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Power Generating Potential on the Grand Banks Using Fixed-Bottom Wind Turbines

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ABSTRACT

C-CORE (2022a) performed an ice risk analysis for floating wind turbines in the Grand Banks region as part of the study "Evaluation of Floating Wind Technology to Reduce Emissions in Newfoundland and Labrador's Offshore Hydrocarbon Industry", funded by the Emissions Reduction Fund (ERF), results of which were summarized in King et al. (2022). The area of interest covered 45°N to 51°N and 45°W to 51°W. Here, the focus is on bottom-founded wind turbines anywhere on the Grand Banks. The report "Regional Assessment of Offshore Wind Development in Newfoundland and Labrador" (McDonald et al., 2025) excluded the Grand Banks based on a very conservative iceberg risk criterion. Here, an iceberg risk analysis is presented for the entire Grand Banks region to evaluate iceberg contact rates with bottom-founded wind turbines, and areas with iceberg contact rates > 0.02 yr^{-1} (50-year return period, no ice management) were excluded. Further filtering was conducted using the same process as the regional assessment, considering criteria such as a coastal buffer zone, critical marine habitat, marine protected areas, marine traffic routes, high vessel traffic, marine conservation areas, proximity to national parks and world heritage sites, community-based coastal resources, and high-density fishing areas. After this process was concluded, remaining areas lay primarily in a band between 45°N and 47°N, with water depths ranging mostly from 60 to 80 m. A review of available offshore wind turbine technologies identified the Fully Restrained Platform (FRP), a monopile variant, suitable for water depths in the 60 to 80 m water depth range. This potentially allows power generation on the order of 100 GW to be developed on the Grand Banks.

KEY WORDS: Wind; Power; Ice; Risk; Monopile

INTRODUCTION

Previous consideration of offshore wind power generation on the Grand Banks was focused on reducing emissions from offshore oil production facilities (C-CORE, 2022a, King et al., 2022). The Area of Interest (AOI) for this work was bounded by 45°N to 51°N and 45°W to 51°W (see Figure 1, left), which covers all production, significant discovery and exploration licenses on the Grand Banks, and in the Flemish Pass and Orphan Basin. The AOI was broken down into half-degree squares (a half degree longitude by a degree latitude). Iceberg impact frequencies and loads corresponding to a 50-year return period were calculated for various structure sizes, including the influence of mooring compliance, with and without ice management. Commercial CFD (Computational Fluid Dynamics) software (Star-CCM+) was used to assess the dynamic response of icebergs and floating wind turbines to the wind, wave and current environment and to provide required inputs to more detailed dynamic modelling of iceberg-turbine collisions using C-CORE's DynIIS^{TM} software. Pack ice conditions were assessed using satellite data and it was found that sea ice entering the AOI had been broken down into smaller floes by wave action and would pose no threat to wind turbines. Other factors assessed included iceberg contacts with mooring lines, analysis of upward-looking sonar (for sea ice thickness), ice management requirements, and structure icing.

The Regional Assessment of Offshore Wind Development in Newfoundland and Labrador (McDonald et al., 2025) initially considered an area covering all offshore Newfoundland and portions of the northern Grand Banks and southern Labrador (Figure 1, right). This was subsequently reduced to a defined focus area based on a conservative assessment of iceberg risk. The criterion used in reducing the initial study area to the focus area was to remove "portions of the Study Area where medium or larger iceberg sightings were recorded between 2002-2021". This will be addressed in the next section.

