POAC'25
St. John's, Newfoundland and Labrador, Canada

Proceedings of the 28th International Conference on Port and Ocean Engineering under Arctic Conditions
Jul 13-17, 2025
St. John's, Newfoundland and Labrador
Canada

# Clyde River Small Craft Harbour – Embracing the Challenges of High Arctic Marine Engineering

David D. Parsons P.Eng.[1], Amaury Camarena P.Eng.[2], Kevin K. Bezanson P.Eng.[2], Alexander T. Wilson P.Eng.[2], George Comfort P. Eng[3]
[1]CBCL Limited, Saint John, New Brunswick, Canada
[2]CBCL Limited, Halifax, Nova Scotia, Canada
[3]G. Comfort Ice Engineering Ltd, Ontario, Canada

## ABSTRACT

Clyde River is a small coastal community located along the northeastern shore of Baffin Island in Nunavut. As part of Federal Government's commitment to Canada's Arctic, the Clyde River Small Craft Harbour brings essential investment in marine infrastructure to develop commercial and community fishery opportunities.

This paper reviews the challenges encountered during the design and construction phases associated with typical high arctic logistics, along with added complications of COVID and a changing climate. Specifically, the study reviews design challenges faced with limited baseline data, community, and cultural expectations for working in Nunavut, geotechnical field programs with melting ice, community and public safety and utilizing community infrastructure, geotechnical considerations, coastal and ice engineering, microbial corrosion, and environmental permitting and reporting. The paper also details additional considerations encountered with construction season variability and working around an active marine environment.

## INTRODUCTION

The design of small craft harbours (SCHs) in the high arctic regions present a unique set of challenges that are different than what is typically encountered in other parts of Canada. Currently, there are very few examples of these SCHs that have been designed and constructed in the arctic; therefore, obtaining details on these projects can be very valuable to designers. This paper will discuss these challenges and provide a general overview on information that may be of use to anyone that is carrying out similar work in the future.

## BACKGROUND

Clyde River is a community in Nunavut located on Patricia Bay, along the eastern shores of Baffin Island, and located about 750km north of the capital, Iqaluit. Clyde River has a population of 1053 (Statistics Canada 2016), and like other Nunavut communities, it is heavily dependant on marine access for traditional hunting, gathering, marine transportation and delivery of bulk goods. The Hamlet is considered a fly in fly out community with access provided year-round by the local airstrip and has bulk shipping provided during the summer months from sea lift operations. Bulk deliveries arrive twice during the later summer months, with the ship mooring offshore and bulk goods lowered onto a barge. Bulk goods offloading takes place at the community sea lift ramp, with fuel delivery occurring with large vessels mooring offshore.

The community is heavily dependant on marine access with a large portion of community members having boats. There is approximately one boat for every three homes in Clyde River; however, there is limited safe shelter for storing them in the water. Most vessels range from wooden freighter canoes to aluminum boats and vary in length from 6-9m. Their shallow draft allows these vessels to access the existing natural harbour. The community constructed a small area protected by boulders that allows a small number of boats (10-12) to be tied off in the water, but was insufficient during larger storm events and vessels have been damaged over time. Currently the community also does not have any infrastructure to support inshore fishing vessels to offload catch or accommodate the larger draft of commercial fishing boats.

In 2018, the Government of Canada identified funding for four (4) small craft harbours in Nunavut, one of which being Clyde River as part of the Inuit Benefit Agreement for the establishment of the Tallurutiup Imanga National Marine Conservation Area (Parks Canada, n.d.). A previous feasibility study (Advisian, 2020) reviewed various harbour layouts in 2018-2019, and in 2020, the project was awarded to the Canadrill-CBCL Joint Venture to complete the detailed design and construction oversight.

## HARBOUR LAYOUT

The layout and design criteria for the harbour was established by the Department of Fisheries and Oceans (DFO) and refined through a feasibility study that DFO oversaw. The study (Advisian, 2020) identified various aspects of the project including community needs with regards to the number/type of vessels that the facility should accommodate, potential quarry locations to obtain the various stone sizes needed, and high-level concept layouts of the SCH. The design criteria required a 30m fixed wharf with 5m draft depth to accommodate inshore commercial fishery, and to provide inner harbour floats to accommodate a total of 140 private vessels, 70 current and 70 future. Draft depth required for the inner harbour was to be -1.5m CD (Chart Datum). See Figure 1.

