financing	**40% Diversion Case**	Project Spending	2656684801			17425000
		Grant Award	1505000000			17425000
		Cost less Grant	1151684801			0
	Total Amount to Finance					
		Comprised of:	**1,273,359,183**			0
		Interest During Construction	**121,674,382**			0
		Project Cost ($2017)	**1,151,684,801**			
		Internal Rate of Return (IRR)	**8.0%**			0
	60% Diversion Case	Project Spending	2657160952			17773500
		Grant Award	1145000000			17773500
		Cost less Grant	1512160952			0
	Total Amount to Finance					
		Comprised of:	**1,716,218,747**			0
		Interest During Construction	**204,057,795**			0
		Project Cost ($2017)	**1,512,160,952**			
		Internal Rate of Return (IRR)	**8.0%**			0

Variables - Option 2 TBM 200% Tolls - Road Tunnel

	40% Diversion Case	60% Diversion Case	
Debt Financing (Real)	8.0%	8.0%	
Long Term Inflation	2.5%	2.5%	
Equity Real	11.0%	11.0%	
Equity Tax Rate	40.0%	40.0%	
Equity Pre Tax - Real	18.3%	18.3%	
Equity PreTax - Nominal	22.5%	22.5%	
% debt financed	0.0%	0.0%	
% equity financed	0.0%	0.0%	
Nominal Grant $ Millions	$1,505	$1,145	
Blended Cost of Capital - Real	0.0%	0.0%	
Blended Cost of Capital - Nominal	0.0%	0.0%	
Financing during Construction	5.0%	5.0%	
Social Discount Rate - Nominal	10.0%	10.0%	
Social Discount Rate - Real	7.5%	7.5%	
Grant Discount Rate	0.0%	0.0%	
Operating Cost	$ 7,648,109	$ 7,648,109	
Tolls			
Per passenger	$22.60	$22.60	
Per passenger vehicle	$95.31	$95.31	
Per commercial vehicle	$241.50	$241.50	
Passenger Labrador - Traditional Growth	2.5%	2.5%	
Passenger Vehicle Labrador - Traditional Growth	2.5%	2.5%	
Commercial Vehicle Labrador - Traditional Grow	2.5%	2.5%	
Passenger Vehicle Labrador - Surge	30.0%	30.0%	
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Passenger Vehicle Gulf - Traditional Growth	-1.0%	-1.0%	
Commercial Vehicle Gulf - Traditional Growth	1.6%	1.6%	
Passenger - Diversion from Gulf	40.0%	60.0%	
Passenger Vehicle - Diversion from Gulf	40.0%	60.0%	
Commercial Vehicle- Diversion from Gulf	40.0%	60.0%	
Ferry Subsidy	$ 8,000,000	$ 8,000,000	

St.Barbe - Blanc Sablon, NL

Rates in effect for travel up to May31, 2018.

Passengers Rates (one way)

	Rates		Total	Blended Rate
Adults 13 - 64 years	$11.75		$11.75	**$9.40**
Children 5 - 12 years	$9.50		$9.50	$0.95
Children under 5	FREE		FREE	
Senior Citizens 65 years +	$9.50		$9.50	$0.95
				$11.30

Vehicle Rates (one way)

Autos with trailers, campers, motor homes, vans, minibuses				
	Rates	**Fuel**	**Total**	**Blended Rate**
Autos, pickups up to 20'	$35.25	$0.00	$35.25	$27.50
Over 20' to 30'	$51.75	$0.00	$51.75	
Over 30' to 40'	$69.00	$0.00	$69.00	$3.45
Over 40' to 50'	$86.25	$0.00	$86.25	
Over 50' to 60'	$103.25	$0.00	$103.25	$15.49
Over 60'	$120.75	$0.00	$120.75	
Minibus up to 30'	$0.00	$0.00	$0.00	
Buses	$86.25	$0.00	$86.25	$0.86
Motorcycles / ATVs	$18.00	$0.00	$18.00	$0.36
Motorcycles / ATVs with sidecar or trailer	$0.00	$0.00	$0.00	
Bicycles	$0.00	$0.00	$0.00	
				$47.66

Commercial Vehicle	$120.75	$0.00	$120.75	**$120.75**

APPENDIX H

Biographies – Project Team

Mark F. Cumby, P. Eng. – Project Sponsor
Regional Director, Energy, Eastern North America, Hatch
Mark Cumby offers over 24 years of progressive and comprehensive experience in a variety of energy projects across the globe. Accomplished in project management, engineering management, and general business management, through work with Tier 1 operators and EPC firms, he has demonstrated a "customer first" focus, with a keen ability to get deliverables driven to closure, and effective problem-solving skills recognized by colleagues and clients.

Prior to joining Hatch in 2016, he was involved in project management and delivery of the drilling modules for the Hebron Project. Presently in the role of Regional Director, Energy for Eastern North America, Mr. Cumby also serves as project manager or sponsor for a number of energy and infrastructure projects in the region.

Mr. Cumby is a registered Professional Engineer in the province of Newfoundland and Labrador.

Jean Habimana, P. Eng., PhD – Project Manager
Director of Tunnel Practice Lead, Eastern North American, Hatch
Jean Habimana is experienced in a variety of aspects of geotechnical and tunnel engineering for both soft ground and hard rock tunneling. He has over 20 years of experience and has worked on design and construction of major projects including tunnels, caverns, shafts, open-cut, cut-and-cover excavations, highways, and bridge foundation. His experience ranges from conceptual design to preparation of engineering final design documents including Geotechnical Baseline Reports, drawings and specifications and providing engineering services during construction.

Mr. Habimana has extensive experience in static and seismic soil-structure interaction analysis and seismic design of tunnels and underground facilities. He notably managed tunnel design and construction projects, and he is skilled in the coordination of different disciplines, the management of client inspections, and completing projects on time and on budget. His experience includes projects in Europe, China, Australia, United States and Canada.

Brian Garrod, P. Eng. – Tunnelling Expert
Director Tunnels, Australasia, Hatch
Brian Garrod is a Director - Tunnelling with Hatch and a world-recognized expert on tunnels and tunnel technology. With multiple publications, he is a sought-after speaker at technical conferences. He has 46 years of general civil engineering experience, the last 36 years devoted solely to tunnelling assignments. Mr. Garrod's technical expertise covers a broad range of tunnel techniques for high and low-strength rocks and soft ground using excavation methods such as earth pressure balance tunnel boring machines (EPB TBM) and the New Austrian Tunnel Method (NATM). Moreover, he specializes in the design of pressurized-face TBM-driven tunnels, one-pass segmental tunnel linings, risk analysis, productivity analyses and cost

estimates for underground projects. Mr. Garrod has developed Hatch's in-house tunnels estimating system that enables his team to produce highly accurate project cost estimates.

With outstanding tunnelling qualifications, Mr. Garrod has been engaged on significant projects around the world such as the Channel Tunnel. In Canada, his expert knowledge has been applied on major projects to expand transit facilities, e.g. Toronto's new Eglinton Crosstown LRT and Vancouver's Skytrain. He also has significant expertise with water conveyance tunnels through various roles on such projects as the new 10 km diversion tunnel at Niagara Falls to serve the Sir Adam Beck hydro power station. Mr. Garrod has significant construction management experience, providing oversight and engineering support during construction for major tunnel projects.

Mr. Garrod was involved in the preparation of the 2004 pre-feasibility study.

Gabriele Mellies, P. Eng. – Rock and Tunnel Engineering
Senior Project Engineer, Geotechnique and Tunnels, Hatch

Gabriele Mellies is a Senior Engineer with over 18 years of experience in consulting engineering in the field of geotechnical, rock and tunnel engineering. Ms. Mellies has extensive technical and project management experience from various civil engineering and mining engineering projects for private and federal clients in Canada and Switzerland with a main focus on tunnel and rock slope stabilization projects. Her areas of expertise include geotechnical analysis and design, geotechnical investigations and data analysis, rock mass characterization, ground support design and installation, rockfall hazard assessments, rock slope remediation and geotechnical monitoring.

Ms. Mellies' experience extends from preliminary to final design and preparation of final design documents, including drawings, technical specifications and geotechnical baseline, data and design reports. Ms. Mellies also has extensive experience in providing engineering services during construction for geotechnical and tunnel projects. She is recognized for her client focus and for delivering complex projects in time and on budget.

Ms. Mellies is a registered Professional Engineer in the provinces of Ontario, Québec and Newfoundland and Labrador.

Djoko Corovic, P. Eng. – Electrical Engineering
Electrical Engineering Design Lead, Hatch

Djoko Corovic is a licensed professional registered in Ontario, Alberta and Quebec with over 25 years of experience in the field. He has significant design and operational improvements experience for projects across North America and globally. His team leadership and project management skills have been proven for numerous transit infrastructures, tunnels and industrial projects, both in private and public sectors. His skills include performance audits, conceptual design, tendering (including P3) and project estimates.

Mr. Corovic's experience includes detail design, construction and commissioning supervision for electrical and communications infrastructures. He has led electrical and systems teams for various projects including for rail and road tunnels, transit yards, transit control centers, underground stations and surface stops. His experience includes HAZOP studies and provisions of safety egress components for rail and road tunnels, elevated structures and underground stations. Mr. Corovic has performed project solutions safety and security analysis and design details including surveillance coverage, intruder protection and access control. He is currently engaged with several DMBF delivery exercises across Canada.

Amir Golpaygan, P. Eng. – Mechanical Engineering
Principal Engineer/ Fire Life Safety & Security, Hatch
Dr. Amir Golpaygan has 20 years of experience in mechanical engineering design and analysis, fire & life safety engineering, tunnel ventilation and engineering management including performance-based fire engineering based on North American fire standards including National Fire Protection Association Standard (NFPA) 130 and 502. Dr. Golpaygan has extensive knowledge and experience in the application of simulation techniques in engineering design, in specific use of Subway Environmental System (SES) and Computational Fluid Dynamics (CFD) as an analysis tool for the design verification, and optimization of tunnel ventilation systems, subway station smoke management, odor control system, ventilation system design and optimization, smoke dispersion analysis, and gas handling systems. He has been responsible for the design of numerous ventilation and smoke control systems where the complexity of the design has required the use of CFD. His work has resulted in many innovate techniques used to assess performance and options available to the design team.

Dr. Golpaygan's experience has involved in the application of the NFPA130 and NFPA502 and the Ontario Building Code (OBC) in the design of normal and emergency ventilation systems for subway systems, light rail transit systems, tunnel fire, analysis of aerodynamics of trains in tunnels, and the prediction of smoke movement and fires in tunnels and underground infrastructures.

John Hemingway, P. Eng., PTOE – Civil Engineering
Senior Project Manager, Hatch
John Hemingway is a Senior Project Manager with more than 40 years of experience in the planning, designing and delivering transportation infrastructure and services for clients across Canada. Mr. Hemingway's areas of specialization include conceptual planning, feasibility studies, travel demand forecasting, trend analysis, economic assessment and business case analysis, traffic operations and safety studies, traffic impact assessment and traffic management plan development. He is a licensed Professional Engineer and is certified as a Professional Traffic Operations Engineer by the Transportation Professional Certification Board of the Institute of Transportation Engineers. Mr. Hemingway has provided expert witness testimony before tribunals, including the Ontario Municipal Board (OMB) and provides peer review services on request.

Michael Lindsay
Global Director, Infrastructure Planning & Advisory, Hatch

Michael Lindsay is the Global Director of Infrastructure Planning & Advisory for Hatch. He leads a global team supporting a set of public and private clients pursuing major infrastructure investment programs and projects. His team integrates technical expertise ("what do we build") with planning expertise ("where do we build") and financial expertise ('what funding/delivery model do we use") to help create viable and valuable infrastructure projects.

Before joining Hatch, Mr. Lindsay was Senior Vice President of Commercial Projects at Infrastructure Ontario. In that role, he was responsible for commercial transactions related to the financing, development, and divestiture of public assets in Ontario (e.g. land, buildings, services, etc.). His team investigated public-private partnerships in connection to critical new infrastructure (e.g. energy, transit, social) and contracted private entities to deliver government services through alternative service delivery (ASD) arrangements. Prior to this, Mr. Lindsay was an Associate Principal with McKinsey & Company, where he was a core leader of the Canadian Public Sector Practice.

Harris Centre Regional Analytics Lab

Preliminary Regional Economic Impact of a Fixed Link Between Labrador and the Island of Newfoundland: An Examination of Transportations Costs and Subsequent Impacts on Regional Economies

Submitted by:
Alvin Simms PhD
Jamie Ward MSc

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INTRODUCTION

This report presents the outcomes from the analysis of the impact of a proposed Fixed Link between Labrador and the Island of Newfoundland. The report examines the overall impact of shifting a portion of passenger traffic (tourist and non-tourist) as well as diverting a percentage of the commercial truck traffic from the Channel-Port aux Basques ferry to the Fixed Link proposed for the Labrador Straits. In general, these impact metrics are presented in terms of:

1. Estimated changes in travel times and costs related to interprovincial commodity flows and their potential impact on the economy;

2. Estimates of potential changes to commodity prices and production costs by domestic industries due to changes in transportation costs;

3. The impact on the costs of imports and exports associated with a change in the mode of transport, and the impact on the general economy; and

4. An estimate of the economic impact of diverting a portion of the passenger and commercial truck traffic from the Marine Atlantic ferry service to the Fixed Link. Note that this scenario assumes that the Marine Atlantic Gulf ferry remains in service.