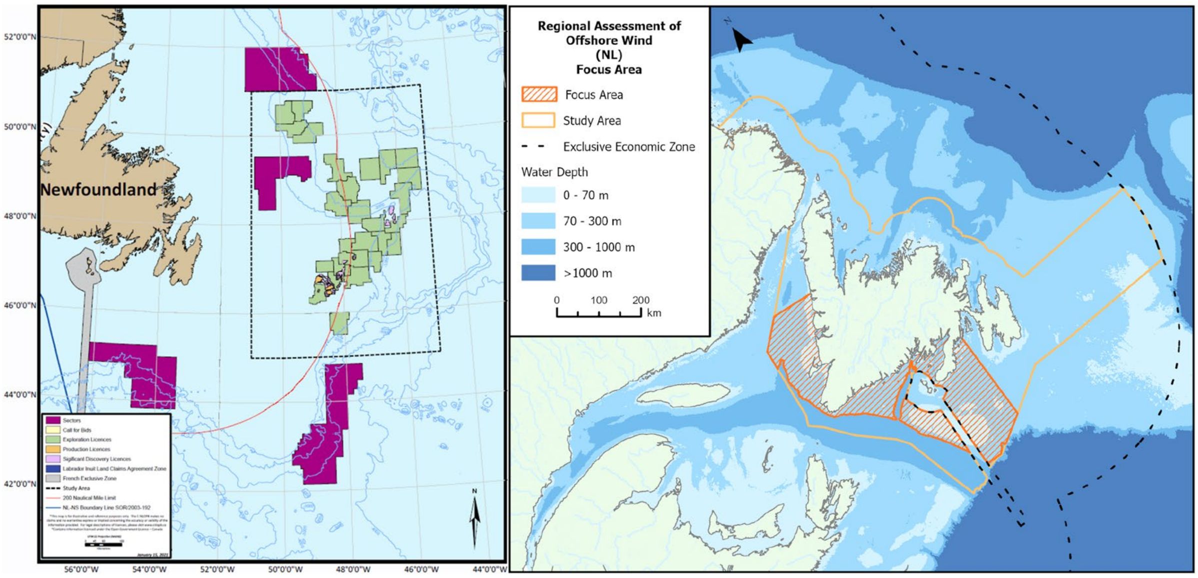

Figure 1. C-CORE (2022a) ERF study area (left, dotted line) and Regional Assessment of Offshore Wind Development in NL (2025) study and focus areas (right)

ICEBERG RISK ANALYSIS

Methodologies and data used to support the offshore oil industry in the region are available and applicable to offshore wind turbines. This less conservative, quantitative approach would add a significant area which can be considered for offshore wind licensing. The methodology used to calculate iceberg risk to offshore wind turbines in King et al. (2022) can be used to assess iceberg contact rates for the defined (study) area, as well as areas on the southern Grand Banks previously excluded from consideration. Inputs for the calculation can be obtained from the Insight Metocean database (https://insight.oilconl.com/ReportViz/Index). An example calculation for the annual iceberg contact rate for a surface facility is presented in Section 9.8 of Volume 1 of the accompanying report (C-CORE, 2022b). The annual iceberg contact rate, N, can be estimated as follows:

$$N=\rho(L+W)Vt \quad (1)$$

where ρ is the average iceberg areal density (km^{-2}), L is the mean iceberg waterline length (m), W is the mean projected structure width (m), V is the mean iceberg drift speed (m/s), and t is the number of seconds in a year.

The Insight Metocean database divides offshore Newfoundland and Labrador into 575 "cells", most of which cover a half degree square. The database contains data on a number of parameters such as wind, waves, currents, visibility, icing, sea ice and icebergs. The sample calculation will use Cell 401, which contains Hibernia, Hebron and White Rose . The average annual iceberg areal density is the average density (number per unit area) of icebergs expected based on repeated surveys over an extended period. The average iceberg areal density, ρ, for Cell 401 is 6.55×10^{-5} km^{-2}, see Figure 1. Figure 2 shows mean iceberg drift speeds, V, and gives a value of 0.29 m/s for Cell 401.

