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Navigating the Arctic

A Call for Better Charting of Canada's Arctic Waters

David H. Gray

Other maps are such shapes, with their islands and capes!
But we've got our brave Captain to thank:
(So the crew would protest) "that he's bought us the best -
A perfect and absolute blank!

- The Hunting of the Snark (An Agony in 8 Fits), by Lewis Carroll

The Arctic is strewn with islands, shallow channels, and capes and makes up one of the most complex coastlines in the world. As shipping grows in the region the country is increasingly being forced to recognize that this complexity creates danger. Indeed, there are many places where the seafloor beneath these channels is terra incognita – there are no soundings and the chart is a blank. In many other locations, Canadian charts have soundings taken during a ship transit (often referred to as "track soundings"); a useful addition but limited in scope. To make matters worse, there are many places in the Arctic where islands and capes are not in their real-world position, but several kilometres away from where they ought to be charted. This is not because of an error in the actual observations but in the accuracy of the exploratory astronomic positioning method being used. This was the case even as late as 1955, when SHORAN[1] became available to connect just over 50 survey points in the Canadian Arctic (being 200 km or more apart) to the geodetic survey network in southern Canada. For instance, Sable Island in Nova Scotia has not moved, although the astronomic positions determined over 200 years and used to position it on charts, suggested that the island had moved by up to three miles. These variations can be expected from exploratory astronomic position determinations and in the Arctic Canada have been slower in being incorporated.[2]

These inaccuracies are naturally worse than a lack of information. A blank chart leads to caution while an inaccurate one to false confidence. As Doug Gray wrote in his book on Canada's early twentieth century Arctic workhorse, *R.M.S. Nascopie:* "It has been said that an inaccurate chart is worse than no chart at all. With no chart, you don't know where the good water is so you proceed with caution. With an inaccurate chart, you go where the good water is supposed to be and find out too late that it isn't."[3]

