Clipper Adventurer Grounding: Background and Geomatics Issues

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1. Abstract

There seems to be a general perception that the increasingly ice-free Arctic waterways are safe for passage, when significant areas have not been adequately surveyed. However, as of 2011, less than 10% of Arctic waters had been surveyed to modern standards.[1] In June 2017, the government Hydrographic Offices of Canada, Denmark, Finland, Iceland, Norway, the Russian Federation and the United States of America publicly reaffirmed the need for caution when using nautical charts of Arctic Waters.[2]

On 27 August 2010, the expedition cruise ship **Clipper Adventurer** went aground at 13.9 knots on a rock shoal whilst travelling in a limited surveyed area of Coronation Gulf, Nunavut. The country of registration (flag) of the vessel was the Bahamas. This paper reviews the background to this grounding, and the geomatics issues related to the grounding.

2. Introduction

The expedition cruise ship **Clipper Adventurer**, length 100.6 metres, beam 16.3 metres and draft 4.7 metres[3], with 128 passengers and 69 maritime crew onboard, was at the end of a fourteen day cruise enroute from Port Epworth to Kugluktuk (the hamlet's name was changed from Coppermine on 01 January 1996), Nunavut.[4] The **Clipper Adventurer** ran aground on a shoal of solid rock with such force that more than half of the vessel's length was embedded on the rock shoal.[5]

On 27 May 2011, nine months after the grounding, a Statement of Claim was submitted by Adventurer Owner Ltd. against the Crown. On 19 August 2011, a Statement of Defence was submitted by the Crown. The official title of this legal case was *Her Majesty the Queen in the Right of Canada v. Adventurer Owner Ltd*. The Federal Court trial was heard in November and December 2016. On 27 January 2017, a decision was hand down by the Federal Court.[6]

At the Federal Court trial the vessel was found to have grounded due to the failure on the part of those interested in the **Clipper Adventurer** to maintain Canadian Hydrographic Service (CHS) Chart 7777 up-to-date.[7] The Crown was awarded damages of just less than C$ 0.5 million for costs and expenses in respect of measures taken to prevent, repair, remedy or minimize pollution

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[1] Statement of Defence dated filled on 19 August 2011, paragraph 118. Also *Canada v. Adventurer Owner Ltd.*, 2017 Federal Court, pages 105 to 141 [henceforth 2017 F.C.], paragraph 30. Online at Federal Court, Federal Court Decisions, Search by File Name T-901-11 at: http://decisions.fct-cf.gc.ca/fc-cf/decisions/en/item/218549/index.do?r=AAAAAQARY2xpcHBlciBhZHZlbnR1cmUB (last accessed: 28 March 2018). Also Transport Safety Board (TSB), Marine Investigation Report M10H0006, Passenger vessel **Clipper Adventurer**, Coronation Gulf, Nunavut [henceforth 2012 TSB Report], section "Canadian Hydrographic Service", paragraph 2. Online at TSB, Marine, Investigation Reports, Search **Clipper Adventurer** at: http://www.bst-tsb.gc.ca/eng/rapports-reports/marine/2010/m10h0006/m10h0006.asp (last accessed: 28 March 2018). The 2012 TSB Report was officially released on 26 April 2012.

[2] Online at Hydro International, News, "Caution Required When Using Nautical Charts of Arctic Waters" posted on 28 June 2017 at: https://www.hydro-international.com/content/news/caution-required-when-using-nautical-charts-of-arctic-waters (last accessed: 28 March 2018).

[3] Online at Wikipedia for MV **Sea Adventurer** at: https://en.wikipedia.org/wiki/MV_Sea_Adventurer (last accessed on 28 March 2018). On 01 October 2012 the vessel was renamed **Sea Adventurer** and taken over by another company.

[4] 2017 F.C., paragraphs 1 to 2.

[5] *Ibid.*, paragraph 3.

[6] *Ibid.,* pages 105 to 141.

[7] *Ibid.*, paragraph 8.

damage.[8] The Adventure Owner had been seeking to be reimbursed for the temporary and permanent repairs, payment to the salvors, business interruption, and related matters of US $ 13.5 million.[9]

In 2012, the Transport Safety Board of Canada (TSB) found that those interested in the **Clipper Adventurer**, which included the vessel owner's management team, the captain and navigation officer, did not investigate the current Notice to Shipping (NOTSHIP) A102/07 information available for CHS Chart 7777. In consequence, these people were not aware of a reported shoal in the area of the Home and Lawford Islands.[10] These were part of a string of small islands east of Kugluktuk.

The TSB did not apportion blame as the TSB looks at causes and contributing factors of a marine incident under its enabling legislation, embodied in section 14 of the *Canadian Transportation Accident Investigation and Safety Board Act*.[11]

On 27 February 2017, an Appeal was filled with the Federal Court of Appeal.[12] The grounds for the Appeal would appear to be about the scope of the Crown's duty of care and by what standard should the exercise of that duty of care be measured, such as the international Convention for the Saving of Life at Sea (SOLAS). The counter argument could be that domestic law predominates and that the amendments to SOLAS on which former owner of the vessel may have relied have not been given the force of Canadian law by regulation.[13] The appeal was heard on 30 January 2018 and the appeal decision released on 07 February 2018 where the appeal was dismissed.[14]

This paper examines the location, other relevant and similar Arctic groundings in 2010, the actual **Clipper Adventurer** grounding and how the Canadian Coast Guard Ship **Amundsen** assisted with hydrographic surveys and passenger evacuation requirements, and the subsequent salvage operation and surveys after the grounding.

The analysis provided examines the following: the voyage planning; the 1997 and 2015 source classification diagrams; the 1965 Canadian Survey Ship **Richardson** survey on which the track of soundings which supposedly the **Clipper Adventurer** followed; the relevant NOTSHIP and Notice to Mariners (NOTMAR); the deck officers and marine crew aboard **Clipper Adventurer** at the time of the grounding; the **Clipper Adventurer** positioning and heading devices and Electronic Chart Systems (ECS) used on the bridge; the planned track; the grounding location; the waypoint selection for the planned route; comparison of the planned track and relevant track of sounding to the actual grounding local; the non-use of the forward looking sonar; object avoidance if the forward looking sonar had been operational; past and subsequent arctic cruises; and improved vessel navigation and the potential for a pilotage regime in the Canadian arctic.

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[8] *Ibid.,* paragraph 2.
[9] *Ibid*., paragraph 4.
[10] 2012 TSB Report, section "Analysis – Navigation in Inadequately Surveyed Areas", paragraph 1.
[11] Statutes of Canada, 1989, Chapter 3. Online at Department of Justice Canada, Justice Laws Website, Consolidated Acts at: http://laws-lois.justice.gc.ca/eng/acts/C-23.4/ (last accessed: 28 March 2018).
[12] Notice of Appeal dated 24 February 2017 and filled on 27 February 2017.
[13] 2017 F.C., paragraphs 95 to 97; and Denis Hains, Hydrographer General of Canada, oral presentation "Arctic Canada: Cold, Hard Facts" at U.S. HYDRO Conference, Galveston, Texas, U.S.A., 21 March 2017, slide 4.
[14] Federal Court of Appeal 2018, case number 34, docket A-65-17 online at https://decisions.fca-caf.gc.ca/fca-caf/decisions/en/item/306090/index.do (last accessed: 28 March 2018).

3. Location Map

The **Clipper Adventurer** grounding occurred in the western portion of Coronation Gulf which lies between Victoria Island and mainland Nunavut. To the northwest it connects with the Dolphin and Union Strait through to the Amundsen Gulf and thence to the Beaufort Sea and Arctic Ocean; to the northeast it connects with Dease Strait and thence to the Queen Maud Gulf.

Figure 1 Location Map[15]

Note: ★ indicates the **Clipper Adventurer** grounding location.

4. Other 2010 Arctic Groundings

In 2010, there were at least two other vessel groundings in the Arctic. On 08 August, the tanker MV **Mokami** ran aground near Pangnirtung, Nunavut,[16] and on 01 September the tanker MV **Nanny** ran aground in Simpsons Strait, about 50 kilometres southwest of Gjoa Haven.[17] Both vessels were under contract to the Nunavut government to deliver bulk fuel shipments to the territory's remote communities during the annual resupply missions. There was no environmental damage, nor any injuries from either grounding. After some offloading of cargo, both tankers were refloated.

[15] Online at http://geology.com/canada/nunavut.shtml (last accessed: 28 March 2018).
[16] Online at CBC News, Canada, North, "Arctic fuel spill fears raised in Pangnirtung" posted on 11 August 2010 at: http://www.cbc.ca/news/canada/north/arctic-fuel-spill-fears-raised-in-pangnirtung-1.899446 (last accessed: 28 March 2018).
[17] Online at CBC News, Canada, North, "Grounded Arctic tanker tries to lighten load" posted on 13 September 2010 at: http://www.cbc.ca/news/canada/north/grounded-arctic-tanker-tries-to-lighten-load-1.961697 (last accessed: 28 March 2018).

Figure 2 Other Vessels Aground in the Arctic in 2010

MV Mokami aground near Pangnirtung[18]	MV Nanny aground near Gjoa Haven[19]
	

The TSB uses five (5) classes of occurrences, with Classes 1 to 3 being posted on the TSB website. Both of these marine accidents were classified as Class 5 occurrences which are occurrences that do not meet the criteria of classes 1 through 4, but are recorded in suitable scope and detail for possible safety analysis, statistical reporting, or archival purposes.[20] The grounding of the MV **Mokami** occurred when the vessel drifted in the harbour and the stern of the vessel grounded on a sand bar. Consequently, at low tide this image appears to exaggerate the severity of the grounding. The TSB report number was M10H0007. The grounding of the MV **Nanny** was caused by vessel navigational issues. The TSB report number was M10H0004.[21] No cases were brought against the Crown for either marine accident.

5. Clipper Adventurer Grounding

On 27 August 2010 at approximately 1832 hours Mountain Daylight Time (the local time in Coronation Gulf at the time), whilst in transit from Port Epworth to Kugluktuk, and sailing in between the Lawford and Home Islands, the **Clipper Adventurer** was steaming at 13.9 knots through the area when it grounded on a rock shoal.[22] The seas were calm without any wind or swells, and sunny conditions and good visibility prevailed.[23] The tide was at its highest and the water was clear.[24] There was no appreciable water current. The **Clipper Adventurer** went off hire the moment

[18] Image from online at CBC News, Canada, North, "Arctic fuel spill fears raised in Pangnirtung" posted on 11 August 2010 at: http://www.cbc.ca/news/canada/north/arctic-fuel-spill-fears-raised-in-pangnirtung-1.899446 (last accessed: 28 March 2018).

[19] Image from Government of Nunavut, Department of Environment, retrieved from online at Nunatsiaq Online, "Fuel tanker runs aground near Gjoa Haven" posted on 02 September 2010 at: http://www.nunatsiaqonline.ca/stories/article/020910_fuel_tanker_runs_aground_near_gjoa_haven/ (last accessed 28 March 2018). Permission from the Government of Nunavut to use the image was received on 05 April 2017.

[20] Online at TSB, Investigations, The Investigation Process, section "What we do", paragraph 2, click on "Occurrence Classification Policy" at: http://www.tsb.gc.ca/eng/lois-acts/evenements-occurrences.asp (last accessed: 28 March 2018).

[21] Private discussions by the author with TSB Media Relations on 04 April 2017.

[22] 2012 TSB Report, section "Summary", paragraph 1, and section "Factual Information – History of the Voyage", paragraph 4.

[23] Statement of Defence dated filled on 19 August 2011, paragraph 28.

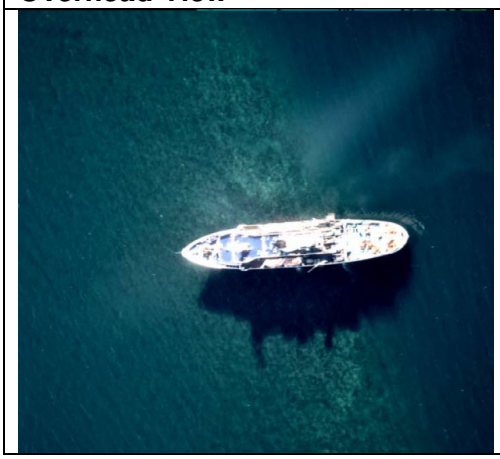
[24] 2012 TSB Report, section "Environmental Conditions", paragraph 1. The maximum tidal range was 0.2 metres. See also footnote number 89 for further tidal details.

the vessel grounded.[25]

The grounding led to 13 of the vessel's double-bottom tanks being breached, some holding fuel, freshwater and sludge.[26] The damage was below the waterline and, consequently, the fuel oil was forced to the top of the tank due to the ingress of sea water. As a result, there was no leakage of the oil. The Canadian Coast Guard (CCG) also verified that at the time of grounding there was no sign of oil pollution in the vicinity of the grounded ship. However, several days following the grounding, a light sheen was visible but it dissipated quickly.[27]

An overhead view of the grounded **Clipper Adventurer**, which clearly shows the rock shoal approximately 60 metres either side of the vessel is provided in the left Figure below. A starboard side view of the vessel with a list of 5 degrees to port shown in the right Figure below.[28]

Figure 3 Clipper Adventurer Grounding

Overhead View[29]	**Starboard Side View**[30]
	

On 29 August 2010, the icebreaker Canadian Coast Guard Ship (CCGS) **Amundsen** arrived on site and evacuated all of the passengers from the **Clipper Adventurer**. The CCGS **Amundsen** had been south west of Sachs Harbour which is on Banks Island. The 540 nautical mile routing allowed the vessel to enter the Coronation Gulf from the north via the Cache Point Channel, follow the surveyed shipping corridor to the south west and then take a track of soundings to the west as shown in the left Figure below.