The first 3 items in the preceding list can be addressed with an adaptive transportation cost model that is generally used to generate the optimal or least-cost outcomes by various modes of transport. For this report, the comparison is the Marine Atlantic ferry versus the Fixed Link. These models require inputs such as the per-unit cost for truck shipments (TEUs[1]) required from suppliers to meet a demand or the number of TEUs required by each destination. The estimated economic impact of the diversion is calculated from a geo-spatial simplex supply chain model that is used to construct sub-regional Leontief input-output matrices and multipliers that can be used to measure the impact of diverting traffic away from Channel-Port aux Basques to the Fixed Link in the Labrador Straits. Local multipliers (e.g., $1 spent in one industry generates another $1.55 throughout the local economy) are required because the diversion does not result in an economic loss provincially but a re-distribution of a percentage of the economy from the Southwestern part of the province to other regions in Labrador and the Northern Peninsula. For example, because there is "no loss" of economic benefit from the provincial economy, the provincial level input-output table multipliers related to the industries affected will not change but instead the multipliers will change at the local or sub-regional level. Thus, calculating the economic impacts associated with diverting traffic from Channel-Port aux Basques requires local rather than provincial multipliers [see endnotes 2, 3 and 4].

[1] TEU or twenty-foot equivalency unit is used to identify the carrying capacity for a specific mode of transport. For example, how many trucks can be loaded on a train, ship or in terms of traffic, how many TEUs can travel through a highway tunnel in one hour?

The report focuses on 3 outcomes from the analysis:

1. Cost differences related to transport cost model analysis.
2. Intra-provincial re-distribution of value associated with relevant sectors of the economy due to diversion of a percentage of the traffic from Marine Atlantic to the Fixed Link.
3. Identification of specific commodities and industries that will be impacted in terms of net gains and losses.

ASSUMPTIONS AND DATA

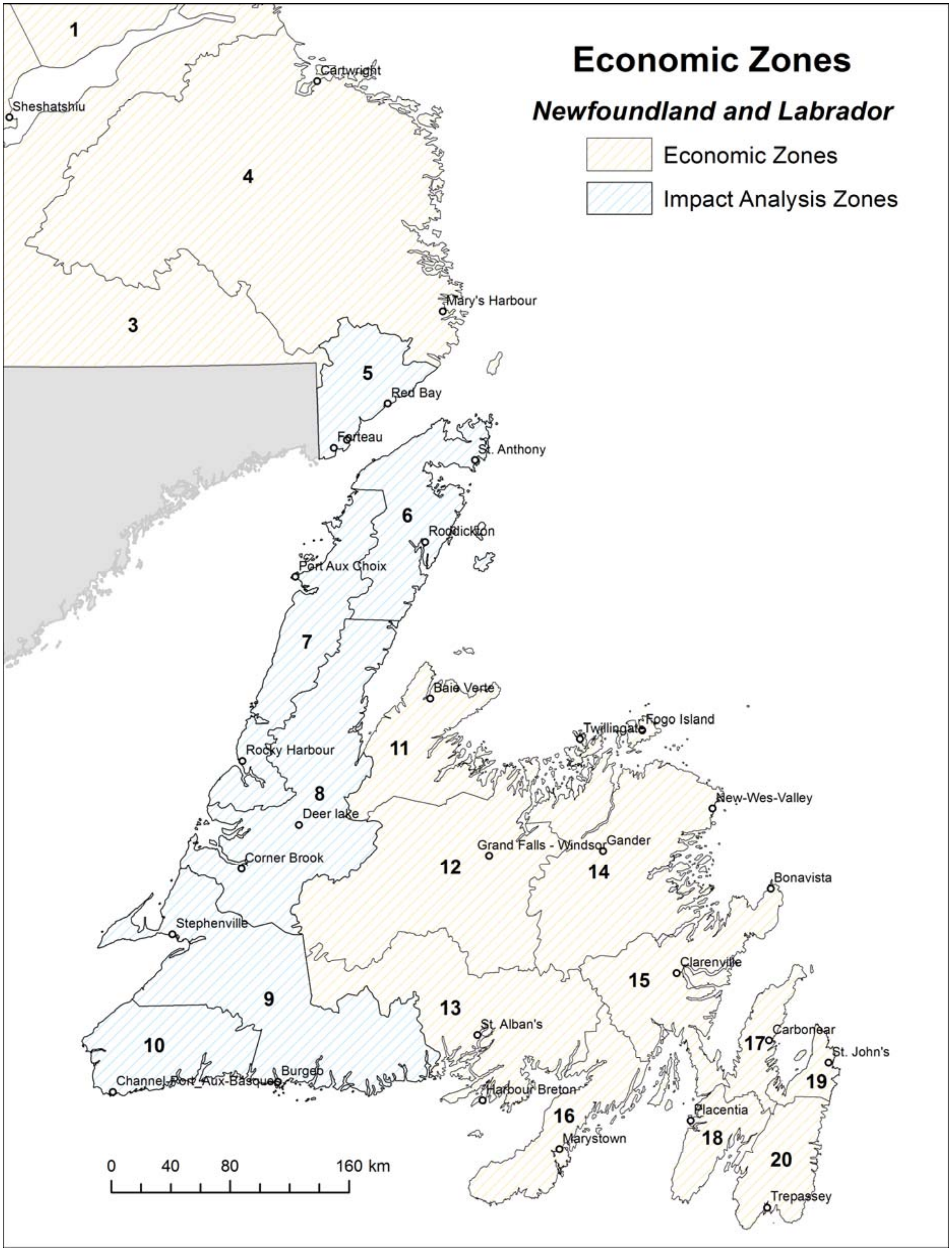
The assumptions for the regional economic impact analysis related to diverting traffic from the Marine Atlantic Gulf ferry service to the proposed Fixed Link in the Strait of Belle Isle are based on terms of reference for the project and on model constraints for estimating commercial transportation impacts (e.g., dollars, travel time), as well as on the redistribution of passenger vehicle traffic. Note that the geography used for the regional impact analysis is the former Economic Zones because the NL Department of Tourism exit surveys that provide information on areas of the province visited by non-resident travelers who stayed at least one night is reported by Economic Zone. These results are required to calculate the portion of the economy dependent on travelers that enter the province via the Marine Atlantic ferry service to Channel-Port aux Basques (Economic Zone 10). Preliminary analysis indicated that redistribution of these travelers and subsequent impacts were more likely to occur in Economic Zones 5 to 10 (see highlighted rows in Table 1 and highlighted regions in Figure 1).

Table 2 List of Newfoundland and Labrador Economic Zones

Economic Zones
Zone 1: Rigolet to Nain
Zone 2: Labrador West/Churchill Falls
Zone 3: Happy Valley/Goose Bay/Northwest River
Zone 4: Mary's Harbour to Cartwright
Zone 5: Labrador Straits (L'Anse Au Clair to Red Bay)
Zone 6: Viking Trail, St. Anthony South West to Plum Point, East to Roddington/Englee
Zone 7: Gros Morne Area, Viking Trail North to and including Plum Point
Zone 8: Deer Lake/Humber Area Corner Brook/Massey Drive
Zone 9: Stephenville/Port-au-Port/Burgeo
Zone 10: Port-aux-Basques/Doyles/Rose Blanche
Zone 11: Baie Verte/La Scie/Green Bay
Zone 12: Grand Falls Windsor Area
Zone 13: Bay D'Espoir Area
Zone 14: Gander/Twillingate East to Terra Nova
Zone 15: Clarenville/Bonavista Peninsula Area
Zone 16: Burin Peninsula
Zone 17: North West Avalon
Zone 18: Argentia/Placentia Area
Zone 19: North East Avalon and St. John's CMA (including Mount Pearl)
Zone 20: Southern Shore Area

Source: 2011 Exit Survey – Program Highlights, Government of Newfoundland and Labrador

Figure 1 Baseline Geography for Impact Analysis: Economic Zones



Source: Newfoundland & Labrador Statistics Agency

For the regional analysis, the assumptions of diverting traffic from Marine Atlantic gulf ferry service to the Fixed Link are as follows:

1. There is no change to the Marine Atlantic Gulf ferry service.
2. This analysis is preliminary and outcomes should be viewed as potential rather than actual. A full impact analysis would require more time and effort, plus additional data on specific construction costs as well as a survey of local businesses in all areas of impact.
3. Economic Zone 10 (Channel-Port aux Basques) is the only region that will be negatively impacted by diversion of travelers.
4. The level of intra-provincial trade (trucking of commodities) is dependent on the size of the population.
5. The impact of intermediate goods (trucking) is constrained to transportation margins (i.e., the % of total expenditures spent on truck transportation).
6. Any changes in travel costs are passed on to the consumer as final demand.
7. Tourism expenditures (on restaurants, accommodations etc.) are simply transferred north (e.g., to Economic Zones 5, 6 and 7) with no changes to local multipliers.
8. Before and after scenarios are relevant for 1 year. (Future impacts are complicated by induced traffic through the tunnel).
9. Before and after scenarios for tourism impacts are based on Hatch's estimated 2.5% annual growth rate in traffic over 42 years.
10. A time series analysis of traffic trends indicates that on average, 60% of the annual traffic could be potentially diverted from the Marine Atlantic ferry service to the Fixed Link. (This relates to all traffic and not just to peak traffic).
11. Diverted commercial truck traffic breakdown is 40% tractor-trailer (4 TEUs) and 60% smaller commercial trucks (2 TEUs). TEU equivalency conversions are based on Hatch's assumptions.
12. The Quebec North Shore Highway 138 link is completed to an acceptable standard and travel times are based on Hatch's 2004 estimates.
13. The travel cost by mode of transport is based on two scenarios: (1) the cost of traveling through the Fixed Link tunnel is the same as traveling on the Marine Atlantic ferry; and (2) the cost of the tunnel passage is equivalent to PEI's Confederation Bridge fee structure.
14. Non-resident expenditure industry distribution from the input-output table is equal to the total non-resident expenditure industry distribution from the NL Tourism survey.

15. All of the commercial trucking and tourism traffic from the Maritime Provinces continues to use the Marine Atlantic Gulf Ferry service (i.e., there is 0% diversion to the Fixed Link).
16. For this analysis, the indirect effects (i.e., industries that buy from or sell to other local businesses) are spin-offs that are restricted to the Channel-Port aux Basques region (Economic Zone 10).

For the trucking cost model, it is important to differentiate the cost of operating a transport truck while stationary on a ferry crossing versus the continuous driving associated with travel to the Fixed Link tunnel. Although the average travel time associated with the Fixed Link (23.5 hrs) is less than that for the ferry route (26.2 hrs) there is a greater portion of the Marine Atlantic ferry route where the truck is stationary and therefore less expensive to operate. Thus, for a portion of the Fixed Link route, the truck is slightly more expensive to operate and this will be accounted for in the transport cost model.

Also, due to provincial regulations in Canada, truck drivers are limited in the number of hours they are permitted to drive. For example, in Ontario and Quebec, drivers can be on duty for 14 hours or drive continuously for 13 hours. This regulation has the effect of lengthening, for long haul trips, the driving time to both the ferry and the Fixed Link through either driver rest stops or switchovers. However, the travel time and costs are somewhat consistent between the two routes and these factors are included in the various transport cost models below.

For this analysis, data were provided directly by Provincial Government agencies or downloaded from Provincial or Federal Government data portals. For example, the Government of Newfoundland and Labrador's Department of Tourism, Culture, Industry and Innovation, as well as the Department of Transportation and Works provided data on tourism exit surveys and marine traffic, respectively. Population data (2016 census) for the Economic Zones was downloaded from NL Statistics Agency's Community Accounts. Input-output (IO) industry transaction data related to tourism "expenditure product breakdown" from provincial IO tables were downloaded from Statistics Canada IO Table(s) web site. Commercial trucking rates, crossing and waiting times for Marine Atlantic and commercial rates for Confederation Bridge are sourced from their respective web pages. Data on operational trucking costs that impact the cost of shipping (e.g., wages, fuel efficiency and required break time for drivers) were acquired through the OECD, and through Provincial and Federal Government data portals. Table 2 provides a list of data sources and where relevant a web portal link.

Table 3 Data Sources and Web Portal Linkages

DataSource	Analysis	Link
Input-Output Table (CANSIM 381-0033)	Tourism (expenditure product breakdown)	http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=3810033&tabMode=dataTable&p1=-1&p2=9&srchLan=-1
NL Tourism Exit Surveys Department of Tourism	Tourism (baseline tourism expenditure/traffic numbers by province)	Government of NL Department of Tourism
Trucking Commondity Origin Destination Survey - Statistics Canada	Trucking (checking result quality)	http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=2741
Marine Atlantic	Trucking (commercial shipments over time)	Government of NL Department of Transportation
Marine Atlantic website	Commercial trucking rates, crossing & waiting times	https://www.marineatlantic.ca/
Confederation bridge website	Commercial trucking rates	http://www.confederationbridge.com/tolls-fees/tolls-fees.html
Ontario ministry of transportation	Required trucking break times	http://www.mto.gov.on.ca/english/trucks/handbook/section1-7-4.shtml
Societe de l'assurance automobile Quebec	Required trucking break times	https://saaq.gouv.qc.ca/en/transportation-goods/driver/driving-and-off-duty-time/
Transport Canada Economic Analysis Directorate - Estimation of Costs of Heavy Vehicle Use Per Vehicle Kilometre In Canada	Trucking cost model	http://www.bv.transports.gouv.qc.ca/mono/0965385.pdf
OECD	Trucking cost model updates (wage burden)	http://www.oecd.org/ctp/tax-policy/taxing-wages-20725124.htm
Statistics Canada (CANSIM 281-0030)	Trucking cost model updates (average wage)	https://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/labr74a-eng.htm
NRCan	Trucking cost model updates (fuel efficiency)	http://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607
NL Statistics Agency Community Accounts (Population by Economic Zone)	Trucking (distribute cost savings throughout island)	http://nl.communityaccounts.ca/mvrc.asp?