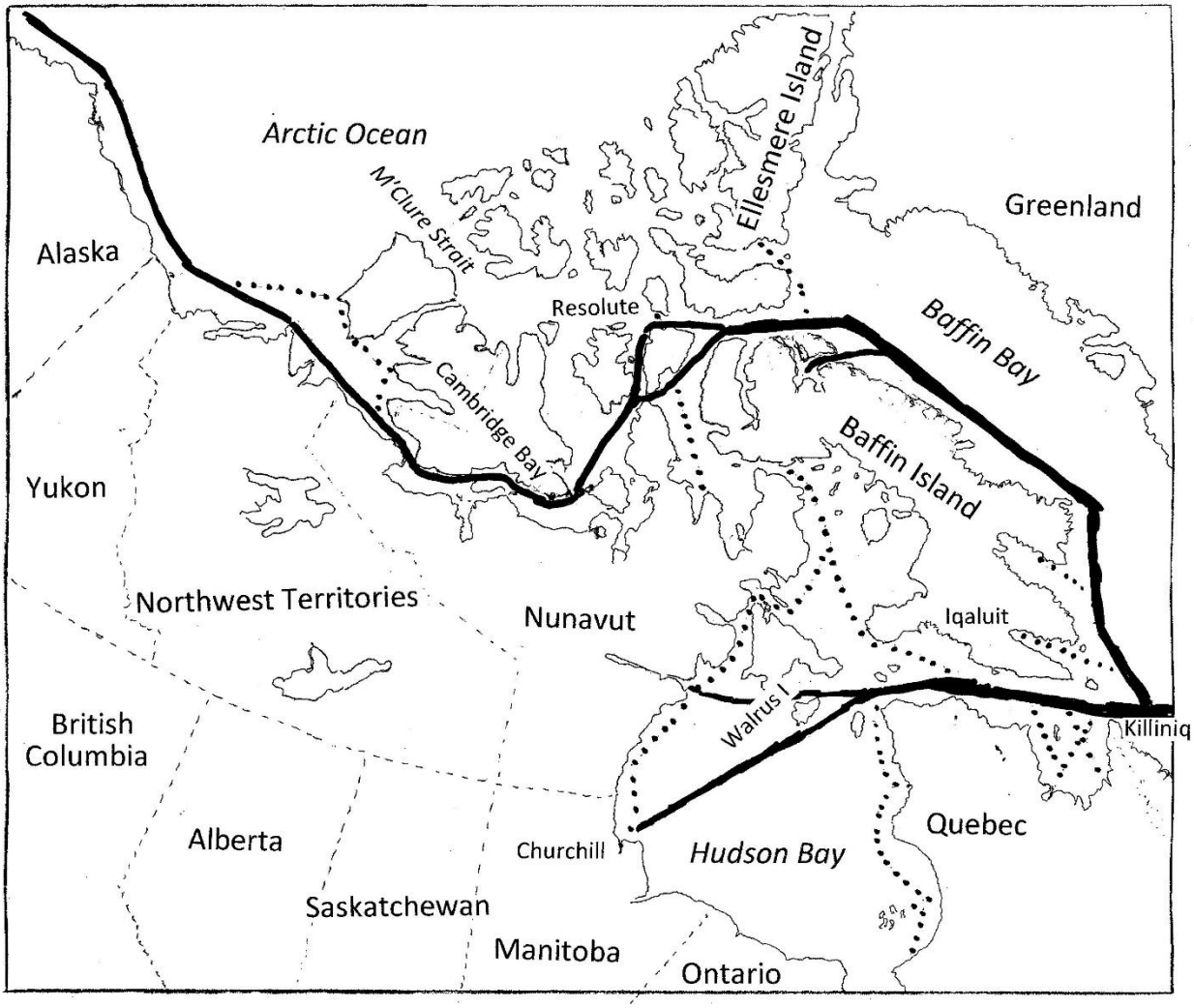

Figure 1: The Canadian Coast Guard identified Arctic shipping corridors based on existing patterns.[4] Primary corridors marked by solid heavy black lines and secondary corridors marked by dotted black lines. Route north of Alaska is as known by the author. Base map may not be totally accurate because it is a rough tracing of a National Geographic Society map of North America. More professional maps are available in the Auditor General's 2014 Report on Marine Navigation in the Canadian Arctic[5] and in Canadian Geographic.[6]

Compounding this danger is the fact that melting sea ice has been tempting ships off better charted sea routes. Figure 1 shows the Canadian Coast Guard's opinion of the primary and secondary routes through the Northwest Passage, however, less well used routes through Prince of Wales Strait (used by *Manhattan* in 1969), through M'Clure Strait and along the west coast of Banks Island (attempted by *Manhattan*, but now more likely to be open due to receding polar ice) are somewhat usable.

Despite efforts to improve the situation, navigation remains dangerous. As late as 2025, Canadian Notices to Mariners acknowledge that only 15% of the waters in the Canadian Arctic (without defining the area) are surveyed to modern standards.[7] The Canadian Hydrographic Service states that 45% of the key navigational routes are adequately surveyed, including the primary and secondary northern low-impact shipping corridors.[8] Critically, the word "key" suggests only the

important ones, “adequately” suggests that the surveys do not meet modern standards, and “low-impact” suggests only the easy to travel routes.

Despite this, the Canadian Coast Guard and other users navigate those waters regularly, albeit cautiously. While the Coast Guard has had few incidents, commercial ships have seen real danger. This becomes even more critical given the rapidly increasing overall use of the passages by resupply, fishing, and cargo ships. Figure 2 shows the transits of ships entering Canadian Arctic waters to deliver goods, harvest resources, or simply visit the area. One may note the great fluctuation in numbers in recent years. This can be explained by the difficult ice conditions in 2018, 2020 and 2021 and COVID reducing the number of adventure seeking travellers. Despite this variability, the upwards pattern is clear.