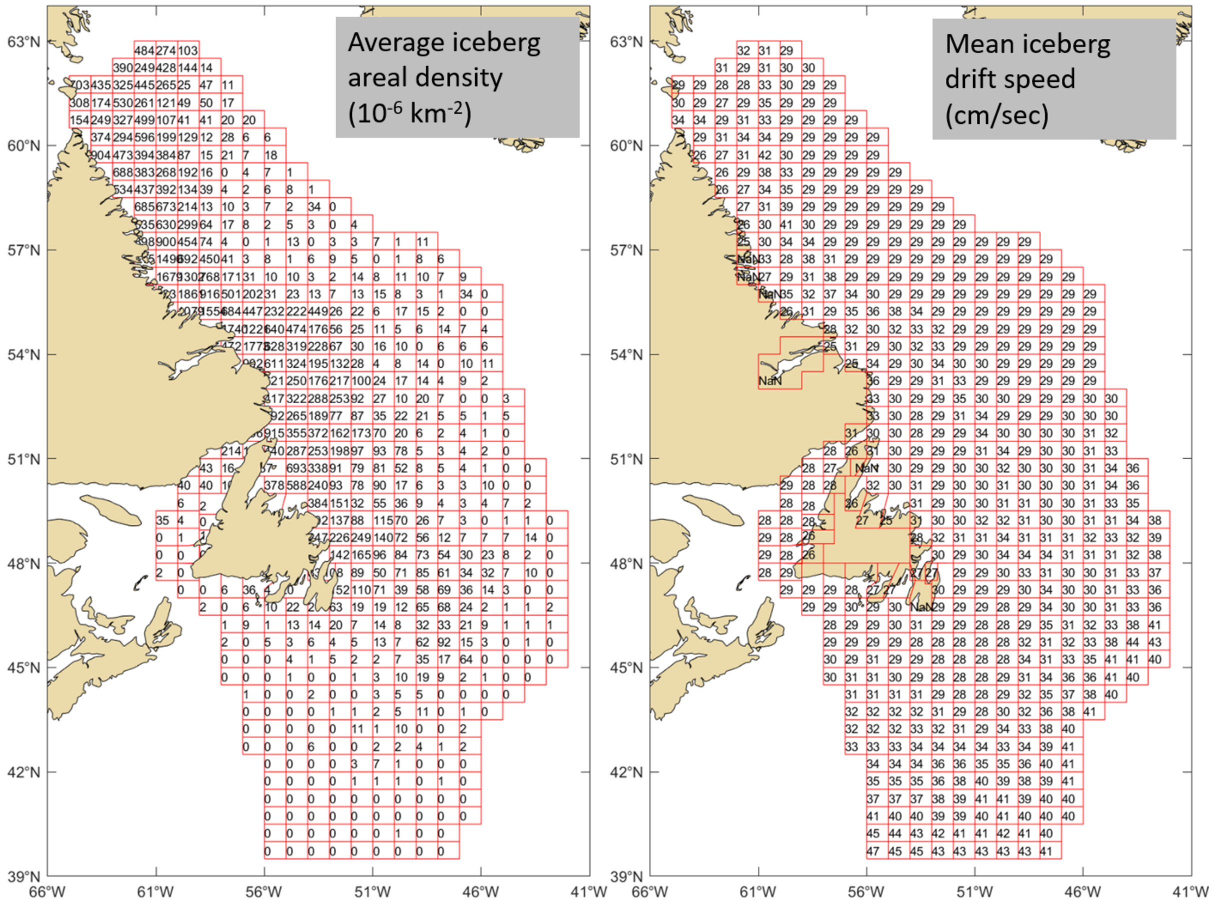

Figure 2. Iceberg frequency (left) and mean drift speed (right), taken from the OilCo Insight Metocean database report (C-CORE, 2022b) and used to calculate iceberg contact rates

As discussed in C-CORE (2022b), waterlines of the iceberg population may be characterized using a negative exponential distribution with a mean of 59 m. However, since icebergs with waterline lengths of less than 16 m are excluded from the areal density values, the mean iceberg waterline length for contact rate calculations must be adjusted accordingly. If a random sample of iceberg waterline lengths with a mean of 59 m is generated (using a negative exponential distribution) and icebergs with waterline lengths less than 16 m are deleted, the mean waterline length of the remaining icebergs is 75 m. An analysis of recent Grand Banks iceberg data indicates a mean waterline length of 50.4 m would be more appropriate (Ralph and King, 2024), but a mean of 59 m will be used here.

The mean projected width of a wind turbine (at the waterline) will vary depending on the design, but can vary from approximately 10 m for bottom-founded monopiles or floating spars, to over 50 to 75 m for barges or semisubmersible floating wind turbines (King et al., 2022). An intermediate value of 40 m will be adopted here for demonstration purposes.

The number of seconds in a year, *t*, is 365.25×24×60×60 = 3.156×10^{7} s/year. The annual iceberg contact rate can then be calculated as follows:

$$N = 6.55\times10^{-5}\ km^{-2} \times (75m + 40m) \times 0.29\ m/s \times 3.156\times10^{7} s/yr \times 10^{-6}\ km^2/m^2 = 0.069\ yr^{-1}$$

The mean return period for iceberg contacts is the inverse of this value, which is 15 years. Figure 3 shows calculated iceberg contact rates going up to 54°N.

