# Analysis of Marine Traffic along Canada's Coasts

*Phase 2 – Part 1: Factors Influencing Arctic Traffic*

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# Analysis of Marine Traffic

***Phase 2 – Part 1: Factors Influencing Arctic Traffic***

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# Abstract

This document describes the results of Phase 2 – Part 1 of the Analysis of Marine Traffic (AMT) Project, conducted under contract W7714-093795. The purpose of this Part is to scope out the various factors that can influence maritime traffic patterns in the Canadian Arctic to the year 2020. The patterns of interest are categorized by ship type, activity type, and location (spatial patterns of the routes). The results will serve as the foundation for the variables included in Phase 2 – Part 2 of the project, during which traffic projections will be modeled. The method was to conduct a thorough survey of the literature, determine what key factors affect current and projected traffic patterns, and identify what sources of information can be used to establish a base case, low case, and high case for each factor. Furthermore, information on current and forecasted ice conditions is summarized, such as the extent, seasonality, and type of ice that will affect accessibility of the various northern routes. All these factors are organized into a framework that will provide structure for developing the traffic forecasting model. The report recommends factors that are the most important to include, and discusses limitations of the information presented.

# Résumé

Le présent document décrit les résultats de la phase 2 – partie 1 du Projet d'analyse du trafic maritime (ATM), exécuté dans le cadre du contrat W7714-093795. Cette partie a pour objet de définir les différents facteurs qui peuvent influer sur les mouvements du trafic maritime dans l'Arctique canadien jusqu'en 2020. Les mouvements d'intérêt sont classés par type de navire, par type d'activité et par endroit (profil spatial des itinéraires). On se fondera sur les résultats pour établir les variables de la phase 2 – partie 2 du projet, au cours de laquelle on procédera à la modélisation des prévisions relatives au trafic. La méthode consistait à effectuer une étude approfondie des publications, à déterminer quels sont les principaux facteurs influant sur les mouvements de trafic actuels et prévus, et recenser les sources d'information qui pourraient être utilisées pour établir un scénario de référence, un scénario bas et un scénario élevé pour chacun des facteurs. De plus, on a résumé l'information concernant l'état des glaces, notamment l'étendue, le cycle saisonnier et le type de glace, qui influeront sur l'accessibilité des divers itinéraires nordiques. Ces facteurs sont répartis à l'intérieur d'un cadre qui servira de structure à l'élaboration du modèle prévisionnel du trafic maritime. Des recommandations sont faites concernant les facteurs jugés les plus importants et les restrictions relatives à l'information présentée.

# Executive Summary

Enhancing safety and security in Canadian Arctic waters involves monitoring maritime activities and improving preparedness to respond to unexpected events. Both of these strategies have long lead times, therefore it is important to not only consider current maritime activity levels in the North, but to produce traffic forecasts so that resources for monitoring traffic and managing incidents can be effectively deployed over time. To this end, projections of traffic densities for the year 2020 will be conducted. The Area of Interest (AOI), defined by the project sponsor, corresponds to waters north of 60° latitude, extending up to and including 300 nautical miles (nmi) from the shoreline of Canadian territory, and also encompasses Hudson Bay and James Bay.

There is a variety of traffic types in the AOI associated with diverse activities such as northern community re-supply, commercial shipping out of Churchill, Manitoba, commercial fishing, and cruise ship voyages. Traffic projections must distinguish between categories of activity for three reasons. First, the factors that may affect changes in traffic levels in the coming decade do not apply equally to all activity types. For example, exploration for oil and gas or minerals will be heavily dependent on the world economy in general, and the demand for resources in particular. In contrast, fishing levels will depend on the relative effectiveness of fishing in the North versus other geographic areas as fish stocks dwindle worldwide. Second, the types of problems, or risks, associated with different categories of ships and activities vary tremendously, so the analysis must produce separate forecasts for each. For example, a major accident involving a large cruise ship may engender drastically higher consequences than the sinking of a relatively small fishing vessel. Third, the quality of existing data, and of factors that may produce change in activity levels by 2020, are not consistent across categories. Large ships are tracked closely in the North, and economic drivers that would alter the shipping levels are fairly well understood. Conversely, trying to predict the number of small pleasure craft that will venture into the Northwest Passage (NWP) as the ice recedes is as much art as science.

Thus, the following categories of vessel types are considered in the study: Merchant/Bulk/Cargo; Fishing; Tanker; Cruise Ship/Passenger; Pleasure Craft; Government (non-military); Research and Exploration; Tugs and Service Vessels. The activity types are classified into the following groups: Trans-Arctic Shipping; Inter-Modal Shipping; Community Re-Supply; Resources – Oil and Gas; Resources – Minerals; Resources – Fisheries; Resources – Other industrial developments; Tourism; Government Services and Research.

Aside from drivers that may increase or decrease traffic levels in the near future, the feasibility of increased traffic is tightly coupled to the changing ice conditions. The duration, extent, and nature of ice coverage are all changing relatively quickly due to global warming, and therefore the opportunity to ply the arctic waters depends on forecasts of spatial projections of ice presence in 2020. There are other system-wide factors that can significantly influence future traffic levels, such as geopolitical factors, northern infrastructure development, and environmental governance, but these are excluded from this study as they are assumed to remain relatively static over the short term.

Since the amount of data on maritime traffic in northern Canada is very low, it is difficult to produce a unique, reliable forecast of traffic levels for the year 2020. Therefore, the approach needed is to generate feasible scenarios, which are derived from possible changes in demand drivers and ice conditions. For each demand driver a base case, low case, and high case will be projected based on information found in the literature, and the effect of the driver on the relevant types of traffic will be estimated. This study determines feasible ranges for each demand driver, and for ice conditions. This information provides the basis for conducting the scenario projections in the next part of this study.

The literature review revealed that projections of sea ice conditions by 2020 have been made by several authoritative agencies, using different scenarios and models. Although projections differ, there are some aspects in which they show agreement. First, most of them foresee a summer free of ice within this century and most likely by mid-century. Second, most experts agree that annual variability will persist. Third, there is general agreement that the NWP will be the last Arctic area covered by ice, or at least where difficult ice conditions would prevail. Fourth, forecasts predict longer ice-free seasons but all models project persisting winter sea-ice in the Arctic. Only a few models predict summer sea-ice free for the Arctic before 2020. A recent summary of projections of ice conditions is provided by the *Arctic Monitoring and Assessment Programme* (AMAP, 2011):

a) Complete summer sea-ice loss is projected as likely to occur by mid-century.
b) Variability in summer sea-ice extent is projected to increase initially, but then to decrease as ice-free summers are approached.
c) First-year ice is projected to dominate in the future, as the amount of multi-year ice diminishes.
d) Projections of annual maximum extent and duration of seasonal sea-ice cover are uncertain and regionally variable (and affected by local bathymetry and weather conditions), but maximum extent and duration are very likely to be less than at present (i.e. with a more northerly distribution, smaller area, shorter duration).
e) The extent and location of the summer/autumn polar pack (i.e. multi-year sea-ice remnants) will be uncertain in future years as the summer ice decline continues, but most models project that pack-ice remnants are very likely to occur along the northwestern margin of the Canadian Archipelago and the north coast of Greenland at least until complete loss.

The key findings in this Phase 2 – Part 1 study with respect to each activity type are as follows.

a) **Trans-Arctic shipping**: It is generally agreed that the NWP will not become a viable commercial route by 2020 due to seasonality, ice conditions, a complex archipelago, draft restrictions, chokepoints, lack of adequate charts, insurance limitations and other costs, which diminish the likelihood of regularly scheduled services from the Pacific to the Atlantic.
b) **Arctic Bridge**: The Port of Churchill connects to the Russian ice-free port of Murmansk in a route known as the "Arctic Bridge". A potential increase in shipping through Port of Churchill is determined by: a) ice conditions in Hudson Bay; b) the recent *Marketing Freedom for Grain Farmers Act*; c) the grain market; d) imports from Russia (Murmansk); e) economic advantages

over the St. Lawrence Seaway in accessing the interior of the country; f) development strategy implemented by Manitoba; and g) public policies in support of the Port. The literature reviewed does not foresee growth for the Port of Churchill or Arctic Bridge. On the contrary, it is widely considered that the implementation of the *Marketing Freedom for Grain Farmers Act* will reduce the importance of the Port. Scenarios for this route must account for these factors.

c) **Community Re-Supply**: Community re-supply is expected to grow. The main driver in the literature is population growth. Consumption per capita was considered relevant in the *Canadian Arctic Shipping Assessment* (CASA, 2007), and a proxy was used considering the lack of historical data. As an alternative, a regional gross domestic product projection may be used to forecast re-supply activity.

d) **Resources – Oil and Gas**: Oil and Gas assumptions and scenarios are centered on three areas. The main driver for oil and gas activity in the Beaufort Sea and Mackenzie Delta is the construction of the Mackenzie Gas Project. Its construction is still uncertain because of the low gas prices as a result of the development of technologies to exploit shale gas. Activity in the Sverdrup Basin and other regions is expected to remain moribund through the period to 2020. CASA (2007) highlights the movement of project cargo to Tuktoyaktuk for furtherance of the oil sands north of Fort McMurray as a potential area of activity over 2010 to 2020 and beyond.

e) **Resources – Metals and Minerals**: Although there are a number of northern mines that are projected to be active by 2020, most of those mines do not rely on marine traffic in the Canadian Arctic for their operation. The mines that may: a) potentially be in operation in 2020; and b) consider marine shipping through Canadian Arctic for supplying the mine's operation or transporting the mineral or metals, are included in this report.

f) **Resources – Fisheries**: Considering that there is already a high demand for fish resources both globally and in Canada, factors that may impact fishing activities in the Arctic include: a) access to the resource; b) changes in the distribution and productivity shifts in marine resources; c) regulatory framework; and d) investment in vessels and harbours. Environmental awareness in the Arctic is expected to be a driver for precautionary management. Trends of current fishing activities in the Arctic confirm a slow development and even a decrease of fishing activities.

g) **Resources – Tourism**: Tourism growth in the Arctic will depend on: a) ice conditions; b) world economy; and c) promotion of the activity by Canadian and local governments. Most studies seem to predict a modest growth but with great annual variability. If existing spatial distribution patterns continue, it is expected that most of the tourism activity will concentrate in the NWP and particularly Route 3 (Baffin Bay, Lancaster Sound, Barrow Strait, Peel Sound, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea), with tourism also growing in the High Arctic (particularly eastern Canadian Arctic) rather than in the lower Arctic (Baffin Bay, Hudson Bay and Newfoundland).

h) **Canadian Government Services and Research**: There is little information on drivers of Canadian government services and research. It is assumed that plausible factors affecting government services and research would be: a) funding; b) infrastructure projects currently in place; c) level of shipping activity and traffic in the Arctic. High levels of Arctic traffic activity would probably imply increased government activity (icebreakers, patrols, search and rescue) although the relationship is not very clearly established by past trends.

# Sommaire

En vue d'accroître la sécurité des eaux de l'Arctique canadien, il faut surveiller les activités maritimes et améliorer notre capacité d'intervention en cas d'événements imprévus. Ces deux stratégies s'étalent sur une longue période. Il est donc important non seulement d'étudier les niveaux d'activité maritime actuels dans le Nord, mais aussi d'établir des prévisions du trafic de manière à pouvoir déployer efficacement les ressources de gestion et de surveillance au fil du temps. À cette fin, on effectuera des projections de la densité du trafic jusqu'en 2020. La zone d'intérêt (ZInt), définie par le responsable du projet, correspond aux eaux situées au nord du 60e parallèle et qui s'étendent sur 300 milles marins (nmi) à partir des côtes canadiennes, et englobent la baie d'Hudson et la baie James.

Il existe dans la ZInt divers types de trafic associés à une variété d'activités telles que le ravitaillement de la collectivité du Nord, la navigation commerciale en partance de Churchill (Manitoba), la pêche commerciale, ainsi que les croisières. Les projections doivent établir une distinction entre les catégories d'activité pour trois raisons. Premièrement, les facteurs qui peuvent modifier les niveaux de trafic au cours de la prochaine décennie ne s'appliquent pas uniformément à tous les types d'activité. Par exemple, la prospection pétrolière, gazière ou minérale dépendra fortement de l'économie mondiale en général, et de la demande liée à ces ressources en particulier. Par contre, les niveaux de pêche seront tributaires de l'efficacité relative de la pêche dans le Nord par rapport aux autres zones géographiques, à mesure que diminueront les stocks mondiaux de poisson. Deuxièmement, les types de problèmes, ou de risques, associés aux différentes catégories de navires et d'activités varient énormément, ce qui fait que l'analyse doit comporter des prévisions distinctes pour chacune des catégories. Par exemple, un grave accident impliquant un gros navire de croisière risque d'entraîner des conséquences beaucoup plus grandes que le naufrage d'un bateau de pêche relativement petit. Troisièmement, la qualité des données existantes, et les facteurs qui peuvent modifier les niveaux d'activité d'ici 2020, ne sont pas uniformes dans toutes les catégories. Les gros navires font l'objet d'une étroite surveillance dans le Nord, et on comprend bien les facteurs économiques qui peuvent influer sur les niveaux. En revanche, essayer de prédire le nombre de petits bateaux de plaisance qui s'aventureront dans le passage du Nord-Ouest (PNO) à mesure que les glaces disparaîtront relève autant de l'art que de la science.

Ainsi, l'étude tient compte des catégories de types de navires : marchands/vraquiers/cargos; de pêche; citernes; de croisière/transport de passagers; bateau de plaisance; gouvernementaux (non militaires); de recherche et de prospection; remorqueurs et navires de service. Les types d'activité sont répartis selon les groupes suivants : navigation transarctique; navigation intermodale; ravitaillement de la collectivité; ressources – pétrole et gaz; ressources – minéraux; ressources – pêches; ressources – autres développements industriels; tourisme; recherche et services gouvernementaux.

Outre les facteurs qui peuvent accroître ou diminuer les niveaux de trafic dans un avenir rapproché, la possibilité d'accroissement du trafic est étroitement liée à l'évolution de l'état des glaces. La durée, l'étendue et la nature des glaces changent relativement rapidement en raison du réchauffement climatique et, par conséquent, la possibilité de naviguer régulièrement dans les eaux de l'Arctique

dépend des prévisions relatives aux projections spatiales de la présence des glaces en 2020. D'autres facteurs à l'échelle du système qui peuvent influencer de façon considérable les futurs niveaux de trafic, notamment les facteurs géopolitiques, le développement des infrastructures du Nord et la gouvernance de l'environnement, mais ceux-ci sont exclus de la présente étude, car on présume qu'ils ne changeront pas à court terme.

Comme nous disposons de très peu de données sur le trafic maritime dans le Nord canadien, il est difficile d'établir une prévision unique et fiable des niveaux de trafic qui prévaudront en 2020. Par conséquent, nous devons créer des scénarios réalistes en nous fondant sur les changements qui pourraient survenir au chapitre des inducteurs de demande et de l'état des glaces. Pour chaque inducteur de demande, un scénario de base, un scénario bas et un scénario élevé seront établis à partir de l'information trouvée dans les publications, et on estimera l'effet de l'inducteur sur les différents types de trafic. Cette étude détermine les éventails possibles pour chaque inducteur de demande, et pour l'état des glaces. On se fonde sur cette information pour établir les projections de scénario dans la prochaine partie de cette étude.

L'examen des publications a révélé que plusieurs organismes autorisés ont fait des projections sur l'état des glaces marines d'ici 2020, en se fondant sur différents scénarios et modèles. Bien que leurs projections diffèrent, ces organismes semblent tout de même s'entendre sur certains aspects. D'abord, la plupart d'entre eux prévoient un été libre de glace au cours du présent siècle, fort probablement d'ici la moitié du siècle. Deuxièmement, la plupart des experts s'entendent pour dire que le climat demeurera variable. Troisièmement, tous sont généralement d'accord sur le fait que le PNO sera la dernière zone arctique couverte de glace, ou tout au moins où les glaces nuiront à la navigation. Quatrièmement, selon les prévisions, les saisons libres de glace seront plus longues, mais d'après tous les modèles, les glaces marines continueront de se former en hiver dans l'Arctique. Seulement quelques modèles prédisent des étés libres de glace dans l'Arctique avant 2020. Le projet SWIPA 2011 a produit dernièrement un résumé des projections sur l'état des glaces :

a) On prévoit que les glaces fondront entièrement en été, probablement vers la moitié du siècle.
b) On prévoit que l'étendue de la glace marine en été augmentera au départ, mais diminuera ensuite à mesure que les étés libres de glace approcheront.
c) On prévoit qu'à l'avenir, c'est la glace de première année qui prédominera, à mesure que la quantité de glace de plusieurs années diminuera.
d) Les projections de l'étendue et de la durée maximales annuelles de la couverture de glace saisonnière sont incertaines et varient selon les régions (et dépendent de la bathymétrie et des conditions climatiques locales), mais l'étendue et la durée maximales seront fort probablement inférieures à ce qu'elles sont actuellement (c.-à-d. elles seront réparties plus au nord, sur une plus faible superficie et demeureront moins longtemps).
e) On ne peut pas vraiment prévoir l'étendue et l'emplacement de la banquise polaire d'été/d'automne (c.-à-d. les restes des glaces marines de plusieurs années) au cours des prochaines années, à mesure que la glace d'été disparaîtra, mais la plupart des modèles projettent qu'il restera fort probablement de la glace compacte le long de la limite nord-ouest de l'archipel canadien et de la côte nord du Groenland, au moins jusqu'à sa disparition complète.

Voici les principales conclusions de cette étude de la Phase 2 – Partie 1 concernant chaque type d'activité :

a) **Navigation transarctique** : On s'entend tous pour dire que le PNO ne deviendra pas un itinéraire commercial viable d'ici 2020 en raison du cycle saisonnier, de l'état des glaces, de la complexité de l'archipel, des limites de tirant d'eau, des points de passage obligé, de l'absence de cartes marines adéquates, des limites imposées par les assurances et les autres coûts, tous des facteurs qui réduisent la probabilité que des services de transport réguliers soient établis entre le Pacifique et l'Atlantique.

b) **Pont de l'Arctique** : Le port de Churchill est relié au port russe de Murmansk, qui est libre de glace, par un itinéraire appelé « pont de l'Arctique ». La navigation par le port de Churchill pourrait augmenter en fonction des facteurs suivants : a) l'état de la glace dans la baie d'Hudson; b) l'adoption récente de la *Loi sur le libre choix des producteurs de grains en matière de commercialisation*; c) le marché de grains; d) les importations de la Russie (Murmansk); e) les avantages économiques qu'offre l'accès à l'intérieur du pays par rapport à l'utilisation de la voie maritime du Saint-Laurent; f) la stratégie de développement mise en place par le Manitoba; g) les politiques gouvernementales à l'appui du port.

   Les publications examinées ne prévoient pas d'augmentation du trafic dans le port de Churchill ou sur le pont de l'Arctique. Au contraire, dans la plupart des ouvrages, on pense que l'application de la *Loi sur le libre choix des producteurs de grains en matière de commercialisation* réduira l'importance du port. Les scénarios concernant cet itinéraire doivent tenir compte de ces facteurs.

c) **Ravitaillement de la collectivité** : On s'attend à une croissance dans ce secteur. Selon les publications étudiées, le principal inducteur est la croissance de la population. La consommation par habitant a été jugée pertinente pour la CASA (2007), et un calcul par approximation a été effectué étant donné le manque de données historiques. Comme solution de rechange, on peut avoir recours à une projection du produit intérieur brut régional pour prévoir le niveau de l'activité de ravitaillement.

d) **Ressources – Pétrole et gaz naturel** : Les hypothèses et les scénarios concernant le pétrole et le gaz naturel se concentrent sur trois secteurs. L'inducteur principal pour l'activité pétrolière et gazière dans la mer de Beaufort et dans le delta de Mackenzie est la construction du Projet gazier Mackenzie. La réalisation de ce projet demeure incertaine en raison de la baisse des prix du gaz découlant du développement de technologies permettant d'exploiter le gaz de schiste. On s'attend à ce que l'activité demeure moribonde dans le bassin de Sverdrup et dans d'autres régions jusqu'en 2020. CASA (2007) souligne que le mouvement des cargaisons de projet vers Tuktoyaktuk pour la poursuite du projet des sables bitumineux au nord de Fort McMurray pourrait être un secteur d'activité de 2010 à 2020 et pour les années qui suivront.

e) **Ressources – Métaux et minéraux** : Bien qu'il soit prévu qu'un certain nombre de mines nordiques seront en activité d'ici 2020, le fonctionnement de la plupart de ces mines ne repose pas sur le trafic maritime dans l'Arctique canadien. Les mines qui pourraient : a) être exploitées en 2020; b) envisager d'avoir recours à la navigation dans les eaux de l'Arctique canadien pour s'approvisionner ou pour transporter le minerai ou les métaux, sont mentionnées dans ce rapport.

f) **Ressources – Pêches** : Compte tenu du fait qu'il existe déjà une forte demande pour les ressources halieutiques, dans le monde et au Canada, les facteurs qui pourraient influer sur les activités de pêche dans l'Arctique sont notamment : a) l'accès aux ressources; b) les changements apportés à la distribution et les variations de productivité au chapitre des ressources maritimes; c) le cadre de réglementation; d) les investissements dans les navires et les ports. La sensibilisation à l'environnement de l'Arctique devrait entraîner une gestion plus prudente de la pêche. L'observation des tendances des activités de pêche actuelles dans l'Arctique confirme un développement lent et même une réduction des activités de pêche.

g) **Ressources – Tourisme** : La croissance du tourisme dans l'Arctique sera fonction de : a) l'état des glaces; b) l'économie mondiale; c) la promotion de l'activité par les gouvernements fédéral et locaux. D'après la plupart des études, on ne prévoit qu'une modeste croissance, qui variera grandement d'une année à l'autre. Si les profils de distribution spatiale actuels se maintiennent, on prévoit que la majorité de l'activité touristique se concentrera dans le PNO et en particulier sur l'itinéraire 3 (baie de Baffin, détroit de Lancaster, détroit de Barrows, détroit de Peel, détroit de Franklin, détroit de Victoria, golfe Coronation, golfe Amundsen, mer de Beaufort), avec une croissance du tourisme également dans le Haut-Arctique (en particulier dans l'Est de l'Arctique canadien) plutôt que dans le Moyen-Arctique (baie de Baffin, baie d'Hudson et Terre-Neuve).

h) **Recherche et Services gouvernementaux canadiens** : On dispose de peu d'information sur les facteurs liés à la recherche et aux services gouvernementaux canadiens. On présume que les facteurs qui pourraient de façon plausible influer sur la recherche et les services gouvernementaux sont : a) le financement; b) les projets d'infrastructure actuellement en cours; c) le niveau d'activité de navigation commerciale et de trafic dans l'Arctique. Un haut niveau d'activité dans l'Arctique risquerait d'entraîner une augmentation de l'activité gouvernementale (brise-glaces, patrouilles, recherche et sauvetage) bien que les tendances passées ne permettent pas d'établir clairement le lien avec ces facteurs.

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# 1 Introduction

## 1.1 Analysis of Marine Traffic: Second Phase

The Analysis of Marine Traffic (AMT) project was initiated with an overall goal of producing spatial and temporal analyses of marine traffic in Canadian waters and their approaches, including Arctic waters. The information is required by Defence Research and Development Canada (DRDC) and the Canadian Forces in a planning environment. Specific end use purposes are best described by the text from the original Statement of Work from DRDC (2010):

> *Canada First* Defence Strategy calls for the Canadian Forces (CF) to work closely with federal government partners to ensure the constant monitoring of Canada's territory and all air and maritime approaches, including in the Arctic, in order to detect threats to Canadian security as early as possible. Canada Command[1] is the national military authority responsible for the conduct of all domestic operations. As such, Canada Command will conduct operations to detect, deter, prevent, pre-empt and defeat threats and aggression aimed at Canada within its area of responsibility (AOR). The Command is also responsible for the effective operation of the federal maritime and aeronautical search and rescue (SAR) system.
>
> Defence Research and Development Canada (DRDC) Centre for Operational Research and Analysis (CORA) is conducting various research activities aiming to help Canada Command and subordinate organizations to improve how operations are planned and conducted. In order for DRDC CORA to accurately simulate marine traffic, surveillance activities, as well as SAR activities, a comprehensive understanding of marine traffic occurring inside and near Canadian waters is required. Analyses of seasonal and geographical patterns in marine traffic help to build this understanding. They also contribute to better estimate the risks of various types of undesired activities and marine incidents to occur inside the Canada Command AOR, and will help Canada Command to allocate resources for maximizing maritime domain awareness and operational effectiveness.

Within this overall plan, the second phase of the project focuses on producing projections of shipping densities in the Arctic for the year 2020. This primary task is defined within Sections 3.2 and 4.2 of the Statement of Work, reiterated here:

> **3.2 Phase 2 – Projected Arctic Shipping Densities**:
> In this phase, the Contractor must produce projections of shipping densities in the Arctic for the year 2020. The projections must be based on a number of scenarios and assumptions agreed with, and accepted with, the Technical Authority. As in the first phase, the results must be delivered in the form of shipping density maps and reports.

---

[1] Since October 2012, Canada Command is now part of the Canadian Joint Operations Command.

The Contractors must again identify, develop and use appropriate track generation algorithms or statistical techniques (as required) to mitigate gaps in the data and produce accurate projections of the estimated densities.

From Section 4 - Tasks, subsection 4.2 Phase 2 – Arctic Marine Traffic Projections:

**4.2.1 Methodology**

The Contractor must develop and propose a methodology for producing projections of shipping densities for the year 2020, taking into account trends in Arctic traffic activity and ice coverage. In order to guide the projections made by the Contractor, the [Technical Authority] will provide the Contractor with an annotated bibliography of scientific papers describing plausible scenarios in terms of climate change, ice coverage reduction, and economic activity. Since the completeness and quality of the shipping data is expected to vary widely for different times, areas, and ship categories, the Contractor must identify, develop and use appropriate track generation algorithms or statistical techniques (or both as required) to mitigate gaps in the data and produce accurate estimate densities.

## 1.2 Objective of the Phase 2 - Part 1 Report

In order to develop and propose a methodology for producing shipping densities for the year 2020 and to map projected shipping densities in a Geographic Information System (GIS), the second phase requires the adoption of one or more scenarios and assumptions on the density and spatial distribution of Canadian Arctic shipping traffic by 2020. Those scenarios and assumptions need to be reviewed and approved by the Technical Authority.

The development of scenarios and assumptions for future Arctic shipping traffic for this particular phase of the study requires information on:

- Past trends in Arctic shipping traffic
- Drivers of Arctic shipping traffic (inputs)
- Projected changes in identified and/or selected drivers (input projections)
- Projected changes in Arctic shipping traffic (output projections)
- Spatial distribution of current and projected traffic
- Current ice coverage and projected changes (spatio-temporal feasibility of rules)

The objective of this Part 1 report is to summarize and systematize the published data for each of the above information needs.

## 1.3 Using the Factors for Building Scenarios

Although it is not known *a priori* which factors are significantly related to changes in Arctic traffic, the process for generating scenarios will be based on the following conceptual model. First of all, the output for each scenario will be a quantification of maritime traffic categorized by:

1. type of vessel: merchant/cargo vessels, fishing vessels, tankers, cruise ships, pleasure craft, non-military government vessels, as well as research/exploration vessels (to be consistent with the grouping in the Phase 1 study);
2. level of activity: for each type of vessel, will the number of transits increase by 2020, decrease, or remain the same at today?; and
3. location: new routes, or shifting of existing routes must be considered.

While there are many input factors that can affect any, or all, of these output variables, the key ones revolve around demand drivers (e.g. mines, oil and gas, fishing, tourism) and climate change drivers, as outlined in Section 3 of the report. Hence the general relationship can be described as:

$$T(\,L(V), S(V)) = f(D, C)$$

where:
T = quantified arctic maritime traffic output
V = vessel type
L = level of traffic (as a function of vessel type)
S = spatial distribution of traffic (as a function of vessel type)
D = demand drivers of traffic
C = climate drivers of traffic

This equation simply serves to illustrate the conceptual relationships that underpin any attempt to develop realistic, consistent, projections. Formal forecasting models are impractical for this study, given the enormous uncertainties surrounding many of the drivers, as well as the paucity of data. Therefore this equation is not used explicitly in the modelling. The independent variables are each composed of a large set of sub-variables, and the purpose of this phase of the study is to determine which ones are germane for this study's scenarios. The dependent variables also present challenges for developing models based on past studies, as there is wide variation in how vessels are categorized and how the current activity (actual or estimated) and future forecasts are represented temporally and spatially. As well, some of the factors must be inferred from surrogate variables. One salient example is that many frameworks incorporate marine traffic based on purpose, or activity type, rather than vessel type. Thus a correlation must be drawn between these two interdependent measures, to be able to aggregate information from diverse reports. These issues are covered in more detail later in this Part 1 report (see Table 3.1).

## 1.4 Methodology

The methodological approach to complete this Phase 2 – Part 1 study is a literature review of Arctic shipping projections, a critical synthesis of the factors that influence or are expected to influence Arctic shipping, and a gap analysis.

The literature review included the references provided by the Technical Authority and a number of complementary studies. The complete list of work is included in the Reference section of this Part 1 Report. While the reviewed studies on Arctic shipping have different scopes and purposes, each provide complementary information necessary to formulate assumptions and to develop scenarios and projections for traffic modeling.

A number of studies focus on, or contain, information of past shipping trends in the Arctic or Canadian Arctic and statistical information on shipping vessels and voyages in the Canadian Arctic. These include:

- Arctic Council. 2009. *Arctic Marine Shipping Assessment 2009 Report* (April 2009) [AMSA 2009].
- The Mariport Group Ltd. 2007. *Canadian Arctic Shipping Assessment, Main Report*. Prepared for Transport Canada (June 2007) [CASA, 2007].
- Judson, B. 2010. *Trends in Canadian Arctic Shipping Traffic – Myths and Rumours*.
- Shipping data provided by the Technical Authority.

The Phase 1 report of the present study provides a snapshot view of current shipping traffic in Canadian waters, including Canadian Arctic.

- Hilliard, R.C. and Pelot, R. 2012. *Analysis of Marine Traffic along Canada's Coasts: Phase 1 Final Report*, DRDC CORA Contractor Report CR2012-060.

A number of studies include projections of future Arctic shipping, considering different timelines and methodologies. These include:

- AMSA, 2009.
- Williams, A., O'Sullivan A.D, and Wilkinson, A. 2011. *The Future of Arctic Enterprise: Long-term Outlook and Implications*.
- Analyse&Strategi. 2011. *Marine Traffic in the Arctic: A Report Commissioned by the Norwegian Mapping Authority*.
- CASA (2007).

Additionally, complementary sectoral studies were reviewed for particular sections of this Part 1 report. Consulted references are listed at the beginning of each section.

As a general observation, it should be noted that reliable information on Arctic shipping traffic is not always available. The collection of data should be considered an ongoing task that will be carried out throughout the second phase.

# 2 Scope of the Second Phase

## 2.1 Area of Interest

The area of interest (AOI) for the second phase of the project is Canada's Arctic waters. They are defined in the Contract Statement of Work as waters above the 60° North extending up to and including 300 nautical miles (nmi) from the shoreline. For this phase, the area was modified to include Hudson Bay and James Bay in order to include traffic from and to Port of Churchill, Manitoba. The resulting AOI was defined and mapped within GIS software (ArcMap) as shown in Figure 2-1. The area is broadly equivalent to the Northern Canada Vessel Traffic Services Zone (NORDREG zone) (Figure 2-2).