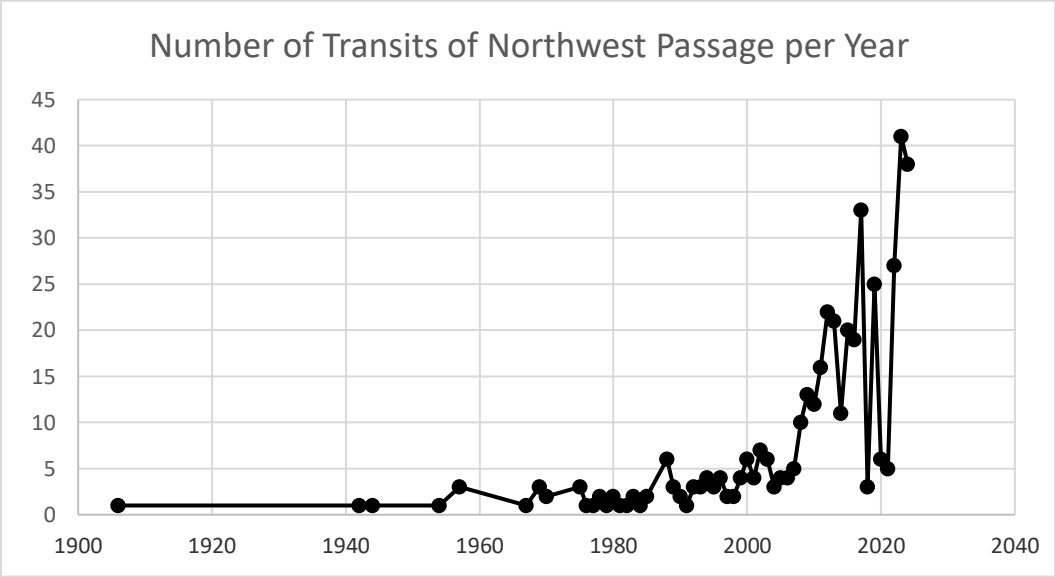

Figure 2: Graph showing the number of ships transiting the Northwest Passage by Year. Source: https://thenorthwestpassage.info/transit-statistics/transits-summary-list (Accessed 20 December, 2025)

As this traffic grows risks are amplified as even a small chance of grounding or accident grows in parallel. Indeed, even experienced mariners and government vessels have seen the consequences. To provide just one example of the risks of operating in the kind of soundings void mentioned earlier, this author points to a 1997 voyage of CCGS icebreaker *Pierre Radisson*. The author was aboard the ship as it approached Port Burwell and the abandoned village of Killiniq, Nunavut, at the northern tip of the Quebec/Labrador peninsula. The Canadian Coast Guard goes there twice each navigation season to turn on and then off a radio repeating station. On this voyage, Captain Bourdeau of the *Pierre Radisson* expressed concern about entering Port Burwell. The conditions that night were far from ideal; it was nighttime, very foggy, and there was shore-fast ice against the steep-to shore so that ship’s officers did not know whether the radar response was from the edge of the ice or from the actual shore. Canadian Hydrographic Service (CHS) chart 5405 (now cancelled and replaced) showed a single line of soundings leading into the harbour, which indicated that the bottom was quite irregular. Yet, off that track-line was a “not examined” pinnacle rock which made him wonder if there were other shoals which could damage his ship. In the past,

the captain had attempted to follow that single line of soundings as closely as possible but that night the ship's officers only had radar as their position fixing tool. On several previous occasions, the captain had the sounder go to zero depth and at least once he had to put the engines into full reverse in fear of an imminent grounding. This phenomenon is due to the strong tidal current generated by the different tidal heights between the Atlantic and Ungava Bay, which flows through McLelan Strait into Forbes Sound – and acts like a fire-hose churning the water of the approaches to Forbes Sound.

The *Pierre Radisson* benefitted from being equipped with a Global Positioning System (GPS) and electronic display for nautical charts (chart 5405 was still available only in a paper version). GPS positioning was not useable on the paper chart, because GPS positions were 44 seconds of longitude (664 metres) different from the associated charted positions, which were based on the astronomic position determination of a single survey point. This discrepancy represented about five centimetres at chart scale. Because there was a need to plot the ship's position in quick succession, the officer doing the plotting could not use the GPS data; he needed directly plottable information. Despite the uncertainty, the ship entered the outer harbour, known as Forbes Sound, and anchored. When morning came and the fog lifted, however, it was discovered to be far too close to shore. Immediately, the captain ordered the weighing of the anchor and moved to a more central part in Forbes Sound. This was an experienced captain and crew aboard an icebreaker. It is easy to imagine a catastrophe if a civilian vessel on a schedule attempted to push beyond its capabilities.