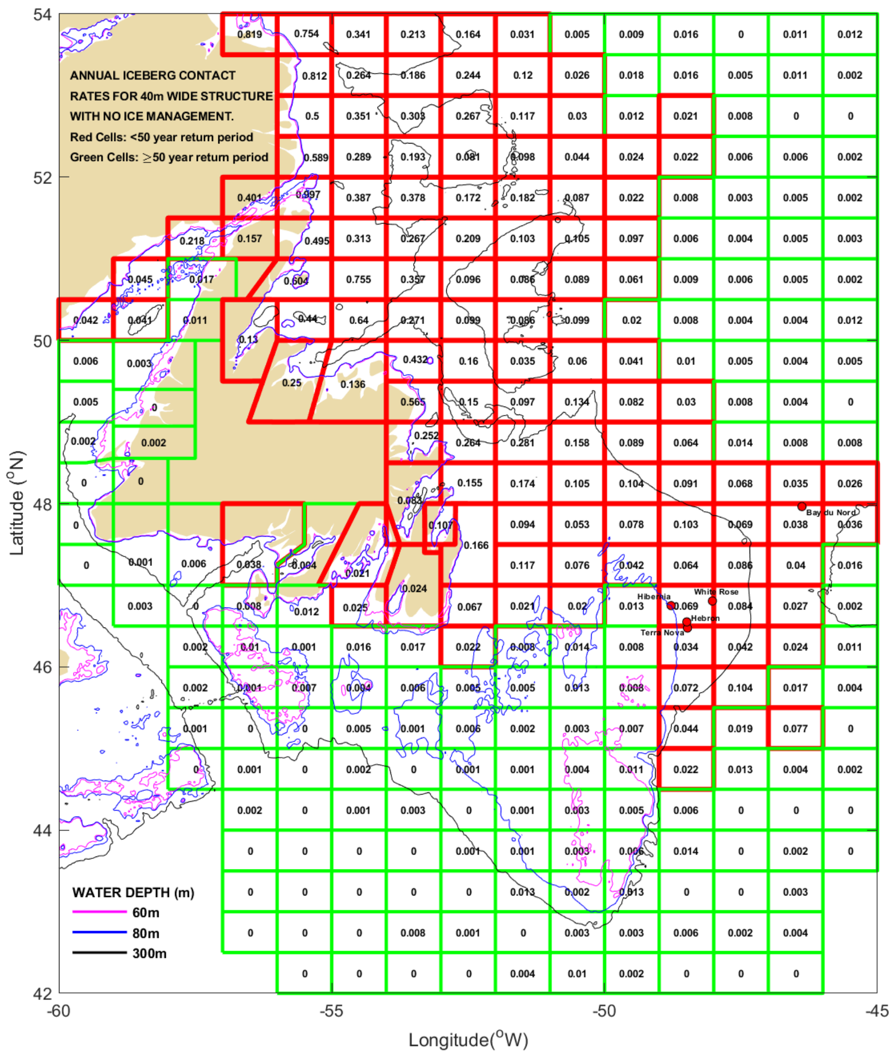

Figure 3. Annual iceberg contact rate for 40 m wide structure (no ice management)

Figure 3 does not include the effect of physical ice management, which has been successfully used for decades on the Grand Banks to reduce iceberg risk for oil exploration and production facilities, and is equally applicable to offshore wind turbines. C-CORE (2022a) used an ice management success rate of 80%. This success rate is based on an analysis that uses the assumption that 16 hours is available for conducting ice management operations. It is highly likely that the available time for ice management operations would be far greater, given iceberg detection capabilities in the region using satellite data and aerial reconnaissance. The actual ice management success rate would be higher, therefore 80% is a conservative estimate of the success rate. Ice management could be accomplished using service vessels doubling as ice management vessels, or dedicated ice management vessels. The effect of ice management on the iceberg contact rate for the previous example may be calculated as follows:

$$N_{managed}=N(1-P_{success}) \qquad (2)$$

$$N_{managed} = 0.069\ yr^{-1} \times (1-0.80) = 0.014\ yr^{-1}$$

corresponding to a return period of 72 years. Almost all of the Grand Banks satisfies a 50-year reliability target (annual contact rate of 0.02 yr^{-1}) with ice management, which is the norm in the offshore wind industry (Figure 4).