METHODS

RAnLab's geo-spatial simplex supply chain and transportation cost linkage model generates a value chain industry-to-industry linkage database by Census Subdivision for the entire provincial economy. It requires the provincial input-output table to initialize the model and establish industry linkages. The input-output tables are best described as an industry transaction table that accounts for the level of sales between industries whereby industries sell commodities and intermediate goods to produce final products that are sold to consumers. The input-output tables can be divided into 4 components:

1. **Industry production relationships (transactions)** are used to identify the linkages between raw materials and intermediate goods and how they are combined and linked to other industries for the production of goods for other industries and consumers

2. **Final Demand and Market Behaviour** are used to identify the consumer, private and government purchasing patterns for the final industry outputs. The export section of the final demand table identifies the external demand for outputs.

3. **Incomes or Value-Added** are used to identify the incomes of various sectors in the economy that includes salaries, industry earnings, and taxes paid. This number is represented as a value-added row in the table. This part of the table also includes payments to external industries (e.g. other regions within the province as well as other provinces or countries) for materials and intermediate goods (e.g., final payments)

4. **Non-Market Transfers** are used to identify government subsidies, taxes and inter-government transfers as well as final demand purchases by external industries.

The four sections of the input-output table are used to identify the income linkages of an economy where the final demand table identifies who consumes the finished goods. The income and value-added section identifies who receives payments for their contribution in the production process while the industry production relationships or transaction table identifies the inter-industry linkages or the market sector of the economy. The non-market transfers identify the government and individual monetary transactions in terms of taxes, labour costs, surpluses, deficits etc.

By itself the input-output table describes rather than analyzes the economy at a particular point in time. However, integrating additional transportation information such as transportation cost matrices (distance/time/dollar costs) and commodity values as well as volume of shipments permits the calculation of the impact of these inputs on the economy as well as on different industries. In addition, including the transportation model also permits an assessment of the likelihood that a particular industry located somewhere in the province can supply inputs to another industry in another part of the province. Thus, for a particular sector one can not only estimate the impact of that enterprise on an economy but the likelihood it can get its required inputs within a region.

The economic spillover effects incurred when adding or removing a portion of industrial activity from the economy are derived by generating local input-output tables from the geo-spatial supply chain linkage model and these tables are used to estimate the regional economic impact of diverting traffic from the Channel-Port aux Basques region. These local input-output tables are used to calculate Leontief multipliers that are used in the impact analysis [4, 5].

Note that the integration of Statistics Canada Business Registry data within the geo-spatial simplex supply chain model is used in the calculation of localized input-output tables as well as local multipliers. The business registry geography is at the census sub-division or municipal level and for this study the outcomes are aggregated to the Economic Zone geography. These supply chain outcomes are used to profile and assess economic impacts of changes in the "local/sub-regional" economies related to the diversion of a portion of the traffic from the Marine Atlantic Gulf ferry service to the Fixed Link.

The re-distribution of traffic (e.g., tourist and non-tourist) and economic spin-offs from the Channel-Port aux Basques area to the Fixed Link location at the Labrador Straits and parts of the Northern Peninsula is estimated with an economic based gravity model [2, 3, 4] where the economic redistribution varies with the magnitude of economic activity (e.g., population, GDP etc.) at the origin and destination and inversely related to the distance between places i and j where:

$$RDE_{ij} = \emptyset \frac{Y_i^{B1} Z_j^{B2}}{Dist_{ij}^{B3}}$$

The original gravity model can be converted to an exponential regression equation where:

$$RDE_{ij} = EXP\ [B_0 + B_1 \ln(Y_i) + B_2\ \ln(Z_j) - B_3 \ln(Dist_{ij})]$$

RDE_{ij} = Redistribution of diverted economic activity from Channel-Port aux Basques to Economic Zones 5, 6, 7, 8, 9. In this instance the origin is the Fixed Link location while the destinations are in Economic Zones 5 to 9

$\emptyset$ = gravity constant = B_0 intercept for exponential regression equation
B_1, B_2, B_3 slope values for regression equation
Y_i^{B1} = indicator for level of economic activity to be diverted (origin)
Z_j^{B2} = indicator for level of economic activity at destination
$Dist_{ij}$ = distance between origin and destination
$\ln = natural\ log$

The steps required to complete the analysis are:

1. **Data preparation:**
   a) Define transport dollar costs associated with ferry and Fixed Link tunnel routes.
   b) Define transport time cost associated with ferry and Fixed Link tunnel routes.

c) Recalibrate geo-spatial simplex supply chain model to use origin and destination time factors.
d) Aggregate tourism exit survey data by Economic Zone and reason for visit.
e) Estimate commodity mode of shipping breakdown by Oceanex versus Marine Atlantic.

2. **Run the geo-spatial simplex supply chain model:**
   a) Generate trade point scenario to calculate local input-output tables and multipliers for the existing ferry system.
   b) Generate trade point scenario with 60% of traffic diverted from Marine Atlantic to the Fixed Link.
   c) Run two scenarios, both modes of transport, with tourist-only and total traffic.

3. **Evaluate the tourism impact from final demand allocations in step 2:**
   a) Remove intervening opportunity tourists (plus their expenditure) from the Channel-Port aux Basques region.
   b) Add "intervening opportunity tourists"[2] to the Labrador Straits and the Northern Peninsula.
   c) Convert the diverted tourism expenditure to an estimated number of jobs.

The final step in the analysis is to organize outputs for interpretation and presentation.

TRUCKING COST MODEL BACKGROUND

Transportation costs have a significant impact on regional economies in that they influence the cost of intermediate goods used in production (imports), and in many cases, transport cost margins determine whether or not a particular industry is competitive in a marketplace. For example, evidence suggests that a 10% increase in transport costs can reduce trade by 20% [15].

The first step required to estimate the impacts of transportation cost changes related to diverting tractor trailer traffic from Marine Atlantic ferry service to the Fixed Link is to estimate the proportion of existing Marine Atlantic traffic originating from each province using the Hatch TEU data and the Trucking Commodity Origin Destination (TCOD) summary file. Statistics Canada's 2007 to 2011 Truck Commodity Origin Destination (TCOD) surveys are utilized to examine trucking and commodity shipment patterns and volumes from other provinces as well as from the USA/Mexico to Newfoundland and Labrador. The TCOD survey purpose is:

> *"to measure the commodity movement and outputs of Canadian trucking. The estimates produced include total tonnage transported by commodity type, and revenues by origin and destination of the shipments [13]."*

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[2] "Intervening opportunity tourists" are those tourists that spend at least one night in Channel-Port aux Basques region after leaving the ferry.

The TCOD data indicates that for Newfoundland and Labrador, approximately 40% of truck transport revenues for this province are associated with traffic using the Marine Atlantic Gulf ferry service. Temporal analysis of the 2007 to 2011 TCOD data indicates that approximately 74% of the commodities shipped by truck through Marine Atlantic originated predominately from Quebec and Ontario and the western provinces including USA and Mexico, whereas 26% of the shipments originate in the Maritime Provinces. An examination of the TCOD data suggests that 81% of the shipments originating outside of Maritime Provinces or an estimated 60% of the total would potentially be diverted to the Fixed Link tunnel route (see Table 3 for detailed listing by province). This is hypothetically associated with existing truck companies that use locations in New Brunswick or Nova Scotia as transshipment points where commodities are redistributed via truck throughout the Maritimes and via Marine Atlantic to Newfoundland and Labrador.

Table 4 Percent of Total Shipments by Truck to Newfoundland & Labrador

Province	% Total Shipment by Province	% Diverted to Fixed Link
PE	0.22%	0.00%
NS	12.03%	0.00%
NB	14.08%	0.00%
QC	19.99%	16.20%
ON	36.62%	29.66%
MB	0.33%	0.27%
SK	0.07%	0.06%
AB	1.05%	0.85%
BC	0.43%	0.35%
YT	0.00%	0.00%
NT	0.01%	0.01%
USMEX	15.16%	12.28%

After the proportional values (Table 3) are assigned by province these values are used in the trucking cost model to estimate the change in costs associated with diverting the TEUs from Channel-Port aux Basques to St. Barbe area (e.g., the tunnel exit point) or the cost of trucking commodities to the Island portion of the province. To estimate cost, the model requires the definition of a truck operating profile. Table 4(A) presents an operating profile of annual “heavy use truck” cost factors [14] while Table 4(B) provides updated cost values used as constants in the model.

Table 4(A) includes the breakdown of the truck operating costs. Importantly, it also provides insight to driving versus non-driving hours. These inputs are used to construct per tonne/kilometer as well as hourly operational costs that can be used to differentiate between continuous driving and completing the required rest times (non-driving) over a long-haul trip, versus those costs associated with driving to the ferry in North Sydney and accounting for when the truck is stationary (non-driving) during the ferry crossing to Channel-Port aux Basques. The values in Table 4(A) are based on a 2006 study [14] while the information in Table 4(B) includes constants in the cost model along with updates for wages, NRCan fuel consumption in L/100 km, wage burden update and recent fuel prices (e.g., Montreal average price for the week of Nov. 1, 2017), etc.

Table 5 Truck Operating Cost Profile (A) and Model Constants (B)

(A) Truck Operating Cost Profile	Value
Annual Distance Travelled (km)	300,000
Avg Trip Driving Time (Hours)	11.11
Avg Daily Driving Time (Hours)	11.11
Avg Annual Driving Time (Hours)	3,333.3
Avg Non Driving_Day (Hours)	2.89
Avg Non Driving_Annual (Hours)	866.7
Total Annual Hours	4,200
Per Vehicle Annual Tonne-km	3,135,600
Per Vehicle Annual Tonne-Hours	34,840
Annual Fuel Consumption	$118,500
Non-Driving Paid Hourly	$22,031
Driving Pay	$84,733
Wage Burden	$33,524
Interest Financing Equipment	$13,271
Insurance Costs	$3,636
Administrative Costs	$18,180
Operator Margin	$9,090

(B) Truck Cost Model Constants	Value
Avg Trip Dist (km)	1,000
# Trips per Day	1.00
# Days per Year Working	300
Avg Speed (km/hr.)	**90**
Avg Non Driving/Trip (Hours)	2.89
Vehicle RGVW (kg)	54,000
Vehicle Tare Weight	14,340
Payload (kg)	16,000
% Loaded (TCOD)	65.33
NRCan Fuel Consumption (L/100 km)	39.50
% Driven_Pavement	100
% Driven_Gravel	0.00
Hourly Wage (CANSIM 281-0300)	**$25.42**
Per km $Pay	$0.28
Pay Binary (Hourly = 0, km = 1)	0
% Wage Burden (OECD taxing Wages)	**31.40**
Fuel Price ($/Litre)	**$1.10**
Repair & Tire Costs ($/km)	$0.27

Table 5 presents the updated annual operating costs using the data in Tables 4(A) and 4(B). For example, note that in the annual operating cost part of the table, the total fuel cost is updated to $129,758 from $118,500 (Table 4(A)) presented in the 2006 study [14]. These values are subsequently converted to tonne per kilometer and per-hour cost (Table 5). These variants on transport costs can account for loads as well as distances in a cost model. Finally, the cost per hour and tonne/kilometre can be converted to TEU equivalencies, using Hatch's TEU conversion formula. In this case, the final truck operating costs are presented in Table 6 where the cost per hour of operation is estimated to be $127.58[3] and cost per hour of waiting or resting time is $64.35. The TEU equivalents are $45.56 per hour of operation and $22.98 per hour of waiting or when the truck is stationary for a rest period on a ferry/tunnel crossing.

[3] For example, hourly truck operating costs are based on *"the annual cost of operating of operating a truck (sum of annual operating cost in Table 4)/annual average driving time in Table 3"*.

Table 6 Annual Operating Costs Conversion to Tonne per Kilometre and Hour

Annual Operating Cost	**Value**
Total Driver	$140,288
Total Fuel	$129,758
Total Repair & Tire	$81,007
Annual Licence Fee	$2,586
Annual Vehicle Ownership (Depreciation)	$27,436
Annual Overhead	$44,177
Tonne per Kilometre Costs	**Tonne*km Value**
Total Driver	$0.045
Total Fuel	$0.041
Total Repair & Tire	$0.026
Annual Licence Fee	$0.001
Annual Vehicle Ownership (Depreciation)	$0.009
Annual Overhead	$0.014
Total	**$0.136**
Tonne per Hour Costs	**Tonne*Hour Value**
Total Driver	$4.03
Total Fuel	$3.72
Total Repair & Tire	$2.33
Annual Licence Fee	$0.07
Annual Vehicle Ownership (Depreciation)	$0.79
Annual Overhead	$1.27

Table 7 Estimating Final Operating and Waiting Cost per Hour with TEU Conversions

Final Truck Operating Costs per Hour	
Cost per Truck*Hour Operation	$127.58
Cost per Truck*Hour Waiting	$64.35
Truck/TEU Conversion	2.8
Cost per TEU*Hour Operation	$45.56
Cost per TEU*Hour Waiting	$22.98

To test the assumptions and the truck cost parameterizing process, a sensitivity analysis was performed to determine if the transportation cost model and its estimates were comparable to known transportation revenues generated by trucking commodities via the Marine Atlantic ferry to Newfoundland and Labrador. In this case Statistics Canada TCOD[4] estimates for revenues generated by trucking of commodities from 2007 to 2011 are used to evaluate the outputs from the transportation cost model.