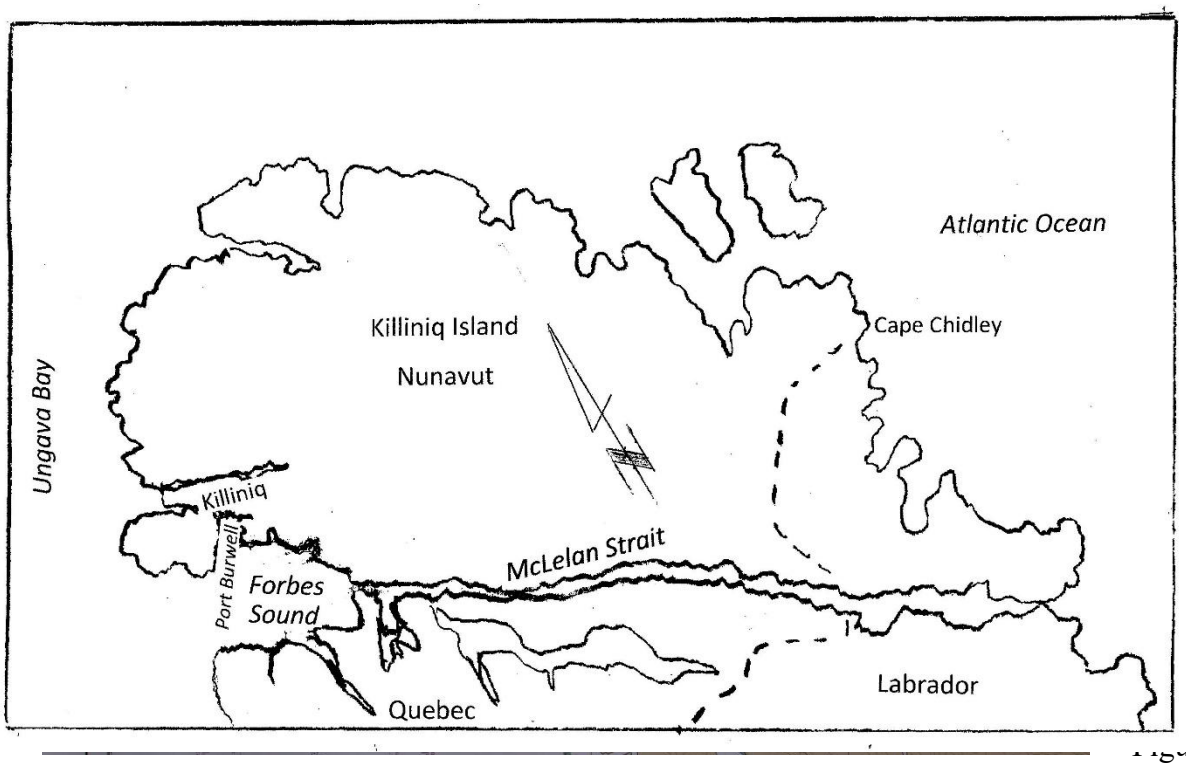

Figure 3a: Sketch map showing features named in this paper.

Figure 3b: View looking north into Port Burwell. The harbour is about 600 metres wide (point on left to point on right side of photo). The abandoned village of Killiniq is behind the rocky hill that is just left of centre. Photo: David Gray, early August 1997.

During this author's time on board *Pierre Radisson* there were four transits into or out of the harbour. During these trips, the ship recorded soundings – which had to be corrected for the ship's draft and the predicted tides – and their positions corrected for differences between chart and GPS latitudes and longitudes. The author also discovered that the predicted tides were about one hour out of synch with reality, requiring a revised tidal reduction since the height of tides in Port Burwell can change by six metres in six hours. The resulting track soundings were added in pencil on the ship's chart. Given the quality of the positioning and of the soundings, these additions were never incorporated as an official chart correction, but remained "pencilled in" on the ship's chart as an indication that there were probably no hazards along the published track-line of soundings. The single line of track soundings leading into the harbour remains on the new chart (CHS 5064), even though CHS has done hydrographic surveys in nearby areas circa 2000.

This *ad hoc* approach is a common feature. This author remembers seeing other charts on the bridge of the *Pierre Radisson* with pencilled-in soundings in otherwise blank areas of some charts. These were obviously to show ship's officers that the ship had been there before and had found "safe" passage. Any prudent captain would have navigated his ship cautiously in those unsurveyed areas.

The reason for this dearth of systematic surveying is easy to understand. Hydrographic surveying is a laborious, methodical process of determining safe conditions for navigation. It includes

mapping depth, minimum height clearance, adverse current possibilities, the locations of visible targets, and navigation aids). Chart limits, scale, and probable size of ships using the chart are all taken into consideration in specifications for the survey. This is an exceptional amount of work and, like all activities in the Arctic, is very expensive.

The nature of charting has also changed dramatically. Before the First World War, most ships entering the Arctic were wooden hulled and had a draft of less than six metres. In the inter-war period, some ships were steel-hulled but had the same draft. In 1954, HMCS *Labrador*, an icebreaker which drew roughly nine metres, was the first deep-draft ship to transit the Northwest Passage. More recently, deeper draft commercial ships, starting with ships like SS *Manhattan* in 1969 and more recently the *Thamesborg*, are frequenting Canadian Arctic waters each season. Given ships this size, it is clear that the charting standards of 50 years ago are no longer acceptable. Areas passable to the *Labrador* may not be suitable for large cruise ships.