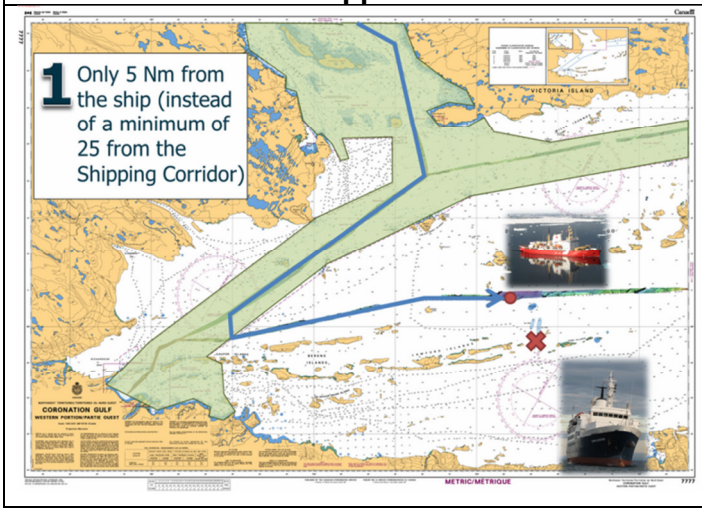
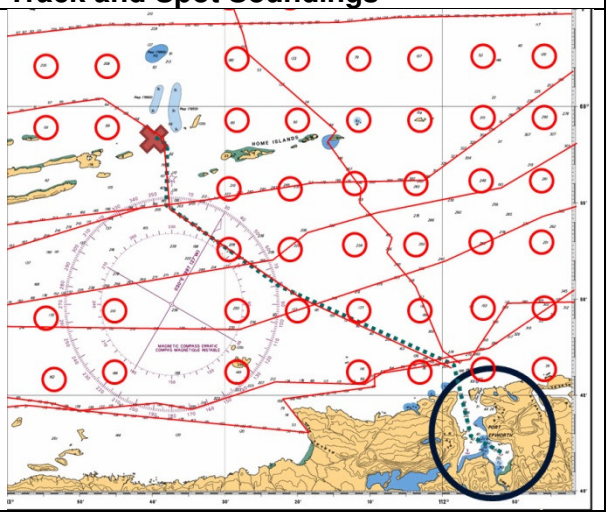
The area in green had been surveyed more completely and accurately, whilst the white space indicated inadequately surveyed areas. At the time the good sea conditions with clear visibility and

[25] 2017 F.C., paragraph 116.
[26] 2012 TSB Report, section "Events Following the Grounding – Salvage Operation", paragraph 1
[27] Online at Ship Source Oil Pollution Fund, 2016-2017 File Portfolio (Incidents and Claims), select **Clipper Adventurer** [henceforth 2010 Ship Source], paragraph 2 at: http://sopf.gc.ca/incidents-and-claims/2-2-clipper-adventurer-2010/ (last accessed: 28 March 2018).
[28] 2012 TSB Report, section "Factual Information – History of the Voyage", paragraph 5.
[29] Image from Denis Hains, Hydrographer General of Canada, oral presentation "Arctic Canada: Cold, Hard Facts" at U.S. HYDRO Conference, Galveston, Texas, 21 March 2017, slide 5.
[30] Image from online at Jim Walker's Cruise Law News, Sinking, "**Clipper Adventurer** Cruise Ship Runs Aground in the Arctic" posted on 29 August 2010 at: http://www.cruiselawnews.com/2010/08/articles/sinking/clipper-adventurer-cruise-ship-runs-aground-in-the-arctic/ (last accessed: 28 March 2018).

with no ice present allowed the CCGS **Amundsen** to only take 40 hours to arrive on site. Had the sea been rougher or fog present, or the rescue had to have been attempted even a couple of weeks later, the transit time could have been much longer.

This brought the CCGS **Amundsen** to within 5 nautical miles of the grounded **Clipper Adventurer** instead of a minimum of 25 nautical miles from the shipping corridor as shown in the left Figure below. However, this area was only covered with spot sounding observed by helicopter every 6 kilometres and track of soundings of various vintages as shown in the right Figure below. The spot soundings observed by helicopter had been observed years before in winter when there was thick ice coverage over Coronation Gulf. The "X" in both images marks the location of the **Clipper Adventurer** grounding as established by the **Amundsen Barge**.

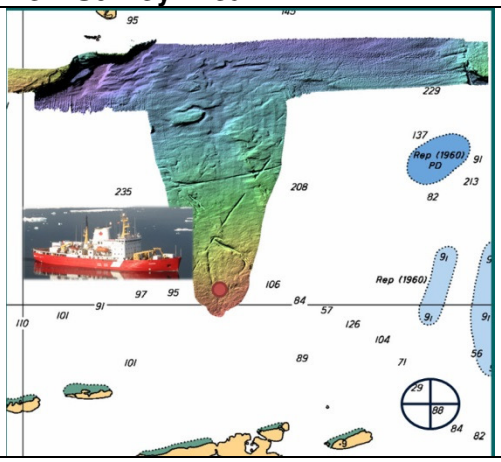
Figure 4 Route to Clipper Adventurer and Soundings

Amundsen Route to Clipper Adventurer[31]	**Track and Spot Soundings**[32]
	

To allow the CCGS **Amundsen** to sail south towards the grounded **Clipper Adventurer**, a route had to be surveyed to the track of soundings to the south as there was no bathymetric coverage in that area. The **Amundsen Barge** was deployed to survey this area as shown in the right Figure below. The crosshairs symbol marks the location of the **Clipper Adventurer** grounding as established by the **Amundsen Barge** in the left Figure below.

[31] Ian Church, Doug Cartwright, John Hughes Clarke, oral presentation "The **Clipper Adventurer**: CCGS Amundsen Response and Risk Mitigation with Near Real-Time Construction of Safe Shipping Corridors" at ArcticNet Scientific Meeting 2010 (ASM 2010) [henceforth 2010 ASM], Ottawa, Ontario, Canada, 15 December 2010, slide 10.
[32] *Ibid.*, slide 4.

Figure 5 Amundsen Barge and New Survey Area

Amundsen Barge[33]	New Survey Area[34]
	

This allowed the CCGS **Amundsen** to sail along the track of soundings to the grounded **Clipper Adventure** to be close enough to safely and efficiently transfer all of the passengers by the evening of 29 August.[35] These evacuees were taken to Kugluktuk and arrived in Edmonton on 30 August.[36] After the passengers were transferred to Kugluktuk, the CCGS **Amundsen** returned to the grounding area and surveyed a narrow corridor from the new survey area shown above, towards the south east to the grounded **Clipper Adventurer** to provide greater confidence of the bottom coverage whilst the salvage operations took place.[37] Once that survey was completed the CCGS **Amundsen** had to depart the area for other work after transferring the bathymetric data to CCGS **Sir Wilfrid Laurier** and the rest of the salvage spread.

The CCGS **Amundsen** was equipped with CNav Real Time Gypsy (RTG) and POSMV horizontal positioning, a POSMV 320 inertial measurement unit (IMU), a Kongsberg EM302 30 kHz multibeam echo sounder (MBES), a Knudsen 3.5 kHz sub-bottom profiler, and a Brooke Ocean Technologies (Moving Vessel Profiler) MVP-300. The **Amundsen Barge** was equipped with CNav RTG horizontal positioning, a CodaOctopus F185 motion sensor, a Kongsberg EM3002 300 kHz MBES, and a survey sound probe. The **Amundsen Barge** had only been carried onboard the CCGS **Amundsen** since June 2010.[38]

6. Salvage Operation

The vessel salvage was awarded to the Resolve Marine Group, a Florida based salvage company,[39] which using 4 tugs, managed to refloat the **Clipper Adventurer** on 14 September. On 31 August, the icebreaker CCGS **Sir Wilfrid Laurier** arrived on site to monitor the salvage of the

[33] *Ibid.*, slide 7.
[34] *Ibid.*, slide 12. Scale of this image is approximately 1 millimetre = 250 metres.
[35] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 144, "Master's Statement of Facts, August 30, 2010", page 3.
[36] Online at CBC News, Canada, North, "Stranded Arctic Cruise Passengers Heading Home" posted on 30 August 2010 at: http://www.cbc.ca/news/canada/north/stranded-arctic-cruise-passengers-head-home-1.930631 (last accessed: 28 March 2018).
[37] 2010 ASM, slide 12.
[38] 2010 ASM, slides 7 to 9.
[39] Online at Resolve Marine Group, Job History, search for **Clipper Adventurer** at: https://resolvemarine.com/job-history/ (last accessed: 28 March 2018).

Clipper Adventurer and any potential pollution from the grounding.[40] Between 11 and 14 September, the vessel sustained further damage due to the deteriorating weather conditions.[41] Roller bags were placed under the hull to minimize the damage and lift the vessel.[42]

On 14 September, the **Clipper Adventurer** anchored safely at Port Epworth. On 17 September, the ship was towed to Cambridge Bay, arriving on 18 September, where the vessel underwent temporary repairs. As the Arctic winter was closing in, the decision was made to tow the **Clipper Adventurer** to Nuuk, Greenland for further temporary repairs.[43]

On 23 September, Transport Canada and the vessel's classification society, which was Lloyd's Registry, granted clearance for the vessel to transit from Cambridge Bay to Nuuk, Greenland.[44] On 25 September, the vessel departed Cambridge Bay under CCG icebreaker escort, and was towed to Pond Inlet where it arrived on 28 September. On 07 October, the vessel departed Pond Inlet under tow and arrived in Nuuk, Greenland on 12 October.[45]

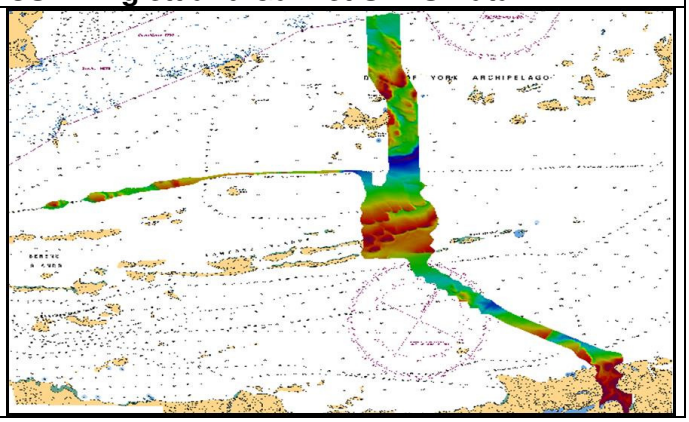
Additional temporary repairs were completed in Greenland. On 28 October, the **Clipper Adventurer** departed Nuuk, Greenland, and proceeded to Iceland for a further inspection. The vessel was then permitted to proceed in its unseaworthy state by hugging the coastline as much as possible. Finally, after a long and torturous route to the Remontowa Ship Repair Yard in Gdansk, Poland, the vessel underwent permanent repairs,[46] which were made from 11 November to 31 December 2010.[47]

7. Surveys After the Grounding

After the grounding of the **Clipper Adventurer**, a team of CHS hydrographers onboard the icebreaker CCGS **Sir Wilfrid Laurier** deployed from the ice breaker the 7.9 metre Canadian Survey Launches (CSL) **Kinglett** and **Gannet** to carry out various hydrographic surveys as shown in the left Figure below. The CSLs were built for the CHS in 2005. First the route from the grounding area to Port Epworth was surveyed, then the route from the grounding to the shipping corridor to the North as shown in the right Figure below.[48]

[40] 2012 TSB Report, section "Events Following the Grounding – Search and Rescue", paragraph 2.
[41] 2012 TSB Report, section "Events Following the Grounding – Salvage Operation", paragraph 6.
[42] Online at Resolve Marine Group, Job History, search for **Clipper Adventurer** then click on Cruise Vessel, Grounding at: https://resolvemarine.com/job-history/cruise-vessel-grounding/ (last accessed: 28 March 2018).
[43] 2012 TSB Report, section "Events Following the Grounding – Salvage Operation", paragraph 9.
[44] 2010 Ship Source, paragraph 5.
[45] 2012 TSB Report, section "Events Following the Grounding – Salvage Operation", paragraphs 8 and 9.
[46] 2017 F.C., paragraph 3.
[47] 2010 Ship Source, paragraph 6.
[48] 2012 TSB Report, section "Events Following the Grounding – Salvage Operation", paragraph 7; and 2017 F.C., paragraph 26.

Figure 6 CSL at Work and Survey Results

Clipper Adventurer and a CSL[49]	CSL Kinglett and Gannet SBES Data[50]
	

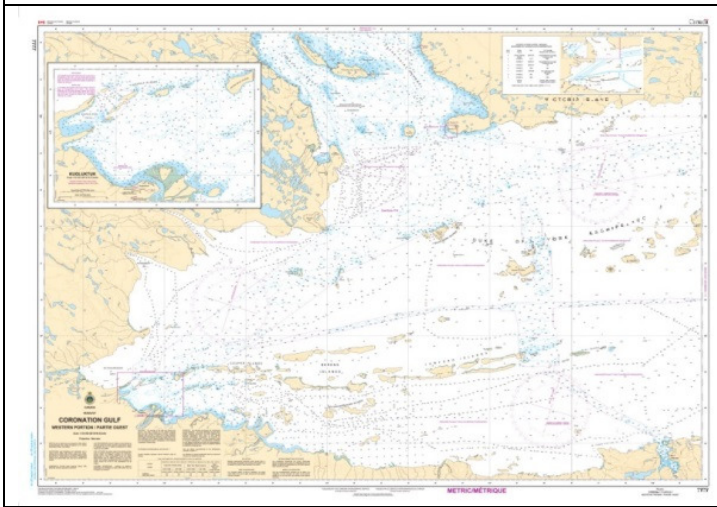
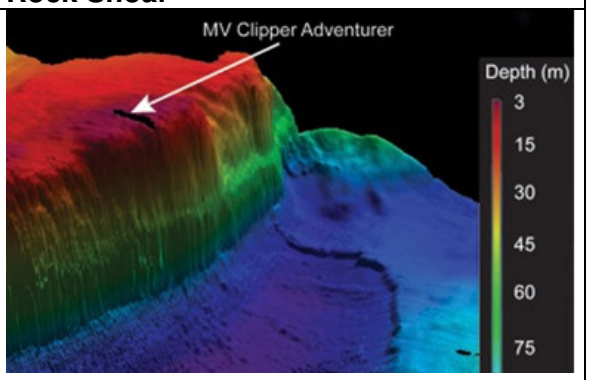
These surveys provided a shipping corridor from the Cache Point Channel in the Dolphin and Union Strait directly to Port Epworth. In the right Figure below, the narrow band of bathymetry running from the grounding area towards Kugluktuk, was acquired by CCGS **Amundsen** in 2005, 2006 and 2010.

