Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study

New Nouveau Brunswick

NOVA SCOTIA
NOUVELLE-ÉCOSSE

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Department of Transportation and Infrastructure
Government of New Brunswick
P. O. Box 6000
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E3B 5H1
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Executive summary

Situated in the Upper Bay of Fundy, in eastern Canada, the Chignecto Isthmus refers to the narrow strip of land that physically connects the Maritime Provinces of New Brunswick and Nova Scotia. This land bridge is approximately 21 kilometres (km) wide and separates the waters of the Bay of Fundy from those of the Northumberland Strait (Figure ES.1). The Isthmus landscape contains private lands including numerous land trusts, conservation organizations, and Rights Holders, agriculture, and forestry. The Chignecto Isthmus also houses critical transportation and utility infrastructure and serves as a major conduit and trade corridor. The estimated value of goods and services through the corridor, inclusive of revenues generated by in-corridor economic activity, is approximately $35 billion per annum.

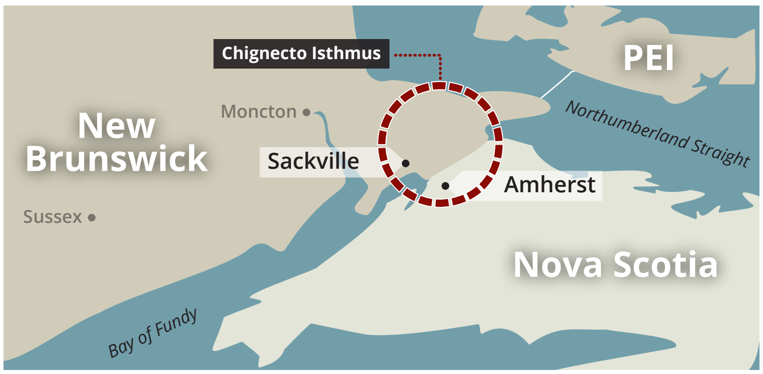

Figure ES.1 Chignecto Isthmus Location

Throughout the Isthmus and Trade Corridor area, protection from the high energy and tides of the Bay of Fundy is primarily provided by historic earthen dykes originally constructed in the 1600s to assist in the development of farmland. The combination of effects by climate change, such as sea-level-rise and increased severity of weather events, with land subsidence have left the Chignecto Isthmus particularly vulnerable, given the area is only slightly above sea level. Presently, the historic earthen dykes along with their re-habilitation conducted in the 1950s protect the coastline: without the current protection provided by the existing earthen dykes, much of the Isthmus would be inundated by today's sea levels resulting in significant negative socio-economic impacts locally, regionally and even nationally. Induced Sea Level Rise (SLR) and coastal subsidence is forecasted to threaten a large portion of the coastal infrastructure in Atlantic Canada before the year 2100. The current Chignecto Isthmus dykes are at risk along with the various Trade Corridor infrastructure components they protect such as: TransCanada Highway, CN Rail, 138 kV and

345 kV electrical transmission lines, fibre-optical cables, a wind farm, agricultural cropland activities and various other utilities. While there have been several studies on the impacts of climate change and rising sea levels, up until this Study, there had not been an engineering analysis assessing the feasibility of potential options to provide protection to the existing transportation network and infrastructure.

Study Governance and Start-Up

The New Brunswick Department of Transportation Infrastructure (NBDTI) and Nova Scotia Department of Public Works (NSDPW) have worked together with Transport Canada to identify the need to complete a comprehensive engineering and feasibility study to identify three (3) viable and potential solutions (Options) for the protection of the Trade Corridor located within the Isthmus. Members of multiple government agencies, representing the Provinces, formed a Project Steering Committee (PSC) to oversee the study and provide guidance, as necessary.

Key directives specified by the PSC included:

- An elevation of required protection from extreme water levels in the estuary at 10.6 m CGVD2013 (11.2 m CGVD1928) was adopted for the purpose of this study. Throughout the report and associated figures, the geodetic reference is inferred to be CGVD2013, unless otherwise stated. Similarly, the design level of protection of a given Option is inferred to be 10.6 m.
- The water level in the estuary is the combined result of tide, storm surge and projected SLR.

- Hydrological modeling and protection of the Trade Corridor from inland flooding are excluded from the scope of work for this study.
- The dyke and aboiteaux concept, in part or in whole, will form part of one, or all solutions.
- The study should provide viable and resilient engineered solutions, using a climate change adaptation lens.
- Projected costs for the 3 Options identified should be estimated to +/- 25%.