This shift was symbolized (though not sustained) in 1969 as the *Manhattan*, an ice-strengthened tanker with a draft of 15.6 metres proceeded through the Northwest Passage to Prudhoe Bay, Alaska. This voyage was to demonstrate that a large tanker could transit the Northwest Passage without coming within three nautical miles of Canada's shoreline and without icebreaker assistance. The trip was a success, in that it arrived in Alaska, though failed to get through M'Clure Strait (even with Canadian icebreaker assistance) and had to go south through Prince of Wales Strait to Amundsen Gulf. While crossing the Beaufort Sea, it and CCGS *John A. MacDonald*, the Canadian icebreaker accompanying the *Manhattan*, went over a pingo-like feature on an otherwise flat sea-floor. This mound of earth and ice, the first such sub-sea feature found anywhere, was almost high enough for a grounding.[9] In later, intense, surveys by CHS, at least 1,000 pingo-like features were found and several of them would have been truly navigational hazards to the *Manhattan* – and these in a 18.5 km wide by 310 km long corridor!

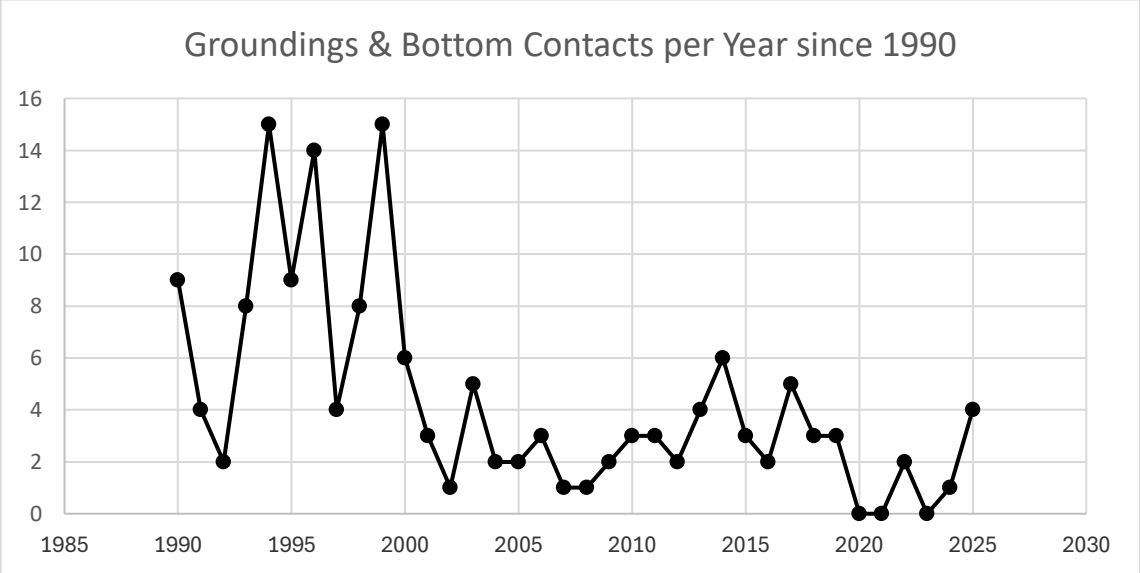

Figure 4: Graph showing the number of groundings and ships contacting the bottom per year in all Canadian coastal waters. Source: Transportation Safety Board website.

As Figure 4 shows, these groundings, while rare, are not so rare as to be unexpected. In total there have been 146 cases[10] of either a grounding (ship needing assistance to get free or being wrecked) or contacting the bottom (ship managing to free itself with little damage) in all Canadian coastal waters available on the Transportation Safety Board [of Canada] website[11] for the years between 1991 and 2025 (inclusive) and shown in Figure 4. Of these, there are only eight that happened in Canadian Arctic waters.[12] While this number seems low, it is very high as a percentage of the transits taking place in the region.