[4] Statistics Canada Trucking Commodity Origin Destination (TCOD) records revenues generated by trucking. This is the cost of transporting commodities between provinces and at this time is the best estimate available.

The TCOD costs per tonne per kilometre over the 5-year period ranged from $0.123 to $0.131 while the calculated value for the transport model was $0.136 or a 3.82% difference. Analysis of the TCOD 2011 survey indicated that $124.27 million in revenues was generated by shipping commodities via truck and the Marine Atlantic gulf service to Newfoundland and Labrador. The comprehensive trucking cost model estimated trucking revenues of $126.69 million, or a 1.94% difference. Thus, any transport cost estimates when comparing the cost of trucking via the ferry versus the Fixed Link are ±1.94%. This variation is only valid within the context of the TCOD values, the transportation cost model and the assumptions used in this study. However, the TCOD values validate the accuracy of the RAnLab model.

Marine Atlantic versus Fixed Link Route Travel Time Outcomes

On average, the Marine Atlantic gulf ferry crossing is 7 hours duration and accounts for 50% of the goods being shipped to and from the Island portion of the province[5]. The assessment of diverting 60% of the truck traffic from the Marine Atlantic gulf service to the Fixed Link tunnel is presented as: (1) time savings relating to driving along a completed HWY 138 to Blanc-Sablon and the fixed tunnel exit in the St. Barbe Area and (2) cost savings in truck cost revenues.

The time savings calculation is based on the distance from the largest centre in each province to the Fixed Link tunnel exit on the Island side, and for Marine Atlantic it is the distance to North Sydney (Nova Scotia) and the loading plus travel time associated with the ferry crossing to Channel-Port aux Basques. For the USA/Mexico originating trucks, the border crossing south of Montreal was selected as the start location. The average for the driving calculations is 90 km/hr and the driving time also includes rest time required for all long-haul trips. For example, federal and provincial regulations[6] in Canada have limits on the number of hours a driver can operate a truck and the time shall not exceed 13 hours and this may be reduced in extreme driving conditions and in some cases the drivers are required to not drive for more than 10 hours per day or have at least 8 hours of rest. Note the 13-hour period includes loading time if required, waiting time in heavy traffic, refueling etc. Thus, on average the actual driving time may not exceed 10 or 11 hours. This is supported by the 2006 study [14] where the average daily driving time is 11.1 hours (see Table 4(A) *"Avg. Daily Driving Time")*. A general solution to these regulations is to switch drivers at pre-determined locations along the long-haul route or to have a second driver on the trip but this option increases operation costs. The switch driver option also results in some non-driving time for refueling, checking the truck, etc.

Table 7 presents the calculated total travel times for both the ferry and Fixed Link routes. The calculated time does not include travel on the Island portion of the province. For example, the distance from Channel-Port aux Basques to Deer Lake is 265 km while the distance from the tunnel exit in St. Barbe area

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[5] Source: https://www.marineatlantic.ca/en/commercial/Commercial-Traffic/

[6] Source: http://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-313/

to Deer Lake is 298 km; the 33 km difference in travel distance is not a significant factor in the overall transport costs. Using the existing road network and Marine Atlantic ferry route, the average travel time from the Maritime Provinces to Channel-Port aux Basques is 14.4 hours. However, if the Quebec HWY 138 and Fixed Link route is used, it increases the average travel time to 30.5 hours or more than twice the Marine Atlantic route including the ferry crossing time (Table 7). There is no comparative advantage for truck shipments originating in the Maritimes to use the alternative Fixed Link route.

Table 8 Calculated Travel Times for the Marine Atlantic Gulf Ferry and Fixed Link Tunnel

Province	Total Travel Time Ferry	Total Travel Time Tunnel	Tunnel Time Addition Factor
PE	15.22	31.11	15.89
NS	13.72	32.11	18.39
NB	14.27	27.22	12.96
QC	26.42	21.51	-4.92
ON	31.94	27.02	-4.92
MB	56.17	51.25	-4.92
SK	67.06	62.14	-4.92
AB	72.06	67.14	-4.92
BC	84.94	80.03	-4.92
YT	99.83	94.92	-4.92
NT	88.94	86.92	-4.92
USMEX	27.42	22.51	-4.92

*Note the NT time savings is 2.0 hours (there's a mathematical trip break line at 66 .66 hours which is in between 65 and 68.25 hours) (trip length = 11.11 hours above)

The average travel time from Ontario and Quebec is 29.18 hours and for the Western provinces the average is 70.06 hours. However, when factors associated with "long-haul trips", described above, are accounted for the travel time for the Fixed Link route is on average 4.9 hours less than the road travel and ferry crossing combined.

Marine Atlantic Route versus Fixed Link Trucking Revenue Outcomes

The transportation cost model is used to estimate the cost differences between diverting 60% of the commercial truck traffic from the Marine Atlantic route to the Fixed Link tunnel route in the Labrador Straits. The cost model is run with the following assumptions:

1. Two Fixed Link toll scenarios where (a) the toll for the tunnel passage is equivalent to the Marine Atlantic commercial truck fee structure (e.g., for a 75' total length truck, the fee would be $582.94) and (2) the toll for the tunnel passage is equivalent to the PEI Confederation Bridge fee structure (e.g., $42.50 for the first 2 axles plus $8.00 for each additional axle). In essence, the

Confederation Bridge fee structure is lower than Marine Atlantic's, which is not surprising given the latter's much longer travel distance.

2. There are two trucking driver models for long haul trips: (1) where the driver takes the required rest period after 13 hours of driving as per regulations, and (2) where the driver is switched or replaced at predetermined locations after driving the requisite time.

Note that in Table 6, the estimated per-hour cost of operating a truck is $127.58 and in waiting mode, when the driver is stopped or resting, it is $64.35. This cost breakdown affects both the Marine ferry crossing where the driver is resting/waiting for 7 to 9 hours during the crossing as well as on the long-haul trip rest times that would be required on the Highway 138 Fixed Link route. For example, the distance from Montreal to North Sydney is 1,429 km while the distance from Montreal to St. Barbe tunnel exit is 1,692 km[7]. Under the driving time regulations both trips are considered long-haul except that on the ferry route there would be more "rest/waiting time" because of the ferry crossing, thus the waiting rate would be applied in this instance.

Table 8 presents the outcomes from the transportation cost model that estimates the cost savings associated with diverting 60% of the commercial truck traffic from the Marine Atlantic gulf ferry service to the Fixed Link tunnel route. Results are presented within the context of two different fee structures as well as trucker driver rest and switch models for long haul trips.

The estimated truck revenue generated by 60% of the traffic using the Marine Atlantic service is approximately $145.1 million and if this volume of traffic was diverted to the Fixed Link route, using the ferry fee cost structure for the tunnel passage, the savings would be approximately $3.25 million, or a 2.24% drop in transport costs. For this study, it is assumed that the cost of transportation associated with the revenues is redirected to the final demand part of the input-output table (i.e., the cost is passed on to the consumer). In this case, the savings per capita is $6.59. When comparing the savings for the whole economy where the $3.25 million reduction in transport cost is applied to the Statistics Canada 2011 TCOD Newfoundland and Labrador total trucking revenues of $391.3 million, the overall impact is a cost decline of 0.83%.

When the Confederation Bridge fee structure is used in the model, the diverted transport cost reduction is $13.1 million or a 9.24% saving. Thus, the final demand or per capita consumer cost saving is increased to $27.22 but in terms of overall consumer purchasing savings. Therefore, differences in the fee structure account for a 7% decrease in transportation costs. At the provincial level the overall diverted savings increase from 0.83% to 3.43% when using the Confederation Bridge fee structure (Table 8).

[7] Calculated from Google Earth and Hatch's 2004 distance calculations for the Fixed Link tunnel

Table 9 Trucking Commodity Shipment Revenue Estimates and Fixed Link Diversion Savings for Long Haul Rest Stop Model

Description	Ferry Fee Cost Option (Long Haul Model With Rest Stops)	Confederation Bridge Fee Cost Option (Long Haul Model With Rest Stops)
Initial estimated truck revenues for diverted truck traffic using existing ferry route	$145,055,252	$145,055,252
Diverted savings ($)	$3,246,510	$13,055,252
Diverted savings (%)	2.24%	9.24%
Initial Truck transport revenues/costs added to final demand and expressed as per captia or consumer cost	$295	$295
Diverted savings per captia	$6.59	$27.22
Statistics Canada TCOD 2011 total trucking revenue for shipping commodities to NL	$391,329,087	$391,329,087
Overall diverted savings (%)	0.83%	3.43%

The results presented in Table 8 are based on both the Marine Atlantic ferry and Confederation Bridge fee structure with a single driver using the mandatory rest period after 13 hours of driving. To determine if there is a significant difference between switching drivers at predetermined locations after reaching maximum daily driving time versus a single driver with an extended rest period (Table 8 outcomes), the model was run with the "switching driver option". Table 9 presents the results of this analysis and there is a negligible cost difference between the two models. For example, for the ferry fee structure the diverted savings was 2.36% versus the 2.24% with the rest stop model (Table 8). Likewise, the results were similar to the Confederation Bridge fee result with a 9.72% saving for the switch model versus 9.24% for the rest stop model. When comparing the per capita and total provincial TCOD revenue there are no differences (Tables 8 and 9).

Table 10 Trucking Commodity Shipment Revenues Estimates and Fixed Link Diversion Savings for Long Haul Switch Driver Model

Description	Ferry Fee Cost Option (Long Haul Model With Switch Driver)	Confederaton Bridge Fee Cost Option (Long Haul Model With Switch Driver)
Initial estimated truck revenues for diverted truck traffic using existing ferry route	$137,847,328	$137,847,328
Diverted savings ($)	$3,246,986	$13,404,381
Diverted savings (%)	2.36%	9.72%
Initial Truck transport revenues/costs added to final demand and expressed as per captia or consumer cost	$280	$280
Diverted savings per captia	$6.59	$27.22
Statistics Canada TCOD 2011 total trucking revenue for shipping commodities to NL	$391,329,087	$391,329,087
Overall diverted savings (%)	0.83%	3.43%

Summary

The amount of estimated savings in transportation cost is very sensitive to the tunnel transit cost. Overall, the estimated savings in transportation costs by diverting traffic from the Marine Atlantic ferry service to the Highway 138 Fixed Link route range between $3.25 million and $13.5 million per year, or between $6.60 and $27.20 per capita. When referenced in the context of the overall economy, this represents approximately 0.8% to 3.4% of the total trucking revenues on 2011 shipments to the province.

The analysis of the “Fixed Link tunnel option” estimates that it would take approximately double the time to travel to Newfoundland for trips originating in the Maritimes. In the future, this factor could potentially disrupt traditional supply routes whereby locations in the Maritimes that are currently used as transshipment points for the Island portion of the province could be replaced by direct shipments via the Fixed Link route.

REGIONAL ECONOMIC IMPACT OF DIVERTING TOURIST AND OTHER PASSENGER TRAFFIC

The regional economic impact of diverting tourist and non-tourist passenger traffic from Marine Atlantic ferry service to the Fixed Link route is calculated from the Government of Newfoundland and Labrador’s tourist exit surveys rom 2011 and 2015, from the Department of Transportation and Works’ ferry traffic database, from Statistics Canada’s 2016 Business Registry database, and from the Leontief local input-output tables and multipliers generated by RAnLab’s geo-spatial simplex survey chain model. The geographical re-distribution of the revenues generated by the diverted passengers is estimated using a GDP economic based gravity model [2, 3 and 4] where the economic redistribution varies with the magnitude of economic activity at the origin and destination and inversely related to the distance between places i and j (see **Methods** above).

The outcomes from the regional impacts analysis are presented as: (1) overall impact on the Channel-Port aux Basques area (Economic Zone 10), (2) Specific industry impacts (dollars and jobs) in the Channel-Port aux Basques region, and (3) dollar value and jobs diverted northwards to the relevant Economic Zones.

To determine the impacts, the supply-chain model requires two runs. The first run is to profile the Channel-Port aux Basques regional economy before passenger traffic is diverted and the second run of the model removes the portion of traffic that will be diverted from the Marine Atlantic ferry service to the Fixed Link route. The impact of diverting passenger traffic is essentially a comparative analysis of the before and after scenarios.

Before the analysis can be initiated, an estimate of the number of passengers that may be potentially diverted from the Marine Atlantic ferry service as well as their expenditures is required. NL Tourism exit surveys are used to determine what portion of the passengers may be diverted by trip origin. The information in Table 10 is used to determine the portion of passengers and vacationers that will be potentially diverted to the Fixed Link route. Note that 60% of the passengers by car are from Quebec west. This percentage is potentially what is diverted to the Fixed Link route.

Table 11 Marine Atlantic Gulf Ferry Service Passenger Information by Origin and Number of Passengers and Vacationers by Car

Passenger Origin	Total Number of Passeners by Car Origin	Number of Vacationers by Car	% Passengers by Car
Maritimes	38171	20613	39.60%
Quebec	4771	2577	4.95%
Ontario	30537	16490	31.68%
Other Canada	7634	4123	7.92%
United States	13360	7214	13.86%
Overseas	1909	1031	1.98%

Source: NL Tourism (Table 2.0)

To estimate an economic impact, the analysis requires an assessment of what portion of the 96,383 passengers arriving by car actually stay in the Channel-Port aux Basques region and this is subsequently used to estimate what spinoffs this cohort has on the regional economy. For this study, the exit survey data that identified passengers that stayed at least one night in Channel-Port aux Basques region was used has an indicator of the potential value that arriving passengers contributed to the regional economy. Table 11 presents a summary of these outcomes as well as the portion of passengers that stayed at least one night in the region. From the exit survey, on an annual basis, 31,035 or 32% of all the passengers stay at least one night (the average is 2.3 nights) with an average nightly expenditure of $56.74 compared to the $67.60 spent by the subset of vacationers.