Supplemental tasks undertaken by the Study Team to identify the three (3) viable Options included: ❶ Gather & Organize Key Documents; ❷ Prepare Project Management Plan; ❸ Develop Preliminary Options; ❹ Rights Holders & Stakeholder Engagement; ❺ Legislative & Regulatory Framework; ❻ Archaeological Assessment Initiation; ❼ Options Comparison; ❽ Geotechnical Assessment and Field Program; and ❾ Options Refinement. In addition, comparative studies of potential environmental, financial outcomes and an infrastructure resiliency risk review between the three Options were undertaken.

To aid in developing potential solutions for protection of the Study Area, the Study Team completed a preliminary document review which consisted of requesting and collecting available information such as existing studies and reports, as-built drawings, inspection reports (bridges, dykes, etc.), property and topographic surveys, photographs, geotechnical logs and previous investigative information. The goal of the document review was to compile factual documents, drawings, and reports to assist with assessing key elements and related conditions within the Study Area and inform the Team as to the information available ahead of developing the Project Management Plan (PMP) and Statement of Work (SoW).

The Study Team developed a PMP and SoW, including all components specified in the RFP. The PMP document was submitted and reviewed by the PSC and has been updated accordingly throughout the course of this Study. The PMP document outlines the Study Team's Work Breakdown Structure (WBS) and general organization of the Team. It also provides the Team's approach to managing various processes including internal organization, resource, schedule and cost management, Communication Plan and Rights Holder and Stakeholder Engagement.

Consultations and Use of Available Information

In keeping with the Communications, Engagement and Management Plans, and to facilitate the exchange of information and providing updates on the Study progression, as requested by the PSC, a list of contacts for First Nations, Rights Holders, landowners, organizations, stakeholders, and individuals was developed and maintained. Various meetings and forums were held to provide an update or overview and request information. All communication activities were conducted in strict compliance with COVID-19 guidelines, health and safety and risk management protocols.

Pertinent information received was incorporated into the Document Review Register (DRR) in an ongoing process. Upon review, the Study Team focused on developing the Preliminary Options to provide protection of the Trade Corridor. The objective was to identify a wide range of possible solutions for protecting critical infrastructure identified within the area to the specified elevation. With the predicted SLR, the existing infrastructure currently below elevation 10.6 m would be vulnerable and require protection. A vulnerability assessment of the existing accessible infrastructure was completed through a combination of field observations and reviews of existing data provided by the Provinces of New Brunswick and Nova Scotia, CN Rail and other Stakeholders.

During this preliminary stage, no significant design constraints or limiting factors were imposed for the consideration of the development of Preliminary Options. The only constraints at this time were the protection of infrastructure to the required elevation of 10.6 m high water mark and that one of the proposed solutions, in part or in whole, must include a dyke/aboiteaux system.

Initially, the Study Area and overall project footprint was divided into three (3) project segments loosely defined using ground surface elevation, and access to infrastructure as general criteria. The use of segment boundaries also allowed for site-specific conditions to be considered during the development of these conceptual or preliminary options. Each of the preliminary options in each of the three segments were reviewed to determine the potential impact on each of the five (5) major infrastructure components: ❶ Highways; ❷ Bridges; ❸ CN Railway; ❹ Dykes; and ❺ Utilities. A review of the potential options by segment noted that there were only slight differences in the options, many of which were combined to eliminate redundancies. Preliminary Options were reviewed for potential challenges/concerns as well as potential benefits/advantages of a given protection option including technical, social, and economic challenges and/or benefits. The initial review of information and development of Preliminary Options resulted in a total of 10 Conceptual Options that were identified for comparison and further evaluation.

Getting to Three Options

The Pairwise Comparison process was selected to evaluate and compare the Preliminary Options with the goal to identify three most viable for further comparative studies. By establishing well-defined evaluation criteria that are easy to understand the Pairwise Comparison process assisted to reduce bias or influence as it produced a consistent understanding and interpretation by everyone taking part in the evaluation. The option evaluation criteria were defined with individual input from each of the PSC members as well as Discipline Leads, resulting in nine (9) clearly defined criteria. The weight, or "importance" of each was then determined by each PSC member, essentially ranking or scoring the importance of each of the nine (9) individual criteria against one and other. The average (of all individual submissions) weighted results of each of the nine criteria were then determined to provide a quantitative means for comparison to provide the framework for ranking individual Preliminary Options. The nine criteria and their weighted representation is shown in Figure ES.2. The small range in weighting percentages indicates there is alignment within the members of the PSC and no overly skewed importance of one criterion was to be considered over another. Each of the ten (10) Preliminary Options were evaluated by Study Team members.