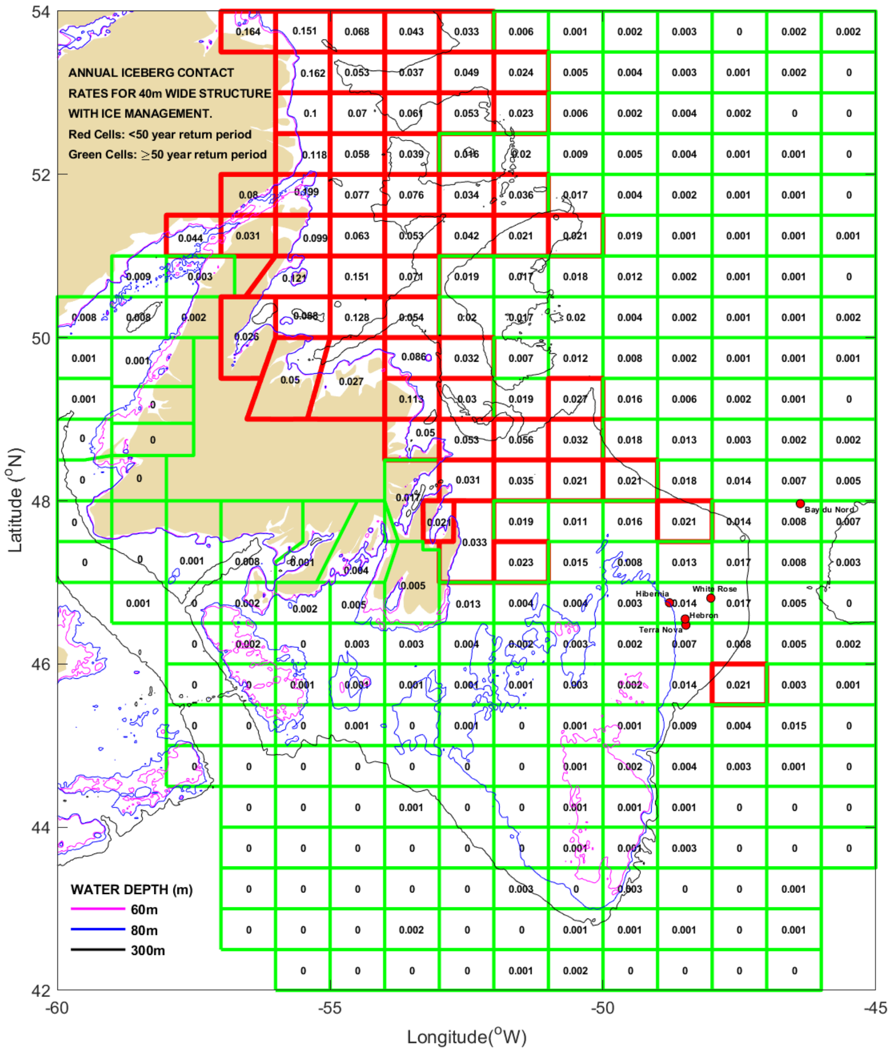

Figure 4. Annual iceberg contact rate for 40 m wide structure (with ice management)

Thus far only iceberg contact rates have been considered. The actual failure rate of turbines due to iceberg contact must consider both the distribution of iceberg impact loads and the capacity of the wind turbines to resist these loads. Given that an offshore wind turbine must be designed and constructed to withstand other environmental loads such as winds and waves, offshore wind turbines should be able to withstand a portion of iceberg impacts. Quantifying this further would require a more in-depth analysis. A risk analysis based solely on iceberg contact rates (with no capacity to withstand impact and no ice management), is very conservative.

CONSTRAINTS ANALYSIS

The constraints analysis used in The Regional Assessment of Offshore Wind Development in Newfoundland and Labrador (McDonald et al., 2025) reduced the initial Study Area to the Focus Area using the previously discussed iceberg criterion and a maximum water depth of 300 m. The constraints analysis process was then applied to the Focus Area using a variety of criteria, including a 10 km coastal buffer, marine critical habitats, marine protected areas, marine traffic routes, national marine conservation areas, viewscapes for national parks and world heritage sites, coastal community uses and high-density fishing areas. The resulting preliminary offshore wind licensing areas satisfying the constraints analysis are shown in Figure 5, broken down into various water depth ranges. Table 1 summarizes the total number of sites for each water depth range indicated in Figure 5 and the total area satisfying the constraints analysis. In the Regional Analysis, water depths less than 60 m are considered suitable for fixed bottom turbines and water depths greater than 80 m are considered suitable for floating turbines Water depths from 60-80 m considered suitable for fixed bottom turbines in the foreseeable future (i.e. Buljan, 2024).

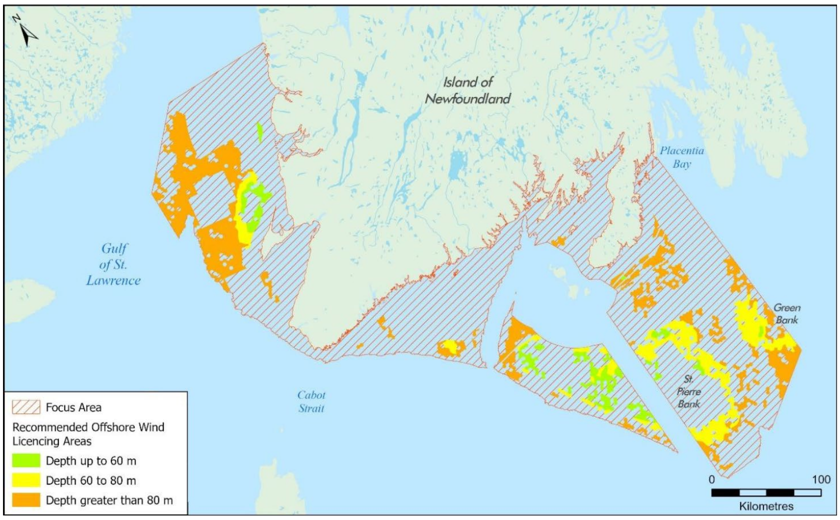

Figure 5. Offshore wind licencing areas resulting from constraints analysis (McDonald et al., 2025)

Table 1. Wind licensing areas, by water depth, number of sites and area (McDonald et al., 2025)