Figure 1. Harbour Layout, developed by CBCL

## ICE ENGINEERING

As with every northern marine project ice played a major role in the design of this site.

### Ice Design Criteria

As ice conditions vary over the winter, ice actions had to be considered separately for the following stages:

- Freeze-up - Ice loads at this time resulted from ice movements into the breakwaters and the fixed wharf area. Winds were the probable environmental agent causing ice movements. The most severe ice action or load at freeze-up was generated by the thickest ice attained before

the ice became immobile during the mid-winter period. As the ice temperature was colder at freeze-up, it was significantly stronger compared to the other stages.
- Mid-winter - During this stage the ice was essentially static. Ice temperature changes were the main, and probably only, mechanism by which ice loads developed.
- Break-up - Ice loads during this time resulted from ice movements contacting the structures, again most likely caused by winds. In contrast to the freeze-up period, the ice was thicker at break-up; however, it was weaker.

The type of ice was another important feature that was considered. The following ice types were included in the analyses:

- Sheets of first-year ice - The ice cover in Clyde River fjord was considered generally devoid of major roughnesses (e.g., large ridges) so level, first-year ice sheets were the main ice feature of concern. Ice design criteria for the SCH were developed considering this type of ice feature.
- Icebergs – It was identified during the community consultations that icebergs have been rarely seen in this area. Based on bathymetric limits at the SCH, it was determined that only iceberg growlers would be able to reach the SCH site.

For the SCH at Clyde River, the design return period used was set at 100 years.

**Ice Load Analysis Approaches**

Loads produced by sheet ice were evaluated using algorithms provided in ISO 19906 (ISO, 2018), Standard, considering the limited exposure of the site. Loads were evaluated using a time step impact analyses taking into account the limited energy inherent in a drifting iceberg growler. It was determined that growlers will not pose a significant threat because the local bathymetry will prevent large iceberg masses from reaching the SCH. As a result, growlers would only be capable of producing small, low-energy ice impact forces, which did not govern the design ice case.

It was further concluded that impacts by growlers would not be a critical design case because:

- The return period for an impact event is substantially more than 100 years; and
- The loads produced by an iceberg growler would be small as they would develop contact areas substantially less than the size of an individual armour stone.

**Ice Loads and Actions on the Breakwaters and the Fixed Wharf Structure**

The ice loads on the breakwaters were evaluated for the following two cases:

- Breakwater face exposed to Clyde River Fjord. For this case forces developed from ice impact against the rock slope was the critical case; and
- Breakwater face inside of the SCH. It was determined that forces created by thermal movements were the governing loading mechanism for the large-scale global loads.

The required armour stone size was evaluated using the method described in CSCE document (Comfort, 2024). As expected, the armour size requirements varied between the exterior and the interior portions of the breakwaters as follows:

- Exterior portions of the breakwaters. It was recommended that the median armour stone weight in this location be 2.4 tonnes, which is equivalent to an armour stone size having principal dimensions of about 1.1 m.

- Interior portions of the breakwaters. It was recommended that the median armour stone weight in this area be 1 tonne, which is equivalent to an armour stone size having principal dimensions of about 0.82 m.

The fixed wharf along an interior breakwater was evaluated separately as it was a special case. The work included assessments of global and local ice loads. The governing large-scale global loads was determined to be produced by thermal ice loads in mid-winter period. The highest local ice contact pressures on the wharf would be exerted during the breakup stage by ice floe impacts originating from within the SCH.

**Ice-Out from the SCH in Spring**

Due to the layout of the breakwaters, the possibility was considered that ice may be locked inside the SCH, possibly delaying ice-out thus decreasing the amount of time that the facility would be in use. This was assessed by considering various scenarios and comparing the SCH design to other Arctic harbour layouts. The final arrangement of the facility was finalized based on this information.

**Potential Effects of Climate Change**

Potential climate change scenarios were considered with respect to their effect on the ice design criteria for the site. The design criteria used considered potential climate changes either because it was considered to be sufficiently conservative, or the event was too rare compared to the design return period. As an overall conclusion, it was expected that the ice design criteria for the SCH would remain reliable in the future should climate changes occur.