Table 12 Marine Atlantic Ferry Passengers Traveling by Car and Staying at Least One Night in the Channel-Port aux Basques Region

Passenger Origin	% Passengers Staying at Least 1 Night	Total All Passengers	Number of Vacationers	Avg. Nightly Expenditures All Passengers	Avg. Nighlty Expenditures by Vacationers
Maritimes	12.8%	12291	6637	$697,337	$448,672
Quebec	1.6%	1536	830	$87,167	$56,084
Ontario	10.2%	9833	5310	$557,870	$358,938
Other Canada	2.6%	2458	1327	$139,467	$89,734
United States	4.5%	4302	2323	$244,068	$157,035
Overseas	0.6%	615	332	$34,867	$22,434
Total	**32.2**	**31035**	**16759**	**$1,760,776**	**$1,132,898**

The portion of "staying passengers" and expenditures from Table 11 are used to calibrate the impact analysis model in order to estimate the regional impacts of passengers that stay at least one night in the Channel-Port aux Basques region.

Table 12 contains the estimates from the before and after impact scenarios that the "stay at least one night" passengers have on the regional economy. The outcomes are for direct plus indirect effects. Direct effects are related to the number of jobs or value created by a business to meet a particular demand, while the indirect effects are related to businesses purchasing/selling supplies from other businesses based on spinoffs from direct effects. The results presented in Table 12 are based on vacationers only staying[8] (17.3%) versus all passengers staying (32%), which are used conceptually as low and high estimates.

Table 13 Total Value of Direct and Indirect Effects of Passengers Staying at Least One Night in Channel-Port aux Basques Region and Impact of Diversion to Fixed Link Route

Diversion Scenario	Vacationers Only	All Passengers
Economy Before Diversion	$3,100,654	$4,819,108
Economic Value After Diversion	$1,227,982	$1,908,558
Amount Diverted	$1,872,673	$2,910,550

The estimated spinoff generated by passengers that stay at least one night ranges from a low of $3.101 million to a high $4.819 million. However, if 60% of these passengers were diverted, the region would lose an estimated $1.873 to $2.911 million in spinoffs. Note that the final demand/consumer spending in the region is estimated at $163.3 million and the impact would be a decline of 0.75% to 1.17%.

[8] "Vacationers Only" is defined as the portion of the total number of passengers who identified themselves as vacationing as reason for visiting and staying "at least one night" in the region while the "all passengers" includes both vacationing passengers and others.

Outcomes presented in Table 13 represent the conversion, using local multipliers, of the direct and indirect spinoff effects in dollars to employment. The estimated number of jobs affected by the diversion is presented as low, medium and high. These intervals are used because of the non-availability of detailed local employment information by industry. When “Vacationers Only” are considered, 26 to 54 jobs could be diverted to other regions while the “All Passengers” outcomes indicate that 40 to 83 jobs could be redistributed to other regions.

Table 14 Estimated Employment Impact Scenarios of Diverting Passenger Cars to Fixed Link Route

Employment Scenarios	Low Estimate	Medium Estimate	High Estimate
Vacationers Only (Before Diverting)	43	66	89
Vacationers Only (After Diversion)	17	26	35
Employment Diverted to Other Regions	**26**	**40**	**54**
All Passengers (Before Diverting)	66	102	138
All Passengers (After Diversion)	26	38	55
Employment Diverted to Other Regions	**40**	**62**	**83**

Channel-Port aux Basques Regional Industrial Impacts

The preceding outcomes provide an overview of potential impacts associated with direct and indirect spinoff in dollars and employment redistribution to other regions in the province if 60% of the passenger traffic was diverted from Channel-Port aux Basques to the Fixed Link route. The following section identifies what specific industries are likely to be impacted with the redirection of passenger traffic out of the region to the Fixed Link route. Table 14 presents the direct and indirect expenditures for all passengers that stay at least one night in the Channel-Port aux Basques region by industry. The “Before Redistribution” is the regional economy before redistribution while the “Redistribution to Other Regions” are the expenditures that are diverted northwards. Finally, the “% Total Before $ Diverted” is a percentage of an industry’s share of the total “Before Redistribution” regional economy that is diverted to other regions or the industry’s percentage removed from the regional economy through redistribution.

The only previous references for the Fixed Link diversion impacts are previous studies where business is diverted to other locations because of a bypass road. These studies indicated that retail sales, accommodations, food and beverage services, as well as gas stations were the businesses most likely to experience a decline in revenues because of diversion [9]. For this impact analysis, all of these sectors in the regional economy are ranked in the top 10 businesses that would be negatively impacted by the diversion of passenger car traffic from Channel-Port aux Basques to the Labrador Straits and the Northern Peninsula (Table 14). In this case, food and beverage services experience the highest impact with $0.711 million of $1.177 million, or 14.75% of the expenditures by all passengers staying at least one night, are removed from the regional economy. This results in an estimated loss of 11 to 23 jobs in this sector (Tables 14 and 15).

Of note, accommodations are the second highest industry impacted but when combined with RV parks, camps and B&Bs, it would be the highest with $0.775 million of $1.284 million being diverted or a 16.10% reduction in overall passenger expenditures. The potential employment decline in these sectors combined is between 11 and 28 jobs (Tables 14 and 15). Gas stations are third on the list with $0.244 million of $0.404 being redistributed or 5.06% of the expenditures. This equates to a decline in employment of 3 to 6 jobs.

For industries with more than 1.0% in diverted passenger expenditures, $2.622 million of $4.341 million is redistributed to regions in Newfoundland and Labrador along the Fixed Link route and this represents 54.4% of the total expenditures by passengers who stay in the region (Tables 14 and 15). It is evident that for this type of analysis examining impacts associated with specific industries provides an insight on those sectors dependent on ferry traffic within the Channel-Port aux Basques region and their sensitivity to changes in passenger traffic flows, especially flows related to stays. From a total regional economy perspective, the "All Passengers" expenditures impact on the estimated total regional GDP of $300 million is less than -1.0%. However, at the industry level breakdown, the passenger expenditures on industries such as retail that are traditionally impacted by a "type of bypass" or diversion, the reduction can be -13.0% or more in the region; this represents a significant decrease for small and medium size enterprises.

Table 15 "At Least One Night Stay All Passenger" Estimated Redistributed Expenditures by Industry

Industry	All Passenger Expenditure $		
	Before Redistribtuion	Redistributed to Other Regions	% of Total Before Diversion
Food services and drinking places	$1,177,175	$710,967	14.75%
Traveller accommodation	$1,040,991	$628,717	13.05%
Gasoline stations	$403,496	$243,696	5.06%
Clothing and clothing accessories stores	$386,163	$233,227	4.84%
Lessors of real estate	$267,614	$161,628	3.35%
Food and beverage stores	$256,178	$154,721	3.21%
RV (recreational vehicle) parks, recreational camps, and rooming and boarding houses	$243,174	$146,867	3.05%
Water transportation	$170,541	$103,000	2.14%
Other transit and ground passenger transportation and scenic and sightseeing transportation	$136,269	$82,301	1.71%
Amusement and recreation industries	$97,259	$58,741	1.22%
Health and personal care stores	$81,737	$49,366	1.02%
Performing arts, spectator sports and related industries, and heritage institutions	$80,644	$48,706	1.01%
Gambling industries	$67,538	$40,790	0.85%
Travel arrangement and reservation services	$63,034	$38,070	0.79%
Miscellaneous store retailers	$62,444	$37,713	0.78%
Community colleges and C.E.G.E.P.s	$58,342	$35,237	0.73%
Sporting goods, hobby, book and music stores	$47,595	$28,746	0.60%
Automotive repair and maintenance	$32,914	$19,879	0.41%
Taxi and limousine service	$31,056	$18,757	0.39%
Hospitals plus nursing and residential care facilities	$30,066	$18,159	0.38%
Personal care services and other personal services	$29,431	$17,775	0.37%
Motor vehicle and parts dealers	$19,348	$11,685	0.24%
Electric power generation, transmission and distribution	$11,623	$7,020	0.15%
Grant-making, civic, and professional and similar organizations, plus other non-profit institutions serving households	$6,718	$4,057	0.08%
Offices of dentists	$6,068	$3,665	0.08%
Miscellaneous ambulatory health care services	$5,700	$3,443	0.07%
Telecommunications	$4,209	$2,542	0.05%
General merchandise stores	$936	$565	0.01%

Table 16 Channel-Port aux Basques Diverted Employment Estimates for Fixed Link Route

Industry	Estimate for Diverted Employment		
	Low	Medium	High
Food services and drinking places	11	17	23
Traveller accommodation	9	15	22
Clothing and clothing accessories stores	3	5	7
RV (recreational vehicle) parks, recreational camps, and rooming and boarding houses	2	4	6
Gasoline stations	3	4	6
Amusement and recreation industries	3	4	5
Food and beverage stores	2	3	4
Other transit and ground passenger transportation and scenic and sightseeing transportation	1	2	2
Lessors of real estate	1	2	2
Miscellaneous store retailers	1	1	2
Health and personal care stores	0	1	1
Sporting goods, hobby, book and music stores	1	1	1
Water transportation	0	0	1

Note: Because of rounding employment numbers will not add up to totals presented in Table 12

The preceding discussion has focused on the amount of passenger expenditures diverted away from the Channel-Port aux Basques region and has not addressed where these impacts would be redistributed geographically. Table 16 presents the estimates produced by the GDP gravity model for redistribution of expenditures by Economic Zone.

Under the assumptions of the gravity model, the Labrador Straits Zone receives $0.641 to $0.997 million or 34.25% of the diverted revenue while the Gros Morne Zone is allocated $0.769 to $1.195 million or 41.05% of the revenue. The Viking Trail and St. Anthony Zone share ranges from $0.257 to $0.399 million of 13.70% (Table 15). Proximity to the tunnel entrance is a comparative advantage for the Labrador Straits and the Viking Trail/St. Anthony Zones, while the Gros Morne region gains an advantage because it is still somewhat proximate to the exit point for the tunnel in the St. Barbe area and the GDP for the Gros Morne area reflects its preferred destination status for vacationers on the Northern Peninsula. To determine impacts by industry or the capacity of the industries to meet the demand and include potential growth factors for each of the regions requires further analysis and is not within the scope of this study.

Table 16 GDP Gravity Model Results for Redistribution of Diverted Passenger Expenditures Via the Fixed Link Route

Economic Zones	GDP Gravity Model % Diversion Factor	Vacationer Only - Revenue Diverted	All Passenger - Revenue Diverted
Zone 5: Labrador Straits (L'Anse Au Clair to Red Bay)	34.25%	$641,428	$996,922
Zone 6: Viking Trail, St. Anthony South West to Plum Point, East to Roddington/Englee	13.70%	$256,618	$398,841
Zone 7: Gros Morne Area, Viking Trail North to and including Plum Point	41.05%	$768,736	$1,194,787
Zone 8: Deer Lake/Humber Area Corner Brook/Massey Drive	9.88%	$185,047	$287,605
Zone 9: Stephenville/Port-au-Port/Burgeo	1.11%	$20,844	$32,396
Totals	**100%**	**$1,872,673**	**$2,910,550**

Summary

Overall, there is an expected diversion of between $1.9 million and $2.9 million in total (direct plus indirect) economic activity from the Channel-Port aux Basques region north to the Fixed Link regions due to the diversion of non-resident tourist expenditures. This represents a median estimate of between 40 and 62 jobs being redistributed. This spending affects some industries more than others, so expenditure and employment in industries such as restaurants, accommodations and gas stations would be affected the most.

Economic Zones 5 and 7 could reasonably be expected to benefit the most from any transfers of tourism expenditure north, due to their existing high concentration of the industries demanded and proximity to the potential Fixed Link, respectively.

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MEMORIAL UNIVERSITY

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Proposal to
The Government of Newfoundland and Labrador
and
The Atlantic Canada Opportunities Agency

To Undertake An Update of the 2004 Study on the Pre-Feasibility Study for a Fixed Link Between Labrador and Newfoundland

Submitted by the Harris Centre
Memorial University of Newfoundland

March 8, 2017

Contents

Proposal

Memorial University of Newfoundland's Leslie Harris Centre of Regional Policy and Development (the Harris Centre) submits this proposal to the Government of Newfoundland and Labrador to undertake a study of a possible fixed link between Labrador and the Island of Newfoundland.

This study is intended as a follow-up to a study already undertaken by the Harris Centre back in 2004, which determined that the best option for a fixed link was a tunnel dug 10 meters under the sea bottom using a tunnel boring machine. Vehicles would be transported through the tunnel using an electric train. The total development cost, including interest during construction and escalation, was estimated at around $1.7 billion. The project was estimated to take 5 years to plan and 5.7 years to construct, for a total project implementation time of 10.7 years.

The purpose of this new study is to determine to what extent new geological research, innovations in tunneling technology, labour costs, inflation or other factors may have an impact (positive or negative) on the original cost and time estimates. Secondly, the study will aim to measure some possible impacts on the economy of the province should the fixed link be constructed and traffic subsequently diverted from the Gulf ferry service.

The engineering partner in the original study was the international consulting firm Hatch Mott MacDonald. This firm has now split into two separate firms, Hatch and Mott MacDonald, with the former having the expertise in tunneling technology. In order not to begin the research from scratch and to build on the existing expertise, it is proposed that Hatch be retained as the engineering consultant for the project.