**Figure 2-1.** AMT Phase 2 AOI

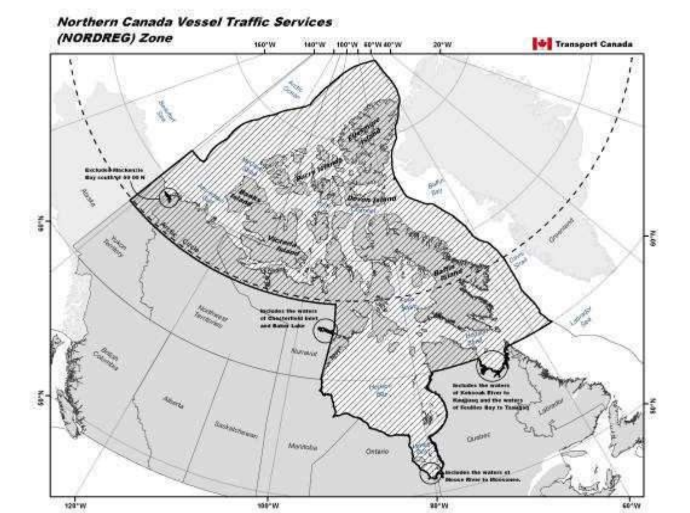



**Figure 2-2.** NORDREG zone. Source: Transport Canada.

Various geographic features of the AOI are mentioned throughout the report. For this reason, a geo-political map of Canada's North that includes main geographic features with particular emphasis on islands, bays and straits is provided below in Figure 2-3.

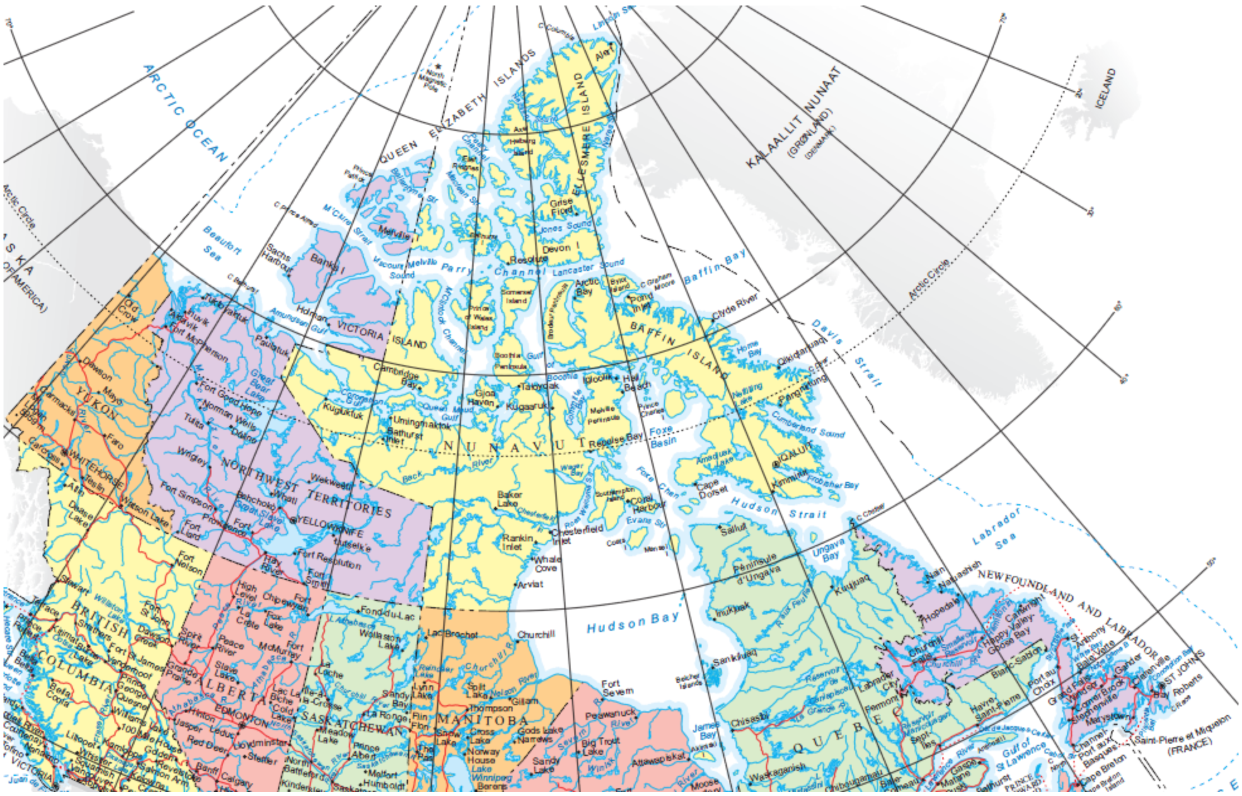


**Figure 2-3.** Canada's North. General reference (detailed) map. Source: The Atlas of Canada.

## 2.2 Zones for Spatial Representation – Spatial Analysis

To address the spatial analysis of projected Arctic marine traffic, the study considered two options:

a) The first and preferred option is to rely on the Shipping Safety Control Zones established by the *Arctic Shipping Pollution Prevention Regulations* (ASPPR) and used as the basis for the *Arctic Ice Regime Shipping System* (AIRSS). These zones are also used by Judson (2010) in his analysis of Arctic shipping traffic. The 16 zones that form the AIRSS Shipping Safety Control Zones are displayed in Figure 2-4. For the most part, Zone 1 is considered to have the most difficult ice conditions and Zone 16 the easiest.

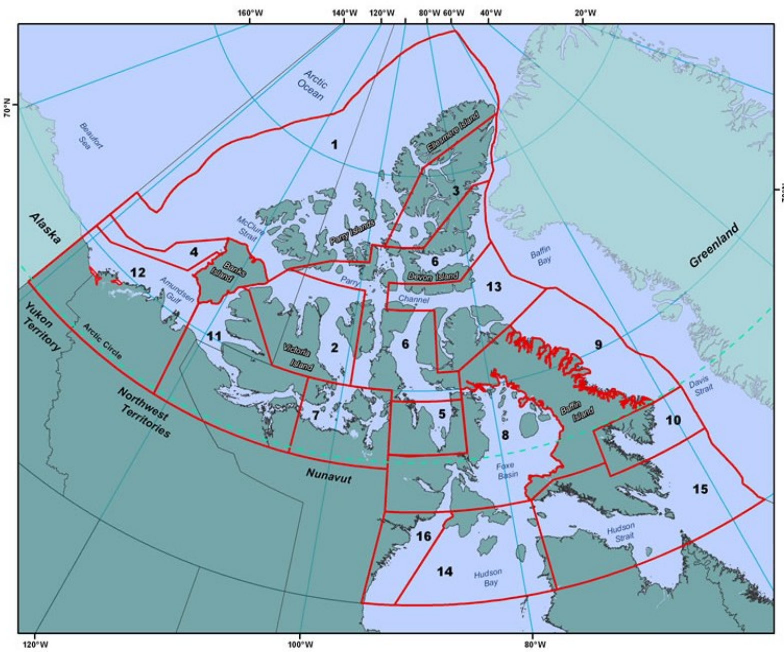
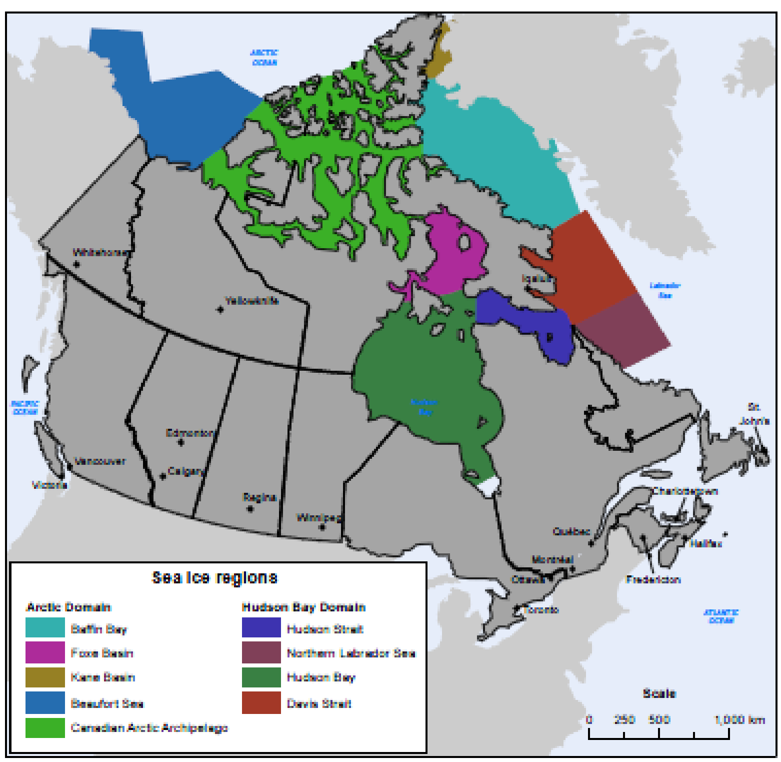



**Figure 2-4.** Shipping Safety Control Zones (ASPPR). Source: Transport Canada

b) A second alternative is to use the Canada's Sea Ice Regions and Domains, as shown in Figure 2-5. These are generally complementary, but less detailed than the AIRSS Shipping Safety Control Zones and for this reason it is not the preferred option for spatial analysis and representation.




**Source(s):** Environment Canada, Canadian Ice Service.

**Figure 2-5.** Canada's Sea Ice Regions and Domains. Source: Statistics Canada

## 2.3 Vessels Included in the Projections

Whenever possible, the projections of shipping densities in the Arctic for the year 2020 include the categories of vessels that were identified in the first Phase of the study, displayed below in Table 2-1.

**Table 2-1.** Vessel Category Labels

| Category | Category Label |
|---|---|
| Merchant / Bulk / Cargo | M |
| Fishing | F |
| Tanker | T |
| Cruise Ship / Passenger | C |
| Pleasure Craft | L |
| Gov't Non-Military | G |
| Research and Exploration | R |
| Tugs and Service Vessels | S |

## 2.4 Transport Activities

Following AMSA (2009), this study identifies different transport activities according to the type or purpose of a voyage or transit activity. AMSA groups these into four "modes", but in this AMT study they are characterized as "activities" instead, a grouping necessary to achieve the desired projections. The identification of navigation purpose is particularly important for this second phase because the factors driving shipping activity and the projections or forecasts vary among the different activity types.

The navigation activity types and sub-types used in the report are:

1. Trans-arctic shipping
2. Inter-modal Arctic shipping
3. Destinational shipping: shipping activities in support of:
    a. Community re-supply
    b. Oil and gas exploration and exploitation
    c. Minerals exploration and exploitation
    d. Fisheries
    e. Tourism
    f. In-Arctic passenger traffic
    g. Other industrial developments
    h. Government services and research

These are discussed in more detail in Chapters 3 and 5.

## 2.5 Canadian Arctic Shipping Routes

Three main shipping routes can be identified in the Canadian Arctic: the Northwest Passage (NWP), the Arctic Bridge, and the Mackenzie River-Tuktoyaktuk route.

### 2.5.1 Northwest Passage

The NWP, the corridor in the Canadian Arctic connecting the Pacific and Atlantic Oceans, is not one but several routes that connect these oceans. AMSA (2009), based on CASA (2007), Pharand (1988) and Sailing Directions, Arctic Canada, Vol.3 5th edition (1994) identifies six potential transit routes reproduced below as Figure 2-6. The six routes, their trajectory, description and special notes, are included in Table 2-2.

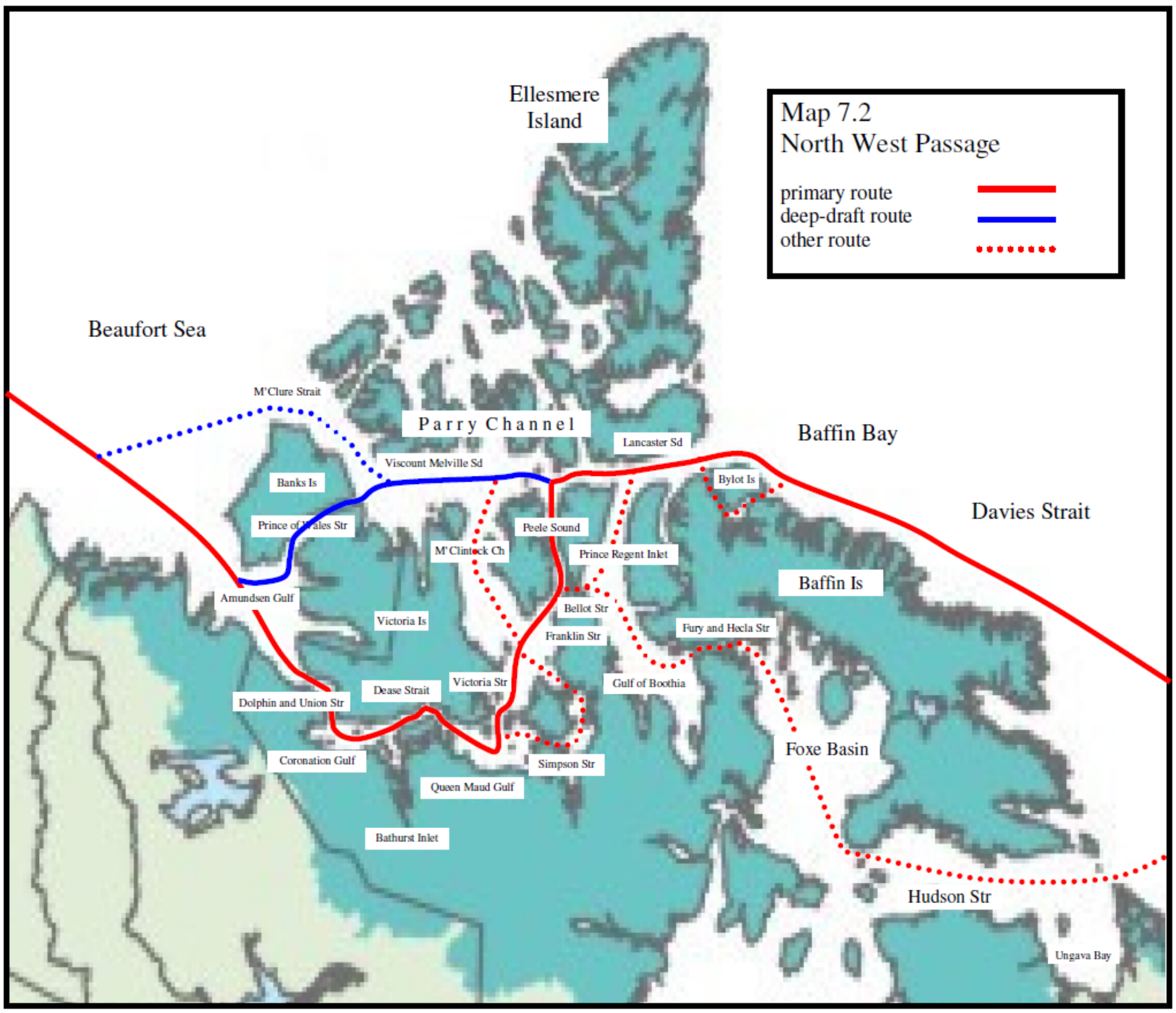



**Figure 2-6.** Northwest Passage Routes. Source: CASA (2007), p. 108.

**Table 2-2.** Navigation Routes of the Northwest Passage. Adapted from AMSA (2009), p. 21

| Route | Routing (East to West) | Description | Of Note |
|---|---|---|---|
| 1 (deep water route) | Lancaster Sound-Barrow Strait-Viscount Melville Sound-Prince of Wales Strait-Amundsen Gulf-Beaufort Sea | **Lancaster Sound:** 80 km wide, 150 km long, deep at over 500 m<br>**Barrow Strait:** 50 km wide, 180 km long, deep, string of islands west of Resolute disrupts clear navigation<br>**Viscount Melville Sound:** 100 km wide, 350 km long, experiences multi-year ice from McClure Strait.<br>**Prince of Wales Strait:** minimum width less than 10 km about half way through the Strait, 230 km long, limiting depth of 32 m<br>**Amundsen Gulf:** irregular shape, 90 km wide entrance, approximately 300 km long | Suitable for deep water navigation |
| 2 | Lancaster Sound-Barrow Strait-Viscount Melville Sound-McClure Strait-Beaufort Sea | **M'Clure Strait:** 120 km wide at East end, 275 km long to Beaufort Sea, deep at over 400m, experiences multi-year ice from Arctic Ocean. | In September 2007 was clear of Arctic pack ice for a limited time since satellite photos have been available; there was more ice in 2008 |
| 3A (primary route) | Lancaster Sound-Barrow Strait-Peel Sound-Franklin Strait-Larsen Sound-Victoria Strait-Queen Maud Gulf-Dease Strait-Coronation Gulf-Dolphin and Union Strait-Amundsen Gulf-Beaufort Sea | **Lancaster Sound:** 80 km wide, 150 km long, deep at over 500 m<br>**Peel Sound:** 25 km wide, deep at over 400 m at south end<br>**Franklin Strait:** 30 km wide<br>**Larsen Sound:** depths vary between 30 and 200 meters<br>**Victoria Strait:** 120 km wide, at southern end is blocked by Royal Geographical Society islands, worst ice conditions along the mainland coast of Canada<br>**Queen Maud Gulf:** eastern entrance 14 km wide, but widens into an irregular area with width of up to 280 km before narrowing to 14 km at entrance to Dease Strait; numerous islands, reefs and shoals<br>**Dease Strait:** 14-60 km wide, 160 km long<br>**Coronation Gulf:** over 160 km long, many islands.<br>**Dolphin and Union Strait:** 80 km wide at Amundsen Gulf: 150 km long, caution should be exercised in passage, several soundings of less than 10 m have been recorded<br>**Amundsen Gulf:** irregular shape, 90 km wide entrance, approximately 300 km long | Of the 3A, 3B and 4 routes, this is considered the best option but with a draft limit of 10 m. |
| 3B | Lancaster Sound-Barrow Strait-Peel Sound-Franklin Strait-Larsen Sound-James Row Strait-Rae Strait-Simpson Strait-Queen Maud Gulf-Dease Strait-Coronation Gulf-Dolphin and Union Strait-Amundsen Gulf-Beaufort Sea | **James Ross Strait:** 50 km wide, but restricted by islands, extensive shoaling<br>**Rae Strait:** 20 km wide, with limiting depths of between 5-18m in mid channel<br>**Simpson Strait:** about 3 km wide at narrowest point, most hazardous navigation are in 3B route | |

| | | | |
|---|---|---|---|
| 4 | Lancaster Sound-Barrow Strait-Prince Regent Inlet-Bellot Strait-Franklin Strait-Larsen Sound-Victoria Strait-Queen Maud Gulf-Dease Strait-Coronation Gulf-Dolphin and Union Strait-Amundsen Gulf-Beaufort Sea | **Prince Regent Inlet**: 80 km wide, free of islands, deep<br>**Bellot Strait:** short and very narrow, strong currents, limiting depth of 22 m. | |
| 5 (southern route) | Hudson Strait-Foxe Channel-Foxe Basin-Fury and Hecla Strait-Gulf of Boothia-Bellot Strait-remainder of 3A, 3B or 4 | **Hudson Strait:** 100 km wide, 650km long, deep, also serves as entrance to Hudson Bay and Churchill port<br>**Foxe Channel:** 130 km wide, deep, with limiting shoal in the middle that can be avoided<br>**Foxe Basin:** very large, many islands in northern end<br>**Fury and Hecla Strait:** 160 km long, very narrow with fast current<br>**Gulf of Boothia:** very large waterway connecting to Prince Regent Inlet to the north (see route 4). No problems for navigation except at exist of Fury and Hecla Strait where Crown Prince Frederick island is to be avoided. | Not generally considered a viable commercial passage for moderate to deep draft ships.<br>It involves two difficult straits and several locations where ice accumulates heavily. (not usually considered NWP). |

### 2.5.2 Port of Churchill and Arctic Bridge

The Port of Churchill in Hudson Bay is Canada's only northern deepwater seaport that can efficiently load Panamax-size vessels, and offer berths for the loading and unloading of grain, general cargo and tanker vessels. It is connected to the interior of Canada and North America in general via railroad, which the Canadian government has recently upgraded. It is an alternative shipping route to North America that eliminates time-consuming navigation, additional handling and high-cost transportation through the Great Lakes and St. Lawrence Seaway.

The Port of Churchill connects to the Russian ice-free port of Murmansk in a route known as the "Arctic Bridge" (Figure 2-7). The route goes through the Labrador Sea, Hudson Strait and then directly across the Bay to Churchill or alternatively just south of Southampton Island southwestward toward the western shoreline and then south into Churchill.

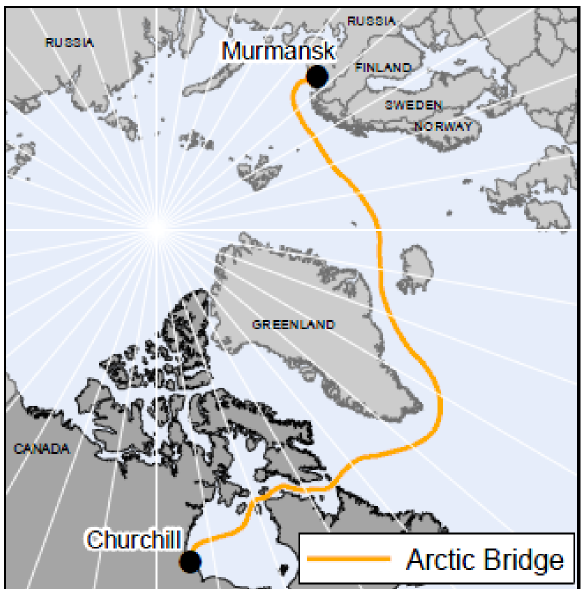



**Figure 2-7.** Arctic Bridge. Source: Statistics Canada (2011)

The route through Hudson Strait historically opens around July 1st but can be delayed by a month during colder years. Churchill and the western shore of Hudson Bay are generally open by the first week of July but can be delayed up to four weeks in colder years, or if the prevailing westerly winds are absent. Over the last decade this area has had generally lighter ice conditions than in the previous two decades with navigation conditions that would warrant an extension to the closing of the shipping season by two to three weeks. According to CASA (2007), it is unlikely for the opening date of this route to change significantly by 2020. By 2050, the frequency of an earlier opening date will increase but with large inter-annual and year-to-year variations.

CASA (2007) notes an aspect that it considers relevant for projecting traffic through Port of Churchill: the isostatic rebound affecting in particular the west coast of Hudson Bay. According to projections, land may rise about twice as fast as sea level during this century, affecting the draft available for ships using the Port of Churchill. Eventually, this may require compensatory dredging on a regular basis to ensure sufficient draft for ships using the Port of Churchill; however, not in the next decade.

### 2.5.3 Tuktoyaktuk, Over-the-Top Route and Arctic Module Inland Transport

Tuktoyaktuk, a relatively deepwater port in western Arctic, serves as a main shipping hub for most cargo in the western Canadian Arctic. Cargo is moved by tugs and barges from Hay River down the Mackenzie River to Tuktoyaktuk for transfer and consolidation. The route is used for community re-supply and also serves the Mackenzie Delta and Beaufort Sea gas and oil exploration and exploitation. Further, an “over-the-top” route to the Arctic has been proposed, which would connect the Arctic with the oil sand developments in Alberta and Saskatchewan either by shipping through the Pacific Ocean, Beaufort Sea, Tuktoyaktuk and Mackenzie River to Fort McMurray or Hay River; or alternative from the Atlantic, the NWP, Tuktoyaktuk, and the Mackenzie River to Fort McMurray or Hay River. The route reduces distance and cargo-size restrictions currently in place in over-land routes leading from ports in British Columbia, as well as shipping distance to Europe.

A preliminary assessment of the route was undertaken by Mariport Group Ltd. in 2006. In 2008, Inuvialuit Corporation, NTCL and Mammoet Canada formed Arctic Module Inland Transportation Ltd. to conduct engineering and feasibility studies of the proposed route. Tests included the possibility of shipping large modules and other oversized cargo up the Mackenzie River and transferring them to surface transportation (either truck or the Mackenzie Northern Railway) at Hay River for delivery to oil sands developments in northern Alberta and Saskatchewan.

According to Ruffilli (2011), the Government of the Northwest Territories believes that the over-the-top route could yield significant benefits both for the territory and for Canada as a whole, including:

- additional economic activity, particularly for the territories’ marine transportation sector and for the communities of Tuktoyaktuk, Hay River and Fort Smith;
- a visible means of asserting Canadian sovereignty in the region through sustained economic activity; and
- an impetus to develop the Mackenzie Valley All-Weather Highway, which, together with the over-the-top route, would provide a potentially significant new gateway corridor.

However, the literature review does not uncover any developments related to the projected shipping route since 2008-2009.

# 3 General Factors Defining Year-2020 Scenarios

The objective of Phase 2 of this study (namely to produce projections of shipping densities in the Arctic for the year 2020 and deliver the results in the form of shipping density maps and reports) requires an understanding of what factors or drivers are expected to impact Arctic traffic, and Canadian Arctic traffic in particular. Several reports have identified and organized factors that are expected to influence the volume and spatial distribution of Arctic shipping in the future. These assessments include: AMSA (2009) (based on the San Francisco workshop, see below); Mariport Group Ltd. (2005); and Williams et al. (2011).

Particular mention must be made of the scenario creation workshop on “The Future of Arctic Marine Navigation in Mid-Century” held in San Francisco, 4-6 April 2007, convened by the Arctic Council’s Protection of the Arctic Marine Environment (PAME) in preparation for AMSA (2009). The participants in the workshop identified and listed more than 120 factors or forces that could impact Arctic marine navigation by 2050, and prioritized them according to the experts’ judgment on their importance and uncertainty. The list of factors identified by the experts is included in Appendix 1.

In an effort to synthesize these previous initiatives, this report has classified the drivers into five general groups: a) climate factors; b) geopolitical and governance factors; c) environmental protection factors; d) infrastructure factors; and e) sector-specific demand factors. This general framework is depicted in Table 3-1.

***Climate factors*** influence the accessibility to the Arctic by vessels that are pursuing commercial shipping, resource exploration and exploitation, tourism, fisheries, research, or other activities. Climate change has a significant impact in the Arctic in general, and specifically on the sea ice conditions, and is indeed one of the fundamental conditions for the expected increase in economic activities. However, it should be noted that the expected developments of some economic activities, and particularly oil and gas and mineral and metals exploitation, have been primarily associated with economic drivers (price of commodities) rather than increased accessibility.

***Geopolitical and governance drivers*** refer to a variety of global and regional elements of political organizations and legal regimes applicable to the Canadian Arctic that are expected to influence and shape shipping activities in the North such as: political and economic power balances, indigenous rights and land claim agreements, Arctic land and maritime boundaries disputes, legal interpretations on the status of the NWP, extended continental shelf submission to the United Nations Commission on the Limits of the Continental Shelf.

The ***environmental protection driver*** derives from another group of factors that may have significant bearing in shaping Arctic shipping by 2020. There is increasing awareness and concern about the risks of increased economic activity in a complex, fragile and under-studied Arctic ecosystem. The ecosystem and the potential impacts of economic activities have been the subject of several previous and ongoing comprehensive studies in Canada and worldwide. These include, among others: the Conservation of Arctic Flora and Fauna's (CAFF) Arctic Biodiversity Assessment and Circumpolar Biodiversity Monitoring Program; and the Fisheries and Oceans Canada's Arctic Ecosystem Status Report and identification of ecologically and biologically significant areas in Canada's Arctic.

These efforts have resulted in a number of proposals to strengthen the environmental governance of the Arctic to prevent damage to the fragile environment. The laws and regulations aimed at protecting the marine environment, the Arctic ecosystem and its components have the potential to impact Arctic shipping traffic in different ways:

a) By requiring compliance with construction or operations standards and practices to prevent damage to the Arctic ecosystem or any of its components;
b) By establishing traffic restricted zones (International Maritime Organization's particularly sensitive sea areas (PSSAs), marine protected areas (MPAs), no-fishing zones, no cruise traffic areas, etc.)
c) By demanding compliance with environmental protection standards to project developments in the Arctic (standards can be contained in special regulations or be conditions within the environmental impact assessment procedures).

***Infrastructure factors*** include a number of physical, scientific and intellectual elements that facilitate safe Arctic shipping traffic. These include: port infrastructure, icebreaker infrastructure, navigational charts, ice information services, marine communications, traffic monitoring and control, search and rescue facilities, certified ship officers and crews, qualified personnel, and Arctic training. As noted by AMSA (2009), both Arctic-wide and in the Canadian Arctic, the lack of infrastructure is a serious constraint to Arctic traffic development. Infrastructure development (of lack thereof) will either enable or hinder Arctic shipping traffic growth.

A further group of variables includes the economic factors that will determine the demand for Arctic shipping and its spatial distribution. These economic factors are both general and sector-specific. Main ***demand factors*** include: population (global and regional), economic development, energy consumption, the price of oil and gas, commodity prices, competition (e.g. shipping routes, alternative energy sources), and operational costs, among others.

Economic factors are the engines of economic activity (and shipping traffic) in the North; how, when and where that shipping traffic will occur is either facilitated or hampered by accessibility, geo-political factors and governance, environmental governance, and available infrastructure. These roles are depicted in Table 3-1, with demand drivers at the core surrounded by the broader overarching influences that may fundamentally change the nature of Arctic activities in the long run.

**Table 3-1.** Synthesis of the Main Factors Influencing Shipping Density and Spatial Distribution in the Arctic

**Climate Factors**

**Geo-Political Factors**

**Demand Factors**

| Vessel Category | | Activity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Trans-Arctic Shipping** | **Inter-Modal Shipping** | **Community Re-Supply** | **Resources: Oil and Gas** | **Resources: Minerals** | **Resources: Fisheries** | **Resources: Other Industrial Developments** | **Tourism** | **Government Services and Research** |
| **Vessel Category** | Merchant - Bulk- Cargo | ● | ● | ● | ● | ● | | | | |
| | Tanker | ● | ● | ● | ● | ● | | | | |
| | Fishing | | | | | | ● | | | |
| | Cruise Ship Passenger | | | | | | | | ● | |
| | Pleasure Craft | | | | | | | | ● | |
| | Gov't Non-Military | ● | ● | ● | ● | ● | | | | ● |
| | Research & Exploration | | | | | | | | | ● |
| | Tugs & Service | | ● | ● | ● | ● | | | | |

**Infrastructure**

**Environmental Governance**

Recognizing the role that each of these groups of factors or drivers plays, and will play, in the Canadian Arctic shipping traffic by 2020 and beyond, it is considered that geo-political factors, environmental protection factors, and infrastructure are too open-ended and uncertain to be incorporated in the development of scenarios for this Phase 2 study. Additionally, it is highly unlikely that any of these factors will face a significant or "paradigm changing" development over the time horizon of this study. For these reasons, it is recommended that the development of scenarios for this phase be based on two groups of factors: climate change and demand factors. It should be mentioned that this approach is consistent with most of the studies that are analyzed in this report, which do not themselves make explicit assumptions on geo-political factors or governance, environmental governance, or infrastructure developments.

Although generally geo-political factors and governance, environmental governance and infrastructure are not included in the analysis, some sector-specific concrete and significant developments expecting to bear a direct impact on Canadian Arctic shipping activities by 2020 have been included in the respective sections of this report. For example, small-craft port construction for fisheries, fisheries conservation and management measures, projected port and roads for mine services, Arctic research facilities in construction, or projected port infrastructure for defence purposes, are considered in the sections on fisheries, research and government services.

The resulting framework is consistent with the four future scenarios developed by AMSA (2009) and depicted in Figure 3-1. These scenarios have been developed on the basis of governance regime (stability and legality) and resources and trade (demand) as depicted in Figure 3-1. The scenarios for the Canadian Arctic shipping projection by 2020 will address the demand axis of the AMSA scenarios.