## RIVER HYDRAULIC ASSESSMENT FOR ARCTIC CLIMATE

A major concern related to the sedimentation study was the impact of the sediment accumulation at the mouth of the adjacent river on the SCH site. An additional challenge was the limited hydraulic information that existed for Clyde River.

As there is no measured flow data at the site, it was necessary to identify a surrogate station that was representative of the Clyde River flows. A hydrologic comparison was conducted on various candidate stations, and the Apex River, Iqaluit, NU was chosen because it had similar watershed characteristics and had over 20 years of flow data, which was adequate for statistical analyses.

On the Apex River, it is understood that the largest bed material is entrained in quantity only when the overbank flow occurs (Carling, 1988). Since the highest flow at the Apex River station was recorded on June 19th, 1994, a two-week period from June 11th, 1994, to June 24th, 1994, was selected to derive the prorated flow for Clyde River.

Potential sources of sediment to the SCH include the surrounding shoreline, offshore sources, and sediment transported by the river. The current riverine sediment flux is believed to be small; however, climate change is expected to cause an increase in riverine fluxes. Previous literature (Holmes et al. (2002), Syvitski (2002), Hasholt et al. (2006)) and empirical equations (Milliman and Syvitski (1992), Syvitski et al. (2003)), were used to estimate possible scenarios of riverine sediment flux. To understand how the sediment could affect the SCH, the annual sediment flux estimates were compared against the remaining space available offshore for alluvial fan accretion. Based on prorating watershed areas, the annual sediment flux estimates calculated for Clyde River were 515,000 kg km-2 yr-1and 196,000 kg km-2 yr-1 based on Milliman and Syvitski (1992) and Syvitski et al. (2003) respectively.

Climate change is expected to have a multitude of impacts on the riverine sediment flux, which can be broadly separated into potential impacts on hydrology and impacts on sediment supply. Although the existing riverine sediment flux at Clyde River is thought to be small, likely because of supply limitations, climate change is projected to increase sediment flux by 122% or up to two orders of magnitude more.

Sediment samples from the site show that median grain sizes are between 0.19 mm to 0.75 mm, which indicated that the sediment in the region ranges from fine to coarse sand. Surficial sediment samples collected were validated against a surficial geology map of Clyde River developed by Smith, et al. (2012).

Based on findings from the hydraulic study, the following inputs were provided to develop the coastal sediment transport model to understand how the sediment could affect the SCH:

- A two-week discharge time series was derived from the Apex River flow gauging station and prorated to Clyde River with the highest flow of 54.5m3/s.
- Low, medium, and high scenarios of annual sediment flux for two-week time series are in an order of magnitude of 1,000's of kg yr-1 km-2, 10,000's of kg yr-1 km-2, and 100,000's of kg yr-1 km-2, respectively.
- Low, medium, and high scenarios of annual sediment concentrations for two-week time series are 15 mg/L, 140 mg/L, and 2,400 mg/L, respectively.
- The median grain size used for low, medium, and high scenarios is 0.3mm.

A PCSWMM hydraulic model was also developed for Clyde River as part of this work using data from Environment and Climate Change Canada (ECCC) (2020), site photos, aerial photography, surveyed topography at the river crossings, existing drawings for the Clyde River bridge, high-resolution contours, and digital surface model (ArcticDEM) information to determine the effects of river flows on the bridge structure spanning Clyde River that is used to access the quarry.

## COASTAL ENGINEERING

The coastal work focused on a design that developed safe access between land and sea, provided a protected low maintenance harbour, aided community fish harvesting, and bolstered commercial fisheries opportunities. It also addressed concerns related to sediment that settled at the mouth of the adjacent river that could potentially transport to the site thereby increasing the frequency of dredging that would be required at the SCH. To accomplish this, a Coastal Engineering review (*200235-RE-001-Modelling, CBCL, 2021*) was carried out as part of this work that utilized numerical modelling tools to assess coastal conditions, including waves, hydrodynamics, and sediment transport, which formed the basis of the harbour layout and identified key features such as breakwater structures, revetments, shore protection and location of the sealift ramp, etc. As previously identified, the proposed SCH layout included two large breakwater structures, floating docks, a community boat launch, a fixed wharf structure, and defined dredging limits within the SCH entrance channel to facilitate navigation.