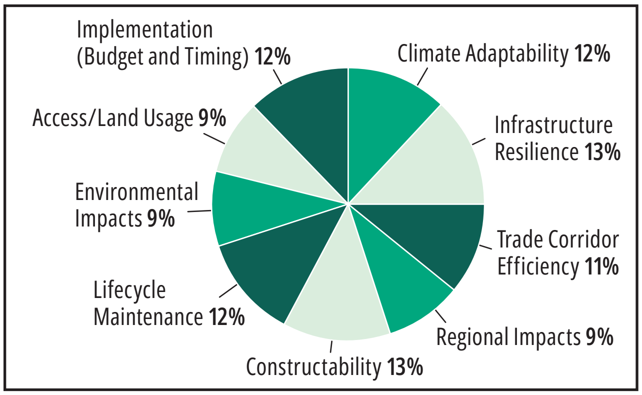

Figure ES.2 Weighted Percentage of Evaluation Criteria

The numerical scores from each team, for each of the options was compiled and the results of the Pairwise Comparison were presented to the PSC for discussion and review. The Study Team prepared generic Option descriptions and high-level conceptual drawings to better illustrate the three highest scoring Options, identified by the letters A, B and C, and summarized below:

Option A – Raise Existing Dykes: Raise existing dykes, as required, to 10.6 m to protect the Trade Corridor (highways, railway, bridges, etc.). Existing infrastructure to remain at present elevation. Where required, existing dykes will be connected by new alignments. Water level control structures required downstream of existing bridges.

Options B – Build New Dykes: A new dyke system to be constructed to 10.6 m to protect Trade Corridor (highways, railway, bridges, etc.) on inland (TCH) side of existing alignment, (*approximate alignment location to be determined*). Existing infrastructure will remain at current elevation. Water level control structures required downstream of existing bridges.

Option C – Raise Existing Dykes + Steel Sheet Pile: Raise existing dykes along existing alignment, as required, to 10.6 m to protect Trade Corridor (highways, railway, bridges, etc.). Install approximately 800 m of Steel Sheet Pile (SSP) walls at selection locations. Where required, existing dykes will be connected by new alignments. Water level control structures required downstream of existing bridges.

Using available information, the Study Team worked with the PSC to outline design considerations for each Option. The PSC approved the top ranked three (3) Preliminary Options described above for further refinement and development. Further design considerations included the general alignment, approximate locations of structures, temporary and permanent access, and permitting considerations.

The Study Team reviewed the potential Options to identify possible federal and provincial permitting and approval requirements. Each selected Option has the potential to require an Environmental Impact Assessment (EIA) Registration in New Brunswick and a Class 1 Environmental Assessment (EA) in Nova Scotia. This would also likely trigger a federal Impact Assessment, depending on final alignment and project funding. The preparation of these assessments will require the field collection of site-specific information. Following the collection and submission of any site-specific information, approval for any provincial EIA/EA is anticipated to take at least six (6) to twelve (12) months. However, due to the spatial extent of the Study Area, the potential for federal involvement, and anticipated requirements for field assessments and consultations, a more realistic timeline would be eighteen (18) to twenty-four (24) months to approval.

Both New Brunswick and Nova Scotia currently have specific legislation enabling/authorizing the construction, alteration, and maintenance of works (i.e., dykes, aboiteaux, drainage) to protect lands from tidal flooding. Whether on private or public lands, the existing dykes, aboiteaux, tidal dam on the Tantramar and inland agricultural lands are designated within their respective provincial legislation. As such, a province(s) can gain access to conduct physical works on privately-owned properties.

A Site Reconnaissance and Geotechnical Desktop Study were performed to develop an initial understanding of the subsurface conditions within the Study Area. Upon completion of the Site Reconnaissance, the Study Team worked in conjunction with the Legislative and Regulatory Framework Team to identify property and landowners and participate in an iterative review of permitting activities, ahead of selecting locations for further geotechnical field investigation.

With access to the existing infrastructure and area possible, soil conditions at selected locations were investigated using available sub-surface data that would help advance geotechnical evaluations at key locations along the proposed alignment(s). The Study Team completed a geotechnical assessment to support the refinement and advancement of the Options.

Parallel to geotechnical investigation, an Archaeological investigation for the Study Area was also completed. This was done in two preliminary phases: ❶ background desktop review for the general Study Area; and ❷ visual surficial field survey for each of the proposed alignment options.