**Figure 3-1.** AMSA Scenarios. Source: AMSA (2009)

If the recommendation is accepted, the scenarios and assumptions that will serve as the basis for the projected Canadian Arctic shipping traffic density and spatial distribution by 2020 will be climate factors (accessibility) and demand factors. Some of the climate factors may also affect demand, such as fish stock relocation.

Arctic climate modeling has been the subject of numerous studies that have developed a number of projections. The objective of this Part 1 report is to summarize the main projections for Arctic climate and particularly sea ice conditions by 2020, including forecasts and projections for the Canadian Arctic and the Northwest Passage. The information provided should be the basis for the development of one or more assumptions on sea ice conditions and accessibility of the Canadian Arctic by 2020. This analysis will be undertaken in Section 4 of this report.

To develop scenarios about demand for the different navigational activities included in the report, it is recommended that the second phase uses, as a starting point, one or more scenarios developed by the Special Report on Emission Scenarios (SRES) (IPCC, 2000). The SRES scenarios were developed in support of the climate change models of the Intergovernmental Panel on Climate Change (IPCC). They were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. The different scenarios make assumptions on the following main drivers: population, economy, technology, energy, land-use, and agriculture.

SRES consist of qualitative storylines, scenario groups and several model-based quantitative scenarios to each storyline. In total, four storylines (A1, A2, B1, B2), six scenario groups (one each for A2, B1, B2, and three for A1) were produced. Six modeling teams produced a total of 40 scenarios across these six groups. Each scenario includes projections of values for the different drivers for each decade until 2100, for the following regions: the world; member States of the Organisation for Economic Co-operation and Development (OECD) as of 1990; Central and Eastern Europe and Newly Independent States of the former Soviet Union; Asia; Africa, Latin America and Middle East. Projections of values include: population, Gross National Product/Gross Domestic Product (mex-market exchange rate and ppp-purchasing power parity), energy use (final and primary), cumulative resource use, cumulative $CO_2$ emissions, carbon sequestration, land use, and anthropocentric emission (SRES, http://sres.ciesin.org/final_data.html).

While the global nature and greenhouse gas (GHG) emissions focus of the SRES scenarios does not necessarily bear direct relationship with expected shipping activities in the Canadian Arctic, it is considered a good starting point for the development of specific scenarios and assumptions for Canadian Arctic shipping traffic for this study for several reasons.

First, SRES scenarios have been used to project climate change and sea ice conditions and therefore are linked to the first driver (accessibility). However, it has been noted that because of the residence time of carbon in the atmospheric system, the climate projections are relatively insensitive to the precise details of which future emissions scenarios are used over the next few decades, as the impacts of scenarios are rather similar before the mid-21st century (SWIPA, 2011, chapter 3, p. 3-8). Therefore, projections of sea ice conditions by 2020 are not heavily dependent of any of these scenarios.

Secondly, SRES scenarios have been used already in several other studies projecting shipping in the Arctic (particularly those studies that aim at projecting greenhouse gas emissions from shipping in the Arctic). The comparison of these studies' projections requires an understanding of the underlying assumptions under which each of the projections was made.

Thirdly, although demand drivers have a strong sectoral component, they are directly and indirectly related to global and regional broader economic assumptions. For example, a fast growing global economy with current energy use patterns will probably determine:

- high prices of oil and gas (with consequences for oil and gas exploration and exploitation and potentially Arctic shipping);
- high prices of commodities (with consequences for Arctic mining);
- increased community re-supply (as a consequence of economic growth in the Canadian North as determined by increased economic activity); and
- increased tourism resulting from more disposable income.

It is proposed that the SRES scenarios, as a general framework, will ensure consistency of the sector-specific assumptions.

Fourthly, the use of SRES scenarios implies the use of global and regional economic driver projections that have been prepared by teams of experts.

If this recommendation is accepted by the Technical Authority as required by the Statement of Work, SRES scenarios will need to be complemented with regional-specific factors and drivers. One of this report's objectives is to identify those regional-specific factors that will be needed to develop Canadian Arctic shipping scenarios and assumptions by 2020, as well as collect information on quantitative and qualitative projections for those factors. When faced with such a large number of scenarios arising from the convolution of multiple variables, it is unreasonable and unhelpful to assess them all. Rather, upper and lower bounds on each variable will be used to as limits on probabilistic distributions for each variable, which can then be combined using Monte Carlo analysis.

# 4 Climate Factors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## 4.1 Introduction

The changes to the Arctic environment that have been recorded for the past decades and are expected in this century are a significant driver for the projected increase in Arctic traffic, although its relative importance varies among the different navigational activity types.

The main changes resulting from warming climate that are expected to have an impact on the density and spatial distribution of Arctic shipping traffic are:

- Ice-coverage
- Age of ice (ice thickness) and concentration of ice types
- The form (floe size) of each ice type
- Length of the ice-free season
- Seasonal variability
- Ice drifts
- Extreme weather incidents
- Other climate hazards

## 4.2 Sea Ice Conditions Projections

Maurette (2010) presents a summary based on a comprehensive literature review of projected ice conditions in the Arctic. The study shows a wide range of projections and a significant degree of uncertainty. The Arctic is expected to be ice-free during a short period during the summer within the time period between 2013 and 2100, with most projections indicating a sea-ice free Arctic midcentury (2040-2060). Maurette summarizes the findings as follows:

> *Over the past few decades, the annual average sea-ice extent in the Arctic has decreased by about 8% or one million square kilometers. The summer minimum in September and the winter maximum in March have also decreased. In 2007, the minimum sea-ice extent was 4.3 million square kilometers, 23% less than in 2005 and 39% smaller than the long-term average from 1979 – 2003. Ice thickness has also decreased considerably, in some areas losing as much as 40% between 1960 and 1990, and about 10% - 15% Arctic-wide. Future projections indicate that as warming continues, first year ice is replacing multi-year ice, leading to a permanent thinning of the sea ice. It is expected that by 2020 the ice extent would be down another 20% in summer and by up to 50% by 2100.*
> *(…) It is expected that there may be a summer ice-free Arctic in the period 2040 – 2080. The Northern Sea Route along Russia's coast is currently navigable 20 – 30 days annually, and the navigable period will increase to 80 -90 days around 2080. The Northwest Passage navigable season has increased from about five weeks in 1970 to seven weeks in 2000. By 2010 to 2015, the Northwest Passage will be open to non-ice-strengthened ships for at least one month each summer. Still, the Northwest route is not expected to become viable as a trans-Arctic route through 2020, though destinational shipping will increase as commercial interest and development grow.*
> *Even in summer, the Northwest Passage will remain difficult to navigate as multi-year ice makes its way south into the Canadian Arctic Archipelago with the melting of first year ice. (…)*

Three sea ice condition projections deserve a special mention because of the authoritative nature of the organization making the projection, the special focus in the Arctic and/or their consideration in the Arctic shipping traffic predictions reviewed. These are: the Arctic Climate Impact Assessment Report (ACIA) 2004, the IPCC Fourth Assessment (2007) and the Snow, Water, Ice and Permafrost in the Arctic Report (SWIPA) 2011.

ACIA assessment was adopted by the Arctic Council in 2004 and published in 2005. It uses the SRES A2 and B2 emissions scenarios (which are in the middle of the range of scenarios provided by the IPCC) and five models to project future sea ice extent. ACIA concluded that the Arctic sea-ice extent decreased by 0.30±0.03 x 106 $km^2$/10 yr between 1972 and 2002, but by 0.36±0.05 x 106 $km^2$/10 yr between 1979 and 2002, indicating a 20% acceleration in the rate of decrease. ACIA 2004 also identified a decreasing trend of multi-year sea ice in the central Arctic Ocean. Multi-year sea ice in the Arctic showed a 14% decrease in winter multi-year sea ice between 1978 and 1998, with particular decrease in the north of the Russian and Alaskan coasts. Another study, based on a comparison of upward-looking sonar data from submarine cruises during 1958–1976 and 1993–1997, found a decrease of about 40% (1.3 meters) in the sea-ice draft (proportional to thickness) in the central Arctic Ocean from the earlier to the later period. In only one of the ACIA-designated models is the Arctic summer ice-free by 2090 (projections for

September) (Figure 4-1). The raw projections for this model, consistently showing the least ice, indicate an ice-free Arctic during September by the mid-21st century, but this model simulated less than half of the observed September sea-ice extent at the start of the 21st century. This model also forecasts the least sea-ice extent in March by the end of the century, at only about 10 million $km^2$ or two-thirds of the 2000 March extent (Figure 4-2).

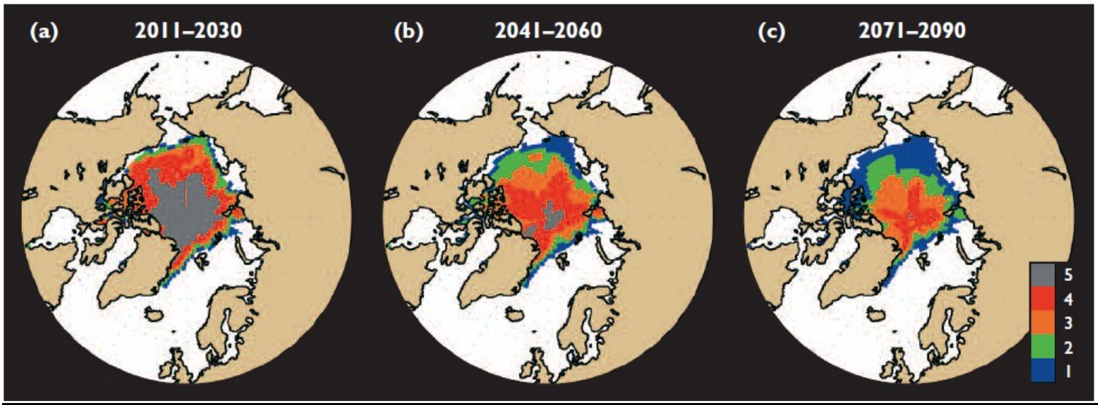


**Figure 4-1.** Five-model composite maps of sea-ice coverage for September expressed in terms of the number of models (out of five) that project the presence of sea ice during September for at least 50% of the years in the time slice. Source: ACIA (2004), chapter 6, p. 194.

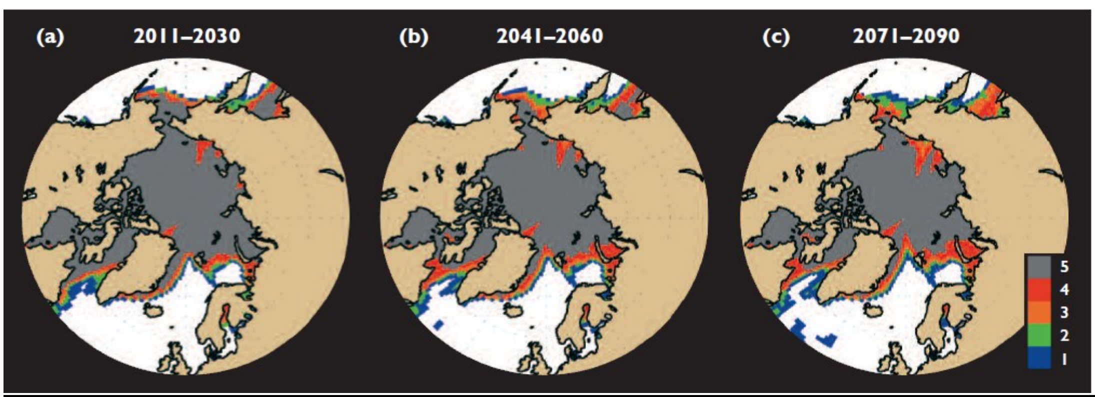


**Figure 4-2.** Five-model composite maps of sea-ice coverage for March expressed in terms of the number of models (out of five) that project the presence of sea ice during March for at least 50% of the years in the time slice. Source: ACIA (2004), chapter 6, p. 194

**Table 4-1.** Changes in mean annual Northern Hemisphere sea-ice extent between 2000 and 2100 projected by the five ACIA-designated models. Source: ACIA (2004), Chapter 6, p. 194.

| | Unadjusted projections | | | Adjusted projections | | |
|---|---|---|---|---|---|---|
| | Ice extent ($10^6$ $km^2$) | | Change (%) | Ice extent ($10^6$ $km^2$) | | Change (%) |
| | 2000 | 2100 | | 2000 | 2100 | |
| CGCM2 | 9.7 | 5.6 | -42 | 12.3 | 6.6 | -46 |
| CSM_1.4 | 16.5 | 14.2 | -14 | 12.3 | 10.8 | -12 |
| ECHAM4/OPYC3 | 11.9 | 8.9 | -25 | 12.3 | 9.3 | -24 |
| GFDL-R30_c | 11.9 | 8.5 | -29 | 12.3 | 8.6 | -30 |
| HadCM3 | 12.8 | 9.4 | -27 | 12.3 | 9.1 | -26 |

The IPCC Fourth Assessment 2007 compared 23 modeling exercices on several scenarios, including three SRES scenarios (A2, A1B, B2, representing ‘low’ (B1), ‘medium’ (A1B) and ‘high’ (A2) scenarios with respect to the prescribed concentrations and the resulting radiative forcing, relative to the SRES range). The IPCC fourth assessment report concludes that “there is a projected reduction of sea ice in the 21st century in both the Arctic and Antarctic with a rather large range of model responses. The projected reduction is accelerated in the Arctic, where some models project summer sea ice cover to disappear entirely in the high-emission A2 scenario in the latter part of the 21st century”.

Soon after the IPCC reports were made public, critics noted that they were likely too conservative and that an ice-free Arctic during summer months could be within the years 2026-2046 (Ho 2010, citing Stroeve et al. 2007). Furthermore, is has been noted that even this latter projection may be conservative because it does not consider the impact of methane releases due to thawing of Arctic lakes, which could trigger a vicious warming cycle as the methane gas released will trap 25 times more of the sun’s heat than carbon dioxide does (Ho 2010).

SWIPA, adopted by the Arctic Council in 2011 as a follow-up of ACIA 2004, is the most recent assessment and projections of Arctic snow, ice and permafrost. Its aim is to update the findings from ACIA and to provide more in-depth coverage of issues related to the Arctic cryosphere. SWIPA assess the IPCC projections with the models that have had better prediction rates and with current data. Its general conclusions are:

> *The average extent of the summer (September) minimum sea-ice cover has declined by 25-30% since estimates based on satellite information began in 1979. The rate of decline increased over the past ten years and is now greater than reported by ACIA. Complete summer sea-ice loss is projected as likely to occur by mid-century. Variability in summer sea-ice extent is projected to increase initially, but then to decrease as ice-free summers are approached. Sea ice is generally thinning and older ice types (5 years old) are being lost with increasing frequency; first-year ice is projected to dominate in the future. (…) Projections of annual maximum extent and duration of seasonal sea-ice cover are uncertain and regionally variable (and affected by local bathymetry and weather conditions), but maximum extent and duration are very likely to be less than present (i.e. with a more northerly distribution, smaller area, shorter duration). (…) The extent and location of summer/autumn polar pack (i.e. multi-year sea-ice remnants) will be uncertain in future years as the summer ice decline continues, but most models project that pack-ice remnants are very likely to occur along the northwestern margin of the Canadian Archipelago and the north coast of Greenland at least until complete loss* (SWIPA, chapter 12-3).

## 4.3 Climate Factor Assumptions in the Shipping Literature

The assumptions about ice conditions made in the basic reference studies are based on ACIA (2004), although in some cases reference to more recent studies are made. The sea ice condition assumptions for the main reports in the literature review are summarized in Table 4-2.

**Table 4-2**. Sea Ice Conditions Assumptions in the Literature

| Report | Year for Projection | Primary Basis | Summary |
|---|---|---|---|
| AMSA (2009) | n/a | ACIA 2004 | Global climate model simulations indicate a continuing retreat of Arctic sea ice through the 21st century. Observed sea ice trends and global climate model (GCM) simulations show coastal Arctic regions to be increasingly ice-free or nearly ice-free for longer summer and autumn seasons. All simulations indicate than an Arctic se ice cover remains in winter.<br><br>Recent sea-ice model simulations indicate the possibility of an ice-free Arctic ocean for a short period of time in summer earlier than mid-century.<br><br>Future sea ice conditions remain uncertain. It is highly plausible that Arctic sea ice will be more mobile in partially ice-covered coastal seas, particularly in spring, summer and autumn. Coastal seas may experience an increase and greater frequency of ice ridging and shorter periods of coastal fast ice.<br><br>The resolutions of GCM simulations are much too coarse for adequate coverage of the complex geographies of the Canadian and Russian Arctic. GMC Arctic sea ice simulations also lack robustness to provide detailed information on future marine operating conditions such as the length of the navigation season, residence time, of ice-free conditions, frequency of leads and ridges and more.<br><br>Recent GCM have not replicated the observed sea ice reductions from the 1950s to today. For example, the model simulations have not shown the drastic decrease of observed sea ice extent during recent years.<br><br>Climate change as indicated by Arctic sea ice retreat is a facilitator for marine access. It is highly plausible there will be greater marine access and longer seasons of navigation, except perhaps during winter, but not necessarily less difficult ice conditions for marine operations. |
| Williams et al (2011) | 2050 | IPCC 2007<br><br>ACIA 2004 | A completely ice-free Arctic is highly unlikely within this century.<br><br>Lengthening of the ice-free season in the marginal zones in the summer months (Northern Sea route: 20-30 days per year in 2004, to 90-100 days by 2080).<br><br>Increase in the area that is free of ice in the seasonal ice zone.<br><br>Other potential climate induced changes: increased surface air temperatures, a reduction in albedo effects, alterations I the freshwater budget through increase in freshwater run-off caused by glacial retreat, increased coastal erosion, increase in the depth of permafrost seasonal thawing.<br><br>Changed circulations patterns with knock-on impacts in the Arctic Region. |
| Analyse&Strategi (2011) | n/a | ACIA 2004 | Observations of minimum sea-ice extent in the eastern and western regions of the NWP illustrate the extraordinary inter-annual variability of ice conditions. Although the trends in sea ice extent are negative in both regions over the period, the year to year variability is extreme and sometimes differs between the two regions. Although climate models for the Arctic, like the ACIA models, indicate a general retreat of sea ice throughout the 21st century, the designated projection models provide no |

| | | | |
|---|---|---|---|
| | | | information on ice thickness (a critical factor for navigation). It is important to note that the horizontal resolution of these models (generally 200 kilometers) is not fine enough to take into account the complexity of the Canadian Archipelago. Hence there is more uncertainty when it comes to predicting future ice conditions in the NWP based solely on the output of climate models. |
| CASA (2007) | 2020 | IPCC 2001 | Arctic temperatures will increase (summer: 1-2° C; autumn: 7-8° C; winter: 8-9° C; spring: 5° C)<br><br>A continuing reduction in Arctic sea-ice extent in the order of 30% by the year 2050.<br><br>A continuing decrease in ice volume likely in the order of 40% by 2050.<br><br>Possible disappearance of summer ice by 2070 but more likely 2100.<br><br>The entire Arctic Basin will remain ice covered during winters of the 21st century.<br><br>Horizontal resolution of the models (generally 200 km) is not fine enough to take into account the complexity of the Canadian Archipelago. |

## 4.4 Sea Ice Conditions in the Canadian Arctic and Northwest Passage: Trends and Projections

The coarse spatial resolution of the IPCC climate models limits its value for finer scales, especially in the Canadian Archipelago, where the complex geography makes its projections less robust than elsewhere in the Arctic. Some studies provide particular description and projections of sea ice conditions in the Canadian Arctic and the Northwest Passage. The following paragraphs summarize those descriptions and projections.

### 4.4.1 Sea Ice Conditions in Canadian Arctic

Stewart et al. (2010b) summarize the sea ice regimes in the Canadian Arctic, citing several recent studies, dividing the area into western and eastern sub-region, both of which contain Queen Elizabeth Islands and span the NWP.

Regions in the western Canadian Arctic can contain as much as 50% multi-year ice because of the influx from the Canadian Basin and in situ formation. The eastern Canadian Arctic presents mainly seasonal first-year ice. Sea ice in the Queen Elizabeth Islands is a mix of first year ice and multi-year ice and in a typical year less than 20% of multiyear ice and 50% of first-year ice melts, thus, sea ice concentrations are high during summer.

Sea ice within the Canadian Basin adjacent to the western Canadian Arctic is not land-fast, instead this perennial multiyear ice circulates according to the predominately anticyclonic circumpolar gyre. As a result, sea ice is forced up continuously against the Queen Elizabeth Islands and ridged heavily, creating some of the oldest and thickest sea ice in the world, potentially reaching over 6-8 meters high.

Using ice charts provided by the Canadian Ice Service for the period from 1968 to 2007 (and particularly the weekly charts for a 17 week time window between 25 June and 15 October), Stewart et al. (2010b) also summarize the changes in the sea ice conditions experienced in the different regions in the Canadian Arctic. The study concluded that:

a) Western Canadian Arctic has experienced decreases in total sea ice coverage of 3.7% per decade and decreases in the multi-year ice component of 5.1% per decade;
b) Eastern Canadian Arctic has experienced decreases in total sea ice coverage of 6.8% per decade and decreases in the multi-year ice component of 2.4% per decade;
c) All decreases are significant at the 99% confidence level except multiyear ice in the eastern Canada, which is not significant at any meaningful confidence level;
d) Despite the observed decreases, light ice years are still interspersed with heavy ice years with points out of cyclic nature of sea ice within the Canadian Arctic;
e) Multi-year ice invasions from high latitudes into the cruise channels of Canadian Arctic exist;
f) Decreases in total sea ice have been observed in Baffin Bay suggesting the entrance via the NWP from Baffin Bay likely would be feasible. However, difficulties arise in the vicinity of Lancaster Sound. There has been an observable increase in multiyear ice in this region from 1968-2005;
g) Choke points become more abundant as the NWP is traversed: Queen Elizabeth Islands contain high concentrations of thick multiyear ice; multiyear ice can flow into the Parry Channel and subsequently in lower regions of the Arctic, creating more choke points; Barrow Strait, Peel Sound and Franklin Strait are susceptible to multiyear ice invasions from Queen Elizabeth Islands.

In 2011, Statistics Canada released a study that shows trends in the average summer sea ice extent in Canada's north over a 43 year period (1968 to 2010). The trends show different conclusions than the projections in Stewart et al. (2010b). The results are summarized in Table 4-3.

**Table 4-3.** Sea Ice Extent and Multi-Year Ice Extent Decline in Canada's North over the Period 1968-2010. Source: Statistics Canada (2011)

| Region | Sea ice extent decline | Multi-year ice extent decline |
|---|---|---|
| Northern Labrador Sea | 1,536 $km^2$, or 17%, per decade | Not present |
| Hudson Strait | 4,947 $km^2$, or 16% per decade | Not present |
| Davis Strait | 6,581 $km^2$, or 14%, per decade | Not present |
| Hudson Bay | 16,605 $km^2$, or 11%, per decade | Not present |
| Baffin Bay | 18,658 $km^2$, or 10% per decade | 385 $km^2$ (21%) decrease in summer coverage of multi-year sea ice. This represents the largest decline of all time series in the study but it should be noted that multi-year ice only covers a very small part of this region. |
| Foxe Basin | Smaller decrease | Results did not indicate statistically significant trends |
| Southern Beaufort Sea | Smaller decrease | Results did not indicate statistically significant trends |
| Kane Basin | Smaller decrease | Results did not indicate statistically significant trends |
| Canadian Archipelago | Smaller decrease | Results did not indicate statistically significant trends |

SWIPA includes a table with trends in sea-ice extent in percentage per decade for several subregions of the Arctic relative to 1979-2009. The Canadian Arctic areas identified, and the respective trends in sea-ice extent, are reproduced in Table 4-4 below:

**Table 4-4.** Trends in Sea-Ice Extent in Percentage per Decade for Four Canadian Subregions of the Arctic relative to 1979-2009. Source: SWIPA (2011)

| Subregion | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hudson Bay | 0 | 0 | 0 | 0 | -0.2 | -5.6 | N/A | N/A | N/A | N/A | -26.7 | -1.6 |
| Baffin Bay | -7.4 | -5.8 | -5.9 | -6.2 | -6.6 | -9.9 | -18.9 | -28.5 | -10.1 | -34.6 | -11 | -11.3 |
| Canadian Archipelago | 0 | 0 | 0 | 0 | -0.1 | -1.3 | -2.3 | -7.5 | -12.3 | -4.3 | 0 | 0 |
| Beaufort Sea | 0 | 0 | 0 | 0 | 0 | -1.2 | -3.1 | -6.7 | -12.9 | -3.1 | 0 | 0 |

### 4.4.2 Sea Ice Conditions in the Northwest Passage

Stewart et al. (2010b), CASA (2007) and Statistics Canada (2011) each provide information on sea ice condition trends and/or projections for the NWP and the Arctic bridge route. A summary of the findings in these reports are summarized in Table 4-5.

**Table 4-5.** Sea Ice Conditions in Northwest Passage: Projections in the Literature

| Route | CASA 2007 | Stewart et al. 2010b | Statistics Canada 2011 |
|---|---|---|---|
| Route 1 | **By 2020, this route could be open for 8-10 weeks during some summers.** Large inter-annual variability will continue and icebreaker escort services will be required. The potential shipping season through this passage will continue to increase through 2050 but the threat of encountering old ice during most years will be significant. There could be an increase in the presence of old ice as the decrease in land-fast ice in the western portion of the Archipelago would allow more old ice from the Arctic Ocean to pass into channels between the islands. There is a stronger decreasing trend than that of M'Clure St. for the same period, however shipping will have to contend with significant amounts of old ice through the year 2050. | Large quantities of multiyear ice in M'Clure Strait, Viscount Melville sound.<br>Considerable quantities of multiyear ice off the western coast of Banks Island.<br>Prince of Wales Strait plugged with multiyear ice. | |
| Route 2 | **By 2020, frequency of an open summer passage will increase**, but with risk of encountering old/multi-year ice. Likely that this passage will remain ice congested for more years. | | Usually blocked by sea ice during all seasons (exception 2007).<br><br>Sea ice extent: no statistically significant trend.<br><br>Multiyear ice: no statistically significant trend. |
| Route 3A | Limited to ships having a draft of less than 10 meters.<br><br>Currently this route is passable from **mid August to mid September.** It is expected that active shipping for this passage will continue to increase. However, old ice will continue to be a significant navigation hazard and once again there will continue to be a large year-to-year variability. | Peel Sound has hazardous multiyear ice.<br>Choke point in the vicinity of Victoria Strait. | Usually blocked by sea ice during all seasons (exception 2007).<br><br>Sea ice extent declining by 6,986 km2 (6%) per decade.<br><br>Multiyear ice: no statistically significant trend. |
| Route 3B | | Peel Sound has hazardous multiyear ice. | |
| Route 4 | | Bellot strait has narrow passages that make it infeasible for larger vessels.<br>Choke point in the vicinity of Victoria Strait. | |

| | | | |
|---|---|---|---|
| Route 5 | Limited to ships having a draft of less than 10 meters.<br><br>It has had light ice years but it will likely remain difficult to traverse throughout 2020. Foxe Basin and Gulf of Boothia can have significant amounts of ice through mid August. Severe ice conditions at, and in the vicinity of, the western approaches to Fury and Hecla can be expected. Bellot Strait will generally be passable during the later part of August and through mid September but strong tidal currents will continue to be a factor for both the movement of ice and ships. **By 2050, the frequency of ice free conditions throughout this route will increase.** However, it is not likely that this route will be of interest to those shipping activities requiring reliable transit times and the probability of requiring an icebreaker escort are much higher than other NWP alternatives. | | |
| Arctic Bridge | Typically the route through Hudson Strait opens around **July 01** but can be delayed by almost a month during colder years. Churchill and the western shore of Hudson Bay are generally open by the **first week of July** but can be delayed up to four weeks in colder years, or if the prevailing westerly winds are absent. Over the last decade this area has had generally lighter ice conditions than in the previous two decades with navigation conditions that would warrant **an extension to the closing of the shipping season by 2-3 weeks.** Climate change will likely increase the probability of a two to three week extension to the closing dates but it is **unlikely that there will be a significant impact on opening date for this route through 2020.** By 2050 the frequency of an earlier opening date will increase. Larger inter-annual and year-to-year variations will continue through the first half of the 21$^{st}$ century.<br><br>Isostatic rebound implies that the rate of land rise is about twice as fast as the project sea level rise during this century, so could potentially have an effect on the depth available for ships using Churchill, unless compensatory dredging is undertaken on a regular basis. | | Arctic Bridge (Canadian portion): sea ice extent declining at a rate of 14,147 $km^2$ (15%) per decade.<br><br>Multiyear ice: not present in the route. |

The current and projected sea ice conditions identify areas of the Canadian Arctic Archipelago were multi-year ice is expected to concentrate, resulting in difficult and dangerous transit conditions. CASA (2007), citing Falkingham et al. (n.d.), includes a diagram of those sea ice areas or "choke points" that will hinder traffic through the NWP despite general declines in sea ice extent and multiyear ice extent, reproduced below as Figure 4-3.

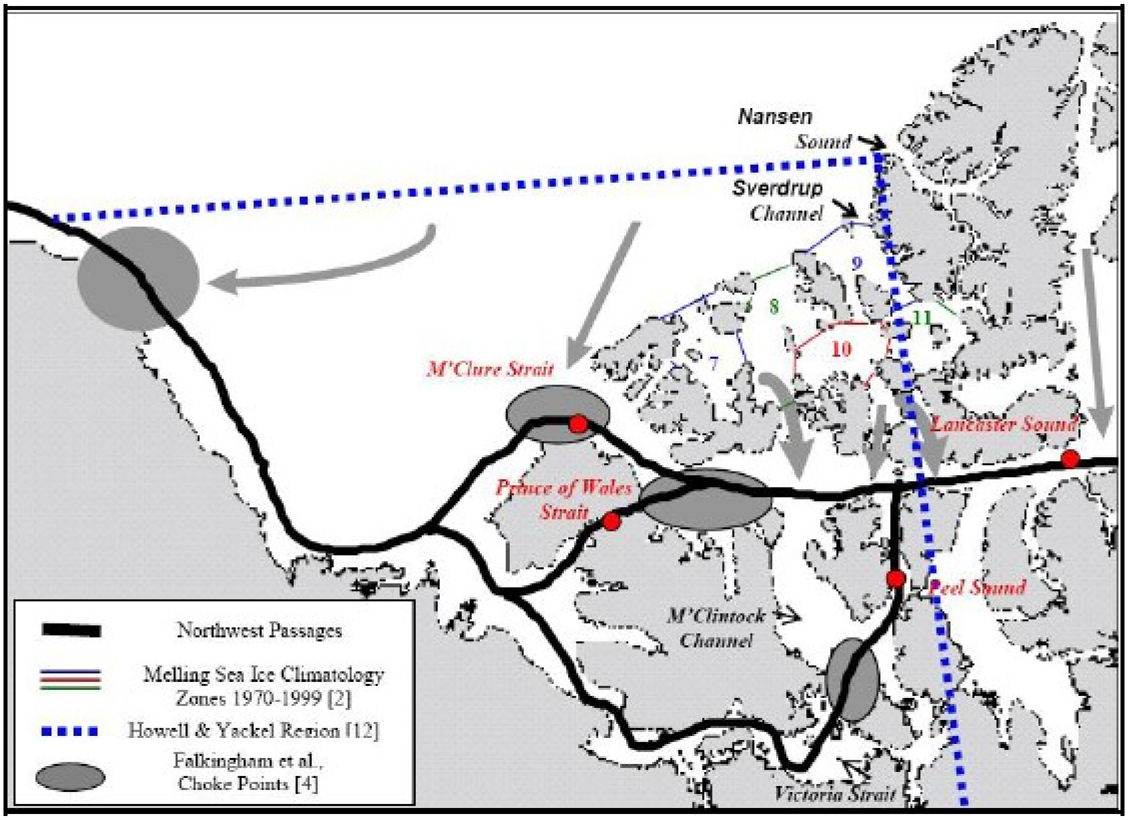


**Figure 4-3.** Arctic Choke Points. Source: CASA (2007)

It should be noted that satellite measurements have confirmed that the NWP (including the northern route) was open for shipping navigation during five consecutive years (2007, 2008, 2009, 2010 and 2011). On two occasions (2007 and 2011), the Northern passage was also open at the same time (Safety4Sea, 2 September 2011). As a consequence, traffic through the NWP has increased significantly. It has been reported that the number of ships transiting the NWP grew from 7 in 2009, to 18 in 2010 and 27 in 2011 (Ruffilli, 2011).