The metocean, wave, hydrodynamic, and sediment transport analyses revealed that winds from the south and southwest significantly governed the harbour design, while projected sea level changes and reduced sea ice cover were not expected to majorly influence operations. The preferred SCH layout provides protection from waves, with low tidal currents and sufficient flushing times to maintain water quality. Sediment transport, including contribution from Clyde River, was found to be limited, and dredging was deemed unlikely to be required within the first 15 years of operation. The wave modelling demonstrated that the geometry of Patricia Bay prevented most offshore wave energy from affecting the SCH site, and the hydrodynamic modelling indicated that peak tidal currents would remain relatively low throughout the SCH footprint.

Design recommendations include specific breakwater slopes and armour stone sizing to accommodate wave and ice interactions, which were identified previously. During the design process, modifications to the SCH layout, such as refining the location, shortening the northern breakwater, and adjusting the sealift breakwater, were proposed to enhance accessibility and reduce costs. The final layout incorporated feedback from community residents, DFO-SCH, Public Works and Government Services Canada (PSPC), sealift operators, and prospective SCH users. The final design provided safe and efficient operations while minimizing environmental impacts and accommodating future changes in coastal conditions.

## GEOTECHNICAL INVESTIGATION

### Geotechnical Program

The geotechnical investigation was conducted by Canadrill Limited's Geotechnical Division (CGD) and focused on three distinct areas: the quarry, the harbour uplands, and the harbour water lot *(Canadrill Limited Geotechnical Division, 2021)*. The primary objectives were to assess the surface and subsurface conditions and provide geotechnical recommendations for the design and construction of the harbour development.

The quarry investigation took place in the Fall of 2020, when the area was partially snow-covered. This made obtaining visual observations and drilling operations difficult. From the drilling results, it was concluded that the quarry bedrock consisted of very strong granitic gneiss with unconfined compressive strength ranging from 108 to 202 MPa. A key component of the quarry investigation was determining what yield rates and stone sizes that could be sourced at the quarry. As the site was used previously, a ten (10)m exposed face was visible which made it possible to see the depth of weathering and bedding planes by using existing photographs and site observations. From this information estimates were developed for various yield rates and stone sizes.

The harbour uplands investigation was carried out in October of 2020, and involved drilling four air-rotary boreholes to depths between 10.1 and 12.0 meters. This phase also included the installation of multibead thermistors to monitor ground temperature profiles. The harbour uplands primarily contained frozen silty sand with gravel, with no bedrock encountered within the depth explored.

The harbour water lot investigation occurred in the Spring of 2021, when the harbour was frozen, and drilling could take place from the ice sheet. Thirteen boreholes were drilled, and it was found that the harbour water lot soils were mostly unfrozen silty sand with occasional cobbles and boulders, and no bedrock was encountered. The porewater salinity in the harbour soils indicated relatively high salt levels. The presence of very dense sand layer offshore where the fixed wharf was to be located posed potential challenges for using driven steel sheet piles (SSP) due to high N-values (the number of blows required to drive the soil sampler into the ground for the second and third 15 cm interval during a standard penetration test) of 124 blows per inch which indicated a layer of very dense soil. Based on temperature probe readings obtained on split spoon samples recovered from depths beneath the proposed wharf area, it does not appear that this area was underlain by permafrost.

### Permafrost

Clyde River is located well within the zone of continuous permafrost; however, permafrost will not necessarily extend into the offshore area of the site. Based on temperature probe readings obtained on split spoon samples recovered from depths beneath the proposed wharf area, it did not appear that this area was underlain by permafrost.

Accurate active layer thickness measurements via long-term thermistor data taken between November 2008 to October 2012 (Canadrill, 2021), for a 15 m deep inland borehole in Clyde River indicated that the active layer thickness was 1.0 m. Based on Environment Canada climate records and simplified empirical methods, it was estimated that the active layer currently varied between approximately 0.9 and 1.5 m, which is consistent with the previously reported value. Stabilized ground temperatures from thermistor installations installed in October 2020 along the beach area where permafrost was confirmed agree with the estimated range of 0.9 to 1.5 m therefore the active permafrost layer was estimated to be approximately 1.5 m.

