Q. It is noted that the review undertaken by Manitoba Hydro International in 2012 "Report on Two Generation Expansion Alternatives for the Island Interconnected Electrical System, Volume 1: Summary of Reviews" commented in section 4.4.3 on the scour data in the area, which surprisingly had shown scouring at depth of 70 to 75m. It is stated that these marks may be from earlier glacial periods, but this cannot be positively confirmed. Therefore, a risk of iceberg damage may still exist even with the deeper exit points of the HDD. Please comment on this potential risk, and provide additional data if available.

A. The presence of relict iceberg scours is not surprising, and has been previously documented in research literature for various locations in offshore Newfoundland and Labrador, including the Labrador Sea and the Grand Banks.

While definitive evidence is unavailable to determine when the scour actually occurred, the unique features of the bathymetry in the Strait of Belle Isle were discussed by C-CORE in Exhibit 35 of the Muskrat Falls review. While icebergs will ground in shallower water in the northeast extent of the strait, the potential exists for them to break up or melt, thus reducing their draft. They also have the potential to then increase their draft and cause damage to the cables installed in deeper water.

Relevant variables in assessing the risk of damage to the cables include:

- Iceberg drift trajectories
- Metocean data, including tidal and non-tidal drifts

- Bathymetry data, including the extent to which bathymetric shielding is provided
- Iceberg roll rates and draft changes
- The rate of icebergs travelling through the cable corridor (iceberg flux)
- The cable layout and breakout water depth

Additional analysis and modelling has been undertaken by C-CORE since the 2011 study was completed, and updated risk analyses have been completed. The most recent risk analysis shows a significant reduction in cable risk, and the projected return period for a mean rolling period of 6 days is 4,500 years at the design breakout depth of 70 m.

A technical note from C-CORE is attached as Attachment 1.

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C-CORE Technical Memorandum

From:	Tony King	**Date:**	April 15, 2016
To:	Keith Drover, Greg Fleming	**Project #**	271261
		Doc No:	TM-1261-001 v1
RE:	**Update of Iceberg Risk to Subsea Cables in Strait of Belle Isle - Summary**		

1 BACKGROUND

In 2011, C-CORE performed an iceberg risk analysis for cables crossing the Strait of Belle Isle (SoBI) for transmission of power from Muskrat Falls. The analysis was based on a simulation of iceberg drift through the site in order to assess the influence of a shoal immediately to the northeast of the crossing route which would filter out deeper draft icebergs, effectively sheltering the cable in deeper water (directional drilling protects the cables in shallower water depths). The objective of new work summarized here was to update the analysis using:

- iceberg trajectory and observations collected in SoBI from 2013-2015;
- metocean data collected in SoBI from 2013-2015;
- bathymetry data collected in SoBI in 2015;
- an improved characterization of iceberg rolling rates and associated draft changes;
- an improved characterization of iceberg flux through the cable crossing site; and
- the actual cable layout (see Figure 1) and breakout water depths.