# 5 Demand Factors

## 5.1 Trans-Arctic shipping

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**Factors**

Accessibility

Global trade

Oil price

Development of Arctic marine technology

Hindering factors:

Lack of route reliability and inability to keep fixed timetables

Cost of building ice class vessels

Cost of operating ice class vessels (e.g. use of icebreakers; insurance premium)

Cost of building supporting infrastructure (e.g. staging ports to transfer cargo from ice-strengthened to non-ice strengthened ships)

Performance of ice-class vessels in open waters

Competitiveness of other sea lanes:

- Safety of other routes
- Capacity of other routes
- Relative costs of other routes (in fuel and time)

- Expansion plans in Panama and Suez Canals
- More favorable ice conditions in Northern Sea route (longer shipping seasons, less multi-year ice, distance to markets)
- More favorable ice conditions in Trans-Polar route (longer shipping seasons, less multi-year ice, distance to markets)
- Lack of critical infrastructure
- Lack of search and rescue capabilities

### 5.1.1 Introduction

Trans-Arctic shipping in this study refers to commercial shipping voyages between the Atlantic and the Pacific Ocean using the Arctic Ocean as a marine link. There are several options for trans-Arctic navigation: directly across the central Arctic Ocean (Trans-Polar route); using Russia's Northern Sea Route and Northeast Passage from the Barents Sea (Kara Gate) to the Bering Strait; and through the Canadian NWP.


**Figure 5-1.** Northwest Passage (left), Northern Passage (centre) and Northeast Passage (right). Source: ArcticPortal.org

### 5.1.2 Arctic-wide Shipping Projections

Several studies have made projections of Arctic shipping traffic with a focus on estimating shipping emissions (Peters et al. (2011) cite the following studies: Ragner (2000); Brunstad et al. (2004); Dalsoren et al. (2007); Verny and Grigentin (2009); Corbett et al. (2010); Kohn et al. (2010); Liu and Kronbak (2010)). The studies use different climate scenarios, regional developments, ship types, reference years and output parameters, making assumptions on shipping traffic volumes and "Arctic diversion", i.e., the amount of traffic that is potentially going to use Arctic routes. The studies are mostly Arctic-wide or focus on the more competitive Northern Sea route. The results of projections made in two of those studies are shown in Table 5-1 below.

**Table 5-1.** Projections of Shipping Traffic and Arctic Diversion in the Literature

| Study | Assumptions | Projections |
|---|---|---|
| Peters et al. (2011) | Study includes trans-arctic shipping and oil and gas production for emission estimates.<br>Considers trade between one European port and three Asian ports (Rotterdam, Tokyo, Hong Kong and Singapore)<br>Volumes estimated by translating IPCC A2 scenario projections for global economic development into global seaborne trade volumes using the strong historical correlation between GDP and seaborne trade | Diversion of 8% of total container trade between Asia and Europe in 2030<br><br>Diversion of 10% of all container traffic between Asia en Europe in 2050 |
| Corbett et al. (2010) | Study includes in-Arctic and trans-arctic shipping emissions estimates.<br>For trans-arctic shipping (or global shipping diversion):<br>Assume annual growth in global shipping (from 2004) to be 3.3% per year (central value between the base case and high-growth scenarios considered in the *Second IMO GHG Study 2009*),<br>Assessment of drivers toward diversion timing and quantity was made by assessing current literature regarding feasibility of Arctic shipping and shipping volumes through the Suez and Panama Canals (~4% and ~8% of global trade volume, respectively)<br>Acknowledging uncertainty as to when diversion traffic may emerge, the study chose to scale the percent diversion. | Emissions estimated assuming 1%, 2% and 5% diversion of global shipping for 2020, 2030 and 2050, respectively.<br><br>Route-specific diversions are offered (NWP 0%). |

### 5.1.3 Trans-Arctic shipping in Northwest Passage: Projections

CASA (2007) concludes that, in open water conditions and based only on steaming distance, the NWP offers comparative advantages for traffic on the following routes:

- Between the east and west coasts of North America for a narrow range of port pairs
- Between Eastern Asia (north of Singapore) and the entire east coast of North America
- Between Northeast Asia and the western Mediterranean (including the Iberia Peninsula)

Despite the shorter distance, there is wide agreement that the projected ice and weather conditions in the NWP in 2020 and for most of this century, even in the presence of ice free summers, will be too dangerous and unpredictable for the development of commercial shipping. AMSA summarizes the reasons for this conclusion: seasonality, ice conditions, a complex archipelago, draft restrictions, chokepoints, lack of adequate charts, insurance limitations and other costs. Projections agree that the Northern Route and even the Trans-Polar route will become feasible commercial sea lanes before the NWP. Indeed, to date there has been no reported trans-Arctic commercial shipping through the NWP.

Two factors that may influence an increased trans-arctic traffic should be mentioned. First, CASA (2007), agrees with the general projection and concludes that unless climate change advances significantly faster than forecasted, substantial in-transit movements through the NWP appear improbable by 2020. However, it points out that one potential growth area is with project cargo and heavy lifts being shipped between east and west, which could use the more accessible southern route (Route 5), which is feasible as such vessel drafts will generally be less than 10 m. It is noted that icebreaker assistance is probably going to be needed. No quantified projections are provided.

Secondly, a study by Somanathan et al. in 2009 evaluated the relative economics of shipping through the NWP and shipping through the Panama Canal considering 1999-2003 ice conditions, and concluded that already in those ice conditions there is a slight economic advantage to the NWP in some shipping routes and that this advantage will become more compelling as sea ice continues to thin and shrink.

The study evaluates the relative economics of shipping considering two source ports on the east coast of North America (New York and St. John's, Newfoundland) and one destination port (Yokohama, Japan). The study considered originally two routes through NWP (Route 2 and Route 3A in this study), but early analysis of the Viscount Melville Sound route indicated that it was essentially impassable to commercial cargo ships, even those with ice breaking capability, for well over half the year. Therefore, this route was dropped from the study and analysis concentrated on Route 3A.

The study developed models to simulate each NWP route in this study, using a commercial simulation software, VSLAM, and the BestFit and @RISK Excel add-ins to develop stochastic models. It incorporates historical ice regime data on ice cover in the Canadian Arctic to prepare probabilistic ice regime, and estimates ship speed based on ice conditions. For the Panama Canal route, the study incorporates probabilistic models of wait time and variability in ship speed. Speed and distance are used to estimate total transit time and the required freight rate for economic shipping, thereby allowing an economic comparison of the alternatives. Canadian Arctic Category (CAC) 3 ships were chosen for the NWP. A 20-knot transit speed was selected, suitable for higher value merchandise typically carried in containers. Identical ship size and open sea speed were chosen for the NWP route.

The comparison showed the following results:

a) Monthly average speeds for a CAC3 ship show little variation with season: monthly average speed in September is 18.4 knots, and in February is 18.2 knots.

b) A ship using the NWP can make 38% more trips per year on the St. John's to Yokohama route, and 13% on the New York to Yokohama route (see Table 5-2).

**Table 5-2.** Statistics for Theoretical Maximum Round Trips per year for a 20-knot Container Ship. Source: Somanathan (2009)

| Route | Transit | Round trips/year | |
|---|---|---|---|
| | | Mean | Standard deviation |
| Arctic | Yokahama–New York | 8.52 | 0.11 |
| Panama | Yokahama–New York | 7.55 | 0.017 |
| Arctic | Yokahama–St. Johns | 9.74 | 0.13 |
| Panama | Yokahama–St. Johns | 7.08 | 0.016 |

c) The higher cost of the CAC3 ship gives a higher required freight rate for the NWP route from New York-Yokohama despite the higher number of round trips per year on that route (see Table 5-3). For the St. John's-Yokohama route the required freight rate is lower for the NWP, therefore there is a slight economic advantage to using the NWP for year round transit.

**Table 5-3.** Calculated Required Freight Rate for 9% Return Capital. Source: Somanathan (2009)

| Route | RFR ($/TEU) | |
|---|---|---|
| | Yokohama–New York | Yokohama–St. John's |
| Panama | 541 | 576 |
| Arctic | 625 | 563 |

d) Although this advantage is not compelling given the uncertainty and risk associated with the NWP, continuing thinning and shrinking of Arctic ice will reduce costs of NWP further, mainly through increased speed (giving more round trips per year) and fuel consumption (which is approximately almost 2/3 of the required freight rate). Even further thinning of Arctic ice would reduce the requirement for ship class from CAC3 to CAC4, reducing the capital cost of the ship, transit time, and fuel usage.

## 5.2 Multi-Modal Arctic Shipping: Port of Churchill, Arctic Bridge and CentrePort

**References**

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Ruffilli, D. 2011. *Arctic Marine and Intermodal Infrastructure: Challenges and the Government of Canada’s Response* (Parliamentary Information and Research Service, Publication 2011-77-E, 21 July 2011).

**Factors**

Accessibility

Global trade

Regional economic development (North America – Murmansk)

Oil price

Hindering factors:

*Marketing Freedom for Grain Farmers Act* S.C. 2011 c.25

Infrastructure limitations (at port, rail line and road connecting to Arctic ports (e.g. highway 283 connecting Nipawin SK and The Pas MB)).

Insurance premium

Short shipping season

Need of icebreakers at the beginning and end of the season

### 5.2.1 Introduction

Port of Churchill in the Hudson Bay is a usual port of export for Canada’s grain industry. It offers a short shipping distance and travel time between Canada and Europe and particularly Russia. The shipping distance and time between Churchill and Murmansk is 3,763 nautical miles or 13 days 2 hours (compared to 5.030 nautical miles and 17 days 11 hours between Murmansk and Thunder Bay). Similar time savings also exist in the route between Churchill and Copenhagen and Churchill and Algiers.

Additionally, Manitoba and the federal government are supporting the CentrePort initiative in Winnipeg, an inland port and foreign trade zone that provides facilities for the warehousing and transshipment of goods transported by air, road and rail. CentrePort is expected to create synergies to boost the efficiency of traffic through Port of Churchill.

Furthermore, Manitoba and other stakeholders have encouraged the Government of Canada to support the development of an Arctic Gateway strategy under the National Policy Framework for Strategic Gateways and Trade Corridors, with the Port of Churchill and CentrePort Canada as key components.

The Port of Churchill, Arctic Bridge and Arctic Gateway initiative face several challenges. The most significant challenge for the implementation of an Arctic Gateway strategy is the need for additional infrastructure investments throughout the region to permit the free flow of goods and people. Despite the CentrePort Canada development and upgrades to the Port of Churchill and Hudson Bay Railway, significant gaps have been identified, including:

- the need for an all-weather road connecting Nunavut with Manitoba capable of supporting the trucking of heavy cargo from Churchill to southern Nunavut;
- the need to develop intermodal container handling capabilities at the Port of Churchill to permit the movement of containerized cargo in northern waters;
- the need to upgrade the port of Iqaluit to handle larger ships and more diverse cargos; and
- the need to upgrade and develop additional smaller ports in the region to facilitate the development of a shortsea (i.e., moving freight on sea on the same continent without crossing an ocean) shipping network to transport goods between Arctic coastal communities.

Additional challenges to the Port of Churchill competitiveness include: the short season (14 weeks average); the need for icebreakers at the beginning and end of the shipping season; and the high insurance rates.

Recent governmental decisions may also affect the potential shipping activity through the Port of Churchill. Currently, the main client (95% of the shipments through the Port of Churchill) is the Canadian Wheat Board and the single-desk marketing system. On December 15, 2011, *An Act to reorganize the Canadian Wheat Board and to make consequential and related amendments to certain Acts* (Bill C-18, short title *Marketing Freedom for Grain Farmers Act*) received Royal Assent. The *Marketing Freedom for Grain Farmers Act*, S.C. 2011 c. 25 (currently under judicial scrutiny) puts an end to the single-desk market system of the CWB, which is expected to greatly decrease the demand of shipping through the Port of Churchill. It is considered unlikely that non-grain exporters will use the port, despite efforts to diversify the Port’s users. The end of the single-desk market system is expected for September 2012.

The federal government pledged financial support for the Port of Churchill, including $5 million a year for five years for incentives to encourage grain companies to use the port for their shipments. As well, Transport Canada will provide up to $4.1 million over three years to help maintain the port.

### 5.2.2 Shipping Trends

Exports through the Port of Churchill show great year-to-year variability. Tables 5-4 and 5-5 below show exports through the port, and current data on number of merchant vessels in the port for 2004-2010.

**Table 5-4.** Exports through the Port of Churchill 2004-2010

| Year | Tonnes | CWB Grain | Non-CWB |
|---|---|---|---|
| 2010 | 658,948 | 603,352 | 55,596 |
| 2009 | 529,300 | 529,300 | 0 |
| 2008 | 424,388 | 424,388 | 0 |
| 2007 | 620,709 | 620,709 | 0 |
| 2006 | 488,754 | 384,162 | 104,592 |
| 2005 | 466,785 | 353,361 | 113,424 |
| 2004 | 400,010 | 360,510 | 39,500 |

Source: Hudson Bay Route Association, online: http://www.hbra.ca/CHfacts.php

**Table 5-5.** Number of merchant vessels in the Port of Churchill 2004-2011

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|
| Nr. of vessels | 14 | 14 | 14 | 18 | 13 | 24 (18 foreign) | n/a | n/a |

Source: DND

Judson (2010) reports an increase of voyages by grain ship over the last 22 years (from between 5-10 voyages to around 15 current voyages, including two peaks of over 25 voyages and over 20 voyage in the 2000s).

### 5.2.3 Projections

CASA (2007) notes that the Port of Churchill has not grown into the viable transportation link that some envisioned. There is little economic activity and the community's population has decline in recent years. There is still some potential in the Churchill-Murmansk route as an alternative to shipping through the St Lawrence Seaway.

Many fear that the *Marketing Freedom for Grain Farmers Act* implies the end of the Port of Churchill, since it has not been able to attract other users.

No other projections are made with respect to future traffic in Port of Churchill.

## 5.3 Community Re-Supply

**References**

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Nunavut Sealink and Supply Inc. (NSSI), online: http://www.arcticsealift.com/en/NSSI.aspx
Desgagnés Transarctik Inc. (DTI), online: http://www.arcticsealift.com/en
Taqramut Transport Inc. (TTI), online: http://www.arcticsealift.com/en/home.aspx?dest=TTI
Nunavut Eastern Arctic Shipping Inc. (NEAS), online: http://www.neas.ca
Woodward Group, online: http://woodwards.nf.ca/coastalshipping.html

**Factors**

Population growth
Consumption per capita
Limitations to construction and operation of winter roads

### 5.3.1 Introduction

Community re-supply is one of the main shipping activities in the Arctic. Navigation is sometimes the only and often the most cost-effective way to supply communities with the goods and materials needed throughout the year. The figures below, taken from CASA (2007), show the location of the different Canadian communities in the Arctic and of the existing and projected roads.

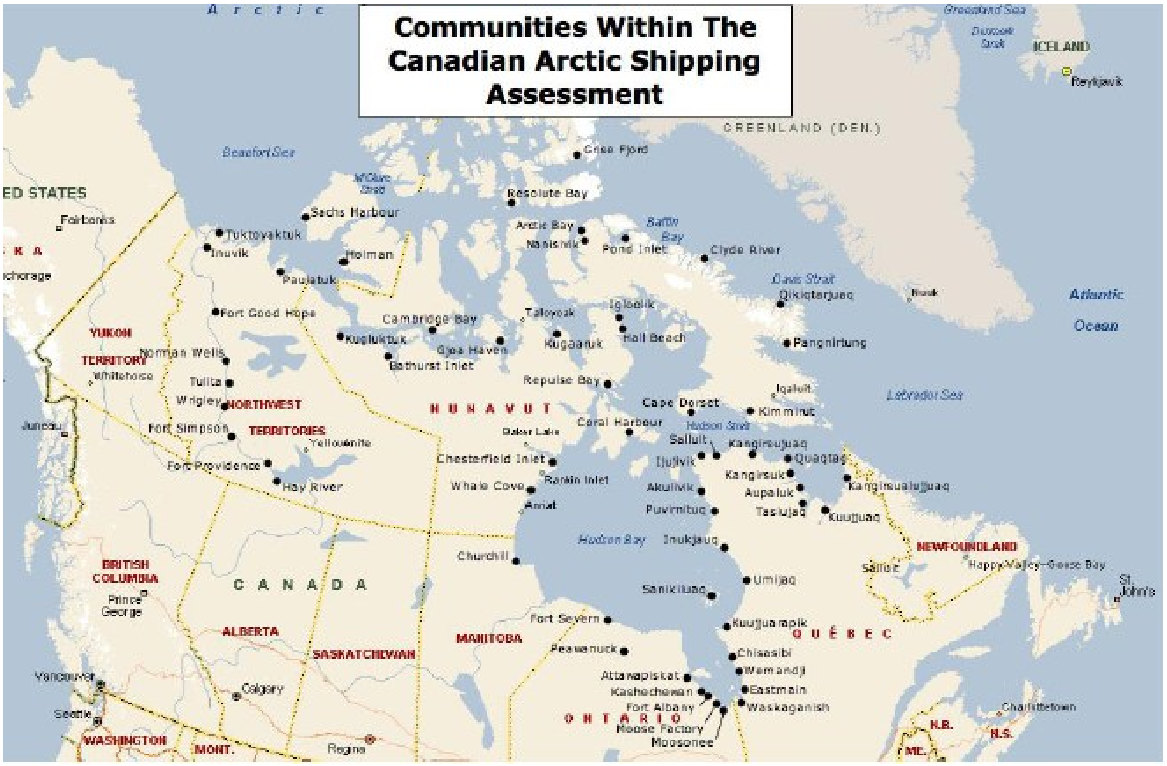


**Figure 5-2.** Communities in Canadian Arctic. Source: CASA (2007), p. 34.


**Figure 5-3.** All weather and Seasonal Roads in the Arctic. Source: CASA (2007), p. 35.

The Northwest Territories (NWT) communities with an impact on marine activity include the Inuvaluit communities of Sachs Harbour, Paulatuk, Tuktoyaktuk and Ulukkaktok (a.k.a. Holman).

The Mackenzie River and Delta communities, also in Inuvialiuit, include Inuvik, Fort Good Hope, Norman Wells, Tulita, Wrigley, Fort Simpson and Fort Providence.


**Figure 5-4.** Canada Arctic Regions

Nunavut territory include more than 25 communities in its three regions: a) Qikiqtaaluk (or Baffin region in Canadian census); b) Kivalliq (or Keewatin Region in Canadian census), and; c) Kitikmeot.

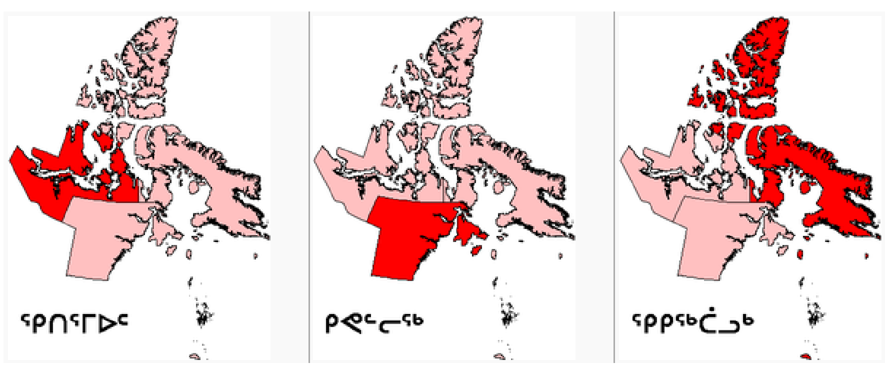


**Figure 5-5.** Kitikmeot, Kivalliq and Qikiqtaaluk (Baffin) regions in Nunavut.

Quebec, Ontario and Manitoba hold the Cree coastal communities around the southern half of Hudson Bay.

Transportation infrastructure and reliance on sealift varies considerably across the three Canadian territories, reflecting important historical, geographic, and demographic differences. Yukon has the most developed and expansive permanent road network of the territories, providing all-weather road access to all communities but one. Additionally, Yukon has strong historic links to the marine transportation network via Alaska.

The road network in the Northwest Territories includes all-weather roads (Dempster Highway or Highway Nr. 1 connecting with Inuvik, Wrigley, Fort Simpson and Fort Providence) and winter roads complemented by vehicle ferries and ice crossings. Four communities depend exclusively on this marine re-supply of bulk commodities (Lutsel'ke, Paulatuk, Sachs Harbour and Ulukhaktok). Eleven communities are served by both marine and all-weather/winter road access. Given the considerable interest in this supply route, the Government of NWT is currently undertaking a study of a northern marine transportation route into the Alberta oil sands and the role of Tuktoyaktuk as a marine service centre (see oil and gas section below).

In Nunavut, nearly all travel between communities within the territory and to external locations is via air transport, whereas goods provision and cargo transport is by vessel or barge. Geographic remoteness and extreme cold conditions make it costly to build and operate transportation infrastructure in the region, with a clear recognition at the territorial level that significant upgrading needs to take place to meet existing demand and to keep pace with and even facilitate resource development. The proposed Bathurst Inlet Port and Road and the Nunavut-Manitoba Road projects would boost the capacity to service mines, and provide alternative and shorter routes for re-supply of fuel and goods to communities in the area.

According to the information provided by Transport Canada (n.d.), there are currently six companies providing community re-supply in the Arctic: a) Northern Transportation Company Limited (NTCL); b) Nunavut Sealink and Supply Inc. (NSSI), its Managing Partner, Desgagnés Transarctik Inc. (DTI), and associate company Taqramut Transport Inc. (TTI); c) Nunavut Eastern Arctic Shipping Inc. (NEAS); and d) Woodward Group. Community re-supply for the western communities is mostly provided by NTCL from Hay River and the Mackenzie River. Eastern Arctic is served by NTCL, NSSI and NEAS from Churchill and Montreal.

Two smaller companies operate in the Mackenzie River and Beaufort Delta. Cooper Barging provides barging service within the Mackenzie River (Fort Simpson to Norman Wells); while Horizon North charts tugs and barges to transport oil and equipment in the Beaufort Delta.

a) NTCL is the largest marine operator for the Mackenzie River Watershed (including the Mackenzie River and Great Slave Lake), the Arctic coast and islands, and Alaska. It utilizes a fleet of 14 tugs and 10 dual-purpose barges. NTCL's principal concerns are bulk petroleum products and dry cargo for communities, as well as defence installations, and oil and gas exploration. The shipping routes of NTCL are shown in Figure 5-6.


**Figure 5-6.** NTCL shipping routes. Source: NTCL (2012)

In 2011, a shipping route through Richmond around British Columbia and Alaska that had started two years earlier to serve western communities and the mine of New Hope (Newmont Mining) was cancelled due to loss of the contract with the mining company, now shipping from the East through Montreal. It was estimated that freight cost was 40% lower using the Richmond-Alaska route than to use several barges up the Mackenzie River to supply those communities (CBC News).

b) NSSI and its Managing Partner DTI service four areas for the Eastern Arctic for re-supply of dry cargo under a 2006 contract by the Government of Nunavut signed for five years, with provisions for extension. The Areas subject to the Agreement with the Government of Nunavut are: Area «B» (Foxe Basin), Area «C» (Iqaluit), Area «D» (South Baffin), and Area «E» (Kivalliq).

TTI serves 14 communities in Nunavik and, if required, may serve other additional destinations therein, such as mining sites, outfitting camps and others. TTI offers a regular service to Nunavik during the shipping Sealift Season.

The companies have 5 vessels, with a combined capacity exceeding 300,000 cubic meters over the sealift season (general cargo and roll-on roll-off vessels). All communities are visited at least twice. Nonetheless upon request, other departures can be added in certain communities.

For the 2012 season, there are three scheduled departures from St. Catherines serving 14 communities in Nunavik and 10 to 11 communities in Nunavut; and 4 departures are scheduled Port of Churchill serving up to 5 communities in the Arctic.

Although NSSI generally serves the eastern Arctic (with NTCL serving the western Arctic communities) in 2008 the opening of the NWP allowed the NSSI-group's vessel MV *Camilla Desgagnés* to transport cargo from Montreal to the hamlets of Cambridge Bay, Kugluktuk, Gjoa Haven and Taloyoak (all in the Kitikmeot region). The preliminary 2012 sealift schedule also considers service for those communities.

c) NEAS serves more than 40 communities in the Arctic with four general cargo and roll-on roll-off vessels. The 2012 schedule shows three departures for this season.

d) Woodward Group supplies bulk fuel to the Nunavut region using two tankers.

A moratorium on commercial ships marine transport fees was declared in 2008 and the Department of Fisheries and Oceans (DFO) recently announced that it will permanently exempt the marine fee from vessels supplying communities north of 60° North. starting in the 2012 season.

### 5.3.2 Community Re-Supply: Trends

AMSA noted that community re-supply throughout the Arctic, and particularly in the Canadian Arctic, made up for most ship traffic. Analyse&Strategi (2011) reports that current shipping demand in the eastern Canadian Arctic involves up to 22 seasonal trips during 100 days of navigation. For the Western Arctic, it reports a current shipping demand of 14-15 seasonal tug-barge trips during a 60 days season between mid-July and mid-September. CASA (2007) provides best estimates of re-supply activity by region, assessed in terms of dry cargo shipping using 3.5m$^3$/tonne of cargo. Petroleum products are estimated in cubic meters of fuel rather than tonnage. Excluded from the estimates are demand by airports and North Warning Stations, exploration and mining activity. CASA (2007) provides the following estimates of current community re-supply activities for each Arctic region and a summary for the CASA area:

**Qikiqtaaluk (Baffin) (NU):** Population 2006: 16,005
Estimated dry cargo: 35,211 tonnes or 124,000 m$^3$
Estimated petroleum demand: 51,216 tonnes or 67,000 m$^3$

**Kivalliq (NU):** Population 2006: 9,266
Estimated dry cargo: 20,385 tonnes or 71,000 m$^3$
Estimated petroleum demand: 29,651 tonnes or 38,500 m$^3$

**Kitikmeot (NU):** Population 2006: 4,741
Estimated dry cargo: 10,430 tonnes or 36,500 m$^3$
Estimated petroleum demand: 15,171 tonnes or 20,000 m$^3$

**NWT coastal communities** Population 2006: 1,861
Estimated dry cargo: 4,094 tonnes or 14,000 m$^3$
Estimated petroleum demand: 5,955 tonnes or 8,000 m$^3$

**Nunavik** Population 2006: 10,783
Estimated dry cargo: 23,723 tonnes or 83,000 m$^3$
Estimated petroleum demand: 34,506 tonnes or 45,000 m$^3$

**Cree Communities** Population 2006: 11,769
Estimated dry cargo: 12,769 tonnes or 44,000 m$^3$
Estimated petroleum demand: 17,654 tonnes or 23,000 m$^3$

**Mackenzie River and Delta communities**
Estimated ~20,000 tonnes dry cargo and ~50,350 tonnes of Petroleum, Oil and Lubricants (POL)

**CASA Area**
Dry cargo 442,500m$^3$; POL 266,955m$^3$
<u>Reported activity in 2005:</u>
12 tugs and tows in western Arctic
18-21 tows on the Mackenzie River
17 dry cargo trips between southern Canada and eastern Arctic
20 tanker trips (14 between southern Canada and eastern Arctic, 6 between Churchill and Kivalliq and other destinations)

### 5.3.3 Community Re-Supply Projections in the Literature

A summary of projections for community re-supply activity in Canada's North is provided in Table 5-6 below.

**Table 5-6.** Community Re-Supply: Projections in the Literature

| Study | Assumptions | Projections |
|---|---|---|
| AMSA (2009) | Regional Futures to 2020: Canadian Arctic and NWP | By 2020, it is projected that annual re-supply demand will increase enough that the current fleet will not be sufficient to meet the needs, despite the likelihood of a longer shipping season. In addition, the current fleet is aging and most ships would likely need to be replaced within that timeframe.<br><br>Some important but manageable expansion in shipping activity is forecast, related to growing populations and for movements of supplies and equipment in support of exploration projects. |
| CASA (2007) | Projections for 2020<br>Forecasts primarily based on populations.<br>Assessment in terms of dry cargo shipping suing 3.5$m^3$/tone of cargo.<br>Consumption per capita based on Mariport's planning quantities.<br>Petroleum related to cubic meters of fuel rather than tonnage because products are light distillates.<br><br>Estimates of future dry cargo traffic for Mackenzie River and Delta communities have been based on 10% increase in current demand. Reasons: communities other than Inuvik and Fort Good Hope are expected to decrease; Inuvik is road connected with relatively little demand for cargo; most of demand for petroleum is met by local gas supplies for power generation. | **Qikiqtaaluk (Baffin) (NU):**<br>Projected population: 21,038<br>Dry cargo: 46,284 tonnes or 162,000 $m^3$<br>Petroleum product demand: 67,322 tonnes or 87,000 $m^3$ |
| | | **Kivalliq (NU):**<br>Projected population: 21,181<br>Dry cargo: 26,978 tonnes or 94,000 $m^3$<br>Petroleum product demand: 38,979 tonnes or 51,000 $m^3$ |
| | | **Kitikmeot (NU):**<br>Projected population: 6,232<br>Dry cargo: 13,710 tonnes or 48,000 $m^3$<br>Petroleum product demand: 19,942 tonnes or 26,000 $m^3$ |
| | | **NWT coastal communities**<br>Projected population: 1,893<br>Dry cargo: 4,164 tonnes or 14,250 $m^3$<br>Petroleum product demand: 6,058 tonnes or 8,200 $m^3$ |
| | | **Nunavik**<br>Projected population: 14,866<br>Dry cargo: 32,705 tonnes or 115,000 $m^3$<br>Petroleum product demand: 47,571 tonnes or 62,000 $m^3$ |
| | | **Cree Communities**<br>Projected population: 16,245<br>Dry cargo: 17,000 tonnes or 60,000 $m^3$<br>Petroleum product demand: 24,368 tonnes or 32,000 $m^3$ |
| | | **Mackenzie River and Delta communities**<br>Dry cargo: 22,000- tonnes or 77,000 $m^3$<br>Petroleum product demand: 58,000 tonnes or 75,400 $m^3$ |
| Williams et al. (2011) | n/a | n/a |
| Analyse&Strategi (2011) | Forecast for 2020 | (West Arctic) It is anticipated that annual re-supply demand will require up to 30 ship trips. |

### 5.3.4 Population Growth: Projections

The main factor that will determine the volume of community re-supply activities in the Arctic is population growth. In a draft working document, based on current population in the territories of ~110,000 inhabitants, Statistics Canada forecasts ~131,000 inhabitants by 2036 under a medium growth rate, and ~146,000 under high growth rate. The projections are for the entire territories. However, the impact on marine sealift for re-supply is determined by the growth of individual communities, which may have population growth rates different than each territory's average.