The CSLs were equipped with NovAtel L-band DGPS horizontal positioning using the Canada wide Differential GPS (CDGPS) corrections (this is a satellite based augmentation system [SBAS]); and a Honeywell HMR3000 which was a digital compass module that provided heading, pitch, and roll outputs for navigation. In addition, a modified four channel Knudsen 320M single beam echo sounder (SBES) which allowed seabed depth data to be recorded on either 50 or 200 kHz, and which also integrated two (2) Airmar Technologies hull mounted side scan sonar staves on the port and starboard of each CSL operating at 200 kHz. This allowed side scan sonar data to be collected as required for any shoal or hazard investigations, especially where the depth was less than 15 metres. Speed of sound profiles were acquired with a static AML Oceanographic SV.Xchange probe.[51]

On 8 October 2010, CHS Chart 7777 was corrected by a permanent indication of the shoal and an updated Notices to Mariners (NOTMAR) was issued.[52] A revised CHS Chart 7777 was issued on 15 May 2015, which was 57 months after the grounding occurred and is shown in the left Figure below. The 85 metre rise in the seabed at the face of the rock shoal is shown in the right Figure below.

[49] Image provided to the author by the CHS on 13 April 2017.
[50] Image provided to the author by the CHS on 13 April 2017, where the SBES data has been overlaid on a CHS Chart 7777 edition 1997. Not to be used for navigation.
[51] Private communication with the CHS on 11 and 13 April 2017.
[52] 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", paragraph 8; and 2017 F.C., paragraph 59.

Figure 7 Revised Chart 7777 and Rock Shoal

CHS Chart 7777 Version 2015[53]	Rock Shoal[54]
	

8. Voyage Planning

In the 2012 TSB Report there were four (4) pages dedicated to Voyage Planning with the following Table and Figure provided to illustrate three (3) possible routes, which could have been considered by the deck officers on the **Clipper Adventurer**.[55]

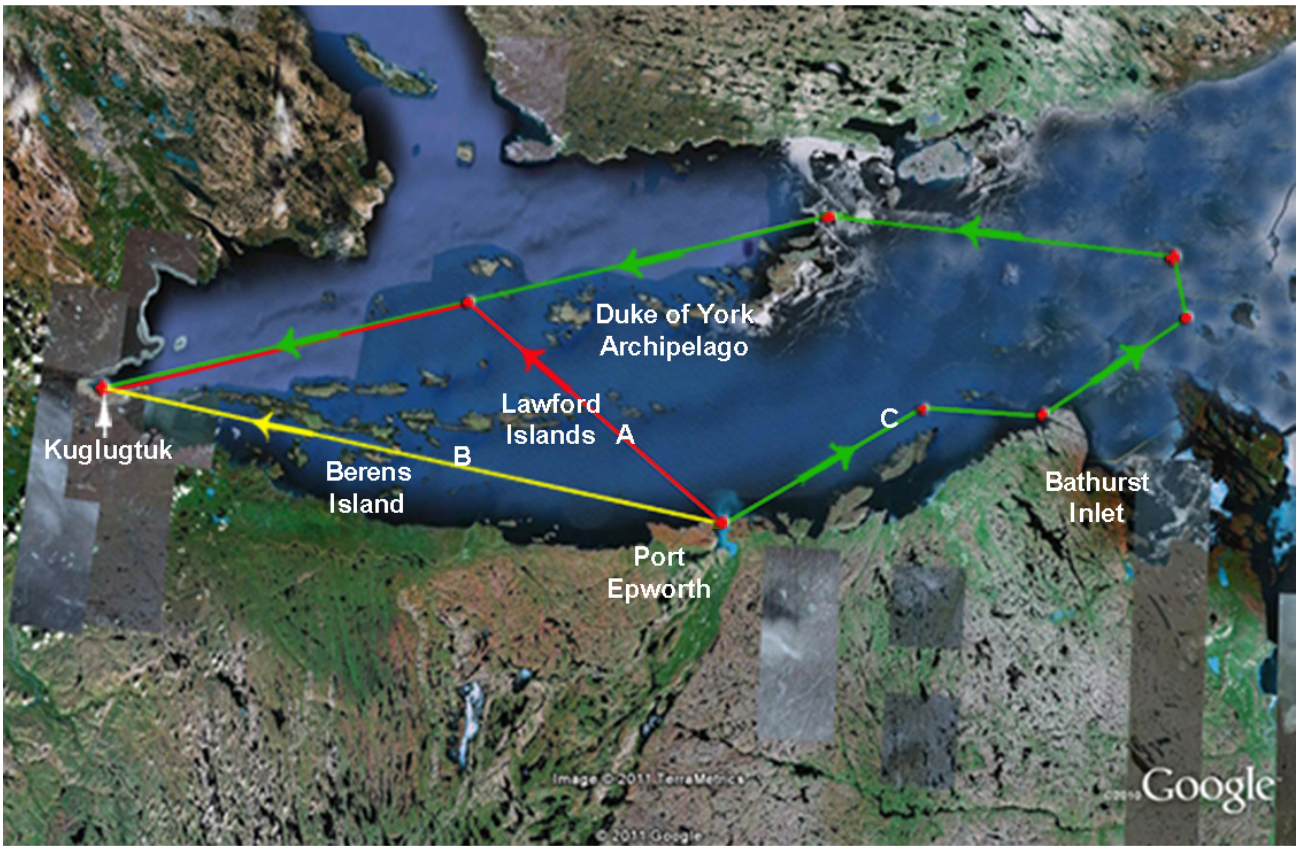
Table – Voyage Planning[56]

Route	Approximate Distance	Required Speed	Time Required to Kugluktuk
A	90 nautical miles	6 knots	15 hours 07 minutes
B	85 nautical miles	6 knots	14 hours 10 minutes
C	200 nautical miles	13 knots	15 hours 23 minutes

Part of Route C had been taken on 26 August 2010 by the **Clipper Adventurer** to arrive at Port Epworth. Interestingly, the **Clipper Adventurer** still referred to Kugluktuk as Coppermine, even though CHS Chart 7777 edition 1997 used Kugluktuk. It should be stressed that the Master of the **Clipper Adventurer** had only planned to take Route A.[57] The TSB calculated the travel times for these routes to show there was no clear reason why the vessel needed to sail at 13.9 knots.

[53] Low resolution copy of CHS Chart 7777 edition 2015 was provided to the author under licence to the CHS. Not to be used for navigation.
[54] Image from 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", Figure 3. The horizontal extent of the rock face shown is approximately 200 metres.
[55] 2012 TSB Report, section "Factual Information – Voyage Planning".
[56] *Ibid.*
[57] Federal Court List of Exhibits, Court Number T-901-11, Exhibit numbers 21, 139 and 140 which are discussed later in this paper.

Figure 8 A) Route Chosen by Clipper Adventurer; B) Second Route Option; C) Reciprocal Route taken on 26 August[58]



"The vessel was scheduled to arrive in Kugluktuk at 0800 on 28 August 2010. This arrival time could have been achieved by either the chosen route (A), 90 nautical miles to Kugluktuk at a speed of 6 knots, or by the longer route (C), 200 nautical miles at a speed of 13 knots. Either route would have allowed the vessel to reach Kugluktuk on schedule."[59]

For unexplained reason(s), the captain made the **Clipper Adventurer** speed to be 13.9 knots over the shorter route,[60] which was not required to meet the vessel's schedule. Perhaps the fuel savings offered by sailing at the vessel's economical cruising speed over Route A was the driving factor in the choice of the route taken.

The Navigation Officer was not on duty when the grounding occurred.[61] At the time of the grounding the Chief Officer was in charge of the watch, assisted by an able seaman (quartermaster) who was responsible for keeping a lookout and to be available should any hand steering be required.[62] The

[58] 2012 TSB Report, Figure 1. A higher resolution image was provided as part of an Access to Information Request submitted to the TSB and answered on 25 April 2017.
[59] 2012 TSB Report, section "Analysis – Route Selection", paragraph 2; and Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 138, "Vessel's Itinerary – August 14 to 28, at August 14", page 2.
[60] Oral deposition of Captain Kenth Grankvist on 24 July 2012 at page 162, the Master of the **Clipper Adventure** at the time of the grounding stated that he had decided to travel at that speed to allow himself and the passengers some rest at anchor before having to disembark the next day.
[61] Oral deposition of David Mora Malca on 21 September 2016 in Panama, video clip 00033.
[62] 2012 TSB Report, section "History of the Voyage", paragraphs 2 and 4.

Master was also on the bridge watching the echo sounder. The ship's doctor was also on the bridge at the time of the grounding.[63]

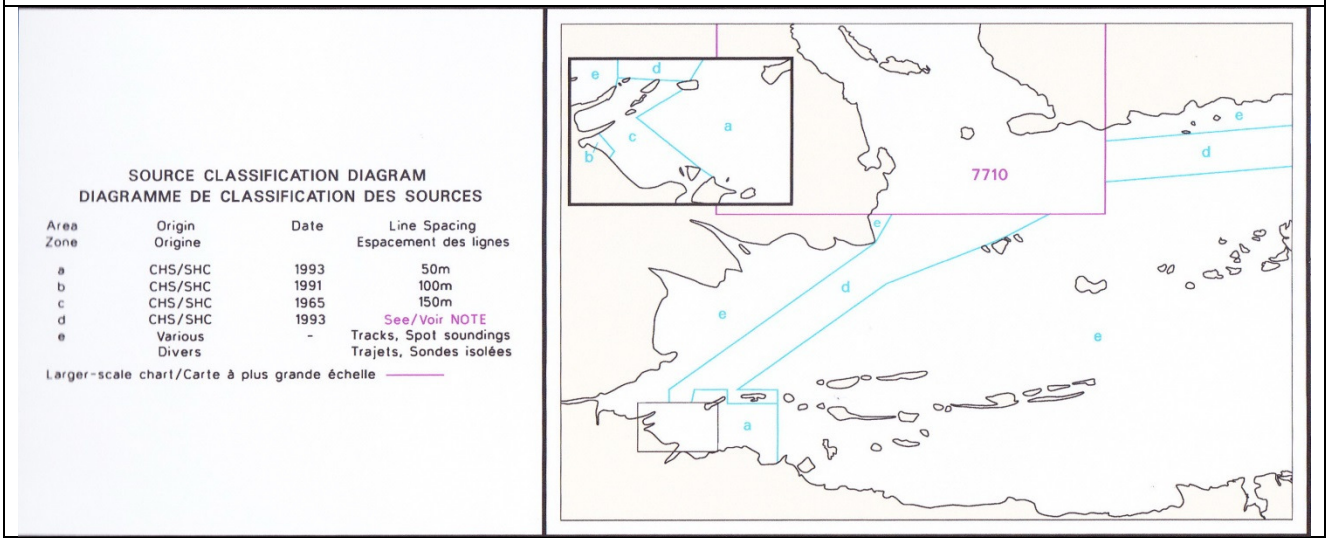
Included in the **Clipper Adventurer** voyage planning should have been an examination of the chart and its associated source classification diagram.

9. Source Classifications Diagrams

The source classification diagrams for CHS Chart 7777 for the 1997 and 2015 editions show the improvements in the bathymetry, and indicate the level of confidence in the soundings printed on the chart. The 1997 edition source classification diagram indicated that the area from below the magenta line which ran from the south west to the north east through the middle of the chart only contained track and spot soundings from various sources with no indication of when the soundings were made and depicted by Area "e".[64]

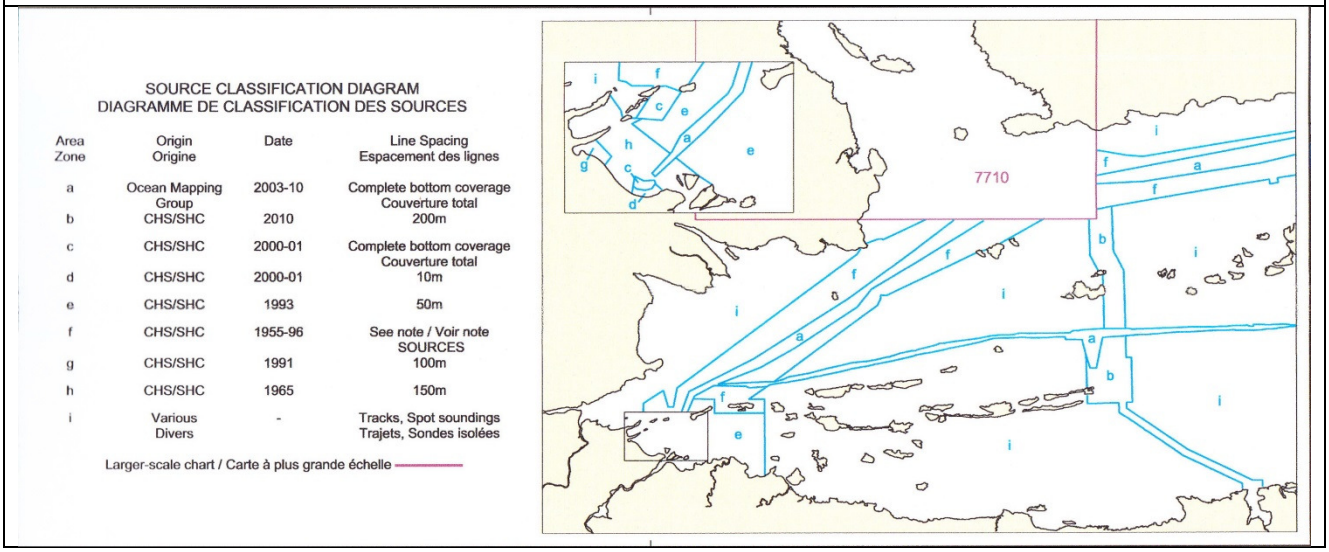
Figure 9 Source Classification Diagrams

CHS Chart 7777 edition 1997



[63] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 144, "Master's Statement of Facts August 30, 2010", page 4.
[64] 2012 TSB Report, section "Chart Dealers and Chart No. 7777", paragraph 2; and 2017 F.C., paragraph 14.

