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Bell Island Lighthouse Relocation Project

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ABSTRACT

Bell Island is a small community located in Conception Bay, Newfoundland and Labrador (NL). The current population on the island is just under 3000 people. The island is very unique given its rich and colourful history, including remnants of the once thriving mining industry of the 1800's and one of the few places in North America that was the target of an enemy attack in World War II. Aside from its unique history, Bell Island is well known for its scenic attractions and artifacts. One of the most common attractions is the lighthouse located at the East End of the island.

The province of NL, in particular, relies heavily on lighthouses to assist marine travellers navigating along our vast, rugged coastline. The Bell Island lighthouse has been in operation since 1940 and has assisted thousands of fishermen and mariners to safely navigate in Conception Bay. In NL, the Canadian Coast Guard oversees and monitors the conditions of the lighthouses across the province to ensure they are fully operational all year round. During the fall of 2000, it had become apparent that the cliff face near the Bell Island lighthouse was experiencing significant coastal erosion; therefore, presenting a major concern for the functionality of the lighthouse, stability of the nearby ground and safety of persons in the area, which led to the relocation of the lighthouse in 2003.

The following paper will focus on the various challenges encountered with relocating the Bell Island lighthouse, including assessment of the land stability, impact of coastal erosion on the cliffs and selection of a new suitable location safe for public access. It will highlight any lessons learned from this project and look at what the future holds for the Bell Island lighthouse.

1 BACKGROUND INFORMATION

The community of Bell Island is located on the northern part of the Avalon Peninsula, in Conception Bay, NL, as illustrated in Figure 1. Primary access to the island is via a provincial ferry service, which is located in Portugal Cove, St. Phillip's. The ferry accommodates both motor vehicles and passengers and operates on a yearly basis to provide daily crossings for the residents of Bell Island and other individuals providing services to the island. The ferry ride is approximately 20 minutes in duration.

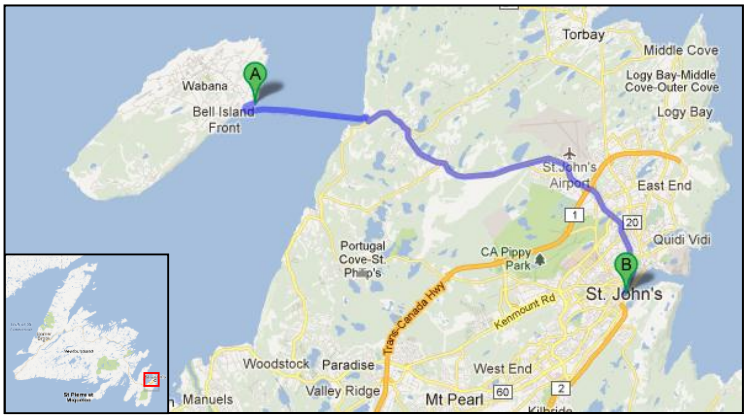

Figure 1: Location Map of Bell Island

It is quite evident from Figure 1 that the ocean environment plays a fundamental role in NL's navigational pathways. As a result, the presence of lighthouses along the rugged coastline is a necessity. During the early 1800's, lighthouses were established in NL to provide a beacon to mariners at sea. As well, in some instances, they were used to provide a link for communication between ships and shore. It has become apparent that modernization has influenced the operation of these lighthouses and therefore, enhancements in technology and equipment has resulted in minimum human intervention required. Historically, lightkeepers lived and worked in isolated areas to maintain the lighthouse operations; however today, lightkeepers live in neighbouring communities and commute to work. They are responsible for daily monitoring of the navigational equipment, weather conditions and reporting any unusual sightings.

Lightstations are an essential part of NL's marine culture and heritage. Consequently, it is imperative for the lightstations to be preserved and protected to ensure that they keep mariners safe. The Canadian Coast Guard play a critical role in maintaining these lightstations and ensuring that they are functioning properly all year round. There are approximately 55 major lightstations in NL, 23 are staffed with lightkeepers. [1]

With increased development initiatives in tourism and eco-tourism, interest in lighthouses as sites of heritage and historic legacy have risen significantly. Thus, the Canadian Coast Guard have been working with community groups, organizations and municipalities to preserve the historic value of lighthouses across NL, where possible. The Bell Island lighthouse, in particular, is one of considerable tourist interest given the location of the lighthouse and the breath-taking view, as shown in Figure 2.

Figure 2: Present Location of the Bell Island Lighthouse

2 PROJECT DESCRIPTION

In the late 1930's, the very first lighthouse was constructed on Bell Island. The lighthouse was located on the eastern point of the island, as illustrated in Figure 3. For many years, the lighthouse was operated by a lightkeeper who lived in a dwelling within close proximity of the lighthouse.