Water Depth Range (m)	No. of Sites	Total Area (km^2)
≤ 60	24	1,994
60 - 80	19	4,942
80 - 300	66	10,060

Figure 6 shows the results obtained by applying the constraints analysis to the previously excluded Grand Banks region. Results are superimposed on a figure showing commercial fishing activity, taken from "The Canada Marine Planning Atlas – Atlantic" (egisp.dfo-mpo.gc.ca/apps/atlantic-atlas-atlantique/?locale=en). Water depth contours for 60, 80 and 300 m are shown, along with a red line showing the boundary between the region to the north where mean iceberg contact return period is less than 50 years and the region to the south where the return period exceeds 50 years. Ice management is (conservatively) not included. Also taken from the Marine Planning Atlas are ecologically sensitive areas (blue) and areas with high vessel traffic (magenta). Other factors considered in Regional Assessment (coastal buffer, conservation areas, world park and heritage sites, and community-based coastal resources) are restricted to sites closer to shore and are not applicable to the Grand Banks sites identified here, and therefore have been omitted for clarity from Figure 6. Six sites with minimal fishing activity in the 60-80 m water depth range are shown. The areas for each site are listed in Table 2. A total of 35,100 km^2 are shown in Figure 6, spread over just 6 sites. The Whale Bank (Site 1) is less than 100 km from the southern tip of the Avalon Peninsula.

Figure 7 shows data on offshore wind farm size (area and power) off the Atlantic coast of the United States. Using this as a basis, the total power generating potential for the sites shown in Figure 6 is 96.5 GW. For comparison, the Churchill Falls and Muskrat Falls hydroelectric developments in Labrador generate 5.5 GW and 0.8 GW, respectively.

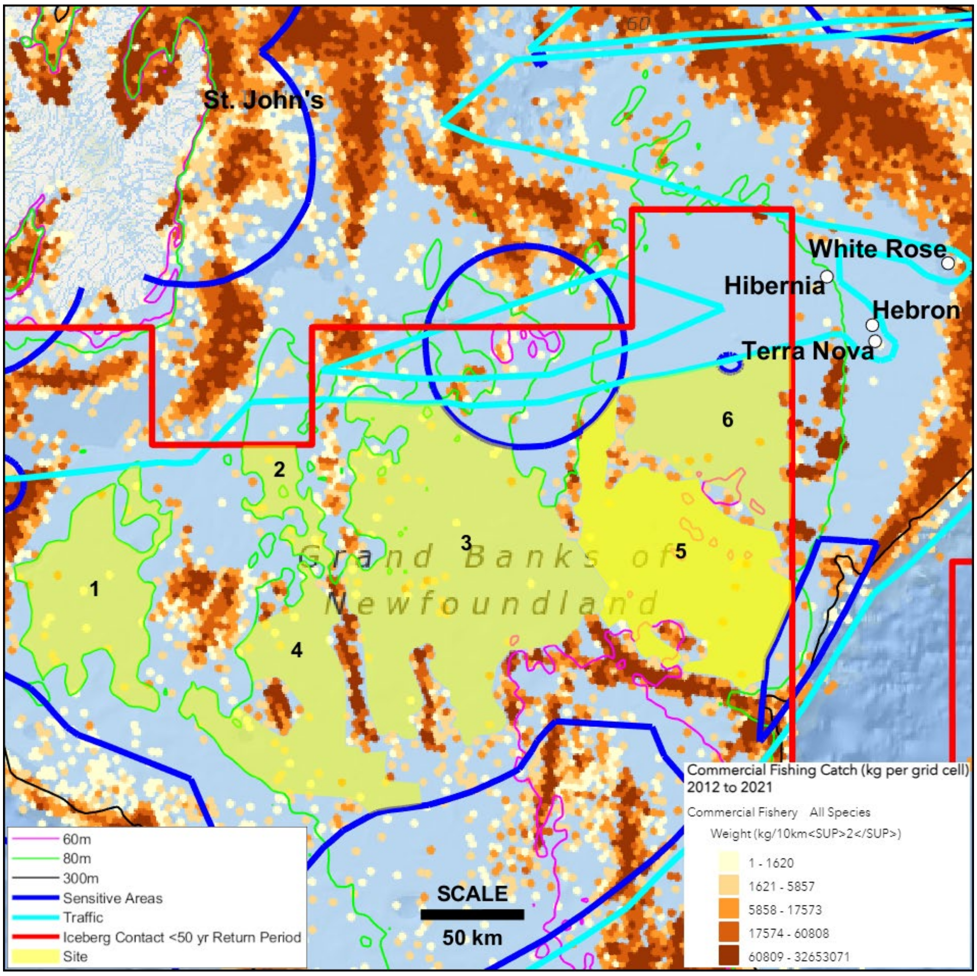

Figure 6. Sites (yellow) on Grand Banks with 60-80 m water depth identified after applying constraints analysis