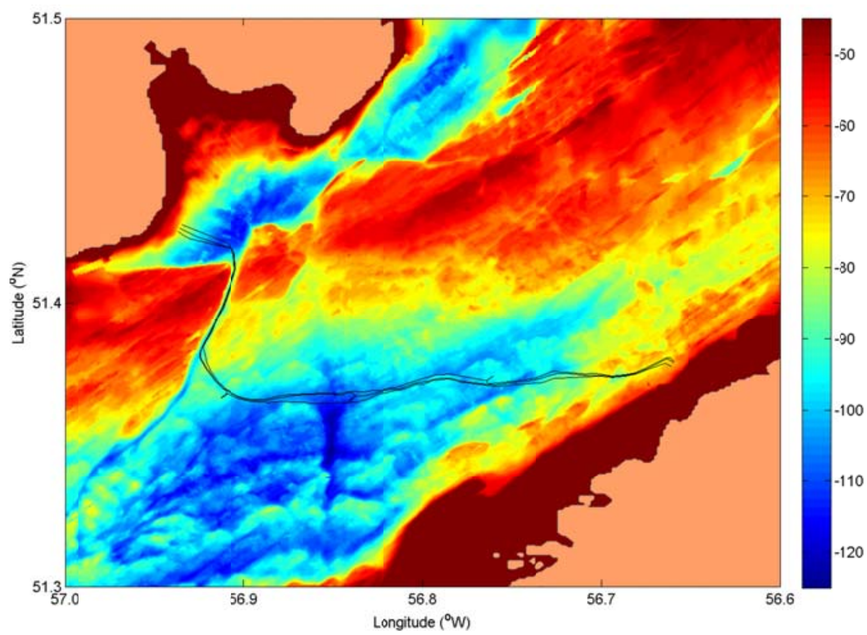

Figure 1. Updated cable layout in Strait of Belle Isle

2 BATHYMETRY UPDATE

The previous analysis (C-CORE, 2011) used regional 500 m resolution bathymetric data from the Canadian Hydrographic Service (CHS) updated with multibeam data collected by Fugro in the immediate vicinity of the cable crossing site (see Figure 2, left). Additional multibeam data collected in 2015 by DOF and Maritime Survey Services was incorporated in order to improve the characterization of the bathymetric shielding effect upstream of the cable crossing site. The updated bathymetric dataset is shown in Figure 2 (right).

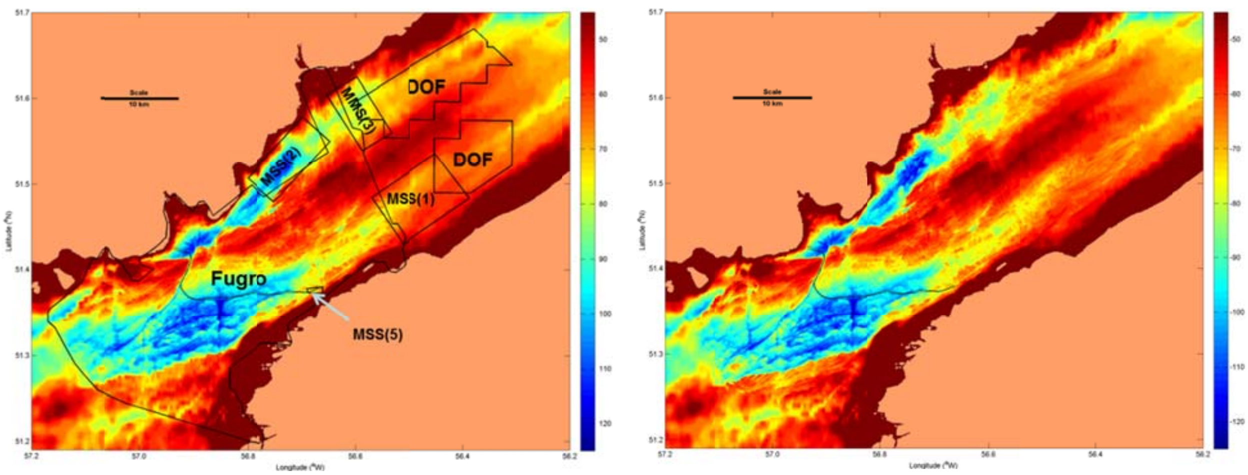

Figure 2. Coverage of multibeam data sets (left) and updated bathymetry (right)

3 METOCEAN ANALYSIS AND UPDATE OF ICEBERG DRIFT MODEL

Iceberg drift was monitored in the vicinity of the cable crossing site by PAL from 2013 to 2015 used a remotely-operated shore-based radar and camera system near the Newfoundland cable landfall site. Amec Foster Wheeler installed current meters (ADCP) at five sites along the cable crossing route (as well as wave buoys at two sites). The current data was analyzed to separate it into tidal components (which by definition is cyclic with tidal motion, and so should cause no net movement of an iceberg over long periods) and non-tidal components (resulting in net drift through the Strait over periods longer than a day). Data from the HYCOM current model was extracted for the larger model area (extending upstream and downstream of the cable crossing site) and parameters were modified to obtain an optimum fit with the measured data. The iceberg trajectory model was developed using the measured iceberg trajectory data (>250 icebergs) and the modified calibrated HYCOM model data. The resulting simulated iceberg drift tracks produced reasonable representations of iceberg drift in the SoBI, exhibiting similar drift speeds and net drift speeds, as well as the tidally-induced looping trajectories often observed at the site.