Figure 3: Old Location of the Bell Island Lighthouse

In 2000, the lightkeeper, at that time, had expressed serious concerns to the Canadian Coast Guard that they could hear noises in a cave below the cliffs, near the lighthouse and lightkeeper's residence. With this concern brought to the Coast Guard's attention, they immediately took action to assess the site. A number of studies were completed including a slope stability assessment by AMEC Earth and Environmental Limited, a risk assessment by C-CORE in collaboration with AMEC and a planning options report by Sheppard Case Architects Inc. Through the recommendations and conclusions established in these engineering studies, a final decision to relocate the lighthouse became apparent and justifiable. It is important to note that the lighthouse was not only accessible by the lightkeeper, but rather locals and tourists visiting the lighthouse on a regular basis. Safety was certainly a key deciding factor for relocating the lighthouse; however, other considerations including economics, engineering liabilities and preservation of community heritage were also influential in the overall decision. [3]

2.1 Slope Stability Assessment

In August 2000, the Canadian Coast Guard engaged AMEC Earth and Environmental Limited to conduct a study of the lighthouse area. The goal of their study was to determine whether the nearby cliffs were stable and if there was any future danger for the infrastructure, Coast Guard personnel and general public. For their study AMEC geologists and engineers examined air photos and municipal maps to determine geometric differences in the cliffs and identify any evidence of mass movement. Fieldwork was also conducted via a rescue craft to examine the cliffs and geological joint/fault orientations in the area.

From inspection of the air photos, there was noticeable erosion of rock and soil between the sea stack at Eastern Head and Bell Island. As well, other points of land at the sea cliffs had changed considerably looking at 1951 and 1978. The municipal mapping was also studied; however, no difference in the coastline area was observed from this information.

It is evident from the initial photographs of the lighthouse that it was located at the edge of a sea cliff. The island and, in particular, the cliffs are subject to erosion by sea and wind conditions. Steep, vertical cliffs surround the site and they are constantly subjected to wave and swell action. Over time, caves have developed and are quite common in the area.

Through AMEC's investigation they identified various geological faults. A cave has been eroded along one fault in particular, completely through Eastern Head, as illustrated in Figure 4. It is believed that the cliff slopes are eroding at a fast rate. AMEC reported that the "slopes in the area are practically bare of any organic growth, which indicates fresh rock is continuously being exposed." The sea caves located beneath the cliffs would be stable if erosion was not a factor. The roof spans and their conditions were not known; therefore, further work would be required to monitor their condition and prevent collapse.

Figure 4: Cave Through Eastern Head

Based on the AMEC report, it was concluded that further information was required to determine the rate of erosion and slope stability. During the study, erosion due to constant wave action was estimated to be 4 to 5 cm per year. AMEC also concluded that the site was in "no imminent danger"; however, rapidity of erosion of the sea cliffs would eventually place the infrastructure in jeopardy. It was recommended that a topographic survey be completed for the site and surrounding cliffs to monitor the movement or loss of material. As well, precise information to determine the location of the caves and their dimensions would assist with determining the rate of erosion. A recommendation to relocate the lightkeeper's residence was suggested; however, the lighthouse could remain where it was until obvious erosion impeded access to the lighthouse, at which point relocation would then be considered. [4] Lastly, when asked if Coast Guard personnel were in any immediate danger, the reply was that a future risk assessment would be required to determine the level of risk to employees and the public. [3]

2.2 Risk Assessment

Following the slope stability assessment, the Canadian Cost Guard retained AMEC Earth and Environmental Limited to complete a risk assessment analysis of the site. AMEC engaged C-CORE to conduct the study in collaboration with AMEC engineers and geologists. The assessment for both the lighthouse and the lightkeeper's residence consisted of identifying possible failure mechanisms on site, and utilizing computer software to conduct stability analysis and risk assessment. In particular, Monte Carlo simulations were performed for rock slope stability to infer probabilities of possible failure mechanisms.

Figure 5: Tension Crack 1 to 3 m From Cliff [5]

Similar to what was noted in the AMEC report, C-CORE also mentioned that the lighthouse area is strongly affected by erosion, with evidence of numerous tension cracks that had developed, as shown in Figure 5. During fieldwork along the coast, C-CORE was able to confirm the average erosional rate of 4 to 5 cm per year estimated in the AMEC report, based on observations and mapping of existing tension cracks.

C-CORE also examined the strength of rock discontinuities in the area. Limited information was available for shear strength; therefore, ranges were assumed for input values to simulations. The risk assessment results were very sensitive to the input data used. As a result, various failure mechanisms were assumed for the lighthouse area and near the lightkeeper's residence and Monte Carlo simulations were performed to examine slope stability and risk assessment. The purpose of using this method was to analyse rock structures with uncertain material and/or geometric properties and loads. Sample values of uncertain quantities (i.e. strength parameters) were generated based on their assumed probabilistic characteristics.