CHS Chart 7777 edition 2015



SOURCE CLASSIFICATION DIAGRAM
DIAGRAMME DE CLASSIFICATION DES SOURCES

Area Zone	Origin Origine	Date	Line Spacing Espacement des lignes
a	Ocean Mapping Group	2003-10	Complete bottom coverage Couverture total
b	CHS/SHC	2010	200m
c	CHS/SHC	2000-01	Complete bottom coverage Couverture total
d	CHS/SHC	2000-01	10m
e	CHS/SHC	1993	50m
f	CHS/SHC	1955-96	See note / Voir note SOURCES
g	CHS/SHC	1991	100m
h	CHS/SHC	1965	150m
i	Various Divers	-	Tracks, Spot soundings Trajets, Sondes isolées

Larger-scale chart / Carte à plus grande échelle

There are many areas in the world, particularly where an expedition vessel could sail, that only have tracks of soundings, sometimes with the depth acquired by lead line. Wherever the mariner is working, acting in a prudent manner based on the source classification diagram on the chart is one of the duties required. Based on the choices made, the bridge team had committed the vessel to dire circumstances where their lack of planning and situational awareness had placed them.[65]

10. 1965 CSS Richardson Survey

In 1965, the track of soundings in question generally followed by the **Clipper Adventurer**, were acquired by the Canadian Survey Ship (CSS) **Richardson**. The vessel was commissioned by the CHS in 1962 and was paid off in 1990. In 1962, the vessel was fitted with the latest electronic navigation and survey equipment. The vessel worked in the Western Arctic from 1962 to 1969 during the months from July to September. Most of the work was in areas adjoining the Beaufort Sea, except for 1965, when the vessel surveyed the approaches to Coppermine, now Kugluktuk.[66]

In 1965, the Arctic work season started on 31 May with arrival of the Hydrographer in Charge (HIC) in Tuktoyaktuk and ended with his departure on 22 September. Due to a late ice break-up, the survey team carried out extensive land based geodetic control surveys in June till mid-July, then executed various bathymetric surveys in Kugmallit Bay west of Tuktoyaktuk, till mid-August.

On 13 August the CSS **Richardson** departed Tuktoyaktuk for Coppermine carrying out track soundings whilst enroute. From 17 August to 02 September the vessel carried out the installation of

[65] Another factor which was not taken into account by the bridge team was the squat of the **Clipper Adventurer** at 13.9 knots. When the **Queen Elizabeth 2** went aground at 25 knots on 07 August 1992 off the coast of Martha's Vineyard and the state of Rhode Island, the squat at was calculated to be 2.4 metres (8 feet). See Captain Nick Perugini, "Grounding of the **Queen Elizabeth 2**: The Rest of the Story", Hydro International, July/August 2009, pages 25 to 29.

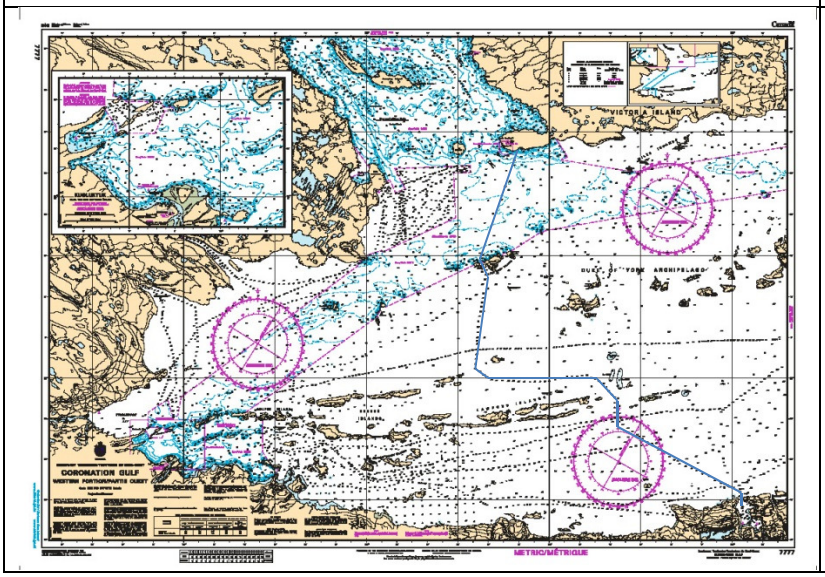
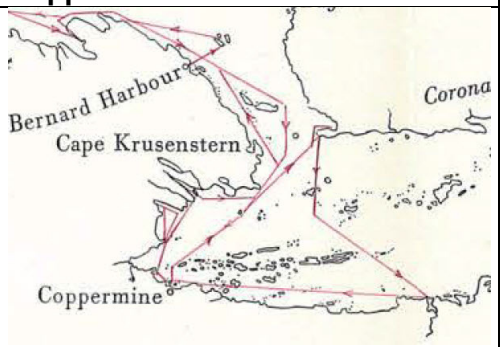
[66] Online at Friends of Hydrography, Ships, and select **Richardson** at: http://fohcan.org/ships/richardson.html (last accessed: 28 March 2018); and also Friends of Hydrography, Surveys, and select Arctic and search for **Richardson** at: http://fohcan.org/surveys/arctic.html (last accessed: 28 March 2018). The vessel is now operated by Seaward Engineering & Research out of Vancouver, British Columbia as the MV **Richardson Point**. See also Statement of Defence dated filled on 19 August 2011, paragraph 87; and 2012 TSB Report, section "Analysis – Navigation in Inadequately Surveyed Areas", paragraph 1.

a tide gauge at Coppermine and then moved it to a better location at Expeditor Cove; completed the Coppermine approach surveys; and carried out various reconnaissance and track sounding surveys.[67] This work was carried out without much interference from either weather or ice.[68]

On 26 August 1965, the CSS **Richardson** left Lady Franklin Point and sailed to Port Epworth, where upon arrival a survey was carried out a survey of the inlet at Port Epworth. From late 27 to 28 August, the vessel carried out various reconnaissance sounding surveys between Port Epworth and Coppermine.[69]

The CSS **Richardson** departed Lady Franklin Point and sailed south southwest to the narrow passage through the Black Berry Islands, then sailed south toward the middle of the Lawford Island chain to the 68 degrees parallel of latitude, then sailed east to the passage between the Lawford and Home Islands and then through that passage, and then sailed south east to Port Epworth. The track of sounding route from Lady Franklin Point to Port Epworth is highlighted in the left Figure below, with the original sketch in the right Figure below.

Figure 10 CSS Richardson Track Sounding Route on 26 August 1965

Chart 7777 edition 1997[70]	**Richardson Voyage to Coppermine[71]**
	

The total distance from Lady Franklin Point to Port Epworth taken by CSS **Richardson** (indicated by the blue line overlaid on CHS Chart 7777 edition 1997 in the left figure above) was

[67] Alard Ages, Hydrographer in Charge CSS **Richardson**, unpublished manuscript "Project and Field Report, CSS **Richardson**, Western Arctic" dated September 1965 [henceforth 1965 **Richardson** Manuscript], pages 2 to 4, and 6 to 8.
[68] Meteorological Branch, Department of Transport, annual report "Ice Summary and Analysis, Canadian Arctic, 1965" (Toronto, Ontario, 1967), see Figures 50, 52, 54 and 56 which show the ice conditions on 13, 20 and 27 August and 10 September 1965 respectively.
[69] 1965 **Richardson** Manuscript, page 4.
[70] Low resolution copy of CHS Chart 7777 edition 1997 – Coronation Gulf – Western Portion, original scale 1:150,000, projection: Mercator, datum: NAD83 was provided to the author under licence from the CHS. Not to be used for navigation.
[71] 1965 **Richardson** Manuscript, Appendix IX.

approximately 70.8 nautical miles. On 26 August, the survey team had carried out a brief beach survey at Lady Franklin Point in the morning. Given that the survey team would generally work a 12 hour day then the speed of the vessel was approximately between 5.5 and 6 knots.

The navigation equipment of interest in the wheelhouse of the CSS **Richardson** consisted of a Decca Type 404 radar, a Sperry Mark XIV gyrocompass,[72] and a Kelvin Hughes MS 26B single beam echo sounder.[73]

In 1965, there was no global navigation satellite system (GNSS), and the Transit navigation satellite system only became publicly available from 1967.[74] Onboard the CSS **Richardson**, the track of soundings in question were positioned by running fixes using the vessel's radar to obtain a distance and bearing from identifiable points on the charted mainland and coast line of the islands, where these coast lines had been derived from uncontrolled aerial photography.[75]

These running fixes were mapped onto the current chart of the time, which was CHS Chart 7617 – Coppermine to Lady Franklin Point.[76] In between these running fixes, the positioning was expected to be by dead reckoning using the gyrocompass for heading and assuming the vessel speed through water was constant. The distance between the track of soundings depth values varied between 0.4 and 0.7 nautical miles[77] (or in the order of 740 to 1,300 metres).

In the area of the grounding the average distance between the track soundings was 1,030 metres or 0.55 nautical miles. At a speed of between 5.5 and 6 knots, there would be 6 and 5.5 minutes between each fix, if the running fixes matched the interval of the track of soundings on the chart.

The horizontal positional accuracy of each sounding was poor compared to current standards. The resolution of the Decca Type 404 radar was ± 0.05 nautical miles (± 100 metres) with an accuracy of ± 0.05 nautical miles.[78] In the 1963 survey report, there was mention that the radar required an overhaul which could be performed by a Northern Transport Company Ltd. (NTCL) technician in Tuktoyaktuk.[79] The required maintenance may have been performed in June 1965 before the start of the survey operations for that year.[80]

The resolution of the Sperry Mark XIV[81] gyrocompass was ± 0.1 degree with an accuracy of ± 0.1 degrees.[82] In 1963, there were continual problems with the gyrocompass data in rough weather.[83] Again, the required maintenance may have been performed in June 1965 before the start of the

[72] Private communication by the author with Seaward Engineering & Research on 27 April 2017.
[73] Radar and echo sounder information from 1965 **Richardson** Manuscript, page 2.
[74] Bruce Calderbank, "Radio Positioning Accuracy", Lighthouse, Spring 2001, Edition 59, pages 12 to 15.
[75] Private communication by the author with the CHS dated 27 March 2017.
[76] 1965 **Richardson** Manuscript, page 10.
[77] 2012 TSB Report, section "Chart Dealers and Chart No. 7777, paragraph 2.
[78] Estimated based on the best information available. This system is no longer in production and the original manufacturer has been merged into other commercial entities.
[79] Tom D.W. McCulloch, Hydrographer in Charge CSS **Richardson**, unpublished manuscript "Survey and Ship Operations, CSS Richardson, Western Arctic" dated September 1963 [henceforth 1963 **Richardson** Manuscript], page 30.
[80] 1965 **Richardson** Manuscript, page 5.
[81] 1963 **Richardson** Manuscript, page 30.
[82] Estimated based on the best information available. This system is no longer in production and the original manufacturer has been merged into other commercial entities.
[83] 1963 **Richardson** Manuscript, page 30.

survey operations for that year.[84]

There is no mention of a gyrocompass calibration where with the vessel fast alongside, the heading data was compared to a heading obtained based on land survey methods. Usually such a calibration would be carried out before the work commenced, but such a procedure was not yet recognized as being a necessary check. Invariably the HIC should have ensured the corrections for speed and latitude would have been manually applied to the gyrocompass.

The estimated horizontal error based on using the islands and mainland features as fixed points which were based on uncontrolled aerial photography, was estimated by the CHS to be approximately ± 100 metres or greater.[85] Consequently the total horizontal positioning error was estimated to be in the order of ± 130 metres.

It was interesting that the track of soundings in the area in questions formed an arc which bowed out towards the east. It would have been expected that the CSS **Richardson** would have maintained a constant heading, where possible, to add in mapping the running fixes.

The track of soundings in question was observed by a Kelvin Hughes MS 26B single beam echo sounder which was standard equipment for the time. The echo sounder used a magneto restrictive transducer and a separate similar receiver which amplified, and converted the received signal to a direct current voltage. The current flowed through a rotating stylus which burned a trace on dry recording paper. The paper record showed the bottom in the form of an “arc display”, which had to be read using a special Kelvin Hughes plastic scale.

A continuous profile should have been acquired provided the echo sounder was operational. The survey team would have had to ensure the stylus was maintained at the correct length whenever the echo sounder was in use. A difference of 0.1 inches longer or shorter than the specified 5.00 inches produced an error of 2.4 feet (0.7 metres) in 120 feet (36.6 metres), or 2%.[86]

For the depth data, invariably the survey team should have conducted a bar check at the start and end of each day, to allow for variations in the speed of sound in water. A bar check is used to calibrate a depth sounder for draft and can also be used for calibrating the speed of sound throughout the water column in survey sites with a maximum water depth of up to 20 metres.[87] In addition, there would have been some variation in the speed of sound in water caused by the fresh water outflows of the Tree River at Port Epworth. It is not expected that any tidal corrections were applied to the depth data as this information was not available for this part of Coronation Gulf. Consequently the total vertical positioning error would be in the order of ± 1 metre.

The HIC explicitly stated that the intent of the track sounding and reconnaissance surveys in Coronation Gulf was only to provide the NTCL with basic positioning and depth information should it be required by NTCL.[88] In 1965, no other user was expected for the bathymetry being provided. Generally, the draft then of a barge would be between 2 and 3 metres, and the draft of a tug used in the Arctic would be between 1 and 3 metres.

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[84] 1965 **Richardson** Manuscript, page 5.
[85] Private communication by the author with the CHS dated 27 March 2017.
[86] G.R. Douglas, R.L.G. Gilbert and D.E. Wells, unpublished manuscript “Accuracy Standards – A Basic Requirement for Automation – Some Initial Proposals”, Bedford Institute of Oceanography, Dartmouth, February 1967, page 1. Online at: http://www.dfo-mpo.gc.ca/Library/49349.pdf (last accessed: 28 March 2018).
[87] Private communication by the author with Tom D.W. MuCulloch on 10 May 2017.
[88] 1965 **Richardson** Manuscript, page 14.