### Unique Challenges and Complications

A complication to the drilling program was that field crews and equipment had to be mobilized via aircraft to Clyde River through Iqaluit during the peak of COVID-19. The scheduling occurred well in advance and standard quarantine procedures were established by PSPC for all travel to the North; however, the field program happened to coincide with a COVID-19 outbreak that occurred in Iqaluit, which required the team to quickly develop additional health and isolation measures that were approved by the Nunavut Department of Health and the Hamlet of Clyde River, specifically for field crews, when arriving in the community.

Higher levels of snow accumulation and unusually high temperatures also led to an unseasonally thinner ice sheet which complicated drilling operations. The harbour water lot investigation required stringent ice safety measures, including daily ice thickness measurements and monitoring for cracking. Additionally, the presence of cobbles and boulders in nearshore boreholes and the potential for permafrost in these areas required careful consideration when advancing holes for the geotechnical investigation.

## MARINE DESIGN

Based on an option analysis it was determined that the preferred choice for the 30 m long fixed wharf structure was a tied back SSP structure. The location and design forces were obtained from the ice and coastal studies. The two major challenges for the design of the wharf were drivability of the piles due to geotechnical conditions and corrosion of the SSP.

### Steel Sheet Pile Wall Drivability

Concerns related to driving the SSP through the dense layer of compacted sand and gravel to the required embedment depth was addressed before construction began as mobilizing additional equipment and material once an issue was encountered on site would have a major impact on the budget and schedule. To mitigate this risk, an alternate design was completed, and the contract included a provision for toe pins which the contractor supplied and installed to support the sheet tips where embedment depth could not be achieved. During construction, only two toe pins were required. This allowed the sheet pile schedule to be maintained as originally planned.

**Microbial Induced or Influenced Corrosion (MIC) and Corrosion Protection**

MIC is a complex form of corrosion caused by the presence and activities of microorganisms, including bacteria, fungi, and algae which can accelerate the corrosion process, leading to unexpected and severe material degradation. The presence of MIC in the Arctic environment, such as Clyde River, is not well-documented, and its potential impact on the fixed wharf structure was uncertain.

**Design Corrosion Rates**

The corrosion protection design for the fixed wharf structure was developed to ensure the longevity and structural integrity of the facility in the harsh Arctic environment. The corrosion rates used for design were compared with historical data from work carried out on Nanisivik Wharf (POAC'11), and the DFO Harbour Accommodation Guidelines 2015 (DFO-SCH, 2015) for the various zones along the height of the SSP wall to meet the 40-year design life.

Due to limited data, research, and literature on this subject, it is not known if MIC contributed to corrosion loss at Nanisivik. It is suggested (POAC'11) that MIC was present for half of the life of the structure therefore measured corrosion rates were doubled to determine the effects attributed to MIC. Also, currently there is no way to know if MIC will be present in Clyde River. Based on this, corrosion rates at Nanisivik were determined using the measured data from Nanisivik excluding the effects of MIC. The worst-case scenario between the corrosion loss at Nanisivik and the moderate corrosion rates from the DFO guidelines were used to establish the design corrosion rates as shown in Table 1.

Table 1. Corrosion Rates

| Corrosion Region* | Elevation (m) | Calculated Average Corrosion Rate for Nanisivik (mm/year) | DFO Guideline Moderate Corrosion Rate (mm/year) | Design Corrosion Rate for Clyde River Wharf (mm/year) |
|---|---|---|---|---|
| Splash Zone | > +2.0 | 0.04 | 0.20 | 0.20 |
| Tidal Zone (LLWMT to HHWMT) | +0.5 to +2.0 | 0.11 | 0.12 | 0.12 |
| Low Water Zone (2m below LLWLT to LLWMT) | -1.9 to +0.5 | 0.26 | 0.25 | 0.26 |
| Immersed Zone (Harbour Bottom to 2m below LLWLT) | -10.0 to -1.9 | 0.14 | 0.18 | 0.18 |
| Embedded Zone | < -10.0 | Unknown | 0.05 | 0.05 |

*Where LLWMT is Lower Low Water Mean Tide, HHWMT is Higher High Water Mean Tide, LLWLT is Lower Low Water Large Tide, and LLWLT is Lower Low Water Large Tide.

If it is determined that MIC exists at Clyde River, the corrosion rates may vary significantly from the rates presented in Table 1.