These incidents were also all groundings as opposed to bottom contacts. They include *Hanseatic* (1994), *Clipper Adventurer* (2010), *Nanny* (2012), *Nanny* (2014), *Akademik Ioffe* (2018), *Kivalliq W* (2022), *Rosaire A. Desgagnes* (2025), and *Thamesborg* (2025). The rapid increase in the frequency of the groundings demonstrated by these eight cases is a direct function of increasing volume of traffic. Of the remaining 138 incidents reported – again in all Canadian coastal waters – 36 of them were "bottom contacts" suggesting only minor damage to the ships. Of the same 138 incidents, about half of them occurred in areas where the ship was in a dredged channel or harbour. The reader should note the distinct drop in the numbers per year in Figure 4 after 2000; that is because the CHS acquired the *F.C.G. Smith* and *Frederick G. Creed*, two ships specifically designed for precision surveys in dredged areas. It is a well-known fact that moving water is the strongest agent in erosion and in accretion; therefore, dredged areas need continual re-dredging to maintain the advertised depths. It is for that reason that dredged areas on charts are marked with the year of post-dredging survey as well as the advertised minimum depth. Furthermore, ships often operate with less under keel clearance than was previously the case, in part because hydrographic survey techniques now have total bottom coverage, as opposed to simple cross-section lines of soundings. There is also a further caveat on the data in Figure 4; not all of these groundings and bottom contacts were the fault of the nautical chart, more than half of them were identified by Transportation Safety Board[13] reports as, or suspected to be, "operator error," including the consequences of machinery failure.

Going back to the quotation about inaccurate charts, this author can remember being on board *Pierre Radisson*'s helicopter as it took a technician to Walrus Island (63° 16.5′N, 83° 41′W) between Southampton and Coats Islands, so that he could do the annual maintenance on the light station. The pilot had toggled the charted geographic position of the light into the GPS receiver for navigation purposes, even though there was good visibility. Once we got to that position, the island was still three miles ahead of us. A cartographer cannot just move the island on the chart because there are soundings close to and farther away from the island that were positioned relative to the island. But, which soundings are affected and which ones are not? Faced with that dilemma, the cartographer must leave the chart the way it is until there is a full and proper hydrographic survey done.

If mariners are using the same means of navigation as was used to determine the position of soundings (in early days, this would be by direct terrestrial reference to the nearest land), the dated track sounding lines may still be of use. However, the admirable precision of GPS means nothing if the available track sounding lines are not plotted in the same geographical frame of reference. For this reason, most modern charts are consistent with, or replotted to, the World Geodetic System 1984 (WGS84) (frame of reference) or equivalent, which is compatible with GPS. This is particularly important if the GPS position is being displayed in real time on a computer screen

with the chart as background. The conversion of all CHS charts to be consistent with GPS latitudes and longitudes started in 1986 and is now well advanced, but not complete.[14]

Harmonizing these systems entails real time and effort. The Canadian Hydrographic Service used to send hydrographers onboard icebreakers equipped with a survey launch, sounder, and positioning equipment, with instructions to carry out hydrographic surveys at specified locations and wherever there were other opportunities. Unfortunately, this practice has decreased significantly. CHS now has few opportunities to do this work, mostly because the ships employed often have so many duties while in the Arctic that they cannot spare the time. Meanwhile, hiring a chartered vessel or arranging for the dedicated use of a Coast Guard ship are far too expensive for CHS's limited budget.

Besides doing thorough hydrographic surveys and the already mentioned surveys of opportunity, CHS has explored the water depths above the geological continental shelf in the Arctic Ocean by spot soundings through the ice at one kilometre spacing using a helicopter for transport and a remotely controlled submersible under the ice. CHS has also surveyed shallower depth areas by spot soundings at closer spacing using a tracked vehicle on the ice, autonomous unmanned survey launches, a sounder being towed by a low-flying helicopter over open water (which is very dangerous). It has also tried innovative approaches such as crowd-sourcing a survey by providing equipment and instructions to locals, contracting out to private companies and using laser interferometry from an aircraft. The last technique gives depths in "shallow" waters (less than 30 m.±) but not in deeper waters when there is no reception of the reflected laser light off the seafloor. That depth threshold is a function of water clarity and sea floor characteristics. As mentioned earlier, to find the pingo-like features CHS carried out a very close sounding-line spacing of an 18.5 km wide by 310 km long corridor in the Beaufort Sea using survey launches from both *Baffin* and *Hudson* working 16 hours per day, seven 7 days per week during three field seasons.

Timing for this work is also extremely tricky. In southern waters, the field season is typically about six months (May to October) with easy access to fuel, accommodation and food. In the Arctic the field season is about two months (mid-July to mid-September) with all provisions and spare parts for all contingencies having to come by ship at the start of the season. There is another window of opportunity in March to do surveys from the ice surface, but again the logistics of fuel, accommodation, provisions, and spare parts is demanding. This makes surveying in the Arctic very expensive and slow.