The footprint of each sounding along the track of soundings in question in the area of the grounding measured between 0.1 and 0.15 minutes of arc Latitude or between 185 and 280 metres in diameter. Even so, a prudent mariner would know that the horizontal position for the track sounding was only related to the centre of the sounding printed on the chart. The blanks in between the soundings would be understood to have mapped the shallowest soundings. Areas outside of the narrow strip between the soundings would be considered to be not surveyed.

In 2010, the reported least depth over the rock shoal was 2.3 metres whilst the draft of the CSS **Richardson** was 2.4 metres.[89] Even allowing for the tidal range of 0.2 metres,[90] if the vessel had travelled over the shallowest point on the rock shoal, then the vessel would have gone aground or the shallow depth would have been noticed.

Subsequently a shoal survey would have been conducted using a star, spiral box or rectangular search pattern, of which the HIC should have been familiar.[91] In 1965, the HIC onboard CSS **Richardson** was an experienced hydrographer who had joined the CHS in the late 1950s. Since World War II, he had been an apprentice deck officer and then had moved up the ranks to second mate in the Nederland Line before immigrating to Canada in 1953.[92] In 1964, he was the other hydrographer onboard CSS **Richardson**.[93] During this period he attended the University of British Columbia during the winters and spent his summers in the Arctic, and eventually obtained a Master's degree in fluid dynamics.[94]

It would appear that the rock shoal was not reported as it was not found on the track of soundings in the area of the grounding. Whatever the horizontal and vertical uncertainties related to this track of sounding survey, they were put to rest by the inclusion of the bathymetry from the track of sounding survey in CHS Chart 7777 edition 1997.

11. NOTSHIP and NOTMAR

The rock shoal on which the **Clipper Adventurer** grounded had been previously discovered on 13 September 2007 by the CCGS **Sir Wilfrid Laurier** while conducting scientific research. However, the initial work of this vessel was deemed not to meet CHS survey standards.[95] Consequently, a NOTSHIP A102/07 was issued on 16 September 2007 which read as follows:

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[89] Online at Friends of Hydrography, Ships, and select **Richardson** at: http://fohcan.org/ships/richardson.html (last accessed: 28 March 2018). Draft was reported to be 8 feet.

[90] Online at Fisheries and Oceans Canada, On the Water, Marine Conditions, Tides, Currents, and Water Levels, Data Available, 2016 Tide Tables, Kugluktuk (station number 6290) at: http://www.tides.gc.ca/eng/data/table/2016/wlev_sec/6290 (last accessed: 28 March 2018). Records for 2010 were not available online but the maximum tidal range of 0.2 metres was expected to be the same. The grounding of the **Clipper Adventurer** occurred in open water towards the geographical centre of the Coronation Gulf which may have allowed some tidal fluctuations. However, for the only other tidal station in Coronation Gulf at Cambridge Bay (station number 6240) the tidal range was the same. Of note is that Kugluktuk had diurnal tides and Cambridge Bay had semidiurnal tides.

[91] The Hydrographer of the Navy, Admiralty Manual of Hydrographic Surveying (Taunton, England, 1969), Volume 2, Chapter 3 – Sounding, Part 6 – Searching for Reported Shoals, pages 130 to 133.

[92] Alard B. Ages, *Guarded by Angels: Memoir of a Dutch Youth* (Trafford Publishing, Victoria, 2007), back dust jacket "About the Author".

[93] Online at Friends of Hydrography, People, and select A for Ages at: http://fohcan.org/people/a.html (last accessed: 28 March 2018).

[94] Alard B. Ages, *Guarded by Angels: Memoir of a Dutch Youth* (Trafford Publishing, Victoria, 2007), back dust jacket "About the Author".

[95] 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", paragraphs 4 and 5,

"A102/07 – WESTERN ARCTIC – CORONATION GULF – SEPTEMBER 16, 2007
A SHOAL WAS DISCOVERED BETWEEN THE LAWSON ISLANDS AND THE HOME ISLANDS IN THE SOUTHERN CORONATION GULF IN POSITION 67 58.25'N 112 40.39' W. CHARTED DEPTH IN AREA 29 METRES. LEAST DEPTH FOUND 3.3 METRES. ISOLATED ROCK. REFER TO NAD83 DATUM. CANCEL NOTSHIP A101/07."[96]

In Canada, permanent corrections to a chart are announced through a NOTMAR, whilst all information relevant to safety of navigation are announced on an urgent basis through a NOTSHIP. NOTMAR's cannot be issued as quickly as NOTSHIP's, since thorough investigations and hydrographic surveys were sometimes needed before publishing a NOTMAR, particularly when a NOTMAR involves a permanent modification to a chart or nautical publication.[97]

NOTSHIP's is not used outside of Canada, and are typically broadcast by radio signal but only for 14 days.[98] A NOTSHIP remains active until a NOTMAR is issued or until the information is no longer necessary.[99] The CHS Central and Arctic region, which was responsible for charting in these areas, relied on NOTSHIP's rather than issuing other corrections which may prove incomplete or inaccurate.[100] The **Clipper Adventurer**'s management company used Marine Press of Canada to provide updates to its CHS Charts, but this did not include notification of any NOTSHIP's.[101]

NOTSHIP A102/07 was supposed to have been replaced by a NOTMAR to be issued in June 2010 based on hydrographic work carried out in the summer of 2009. Unfortunately, due to CHS internal management issues, the update was not carried out.[102] A primary contention of the Adventurer Owner Ltd. legal team which that this failing made the Crown liable for the damages caused.[103]

However, NOTSHIP A102/07 was still available on the CCG website, although according to the Adventurer Owner Ltd. legal team this did not meet international standards.[104] However, the vessel owners management was aware that Canada issued NOTSHIP's and that copies of these were not provided by Marine Press.[105] The **Clipper Adventure** managers had not subscribed to a service where NOTSHIP's would be faxed to the vessel.[106]

It should be noted that there would appear to be a positioning blunder in the Federal Court decision with respect to geographical coordinates reported for NOTSHIP A99/10. In paragraph 58, the position of NOTSHIP A99/10 was reported as 67º 58.2716N, 112º 48.3400W,[107] which should have

[96] 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", paragraph 2; and 2017 F.C., paragraph 22.
[97] Statement of Defence dated filled on 19 August 2011, paragraphs 13 and 81.
[98] Russell Robertson, "Cruising in Canada's Arctic: The Mis-Adventures of the **Clipper Adventurer**", BC Shipping News, April 2017, page 42.
[99] 2012 TSB Report, section "Canadian Hydrographic Service – Notices to Shipping and Notices to Mariners", paragraph 1.
[100] 2012 TSB Report, section "Canadian Hydrographic Service – Notices to Shipping and Notices to Mariners", paragraph 6.
[101] 2012 TSB Report, section "Chart Dealers and Chart No. 7777", paragraph 1.
[102] 2017 F.C., paragraphs 38 and 39.
[103] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 287, "Expert Report in Respect of MV **Clipper Adventurer** Grounding in Canadian Arctic Waters" dated 27 August 2010, page 1.
[104] *Ibid.*
[105] 2017 F.C., paragraph 91.
[106] Russell Robertson, "Cruising in Canada's Arctic: The Mis-Adventures of the **Clipper Adventurer**", BC Shipping News, April 2017, page 42.
[107] 2017 F.C., paragraph 58. The 8 minute difference is the grounding locations are highlighted in yellow.

been 67º 58.2716N, 112º 40.3400W.[108] The Federal Court reported position was 5.5 kilometres from NOTSHIP A102/07, when their positions were actually 53 metres apart. See Section 15 for details.

12. Deck Officers and Marine Crew

During the cruise in question, the **Clipper Adventurer** had entered Canadian waters from Greenland on 19 August 2010.[109] At the time of the grounding on 27 August 2010, there were three (3) deck officers and the master onboard **Clipper Adventurer**. The deck officers were the Chief Mate who was also the Safety Officer, the Second Officer who was also the Navigation Officer, and a Third Officer.[110] Their duty hours were as follows: Third Officer from 0000 to 0400 and 1200 to 1600 hours; Chief Mate from 0400 to 0800 and 1600 to 2000 hours; and Second officer from 0800 to 1200 and 2000 to 2400 hours. The Master was on call throughout the day.

The Master joined the **Clipper Adventurer** on 21 July 2010. The Navigation Officer joined the **Clipper Adventure** in Copenhagen, Denmark on 24 June and was signed off the vessel at Nuuk, Greenland on 28 October 2010. At Copenhagen on 24 June, the on duty Second Officer became the Chief Mate and the new deck officer was allocated the position of Second Officer.[111]

The crew were from numerous maritime nations. The Master was from Sweden, the Chief Mate was from Argentina, the Second Officer was from Panama, and the Third Officer was from the Philippines. The remainder of the deck crew were from, in alphabetical order, as follow: Indonesia, Nicaragua, the Philippines and Ukraine.[112] The working language onboard was English.[113]

13. Clipper Adventurer Positioning

The **Clipper Adventurer** used two global positioning systems (GPS),[114] but neither was described in the 2012 TSB Report or in the Federal Court decision, nor was the performance of these systems discussed in either. However, in the Federal Court Exhibit List for the case, exhibit number 11 provided a partial "List of Bridge Equipment, **Clipper Adventurer**".

The primary GPS was a Leica model MX420 navigation system and the secondary GPS was a Furuno model GP-80 marine GPS navigator. Both systems were 12 channel L1 receivers. The accuracy of the Leica system was quoted as 3 metres 2DRMS[115] without corrections,[116] and for the

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[108] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 220, "NOTSHIP A99-10 xcna-sharp4501n@dfo-mpo.gc.ca_20110926_103900", page 2. NOTSHIP A99/10 was issued on 05 September 2010.

[109] Statement of Defence dated filled on 19 August 2011, paragraph 102.

[110] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 133, "Crew List at Time of Grounding", page 2.

[111] Video disposition of David Mora Malca on 21 September 2016 in Panama, video clip 00033. Mr. Mora was the Navigation Officer at the time of the grounding. He could not come to Canada due to his then current employment. Each video clip was 20 minutes long except for the last video clip. Lawyers for both parties were in Panama, and the video was live streamed to the Federal Court in Ottawa.

[112] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 133, "Crew List at Time of Grounding", page 2.

[113] Video disposition of David Mora Malca on 21 September 2016 in Panama, video clip 00034.

[114] 2012 TSB Report, section "Vessel Description", paragraph 1.

[115] 2DRMS means twice the Distance Root Mean Squared (DRMS). See explanation provided in "GPS Positioning Accuracy Measures", APN-029, NovAtel dated 03 December 2003 online at: http://www.novatel.com/assets/Documents/Bulletins/apn029.pdf (last accessed: 28 March 2018).

[116] Leica, MX420 Navigation System, Installation and Service Manual, section "Technical Specifications",

Furuno system was quoted as 10 metres without corrections.[117] Both systems were checked on 27 July 2010 whilst the **Clipper Adventurer** was in Isabella Bay at Baffin Island.[118] Invariably this was only a performance check and not a GPS health check where with the vessel fast alongside, the GPS antenna positioning was compared to positioning obtained based on land survey methods.

Both systems had the option for DGPS input but there is no indication that this was activated for either GPS system during the voyage. Both systems offered a route monitoring facility but there is no indication that this was used by for either GPS system during the voyage. There was no indication of when each system was serviced, particularly the GPS antenna connections at the exterior navigation mast.

The **Clipper Adventurer** used an Anschütz gyrocompass. Unfortunately, exhibit number 11 does not specify the model of gyrocompasses in use. It is expected that the speed and latitude corrections for the gyrocompass were automatically updated from the primary GPS data. Although it is not expected the gyrocompass had been checked with the vessel fast alongside, where the heading data was compared to a heading obtained based on land survey methods, on 25 May 2010 the gyrocompass was adjusted by one (1) degree.[119]

For GPS week 1826, from 23 to 29 August 2010 in which the grounding occurred, the solar activity was at very low levels.[120] Consequently, the GPS data provided to the ECS and subsequently to the Anschütz autopilot should have been stable and consistent. Unfortunately, exhibit number 11 does not specify the model of autopilot in use. However, the autopilot should have been able to maintain the selected course to within ± 10 metres of the waypoints input into the ECS.

The **Clipper Adventurer** used TimeZero software by MaxSea for route planning and Transas Navi-Sailor 3000 as the electronic chart system (ECS).[121] The ECS system incorporated weather forecasting, multiple chart display and user-selectable screen layout; advanced Route Planning, Radar Overlay and Playback facilities; North-Up/Course-Up/Head-Up chart display modes; Relative and True Motion display; and advanced (U)AIS transponder interface. The Navi-Sailor 3000 had been designed in compliance with the International Maritime Organization (IMO) requirements for Integrated Navigational Systems (draft IEC61924).[122]

It would not be expected that the **Clipper Adventure** would be turned exactly at each waypoint. The ECS and interconnected autopilot should have taken a curved course inside the acute angle to

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page 11. Online at Navcom Marine Electronics, Leica MX420 Navigation System, Documents, Installation and Service Manual at: http://www.navico-commercial.com/Root/SimradProSeries_docs/MX420_Install%20manual.pdf (last accessed: 28 March 2018).

[117] Online at Furuno USA, Support, search for GP80, Documents, Brochures, GP80 Brochure, page 2 at: https://www.furunousa.com/-/media/sites/furuno/document_library/documents/brochures/brochures/gp80_brochure.pdf (last accessed: 28 March 2018).

[118] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 11, "List of Bridge Equipment, **Clipper Adventurer**".

[119] *Ibid*.

[120] Space Weather Highlights, PRF1826, 23 August to 29 August 2010, page 1. Online at National Oceanic and Atmospheric Administration, Space Weather Prediction Center, Products and Data, Weekly Highlights and 27-Day Forecast, History, select ftp://ftp.swpc.noaa.gov/pub/warehouse, select Directory 2010, select 2010_WeeklyPDF.tar.gz, select prf1826 (last accessed: 28 March 2018).