### Required SSP Section

The size of the SSP wall sections, designated by their shape, thickness and width, i.e. AZ-20 700, can be determined satisfying two criteria. The first is to determine the size required based on resisting the forces developed from a structural analysis of the steel sheet pile including future section loss due to corrosion. The second is to determine the web thickness required to maintain approximately two (2) mm of steel that will prevent the fill material from escaping from behind the SSP wall thereby allowing seawater to corrode the SSP from both sides. The recommended SSP sections based on the worst case of both methods are summarized in Table 2.

Table 2. SSP Section Sizing

| Corrosion Region | Required Uncoated SSP Section Size |
|---|---|
| Splash Zone (HHWMT to Top of Wharf) | AZ-20-700 |
| Tidal Zone (LLWMT to HHWMT) | AZ-20-700 |
| Low Water Zone (2m below LLWLT to LLWMT) | AZ-40-700N |
| Immersed Zone (Harbour Bottom to 2m below LLWLT) | AZ-32-750N |
| Embedded Zone (SSP Tip to Harbour Bottom) | AZ-25-800 |

The AZ-40-700N section was the governing SSP size.

## CONSTRUCTION CONSIDERATIONS

### Community Infrastructure and Safety Considerations

The harbour is located at the opposite end of town from the quarry. Various options were reviewed to determine the best route, considering community interaction. Pedestrian safety and the use of heavy rock trucks on community roads were reviewed with the design team and the Hamlet. Secondary haul routes along the coast were considered but found to have a greater impact to the surroundings by disturbing vegetation and affecting community members with homes near the haul route.

Trucking plans were developed and included in the specification documents to limit truck times when students would be walking to and from school. Escort vehicles were also required, along with moving vehicles in convoys. Additionally, flaggers were stationed at key intersections with high pedestrian traffic to enhance control and assist with potential blind spots for truck drivers.

The increased off-road truck traffic was expected to degrade the road, which was constructed from local borrow pit materials and was not designed for overweight vehicles. Contract specifications required that the contractor had to maintain the existing roads and culverts.

**Construction Environmental Monitoring and Report**

Work in Nunavut required strict environmental monitoring and reporting. The project involved multiple sites, including a quarry, river crossing, haul road, uplands, and water lot infill. Each location required different considerations and mitigation, along with seasonal construction activity reporting.

The Clyde River is home to Arctic Char. These fish migrate to the bay after ice melts and return to the lakes in late summer and early fall. Seasonal consideration for Char migration was necessary during river access to the quarry. Although the existing bridge was upgraded, some of the quarry equipment was too heavy to cross the bridge; therefore, permits were obtained for seasonal river fording. Local hunters and fishers helped monitor Char migration during these crossings.

Continuous monitoring of the harbour was required during pile work for the wharf. A 500m exclusion zone was established, and local experts monitored for marine mammals and if any entered the zone, noise-generating work stopped until they left. Sound monitoring was also conducted, including below the ice surface until the work was complete.

**SUMMARY**

The Clyde River Small Craft Harbour Project shown in Figure 2, is a significant investment in marine infrastructure for Clyde River, Nunavut. The project faced many challenges. Key aspects included the design and construction of breakwater structures, floating docks, and a fixed wharf. Ice, coastal and hydraulic studies defined the layout, geotechnical investigations revealed unique subsurface conditions that influenced the design, while continuous environmental monitoring protected local wildlife. Corrosion protection measures were implemented to ensure the wharf's longevity. The project is scheduled to be completed during the 2025 summer construction season.

Figure 2. Clyde River SCH, under construction September 2024. Dredge haul roads still in place.

## REFERENCES

Advisian (2020), Clyde River Harbour Development Feasibility Study, 307071-01306 – 00-MA-REP-000, 16 January 2020

Canadrill Limited Geotechnical Division. Geotechnical Investigation Harbour Development Clyde River, NU: Final Factual Report. Prepared for Public Services and Procurement Canada, Project Number CLY-G2002, December 16, 2021.

Carling, P. (1988). The concept of dominant discharge applied to two gravel-bed streams in relation to channel stability thresholds. Earth surface processes and landforms, 13(4), 355-367

Comfort, G., 2024, A Rationally-Based Approach for Predicting Ice-Related Armour Stone Requirements, proc. CSCE Conference, Niagara Falls. 2. ISO, 2018, Petroleum and Natural Gas Industries – Arctic Offshore Structures, International Standards Organization ISO/DIS 19906, FDIS (Final Draft International Standard).