Table 2. Areas for Sites

Site #	Area (km^2)
1	4,500
2	1,100
3	12,700
4	5,000
5	7,400
6	4,400
Total	35,100

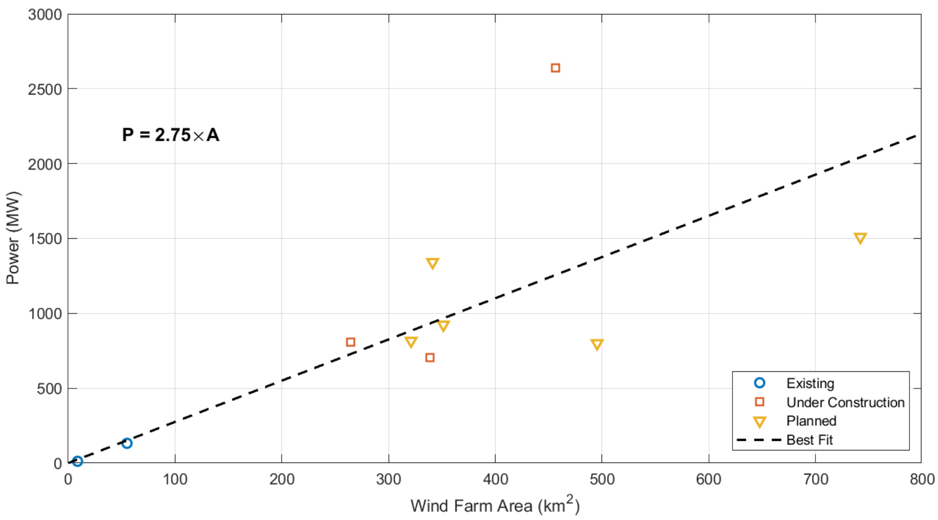

Figure 7. Areas and power production for wind farms offshore the U.S. Atlantic coast (from en.wikipedia.org/wiki/List_of_offshore_wind_farms_in_the_United_States)

WIND TURBINE TECHNOLOGY

Development of the sites shown in Figure 6 will require a cost-effective solution suited to the 60-80 m water depth range. As previously noted, the maximum water depth for conventional fixed-bottom wind turbines is around 60 m. Floating wind turbines (i.e., TLPs) can be deployed in this water depth range, but are a more expensive solution. Likewise, a deep-water jacket is well-established technology but also has the disadvantage of higher cost. As noted in The Regional Assessment of Offshore Wind Development in Newfoundland and Labrador (McDonald et al., 2025), newer, more cost- effective technologies will be required to exploit this water depth range, with the Fully Restrained Platform (FRP) monopile, being cited as an example (Buljan, 2024). The FRP monopile is shown in Figure 8.

Figure 8. Fully Restrained Platform (FRP) monopile (www.entrionwind.com/)

The FRP monopile is stabilized for use in deeper water by using mooring lines and pile anchors. In 2023 the DNV awarded Entrion Wind with a Statement of Feasibility for the FRP monopile (Memija, 2023), and in 2024 received a US patent for the concept (Buljan, 2024). The FRP monopile can be used in water depths up to 100 m. An advantage of this system is that the 10 m diameter monopile is a standard component fabricated for applications in the Gulf of Mexico, which reduces cost and simplifies construction. Preparations are currently underway for a demonstration program off the coast of France.

The installation of an FRP monopile on the Grand Banks will require sufficient sediment thicknesses to achieve required penetration depths (on the order of 30 m). While useful borehole data in the zones previously identified could not be obtained for inclusion here, some indications of overburden thickness can be inferred from an analysis of seismic reflection profiles collected by the Geological Survey of Canada – Atlantic (King, 2014), shown in Figure 9. While areas show in green (25-50 m) or blue (50-120) are limited, it should be noted that the thickness range in the Jeanne d'Arc Basin (the cluster of seismic survey tracks to the northeast, where Hibernia, Hebron, Terra Nova and White Rose are located) is given as 0-3 m. Yet, several excavated drill centres with depths on the order of 10 m have been constructed there, and mooring piles with penetration depths exceeding this depth have been installed in this area. Hence it is reasonable to conclude that the installation of FRP monopiles in the identified zones should be possible. In-situ measurements (i.e., boreholes) are recommended for confirmation.