The regional development portion of the study will be undertaken by RAnLab, a program of the Harris Centre in collaboration with the Department of Geography at Memorial University.

The Harris Centre will act as the proponent for this study, with Hatch and RAnLab as subcontractors. The Harris Centre will be responsible for project management, monitoring progress, contract management, payments to subcontractors, accountability to the funder, etc.

Proponent

The Leslie Harris Centre of Regional Policy and Development is a unit of Memorial University of Newfoundland. It was named in honour of scholar and former Memorial University president, Dr. Leslie Harris. Dr. Harris was known for his integrity and independence while making a practical contribution to Newfoundland and Labrador. Established in 2004, the Harris Centre continues this commitment by coordinating and facilitating Memorial's educational, research and outreach activities in the areas of regional policy and development.

The final product offered to the community, whether in the form of research, teaching or outreach, is based upon the independence and integrity of Memorial's faculty, staff and students in applying their professional expertise in contributing to regional policy and development in Newfoundland and Labrador.

Scope of Work

Engineering and Geotechnical

This component of the work is described in detail in the appendix.

Regional Development

This component of the work will determine to what extent the proposed fixed link would impact:

- The province's export sectors (tourism, fishery, forestry, manufacturing, etc.) related to such factors as: on-time delivery, quality of product, cost, etc.

- The province's imports (perishables, other foods, retail, vehicles, etc.) related to such factors as: on-time delivery, quality of products, cost, etc.

- Different regions of the province, in particular: Southwestern Newfoundland, Bay St. George and Corner Brook; and Labrador West, Central Labrador and the Northern Peninsula.

The analysis will identify the key industry stakeholders, their associated geo-spatial supply chain networks and how costs will vary by mode of transport. It will look at the dependency of various industries on the transportation sector and how disruptions could potentially impact transportation supply chains. The analysis will permit the construction of transportation and industry supply chains that identify not only the geographical linkages and industry dependencies but also the value of those links in terms of dollars and value to the province's sub-regional economies.

The final products for this analysis will be a written report that includes:

- Estimates of potential changes to commodity prices and production costs by domestic industries due to changes in transportation costs.

- Estimated changes in travel times for interprovincial commodity flows by mode of transportation, and the impact of these changes on the economy.

- The impact on the costs of imports and exports associated with a change in the mode of transportation and how these changes impact the provincial economy overall.

- An estimate of the economic impact (in dollars and jobs) on the Southwestern Newfoundland, Bay St. George and Corner Brook regions, along with an estimate of the impacts of increased traffic on the relevant regions in Labrador and the Northern Peninsula.

Project Staff

The project will be managed by **Mike Clair, Associate Director (Public Policy)** at the Harris Centre. Mike is an experienced project manager with 23 years' experience with the Government of Newfoundland and Labrador, and another 12 years in academia. While in government, he led the process that resulted in the creation of The Rooms, the largest investment in heritage in the province in a hundred years. He has experience in tourism, culture, regional development, public policy, governance and post-secondary education administration.

He will be assisted at the Harris Centre by **Kim Crosbie, Operations Manager**. Kim is a recent hire, arriving at the Harris Centre after over 20 years of business consulting experience. She has extensive experience in private/public collaborations and structuring multi–partner agreements.

Alvin Simms, PhD, will lead the component of the project dealing with regional development. He is an Associate Professor in the Department of Geography at Memorial University and an Adjunct Professor in the Department of Agricultural and Rural Economics at the University of Kentucky. He has acted as consultant for municipal, provincial and federal governments as well as industry. His research focuses on the integration of regional economic and spatial analysis methods to develop dynamic models to aid in the assessment of the sustainability of places for the purpose of informing evidence-based policy and strategies for regional development. Current and past research projects include studies on assessing the value and impact of intra- and inter-regional industry-to-industry and occupation linkages on economies, analyzing the impact of transportation supply chains, as well as the importance of small and medium-sized enterprises in rural economies, resilient communities, rural-urban interaction, functional economic regions, sustainability and capacity issues in rural communities, as well as forecasting population shifts and demands for public and private services.

Jamie Ward, MSc will assist Dr. Simms with the regional development research. Mr. Ward was a member of the team that developed the Regional Economic Capacity Index (RECI). He has spent the past several years working closely with a wide group of collaborators and community partners to help make the often-complex world of statistical comparison more accessible to regional planners and developers. Jamie's research has involved using regional science methods to model and gain a better understanding of some of the determinants of economic growth in Newfoundland and Labrador labour markets. Specifically, this research attempts to address questions relating to the potential applicability of neoclassical growth models to provincial labour markets, and the magnitude of potential negative effects of outmigration on rural labour markets.

The personnel from Hatch assigned to work on this project are listed in the appendix.

Budget

Engineering and geotechnical (Hatch)	$150,000
HST (15%)	22,500
Student research (RAnLab)	25,000
Project management (Harris Centre)	25,000
TOTAL	**$222,500**

Timeline

The engineering and geotechnical component of this project is estimated to take 4 months to complete. At that point, a draft final report will be presented to Government for review. The schedule allocates one month for Government review and comments.

The regional development component of the project is estimated to take 3 to 4 months to complete, depending upon the availability and the quality of the data.

Steering Committee

The project will be overseen by a steering committee composed of representatives from the Government of Newfoundland and Labrador, Hatch, and Memorial University of Newfoundland.

It is anticipated that this committee will meet at least three times:

1. At the beginning of the project to confirm the scope of work, timelines and budget.
2. Mid-way through the work to provide an update on progress.
3. Near the end of the project, when the final draft report is ready for review.

Meetings of the committee will be convened and chaired by the Harris Centre.

Appendix: Engineering and Geotechnical

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March 6, 2017

Michael Clair
Leslie Harris Centre of Regional Policy and Development
Memorial University of Newfoundland
St. John's, NL
A1C 5S7

Dear Mr. Clair:

Subject: Proposal for Updated Pre-Feasibility Study for Newfoundland and Labrador Fixed Link

Hatch is please to submit the attached Offer for Engineering and Consultancy Services which outlines the scope, the approach that will be used to complete the study, the deliverables and our commercial offer.

Hatch will perform the work outlined in this Offer for Engineering and Consultancy Services to update the previous study that was carried out in 2004. This letter, the Statement of Work and Hatch Standard Terms and Conditions form the whole agreement between Leslie Harris Centre of Regional Policy and Development and Hatch.

The overall cost is $150,000 plus HST on a lump sum cost basis.

If this offer is acceptable to Leslie Harris Centre of Regional Policy and Development, please sign the attached Acceptance and we can mobilize the team to start to undertake this work in time manner. If you would like to meet with me to clarify and further discuss any aspect of this offer, please call me at 709 701 0075.

Regards,

Mark Cumby, P. Eng.

MC:sr

cc: Steve Routledge, P. Eng.
Jean Habimana, P. Eng.

Michael Clair
Leslie Harris Centre of Regional
Policy and Development
March 6, 2017

OFFER FOR ENGINEERING AND CONSULTANCY SERVICES

for

Proposal for Updated Pre-Feasibility Study for Newfoundland and Labrador Fixed Link

March 6, 2017

Client Name:	Leslie Harris Centre of Regional Policy and Development
Project Name:	Proposal for Updated Pre-Feasibility Study for Newfoundland and Labrador Fixed Link
Client Contact:	Michael Clair
Hatch Contact:	Mark Cumby, P. Eng.
	mark.cumby@hatch.com
	Phone: 709 701 0075
Proposal Number:	17-1033, Rev. A
Estimated Start Date:	Apr 1, 2017
Cost Basis:	Lump Sum Cost Basis
Project Estimate:	$150,000 + HST

Introduction

In 2004, Hatch Mott MacDonald (now Hatch) performed a pre-feasibility study of fixed link concepts between the island of Newfoundland and mainland Labrador for the Government of Newfoundland and Labrador. The Government is now looking to update that pre-feasibility study to account for new available investigation and survey data of the tunnelling options as well as validate or update the conclusions reached during the pre-feasibility phase.

With experts in the tunnelling industry worldwide, some of whom were a part of the pre-feasibility study, Hatch is well positioned to provide a clear and concise summary report that brings the pre-feasibility of a fixed link to current state of the practice as well as socio-economic realities.

Scope of Work

The goal of this study is to update the previous study to account for new information collected as well as current realities by utilizing experience gained worldwide for similar projects. As part of this, Hatch's scope of work will consist of:

1. Update based on any new background information available relating to the following
    a. Geotechnical information
    b. Survey data
    c. Environmental information
    d. Regulatory considerations
2. Validation of previous assumptions related to the following and updating as required
    a. Ridership
    b. Tunnel utilization
    c. Design criteria
    d. Alignment Update
3. Update of experience gained for fixed links worldwide:
    a. Similar projects
    b. Gained technological experience
4. Update of alternatives comparison for the fixed link and recommendation of preferred option
5. Update of cost estimate
6. Update of schedule

It should be noted that aspects listed under Item 1 above relate to review of existing information that has become available since the pre-feasibility study was completed and that performing a new geotechnical investigation, topographic survey, or environmental assessment is outside Hatch's scope of work.

Schedule

Tasks	Duration After Award
1. Update background information	1st Month
2. Validate previous assumptions	2nd Month – 3rd Month
3. Update experience for fixed links	2nd Month 3rd Month
4. Update comparison alternatives	3rd Month – 4th Month
5. Update cost estimate	4th Month
6. Update schedule	4th Month
7. Preliminary Report	End of 4th Month
8. Client Comment	5th Month
9. Final Report	End of 6th Month

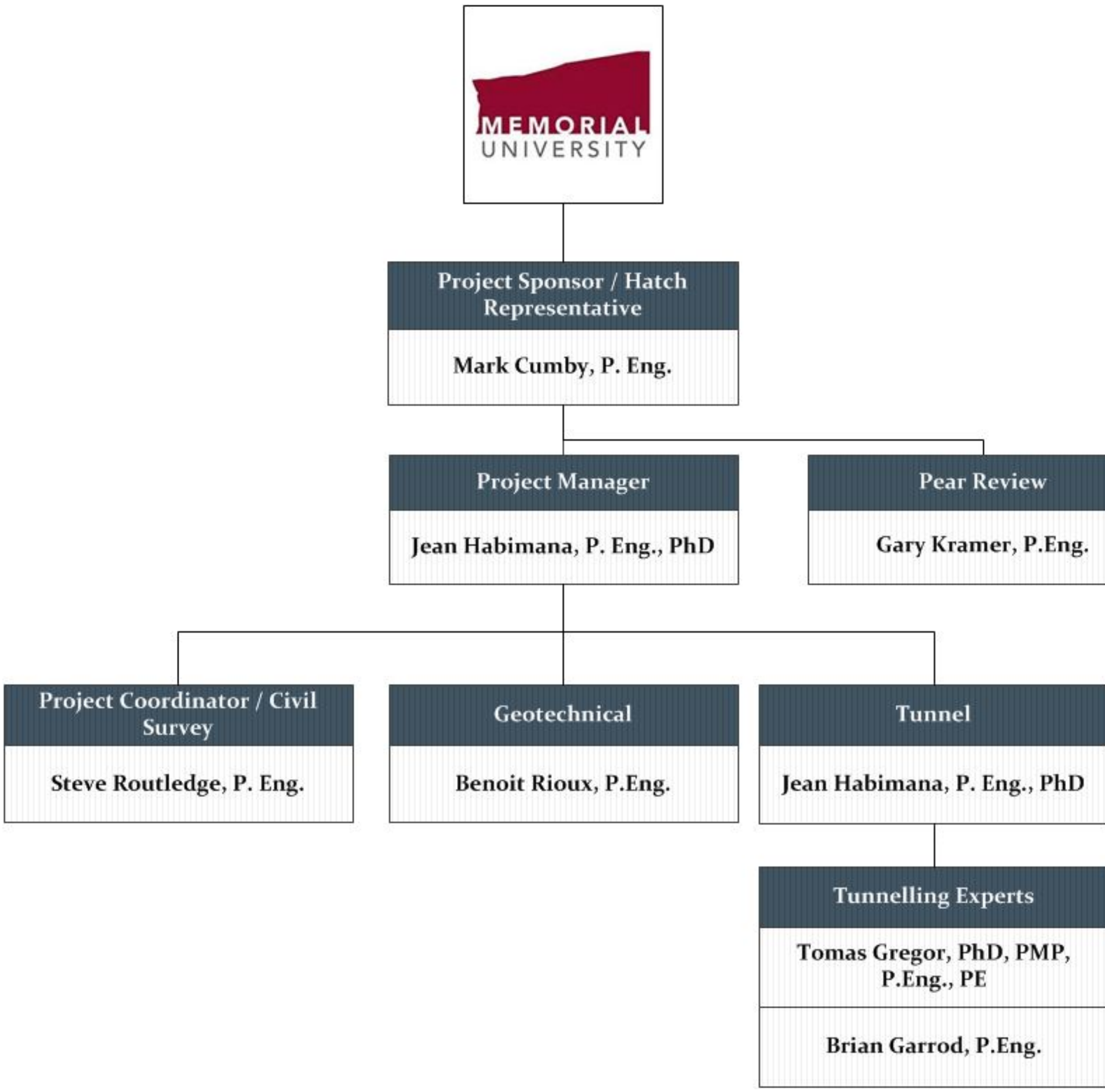
Execution Plan

Upon award, Hatch will commence with research on new tunnelling technologies that have been introduced since 2004 as well as any experience gained through similar projects worldwide. In conjunction with this, we will determine what factors have changed since 2004 that could impact the feasibility of the proposed tunnelling options. Hatch understands the client will make available supplemental geological data upon award of this contract.