The first phase of the Archaeological investigations involved a background desktop review of the general Study Area to identify and assess the existence of known and/or potential archaeological resources within the footprints of the three proposed Options, as well as in the general area around the potential Study impact areas. The second phase of the Archaeological investigations involved a surficial visual survey of the alignments for each of the three proposed Options. Both phases identified numerous heritage resources in the vicinity of the Study Area. Regardless of which of the three Study options is selected for construction, a full Archaeological assessment (AIA/ARIA) will require completion prior to construction.

Cost Estimates of the Three Options

Following the field assessments, the Study Team refined the Options and began to outline preliminary design considerations and costing for each Option, as presented below. Note that the dyke construction for each Option is to the PSC recommended elevation of 10.6 m.

Option A – Raise Existing Dykes

Figure ES.3 General Arrangement Drawing for Option A

As shown on Figure ES.3, Option A (red color line) follows the existing dyke alignment and crosses the Tantramar River at the mouth of the Bay of Fundy. Reconnection of the existing dyke alignment occurs east of the Tantramar Marsh and continues to the termination point near Fenton Road. This option would require the construction of a large water control structure.

Option B – Build New Dykes

Figure ES.4 General Arrangement Drawing for Option B

Shown in Figure ES.4, Option B (red color line) would include construction of new dykes on the landward side, generally following the existing dyke alignment. The dyke would start south of Sackville and follow existing dyke alignment up to the mouth of the Tantramar River. This option would require the construction of a large water control structure and connect to the existing dyke alignment on the east side of the Tantramar marsh before continuing to the termination point near Fenton Road.

Option C – Raise Existing Dykes + Steel Sheet Pile

Figure ES.5 General Arrangement Drawing for Option C

As shown in Figure ES.5, Option C (red color line) provides a similar construction to Option A with the exception of a new SSP wall, approximately 800 m in length, from the new aboiteaux structure through Tantramar Marsh to Aulac River. A new dyke will be constructed to tie into the existing dyke, which continues to the termination point near Fenton Road.

The preferred Options all rank "high" in terms of constructability and "low" in negative impacts or disruptions related to the Trade Corridor. Given that all three Option alignments are at a considerable offset from the existing TransCanada Highway and the CN Rail line, there are no discernable impacts to traffic operations within the Trade Corridor such as detours or reduced live loads during structure replacement. The new dykes, aboiteaux and water control structures can be constructed in isolation and independent from the Trade Corridor operations. Similarly, there are minimal impacts on source material, site access, structures, while the environmental considerations remain familiar with this type of construction activity. An estimated 5-year construction period was determined, taking into consideration government planning, budgeting horizons and including a period for soil consolidation, where necessary.

Preliminary quantities were derived for the top three Options to develop costs for items such as piled foundations, concrete, reinforcing steel, structural steel, steel gates, backup power supply and other related items. A quantities contingency allowance of 10% was included to account for items that could not be quantified or costed such as site access and development, laydown area construction, power supply, miscellaneous materials related to the hydraulics, mechanical and electrical systems, etc. In addition, the Preliminary Option Construction Cost Estimate includes a series of allowances and contingency amounts to cover other costs that could not be directly quantified and were based on information that is typical of the heavy civil industry.

The estimated capital cost of each Option is summarized in Table ES.1.

Table ES.1 Estimated Capital Cost

Description	Option A - Raise Existing Dyke	Option B - Build New Dyke	Option C - Raise Existing Dyke + SSP
Estimated One Time Capital Cost	$200.2M	$189.2M	$300.8M

Comparative Studies

A Comparative Environmental Review (CER) was completed on the three Options to contribute to the selection of a preferred Option by comparing, at a high-level, the anticipated environmental, social, or economic outcomes of each of the Options, based on the current information available. The CER demonstrates that the three Options, while differing in some elements, will result in similar environmental effects. Although there are differences in the magnitude, extent, and duration of some potential effects, the pathways of interaction are the same, with a few exceptions (e.g., pile driving would be required for Option C, and changes from farmland to salt marsh for Option B). Standard mitigation measures will be incorporated into the design and construction of the selected option to effectively avoid or reduce potential environmental interactions that have been identified at the feasibility stage.