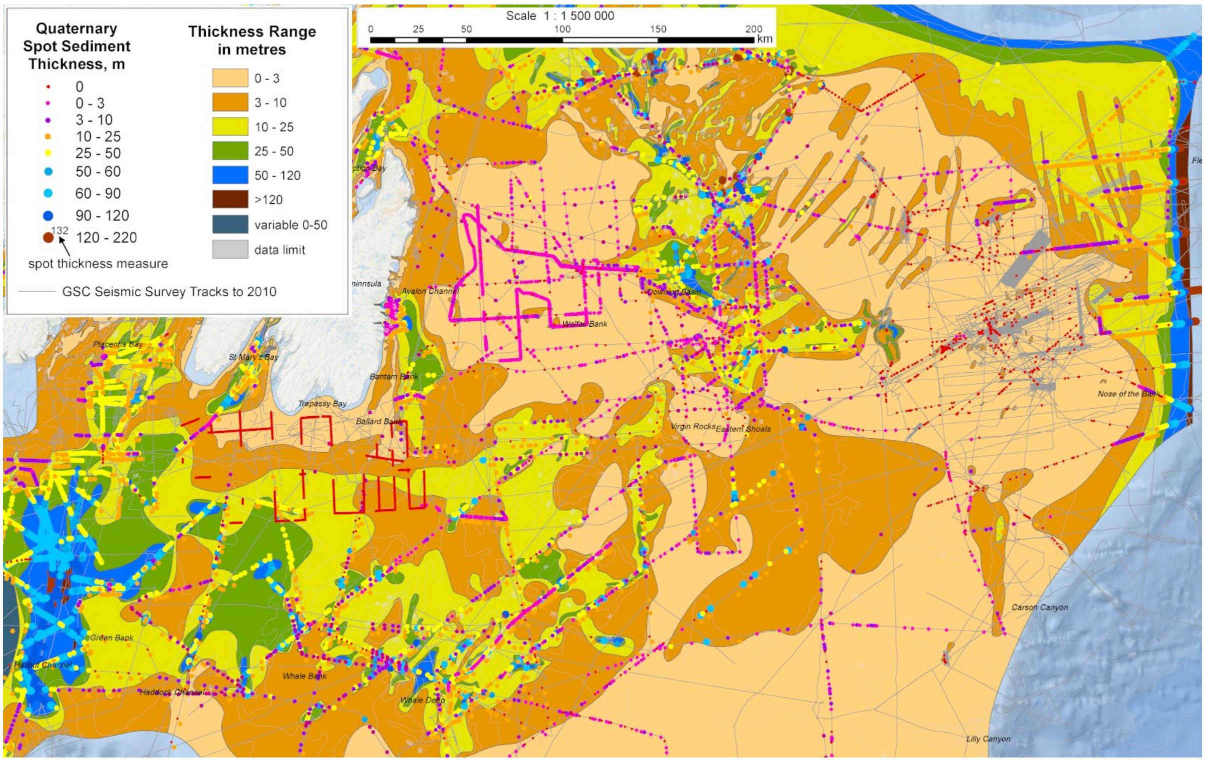

Figure 9. Grand Banks unconsolidated Quaternary sediment thickness (from King, 2014)

CONCLUSIONS

The analysis presented here shows a substantial area (>35,000 km^2) on the Grand Banks that can potentially be developed using fixed-bottom wind turbines. This area represents power generating potential on the order of 100 GW. The identified areas lie primarily in the 60-80 m water depth range, which requires an innovative structure for economic development. The FRP Monopile is presented here as a potential candidate.

The area identified on the Grand Banks for the 60 to 80 m water depth range is double that identified in the Regional Analysis for water depths up to 300 m, and five times the area identified water depths less than 80 m. The identified area on Grand Banks that could be developed would be increased by considering a 100 m maximum water depth (reflecting the maximum water depth for use of the FRP Monopile), doing a more in-depth analysis of the GIS data, and including ice management in the iceberg risk analysis.

Should a reliability target greater than the 50-year return period used here be desired, a more rigorous iceberg risk analysis could be conducted considering ice management, the distribution of potential loads generated during iceberg impacts and the load capacity of the FRP monopile. The potential consequences of direct contact of iceberg keels with supporting cables should also be considered. A subsea iceberg risk analysis could be conducted for power cables connecting the individual turbines to substations, then transmitting the power to shore. Consideration could also be given to a central hub located on the Grand Banks where generated power could be used to manufacture hydrogen or ammonia for export. Generated power may also be used to provide power to oil production facilities in the Jeanne d'Arc and the Grand Banks region. Wind turbines in the vicinity of oil production platforms would benefit from ice management operations conducted on behalf of the operators, and marine traffic would also be monitored and controlled, significantly reducing risk.

It is worth noting that sea ice conditions in the southern Grand Banks are much less severe than much of the Gulf of St. Lawrence. Also, it is expected that the number of icebergs on the Grand Banks will decrease as a result of climate change (King and Turnbull, 2022).

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