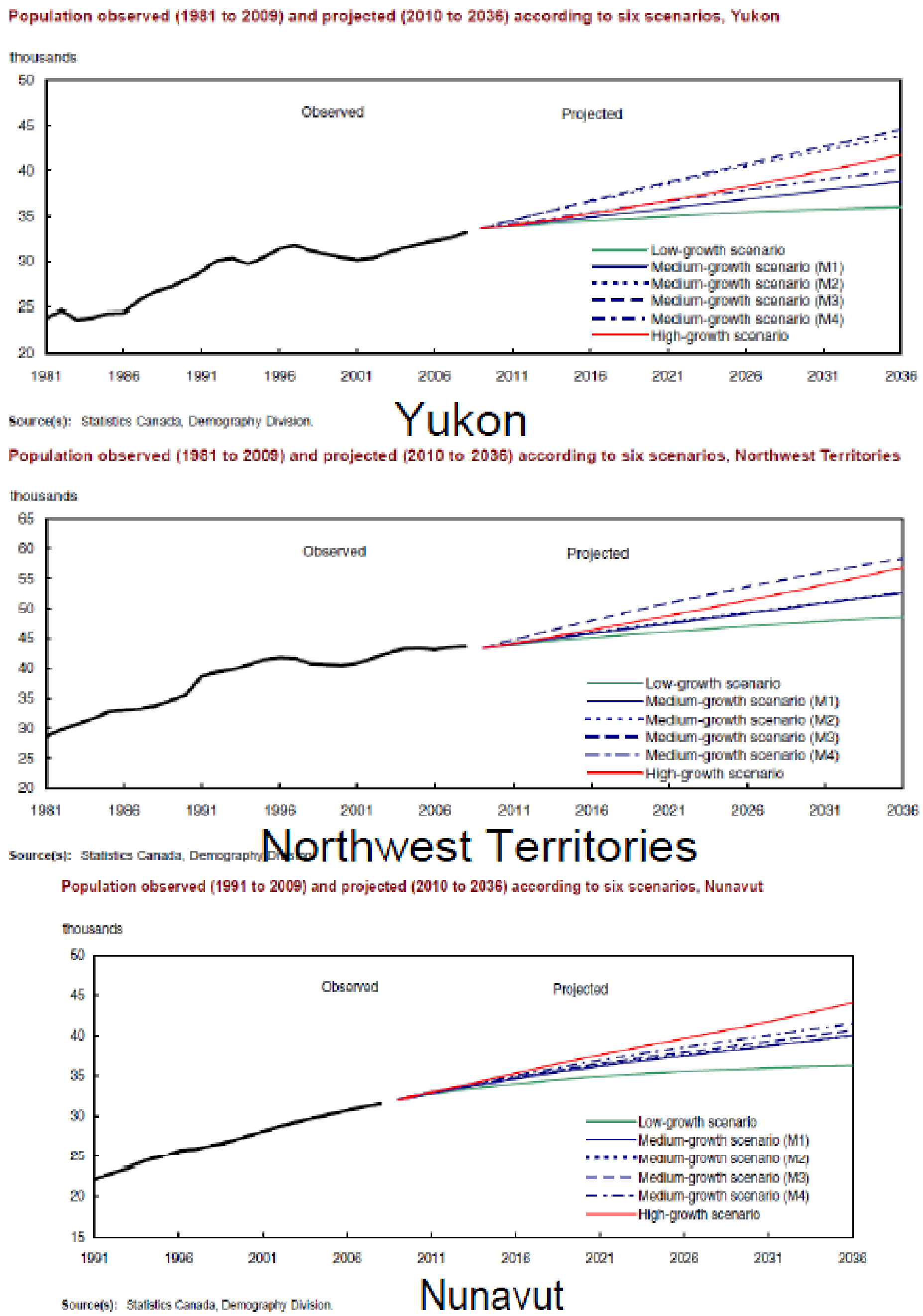


**Figure 5-7.** Population projections for the territories. Source: Statistics Canada (2010)

The last census shows growth rates for the 2006-2011 period. Selected census regions of the territories, based on their need for marine sealift re-supply, are included in Table 5-7 below.

**Table 5-7.** Population in 2006, 2011, and rate of change. Source: Statistics Canada, Census 2011

| | Population 2006 | Population 2011 | % change |
|---|---|---|---|
| **Yukon Region 1 North** | 6,718 | 6,712 | -0.1 |
| **Northwest Territories** | 41,464 | 41,462 | 0 |
| **Nunavut** | 29,474 | 31,906 | 8.3 |
| **Nord-du-Québec Census Division** | 39,817 | 42,579 | 6.9 |

### 5.3.5 Per Capita Consumption Projections

Another factor expected to influence the volume of community re-supply is the *per capita* consumption. In the absence of historical data, CASA (2007) uses its own planning quantities as a *per capita* consumption proxy for projecting community re-supply. Other projections are based exclusively on population growth. No other indicator of per capita consumption is provided in the literature.

## 5.4 Resources: Oil and Gas

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**Factors**

Oil price, including stability

Gas price, including stability

Existing projects, production yield, and lifetime

- Alberta Oil Sands and project cargo to Tuktoyaktuk (via Mackenzie, Great Slave Lake, Slave, Pace and Athabasca Rivers)

Existing explorations and development timelines

New resource exploration and exploitation

- Driven by Mackenzie Gas Project
    - Mackenzie Delta and Beaufort Sea
- Northwest Baffin Island
- Sverdrup Basin (Drake and Hecla gas fields)

Oil and gas discoveries and developments in other areas of the world:

- Bakken formation

- Middle East crisis

Growth of unconventional resources such as oil sands and shale gas

Hindering factors:

Geological nature of deposits
Development costs
Transportation infrastructure
Transportation cost
Human capacity
Infrastructure
Pipeline infrastructure
Environmental sensitivity (bad press)
Governance: regulatory regime
Governance: environmental protection
Governance: Indigenous rights, land claim agreements, royalty sharing agreements
Governance: results of Extended Continental Shelf Claim, continental shelf boundary with U.S.A. (related to Beaufort maritime dispute)
Governance: investment climate (tax incentives; dominance of investment trusts)
Insurance cost

### 5.4.1 Introduction

Oil and gas exploration and exploitation may impact shipping activity in different forms:

a) Exploration activities offshore;
b) Industrial supply for construction for sites offshore;
c) Industrial supply for operation for sites offshore;
d) Transport of oil and gas from offshore sites;
e) Industrial supply for construction of facilities onshore;
f) Industrial supply for operation of onshore sites;
g) Transport of oil and gas from onshore sites.

In 2010, there were two productive oil sites (Norman Wells and Cameron Hills) and six productive gas sites (Norman Wells, Ikhil, Cameron Hills, Fort Liard F-36, Fort Liard F-29, and Southeast Fort Liard) (Aboriginal Affairs and Northern Development 2011). Only Ikhil gas site is located in the Mackenzie Delta. Production in all sites decreased between 2009 and 2010 between 1.67% and 11.21% (Aboriginal Affairs and Northern Development 2011).

According to Aboriginal Affairs and Northern Development Canada (n.d.), Northern Canada is estimated to contain one third of Canada's remaining potential for conventional oil and natural gas. This resource is distributed throughout the North in the following regions:

- Mackenzie Valley: 28 discoveries and two producing fields: the Norman Wells oil field has produced over 260 million barrels of oil since coming on full production in 1985. Since 2002, the Cameron Hills field in the southern Northwest Territories has produced both oil and gas for export to Alberta.
- Arctic Islands: 19 discoveries after fewer than 200 exploration wells; the Bent Horn field in the Arctic Islands, now abandoned, produced high-quality light oil for many years on a seasonal basis for shipment by tanker through the NWP.
- Mackenzie Delta/Beaufort Sea: discovered resources in excess of one billion barrels of oil and ten trillion cubic feet (tcf) of gas in 60 significant discoveries. Industry has identified six trillion cubic feet of marketable gas in three onshore discoveries anchoring a potential Mackenzie Gas pipeline, and offshore discoveries include over 200 million barrels in the Amauligak field. On the Mackenzie Delta, the Ikhil gas discovery supplies natural gas to the town of Inuvik for power generation and domestic use. Gas is transported mostly through pipelines and marine shipping activity would probably be limited to construction activities and maintenance of sites.

The spatial distribution of current oil and gas reserves is analyzed in more detail in the next section.

### 5.4.2 Oil and Gas Activity: Spatial Distribution

Oil and gas exploration is currently focused on gas and concentrated in two Arctic areas: Beaufort Sea/Mackenzie Delta and Sverdrup Basin (Bent Horn, Hecla and Drake), with some exploration licenses issued in Eastern Arctic. Development and exploitation is dependent upon transportation mechanisms, and in particular the construction and operation of the Mackenzie Gas Pipeline.

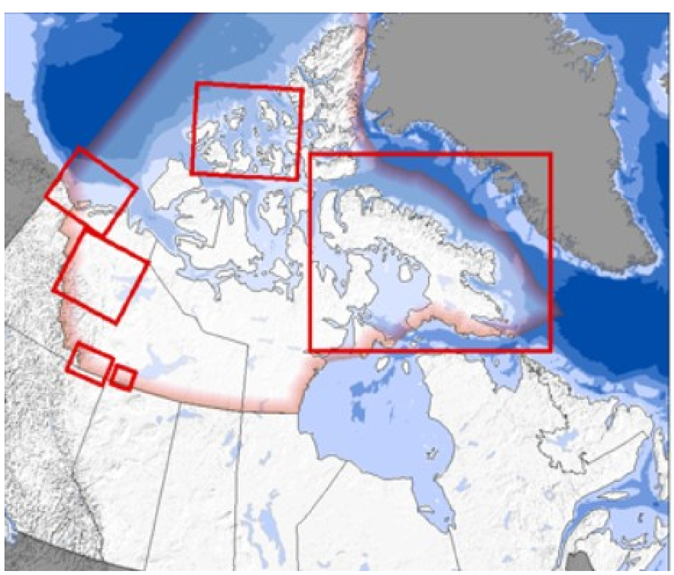


**Figure 5-8.** Regions in Canada North with oil and gas interest: Beaufort Sea and Mackenzie Delta; Central Mackenzie Valley; Southern Northwest Territories (Fort Liard and Cameron Hills); and Arctic Islands of Nunavut (Sverdrup Basin and Eastern Arctic) Source: Aboriginal Affairs and Northern Development Canada

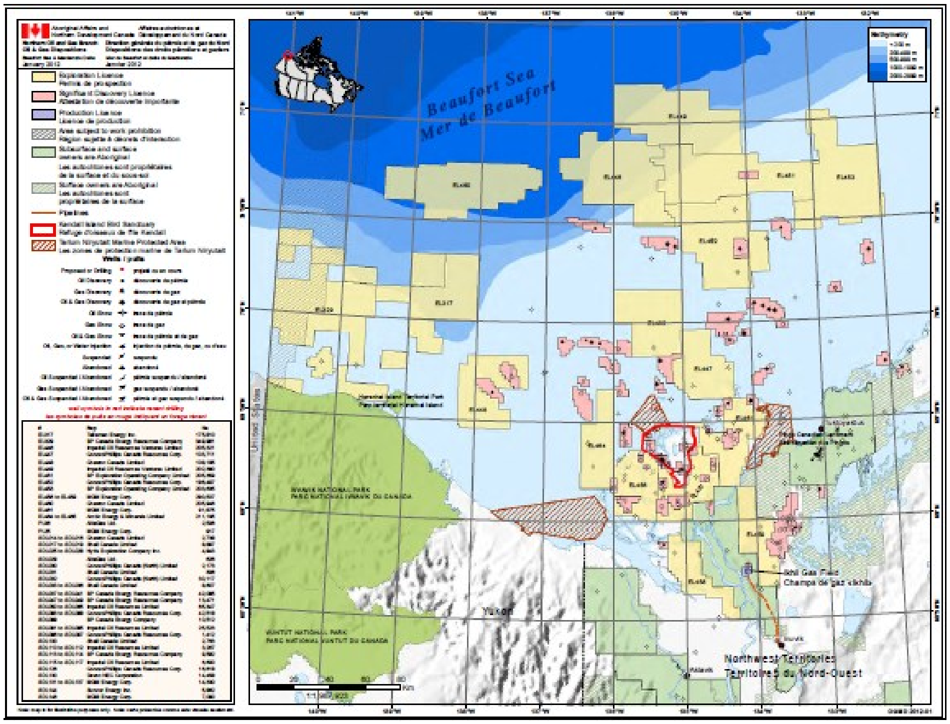



**Figure 5-9.** Beaufort Sea and Mackenzie Delta: Oil and Gas Dispositions. Source: Aboriginal Affairs and Northern Development Canada

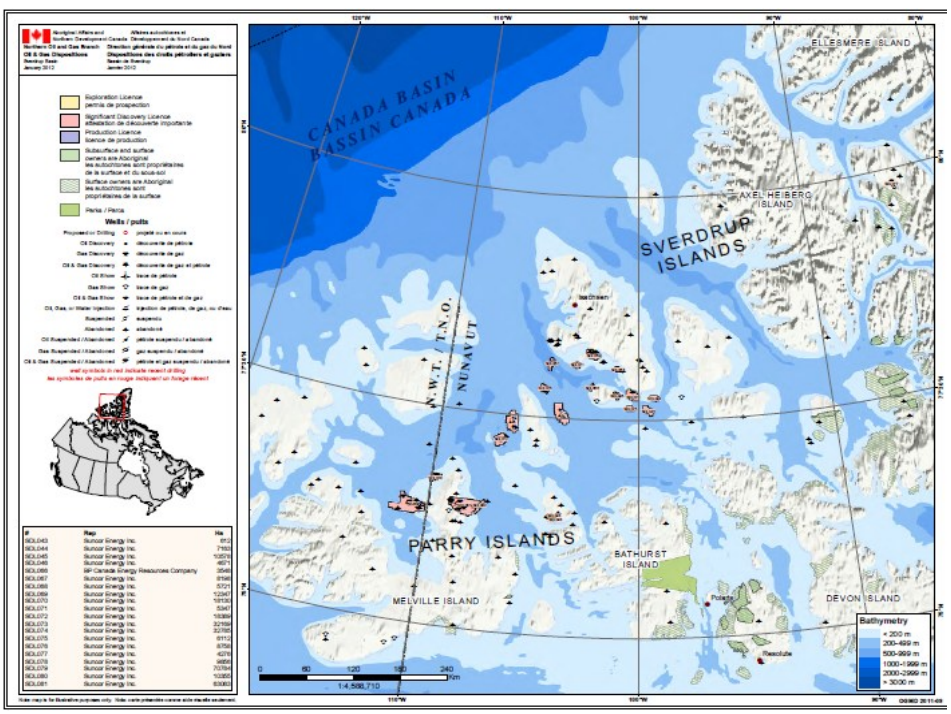



**Figure 5-10.** Sverdrup Basin Oil and Gas Dispositions. Source: Aboriginal Affairs and Northern Development Canada

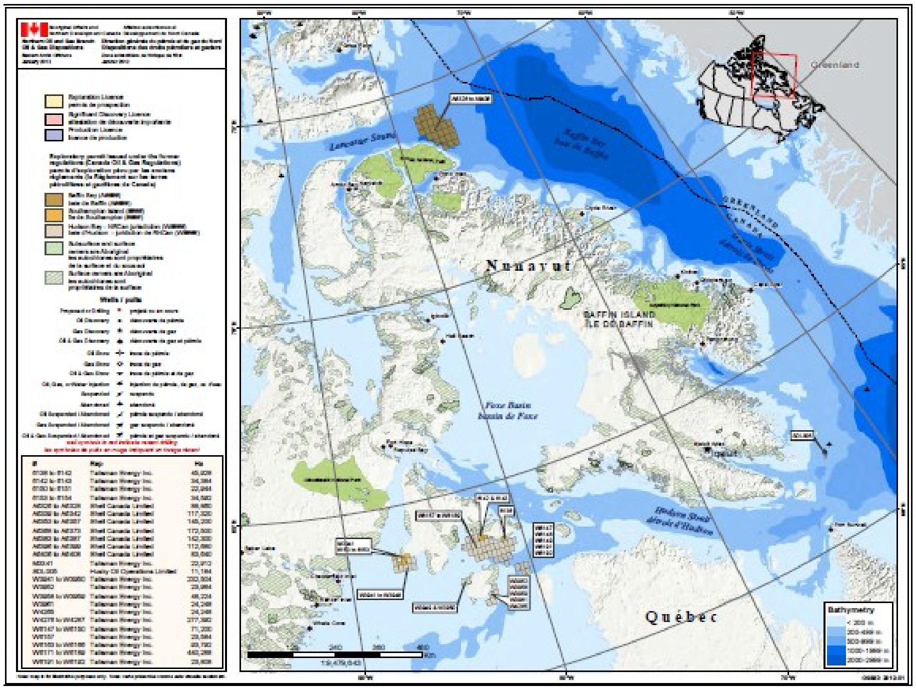



**Figure 5-11.** Eastern Arctic Oil and Gas Dispositions. Source: Aboriginal Affairs and Northern Development Canada

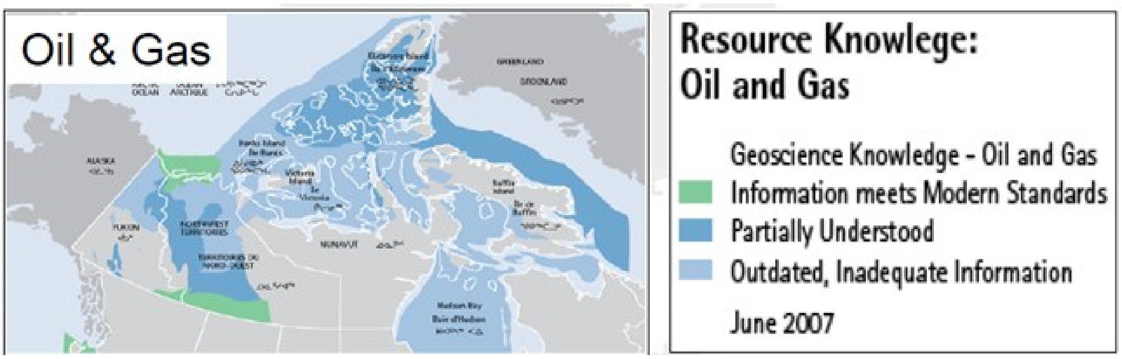



**Figure 5-12.** Oil and Gas. Source: Canada's Northern Strategy (2009)

### 5.4.3 Arctic Traffic for Oil and Gas: General Trends

Information on current traffic resulting from oil and gas activities in the Canadian Arctic is summarized in Table 5-8 below.

**Table 5-8.** Arctic Traffic for Oil and Gas Activities in Canada's North: Trends

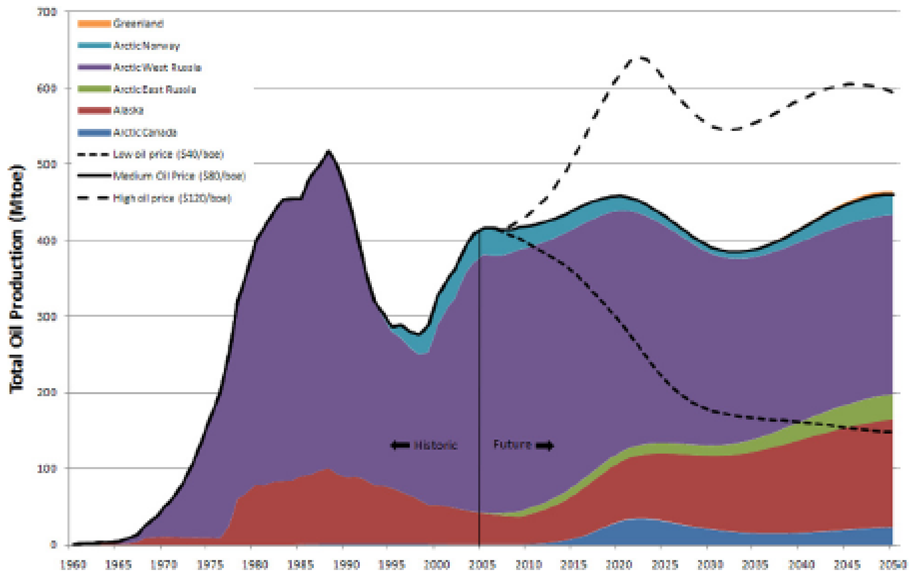
| Study | Summary |
|---|---|
| AMSA 2009 | Recently, there has been heavy demand for logistics and supplies in both the eastern and western Arctic, particularly in the Beaufort Sea (…). |
| CASA 2007 | No oil and gas exploration activities planned in Arctic waters.<br>Industry is awaiting more certainty on their ability to ship their oil and gas resources out of the Arctic, and this currently hinges on the fate and timing (now set at 2014) of the Mackenzie Gas Project. |

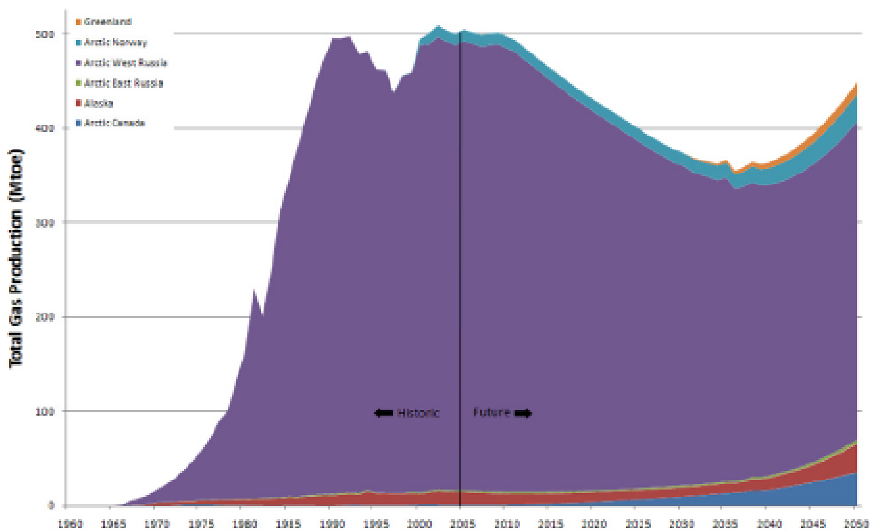
### 5.4.4 Arctic Traffic for Oil and Gas: Projections in the Literature

Future Arctic traffic for oil and gas activities, as projected in different studies, is summarized in Table 5-9 below.

**Table 5-9. Arctic Traffic for Oil and Gas Activities in Canada's North: Projections**

| Study | Summary |
|---|---|
| AMSA 2009 | For (…) Canada, where offshore Arctic leases sales were held for the (…) Beaufort seas in 2008, the future remains uncertain. The leases represent long-term, strategic investments. Marine exploration of the Arctic offshore should continue during the next decade. |
| CASA 2007 | Under several assumptions specified in the Report, including approval of Mackenzie Gas Project (MGP):<br><br><u>Beaufort Sea Regime</u><br>Construction of MGP will create an incremental demand for 245 millions of cubic feet per day (mmcfd) of gas supply connecting discovered reserves to maximize the Inuvik Area Gas Plant capacity of 1,075 mmcfd. There are enough discovered reserves on the Mackenzie Delta to fill the pipe at its initial design capacity slowing the immediate need for exploration activity.<br><br>MGP will influence shipping activity: moving complete units in to handle gas production and processing in the delta region; possibility of shipping oil requirements around Alaska as an alternative to railing oil to Hay River and then barging it down the Mackenzie.<br><br>Exploration activity in the Arctic ocean is expected to stay moribund until 2015 as new supplies of gas will not be required until production from existing field begin to decline (2025). It is assumed to proceed at levels a little higher than that experienced in 2004 and 2005 time frame at two to four exploration wells per year. For each discovery well, two delineation wells are anticipated. Seismic activity is assumed to include on 260 km 2-Dimensional (2D) program that will be run for every four exploration wells drilled, and one 200 km2 3-Dimensional (3D) program for each well.<br><br><u>Alberta Oil Sands</u><br>Potential traffic in 2010 to 2020 and beyond is the movement of project cargo to Tuktoyaktuk for furtherance to the oil sands north of Fort McMurray. A preliminary analysis of an Arctic route for offshore sourced process equipment shows significant transportation cost benefit over conventional route by ship to Duluth and then by rail and road. Additionally weight limitations of about 450 tonnes are increased to over 1,000 tonnes, and size limitations are removed. Volume of traffic unknown, but one company indicates that they could move as many as 40 heavy loads over 2010 to 2012 period.<br><br><u>Sverdrup Basin and other Regions</u><br>Activity is expected to remain moribund to 2020. Industry collected significant amount of 2D seismic data. If any activity occurs, industry may select 3D seismic activity in areas with existing significant discovery license. Stranded giant gas fields at Drake and Hecla are not likely to be developed within this period. Suggestions have been made to develop these by way of a Gas to Liquid Plant to make it accessible to Canadian and international markets. |
| Willliams et al. 2011 | Arctic-wide projection based on Peters et al.: 0.6% rate of change per year.<br>Sea ice projection based on IPCC: -1.2% rate of change per year |
| Peters et al. 2011 | Very little academic research on future oil and gas production in the Arctic relative to non-Arctic production. Only other one: Wood Mackenzie and Fugro Robertson. There is a recent working paper with more details on the analysis of Arctic activities (Lindholdt and Glomsrød, 2011). Projections of oil and gas production are based on a model of the global energy markets (FRISBEE). Estimates consider projections with price at $120, $40, and $80 (reference) per barrel oil. |

<table>
<tr><td></td><td>Future oil production as share of total accumulated production is 67% for West Russia, 21% for Alaska, 5% for Norway, and 4% for Arctic Canada and East Russia. Future cumulative Arctic gas production is 90% for West Russia, 4% for Norway, 3% for Alaska and 2! For Arctic Canada with smaller amount in East Russia and Greenland.<br>


Historic and estimated oil production in the Arctic with an oil price of $80/boe (by region) compared to a low ($40/boe) and high ($120/boe) oil price.<br>


Historic and estimated gas production in the Arctic.</td></tr>
<tr><td>Lindholdt and Golmsrød 2011</td><td>Arctic oil projections (in barrel of oil equivalent (boe)) and gas projections (in metric tons of oil equivalent (Mtoe)) using FRISBEE, with three oil price assumptions for 2030:<br>Reference: US$100/boe in 2020, US$115/boe in 2030 and constant afterwards (International Energy Agency (IEA) reference scenario)<br>Low: US$90/boe in 2016 and constant afterwards (IEA 2°C scenario)<br>High: US$140/boe in 2030 and constant afterwards<br><br>Canada remains a minor producer of oil, showing a steeply rising but rapidly peaking production around 2025.</td></tr>
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**Figure 5** Arctic oil production. Reference scenario. Mtoe.

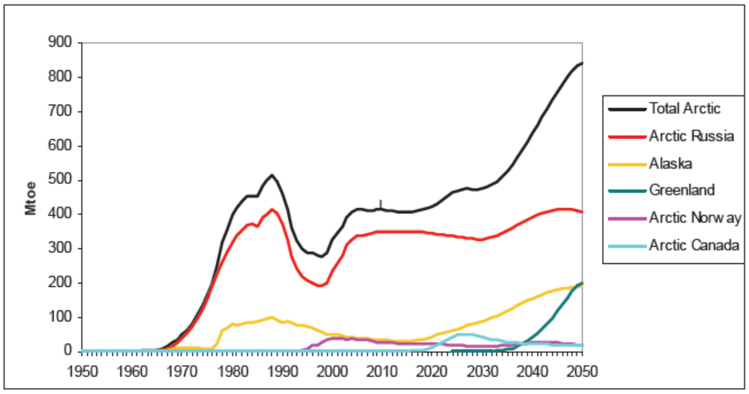



**Figure 12** Regional distribution of West Arctic oil production. Reference and low oil price scenarios. Mtoe

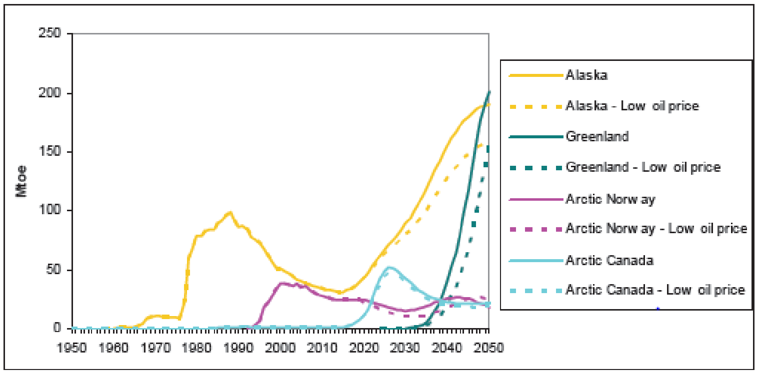



**Figure 14.** Arctic oil production. Reference and high oil price scenarios. Mtoe

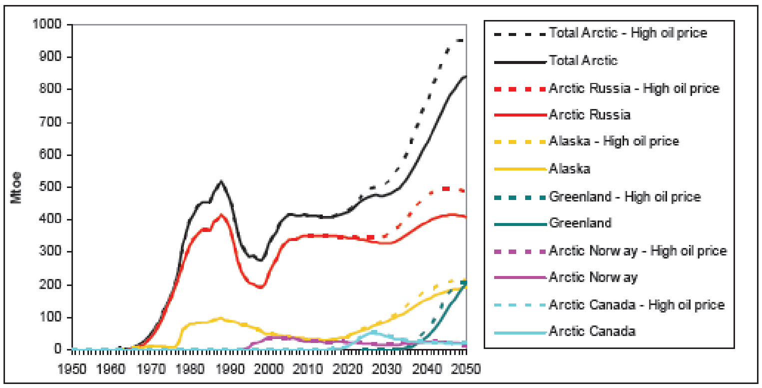
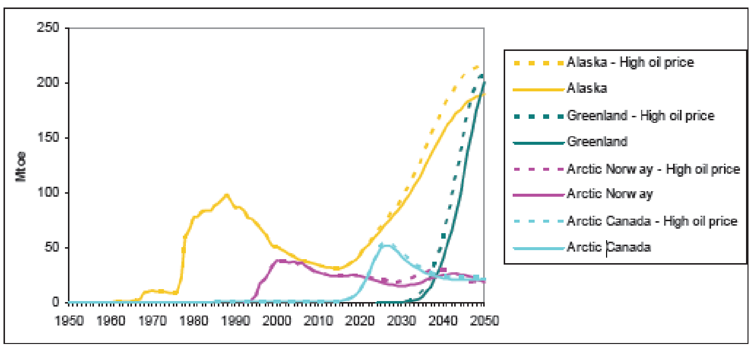



**Figure 15.** Regional distribution of West Arctic oil production. Reference and high oil price scenarios. Mtoe



NRTEE 2009

| Crude oil (millions of barrels) | Yukon | Northwest Territories | Nunavut |
|---|---|---|---|
| Production 2005 (mb/yr) | None | 7 | None |
| Production forecast 2020 (mb/yr) | None | 7 | None |
| Proven reserves | 10 | 1,500 | 523 |
| **Natural gas (billion cubic feet)** | **Yukon** | **Northwest Territories** | **Nunavut** |
| Production 2005 (bcf/yr) | 7 | 18 | None |
| Production forecast 2020 (bcf/yr) | No forecast | 694 | 345 |
| Proven reserves | 84 | 11,000 | 12,300 |

*Source: The Council of the Federation (2007).*

### 5.4.5 Canadian Arctic Oil and Gas: Current Licenses

Considering the prolonged time that elapses between the discovery and development phases in the Arctic, a good estimate of potential oil and gas activity by 2020 is given by the current levels of exploratory licenses. Considering that the Arctic falls under different areas of jurisdiction (see Figure 5-13 below), potential licenses can be issued by three different public agencies: Aboriginal Affairs and Northern Development Canada (AANDC), Natural Resources Canada, and the Canada-Newfoundland Offshore Petroleum Board. However, offshore Newfoundland does not currently have licenses (exploratory, significant discovery or production) above 60° North (Canada-Newfoundland Offshore Petroleum Board 2011). Hudson Bay does not appear to have oil and gas exploration or exploitation either.