A comparative Climate Change Resilience Assessment Risk Review (CCRA) was completed based on a streamlined application of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol, which is an Infrastructure Canada approved methodology to conduct this type of CCRA. This assessment does not consider the existing infrastructure in the corridor as there is no change proposed to the linear alignment or physical characteristics to these assets (i.e., TransCanada Highway, CN Rail). Rather, the assessment is focused on three proposed Options, which will offer protection to the value-generating assets from projected climate change hazards. The CCRA assessment focuses on the potential interaction between a given Option infrastructure components and climate change hazards. The ten (10) climate change hazard categories considered in this assessment, identified through the Climate Science Analysis for the Chignecto Isthmus region and in consideration of the Options' characteristics, are: ❶ Sea Level Rise; ❷ Freeze Thaw Cycle; ❸ Heavy Rain / Daily Total Rain; ❹ Winter Rain / Freezing Rain; ❺ Storm Surge; ❻ Coastal Erosion; ❼ Hurricane / Tropical Storm; ❽ High Wind; ❾ Thunderstorm / Hail / Lightning; and ❿ Wave Uprush.

Based on the risk ranking scoring, the results for the three Options are shown in Table ES.2.

Table ES.2 PIEVC Risk Ranking Summary

Metric	Options A / B	Option C
Total Number of Interactions	178	188
Interactions in the "High" Category	0	0
Interactions in the "Medium" Category	94	99
Interactions in the "Low" Category	84	89
Climate Change Hazards Exhibiting the Highest Number of Interactions	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm Thunderstorm Wave Uprush	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm Thunderstorm Wave Uprush

The CCRA concluded that the proposed infrastructure components in the three Options represent an overall "medium" risk from the potential impacts of projected climate change hazards. The medium risk reflects a "grey area", where it is uncertain whether the severity or duration of the impact could trigger the need for further action. The current effort is primarily a screening effort to inform selection of a preferred Option. It must be recognized that climate science is a rapidly changing landscape and extreme weather events that can cause catastrophic damage are difficult to predict in terms of timing, intensity, duration, and consequences. As the Options are further refined, design and construction should proceed in a manner that anticipates, adapts to, and mitigates projected climate change impacts.

The value-generating assets in the trade corridor include the TransCanada Highway, CN Rail, 138 kV and 345 kV electricity transmission lines, fibre optical cables, a wind farm, agricultural cropland activities, and various other utilities. The estimated value of goods and merchandise transported through the corridor, including revenues generated by in-corridor economic activity ("benefits") is estimated at approximately $35 billion per annum. Comparatively, the Option capital costs ("costs") range from approximately $200 million to $300 million. As a result of the imbalance between the "benefits" and "costs" a comparative quantitative benefit cost analysis is not considered to be relevant, and an annualized Return on Investment (ROI) analysis was deemed more useful. The ROI is a function of the monetized value generated by the assets in the Trade Corridor that will be protected from future climate change hazards and extreme weather events compared to the total capital cost of the Option, in addition to operation and maintenance costs.

The ongoing operating costs for the Options were determined as a percentage distribution of the capital costs and are based on industry experience. The ongoing annual operating cost for each Option is summarized in Table ES.3.

Table ES.3 Estimated Annual Operating Cost

Description	Option A - Raise Existing Dyke	Option B - Build New Dyke	Option C - Raise Existing Dyke + SSP
Estimated Annual Operating Cost	$7.31M	$6.90M	$10.98M

This analysis employed an amortization period of 30 years and an interest rate of 3.5% to determine a future annual payment stream and adding the annual operating cost yields a total annual cost. The findings of the annualized ROI analysis in Table ES.4 indicate that all Options exhibit a significant positive return on investment.

Table ES.4 Option ROI Analysis

Metric	Option A	Option B	Option C
Amortized Total Capital Cost ($M, rounded)	10.9	10.3	16.4
Annual Total Operating Cost ($M, rounded)	7.31	6.90	10.98
Annual Cost of Investment ($M, rounded)	18.21	17.2	27.38
Simple ROI	120%	133%	46%

In addition, Option B exhibits the highest ROI due to lower one-time total capital cost and annual total operating cost. However, the analysis is skewed by the significant value generated by the assets in the trade corridor compared to the cost of the Options and should be used with caution.

Recommendations

The Study Team's mandate was to develop three (3) viable solutions to protect and sustain the Chignecto Isthmus Trade Corridor. This report aims to outline the Options identified and their associated impacts based on the information available at the time of this Study. In addition, this report provides guidance and recommendations to additional activities and studies which would refine uncertainties and improve the cost estimating accuracy. At a minimum, these recommendations include: ❶ early engagement with Rights Holders / Stakeholder / Regulatory Engagement; ❷ completing a site-specific and detailed hydrotechnical analysis; and ❸ detailed geotechnical analysis including a site-specific seismic hazard assessment.