4 ICEBERG FLUX THROUGH THE CABLE CROSSING SITE

Previously, the number of icebergs passing through the cable crossing site was estimated using Canadian Ice Service iceberg charts (C-CORE, 2011). An analysis of International Ice Patrol aerial reconnaissance data was used to calculate the average iceberg density in the zone which was monitored by PAL using the shore-based radar (Figure 3). The iceberg trajectory data collected during the iceberg monitoring program was analyzed to calculate the mean time each iceberg spent (residence time) inside the monitoring area. The average iceberg flux through the monitoring area, calculated using the average iceberg density and residence time (iceberg flux=iceberg density/residence time), was 70 icebergs per year. The iceberg risk simulation starts icebergs upstream of the cable crossing site (on the other side of the shoal) and icebergs move down through the cable crossing site using the drift model, during which time the icebergs melt, roll and change draft. The number of simulated icebergs that moved through the monitoring area (total flux) was divided by the average annual flux (70 icebergs/year) to convert model output to an equivalent model time.

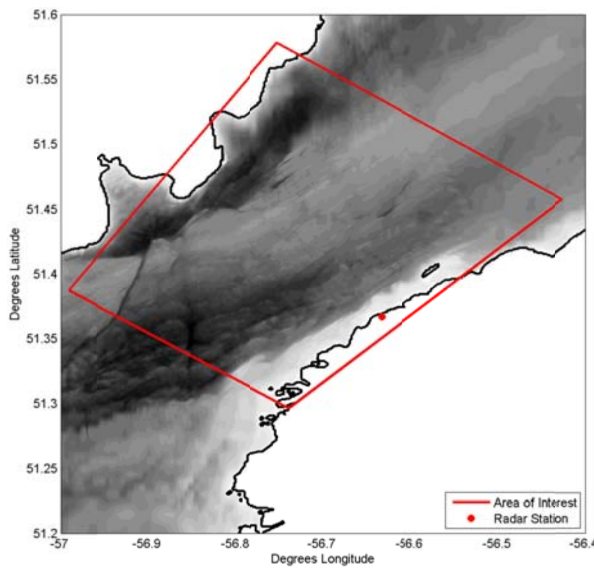

Figure 3. Monitoring area for radar installation (C-CORE, 2013)

5 ICEBERG ROLLING RATE AND ASSOCIATED DRAFT CHANGES

The previous analysis (C-CORE, 2011) assumed that the mean time between iceberg rolling events that were significant enough to cause an appreciable change in draft was on the order of three days. This was based on a field program in which two small icebergs grounded off the coast of Newfoundland (≈50 to 60 m waterline length) were observed continuously for a period of approximately one week (Veitch et al., 2001). In 2015 a field program was conducted where 50 icebergs were observed over a period of 23 days, yielding a mean rolling period of 6 days (C-CORE, 2016). An analysis of iceberg photographs collected at the radar site in SoBI (C-CORE, 2013) supports the longer average rolling period for icebergs (10 days was estimated, based on a relatively limited dataset).

When icebergs deteriorate through melting or calving they often roll and change draft. This process allows icebergs in the SoBI to drift over the shoal upstream of the cable crossing site, roll, adopt a deeper draft and impact the cable which would otherwise be shielded from icebergs. There are very few measurements of iceberg draft before and after a rolling event on which to base an assessment of the magnitude of draft changes. Previously, iceberg draft was calculated from iceberg mass (based on observed iceberg mass/draft data) with a best fit relationship and a scatter term included to characterize the scatter of the actual data. In the risk model, when an iceberg rolling event was simulated a new scatter term was sampled, generating a new draft (C-CORE, 2011). However, this could lead to very large changes in draft due to the large amount of scatter around the best fit line in the original data (which included different types of icebergs with varying geometry). An updated approach was developed that used measured 3D iceberg shape data, simulated calving by removing random slices of the icebergs, and comparing the new and previous drafts. This approach was used to generate a new scheme for generating new drafts after a rolling event. The magnitude of the draft changes were reduced, however it is possible to get a significant increase in draft.