This expense is unfavourably viewed by government mandarins when determining priorities. Specifically, the number of ships in Canadian Arctic waters per year is probably in the low hundreds, whereas there are thousands of ships heading to and from ports such as Vancouver (Canada's busiest port), Halifax, the ports along the St. Lawrence River and Seaway, and in the Great Lakes. Given that some of these southern waters need dredging periodically, and critical sections are surveyed annually, one can appreciate why the CHS has spent its money in the South in those waters most heavily used and most important for Canada's economic well-being. The Canadian Arctic waters are thus relegated to "Cinderella" status for hydrographic surveying and charting.

This status may be changing however. With cruise ships exploring the Canadian Arctic, there have been, and will be, accidents where the ship's passengers need evacuation to an airport, (which are

few and far between). Resupply activity is also growing, as is fishing. These activities change the risk profile associated with the nautical charts of the Arctic, and thus hydrographic surveys and charting of the Canadian Arctic waters need to move up in the order of priorities at CHS.

There is also a growing need to deploy naval vessels into the region, with the Royal Canadian Navy (RCN) now in possession of six Arctic and Offshore Patrol Vessels (AOPV). The RCN is also framing its submarine replacement as, in part, a need to defend the Arctic. A submarine's problem is its upper and lower safety clearances. These vessels' precise depth keeping can be difficult and so they keep a large margin of safety below (and above in ice). Submarines operating under sea-ice need forward and upward looking sonar to detect the clearance under the ice, which can have depths of up to 50 metres, and those depths cannot be reliably charted because the ice is always moving. If ever a ship needs good knowledge of the sea bottom, it is a submarine in the Arctic.

Both surface ships (naval and coast guard) and submarines cannot be expected to navigate solely within the standard shipping corridors since they need far greater freedom to operate throughout all the Canadian Arctic waters. From a strategic perspective, therefore, the Canadian Hydrographic Service is doing a disservice to the Coast Guard and Navy by limiting the areas of the Canadian Arctic where their ships can operate. Those two organizations are the ones that the CHS counts on for logistical support in carrying out the CHS mandate of producing charts and nautical publications for the navigable waters of Canada.

Having built the case that more hydrographic surveying and charting is necessary, the setting of priorities needs to be examined. Obviously, the current and projected trade routes are important and have been identified, not only because they need to be brought up to modern standards – beyond just "adequate" – but also because they need to be assessed as to whether they address the environmental, fish habitat, and Inuit livelihood concerns. The other spaces amongst the Arctic Islands are important for transportation to other settlements, search and rescue, illegal drug and immigration interdiction, and for security concerns and must not be forgotten. It is not just a case of shuffling the present resources to address the new priorities but rather a need for the government to commit additional resources to this long-standing, but neglected, priority.

The Auditor General's 2014 Report on *Marine Navigation in the Canadian Arctic* reached the same conclusion; namely, "that many higher-risk areas in the Canadian Arctic are inadequately surveyed and charted, and that capacity for this work is limited. Only a small percentage of the region has modern hydrography coverage. This means that many charts available to mariners may not be current or reliable."[15] Also, the Auditor General found "that large areas of Canadian Arctic waters, including many of the main traffic corridors, have either non-existent or inadequate hydrographic data coverage. The CHS estimates that about one percent of Canadian Arctic waters are surveyed to modern standards."[16] This is perhaps a case of "lying with statistics" on the part of the Auditor General's report in that it might have included large areas that are not frequented by shipping. But a real issue is the fact that modern mariners would prefer to use Electronic Navigation Charts (ENCs) in a computer display system, not charts printed on paper. In the shipping corridors of the Canadian Arctic, there are significant gaps and discontinuities in the ENC coverage. Circa 1975, J.W. Hogarth in *Nautical Magazine* welcomed Rear Admiral D.W. Haslam to his post as the new U.K. hydrographer of the Navy with these words: "Hydrography is a never-

ending battle of too few resources against too many tasks. The situation has been like that since Alexander Dalrymple became the first Hydrographer in 1795. And it will never be any different in the future. Never."[17] Fifty (50) years later, this statement still holds true for Canadian hydrography.

Given these conditions and requirements, how does CHS survey and produce charts of Canadian Arctic waters in a timely fashion? Major projects get done because if they have the finances, staffing, equipment, research and development, and commitment to see them through to completion in a timely manner. This is not there in the Arctic and this must change.