[121] The 2012 TSB report classified the Transas Navi-Sailor 3000 as an ECS when in fact the system was a type-approved Electronic Chart Display Information System (ECDIS).

[122] Online at Transas, Press Centre, News, "Navi-Sailor 3000 from Transas: More than ECDIS", paragraph 3 at: http://www.transas.com/navi-sailor-3000-from-transas-more-than-ecdis (last accessed: 28 March 2018).

provide a smooth and comfortable passage for the passengers.

14. Planned Track

At the Federal Court trial, it was accepted that the planned track was established by the Navigating Officer which was approved by the Master.[123] The **Clipper Adventurer** used paper charts for navigation, including CHS Chart 7777 edition 1997, on which the desired course was plotted and the waypoints transferred to the route planning software and the ECS.[124]

The Navigation Officer was not familiar with Canadian charts or Arctic shipping operations,[125] and had only previously been to one Canadian port (Vancouver) in 2015, all of which the Master was aware.[126] The only other time the Navigation Officer planned an Arctic cruise was the immediately previous **Clipper Adventure** cruise in the Arctic from 26 July to 09 August 2010.[127] During this cruise, the Navigation Officer compiled the voyage plan for the next cruise.[128] The TSB found there were a number of procedural errors and omissions in the voyage planning.[129]

Unfortunately, the Navigation Officer "wrongly assumed that Marine Press of Canada [the providers of the CHS Charts to **Clipper Adventurer**] had provided them with all the information they needed to have. There was no communication with MCTS [the CCG, Marine Communications and Traffic Services in Iqaluit] except to report their positions, as required. No inquiry was made as to outstanding NOTSHIP's."[130]

The captain had previously completed over 60 Arctic voyages, although never to Port Epworth.[131] It was the second year in a row that **Clipper Adventurer** had sailed in the Canadian Arctic and the Coronation Gulf.[132] On 23 February 2010, the extension of the cruise to include Port Epworth was added at the request of the Canadian charterer, as Port Epworth was a geological point of interest.[133] Port Epworth is a protected inlet into which the Tree River flows.

In 2009, the **Clipper Adventurer** purchased CHS Chart 7777 edition 1997, which used a scale of 1:150,000 at 68 degrees 30 minutes on the Mercator projection using the North American Datum 1983 (NAD83). This chart was stamped as being corrected with NOTMAR up to 25 July 2008. The last NOTMAR related to Chart 7777 was dated 04 June 2004 and had been applied to CHS Chart 7777.[134]

Consequently, latitude values could be extracted from the chart within 3 seconds of arc, and longitude values could be extracted from the chart within 6 seconds of arc. The corresponding metric equivalents, in the area of the grounding, were respectively 93 metres and 70 metres or with an accuracy of ± 58 metres. However, for the route planning software and the ECS, the **Clipper**

[123] 2017 F.C., paragraph 50; and Plaintiff's Opening Statement dated 14 December 2016, paragraph 6.
[124] 2017 F.C., paragraph 50.
[125] 2017 F.C., paragraph 50.
[126] Video deposition of David Mora Malca on 21 September 2016 in Panama, video clips 00034 and 00035.
[127] Statement of Defence dated filled on 19 August 2011, paragraph 102.
[128] 2012 TSB Report, section "Factual Information – Voyage Planning", paragraph 6.
[129] 2012 TSB Report, section "Factual Information – Voyage Planning", paragraph 7.
[130] 2017 F.C., paragraph 57.
[131] 2017 F.C., paragraph 47.
[132] Statement of Defence dated filled on 19 August 2011, paragraph 25.
[133] 2012 TSB Report, section "Factual Information – Voyage Planning", paragraph 6. Confirmed with paper copy of CHS Chart 7777 edition 1997 provided to the author by the CHS under licence.
[134] 2012 TSB Report, section "Chart Dealers and Chart No. 7777", paragraph 1.

Adventurer deck officers only entered latitude and longitude values to 0.1 minute or 6 seconds of arc. Hence, the corresponding metric equivalents were respectively 186 metres and 70 metres or with an accuracy of ± 99 metres. The ECS should have been able to select the centre of each sounding that were used as waypoints, and hence follow the track of soundings more closely.

In the Arctic, following a track of soundings is common practice due the sparse soundings available.[135] During an interview on or about 28 August 2010 on the CBC news channel, Adventure Canada Chief Executive Officer Mathew Swan, stated that the vessel had been following a track of soundings, which was actually an incorrect statement but at least showed the vessel management team was aware of and the need to follow, a track of soundings.[136]

In the 1997 edition source classification diagram below the magenta dashed line which ran from the south west to the north east through the middle of the chart only contained track and spot soundings. In the 2015 edition source classification diagram above these same areas, but not including the surveys by the **Amundsen Barge** or the CLS **Kinglett** and **Ganett**, there was an "Inadequately Surveyed" notation added to those parts of the chart.

As shown in both Figures below, following a track of soundings could be an artistic endeavour. The presentation in 2012 TSB Report was compiled by TSB staff. Unfortunately, the compilation appears to have ignored information that was, or should have been available to the TSB when compiling the plot in the left Figure below. For instance, the TSB had similar information to that presented in the Federal Court exhibit number 140 which showed the waypoints used on 27 August.[137] The CHS Chart 7777 edition 1997 used onboard **Clipper Adventurer** was produced as a Federal Court exhibit and a portion of which is included in the right Figure below.

On the portion of the planned track on a heading of 301 degrees True (shown as 300 degrees True on the TSB plot), the maximum distance from the track of soundings in question to the planned track was 1,170 metres or 0.63 nautical miles. On this leg of the voyage, based on the CHS Chart 7777 edition 2015, the soundings ranged from 50 to 200 metres.

Further, as shown in the top left hand corner of each plot, the planned track proposed to cross an unsurveyed area ["white space"[138]] on heading 310 degrees True (shown as 311 degrees True on the TSB plot) to reach a track of soundings to the north. This corresponded to 10,480 metres or 5.64 nautical miles of planned track for which there was no bathymetry data at all.

Unfortunately, the vessel data recorder (VDR) onboard **Clipper Adventure** was not backed up properly after the grounding.[139] Hence whatever course the **Clipper Adventure** took before and up to the grounding cannot be examined. However, several of the Federal Court Exhibits provide the selected waypoints for comparison which is provided in the next section.

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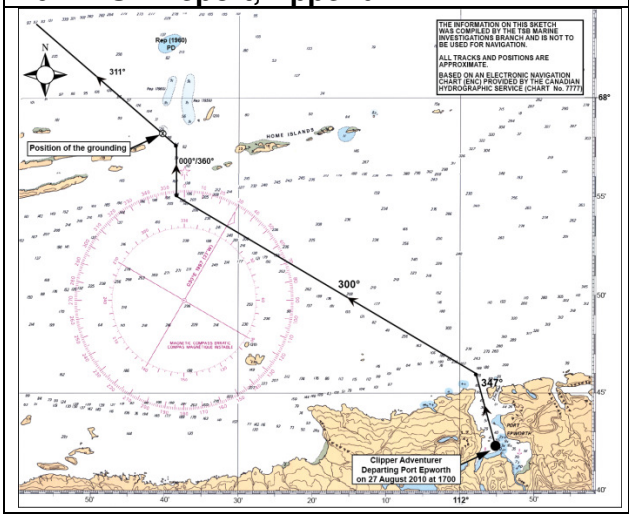
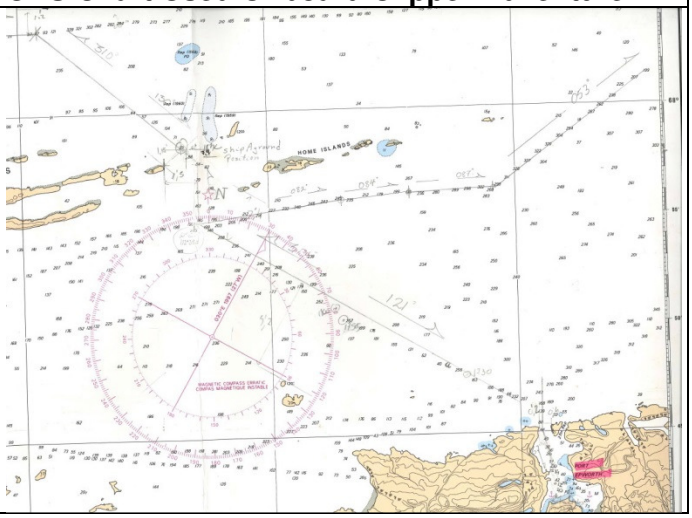
[135] 2017 F.C., paragraph 49.
[136] Emma Stewart and Jackie Dawson, "A Matter of Good Fortune? The Grounding of the **Clipper Adventurer** in the Northwest Passage, Arctic Canada", page 264, online at University of Calgary, Arctic Institute of North America, Arctic Journal, Arctic Contents Page, Volume 64, Number 2, pages 263 to 267 at: http://pubs.aina.ucalgary.ca/arctic/Arctic64-2-263.pdf (last accessed: 28 March 2018).
[137] Private communications by the author via an Access to Information Request submitted to the TSB and answered on 12 May 2017.
[138] 2017 F.C., paragraph 18.
[139] 2012 TSB Report, section "Voyage Data Recorder", paragraph 3.

Figure 11 Planned Track of Clipper Adventurer

2012 TSB Report, Appendix D[140]	CHS Chart Used Onboard Clipper Adventurer[141]
	

15. Grounding Location

It is not clear why the parties at Federal Court agreed to a grounding location that was 340 metres West of the actual grounding location as provided by either the Federal Court exhibit number 141 or by the **Amundsen Barge** as shown in the Table below. It is also not clear why the TSB provided a grounding location that was 122 metres South of the actual grounding location.

Table – Grounding Locations

Source	Latitude (N)	Longitude (W)	Grid Differences	
			Distance (m)	Bearing
2017 Federal Court[142]	67º 58.26’	112º 40.3’		
2012 TSB Report[143]	67º 58.2’	112º 40.3’	366.2	109.3
Amundsen Barge[144]	67º 58.2658’	112º 40.3461’	122.4	359.5
Exhibit Number 141[145]	67º 58.2652’	112º 40.3149’	6.2	259.9
2017 Federal Court location to Exhibit Number 141			338.6	89.9

Note: The latitude and longitude coordinates were converted to UTM coordinates using Norcom Technology, Geodetic software version 3.2.11.99.

[140] Portion of CHS Chart 7777 edition 1997 – Coronation Gulf – Western Portion, original scale 1:150,000, projection: Mercator, datum: NAD83 from 2012 TSB Report, Appendix D – Chart of the Area of the Grounding. Not to be used for navigation.
[141] Portion of CHS Chart 7777 edition 1997 – Coronation Gulf – Western Portion, original scale 1:150,000, projection: Mercator, datum: NAD83 from Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 68, “Original chart #7777 produced during examination of Mr. Mora”. Not to be used for navigation.
[142] 2017 F.C., paragraph 1. These were also the same grounding coordinates provided in the Agreed Statement of Facts dated 21 November 2016, paragraph 5.
[143] 2012 TSB Report, section “History of the Voyage”, paragraph 5.
[144] Private communication by the author with Ian Church on 11 May 2017.
[145] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 141, “GPS screen shot August 27, 2010, page 2. The screen shot was from the primary GPS system as the display was from a Leica MX420 Control and Display Unit (CDU).

As the **Clipper Adventurer** grounding location was confirmed separately by the **Amundsen Barge**, then the location provided in exhibit number 141 is considered the actual grounding location. The various locations for the rock shoal are compared in the Table below.

Table – Rock Shoal Location Differences

Source	Latitude (N)	Longitude (W)	Grid Differences	
			Distance (m)	Bearing
NOTSHIP A102/07[146]	67º 58.25'	112º 40.39'		
NOTSHIP A99/10[147]	67º 58.2716'	112º 40.3400'	53.3	42.5
Exhibit Number 141	67º 58.2652'	112º 40.3149'	21.3	126.1

Note: The latitude and longitude coordinates were converted to UTM coordinates using Norcom Technology, Geodetic software version 3.2.11.99.

The NOTSHIP's reported least depth over the rock shoal in 2007 and 2010 respectively. Hence some difference was expected. The similarity of the least depths reported in these NOTSHIP's, of 3.3 and 2.3 metres respectively, shows the uniformity of the rock surface at the top of the shoal. Unfortunately, neither NOTSHIP A102/07 nor NOTSHIP A99/10 provided any information as to the extent of the shoal area, only the least depth found.

16. Waypoint Selection

Federal Court exhibit number 21 provided the Voyage Planning Forms used by the Navigation Officer when planning the voyage during the previous cruise in the Canadian Arctic. All of the forms were dated 03 August 2010.

Table – Exhibit Number 21 – Voyage Planning Form – 03 August 2010[148]

Point	Latitude	Longitude	Rhumb Line Distance	Heading degrees True			Seconds Difference	
				Calculated	Exhibit	Diff	Latitude	Longitude
# 0	67º 42.3'	111º 55.3'						
# 1	67º 45.8'	111º 57.6'	3.61	346.02	346	0.02		
# 2	67º 46.4'	111º 59.9'	1.06	304.56	303	1.56		
# 3	67º 55.0'	112º 38.6'	16.95	300.49	301	-0.51		
# 4	67º 57.5'	112º 38.6'	2.50	0.00	0	0.00		
# 5	68º 03.7'	112º 57.8'	9.50	310.75	311	-0.25		

Notes: The Rhumb Line distances and bearings from the latitude and longitude coordinates were calculated using Norcom Technology, Geodetic software version 3.2.11.99. Rhumb Line Distance is in nautical miles. The Seconds Difference column is used in the tables below.

Federal Court exhibit number 139 provided a screen grab of the TimeZero route planning software by MaxSea. Though the start point at Port Epworth may have needed to be changed, the other alterations show that instead of using the planned route from 03 August, on or about 27 August the

[146] 2012 TSB Report, section "Discovery of the shoal", paragraph 2; and 2017 F.C., paragraph 22.
[147] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 220, "NOTSHIP A99-10 xcna-sharp4501n@dfo-mpo.gc.ca_20110926_103900", page 2.
[148] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 21, "**Clipper Adventurer** Voyage Plans", page 15. The copy for this page was a bit blurry although readable and this was the clearest copy available.

planned track was changed.