The final deliverable will be a summary report that brings the previous report into today's realities and standards to determine the viability of a fixed link between Newfoundland and Labrador.

The anticipated timeline would see a draft of the summary report submitted for review 4 months after award and a final summary report would be submitted 1 month after a client review period. Our schedule allocates one month for client comments.

Hatch Project Team



MARK CUMBY, P. Eng. - Project Sponsor/Hatch Representative

Project Director, Hatch - Accomplished in project management, engineering management, and general business management, Mr. Cumby offers over 22 years of progressive and comprehensive experience in a variety of oil & gas projects across the globe. Through work with Tier 1 producers and EPC firms, he has demonstrated a "customer first" focus, with a keen ability to get deliverables driven to closure, and effective problem solving skills recognized by colleagues and clients. In addition, he has extensive experience in pressure equipment and modular skid design and fabrication with emphasis on: produced water treating equipment (hydrocyclones, traditional separators, water polishing); hydrocarbon filtration; gas /oil separation.

JEAN HABIMANA, P. Eng., PhD - Project Manager

Director of Tunnel Practice Lead, East North American, Hatch - Mr. Habimana is experienced in a variety of aspects of geotechnical and tunnel engineering for both soft ground and hard rock tunneling. He has over 20 years of experience and has worked on design and construction of major projects including tunnels, caverns, shafts, open-cut, cut-and-cover excavations, highways, and bridge foundation. His experience ranges from conceptual design to preparation of engineering final design documents including Geotechnical Baseline Reports, drawings and specifications and providing engineering services during construction. Mr. Habimana has an extensive experience in static and seismic soil-structure interaction analysis and seismic design of tunnels and underground facilities. He notably managed tunnel design and construction projects, and he is skilled in the coordination of different disciplines, the management of client inspections, and completing projects on time and on budget. He experience include projects in Europe, China, Australia, United States and Canada. Most notably he has worked on the Swiss Lotschberg Tunnel Project, the SR99 Alaskan Way Replacement Project in Seattle, Washington, the San Francisco Bay Area Caldecott Tunnel, The Toronto Eglinton Crosstown Light Rail Project, the Montreal Blue Line Extension Project, and is currently working on the Montreal Light Rail Project.

BRIAN GARROD, P. Eng. – Tunneling Expert:

Director Tunnels, Australasia, Hatch - Mr. Garrod is a Director - Tunnelling with Hatch and a world-recognized expert on tunnels and tunnel technology. With multiple publications, he is a sought-after speaker at technical conferences. He has 46 years of general civil engineering experience, the last 36 years devoted solely to tunnelling assignments.

Brian's technical expertise covers a broad range of tunnel techniques for high and low-strength rocks and soft ground using excavation methods such as earth pressure balance tunnel boring machines (EPB TBM) and the New Austrian Tunnel Method (NATM). Moreover, he specializes in the design of pressurized-face TBM-driven tunnels, one-pass segmental tunnel linings, risk analysis, productivity analyses and cost estimates for underground projects. Brian has also developed Hatch's in-house tunnels estimating system that enables his team to produce highly accurate project cost estimates.

With outstanding tunnelling qualifications, Brian has been engaged on significant projects around the world such as: the Channel Tunnel; the Boston Outfall; Dulles Airport tunnels in Washington DC; Beacon Hill tunnels in Seattle; BART to San Jose tunnels; Tel Aviv metro tunnels; Los Angeles Metro Red Line, Sewer Tunnel in Columbus OH, Seattle Combined Sewer Outflow (CSO) and sewer tunnels; river and strait crossings in Sarnia, New Jersey, Sacramento, Detroit and Newfoundland and road tunnels in Brazil. At home in Canada, Brian's expert knowledge has been applied on major projects to expand transit facilities, e.g. Toronto's new Eglinton Crosstown LRT and the Spadina Subway Extension and Sheppard Subway (among many others for the Toronto Transit Commission), in addition to Vancouver's Skytrain and the new Evergreen Line, Edmonton LRT and the Green Line LRT in Calgary. He also has significant expertise with water conveyance tunnels through various roles on such projects as the new 10 km diversion tunnel at Niagara Falls to serve the Sir Adam Beck hydro power station, the new 15 km Southeast Collector sewer tunnel in York and Durham Regions and for others in Vancouver and Toronto.

He has significant construction management experience, which includes the Detroit River Tunnel, oversight for Seymour-Capilano twin tunnels, the 19th Avenue Tunnel in York Region, the Toronto Coxwell Bypass Tunnel, and engineering support during construction of the Sheppard Subway, Spadina Subway Extension, Eglinton CrossTown LRT, Vancouver ALRT, Dulles Airport tunnels, Sacramento River crossings and the Beacon Hill tunnels.

Mr. Garrod was involved in the preparation of the 2004 pre-feasibility study.

TOMAS GREGOR, PhD, PMP, P. Eng. – Tunneling Expert

Sub Division Manager, Underground Infrastructure, Hatch – Mr. Gregor is a Civil and Structural Engineer as well as an internationally known tunnelling specialist. He has extensive experience in the planning, design and project management of transportation and heavy civil engineering projects. Over the past years, Mr. Gregor has used his technical knowledge as the basis for his work on the management of tunnel design for the Scarborough Subway Extension, participation in the program management of the Toronto-York Spadina Subway Extension, and he was the Hatch Project Manager on the design of the Eglinton Scarborough Crosstown Twin Tunnels and the Pre-AFP Reference Design (six stations and at-grade section) for the LRT line. On the analytical side, Tomas was the Lead Structural Engineer for the Sheppard Subway Twin Tunnels in Toronto and the Beacon Hill Station and Tunnels project in Seattle, WA. Mr. Gregor has been responsible for the design of over 25 precast tunnel linings for various tunnels in Canada, the US and Russia. He also performed detail design and design management for a number of significant bridge projects earlier in his career. Mr. Gregor's broad range of project work has given him an understanding of all aspects of transportation projects, including rehabilitation, design management, analysis and design of concrete (reinforced, pre-stressed and fiber reinforced), steel structures, foundation design, tunnel design, cost estimates, client and contractor communications, and knowledge of numerical analysis and design computer software.

Mr. Gregor was involved in the preparation of the 2004 pre-feasibility study.

GARY KRAMER, P. Eng. – Peer Review

Global Tunnel Practice Lead, Hatch - Mr. Kramer has over 30 years of experience (27 years in consulting engineering with Hatch) in project, design and construction management on multi-disciplinary large tunnel projects for transit, highway, sewage, rail, earthwork, marine (intake and outfall) and hydroelectric works. He is Hatch's Practice Lead for Tunnels responsible for technical leadership and quality excellence on tunnel, shaft and trenchless projects.

Throughout his tenure at Hatch, he has been directly responsible for coordination of civil design disciplines - structural, geotechnical and end use functionality (hydraulic, transit, storage and energy) and construction management associated with tunnelling, shaft and marine related work. The last 24 years has been virtually exclusively in tunnel related projects during which he has held major roles (PM, design manager, lead tunnel and/or resident engineer) on over 130 km of constructed tunnels in soft ground and rock with 71 km of those 5 metres or more in diameter.

He received the Bickel Award for tunnelling from the American Society of Engineers in 1998 and was recently invited by the British Tunnelling Society to give a presentation on tunnel lining systems in seismic areas. As a result, he was invited by the International Tunnelling Association to act on their Seismic Committee. He is actively involved with the Tunnelling Association of Canada, sitting on the executive of the Ontario Chapter.

STEVE ROUTLEDGE, P. Eng. – Project Coordinator / Civil Survey

Structural Engineer, Hatch - Mr. Routledge has over 10 years of experience in the engineering field. His primary experience lies in the design and construction of steel, concrete, and wood framed buildings and other structures as well as coordinating lift studies for moving heavy equipment. He is knowledgeable in many aspects of this process, including inspection and surveying, static analysis and design, and finite element analysis. He also has project management and project coordination experience on a number of projects ranging from building rehabilitation and structural steel frames to large span bridge proposals. He is fluent in both English and French.

BENOIT RIOUX, P. Eng. – Geotechnical

Senior Project Engineer – Tunnels, Hatch - Mr. Rioux has a strong experience as a Geological Engineer specialized in rock mechanics and geotechnics. From 2004 to 2009, Mr. Rioux has worked as a Geotechnical Project Manager and as an Exploration Geologist as part of five geotechnical investigation campaigns on the Rupert-Eastmain-1A Hydroelectric Projects. Mr. Rioux also worked as a Site Geological Engineer for the construction of the Keeyask Hydroelectric Project from 2015 to 2016 and Eastmain-1A Hydroelectric Project from 2009 to 2010. From 2010 to 2015, he worked as a Geotechnical and a Rock Mechanics Project Manager. He managed the geotechnical exploration campaigns for a major underground retention basin and a subway extension project in Montreal. Mr. Rioux was also V.P. of the Canadian Geotechnical Society for the Western Quebec Chapter from 2006 to 2009 and he was the Technical Short Courses Manager for GeoMontreal 2013.

Payment Schedule

The overall cost is $150,000 plus HST to be paid on a lump sum cost basis.

1st Month	$30,000
2nd Month	$30,000
3rd Month	$30,000
4th Month – Preliminary Report Submission	$30,000
6th Month – Final Report Submission	$30,000

Hatch will perform the work outlined in this Offer for Engineering and Consultancy Services in accordance with the attached Professional Services Terms and Conditions. This letter, the Statement of Work, and Hatch Standard Terms and Conditions form the whole agreement between Leslie Harris Centre of Regional Policy and Development and Hatch.

This offer remains valid for a period of 30 days from the date of this letter.

Acceptance of Offer

Leslie Harris Centre of Regional Policy and Development accepts this proposal and requests Hatch to undertake the assignment as detailed above.

Signed on behalf of Hatch by:

____

Name: Nancy Fréchette
Title: VP Infrastructure, Hatch
Date: ______________________

Signed on behalf of Leslie Harris Centre of Regional Policy and Development by:

____

Name: ______________________
Title: ______________________
Date: ______________________

Attachment A – Terms and Conditions

CLAUSE 1 AGREEMENT

1.1 Unless a written agreement is entered into, Client's acceptance of a proposal, whether written or oral (the "*Proposal*"), from Hatch Corporation ("or "*Consultant*") or a request by Client for some or all of the services included in the Proposal, constitutes a binding contract between Client and Consultant (the "*Agreement*"). The Agreement incorporates and is subject to these Terms and Conditions and the terms and conditions included in the Proposal, including the description of the services to be provided by Consultant (the "*Services*"). If there is any conflict between the Proposal and these Terms and Conditions, the Terms and Conditions will govern. Any terms appearing on any orders or other documents produced by or on behalf of Client are excluded.

CLAUSE 2 CONSULTANT SERVICES AND RESPONSIBILITIES

2.1 Consultant will (a) perform the Services with due care, skill and diligence in accordance with the standard of care normally exercised by professionals providing similar services under similar circumstances, and (b) re-perform any Services that fail to comply with this standard of care if Client gives Consultant notice of such failure within 12 months of performance of such Services. Consultant may subcontract the performance of any of the Services to an affiliate.

2.2 Consultant is not liable or responsible for (a) the work or products of any third party contractors or suppliers engaged by or on behalf of Client, including any means, methods, sequences, control, procedures or techniques used by construction contractors, (b) any goods, equipment or materials procured on behalf of Client, provided that Consultant will use reasonable efforts to obtain appropriate warranties from the suppliers of such goods, equipment or materials for Client's benefit, or (c) the safety and security at any Client premises or the project site, provided that Consultant will comply with all relevant laws and those site requirements relating to safety and security that have been notified to Consultant.

CLAUSE 3 CLIENT RESPONSIBILITIES

3.1 Client will (a) make available to Consultant all information, documents and assistance necessary or reasonably requested by Consultant in order to enable it to perform the Services in a timely manner, (b) make decisions, provide approvals and obtain all necessary authorisations, licences and permits required in order to permit the timely performance of the Services, (c) notify Consultant if it becomes aware of any matter that may change the scope, timing, order or complexity of the Services, and (d) act reasonably and in good faith in all respects in connection with the Agreement.

CLAUSE 4 INVOICING, PAYMENT AND TAXES

4.1 Unless otherwise provided in the Proposal, (a) Services (including any additional services provided at the request of Client or pursuant to Clause 4.4) and all costs incurred by Consultant in connection with the Services, will be charged to Client in accordance with Consultant's schedule of rates, (b) amounts invoiced to Client by Consultant are due and payable within the period stated in Consultant's schedule of rates or, if not so stated, within 30 days of receipt of invoice by Client, and (c) interest will be paid on past due amounts at the rate stated in Consultant's schedule of rates or, if not so stated, at the prime rate quoted by Consultant's main bank in the Jurisdiction plus 3%.

4.2 Consultant's rates are exclusive of all taxes, duties, royalties, levies and other governmental or regulatory charges, other than taxes on payroll and Consultant's net income. If any such taxes, duties, royalties, levies or charges are levied on or applicable to amounts payable to Consultant, they will be borne by Client and (a) if Consultant is required to pay any such taxes, duties, royalties, levies or charges, the amount of such payments will be reimbursed to Consultant by Client, and (b) if they are required to be withheld or deducted from amounts payable to Consultant, the amounts payable will be grossed up so that Consultant receives the entire amount that is due pursuant to the terms of the Agreement.

4.3 If Client disputes any portion of an invoice, it will pay those amounts that are not in dispute and notify Consultant in writing of the reasons for the dispute within 10 days of receiving the invoice. Failure to notify Consultant of the dispute within the required time will be deemed as acceptance of the invoice. If it is determined that any amounts in dispute should have been paid at the time it was invoiced, then Client will promptly pay such amount, together with interest at the rate set out in Clause 4.1.