The resulting risk levels obtained from the Monte Carlo simulations were compared with failure probabilities for various geotechnical works (earthworks, earth retaining structures, onshore and offshore foundations), since determination of an "acceptable" level of risk for loss of human life is very difficult to quantify. Based on the estimated annual failure probability for a deep slide near the lighthouse, the area could be considered acceptable if the lighthouse was not manned and if required maintenance was not performed during severe weather conditions, such as long rainy periods and large swells. However, if a permanent office were located in the lighthouse, this would place the lightkeeper at a risk compared to fatality risks encountered in the mining industry, which is considered a "high-risk" environment. Based on the estimated annual failure probability for a deep slide near the lightkeeper's residence, this area would be a "high-risk" zone. Such an event would lead to destruction of the lightkeeper's residence and potential loss of life for the inhabitants.

Overall, C-CORE's study indicated that the lightkeeper's residence was located in a relatively unsafe zone, affected by the presence of active erosion at sea level and extensively weathered rock onshore. It was recommended that the residence be relocated to a position on the land where potential risk would be reduced to an appropriate level. As well, consideration to relocate the access road and electric poles further inland was recommended if the lightkeeper's residence was to remain in the present location. Visual observations of nearby surficial slides were observed and it was concluded that the area of the access road was relatively unsafe. [5]

2.3 Planning Options

Prior to 2002, Sheppard Case Architects Inc. assumed a consultant role to perform a detailed assessment of the lighthouse building condition. Subsequently, contract documents were prepared for complete renovation of the lighthouse. This renovation included all new exterior and interior upgrades. Upon completion of the construction contract documents in late 2000, Sheppard Case Architects Inc. was informed about the results of the risk assessment conducted by AMEC, as discussed earlier. As a result, renovations to the Bell Island lighthouse were put on hold. The lighthouse and lightkeeper's residence would eventually be put in jeopardy given the constant wave erosion in the area. Following the results of the assessments, in late 2000, the lightkeeper was removed from the site and additional security measures were taken to secure the site. A gate was erected at the beginning of the access road and signage was put in place to make the public aware of the risks associated with going on the site, as illustrated in Figure 6.

Figure 6: Security Measures Put in Place for the Lighthouse Area [6]

In September 2002, Sheppard Case Architects Inc. was instructed to determine the planning options available and viable for the Canadian Coast Guard, with regards to the Bell Island site. Cost estimates were generated to compare each option based on a class "D" concept estimate (±20%) and a broad scope project solution. The cost did not include land purchase costs and soft costs for acquiring the land.

During the initial consideration of options for the lighthouse, there were many questions raised as to who should take ownership of the site (i.e. Canadian Coast Guard or Town of Wabana). Either way, both would be faced with significant liability concerns no matter who owned the site.

In total, Sheppard Case Architects Inc. provided *five* options available for short term and long-term strategies for the Bell Island lighthouse and lightkeeper's residence. A preliminary cost estimate was also prepared for each to give the Coast Guard an idea of the funds required. Table 1 provides an overview of the options considered for the Bell Island lighthouse and lightkeeper's residence.

Table 1: Options Considered for the Bell Island Lighthouse and Lightkeeper's Residence

Option	Title	Description	Cost Estimate
Option 1A	Status quo	Lightkeeper's residence would remain boarded up and the lighthouse would be maintained as required. Liability concerns would arise for the owner given the geological instability of the area.	Minimum budget of ~$20000, however depends on the work required.
Option 1B	Demolish lightkeeper's residence	Variation of Option 1A, except the lightkeeper's residence would be demolished and the area backfilled. This option removes future liability or cost that may arise through unauthorized entry or vandalism.	Minimum budget of ~$32000, which included additional demolition costs.
Option 2	Demolish lightkeeper's residence and restore lighthouse	Similar to Option 1B, demolition of the lightkeeper's residence. Since the site is in "no imminent danger" it may be viable to restore the existing lighthouse. The public would not be permitted on site, unless at their own risk.	Based on a pre-tender estimate, a minimum budget of ~$192000, which included demolition.
Option 3	Demolish lightkeeper's residence and lighthouse	Represents shutting down the site. Navigational aids would continue to be maintained; however, existing aids would be modified to operate in an equipment shed. Public criticism could arise given their view of the lighthouse as historically significant.	Minimum budget of ~$60000, which included demolition.
Option 4	Demolish lightkeeper's residence and relocate lighthouse	Demolition of the lightkeeper's residence, as discussed in previous options, and relocation of the lighthouse to a site beyond the fault zone determined by AMEC. A new slab-on-grade would be required at the new location.	Minimum budget of ~$280000.