6 UPDATED CABLE RISK ANALYSIS

Figure 4 shows modeled iceberg groundings (black dots) in the cable crossing site using a mean 6 day rolling period. Over 5 million grounding events are shown in Figure 4. Figure 5 (top) shows the water depth along each cable and Figure 5 (bottom) shows where modeled iceberg contacts with the cables occur. The average contact rate (scouring and free-floating icebergs) for the three cables was 2.25×10^{-4} yr^{-1}, or a mean return period of 4,500 years. The majority of the iceberg contact events occur on the Newfoundland side of the cable route in shallower water depths.

The model period associated with this result is 140,000 years (based on the number of modeled icebergs passing through the iceberg monitoring zone shown in Figure 3). This dataset is being expanded to 1,000,000 years model time to reduce uncertainty in the results. Table 1 shows the influence of the rolling period on the iceberg contact rates with the cables. This is a significant reduction from the previous (C-CORE, 2011) analysis, which gave (for a 70 m breakout depth) approximately a 200 year return period for iceberg contacts for a 3 day rolling period and a 1,000 year return period for cable contacts for a 10-day rolling period (both a factor of 10 increase in the mean return period).

Table 1. Influence of mean iceberg rolling period on cable contact rates

Mean Rolling Period (Days)	Mean Return Period Between Cable Contacts (Years)
1	900
3	1,900
6	4,500
10	12,000

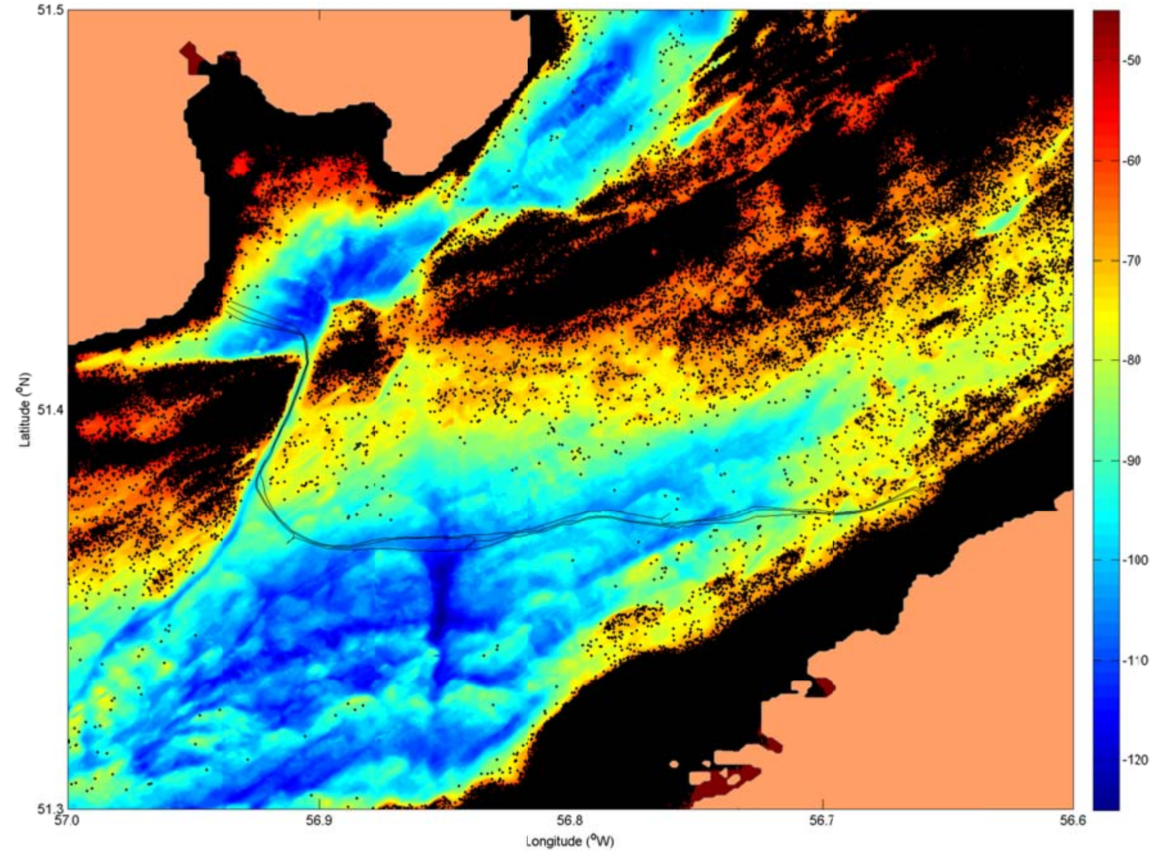

Figure 4. Simulated iceberg groundings (black dots) and cables, 6 day mean rolling period