4.4 If, (a) Consultant is required to perform Services in circumstances other than those expressly or reasonably assumed and normally pertaining to services of a similar nature (b) Consultant incurs costs arising or resulting in whole or in part from any site conditions existing on or after the date of the Agreement, (c) there is a change in the scope, timing, order or complexity of the Services or claims filed by Clients subcontractors, (d) there is a force majeure event which impacts Consultant, or (e) additional costs are incurred as a result of a change in any laws, regulations or rules or the interpretation thereof then any resulting costs will be borne by Client and Consultant will be entitled to such amendments to the Agreement that are fair and reasonable.

CLAUSE 5 LIMITATION OF LIABILITY

5.1 To the maximum extent permitted by law and notwithstanding and superseding anything to the contrary in the Agreement:

(a) subject to Clause 5.2, the aggregate liability of Consultant arising out of the performance or non-performance of the Services or otherwise in connection with the Agreement is limited to the sum of (i) the amount of the professional fees paid to Consultant pursuant to the Agreement up to $100,000 and (ii) 10% of such fees paid in excess of $100,000, provided that in no event will Consultant's aggregate liability exceed $1,000,000;

(b) in no event will Consultant be liable to Client or its directors, officers, employees, agents, contractors, subcontractors, parent or affiliated corporations, vendors or materialmen for any claim, action, proceeding, loss, damage or cost that (i) in any manner relates to a loss of revenue, profits, opportunity or production, loss or denial of use of any equipment or facility, increased expense of construction, operation or maintenance, economic loss, loss of goodwill or reputation, delay, business interruption or the cost of repair to or replacement of equipment, facilities or goods and related third party services, (ii) in any manner can be construed as indirect, incidental, special, punitive or consequential losses or damages, or (iii) is not a direct result of a material breach by Consultant of the Agreement; and

(c) Consultant does not guarantee any specific outcomes or results, including fit for purpose, project costs or quantities or the ability of any process, technology, equipment or facility to meet specific performance specifications.

5.2 Consultant's liability for claims or losses covered by the insurance policies referred to in Clauses 7.1(b) and (c) shall not be subject to Clause 5.1 and shall instead be limited to the proceeds of the types and specific amounts of insurance up to the amounts specified in Clause 7.1.

5.3 All statutory, express or implied warranties (including those in any relevant trade practices or sale of goods laws relating to the quality or fitness for purpose of the Services or any goods, equipment or materials supplied by Consultant in connection with the Services) are excluded or limited to the maximum extent permitted by law.

5.4 Any action or claim against Consultant in connection with the Agreement or the performance or non-performance of Services, whether in contract, tort, equity, statute or otherwise, must be made within 12 months of the date of the performance or non-performance of the relevant Services.

5.5 Client indemnifies, defends and holds harmless Consultant for any claims, actions, proceedings, liabilities, losses, damages or costs: (a) it suffers or incurs in connection with the Services and which result other than from a material breach of the Agreement by Consultant or (b) that result from any material breach of the Agreement by Client (c) that result from the site conditions existing prior to or after the date of the Agreement.

CLAUSE 6 USE AND OWNERSHIP OF INFORMATION

6.1 Each party retains title to all intellectual property (including all patents, trademarks, copyright, trade secrets and know how) owned or possessed by it or any of its affiliates and used by it in fulfilling its obligations under the Agreement, including any modifications or improvements made thereto ("*Background IP*"). All new and original intellectual property created by Consultant during the course of performing the Services ("*Project IP*") is the property of Consultant. Consultant grants Client a non-exclusive, non-transferable and, unless otherwise agreed, royalty-free license to use (a) any Consultant Background IP used in the performance of the Services but only to the extent required to use any deliverables provided by Consultant for the purpose for which they have been provided (excluding any software source code), and (b) Project IP for any purpose whatsoever.

6.2 Upon receipt of full payment for the related Services and subject to Clause 6.1, all reports, drawings and other deliverables provided to Client by Consultant will become the property of Client.

6.3 Any information or deliverable provided by Consultant to Client in connection with the Services are provided solely for Client's own use and for the specific purpose for which the Services were engaged. In no case will any such information or deliverable be used in connection with any public or private stock, bond or other financial offering, any investment decision, the sale of securities or any other financing transaction or otherwise be made available to the public generally. Consultant makes no warranty or representation and assumes no liability in respect of and Client shall bear all losses or damages resulting from (a) the wrongful or unauthorised use of information or deliverable by Client or third parties, and (b) the accuracy or completeness of information based on data gathered from Client or provided by third parties on behalf of or at the instruction of Client (and Consultant is able to rely on such information without verification in the performance of the Services).

6.4 Each party will keep confidential all Confidential Information disclosed to it by the other party; provided that (a) Consultant is able to disclose Client's Confidential Information to those persons who need to know such information for purposes that relate to the performance of the Services, (b) Client is able to disclose Consultant's Confidential Information to the extent required in connection with the purpose for which the information was disclosed, and (c) either party is able to disclose Confidential Information required to be disclosed by law, provided that the receiving party immediately notified the disclosing party of the requirement to disclose and took all reasonable steps to lawfully resist or narrow the requirement to disclose the Confidential Information. Except as specifically provided herein, neither party will acquire any right, title or interest in or to the Confidential Information of the other party.

6.5 "*Confidential Information*" means any information in any form disclosed by or on behalf of one party to the other party at any time before or after the execution of the Agreement in connection with the Services; excluding only information which (a) was at the time of disclosure or thereafter became part of the public domain through no act or omission of the receiving party, (b) became available to the receiving party from a third party who did not acquire such confidential information under an obligation of confidentiality either directly or indirectly to the disclosing party, or (c) was known to the receiving party at the time of disclosure by the disclosing party and such knowledge can be demonstrated by written records that were in existence at the time of disclosure.

CLAUSE 7 INSURANCE

7.1 Consultant will have in effect for the duration of the Services the following insurance (a) workers compensation, in accordance with statutory requirements, (b) comprehensive general (or public) liability ($5,000,000 per occurrence/aggregate); (c) automobile liability ($5,000,000 per occurrence/aggregate), and (d) professional indemnity (E&O) liability ($1,000,000 per claim/aggregate on a claims made basis).

7.2 During the period in which the Services are being performed, Client will, at its own expense, maintain insurance to limits which are normal and customary in the circumstances. Client, on behalf of itself and its insurers, waives all rights of subrogation against Consultant for, and releases Consultant from any liability for damage to Client's property howsoever caused to the extent that Client is compensated for such damage under an insurance policy.

CLAUSE 8 TERMINATION AND SUSPENSION

8.1 Client may suspend the Services or terminate the Agreement for its convenience on 30 days prior written notice to Consultant; provided that, if the aggregate duration of all suspensions under the Agreement exceeds 60 days, Consultant will have the right to terminate the Agreement.

8.2 Either party may terminate the Agreement immediately if anything happens to the other party that reasonably indicates that there is a significant risk that the other party is or will become unable to pay its debts generally as they come due.

8.3 Either party is entitled to terminate the Agreement on 30 days prior written notice to the other party in the event that the other party is in substantial default under the Agreement and such default has not been corrected or reasonably commenced to be corrected within 15 days following notice of such default. Consultant may, by providing 5 days prior notice to Client, suspend Services if Client is in breach of Clauses 3 or 4.

8.4 In the case of any suspension or termination of the Agreement, Client will pay Consultant for all Services provided and costs incurred up to the effective date of suspension or termination. In the event of any suspension or termination pursuant to Clause 8.1 or any suspension or termination by Consultant pursuant to Clauses 8.2 or 8.3, Client will also pay Consultant for any Services provided or costs incurred that are necessary or incidental to suspension or termination, including demobilization costs.

CLAUSE 9 NON-SOLICITATION

9.1 Client will not, during the term of the Agreement or for 12 months thereafter, either directly or indirectly on its own behalf or jointly with or on behalf of any other person, solicit, engage or employ any employee or independent contractor of the Consultant (or any of its affiliates) that has been involved in the provision of Services or with whom the Client has otherwise had contact in connection with the Agreement.

CLAUSE 10 DEFINITIONS AND INTERPRETATION

10.1 Reference to (a) "*affiliate*" means with respect to a party, one or more entities that control, are controlled by, or are under common control with, the party, (b) "*costs*" means any and all costs and expenses, including reasonable legal fees, (c) "*force majeure*" means acts of God, strikes, lockout, other industrial action, war or civil disturbance, terrorism, unusually inclement weather, storm, flood, earthquake, lightning, fire, explosion, nuclear or radioactive contamination, epidemics or pandemics, governmental action or inaction, change in law, extraordinary market conditions affecting the availability of labour, late or inadequate execution of work or supply of goods by third parties and any other event beyond the reasonable control of the affected party, (d) "*Consultant's schedule of rates*" means Consultant's standard hourly rates and reimbursable charges as notified by Consultant from time to time, provided that any changes to the schedule of rates will be communicated to Client before they take effect and will not occur more than once every six months, (e) "*liability*" includes any and all liability whatsoever, whether arising under the law of contract, tort (including negligence), equity, statute or otherwise, whether arising in connection with the performance or non-performance of the Services or otherwise in connection with the Agreement and whether to Client or other persons, and "*liable*" has a corresponding meaning, (f) "*site conditions*" means any conditions in, on, under or around the project site that affect the project or the performance of Services, including any plant and subsurface conditions and any hazardous, radioactive, special, toxic, residual or regulated substances, waste or materials, (g) "*Jurisdiction*" means the Province of Canada where Consultant's office providing the Services is located or if the Services are being provided in multiple offices, then the laws of Ontario, Canada, and (h) "*$*" means the currency of Canada unless specified otherwise.

10.2 Headings are for convenience only and will not be taken into account in interpretation and words importing the singular include the plural and vice versa. If any provision of the Agreement is held to be void, illegal or unenforceable, then: (a) it is severed and the rest of the Agreement remains in force, and (b) the parties will replace the provision with one that is in accordance with applicable law and as close as possible to the parties' original intent. Any rules of contract interpretation that result in the Agreement being construed contrary to the interests of Consultant do not apply in the interpretation of the Agreement.

CLAUSE 11 GENERAL

11.1 The Agreement will be governed by and construed in accordance with the laws of the Jurisdiction, without giving effect to conflict of law considerations. All disputes will be submitted to senior management for discussion. If the parties are unable to resolve a dispute through such discussions, either party may submit the dispute to arbitration. The arbitration will be held in English and at the location of Consultant's contracting office. The arbitration panel will consist of one arbitrator. Any arbitration award will be final and binding on the parties without any right of appeal. Each party will bear the costs of arbitration. No legal proceedings may be commenced by either party in connection with the Agreement or the Services other than in accordance with this Clause 11.1; provided that either party may apply to a court of competent jurisdiction for interlocutory relief during the course of such proceedings or to enforce any order or award obtained in accordance with this Clause 11.1.

11.2 The Agreement represents the entire agreement between the parties regarding the subject matter hereof and supersedes all prior representations, understandings or agreements, whether written or oral and whether express or implied; provided that, if the parties have previously entered into a confidentiality (or similar) agreement regarding the subject matter hereof, such agreement will survive and Clauses 6.4 and 6.5 will be of no force and effect. Amendments to the Agreement are effective only if executed in writing by authorized representatives of both parties.

11.3 Neither party may assign (other than to its affiliate) the Agreement or any interest therein, in whole or part, without the prior consent of the other party. The Agreement will enure to the benefit of and be binding upon the parties and their respective successors and permitted assigns.

11.4 Neither party will be considered to be in breach of its obligations under the Agreement, except obligations to make payment, to the extent that performance is prevented or delayed by force majeure. Each party will use best efforts to overcome any force majeure as soon as possible.

11.5 The limitations and exclusions on liability expressed in this Agreement will apply even in the case of the fault, negligence or strict liability of the party who is the beneficiary of the clause, and will extend to the officers, directors, employees, agents, representatives, subconsultants and affiliates of such party.

11.6 Any notice, consent or other communication given hereunder will only be deemed to have been given if it is in English, in writing and is sent to the recipient's authorized representative at the usual business address of the recipient by (a) registered mail, (b) fax, (c) e-mail (but only when receipt is confirmed in writing by reply e-mail or otherwise) or (d) personal delivery for which a receipt is obtained. Notice given by fax, personal delivery or e-mail will be deemed to have been given on the business day following delivery. Notice given by mail will be deemed to have been given on the fifth business day after mailing.

11.7 No waiver by either party of any breach of the Agreement will be binding unless made in writing and any such waiver will extend only to the specific breach waived and not to any future breach.

11.8 Consultant is an independent contractor in performing the Services. Nothing in the Agreement will create or will be construed so as to create the relationship of principal and agent between Client and Consultant.

11.9 Client and Consultant shall strictly comply with all applicable laws and regulations prohibiting illegal activity of any kind, shall act in an ethical manner with all professional levels of integrity and shall not engage in any acts of corruption, bribery or do anything to improperly influence decision makers.

11.10 Electronic files provided to Client are for reference only and Consultant makes no warranties as to the correctness of information contained in the same after transmittal to Client and nothing therein shall serve to modify Clauses 2 and 5 respectively. In the event of a conflict between electronic files and non-electronic documents, the non-electronic documents shall control and Consultant retains all ownership rights in the electronic files per the terms of this document.

11.11 The provisions of Clauses 1, 2.2, 4, 5, 6, 8, 8.4, 9, 10 and 11 survive the termination of the Agreement.

The Leslie Harris Centre of Regional Policy and Development, Memorial University
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