Up-to-date information from Aboriginal Affairs and Northern Development is included in the Northern Oil and Gas Annual Report 2010 (Annual Report 2011, not available at time of writing) which includes both onshore and offshore exploration and exploitation projects (see Table 5-10). The report also provides information on seismic surveys and current developments (see Table 5-11). According to this report, in 2010 there were no producing fields in Nunavut or in offshore Arctic waters.

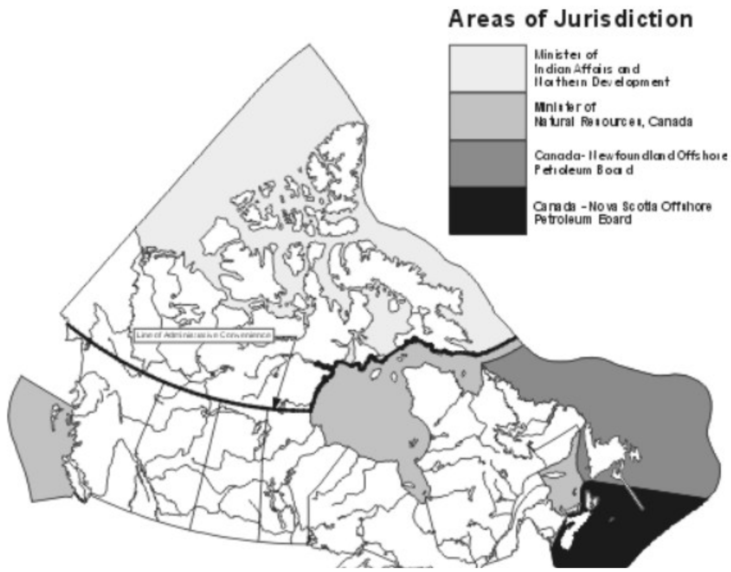



**Figure 5-13.** Oil and Gas Areas under the Jurisdiction of Aboriginal Affairs and Northern Development Canada, Minister of Natural Resources Canada, Canada – Newfoundland Offshore Petroleum Board, and Canada- Nova Scotia Offshore Petroleum Board. Source: AANDC.

**Table 5-10.** Land Disposition as of 31 December 2010. Source: AANDC, Northern Oil and Gas Annual Report 2010.

| Region | Exploration Licence | Significant Discovery Licence | Production Licence | Former Rights[1] | Total |
|---|---|---|---|---|---|
| **In hectares** | | | | | |
| Arctic Islands | 0 | 332,882 | 0 | 0 | **332,882** |
| Eastern Arctic Offshore | 0 | 11,184 | 0 | 862,500 | **873,684** |
| Hudson Bay[2] | 0 | 0 | 0 | 126,376 | **126,376** |
| Beaufort Sea | 1,892,144 | 205,636 | 0 | 0 | **2,097,780** |
| Mackenzie Delta | 56,624 | 134,109 | 3,423 | 0 | **211,578** |
| Central Mackenzie Valley | 985,561 | 52,725 | 0 | 654 | **1,038,286** |
| Southern Northwest Territories | 0 | 65,729 | 32,842 | 24,315 | **122,886** |
| **Total** | **2,934,329** | **802,265** | **36,265** | **1,013,845** | **4,786,704** |

| Region | Exploration Licence | Significant Discovery Licence | Production Licence | Former Rights[1] | Total |
|---|---|---|---|---|---|
| **By Interest Type (number of licences)** | | | | | |
| Arctic Islands | 0 | 20 | 0 | 0 | **20** |
| Eastern Arctic Offshore | 0 | 1 | 0 | 30 | **31** |
| Hudson Bay[2] | 0 | 0 | 0 | 8 | **8** |
| Beaufort Sea | 11 | 39 | 0 | 0 | **50** |
| Mackenzie Delta | 1 | 37 | 2 | 0 | **40** |
| Central Mackenzie Valley | 12 | 11 | 0 | 6 | **29** |
| Southern Northwest Territories | 0 | 31 | 21 | 9 | **61** |
| **Total** | **24** | **139** | **23** | **53** | **239** |

**Table 5-11.** Seismic Acquisition. Source: AANDC, Northern Oil and Gas Annual Report 2010.

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| 2D Seismic (in km) | 2,506 | 586 | 189 | 564 | 3,917 | 6,028 | 12,684 | 1,488 | 6,165 |
| 3D Seismic (in sq. km) | 4,060 | 194 | 804 | 635 | 1,100 | 0 | 1,638 | 1,577 | 0 |

### 5.4.6 Mackenzie Gas Project

The Mackenzie Gas Project is one key element that will define the gas activity in the Mackenzie Delta and Beaufort Sea, but its status is still uncertain. The project received approval from the National Energy Board on December 2010, conditioned on meeting the 264 environmental, financial, and cultural commitments contained in the National Energy Board's report. The Canadian Government approved the project in March 2011. The certificate will expire if construction has not begun by December 31, 2015.

According to the National Energy Board Report, the proponents indicated that the earliest they would make their final decision on whether or not to proceed with the Mackenzie Gas Project would be at the end of 2013, subject to regulatory approval and receipt of required permits. Should the project proceed as proposed, the detailed design and construction phases of the pipeline and related facilities would commence by 2014 and would be expected to continue into 2018 (NEB, 2010).

A schedule of the work presented in June 2011 at the Inuvik Petroleum Show considers the following schedule:

- The “Earliest Possible” schedule assumes September 2011 decisions on a fiscal agreement and project restart
- Three years required from project restart to decision to construct
  - Year 1: re-staff project teams, select prime contractor, advance field programs
  - Year 2: progress engineering, finalize right of way, submit permit applications
  - Year 3: permitting process, continue engineering, update cost estimate
- Possible decision to construct in late 2014
  - Four winter construction seasons required
  - Summer barging of supplies in advance of each winter
- Earliest possible project start-up is late 2019

Decision on the construction of the Mackenzie Gas Project has two main constraints: the price of gas (which is influenced by the availability of shale gas, which only through recent technology has become cost-effective to exploit and that has a fast growth in the United States and potentially other countries); and discovery of gas in the Beaufort Sea/Mackenzie Delta. It has been suggested that the three main discoveries in the 1970s are not enough to maintain the project in operation for the 30 years required for the project to be economically viable. Although further discoveries are expected, it is a risk for the project owners.

Even in case of construction of the Mackenzie Gas Project, shipping traffic is not expected to be high since transport of gas will occur through pipelines. Currently, the project is anchored on the production of natural gas from three onshore development fields near the edge of the Mackenzie Delta (Niglintgak, Taglu, and Parsons Lake). Shipping activity is considered for the construction of two of those fields (Niglintgak and Taglu), in the form of barges from Beaufort Sea up the Mackenzie River, for short periods of time during the construction phase (schedule for summer of 2014, and summer of 2016 and 2017, respectively).

In the case of Ninglintgak, Shell plans to tow the gas conditioning facility barge through the Beaufort Sea and into Little Kumak Channel in the Mackenzie Delta, where it would be set down on the Kumak Channel flood plain at a location north of the Little Kumak Channel. The current design calls for a barge with a 1.5-meter draft that stretches 50 meters across and 150 meters in length. Once the barge reaches its final location, it would be installed onto steel-pile foundations.

In the case of Taglu, Imperial plans to enter the East Channel of the Mackenzie River through Kittigazuit Bay, where there is a historical shipping channel.

In addition, other companies are exploring for natural gas in the region. They would want to ship the gas they find on the Mackenzie Valley Pipeline. According to the project, they would have a right to use the gathering and transmission pipelines but the companies are concerned about conditions for using them and the possible transportation costs. They also expressed concern about the capacity of the gathering system north of Inuvik.

### 5.4.7 Oil and Gas Prices

A key factor driving the oil and gas activity in the North is the price of oil and gas. Although this is an uncertain value, the literature reviewed provides some projections of future oil and gas price. In particular, the projections by the International Energy Agency (IEA) as summarized by Lindholt and Glomsrød 2011, and by the Energy Information Agency (EIA) are considered in this report.

The IEA expects the real oil price to recover and rise to 100 USD by 2020 and 115 USD by 2030. This price forecast is slightly lower than in the reference scenario of EIA, but higher than the estimate made by the Organization of the Petroleum Exporting Countries (OPEC). The OPEC World Oil Outlook sticks to previous assumptions that the nominal oil price will be in the range from 70 USD to 90 USD over the decade 2010-2020 (Lindholt and Glomsrød 2011). The latest projections of the IEA contained in the World Energy Outlook 2011 confirms the trend: "Short-term pressures on oil markets may be eased by slower economic growth and by the expected return of Libyan oil to the market, but trends on both the oil demand and supply sides maintain pressure on prices. We assume that the average IEA crude oil import price remains high, approaching $120/barrel (in year-2010 dollars) in 2035 (over $210/barrel in nominal terms) in the New Policies Scenario although, in practice, price volatility is likely to remain".

EIA's Annual Energy Outllook 2012 gives the following forecast:


**Figure 5-14.** Average annual world oil prices (in real 2010 dollars) for three cases 1980-2035. Source: EIA 2012.

<u>Natural Gas</u>

EIA's Annual Energy Outlook (AEO) 2012 projects average annual wellhead prices for natural gas to remain below $5 per thousand cubic feet (2010 dollars) through 2023 in the AEO 2012 reference case. The projected prices reflect continued industry success in tapping extensive shale gas resource. The resilience of drilling levels, despite low natural gas prices, is in part a result of high crude oil prices, which significantly improve the economics of natural gas plays that have high concentrations of crude oil, condensates, or natural gas liquids.

After 2023, natural gas prices are expected to increase as the numbers of tight gas and shale gas wells drilled increase to meet growing domestic demand for natural gas and offset declines in natural gas production from other sources. Natural gas wellhead prices (in 2010 dollars) are projected to reach $6.52 per thousand cubic feet in 2035 (2010 dollars), a slight increase from the AEO 2011 projection of $6.48 per thousand cubic feet (2010 dollars).

## 5.5 Resources: Minerals

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**Factors**

Global commodities markets

Global commodities prices (current and future minerals and metal prices)

Overall economic conditions

Existing sites, lifetime projections

Discoveries and discovery potential for commodities of interest

Regulatory regimes (land access, security of tenure, permitting and approvals)

Region's investment climate versus those of competing jurisdictions

Access to financing

Sovereignty

Hindering factors:

Operation-specific cost constraints (geographical, engineering, transportation, etc.)

Lack of critical infrastructure

Transport cost

Environmental concerns

Indigenous rights

New resources discoveries elsewhere

### 5.5.1 Introduction

Mineral and metal exploitation in the North is focused particularly on diamonds, copper, nickel, high grade iron ore and lead/zinc. Although there is a number of mines in operation or in different stages of the approval process (see Table 5-14 on page 65), many of them do not rely on Arctic shipping for supply or transport of minerals and metals.

### 5.5.2 Mineral Exploitation: Current Trends

Current information on minerals and metals exploration and exploitation in Canada's North is summarized in Table 5-12 below.

**Table 5-12.** Mineral and Metals Exploitation: Current Trends

<table>
<tr><th>Study</th><th>Summary</th></tr>
<tr><td>AMSA 2009</td><td>Year round operation of nickel from Deception Bay in northern Quebec because they degrade if left too long without processing.<br><br>In September 2008, a test shipment of some of the purest iron ore found on the planet was delivered to Europe from the Baffinland mine in Mary River on Baffin Island.</td></tr>
<tr><td>CASA 2007</td><td>With closure of Polaris and Nanisivik mines, there are no mines operating at present in Nunavut or the NWT that involve Arctic shipping. Jericho diamond mind in Nunavut is inland, and other activities are at present exploration and/or development related.<br><br>Major mine in operation is currently <u>Raglan nickel mine</u> in the Cape Smith Belt. Mine ships through Deception Bay using storage facilities and loader. Shipping commenced in 1998 at about 130,000 tons per year (tpy). Upgrades planned for 2007 should see shipping tonnages of 150,000tpy through to 2015, which is when the ore will be probably worked out. MV Arctic generally brings in petroleum products and other logistics materials to supply the mine on its return trip from Quebec city. Ore is railed from Quebec city to Sudbury for processing. Current traffic (2007) is 4-5 trips per season. This will increase to 5-6 trips with the higher concentrate production.</td></tr>
<tr><td>NRTEE 2009</td><td>
<table>
<tr><td colspan="5">Mining's continued significant role</td></tr>
<tr><td></td><td>Closed sites</td><td>Operating mines</td><td>Under review</td><td>Exploration phase</td></tr>
<tr><td>Yukon</td><td>13</td><td>1</td><td>4</td><td>150</td></tr>
<tr><td>Northwest Territories</td><td>32-33</td><td>4</td><td>5</td><td>45</td></tr>
<tr><td>Nunavut</td><td>6</td><td>1</td><td>3</td><td>20</td></tr>
</table>
</td></tr>
</table>

### 5.5.3 Mineral Exploitation and Exploration: Projections in the Literature

Future activity on minerals and metals exploration and exploitation in Canada's North, as projected in different studies, is summarized in Table 5-13:

**Table 5-13.** Mineral and Metals Exploitation: Projections

| Study | Projection summary |
|---|---|
| AMSA 2009 | **Canadian Arctic:** It is anticipated that **the primary cause of increased marine activity will be resource driven**. During the next 20 years, new bulk exports are expected to include:<br>• **Mary River** iron ore from a port at Steensby Inlet in the Foxe Basin, with possible commencement in 2010;<br>• **Roche Bay** magnetite from a port near Igloolik in the Foxe Basin, possibly beginning in 2015; and<br>• **High-Izok Lake** lead-zinc-copper concentrate, shipping from either Gray's Bay or Bathurst Inlet, possibly starting the same year.<br>Imports would likely include logistics and fuel, as well as barge-mounted production modules to the Alberta Oil Sands, among others. |
| CASA 2007 | **Raglan nickel mine:** Upgrades planned for 2007 should see shipping tonnages of 150,000tpy (up from 130,000tpy) **through to 2015**, which is when the ore will be probably worked out.<br><br>Current (2007) traffic is 4-5 trips per season. This will increase to 5-6 trips with the higher concentrate production. Although exhaustion is expected by 2015, but it could run longer than originally planned if additional resources are discovered and or metal price increase. **Raglan South** property may generate one ship load of concentrate.<br><br>**Qikiqtaaluk region**: project is expected to be operational within the 2020 time frame. **Baffinland Ore Mines** have initiated shipment levels of about 12m tones pa, but quantities cold be more or less depending on contracts and where the mine is in its ramp-up period. Assuming 200,000 deadweight tonnes (dwt) vessels there would be about 60 loaded transits each season.<br><br>**Kivalliq region**: Mineral opportunities include: gold, diamonds, uranium. Shipping is not required such for products because they are more readily flown out. Logistic materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present.<br><br>**Meadowbank gold** prospect near Baker lake is in active development. **Kiggavik and Meliadine gold** could also be operational, requiring inbound logistics and fuel.<br><br>**Kitikmeot region**: Wolfden's **High Lake** mine is expected to be operational within 2020 timeframe, as is **Hope Bay** gold and possibly **Ulu**. Other projects are not sufficiently advanced to make predictions regarding timeframes.<br><br>**High Lake** and associated gold operations could require 52,000 tonnes of dry cargo and 140,000 $m^3$ of inbound POL each season with 300-400 tonnes of concentrates outbound. Vessel transit could be in the range 6-12 during an extended season. If re-supply routes to the diamond mines at Jericho, Diavik, Ekati, and Snap Lake are reversed, it could add 100,000 tonnes of dry cargo and 250,000$m^3$ of oil to annual volumes.<br><br>**Nunavik**: The region is effectively unexplored, although exploratory activities are supported by the Quebec Government. It is unlikely that a new deposit could be brought on line prior to 2020.<br><br>**Hudson Bay**: Victor diamond mine near Attawapiskat, served by winter road. |

| | |
|---|---|
| Williams et al. 2011 | Arctic-wide projections under a BAU trajectory and on the basis of the 30-year average number of large mines in Fennnoscandia: 1.1% rate of change per year.<br><br>Sea ice projection based on IPCC: -1.2% rate of change per year.<br><br>The projection considers the increase over the past 30 years and notes that perhaps it will be slightly higher than historical rate as demand for mineral resources grows globally in coming decades. |

### 5.5.4 Mineral Exploitation: Current Sites and Projects

Table 5-14 contains a summary of the current sites on exploitation, development or exploration in Northern Canada, as well as a description of the shipping requirements for construction or operation phases.

It should be noted that many mines are served by air and by winter roads. Studies have shown increasing difficulties to construct and operate winter roads in shorter operational seasons as a result of climate change. Stephenson et al. (2011) project a 13% decline in annually averaged changes in inland and maritime transportation accessibility by mid-century (2045–2059) versus the baseline (2000–2014). Studies also project that the Tibbitt-Contwoyto winter road, the Northwest Territories' longest winter road and one important service road for diamond mines, will lose about 17% of its operating season between 2008 and 2020 (Stephenson et al., 2011).

The potential loss of winter roads may have an impact on the mine transportation systems, which could increase demand for Arctic shipping. Alternatively, airlift could replace winter roads as a transport system for some supplies, or all-weather roads could be the preferred infrastructure solution.  The literature review could not find strategic approaches or action plans on this particular issue.

**Table 5-14.** Summary of Mining Projects and Mines with Shipping Traffic Projections

| Mine/Project | Expected construction<br>Expected lifetime | Transportation system | Shipping estimates |
|---|---|---|---|
| **North QUEBEC** | | | |
| **Raglan**<br>(nickel) | Exhaustion is expected by 2015. | | 2007 traffic was 4-5 trips per season. This will increase to 5-6 trips with the higher concentrate production |
| **North ONTARIO** | | | |
| **Victor**<br>(diamond) | Production began in 2008. | Served by winter road | |
| **NUNAVUT** | | | |
| **Meadowbank**<br>(gold) | Expected lifetime: 2017 (originally 2020). | | Logistics materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present. |
| **Hope Bay**<br>(gold) | Put on hold indefinitely. | | Logistics materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present. |
| **Mary River**<br>(iron ore) | Expected construction: 2013-2016.<br>Expected production: late 2016.<br><br>Currently: hearing for EIA expected for July 2012. | Part of the reason the project is so attractive is that the ore could be sent directly by rail to a port that would be built nearby and then shipped out from there without any additional processing. The iron ore will be shipped to Europe aboard enormous icebreaking freighters. | Assuming 200,000dwt vessels there would be about 60 loaded transits each season.<br><br>Steensby Port in Steensby Inlet: will remain operational year-round. Iron ore will be stored in stockpiles and then loaded onto ore carriers for shipment throughout the year, the majority of trips for the re-supply of materials and equipment will be delivered during the open-water season, defined as mid-July through mid-October. On average, 12 ore carriers will be received at the ore dock each month. During the open-water season, non-icebreaking vessels will be chartered to carry additional ore, with the dock receiving up to a maximum of 17 vessels per month.<br>Steensby Port to Europe throughout the year will require specialized ships capable of withstanding the winter ice. Baffinland has proposed that 10 to 12 ice class cape-size vessels each with a capacity of 160 000 to 190 000 dwt be constructed for the transport of the ore to European markets (Baffinland, 2011, Vol. 3, p.100). It is expected that together, these ore carriers will make 102 round trips from Steensby Port to ports across the Atlantic Ocean each year.<br>The frequency of vessel traffic will increase during the open-water season, as other vessels are chartered to ship additional ore and to re-supply equipment and fuel.<br>Icebreaker ore carriers (Polar Class 4).<br>Shipping route: through Hudson Bay and Foxe Basin |

| | | | |
|---|---|---|---|
| **Meliadine**<br>(gold) | Development: 2012–16.<br>Production: 2017. | Equipment, fuel and dry goods transported during warm weather season by sealift by barge to Rankin Inlet via Hudson Bay.<br>Personnel, perishables and lighter goods arrive at the Rankin Inlet regional airport by commercial or charter airline.<br>They can then be transported along the winter road or flown to the property by chartered helicopter.<br>An all-weather gravel road extends from Rankin Inlet to the bank of the Meliadine River, approximately 15 kilometres away from the property.<br>A 27-kilometre-long continuation of the existing all-weather, open-access road to the Meliadine project was authorized in February 2012. Road construction to be completed by April 2013. | Logistics materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present. |
| **Jericho**<br>(diamond) | Closed in 2008, the mine could reopen if market conditions make the project profitable. | Accessible by air all year and by winter road from Yellowknife.<br>Proposed Bathurst Inlet Port and Road. | |
| **Tiriganiaq** and **Wesmeg**<br>(gold) | Reserves found. | | |
| **High Lake**<br>(copper/zinc) | Project put on hold for three years in 2008. No new developments. | Project: all weather road connection to Gray's Bay. | Could require 52,000 tonnes of dry cargo and 140,000 $m^3$ of inbound POL each season with 300-400 tonnes of concentrates outbound. Vessel transit could be in the range 6-12 during an extended season. If re-supply routes to the diamond mines at Jericho, Diavik, Ekati, and Snap Lake are reversed, it could add 100,000 tonnes of dry cargo and 250,000$m^3$ of oil to annual volumes. |
| **Izok Lake**<br>(zinc) | Project put on hold for three years in 2008, concentrating on exploration. No new developments. | Considers shipping for operation, restricted to 100 days of sea-ice free ocean.<br>Expected to be shipped out from Gray's Bay or Bathurst Inlet. | |
| **Lupin** | Closed in 2005<br>Could re-open to recover last reserves of ore. | During the winter, the mine is served by the Tibbitt-Contwoyto Winter Road | |
| **Ulu Project**<br>(gold) | Exploration phase. No new developments. | | |
| **Roche Bay**<br>(iron ore) | Advanced explorations. | Shipping is expected out from Gray's Bay or Bathurst Inlet. | |

| | | | |
|---|---|---|---|
| **Kiggawick Project** (uranium) | January 2012: Nunavut Impact Review Board rejected an 11-volume draft environmental impact statement from Areva Canada on its proposed Kiggavik uranium extraction project near Baker Lake. | Reagents, fuel and supplies would be barged to a storage facility near Baker Lake and then transported to Kiggavik via truck on a 90 – 100 km access road. An airstrip would be constructed on site for the transport of both employees and materials. The airstrip would also be used to transport drums of uranium concentrate by air to southern Canada. A limited number of concentrate drums may be shipped by barge during the open water season. | Logistics materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present. |
| **NORTHWEST TERRITORIES** | | | |
| **Diavik mine** (diamond) | In operation, full underground production reaching full levels in 2013. New pits expected to begin in 2015. | The Tibbitt to Contwoyto winter ice road is considered the lifeline to the Diavik Diamond Mine's operation, stretching approximately 600 kilometres (mine located at kilometre 360) open for eight to nine weeks each year, from February to the beginning of April (depending on weather and the season's load requirements).<br><br>Mine also has an airstrip capable of accepting Boeing 737 jet service and Hercules transport. | |
| **Ekati** (diamond) | In operation. Older pits at the mine are being closed (Panda pit closed in 2010) even as new ones are opened (Koala North opened in 2010; Misery open-pit is projected to produce ore from late 2015 to mid-2017). Closure and reclamation planned for 2018. | Accessible by air and seasonally by a 475 kilometre ice road. | |
| **Snap Lake** (diamond) | Commercial production: January 16, 2008. Official Mine Opening took place on July 25, 2008. | Airplane<br>Seasonal ice road (six to eight weeks of the year) used to re-supply the mine with equipment, parts and other materials needed to operate the mine. | |
| **Gahcho Kué** (diamonds) | In July 2011, the Gahcho Kué Environmental Impact Review Panel issued a conformity statement for the EIS and set the work plan for the EIR. The panel decision is expected by July | An airstrip capable of handling the aircraft needed to fly workers and supplies to the site.<br>120 km winter road that follows the route established during exploration of the site would be build to the site each year, connecting to the Tibbitt-Contwoyto winter road near the top end of MacKay Lake. | |

| | | | |
|---|---|---|---|
| | 2013. Commercial production is expected to begin in 2016. | | |
| **(Pacific coast) Cantung** (tungsten) | Resumed operations in October 2010 after a year-long suspension. Absent any disruptions, operations should continue through the end of 2014. | The town and mine are serviced with an all-weather road to Watson Lake and a 3700' x 100' airstrip. | |
| **Fortune Mineral's NICO project**: (gold-cobalt-bismuth-copper) | Commercial operation expected to begin in 2013 and rise to full production levels in 2014. The mine is expected to be active for 18 years. | Currently accessible by winter road Canadian, Northwest Territories and Tlicho governments, together with private industry, are re-aligning this road for upgrade to an all-season gravel road | |
| **Avalon Rare Metal's Nechalacho rare earth elements project:** | Estimated production starting in 2015, with production levels predicted to increase in the following few years. | No information on transport, but it is located at the southern limit of the territory so probably no shipping required | |
| **YUKON** | | | |
| **Minto mine** (copper-gold) | Opened in 2007. | Concentrates are currently being bagged in two-tonne supersacks in the concentrate storage shed at the Minto mine, which are then delivered by flat-deck trucks to the port of Skagway (Alaska). | |
| **Bellekeno mine** (silver) | Production: late 2010; officially in January 2011. | Concentrate shipping began in early December 2011, through the port of Skagway in Alaska. | |
| **Wolverine mine** (zinc-silver-copper) | Production: 2011. | Connected by the Robert Campbell Highway leading southward through Watson Lake to the existing Stewart Bulk Terminal in Stewart, B.C. | |
| **Eagle project** (nickel-copper) | Estimated production starting in the first quarter of 2014. | | |
| **Copper North's Carmacks project** (copper) | Estimated production starting in 2014. | High-purity copper cathodes will be produced in an electrowinning plant for shipment from the ice-free port of Skagway. | |

## 5.5.5 Mineral Exploitation: Spatial Distribution

The spatial distribution of the mines is displayed in Figure 5-15 (CASA, 2007), Figure 5-16 and Figure 5-17 (Arseneau 2010). The latter figure also shows projected infrastructure of relevance for Arctic traffic, in particular: the Bathurst Inlet port and road project, and the all-weather road project to Bakers Lake.


Figure 5-15. Resource Areas and Activities in the Canadian Shipping Arctic Assessment. Source: CASA (2007)

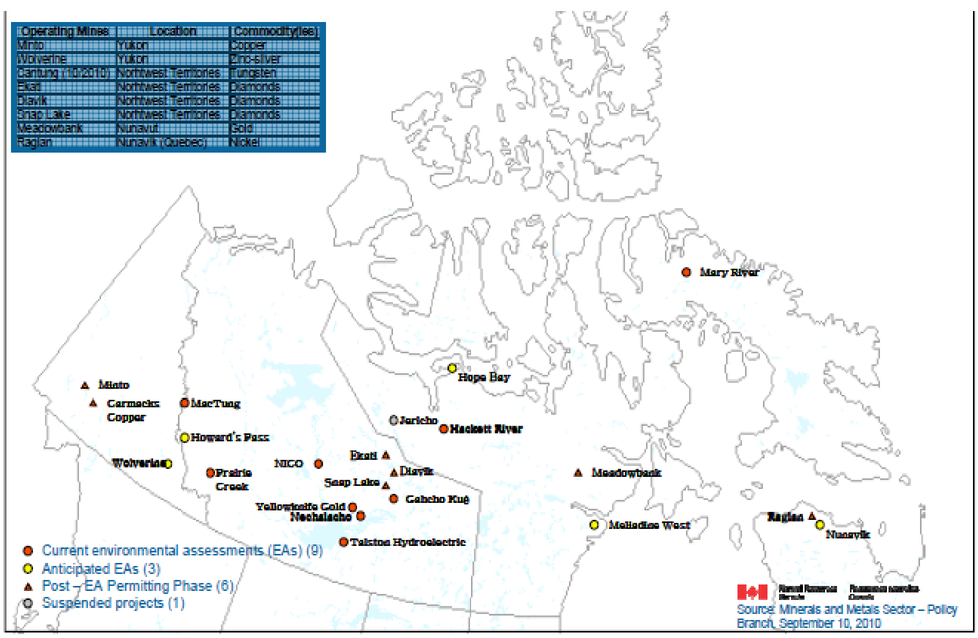


Figure 5-16. Mineral Exploration and Mining in Canada's North. Source: Arseneau (2010)

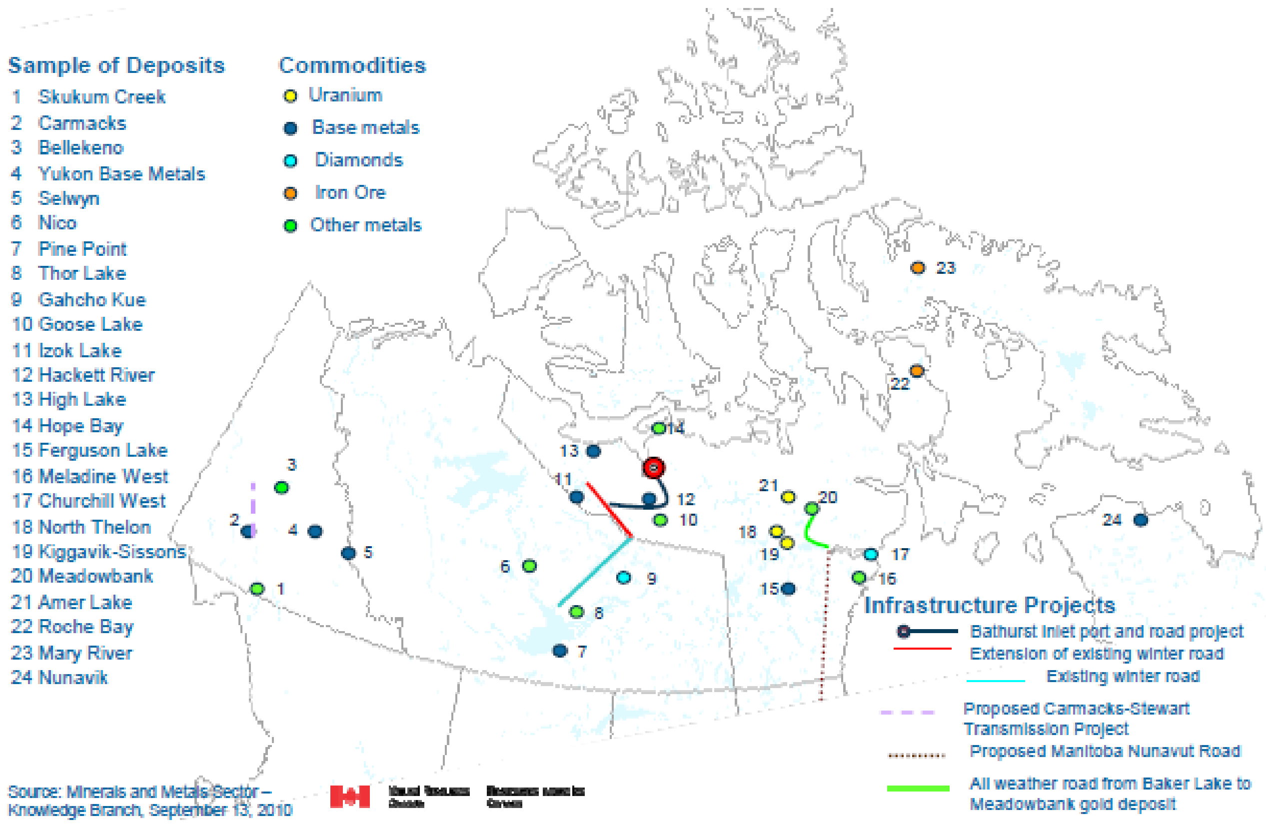


**Figure 5-17.** Mineral Exploration and Mining in Canada's North. Source: Arseneau (2010)

## 5.6 Resources: Fisheries

**Resources**

Arctic Council. 2009. *Arctic Marine Shipping Assessment 2009 Report* (April 2009).