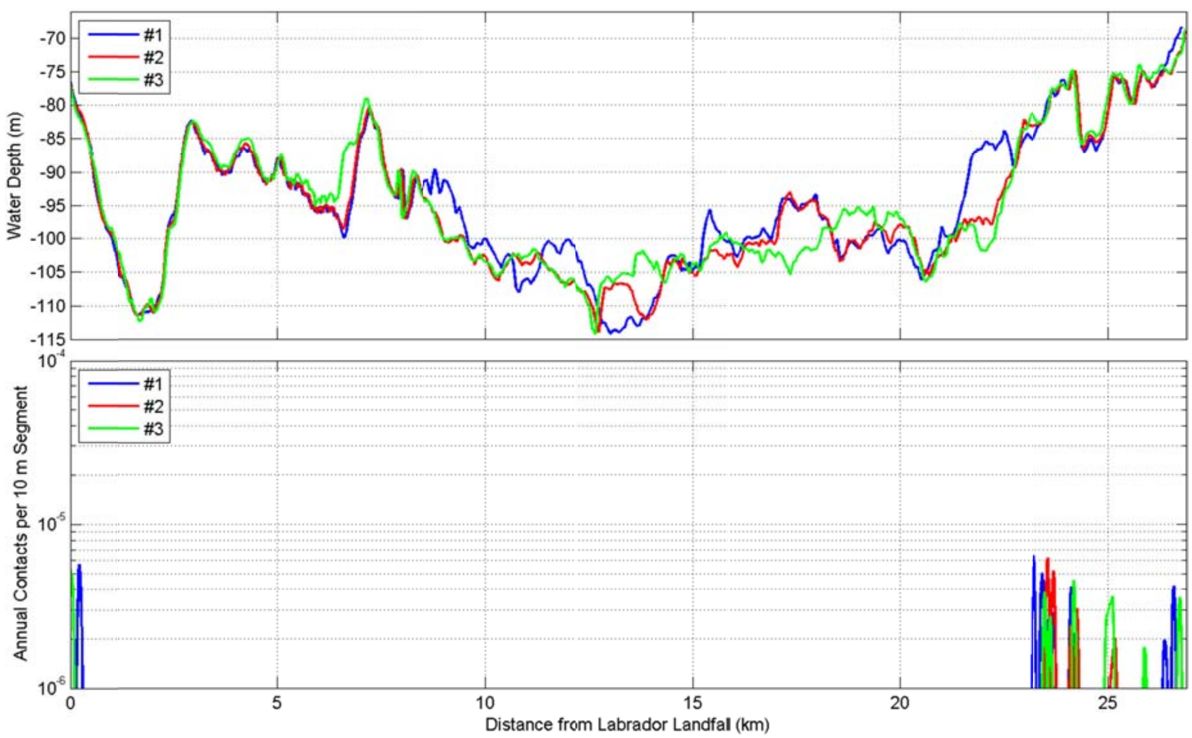

Figure 5. Water depth along cables (top) and cable contacts (bottom)

7 CONCLUSIONS AND RECOMMENDATIONS

The analysis presented here shows a significant reduction in cable risk with updated inputs, with approximately an order of magnitude reduction in iceberg contact rates. The factor which contributes most to this reduction is the revised relationship for draft changes associated with iceberg rolling. Additional field data collection is recommended in the Strait of Belle with an iceberg profiling system to monitor iceberg rolling events and to measure associated draft changes.

8 REFERENCES

C-CORE (2011). Iceberg Risk to Subsea Cables in Strait of Belle Isle. Report R-10-039-781 V3, September.

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