DFO-SCH (2015), Harbour Accommodations Guidelines for Small Craft Harbours Branch, Fisheries and Oceans Canada (DFO-SCH), Public Works and Government Services Canada, Version 1.2: 2015-04-13.

Environment and Climate Change Canada (2020), Hourly Data Report [online] Available from:https://climate.weather.gc.ca/climate_data/hourly_data_e.html?timeframe=1&Year=2013&Month=1&Day=10&hlyRange=1953-01-01%7C2013-01-10&dlyRange=1933-09-01%7C2008-07-28&mlyRange=1933-01-01%7C2007-09-01&StationID=1743&Prov=NU&urlExtension=_e.html&searchType=stnName&optLimit=yearRange&StartYear=1840&EndYear=2021&selRowPerPage=25&Line=0&searchMethod=contains&txtStationName=Clyde+A

Hasholt, B., Bobrovitskaya, N., Bogen, J., McNamara, J., Mernild, S. H., Milburn, D., & Walling, D. E. (2006). Sediment transport to the Arctic Ocean and adjoining cold oceans. Hydrology Research, 37(4-5), 413-432. doi:10.2166/nh.2006.023

Holmes, R. M., McClelland, J. W., Peterson, B. J., Shiklomanov, I. A., Shiklomanov, A. I., Zhulidov, A. V., Gordeev, V. V., & Bobrovitskaya, N. N. (2002). A circumpolar perspective on fluvial sediment flux to the Arctic Ocean. Global Biogeochemical Cycles, 16(4), 1098. doi:10.1029/2001GB001849

ISO, 2018, Petroleum and Natural Gas Industries – Arctic Offshore Structures, International Standards Organization ISO/DIS 19906, FDIS (Final Draft International Standard)

Kullmann, H., Graff, M., & Watson, R. (2011). Microbial Induced Corrosion on a Wharf in the Canadian Arctic. Proceedings of the 21st International Conference on Port and Ocean Engineering under Arctic Conditions (POAC'11), Montreal, Canada

Milliman, J.D., & Syvitski, J.P.M. (1992). Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers. The Journal of Geology, 100(5), 525-544. DOI: 10.1086/629606

Parks Canada. (n.d.). Tallurutiup Imanga National Marine Conservation Area Agreement. Parks Canada. Retrieved March 17, 2025, from https://parks.canada.ca/amnc-nmca/cnamnc-cnnmca/tallurutiup-imanga/entente-agreement

Smith, I R; Irvine, M L; Bell, T. (2012), Surficial geology, Clyde River, Baffin Island, Nunavut, Geological Survey of Canada, Canadian Geoscience Map 58, (ed. prelim.), 2012, 1 sheet; 1 CD-ROM, https://doi.org/10.4095/289603

Smith, I R; Irvine, M L; Bell, T. (2012a). Surficial geology, Clyde River, Baffin Island, Nunavut. Geological Survey of Canada, Canadian Geoscience Map 58, 2012, 1 sheet; 1 CD-ROM, https://doi.org/10.4095/289603.

Smith, I R; Irvine, M L; Bell, T. (2012b). Periglacial and permafrost geology, Clyde River, Baffin Island, Nunavut. Geological Survey of Canada, Canadian Geoscience Map 57, 2012, 1 sheet. https://doi.org/10.4095/289602.

Statistics Canada. (2016). Census Profile, 2016 Census: Clyde, Subdivision A, Nova Scotia. Statistics Canada. Retrieved March 17, 2025, from https://www12.statcan.gc.ca/census-recensement/2016/dp-d/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6204015&Geo2=PR&Code2=10&Data=Count&SearchText=Clyde&SearchType=Begins&SearchPR=01&B1=All

Syvitski, J. P. M. (2002). Compilation of databases for 28 Arctic rivers. Sediment discharge variability in Arctic rivers: implications for a warmer future. Polar Research, 21(2), 6494. doi:10.3402/polar.v21i2.6494

Syvitski, J.P.M., Vörösmarty, C.J., Kettner, A.J., & Green, P. (2003). Predicting the terrestrial flux of sediment to the global ocean: a planetary perspective. Sedimentary Geology, 162(1-2), 5-24. DOI: 10.1016/S0037-0738(03)00232-X00232-X)