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**Factors**

Governance: management measures

- Moratorium for commercial fishing licenses in Beaufort Sea
- Quotas

Exploratory fisheries

Fishing developments in coastal communities

- Pangnirtung small craft harbor

Fishing practices shifts

Changing climate and its implications for fisheries (Cheung et al. 2010)

Hindering factors:

Distances between Arctic communities

Legal conflict over fishing governance (land claims agreements)

Underdeveloped infrastructure

Underdeveloped economies

### 5.6.1 Introduction

Warmer areas of the Arctic Ocean have supported commercial and subsistence fishing activities for decades but, until recently, they have been relatively minor due to the limited accessibility and the harsh environment. Fishing, hunting and trapping for fish and marine mammals such as narwhal, whales, seals, Arctic char, and salmon has been an integral part of the traditional lifestyle of the northern communities for centuries, but it has been kept at relatively low levels. Commercial whaling was banned in Canada during the 20th century. More recently, a few stocks, particularly Greenland halibut (turbot) and northern shrimp in Baffin Bay and David Strait, support small but increasingly relevant commercial fisheries in the Eastern Arctic. Arctic char, snow crab, salmon are other important fish products.

Several fishing activities are subject to international or regional management or cooperation arrangements: salmon, Greenland halibut, Northern shrimp, Beluga and Narwhal, are examples thereof. The domestic governance of Arctic fishing is particularly complicated with Fisheries and Oceans Canada acting as the lead federal agency and strong indigenous involvement through natural resources management boards established under the different land claim agreements.

Fisheries and Oceans Canada manages fisheries under the Sustainable Fisheries Framework. New fisheries are authorized on a step-by-step process guided by the precautionary approach following the Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas and the Emerging Fisheries Policy.

Additionally, Fisheries and Oceans Canada signed a Memorandum of Understanding with the Inuvailuit in Inuvik, Northwest Territories, which prohibits the issuance of any new commercial fishing licenses for the Beaufort Sea at least until a fisheries management plan is developed and implemented for the area. There is no timeline for finalizing the management plan.

The retreat of Arctic sea ice is opening up new parts of the Arctic Ocean to fishing vessels. Additionally, fishing opportunities may change as a result of the warming climate. Many factors will affect Arctic marine ecosystems, such as warmer Arctic surface and water temperatures, reductions in sea ice coverage and thickness, reduced salinity, increasing acidification and other oceanographic and meteorological changes. The cumulative effect of these factors is not known. The composition of Arctic marine ecosystems will undoubtedly change, qualitatively, quantitatively, spatially and temporally. However, where new fishing opportunities will occur and with respect to which species or category of species is difficult to predict. Additionally, some species are expected to collapse due to warming waters (e.g., polar bear, crustaceans). Furthermore, competition between new commercial fisheries with subsistence fisheries, and interference for fisheries from other economic developments, are also unknown factors.

Another significant difficulty in projecting future fisheries in the Arctic is the lack of reliable baseline data on the number of vessels, fishing trips, and catches. Translating potential increases in fishing opportunities without that baseline will require further research and assumptions.

### 5.6.2 Trends in the Literature

Considering the lack of information baseline and the failure of States to report their Arctic catches to the United Nations Food and Agriculture Organization (FAO), Zeller et al. (2011) reconstructed the catches in the Arctic, including Canadian Arctic. The study claims to be the first to estimate the full extent of Canada's historic marine fish catches in the Arctic, since there has been no consistent or substantial effort undertaken for the small-scale fisheries sector, with previous studies documenting subsistence fisheries over relatively short timespans (e.g., Gamble 1988) with no expansion to consider the entire Canadian Arctic.

The study results are shown in Figure 5-18, which show:

a) reconstructed total catches versus catches (x $10^3$ tonnes) reported to FAO in the Amerasian Arctic between 1950 and 2006; and
b) reconstructed total catches (x $10^3$ tonnes) by the three countries covered by FAO Statistical Area 18 (Russia, USA, Canada) between 1950 and 2006;

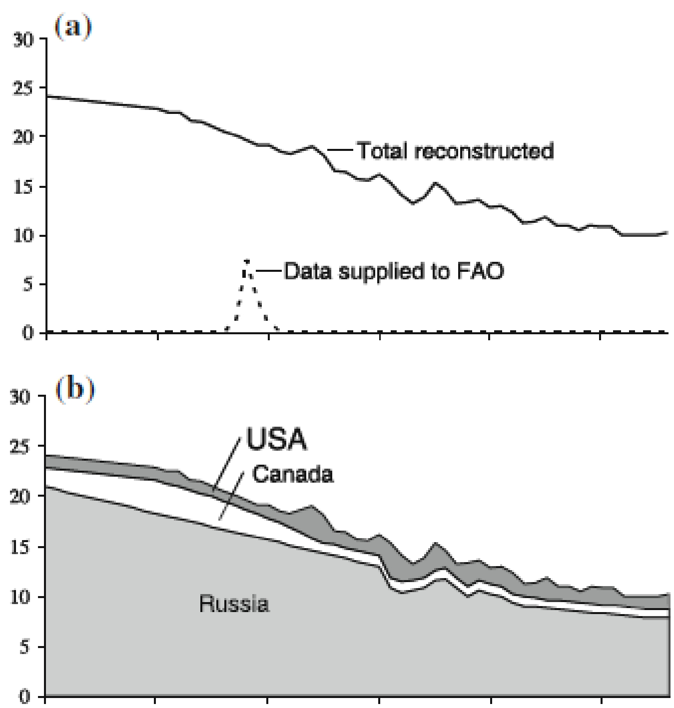


**Figure 5-18.** Reconstructed Arctic Fish Catches from 1950 to 2006. Source: Zeller (2011)

Zeller et al. (2011) show a decreasing trend in Canadian Arctic fisheries. Williams et al. (2011) also note this trend, having gone from 254,000 tonnes per year to just over 10,000 tonnes in over 60 years, and with marked reliance of relatively large local populations on coastal marine resources.

Niemi et al. (2010) summarizes fishing activities by the different Arctic marine ecosystems as follows:

a) Beaufort Sea Marine Ecosystem:
- There is currently no commercial fishery in the Beaufort Sea Marine Ecosystem;
- In 2006/07 there were six exploratory fisheries (stage I feasibility) that included different species of fish, shrimp and shellfish;
- In 2007/08 there were only two exploratory fisheries, both for Arctic Char;
- In 2009 there was only one exploratory char fishery.

b) Hudson James Bay
- Iceland scallop (Chlamys islandica) was harvested by exploratory commercial fisheries in Hudson and Strait and in Ungava Bay. However, no commercial fishery was developed for the scallop. This ecozone also has commercial fisheries for Arctic Char. The number of commercial fisheries in the Hudson Bay area decreased from 209 in 2005 to 42 in 2009.

c) Canadian Arctic Archipelago
- The area has a mixture of commercial and exploratory (stage I and II feasibility) fisheries.
- Between 2005 and 2008 the number of commercial and exploratory (stage I and II combined) fisheries averaged, 140 and 160, respectively. However, in 2009 the number of commercial and exploratory fisheries dropped to 9 and 21, respectively.
- An important commercial fishery, established in 1986, is the inshore winter turbot fishery in Cumberland Sound.
- The offshore turbot fisheries in Northwest Atlantic Fisheries Organization (NAFO) areas 0A and 0B, including the Davis Strait/Baffin Bay area of this Ecozone, are economically important for Northern communities. In 2006 a portion of fishery area 0A, near southern Baffin Bay, was closed to protect southern Narwhal overwinter grounds and deep-sea coral habitat.
- Commercial shrimp fisheries for Northern (*Pandalus borealis*) and striped (*Pandalus montagui*) shrimp began in the late 1970s off Baffin Island and expanded southward to the area of Resolution Island (Hudson Strait) in the mid-1990s, where the main fishery remains to date. The distribution of shrimp fishing effort in recent years remains unchanged. Offshore fishery licences for turbot and shrimp are summarized in Table 5-15.

**Table 5-15.** Offshore licences in the Canadian Arctic Archipelago. Source: Niemi et al. (2010)

| Year | Number of Licences | |
|---|---|---|
| | Turbot | Northern Shrimp |
| 2009/10 | 13 | 2 |
| 2008/09 | 8 | 2 |
| 2007/08 | 6 | 4 |
| 2006/07 | 8 | 4 |

### 5.6.3 Time Series

The information on number of fishing vessels and voyages in the Canadian Arctic is summarized in Table 5-16 below (DND, 2012):

**Table 5-16.** Arctic fishing activity 2010-2011: number of active vessels and voyages

| | 2010 | 2011 |
|---|---|---|
| Nbr. of vessels | 26 | 26 |
| Nbr. of voyages | 124 | 144 |

### 5.6.4 Projections in the Literature

AMSA (2009) does not provide projections for fisheries in the Canadian Arctic region. CASA (2007) does not provide specific projections, but notes how development in the Arctic will depend heavily on infrastructure: a protected dock; access to marine fuels; adequate afloat maintenance and repair resources; warehousing and storage; temperature controlled facilities. CASA notes that without this support, Arctic commercial fishing is unlikely to grow.

Judson (2010) does not address fisheries. Corbett et al. (2010), in their emission inventories for future Arctic-wide shipping scenarios, include fishing vessels estimates for comparison, but caution that estimates for fishing vessels should be considered very uncertain.

Williams et al. (2011) base its forecast in Cheung et al. (2010), and under a BAU model predicts an Arctic-wide increase for fisheries of 0.4% per year (Sea ice projection based on IPCC: -1.2% rate of change per year).

Cheung et al. (2010) make general projections of changes in marine fish productivity under two different climate change scenarios, each representing a high- and a low-range greenhouse gas emissions (SRES A1B – $CO_2$ concentrations at 720ppm in 2100; and stable-2000 – $CO_2$ concentrations at 365ppm, respectively). The study predicted annual primary production in the world's oceans from 2001 to 2060 for the two climate change scenarios using algorithms identified in the paper. Although the global catch potential between 2005 and 2050 varies little (+/- 1%), climate change may significantly alter the distribution of catch potential, particularly between tropical and high-latitude regions. Arctic fisheries are projected to increase their catch potential by more than 50% by 2055, although the pattern of change in catch potential is less clear under a low greenhouse gas emission scenario.

The study's spatial analysis of expected changes in catch potential projects a small increase in expected catch potential in Canada, as shown in the Figure 5-19.

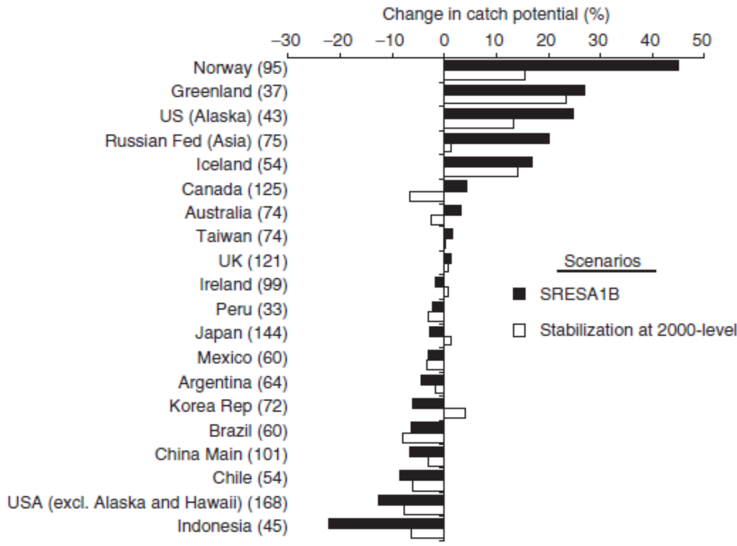


**Figure 5-19.** Projected changes in 10-year averaged maximum catch potential from 2005 to 2055. Numbers in parentheses represent the number of species considered in the analysis. Source: Cheung et al (2010)

### 5.6.5 Expected Developments in the Arctic

As part of Canada's Action Plan, the Canadian Government committed to the construction of a small craft harbor in Pangnirtung with an investment of over 25 million dollars. The craft port would enable the community to access the Cumberland Sound Greenland Halibut (Turbot) summer fishery, with 500 tonnes quota. The quota is currently not caught because of lack of port support. Construction started in June 2010.

## 5.7 Tourism (Passenger Shipping)

**References**


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Arctic Council. 2009. *Arctic Marine Shipping Assessment 2009 Report* (April 2009).

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Johnston, A.E. 2011. “Is Canada Ready for Increased Arctic Cruise Tourism? Perspectives from the Federal Government” [Conceptual Framework for Vulnerability Assessment].

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Shipping Statistics 2004-2009 (provided by Technical Authority, citing DND)

Shipping Statistics 2010 (provided by Technical Authority, citing DND)


**Factors**

Accessibility

Global economy

Popularity of cruising worldwide

Quality of natural attractions (level of satisfaction of ice-seeking customers depends on natural features and wildlife, such as icebergs and polar bears).

Product development (i.e. cruise company offerings)

Public policies

Regulations

Infrastructure

- five-year small craft marine infrastructure investment in Nunavut
- investments in cultural centres/art schools have been announced in Nunavut

  (all of the above with little influence in short-term projections for number of passengers)

International Convention for the Safety of Life at Sea (SOLAS Convention) amendment adopted in 2006 and entered into force on July 2010

Hindering factors:
Costs
Jurisdictional restraints
Environmental or cultural restraints
Lack of Infrastructure: available suitable vessels, available port facilities, available hotels, etc. (in particular for emergencies), human resources.
Perceived risk: stranding of cruise ships

- in August 2010, the expedition cruise ship Clipper Adventurer stranded itself on an escarpment in Coronation Gulf [Stewart, E. and Dawson, J., 2011].

### 5.7.1 Introduction

Tourism has been considered the fastest growing sector in the Canadian Arctic. Two types of vessels are included in this category: cruise ships, and pleasure craft. Although trends and projections for cruise ships could be found in the literature, much less information was found on pleasure craft.

### 5.7.2 Tourism Activity: Trends

Current patterns of tourism activity in the Arctic and in the Canadian Arctic are summarized in Table 5-17 below.

**Table 5-17.** Tourism Activity: Trends

| Study | Summary |
|---|---|
| AMSA 2009 | Cruise ship traffic in the Arctic region has increased significantly in the four years that have passed since the AMSA database was developed. An independent survey indicated more than 1.2 million passengers traveled in 2004 to Arctic destinations aboard cruise ships; however by 2007 that number had more than doubled. |
| Analyse& Strategi 2011 | Complete data for all Arctic cruises are hard to obtain, but some indications of the development in later years can be found in data from:<br>• Greenland: number of arrivals of cruise ships in Greenland ports has increased by an average of 48.9% per year from 2005 to 2008.<br>• Longyearbyen, Svalbard: Average growth rate 2011-2008 of passengers arriving is 14% per year.<br>AMSA estimates seem much too high, representing 15% of all cruise passengers worldwide |
| Williams et al. 2010 | Tourism comprises a small proportion of total Arctic activity. Around 2.5 million tourists visited the region as part of cruises in 2007. Mostly confined to coastal trips, particularly along the Norwegian, Svalvard, and west Greenland coasts. Other popular routes are direct to the North pole from Norway and Russia, and through Canada’s NWP. |

<table>
<tr><td>Stewart et al. 2010a</td><td>No one agency is taking the lead in monitoring or collecting data from cruise ships entering Canadian Arctic waters. Although several agencies collect some data, none of these data sources are comprehensive, providing only a partial evidence base from which to evaluate cruise visitation to Arctic Canada.<br><br>Between 1992 and 2005, there were between 1 and 3 successful expedition cruises through the NWP completed each year, as well as cruise ships visits to Baffin Island, Hudson Bay and Ellesmere Island. A turning point came in 2006 when the number of cruise ships visiting the Canadian Arctic doubled to 22 cruises up from 11 separate cruises in the previous season. During 2007 growth stabilized with 23 separate cruises planned by six different companies, who together brought approximately 2110 visitors to the Canadian Arctic. During the 2008 cruise season, six vessels operated in the Canadian Arctic carrying passengers on 26 separate cruises. Despite deepening concerns about the global economic climate, seven vessels planned to carry passengers on 25 separate cruises that will make ports of call in the Canadian Arctic in 2009. However, in early 2009 anecdotal evidence suggested that at least four of these 25 cruises may be cancelled due to low bookings (not verified).<br><br>2009 data
<table>
<tr><th>Operator</th><th>Vessel</th><th>Ice rating</th></tr>
<tr><td>Quark Expeditions</td><td>Kapitan Khlebnikov</td><td>IceBreaker LL2</td></tr>
<tr><td>Quark Expeditions</td><td>Akademik Ioffe</td><td>IA2</td></tr>
<tr><td>Polarstar Expeditions</td><td>Polar Star</td><td>IA</td></tr>
<tr><td>Cruise North / Quark Expeditions</td><td>Lyubov Orlova</td><td>IA2</td></tr>
<tr><td>Hapag-Lloyd Cruises</td><td>Bremen</td><td>E4</td></tr>
<tr><td>Hapag-Lloyd Cruises</td><td>Hanseatic</td><td>E4</td></tr>
<tr><td>Quark Expeditions</td><td>Clipper Adventurer</td><td>IA</td></tr>
</table></td></tr>
<tr><td>Stewart et al. 2010b</td><td>Industry has moved beyond its infancy and is now entering a maturing phase with increased numbers of vessels, a lengthening season, more demanding routes, and more regular and predictable patterns of activity.<br>Optimal period for navigation season: 25 June to 15 October (17 weeks).</td></tr>
<tr><td>Kaltentstein 2010</td><td>Have increased at an annual rate of 9.5 percent on average between 2006-2010.</td></tr>
</table>

### 5.7.3 Tourism Activity: Time Series

Table 5-18 summarizes information on number of cruise ships and pleasures craft entering the Canadian Arctic between 2004 and 2011, number of ships' voyages, and season length as obtained from different sources.

**Table 5-18.** Tourism Activity in the Canadian Arctic: 2004-2011

| Study | Parameter | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| DND Stats | Cruise ships | 7 | 11 | 9 | 9 | 6 | 7 | 11 | 7 |
| | Pleasure craft | 5 | 9 | 5 | 6 | 9 | 11 | 24 | 33 |
| | Cruise ships voyages | | | | | | | 18 | 11 |
| | Pleasure craft voyages | | | | | | | 24 | 33 |
| Judson | illegible | | | | | | | | |
| Stewart et al. 2010a | vessels | | | | | 6 | (7) | | |
| | cruises | | 11 | 22 | 23 | 26 | (25) | | |
| Stewart et al. 2010b | season | | | 95 days 26 Jun-28 Sept | | 126 days 11 Jun-14 Oct | | | |

### 5.7.4 Tourism Activity: Projections

Future tourism related traffic, as projected in different studies, are summarized in Table 5-19 below.

**Table 5-19.** Tourism Activity in the Arctic: Projections

| Study | Scope | Summary |
|---|---|---|
| AMSA 2009 | Arctic-NWP | A plausible future for Arctic marine tourism is that it will continue to grow, diversify and geographically expand as current obstacles are overcome. Arctic marine tourism's likely future will consist of a larger numbers of tourists traveling aboard increased number of ships of all types, will be spending more time at more locations. The cruise ship industry responding to the popularity of polar tourism and clear evidence of profitability is committed to send more ships with larger passenger capacities to Arctic destinations.<br>In the Canadian Arctic: destinational shipping is anticipated to increase in the Canadian Arctic. This will be driven largely by the demand for goods by growing communities, expanding resource development projects, as well as increasing tourism.<br>Tourism projections of modest but largely unpredictable growth. |
| Analyse& Strategi 2011 | Arctic | In the near future, specialist operators will continue to offer cruises in all three passages. |
| Williams et al. 2010 | Arctic | Arctic-wide projection on a BAU trajectory, based on 10-year average of number of cruise ship arrivals at Greenland ports: tourism will see the highest increase in activity to 2050 (24.9% change per year).<br>This is due to the relatively small number of tourist ships already active in the Arctic region, combined with the forcing factor of the vast increase over the past 10 years the sector has already seen. |

<table>
<tr><td rowspan="4">Corbett et al. 2010</td><td rowspan="4">Arctic</td><td colspan="6">Input growth rates by vessel type from scenario model used in the Second IMO Greenhouse Gas Emission Study (Buhaug et al 2009). Passenger vessels:</td></tr>
<tr><td colspan="2">2004 to 2020</td><td colspan="2">2004 to 2030</td><td colspan="2">2004 to 2050</td></tr>
<tr><td>BAU growth</td><td>High-growth</td><td>BAU growth</td><td>High-growth</td><td>BAU growth</td><td>High-growth</td></tr>
<tr><td>0.68%</td><td>1.53%</td><td>0.84%</td><td>1.58%</td><td>0.99%</td><td>1.66%</td></tr>
<tr><td>CASA 2007</td><td>Canadian Arctic</td><td colspan="6">As this will remain a seasonal activity, and the number of ships is limited, there is unlikely to be any significant change over current levels. The fleet may actually decline with the entry into fore of SOLAS Convention modification in 2010, depending on the status of the ships and the willingness of the owners to invest in the ships. A forecast for the numbers of ships and trips is not possible.</td></tr>
</table>

### 5.7.5 Tourism Activity: Spatial Distribution

Stewart et al. (2010a) makes a spatial analysis of cruises distribution in the Canadian Arctic using 2006, 2008 and 2009 data. For this purpose they identify four regions: High Arctic, NWP, Baffin Bay and Hudson Bay. It is noted that all regions in Canada's Arctic (apart from ice-infested Queen Elizabeth Islands) experience cruise activity. However, cruise tourism is highly variable across Arctic Canada. Of the four regions reviewed, the NWP is the only region that experienced growth in the period under analysis, while communities along southern and eastern Baffin Island and some locations in the Hudson Bay area appear to be experiencing a decline in cruise visits. The study notes that information has been taken from websites that advertise cruises to Arctic Canada, which is focused on intended cruises and locations visited. This can differ from real locations visited considering the dynamic variability of the Arctic environment that makes actual ship routing unpredictable.

Numbers of visits to coastal communities and shore visits in each of the four regions identified by Stewart et al. (2010a) are included in the Tables 5-20 to 5-23 below.

**Table 5-20.** Community and Shore Visits in **High Arctic**. Source: Stewart et al. (2010a), citing Quark Expeditions (2009)

| Community/shore visit | 2006 | 2008 | 2009 |
|---|---|---|---|
| **Community visits** | | | |
| Grise Fjord | 3 | 3 | 1 |
| **Shore visits** | | | |
| Axel Heiberg | 1 | 1 | 1 |
| Eureka | 0 | 1 | 1 |
| Fort Conger | 0 | 1 | 1 |
| Coburg Island | 3 | 7 | 5 |

**Table 5-21.** Community and Shore Visits in **NWP**. Source: Stewart et al. (2010a), citing Cruise North (2009) Hapag-Lloyd Cruises (2009); Quark Expeditions (2009);

| Community/shore visit | 2006 | 2008 | 2009 |
|---|---|---|---|
| **Community visits** | | | |
| Cambridge Bay | 3 | 2 | 6 |
| Gjoa Haven | 0 | 2 | 3 |
| Holam (Ulukhaktok) | 1 | 2 | 4 |
| Resolute | 16 | 17 | 21 |
| **Shore visits** | | | |
| Beechey Island | 11 | 15 | 16 |
| Dundas Harbour; Devon Island | 5 | 8 | 8 |
| Jenny Lind Island | 1 | 1 | 3 |
| King William Island | 1 | 2 | 2 |
| Prince Leopold Island | 3 | 3 | 7 |

**Table 5-22.** Community and Shore Visits in **Baffin Bay**. Source: Stewart et al. (2010a), citing Cruise North (2009); Hapag-Lloyd Cruises (2009); Quark Expeditions (2009)

| Community/shore visit | 2006 | 2008 | 2009 |
|---|---|---|---|
| **Community visits** | | | |
| Arctic Bay | 3 | 1 | 0 |
| Cape Dorset | 6 | 1 | 2 |
| Clyde River | 1 | 2 | 0 |
| Iqaluit | 8 | 14 | 4 |
| Kimmirut | 5 | 1 | 1 |
| Pangnirtung | 4 | 6 | 3 |
| Pond Inlet | 13 | 9 | 8 |
| Qikiqtarjuaq | 2 | 3 | 2 |
| **Shore visits** | | | |
| Auyuyittuaq | 4 | 2 | 0 |
| Cape Hay | 1 | 3 | 3 |
| Monumental Island | 0 | 6 | 2 |

**Table 5-23.** Community and Shore Visits in **Hudson Bay Region**. Source: Stewart et al. (2010a), citing Cruise North (2009); Polar Star Expeditions (2009); Quark Expeditions (2009)

| Community/shore visit | 2006 | 2008 | 2009 |
|---|---|---|---|
| **Community visits** | | | |
| Churchill | 2 | 2 | 2 |
| Inukjuak | 4 | 0 | 0 |
| Kangiqsujuaq | 4 | 3 | 3 |
| Kangirsuk | 4 | 0 | 1 |
| Kuuijuaq | 11 | 7 | 7 |
| Nain | 0 | 2 | 1 |
| **Shore visits** | | | |
| Akpatok Island | 9 | 7 | 7 |
| Digges and Mansel Islands | 5 | 3 | 2 |
| Hebron | 2 | 2 | 1 |
| Killiniq | 3 | 5 | 3 |
| Lower Savage Islands | 2 | 2 | 1 |
| Torngat Mountains | 1 | 4 | 1 |
| Quaqtaq | 2 | 2 | 2 |

Stewart et al. (2010b) points out that from the variety of existing routes through the NWP, by far the most commonly traversed route for tourism vessels is route 3 (Baffin Bay, Lancaster Sound, Barrow Strait, Peel Sound, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea). Favorable ice conditions, spectacular scenery, good wildlife sightings, and opportunities to also visit Greenland make the eastern Canadian Arctic the target of most cruises in the Canadian Arctic.

Consistent with Stewart et al. (2010b) findings, Kaltenstein et al. (2010) also observed a marked shift in cruise ship travel within the Canadian Arctic. Community and shore landings by cruise ships in the High Arctic and NWP have increased by 63% and 57% respectively, from 2006 to 2010, whereas voyages to lower Arctic latitude destinations including Baffin Bay, Hudson Bay, and Newfoundland have tapered off.

### 5.7.6 Other Passenger Traffic

In the Canadian Arctic ferry services are non-existent (AMSA, 2009). None of the reports reviewed consider ferry services to be provided in the future.

## 5.8 Resources: Other Industrial Developments

**References**

Williams et al. 2011. *The Future of Arctic Enterprise: Long-term Outlook and Implications*. Smith School of Enterprise and the Environment, University of Oxford (Oxford: University of Oxford, November 2011).

**Factors**

Global commodities markets

Global commodities prices

Hindering factors:

Development costs

Transport cost

Environmental concerns

Governance

Indigenous rights

### 5.8.1 Introduction

Williams et al. 2011 mention several activities that are not currently relevant in the Arctic but that can develop in the future, and that may impact the volume of Arctic traffic. These potential new uses of the Arctic, complemented by other proposed uses found in the literature, are:

a) Aquaculture
b) Bio-prospecting
c) Deep sea mineral prospecting
d) Carbon capture and storage
e) Renewable energy
f) Freshwater use
g) Setting of fiber optic cable

### 5.8.2 Trends and Projections

Generally, the literature does not address these new activities. Williams et al. (2011) does provide some general Arctic-wide trends on these activities, highlighting the prospects for bio-prospecting and aquaculture and noting that at present there is no clear indication that deep-sea mineral prospecting, carbon capture and storage, or renewable energy production will migrate to the Arctic Ocean in the short term.

Prospects of those activities being developed in the Canadian Arctic could not be found. For example, aquaculture for Arctic char has been identified as a potential area of growth but the species is currently raised in land-based system in Canada. The literature review did not succeed in finding information on prospected aquaculture projects in Arctic waters.

One new use of the Arctic that may have implications for Arctic shipping traffic is the deployment of fibre-optic cable in the Arctic waters. A recent project is to lay fiber-optic cable connecting London and Tokyo by way of the NWP, taking advantage of the ongoing reduction in the Arctic sea ice. The project was proposed in January 2010 by the telecoms cable specialist Kodiak-Kenai Cable. The proponent considers that the system would nearly cut in half the time it takes to send messages from the United Kingdom to Japan. DiscoveryNews reports that three different projects are planned, two of them running under Canadian waters (Arctic Fiber and Arctic Cable Company), and with the first starting in 2012. One of the projects connecting London and Tokyo will offer branches to Arctic communities in Canada that have largely depended on satellite links. It has also been reported that laying down these cables will be daunting; the ships designed to do it were not designed to operate in the Arctic, and they will likely need ships to help them get through the ice and deploy the cable (http://news.discovery.com/tech/first-time-internet-cables-cross-arctic-120321.html). Cost of the projects range between $650 million and $1 billion dollars.

## 5.9 Government Services and Research

**References:**

Beaulieu, J.-M., Bennett, J., and Bigras, S. (eds.). *Research Infrastructure in Canada's Arctic and Subarctic*. 2008. (Canadian Polar Commission 2008).

**Factors:**

Funding
Increased shipping demanding more search and rescue
Demand for charts and navigation aid
Sovereignty threats
Extended continental shelf claims
Potential cases in international courts
Demand for environmental research and climate change research

### 5.9.1 Introduction

There is little information on Arctic traffic for research or Government (non-military) purposes. CASA (2007) does not consider this navigation activity type in its analysis and projections. AMSA (2009) notes that this activity type represents a relatively small proportion of the total vessel traffic in the Arctic, with 83 vessels reported in 2004 (but many States did not report Government vessels in their submissions). Eight voyages reached the North Pole in 2004; 33 icebreaker transits to the North Pole for science and tourism were registered from 2004 to 2008. The Report does not provide specific current information or projections for Canadian Arctic.

AMSA (2009) also noted that an increasing number of States are conducting geological and geophysical research throughout the central Arctic Ocean related to establishing the limits of the extended continental shelf under the United Nations Convention on the Law of the Sea (UNCLOS). Arctic states claiming an extended continental shelf must make a submission to the United Nations' Commission on the Limits of the Continental Shelf within 10 years of their ratification to the UNCLOS Convention. Russia and Norway already made their submissions, and Russia's is currently in revision process for re-submission. Canada has not yet made its submission; its deadline to do so is November 2013. Denmark's deadline is November 2014. The United States have not ratified UNCLOS but considers that the extended continental shelf is part of customary international law of the sea. Considering the timeline for submissions to the UN Commission, it is unlikely that by 2020 there would be significant research activity related to extended continental shelves submissions.

Government non-military services in the Arctic include border patrol, shipping monitoring and search and rescue. Judson (2010) notes that Canadian Coast Guard voyages in the Arctic have remained nearly constant since 1991 (at approximately eight voyages every year) despite the increased shipping activity in the Arctic. Research, in turn, has trended upward over the last 10 years with a steep increase after 2007.

Neither the current trends nor the literature provide enough information to make projections on volume of Arctic traffic related to research or government services, nor the expected spatial distribution. An analysis of expected developments in Arctic research and search and rescue infrastructure could provide additional basis for projections. This analysis is included below.

## 5.9.2 Current and Projected Research and Government Arctic Terrestrial and Marine Infrastructure

Beaulieu et al. 2008 report the existing terrestrial research facilities in Canada North, noting that they were in need of attention ranging from upgrades to complete rebuilding.