Table – Exhibit Number 139 – Screen Grab of MaxSea[149]

Point	Latitude	Longitude	Rhumb Line Distance	Heading degrees True			Seconds Difference	
				Calculated	Exhibit	Diff	Latitude	Longitude
# 0	67º 42.2'	111º 55.4'					6	-6
# 1	67º 45.8'	111º 57.6'	3.70	346.95	347	-0.05	0	0
# 2	67º 46.4'	112º 00.0'	1.09	303.43	303	0.43	0	6
# 3	67º 55.0'	112º 38.6'	16.92	300.55	301	-0.45	0	0
# 4	67º 57.6'	112º 38.6'	2.60	0.00	0	0.00	-6	0
# 5	68º 03.8'	112º 57.8'	9.50	310.75	311	-0.25	-6	0

Notes: The Rhumb Line distances and bearings from the latitude and longitude coordinates were calculated using Norcom Technology, Geodetic software version 3.2.11.99. Rhumb Line Distance is in nautical miles. The Seconds Difference column compared the previous Table with this Table.

Federal Court exhibit number 140 provided a screen grab of the Transas Navi-Sailor 3000. Unfortunately, there appears that a blunder was made entering the chosen geographical coordinates for Waypoint #5 into the ECS. A visual inspection by the bridge officers at the time would not have highlighted the deviation.

Table – Exhibit Number 140 – Screen Grab of Transas[150]

Point	Latitude	Longitude	Rhumb Line Distance	Heading degrees True			Seconds Difference	
				Calculated	Exhibit	Diff	Latitude	Longitude
# 0	67º 42.2'	111º 55.4'					0	0
# 1	67º 45.8'	111º 57.6'	3.70	346.95	347	-0.05	0	0
# 2	67º 46.4'	112º 00.0'	1.09	303.43	303	0.43	0	0
# 3	67º 55.0'	112º 38.6'	16.92	300.55	301	-0.45	0	0
# 4	67º 57.6'	112º 38.6'	2.60	0.00	0	0.00	0	0
# 5	68º 03.8'	112º 57.6'	9.44	311.05	311	0.05	0	12

Notes: The Rhumb Line distances and bearings from the latitude and longitude coordinates were calculated using Norcom Technology, Geodetic software version 3.2.11.99. Rhumb Line Distance is in nautical miles. The Seconds Difference column compared the previous Table with this Table.

17. Relationship of Planned Tracks and Track of Soundings to the Grounding Location

According to the 2012 TSB Report the rock shoal was located on the planned track of the **Clipper Adventurer**.[151] However, this determination was based on the incorrect track established by the TSB, instead of the coordinate listing provided in Federal Court exhibit number 140 which should have been available to the TSB.[152] Using the grounding location provided in Federal Court exhibit

[149] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 139, "MaxSea Route 871 Print Out – Port Epworth to Coppermine", page 2. The copy for this page was a bit blurry although readable and this was the clearest copy available.
[150] Federal Court List of Exhibits, Court Number T-901-11, Exhibit number 140, "Transaas (sic) – Port Epworth to Coppermine – 20100827 August 27, 2010 Electronic chart showing planned root (sic)", page 2.
[151] 2012 TSB Report, section "Chart Dealers and Chart No. 7777, paragraph 2.
[152] Private communications by the author via an Access to Information Request submitted to the TSB and

number 141 and the Waypoints #4 and #5, the perpendicular distance from each of the Waypoint Selections to the grounding location was as shown in the Table below. The planned track established by Waypoints #4 to #5 for all of these perpendicular distances were to the West to the actual grounding location.

Table – Perpendicular Distance from Leg #4 to #5 to Exhibit Number 141 (metres)

Waypoint Selection	Perpendicular Distance	Differences
Exhibit 21 – Voyage Planning Form – 03 August 2010	292.0	
Exhibit 139 – Screen Grab of MaxSea	151.5	140.5
Exhibit 140 – Screen Grab of Transas	142.5	9.0

Note: The latitude and longitude coordinates were converted to UTM coordinates using Norcom Technology, Geodetic software version 3.2.11.99. Perpendicular Distance and Differences distance in metres.

Unfortunately, the various changes to the planned track that occurred on or about 27 August and the blunder entering the longitudinal value for Waypoint number 5, brought the **Clipper Adventurer** closer to the rock shoal and the grounding location. If the **Clipper Adventurer** had actually followed the Transas planned track between Waypoints #4 and #5, the minimum depth would have been 6.1 metres, enough to allow the for the **Clipper Adventurer** draft of 4.7 metres.[153]

Why the **Clipper Adventurer** was off course does not appear to have been examined in either the 2012 TSB Report or during the Federal Court trial. For whatever reason, the **Clipper Adventurer** deck officers did not use the off track alarms available via the ECS or the Anschütz autopilot, or these alarms were switched off.

The centre for each individual sounding in the area of the grounding was taken from the Electronic Navigation Chart (ENC) version of CHS Chart 7777 edition 1997.[154] The perpendicular distance from the Transas planned track between Waypoint #4 and #5 to the centre of each individual sounding were computed using Universal Transverse Mercator grid coordinates, which over these short distances would have not have caused any distortion. The Grid heading in degrees between each set of individual soundings is also provided.

Table – Perpendicular Distances from Leg #4 to #5 to Track of Soundings Water Depths

Point	Depth (metres)	Latitude (North)	Longitude (West)	Grid Dist. (metres)	Grid Hdg (degrees)	Distance off Leg #4 to #5
A	84	67º 57’ 40.58”	112º 38’ 30.36”			150.0
B	88	67º 58’ 01.55”	112º 39’ 26.10”	918.0	316.6	211.5
C	29	67º 58’ 26.77”	112º 40’ 28.37”	1,065.1	318.7	323.0
D	71	67º 58’ 55.66”	112º 41’ 10.90”	1,022.3	332.6	671.5
E	104	67º 59’ 20.67”	112º 42’ 11.77”	1,049.0	319.2	789.0
F	126	67º 59’ 37.81”	112º 43’ 39.43”	1,148.4	299.1	519.5
G	57	67º 59’ 54.37”	112º 44’ 57.15”	1,038.3	301.2	312.5
H	64	68º 00’ 05.21”	112º 46’ 15.66”	971.6	291.8	-34.0
			Average	**1,030.3**		

Note: The latitude and longitude coordinates were converted to UTM coordinates using Norcom

answered on 12 May 2017, as well as the same information was available as Exhibit number 140.

[153] Private communications by the author with Ian Church dated 12 May 2017.

[154] Private communications by the author with Ian Church dated 11 May 2017.

Technology, Geodetic software version 3.2.11.99.

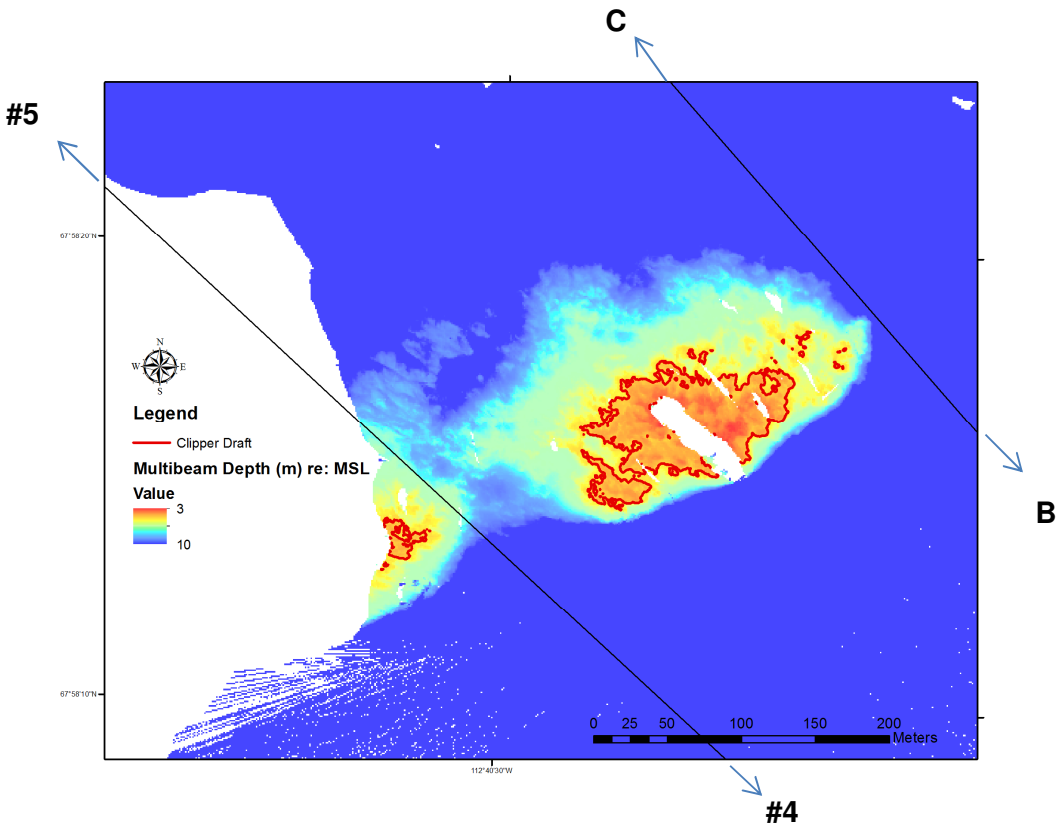
The perpendicular distance from the track of soundings in question between water depth Points B and C to the Federal Court exhibit number 141 grounding location was 147.5 metres. The track of sounding in question was to the East to the actual grounding location.

Consequently, the **Clipper Adventurer** was neither following the Transas planned track nor was the vessel following the track of soundings. The course taken was in between, where the former and the latter offered safe passage. Unfortunately, the course taken by the **Clipper Adventurer** took the vessel over the shallowest part of the rock shoal.

Based on the multibeam echo sounder survey carried out by the **Amundsen Barge** the heading of the **Clipper Adventurer** when aground was 309.8 degrees True.[155] The Figure below shows the **Amundsen Barge** multibeam echo sounder data in the grounding area with the 4.8 metre contour. The line in the lower portion of the Figure is the Transas planned track between Waypoint #4 and #5. The line in the upper portion of the Figure is the line between water depth points B and C.

Figure 12 Grounding Area[156]

Grounding Area with Waypoints #4 and #5 and Water Depth Point B to C



[155] Private communications by the author with Ian Church dated 11 May 2017.
[156] Image provided to by the author with Ian Church on 15 May 2017. The rectangular white from on the rock shoal is the outline of the hull of the **Clipper Adventurer**.

18. Forward Looking Sonar

The **Clipper Adventurer** could also have been handicapped by an inoperable forward sonar, which when functional would have provided some warning of the shoal. "In 2006, the **Clipper Adventurer** was equipped with a [FarSounder FS-3] 3–dimensional forward looking sonar that was fitted into the bulbous bow and was mainly used to determine ice–aging. This unit can be used to detect hazards, notably when operating in inadequately surveyed waters. The unit would have enabled a range of 330 metres with a 90° field–of–view, or 440 metres with a 60° field–of–view."[157]

The FarSounder FS-3 could be coupled with an electronic navigational chart system so users could not only see obstacles and the seafloor ahead of them, but also easily see their geographic position by being interfaced to a ECS with C-Map vector charts. The FarSounder FS-3 generated a complete 3-D image on one ping every two or three seconds.[158]

The FarSounder FS-3 transducer would be connected by a custom cable to a power module about the size of a briefcase. The user interface ran Sonasoft, a Windows XP-based graphical program that could be run on a laptop or marine computer. The user-friendly, 3-D volumetric navigational display provided vessel location on electronic charts, depth profile, colour mapped depth scale, user-selectable depth and detection thresholds. It could also display GPS, vessel speed and heading data. The system could easily be set up so alarms would sound if obstacles or particular depths were encountered.[159]

However, in the spring of 2010, the unit was found to be not operational, and during a subsequent dry docking the cabling to the unit was extensively damaged but only discovered once out of dry dock.[160] To be useful the forward looking sonar display would have to be incorporated into the bridge management system so that the display was capable of being continuously monitored by the bridge officer.[161]

19. Object Avoidance

Even if the forward looking sonar have been operational in 2010, at 13.9 knots the maximum ranges would have only allowed a total reaction time of 46 seconds or 61 seconds before impact,[162] for the possible forward looking sonar maximum ranges of 330 or 440 metres respectively. The **Clipper Adventurer** had 2 controllable–pitch propellers and 2 semi–balanced articulated flap rudders for improved vessel manoeuvrability,[163] both of which would have helped reduce the vessel

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[157] 2012 TSB Report, section "Factual Information – Forward Looking Sonar", paragraph 1. During the oral deposition of Captain Kenth Grankvist on 24 July 2012 at page 151, he stated he was not aware the **Clipper Adventurer** had a forward looking sonar as during all of his time onboard over the preceding years the equipment had not been operational.

[158] Online at FarSounder, Media Coverage, page 3, "FS-3 featured in The Yacht Report, Marine News, Ocean News and Technology, and Maritime Security Source Book" posted date not provided, paragraph 9 at: http://www.farsounder.com/media-coverage/fs-3-featured-yacht-report-marine-news-ocean-news-and-technology-and-maritime (last accessed: 28 March 2018).

[159] *Ibid.*, paragraph 12.

[160] 2012 TSB Report, section "Factual Information – Forward Looking Sonar", paragraph 2.

[161] R. Glenn Wright and Ian Russell, "Use of Navigation Sonar in Maritime Frontier Exploration", Soundings, Issue 71, Spring 2017, pages 33 to 36.

[162] 330 metres at 13.9 knots or 7.15 metres / second = 46 seconds; 440 metres at 7.15 metres / second = 61 seconds. At 6 knots the times would have been 107 and 142 seconds respectively. 2012 TSB Report, section "Analysis – Forward Looking Sonar – Status", paragraph 1 allowed 48 seconds at 13.9 knots for 330 metres.