Option 5A	Construct new office and lighthouse	Building a new office/lighthouse outside the fault zone identified by AMEC. The navigational aids in the existing lighthouse would be included in the new design. The design would include an office station for the lightkeeper as well as an area to display the artifacts of the existing lighthouse.	Minimum budget of ~$250000.
Option 5B	Construct new office and lighthouse (with light tower)	Similar to strategies discussed in Option 5A; however, a different design was proposed for the new office/lighthouse. The light would be incorporated into a new tower, included with the design of the office/lighthouse. A spiral staircase would permit visitors to view the light from within the building.	Similar to Option 5A, the budget for this option would be ~$250000.

Based on the options presented above, Sheppard Case Architects Inc. recommended that either *Option 4 or 5* would be viable and commendable for the Bell Island site. The decision as to which option to proceed with would ultimately be determined by the Canadian Coast Guard, in conjunction with the Department of Fisheries and Oceans (DFO). As well, consultation with the Town of Wabana for review and input would alleviate criticisms that may arise in the future. [6]

3 PROJECT CHALLENGES

Upon examination of the studies completed to assess relocating the Bell Island lighthouse, it is evident that there are various challenges inherent with this engineering case study.

3.1 Safety Concerns

As alluded to earlier, NL's coastline is greatly influenced by the ocean environment. It is evident from photographs and site visits that the waves have a significant impact on the cliff erosion. The U.S. Army Corps of Engineers Coastal Engineering Manual discusses erosional coastal processes experienced by cliffs. For a straightened coast, waves attack the shore and erode headlands, producing steep sea cliffs. Near sea level, the waves forcefully attack the cliffs, especially where weak joints and softer strata are present. As exhibited on Bell Island, the cliffs are undermined and caves are formed. Once a cliff has been undercut at its base, the overlying rock is left unsupported. This may result in collapse and sliding of the material down to the shoreline. [7] Although the cliffs surrounding the island may still be intact today, the rate of erosion due to wave action will need to be monitored to ensure safety and stability of the cliffs and neighbouring land.

3.2 Public Relations

The Canadian Coast Guard's final decision was significantly affected by the social implications associated with relocating the lighthouse on Bell Island. Although the lighthouse may not be deemed as a "historic site" for NL, it holds deep sentimental value to the residents of Bell Island. It is an artifact that has been part of the island's culture, heritage and legacy for over 50 years. As well, the lighthouse is a fundamental tourist attraction for visitors to the island. It provides an astonishing view of NL's unique landscape and ocean environment. The advantage of *Option 4 or 5* is that it will generate

positive public relations for the Coast Guard and the community. Coast Guard's effort to save and restore the original lighthouse would be seen as an immense contribution to the tourism activities on Bell Island. [6]

4 CONCLUSIONS

On February 4, 2003, the Canadian Coast Guard held an information session on Bell Island to decide on the best option for the lighthouse. It was decided at that meeting to proceed with Option 4, to renovate and relocate the existing lighthouse to a safe zone. The Town Council also agreed that they would construct a new foundation for relocating the lightkeeper's residence; however, DFO would be responsible for relocating and installing the residence on the foundation.

Following that meeting with the Town, Sheppard Case Architects Inc. conducted further investigation on the lighthouse, which revealed that there was extensive rot in the lighthouse building. This would greatly increase renovations costs that were previously anticipated. As a result, DFO decided that it would viable and justifiable to proceed with Option 5, to demolish the existing lighthouse building while salvaging artifacts that could be included in the new building. As well, according to the cost estimates presented in the Planning Options Report, restoration of the existing lighthouse building (Option 4) would likely cost more than the construction of a new building (Option 5).

In late 2003, the lightkeeper's residence was relocated and installed on a new foundation built by the Town of Wabana and a new lighthouse building was constructed in a stable location while restoring artifacts of the existing lighthouse, including the original light. [3] Although the lighthouse is presently in a reasonably safe zone, it is imperative that the Coast Guard continue to monitor the impact of coastal erosion. Geological monitoring of the site and surveys of the cliffs and cave formations will assist with the Coast Guard with maintaining public safety on site.

REFERENCES

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[3] Mr. Rick Bennett, Small Craft Harbours & Real Property Branch, Department of Fisheries and Oceans, "Letter to Town of Wabana RE: Relocation of Bell Island Lightstation", April 10, 2003

[4] AMEC Earth & Environmental Limited, "Slope Stability Assessment Lighthouse, Bell Island, NF", December 15, 2000

[5] C-CORE, "Risk Assessment Lighthouse, Bell Island, NF, Final Report", December 2000

[6] Sheppard Case Architects Inc., "Bell Island Lightstation Planning Options Report", November 12, 2002

[7] U.S. Army Corps of Engineers, Coastal Engineering Manual – Part III. Chapter 5 – Erosion, Transport, and Deposition of Cohesive Sediments. Publication Number EM 1110-2-1100. Publication Date: April 30, 2002