That change may come. The world is changing as geopolitics are shifting and trading relationships and resource exploitation are changing the Arctic landscape. Climate is changing, the extent of Arctic ice is changing, maritime trade routes are changing, and so too are military requirements. If only 15% of Canadian Arctic waters are charted to modern standards, the Canadian government, Department of Fisheries & Oceans, Canadian Hydrographic Service, and any government department or agency wishing to absorb the CHS, needs to realize that these pressures exist and to address them with concrete efforts to accelerate hydrographic surveying in the Canadian Arctic and to produce better nautical charts. This author suggests that the Canadian government adapt the Chinese proverb about planting trees to the present charting inadequacy: "The best time to plant a tree was twenty years ago. The second-best time is now."

David H. Gray worked for 34 years at Canadian Hydrographic Service, Dept. Fisheries and Oceans, providing geodetic, maritime boundary and radio positioning calculations. While at CHS, he computed the Canada-Greenland boundary, the Nova Scotia-Newfoundland & Labrador offshore petroleum resource boundary and was a member of the Canadian Team for the Canada/France maritime boundary arbitration. Since leaving CHS, he was the tribunal's technical expert in four maritime boundary arbitrations at the Permanent Court of Arbitration (in The Hague).

Mr. Gray has been an expert witness in over 25 fisheries violation cases in court: determining a ship's position, assessing its accuracy, and locating that position relative to national boundaries or domestic fishing limits. He also defended CHS's right to copyright its charts.

Mr. Gray has a B.A. Sc. and a M.A.Sc. in survey engineering from the University of Toronto. He is a Professional Engineer in Ontario and a Canada Lands Surveyor and has published 35 peer-reviewed papers in professional magazines on a wide range of surveying topics.

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Notes

[1] SHORAN, an acronym for short range navigation was an airborne line-crossing technique to measure 200 to 500 km lines adapted from a Second World War navigating system for bombing. For more information, see Gray, David H., SHORAN in Canada Revisited, *Geomatica*, Vol. 54, No. 3, 2000 and SHORAN Pot Pourri, in the same issue.
[2] David H. Gray, Bringing Old Mapping of Sable Island into a Modern Geographic Reference Frame, *Nova Scotian Institute of Science*, Vol. 48, Part 2, 2016. Or David H. Gray, Where has Sable Island been for the past 200 years?, *CISM Journal ACSGC*, Vol. 46, No. 3, Autumn 1992, reprinted in *International Hydrographic Review*, Vol. 69, No. 2, Sept. 1992.
[3] Doug Gray, *R.M.S. Nascopie: Ship of the North*, The Golden Dog Press, Ottawa, 1997, p. 18.
[4] Map 2 on page 14 of The Integrated Arctic Corridors Framework (PDF document) available at https://oceansnorth.org/2016/04/27/the-integrated-arctic-corridors-framework/ Accessed 2 January 2026.
[5] https://www.oag-bvg.gc.ca/internet/English/parl_cesd_201410_03_e_39850.html#hd4a Accessed 9 January 2026.
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[8] CHS statement on Arctic charting at https://www.charts.gc.ca/arctic-arctique/index-eng.html Accessed 31 December, 2025.
[9] The incident is described in detail in Fillmore, Stanley & R.W. Sandilands, *The Chartmakers*, NC Press Ltd. 1983. Pp. 192-3.

[10] Size of ships were limited to those larger than fishing vessels.
[11] Marine transportation safety investigations and reports - Transportation Safety Board of Canada (tsb.gc.ca) Accessed 20 December, 2025.
[12] I am defining "Canadian Arctic waters" to be salt water north and west of the north end of Labrador to the Canada-USA border at 141°W, including James Bay and Hudson Bay.
[13] The Transportation Safety Board of Canada is an independent agency that advances transportation safety by investigating occurrences in the air, marine, pipeline and rail modes of transportation. Its mandate is to identify changes so that similar accidents are less likely to occur but does not include determining blame.
[14] David H. Gray, Ten Years of Experience in Converting Canadian Hydrographic Service Charts to a World-based Geodetic System, *International Hydrographic Review*, Vol. 75, No. 1, March 1998.
[15] https://www.oag-bvg.gc.ca/internet/English/parl_cesd_201410_03_e-39850.html#hd3a Paragraph 3.16. Accessed 9 January 2026.
[16] *Ibid*, Paragraph 3.17.
[17] J.W. Hogarth, *Nautical Magazine*, Glasgow, 214, 6, p. 321-2.