[163] 2012 TSB Report, section "Factual Information – Description of the Vessel", paragraph 1.

speed if an object ahead had been observed.

There are many variables to consider when trying estimating a vessel's stopping distance such as the size (length, beam, draft and subsequent cross sections) of the vessel, engine type and capacity, loaded or light ship, the vessel windage, original speed, weather conditions, water currents, trim, hull hydrodynamics including ship fouling, to name some of the most important. Although, the faster the vessel is travelling, the quicker the speed comes off due to water pressure, even if the forward looking sonar had been operational, had provided an audio and a visual alarm, and the bridge officer had acted immediately, there would have been insufficient time to stop the **Clipper Adventurer** before the grounding, given the time to impact. The water depth of 87 metres would not have caused any drag to reduce the vessel speed.

Possibly a "crash stop" could have been employed, where the engine is switched from full ahead, to stop, and then to go to full astern. During such a crash stop, the engine controls on the bridge would have to be transferred immediately to the engine room. The engine room officers and staff would then have to carry out various procedures to stop the engines and put them into reverse. Some of the engine safeties would need to be bypassed to avoid tripping an engine(s) in the middle of the emergency.

Generally, the only time this would be done deliberately, would be when the vessel was a new build on sea trials, before leaving the builders yard and before the owner took delivery, as this manoeuvre could damage the engine(s). The maximum vessel stopping distance based on international shipping regulations, stipulates that a vessel must be able to stop within fifteen ship lengths. Allowing for 30 seconds for the engines to run from full ahead to full astern, then to come to a full stop would have taken up to 7.2 minutes,[164] well in excess of the time available.

Generally, turning out of trouble would be far more preferable than to trying to stop the vessel. However, with only some 330 or 440 metres before impact, there were very limited options. The bridge officer could have veered sharply to port or starboard, even at reduced speed, without any clear knowledge of what other obstacles could be encountered, whichever direction was taken. The **Clipper Adventurer** was equipped with a forward through hull thruster, but this would not have been running whilst in transit, and would have taken precious minutes to start up, consequently the forward thruster could not have been used to help turn the head of the vessel.

If a sharp turn had been taken, this could have exposed one side of the vessel to extensive damage. Depending on the angle at which the turning vessel struck the rock face, the vessel could have mounted the rock shoal or run along the rock face for some time. If the later, the vessel could have been severely holed, with the eventual possibility of sinking. Consequently, in some respects, going aground as the vessel did was perhaps a better option than tuning away from the danger, given the vessel's speed.

In addition, the master did not make use of one of the vessel's zodiac, mounted with a portable echo sounder, to ensure sufficient depth was available, which had been done in the past.[165]

[164] Private communications by the author with Interocean Canada on 24 April 2017. At 6 knots coming to a full stop would have taken up to 3.6 minutes.
[165] 2017 F.C, paragraph 102. There were 4 zodiacs carried on the upper deck of **Clipper Adventurer**.

20. Past Arctic Cruises

On 4 September 2008, the Russian "passenger vessel **Akademik Ioffe** transited south into Port Epworth along the same line of soundings as the **Clipper Adventurer** was to later follow".[166] The vessel was not aware of NOTSHIP A102/07. In September 2008, the NOTSHIP A102/07 was no longer being broadcast by radio but was available by other means, notably online.[167] This vessel was the only other ship of any size to have called at Port Epworth in the 18 years prior to the grounding.[168]

The position given in the 2012 TSB Report for the **Akademik Ioffe** was 67º 58.4'N, 112º 40.0'W and the vessel was supposedly following the track of soundings in question.[169] This position was 390 metres north east of the position given for NOTSHIP A102/07, which would have been further east of the track of soundings in question. However, at least the vessel passed the rock shoal safely, if unknowingly.

The 2012 TSB Report noted that "until 1988, there were few passenger ships voyaging to the Arctic. In the years 1980 to 1987, there were only 4 Arctic passenger voyages conducted by one passenger vessel. However, [from 2006 to 2012], there have been a total of 105 distinct cruise ship voyages conducted by 7 different passenger vessels. During this time, there has been an average of 9 passenger vessels per year conducting a total of 15 voyages per year.[170] There were 22 cruise ship voyages in 2010,[171] and these numbers have continue to grow since.

This was not the first cruise ship to go aground in the Canadian Arctic. On 26 August 1996, the expedition cruise ship **Hanseatic** of the Hanseatic Tour cruise line went aground on a sand bar in the Simpson Strait near Gjoa Haven, Nunavut.[172] This was in a similar area to the grounding of MV **Nanny**.

The 1998 TSB Report stated that the **Hanseatic** grounded because the bridge team did not strictly adhere to the plan that had been prepared for navigating the vessel through the strait. In addition, reliance upon a navigation buoy left in the strait from the previous navigation season contributed to the grounding.[173] No case was brought against the Crown by the Hanseatic Tour cruise line, which sold itself to the Hapag-Lloyd Cruise line in 1997.

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[166] 2017 F.C., paragraph 27.
[167] 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", paragraph 6.
[168] 2017 F.C., paragraph 27.
[169] 2012 TSB Report, section "Canadian Hydrographic Service – Discovery of the Shoal", paragraph 6.
[170] 2012 TSB Report, section "Safety Action – Identifying Navigational Hazards in the Arctic, I. Communication of Notices to Shipping in the Arctic", paragraph 4. Clarification of time period based on communications with TSB Media Relations on 13 April 2017.
[171] Adrianne Johnston et al., poster session "Climate Change and Cruise Tourism: The Readiness of Nunavut for Future Cruises", ArcticNet Scientific Meeting 2010, Ottawa, Ontario, Canada, Proceedings, page 130.
[172] TSB, Marine Investigation Report M96H0016, Grounding - Passenger vessel **Hanseatic**, Simpson Strait, Northwest Territories (henceforth 1998 TSB Report). Online at TSB, Marine, Investigation Reports, Search **Hanseatic** at: http://www.tsb.gc.ca/eng/rapports-reports/marine/1996/m96h0016/m96h0016.asp (last accessed: 28 March 2018).
[173] 1998 TSB Report, section "3.2 Causes", paragraph 1.

21. Subsequent Arctic Cruises

From 16 August to 16 September 2016, the large scale (length 253 metres) cruise liner **Crystal Serenity** traversed from Anchorage, through the Bering Strait, into the Chukchi and Beaufort seas, through the Northwest Passage, past Greenland, down the Eastern Seaboard to New York City taking 32 days to complete the cruise.[174] This cruise was repeated from 15 August to 16 September 2017.[175] The **Crystal Serenity** was the first large-scale cruise liner to transit the Northwest Passage, and carried more than 1000 passengers and more than 650 crew members.[176] The **Crystal Serenity** was built with an ice-strengthened hull that's one level below an icebreaker.[177]

Crystal Cruises carried out comprehensive planning, and logistics were put in place to ensure a safe and enjoyable passage. The ship was outfitted with a forward looking sonar, ice searchlights, ice radar, and a thermal imaging system were installed. There were also ice navigation specialists onboard supported with satellite based ice imagery equipment. **Crystal Serenity** travelled with a chartered icebreaker Royal Research Ship (RRS) **Ernest Shackleton**, operated by the British Antarctic Survey, with two helicopters, based on the ice breaker, available to scout ahead to examine the ice coverage.[178]

The **Crystal Serenity** and the ice breaker both used low-sulphur diesel, rubbish was stored or incinerated on board, and waste water was not discharged until the ship is at least 12 nautical miles from shore.[179]

In March 2017, the captain of the **Crystal Serenity** stated that "the transit through the Northwest Passage was planned with an average speed of around 12 knots, plus / minus. On some legs the speed was less, some a bit more. We had many reasons for sailing at low speeds. The main reason being to ensure that the vessel had plenty of time to safely navigate areas with potential high ice concentration, as well as to cruise most of the passage with only two of our six engines running in order to ensure our air emissions were kept at a minimum."[180]

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[174] Online at Business Wire, "Mission Accomplished: Crystal Serenity Completes 32-Day Northwest Passage Journey" posted on 16 September 2016, paragraph 1 at: http://www.businesswire.com/news/home/20160916005705/en/Mission-Accomplished-Crystal-Serenity-Completes-32-Day-Northwest (last accessed: 28 March 2018).

[175] Online at Serenity Cruises, "Mission Complete: Scenes from the 2017 Northwest Passage" posted 19 September 2017 at http://blog.crystalcruises.com/tag/northwest-passage/ (last accessed: 28 March 2018).

[176] Denis Hains, Hydrographer General of Canada, oral presentation "Arctic Canada: Cold, Hard Facts" at U.S. HYDRO Conference, Galveston, Texas, 21 March 2017, slide 8. Crystal Cruises could not provide more accurate persons on board numbers.

[177] Online at CBC News, Canada, North, "1st Cruise Ship set for Northwest Passage clears Alaskan Inspection" posted on 24 June 2016, section "Abandon Ship Drill a Success", paragraph 5 at: (http://www.cbc.ca/news/canada/north/crystal-serenity-alaska-inspection-1.3651215 (last accessed: 28 March 2018).

[178] Online at Business Wire, "Mission Accomplished: Crystal Serenity Completes 32-Day Northwest Passage Journey" posted on 16 September 2016, paragraph 3 at: http://www.businesswire.com/news/home/20160916005705/en/Mission-Accomplished-Crystal-Serenity-Completes-32-Day-Northwest (last accessed: 28 March 2018).

[179] Online at BBC, UK, Science & Environment, "UK-funded Ice Breaker in 'Elite' Arctic Tourism Row" posted on 17 June 2016 at: http://www.bbc.com/news/science-environment-36541583 (last accessed: 28 March 2018).

[180] Private communications by the author with Crystal Cruise Line dated 28 March 2017.

22. Improved Vessel Navigation and Pilotage

"Starting with the 2012 Arctic navigation season, the Canadian Coast Guard will utilize the mandatory NORDREG vessel reporting system to proactively provide all vessels with a list of NOTSHIP's that are applicable to Arctic waters north of 60 degrees" prior to their entrance into Canadian waters.[181] NORDREG means the Northern Canada Vessel Traffic Services Zone.[182]

From "2013, the CHS will establish a procedure to update navigational charts north of 60 degrees when a hazard to navigation is discovered by a credible source, as per international protocols."[183] Hopefully these more active measures will help minimize the possibility of future groundings.

As the North West Passage becomes increasingly attractive for shipping companies as a shorter route from Europe to China, there will be increased shipping traffic in the Arctic. Unfortunately, many of the mariners engaged in these new routes will have little understanding of the North West Passage route and the circumstances related to the surveying of those waters. "The master of the **Clipper Adventurer** had been to the Arctic 60 times and … he seems to have met the requirements of an ice navigator for the [Arctic] waters, thus being in compliance with Canadian maritime law, but there was no requirement for the ice navigator to have local knowledge of these waters."[184]

There is no compulsory pilotage regime in the Canadian Arctic. It would be ideal if a marine pilot was employed, whose underlying skill in having knowledge of the local waters was there to provide the Master with navigational advice.

23. Summary and Conclusions

With any vessel grounding or offshore incident, but especially where litigation could be involved, the survey, navigation and positioning issues should be considered along with any legal liability issues to ensure the best case is put forward.

The survey, navigation and positioning issues which are related to the grounding of the **Clipper Adventurer** were as follows:

- The master decided to sail at 13.9 knots in a known limited surveyed area, when the voyage plan only required 6 knots which would appear to be arguably reckless.
- The information in the CHS Chart 7777 edition 1997 source classification diagram does not appear to have been appreciated by the bridge team.
- The track of soundings in question was only followed in a general manner, where part of the planned track was 1.2 kilometres from the track of soundings in question.
- Had the voyage continued, the **Clipper Adventurer** would have sailed 10.5 kilometres over an area which had never been surveyed.
- The Voyage Planning route was not followed but another was created on or about 27 August

[181] 2012 TSB Report, section "Safety Action, I. Communication of Notices to Shipping in the Arctic", paragraph 7.
[182] Online at Justice Laws, Consolidated Regulations, Northern Canada Vessel Traffic Services Zone Regulations, SOR/2010-127 at: http://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-127/FullText.html (last accessed: 28 March 2018).
[183] 2012 TSB Report, section "Safety Actions, II. Chart Corrections in the Arctic", paragraph 6.
[184] Online at Canadian Sailings, Arctic Shipping, "The Case of **Clipper Adventurer**: Between a Rock and a Hard Place" posted on 12 March 2017, page 27 at http://www.canadiansailings.ca/the-case-of-clipper-adventurer-between-a-rock-and-a-hard-place/ (last accessed: 28 March 2018).

and when input into the ECS the longitudinal coordinates for the planned track alongside the rock shoal was input incorrectly.
- The grounding location provided by the 2012 TSB report and in the Federal Court decision did not match the actual grounding location.
- At the time of the grounding the **Clipper Adventure** was off track by 142 metres to the East. If the planned track had been followed the vessel would NOT have gone aground.
- At the time of the grounding the **Clipper Adventure** was not following the track of soundings but was 147 metres to the West. If the planned track of soundings had been followed the vessel would NOT have gone aground.
- If operational, the forward looking sonar would not have provided sufficient time to act as the **Clipper Adventurer** was sailing at 13.9 knots.
- A pilotage regime may be necessary as more vessels use the North West Passage.

Going outside of a channel or a track of soundings is the prerogative of the captain, but the consequences of that decision are the captain's to bear.

24. Acknowledgements

The author wishes to thank Jeffrey Smith, Norman Paterson School of International Affairs, Carleton University, Ottawa and Ian Church, Assistant Professor, Ocean Mapping Group, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton for reviewing this paper.

The author wishes to thank the following for their help providing information for the paper in alphabetical order:
- Chris Hill of Canatec Consultants, Calgary
- Anne Lomas, Library Assistant at Library Services, Fisheries and Oceans Canada, Sidney
- Madhan Mohan of Interocean, Aberdeen.
- Emily Price and Catherine Doré at the Federal Court Registry, Ottawa
- Rosemary Richards, ATIP Analyst at TSB Access to Information and Privacy, Ottawa
- Sophie Wistaff, Media Analyst at TSB Media Relations, Ottawa

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