**Figure 5-20.** Canadian Terrestrial Research Infrastructure in the Arctic. Source: Beaulieu et al. (2008), p. 12

Recent developments on Arctic research stations include:

a) The expansion of Natural Resources Canada's Polar Continental Shelf Program (PCSP) facility in Resolute Bay, Nunavut. Beginning in April 2011, the PCSP facility in Resolute nearly doubled its capacity to accommodate scientists.
b) The New Canadian High Arctic Research Station to be located in Cambridge Bay, Nunavut. The $81-million Canada High Arctic Research Station (CHARS) currently in design stage, is set to open in Cambridge Bay in 2017.
c) The closure of the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut, mainly because of discontinuation of government funding to the Canadian Foundation for Climate and Atmospheric Sciences. The station will cease year-round operations on April 30, 2012. Equipment will be removed and the building will remain available only for intermittent, short-term projects.

The most relevant marine infrastructure is icebreakers. Canadian Coast Guard lists the following icebreakers in its fleet:

Heavy Icebreakers

CCGS Louis S. St-Laurent
CCGS Terry Fox

Medium Icebreakers

CCGS Amundsen (dedicated to Science in the summer)
CCGS Des Groseilliers
CCGS Henry Larsen
CCGS Pierre Radisson

Light Icebreakers

High Endurance Multi-Tasked Vessels

CCGS Ann Harvey
CCGS Edward Cornwallis
CCGS Georges R. Pearkes
CCGS Griffon
CCGS Martha L. Black
CCGS Sir Wilfrid Laurier
CCGS Sir William Alexander

Medium Endurance Multi-Tasked Vessels

CCGS Earl Grey
CCGS Samuel Risley
CCGS Tracy

Air Cushioned Vehicles

CCGS Mamilossa
CCGS Sipu Muin

The refitted CCGS Amundsen has greatly increased northern marine (and terrestrial shoreline) capacity, but it is not equipped to penetrate the thickest ice. A large area of the northwest Arctic is only accessible to a ship of the class of the *Louis S. St-Laurent,* and this is likely to remain so for the next 20–25 years even with the predicted effects of climate change. The CCGS Louis S. St-Laurent scheduled for decommissioning in 2017, the CCGS Terry Fox scheduled for decommissioning in 2020.

Projected infrastructure includes:

a) A Deepwater port at the old mining town of Nanisivik in Nunavut on Baffin Island, to be used primarily by the Department of National Defence. The project schedule considers beginning of construction in 2013 and beginning of operation in 2016 (Ruffilli, 2011). The original proposal has been recently downgraded. Unexpected high costs of building in the North made the cuts necessary to keep the project within its $100 million budget (CTV News, March 25, 2012)

b) Six to eight Polar Class 5 Arctic Offshore Patrol Ships;
c) A Polar Icebreaker, the CCGS John G. Diefenbaker, expected to join the fleet in 2017 as a replacement for the nation's largest icebreaker and the flagship of the coast guard, the CCGS Louis S. St-Laurent.

### 5.9.3 Time Series

Information on the number of Government and research vessels active in the Arctic between 2004 and 2011, as well as the number of their voyages, is summarized in Table 5-24 below.

**Table 5-24. Government and Research Vessels: 2004-2011. Source: DND (2012)**

| Vessel/Voyage | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|
| Government services (Coast Guard, CF) Nr. of Vessels | n/a | n/a | n/a | n/a | n/a | n/a | 14 | 15 |
| Research: Nr. of Vessels | 2 | 2 | 5 | 6 | 16 | 11 | 5 | 8 |
| Government services (Coast Guard, CF) Nr. of Voyages | n/a | n/a | n/a | n/a | n/a | n/a | 14 | 20 |
| Research: Nr. of Voyages | n/a | n/a | n/a | n/a | n/a | n/a | 8 | 11 |

### 5.9.4 Research and Government Arctic Traffic: Trends and Projections

There are no projections for Arctic traffic related to research or Government services in the literature reviewed.

# 6 Summary

The review included in this Part 1 report allows for the drawing of relevant conclusions for the development of scenarios and assumptions required for the next part of this study on Arctic shipping projections. These are summarized below.

**1. Area of Interest**

It is recommended that the AOI for traffic projections includes Hudson Bay and James Bay, as shown in Figure 2-1, which is broadly equivalent to the current NORDREG zone.

**2. Spatial Representation**

It is recommended that the spatial representation of projected densities of Arctic traffic be based on the Shipping Safety Control Zones (Figure 2-4) established by the Arctic Shipping Pollution Prevention Regulations (ASPPR) and used as the basis for the Arctic Ice Regime System (AIRSS).

**3. Conceptual Model for Developing Scenarios**

The process for generating scenarios will be based on the following conceptual model.

a) First, the output for each scenario will be a quantification of maritime traffic categorized by:
   1. type of vessel: merchant/cargo vessels, fishing vessels, tankers, cruise ships, pleasure craft, non-military government vessels, as well as research/exploration vessels (to be consistent with the grouping in the Phase 1 study);
   2. level of activity: for each type of vessel, will the number of transits increase by 2020, decrease, or remain the same at today?;
   3. location: new routes, or shifting of existing routes must be considered.

b) While there are many input factors that can affect any, or all, of these output variables, the key ones revolve around demand drivers (e.g. mines, oil and gas, fishing, tourism) and climate change drivers. Hence the general relationship can be described as:

$$T\big(L(V), S(V)\big) = f(D, C)$$

where:
T = quantified arctic maritime traffic output
V = vessel type
L = level of traffic (as a function of vessel type)
S = spatial distribution of traffic (as a function of vessel type)

D = demand drivers of traffic
C = climate drivers of traffic

c) Although formal forecasting models are impractical for this study, given the enormous uncertainties surrounding many of the drivers as well as the paucity of data, these conceptual relationships underpin any attempt to develop realistic, consistent, projections.

## 4. Development of Canadian Arctic Traffic Scenarios by 2020

This Part 1 report has classified the drivers into five general groups: a) climate factors; b) geopolitical and governance factors; c) environmental protection factors; d) infrastructure factors; and e) sector-specific demand factors. Recognizing the role that each of these groups of factors or drivers plays, and will play, in the Canadian Arctic shipping traffic by 2020 and beyond, it is considered that geo-political factors, environmental protection factors, and infrastructure are too open-ended and uncertain to be incorporated in the development of scenarios for this Phase 2 study. Therefore, it is recommended that the scenarios and assumptions that will serve as the basis for the projected Canadian Arctic shipping traffic density and spatial distribution by 2020 will be climate factors (accessibility), and demand factors.

To develop scenarios about demand for the different navigational activity types included in the report, it is recommended that the second phase uses, as a starting point, one or more scenarios developed by the Special Report on Emission Scenarios (IPCC, 2000), complemented by regional-specific factors. Section 5 of the Report, summarized in the respective sections below, provides the information necessary to identify those regional-specific factors.

Using those general scenarios as a basis, it is recommended that one or more Canadian Arctic shipping traffic be developed on a sector-by-sector (or activity-by-activity) basis considering the particular demand drivers and constraints of each navigational activity type as well as the particular spatial distribution of current and projected Canadian Arctic traffic resulting from each activity type.

## 4. Sea Ice Conditions

Projections of sea ice conditions by 2020 have been made by several authoritative agencies, using different scenarios and models. Although projections differ, there are some aspects in which they show agreement. First, most of them foresee a summer free of ice within this century and most likely by mid-century. Second, most experts agree that annual variability will persist. Third, there is general agreement that the NWP will be the last Arctic area covered by ice, or at least where difficult ice conditions would prevail. Fourth, forecasts predict longer ice-free seasons but all models project persisting winter sea-ice in the Arctic.

Only a few models predict summer sea-ice free for the Arctic before 2020.

A summary of up-to-date projections of ice conditions are provided by SWIPA 2011:

a) Complete summer sea-ice loss is projected as likely to occur by mid-century.
b) Variability in summer sea-ice extent is projected to increase initially, but then to decrease as ice-free summers are approached.
c) First-year ice is projected to dominate in the future, as the amount of multi-year ice diminishes.
d) Projections of annual maximum extent and duration of seasonal sea-ice cover are uncertain and regionally variable (and affected by local bathymetry and weather conditions), but maximum extent and duration are very likely to be less than at present (i.e. with a more northerly distribution, smaller area, shorter duration).
e) The extent and location of the summer/autumn polar pack (i.e. multi-year sea-ice remnants) will be uncertain in future years as the summer ice decline continues, but most models project that pack-ice remnants are very likely to occur along the northwestern margin of the Canadian Archipelago and the north coast of Greenland at least until complete loss.

Ice conditions in the Canadian Arctic are expected to remain difficult for navigation by 2020. However, trends show a rapid decline of sea ice in Baffin Bay and also lighter ice conditions in Hudson Bay. The ice conditions for each NWP route and the Arctic Bridge in 2020, as described in the literature, are described below:

| | |
|---|---|
| Route 1 | By 2020, this route could be open for 8-10 weeks during some summers. Large inter-annual variability will continue. Large quantities of multiyear ice in M'Clure Strait and Viscount Melville sound. Considerable quantities of multiyear ice off the western coast of Banks Island. Prince of Wales Strait plugged with multiyear ice.<br>There could be an increase in the presence of old ice as the decrease in land-fast ice in the western portion of the Archipelago would allow more old ice from the Arctic Ocean to pass into channels between the islands. |
| Route 2 | By 2020, frequency of an open summer passage will increase, but it is likely that this passage will remain ice congested for more years. |
| Route 3A<br><br>(primary route) | Currently this route is passable from mid August to mid September. It is expected that active shipping for this passage will continue to increase. However, old ice will continue to be a significant navigation hazard. Particularly, Peel Sound has hazardous multiyear ice; and choke point in the vicinity of Victoria Strait. There will continue to be a large year-to-year variability.<br>Route is limited to ships having a draft of less than 10 meters. |

| | |
|---|---|
| Route 3B | Peel Sound has hazardous multiyear ice. |
| Route 4 | Bellot strait has narrow passages that make it infeasible for larger vessels.<br>Choke point in the vicinity of Victoria Strait. |
| Route 5<br><br>(southern route) | It has had light ice years but it will likely remain difficult to traverse throughout 2020. Foxe Basin and Gulf of Boothia can have significant amounts of ice through mid August. Severe ice conditions at, and in the vicinity of, the western approaches to Fury and Hecla can be expected. Bellot Strait will generally be passable during the later part of August and through mid September but strong tidal currents will continue to be a factor for both the movement of ice and ships.<br><br>Limited to ships having a draft of less than 10 meters. |
| Arctic Bridge | Typically the route through Hudson Strait opens around July 01 but can be delayed by almost a month during colder years. Churchill and the western shore of Hudson Bay are generally open by the first week of July but can be delayed up to four weeks in colder years, or if the prevailing westerly winds are absent. Over the last decade this area has had generally lighter ice conditions than in the previous two decades with navigation conditions that would warrant an extension to the closing of the shipping season by 2-3 weeks. Climate change will likely increase the probability of a two to three week extension to the closing dates but it is unlikely that there will be a significant impact on opening date for this route through 2020. Larger inter-annual and year-to-year variations will continue through the first half of the 21st century. |

## 5. Trans-Arctic Shipping

Studies have found a correlation between marine shipping and GDP (Peters et al. 2011), which makes the projection of marine shipping for a particular GDP scenario possible. However, the diversion of marine shipping to the Arctic depends on other factors, most notably: a) shipping route; b) ice conditions; c) price of oil; d) insurance premiums and other shipping fees; e) security. Limited economic analyses have been undertaken to compare advantages of Arctic routes over traditional shipping routes and to determine the conditions that need to be met to make Arctic shipping competitive. Additionally, several factors have significant uncertainties.

It is generally agreed that the NWP will not become a viable commercial route by 2020 due to seasonality, ice conditions, a complex archipelago, draft restrictions, chokepoints, lack of adequate charts, insurance limitations and other costs, which diminish the likelihood of regularly scheduled services from the Pacific to the Atlantic. Considering this concurrence by experts, the uncertainties surrounding Arctic shipping prospects, and the lack of economic studies, it is reasonable to assume no changes in trans-arctic commercial shipping through the NWP for this study.

## 6. Arctic Bridge

A potential increase in shipping through Port of Churchill is determined by: a) ice conditions in Hudson Bay; b) the recent *Marketing Freedom for Grain Farmers Act;* c) the grain market; d) imports from Russia (Murmansk); e) economic advantages over the St. Lawrence Seaway in accessing the interior of the country; f) development strategy implemented by Manitoba; and g) public policies in support of the Port.

The literature review did not show comparative studies of the economies of the Arctic Bridge vs. the St. Lawrence Seaway that allow identifying the assumptions under which the Arctic Bridge becomes competitive.

Literature reviewed does not foresee growth for the Port of Churchill or Arctic Bridge. On the contrary, it is widely considered that the implementation of the *Marketing Freedom for Grain Farmers Act* will reduce the importance of the Port.

Considering the insufficient information in the literature and the open-ended and uncertain nature of the relevant factors that will determine the potential traffic of shipping through the Port of Churchill, it is proposed that the second phase:

a) Continues research on projected trade between Port of Churchill and Murmansk;
b) Considers two or three alternative scenarios on Arctic Bridge traffic for its projections.

## 7. Community Re-Supply

Community re-supply is expected to grow. The main driver in the literature is population growth. Consumption per capita was considered relevant for CASA (2007), and a proxy was used considering the lack of historical data. As an alternative, a regional GDP projection may be used to forecast re-supply activity.

For spatial representation purposes, the current shipping routes by the companies serving the Arctic provide a reasonable basis, since it is not expected that new communities will be developed by 2020 nor that new routes would be found that are more convenient.

It is foreseen that the construction and maintenance of winter roads may become more difficult in the warming Arctic, and that they could be available for shorter periods in the winter. However, there is no data or projections to determine where those problems will arise and the potential impacts on marine shipping activity within a multimodal transportation perspective in the North. It is recommended that loss of winter road not be considered as an assumption for the Canadian Arctic traffic projections.

## 8. Resources: Oil and Gas

Oil and Gas assumptions and scenarios are centered on three areas: Beaufort Sea and Mackenzie Delta, Sverdrup Basin and other regions, and Alberta oil sands.

Beaufort Sea and Mackenzie Delta

The main driver for oil and gas activity in the Beaufort Sea and Mackenzie Delta is the construction of the Mackenzie Gas Project. Its construction is still uncertain because of the low gas prices as a result of the development of technologies to exploit shale gas. Three scenarios are possible for 2020:

a) The Mackenzie Gas Project is not constructed.
b) The Mackenzie Gas Project is under construction.
c) The Mackenzie Gas Project is in operation.

In the first scenario, there would be no projection of increased oil and gas related shipping activity in the Beaufort Sea or Mackenzie Delta.

In the second scenario, it is reasonable to foresee additional traffic related to the construction of the pipeline but no additional traffic related to exploration of gas since there are enough discovered reserves to fill the pipe to its initial design capacity, slowing the immediate need for exploration activity. Construction related shipping has not been quantified, and further research is required to determine the volume of such traffic.

In the third scenario, increased traffic will be determined by operational traffic and by new exploration. Shipping traffic will be required for: moving complete units in to handle gas production and processing in the delta region; providing the possibility of shipping oil requirements around Alaska as an alternative to railing oil to Hay River and then barging it down the Mackenzie. Further research is required to determine the volumes of traffic potentially required for the operational stage of the project. Exploration of new supplies of gas may take place before production of existing field begins to decline approximately 10 years after the beginning of operations. Exploration activity have been projected at levels a little higher than that experienced over the 2004 and 2005 time frame at two to four exploration wells per year. For each discovery well, two delineation wells are anticipated. Seismic activity is assumed to include on 260 km 2D program that will be run for every four explorations wells drilled, and one 200 $km^2$ 3D program for each well.

Sverdrup Basin and other Regions

Activity is expected to remain moribund through the period to 2020.

Alberta Oil Sands

CASA (2007) highlights the movement of project cargo to Tuktoyaktuk for furtherance of the oil sands north of Fort McMurray as a potential area of activity over 2010 to 2020 and beyond. Further research is required to determine the basis for this assumption, and the potential volumes and shipping routes to Tuktoyaktuk.

## 9. Resources: Metals and Minerals

Although there are a number of northern mines that are projected to be active by 2020, most of those mines do not rely on marine traffic in the Canadian Arctic for their operation. The mines that may: a) potentially be in operation in 2020; and b) consider marine shipping through Canadian Arctic for supplying the mine's operation or transporting the mineral or metals, are included in Table 6-1 below.

**Table 6-1. Mines potentially requiring Arctic shipping in 2020**

| Mine | Status/Expected year of operation | Marine shipping requirements |
|---|---|---|
| **Hope Bay** (gold) | On hold | Logistics materials inbound will probably be shipped. Actual quantities of dry cargo and fuel cannot be estimated at present. |
| **Mary River** (iron ore) | 2016 | Assuming 200,000dwt vessels there would be about 60 loaded transits each season.<br>Shipping route: through Hudson Bay and Foxe Basin |
| **Meliadine** (gold) | 2017 | Equipment, fuel and dry goods depend for transportation on the annual, warm-weather sealift by barge to Rankin Inlet via Hudson Bay. |
| **High Lake** (copper/zinc) | On hold | Project considers an all-weather road to Gray's Bay.<br>Could require 52,000 tonnes of dry cargo and 140,000 $m^3$ of inbound POL each season with 300-400 tonnes of concentrates outbound. Vessel transit could be in the range 6-12 during an extended season. If re-supply routes to the diamond mines at Jericho, Diavik, Ekati, and Snap Lake are reversed, it could add 100,000 tonnes of dry cargo and 250,000$m^3$ of oil to annual volumes. |
| **Izok Lake** (zinc) | On hold | Considers shipping for operation, restricted to 100 days of sea-ice free ocean. Expected to be shipped out from Gray's Bay or Bathurst Inlet. |
| **Ulu Project** (gold) | Exploration phase | Connected by all-weather road to High Lake and Gray's Bay. |
| **Kiggawick Project** (uranium) | January 2012: EIA rejected | Reagents, fuel and supplies would be barged to a storage facility near Baker Lake and then transported to Kiggavik via truck on a 90 – 100 km access road. A limited number of concentrate drums may be shipped by barge during the open water season. |
| **Roche Bay** (iron ore) | Advanced exploration | Shipping is expected out from Gray's Bay or Bathurst Inlet. |

Other projects are unlikely to be operational by 2020, considering their stage in the regulatory process and the lengthy timelines involved. Confirmation of this data through further research is recommended.

The operation of the mines listed in the table depends on the prices of metals and minerals and the approval process in the case of mines that have yet to finish that stage. Scenarios may be developed on the basis of two assumptions reflecting high and low commodity prices. Environmental approval processes are too uncertain to forecast, although the just-released Federal Budget (March 30, 2012) may limit the duration of such assessments. Additional research may determine trends on average approval times and compare them to the current status of EIA processes, when applicable.

Further research is required to determine more detailed information on expected volume of marine traffic (in number and types of vessels and number of voyages) and shipping routes in relation to the construction or operation of the different mines. The project description of each EIA (Canadian Environmental Assessment Registry, Environmental Impact Review Board (Inuvaliut), Nunavut Impact Review Board) may be further consulted to refine these assumptions.

Most diamond mines are served by airlift and/or winter roads. As mentioned above, it has been foreseen that the construction and maintenance of winter roads may become more difficult in the warming Arctic, and that they could be available for shorter periods in the winter. If this situation arises, diamond mines may face transport difficulties and may need to consider alternative means of transportation. However, there is no data or projections to determine where those problems will arise. Therefore, there is not enough information to include this factor in the 2020 scenarios.

## 10. Resources: Fisheries

Considering that there is already a high demand for fish resources both globally and in Canada, factors that may impact fishing activities in the Arctic include: a) access to the resource; b) changes in the distribution and productivity shifts in marine resources; c) regulatory framework; and d) investment in vessels and harbors.

Although access to the resource due to sea ice melting is expected to increase, the changes in distribution and productivity of marine fisheries in the fragile and under-studied Arctic ecosystem are too uncertain to make projections. Additionally, fisheries governance is extremely complex in the North, with regional and multilateral cooperative arrangements, strong involvement of indigenous communities, and a precautionary approach to the development of new fisheries. Environmental awareness in the Arctic is expected to be a driver for precautionary management.

Trends of current fishing activities in the Arctic confirm a slow development and even a decrease of fishing activities. The Beaufort Sea Marine Ecosystem does not have commercial fisheries, exploratory fisheries in the past did not develop to a commercial phase, and there is currently a moratorium on new fishing licenses. Hudson Bay and James Bay area has a decreasing number of commercial fisheries (from 209 in 2005 to 42 in 2009). The Canadian Arctic Archipelago has a mixture of commercial and exploratory fisheries, but both have dropped significantly from over 140 and 160 in 2005-2008 to 9 and 21 respectively in 2009. Important commercial fisheries are managed through quotas in collaboration with Greenland and regional fisheries organizations (NAFO). While the number of licenses for turbot has increased over the past years (from 8 to 13), the number of licenses for Northern shrimp has decreased (from 4 to 2). The construction of the Pangnirtung small craft harbor is not expected to increase the number of vessels or fishing trips significantly.

With this information, it is reasonable to assume low levels of growth for fishing activities in the Eastern Arctic by 2020. Following current spatial patterns of activity, it is expected that fishing would concentrate in Davis Strait/Baffin Bay, including Cumberland Sound, and Resolution Island. In the case of Western Arctic, assumptions can include: a) continuation of moratorium and therefore no commercial fishing activity; b) end of the moratorium and low levels of growth for fishing activities.

## 11. Resources: Tourism

Tourism growth in the Arctic will depend on: a) ice conditions; b) world economy; and c) promotion of the activity by Canadian and local governments.

Although projections generally agree that cruise ship activity will continue to grow, the rate of change varies widely among different studies. Most studies seem to predict a modest growth but with great annual variability.

If existing spatial distribution patterns continue, it is expected that most of the tourism activity will concentrate in the NWP and particularly route 3 (Baffin Bay, Lancaster Sound, Barrow Strait, Peel Sound, Franklin Strait, Victoria Strait, Coronation Gulf, Amundsen Gulf, Beaufort Sea), with tourism also growing in the High Arctic (particularly eastern Canadian Arctic) rather than in the lower Arctic (Baffin Bay, Hudson Bay and Newfoundland).

Private pleasure craft have not been included in the studies reviewed. The number of pleasure craft has experienced the largest increase in recent years in the Arctic. Development of drivers and projections for pleasure craft activity require further research.

### 12. Resources: Other Industrial Developments

Although several activities are considered to be potentially viable in the Arctic, there are no studies focusing on its current or projected levels. Considering the extended timeframes between project development and execution in particular in the Arctic, it is reasonable to estimate that no other industrial development will have significant developments to 2020. It is proposed that this assumption be verified by an analysis of projects submitted for environmental impact assessment in the Arctic region.

### 13. Canadian Government Services and Research

There is little information on drivers of Canadian government services and research. It is assumed that plausible factors affecting government services and research would be: a) funding; b) infrastructure projects currently in place; c) level of shipping activity and traffic in the Arctic.

A reasonable basis for projected scenario would be to assume funding based on a global and regional economic scenario, and an activity growth associated to current and projected infrastructure. High levels of Arctic traffic activity would probably imply increased government activity (icebreakers, patrols, search and rescue) although the relationship is not very clearly established by past trends (Judson 2010).

Government Arctic traffic may also be determined by sudden developments in Arctic geo-political factors. However, this scenario would be outside the scope proposed for this study.

### 14. Translating General and Activity-specific Scenarios into Traffic Patterns

The different sections of this report provide information on number of vessels and number of voyages when available. However, information could not be found in all cases. A task that needs to be addressed during the next part of the second phase is translating the scenarios and assumptions into traffic volume projections by vessel type, based on the information already provided and/or complementary research.

### 15. Temporal Dimension of Projections

A further task is to determine a methodology for temporal representation of Arctic traffic, since shipping is not distributed evenly throughout the year. Shipping season length projections have been included whenever available but for many Arctic routes the reviewed information is insufficient to make assumptions.

# 7 Next Steps

It is proposed that the next steps adopted for the Second Phase should include:

a) Continue research on information gaps identified in the previous section;
b) Develop scenarios and assumptions on the basis of the information and recommendations provided in the previous section and the input of the Technical Authority;
c) Develop traffic projections (volume and spatial distribution) for the scenarios and assumptions developed;
d) Translate traffic projections into expected number of vessels and voyages by vessel type and route;
e) Submit the scenarios, assumptions and projections to expert opinion for validation; and
f) Represent the 2020 traffic projections in GIS.

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# 9 List of Acronyms

| | |
|---|---|
| AANDC | Aboriginal Affairs and Northern Development Canada |
| ACIA | Arctic Climate Impact Assessment |
| AEO | Annual Energy Outlook |
| AIRSS | Arctic Ice Regime Shipping System |
| AMAP | Arctic Monitoring and Assessment Programme |
| AMSA | Arctic Marine Shipping Assessment |
| AMT | Analysis of Marine Traffic |
| AOI | Area of Interest |
| AOR | Area of Responsibility |
| ASPPR | Arctic Shipping Pollution Prevention Regulations |
| BAU | Business as usual |
| boe | Barrel of oil equivalent |
| CAC | Canadian Arctic Category |
| CAFF | Conservation of Arctic Flora and Fauna |
| CASA | Canadian Arctic Shipping Assessment |
| CCGS | Canadian Coast Guard Ship |
| CF | Canadian Forces |
| CHARS | Canada High Arctic Research Station |
| CWB | Canadian Wheat Board |
| CORA | Centre for Operational Research and Analysis |
| DFO | Department of Fisheries and Oceans |
| DND | Department of National Defence |
| DRDC | Defence Research and Development Canada |
| dwt | deadweight tonne |
| DTI | Desgagnés Transarctik Inc. |
| EIA | U.S. Energy Information Administration |
| FAO | United Nations Food and Agriculture Organization |
| GCM | Global Climate Model |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GIS | Geographic Information System |
| GNP | Gross National Product |
| IEA | International Energy Agency |
| IMO | International Maritime Organization |
| IPCC | Intergovernmental Panel on Climate Change |

| | |
|---|---|
| MARIN | Maritime Activity and Risk Investigation Network |
| mmcfd | millions of cubic feet per day |
| MPA | Marine Protected Area |
| Mtoe | Million Tons of Oil Equivalent |
| NAFO | Northwest Atlantic Fisheries Organization |
| NEAS | Nunavut Eastern Arctic Shipping Inc. |
| nmi | nautical mile(s) |
| NORDREG | Northern Canada Vessel Traffic Services Zone |
| NRTEE | National Round Table on the Environment and the Economy |
| NSSI | Nunavut Sealink and Supply Inc. |
| NTCL | Northern Transportation Company Limited |
| NWP | Northwest Passage |
| OECD | Organisation for Economic Co-Operation and Development |
| PAME | Protection of the Arctic Marine Environment |
| PCSP | Polar Continental Shelf Program |
| PEARL | Polar Environment Atmospheric Research Laboratory |
| PNO | Passage du Nord-Ouest |
| ppm | Parts per million |
| PSSA | Particularly Sensitive Sea Area |
| SAR | Search and Rescue |
| SOLAS | International Convention for the Safety of Life at Sea |
| SRES | Special Report on Emission Scenarios |
| SWIPA | Snow, Water, Ice and Permafrost in the Arctic Report |
| TA | Technical Authority |
| tcf | trillion cubic feet |
| tpy | tons per year |
| TTI | Taqramut Transport Inc. |
| UNCLOS | United Nations Convention on the Law of the Sea |
| ZInt | Zone d’intérêt |

# 10 Appendix 1

Excerpt from Global Business Network (GBN) (comp.). 2007. *The Future of Arctic Marine Navigation in Mid-Century: Scenario Creation Workshop Notes*. Arctic Marine Shipping Assessment (AMSA) of the Arctic Council Protection of the Arctic Marine Environment (PAME) (April 2007), pages 4(sic)-6.

### *Day 1 — Brainstorming Uncertainties*

*Workshop participants brainstormed a list of nearly 120 Factors and Forces that could impact the Future of Arctic Marine Navigation in Mid-Century. They then voted individually, first for those items they deemed most Important, and then in another vote for those deemed most Uncertain. The table below lists all of the Factors and Forces, ordered by the sum of Importance and Uncertainty votes.*

| **Factors and Forces** | **Importance** | **Uncertainty** | **Sum** |
|---|---|---|---|
| Stable legal climate | 12 | 12 | **24** |
| Radical change in global trade dynamics | 9 | 14 | **23** |
| Climate change is more disruptive sooner | 7 | 15 | **22** |
| Safety of other routes | 7 | 12 | **19** |
| Socio-economic impact of global weather changes | 5 | 14 | **19** |
| Oil Prices | 7 | 11 | **18** |
| Major Arctic shipping disasters | 8 | 9 | **17** |
| Limited windows of operation (economics) | 7 | 7 | **14** |
| New Ice Age because gulf stream stops | 3 | 11 | **14** |
| Maritime Insurance Industry | 4 | 8 | **12** |
| China and Japan become Arctic maritime nations | 5 | 6 | **11** |
| Transit fees | 4 | 7 | **11** |
| Conflict between indigenous & commercial use | 7 | 3 | **10** |
| Arctic enforcers (police force) | 5 | 5 | **10** |
| Escalation of Arctic maritime disputes | 4 | 6 | **10** |
| Shift to nuclear energy | 4 | 6 | **10** |
| New resource discovery | 2 | 8 | **10** |
| World trade patterns | 5 | 4 | **9** |
| Catastrophic loss of Suez or Panama (combined with "Safety of other routes") | 2 | 6 | **8** |
| Global agreements on construction rules and standards | 3 | 3 | **6** |
| Development of shipping infrastructure | 5 | 0 | **5** |
| Nationalist energy security policies | 4 | 1 | **5** |
| Unilateral shipping policy | 4 | 1 | **5** |
| 3rd gen. Avian flu epidemic | 2 | 3 | **5** |
| Major changes and shifts in ecosystems | 1 | 4 | **5** |
| Unresolved rights of passage | 4 | 0 | **4** |
| Arctic port development? | 3 | 1 | **4** |
| Highly restrictive shipping policies | 3 | 0 | **3** |

| | | | |
|---|---|---|---|
| Competition from other routes | 3 | 0 | **3** |
| Strategic navigation aids | 3 | 0 | **3** |
| Seasonal fee structures for the Suez and Panama | 3 | 0 | **3** |
| Global dimming in the Arctic area | 2 | 1 | **3** |
| Methane becomes an energy source | 2 | 1 | **3** |
| Resolution of continental claims | 2 | 1 | **3** |
| Land-based mineral mining | 2 | 1 | **3** |
| Security aspects of the Arctic | 1 | 2 | **3** |
| Search for oil and gas | 2 | 0 | **2** |
| Decrease in other accessible oil and gas reserves | 2 | 0 | **2** |
| Potential transit fees | 2 | 0 | **2** |
| Additional release of methane accelerated | 1 | 1 | **2** |
| Disappearance of aboriginal culture | 1 | 1 | **2** |
| Explosive growth of aboriginal culture | 1 | 1 | **2** |
| Disintegration/integration of free trade | 1 | 1 | **2** |
| Collapse or entrenchment of the Arctic Council | 1 | 1 | **2** |
| Safety and rescue activities | 1 | 0 | **1** |
| Just-in-time production | 1 | 0 | **1** |
| High-Arctic becomes a world heritage park | 1 | 0 | **1** |
| Risk and fear of environmental spill | 1 | 0 | **1** |
| Inadequate navigation aids | 1 | 0 | **1** |
| Port development and expansion | 1 | 0 | **1** |
| Social and economic issues in the north | 1 | 0 | **1** |
| Capacity of existing communities to deal with change | 1 | 0 | **1** |
| Shipping super-cycles | 1 | 0 | **1** |
| Application of UNCLOS to Arctic Ocean in the next 10 years | 1 | 0 | **1** |
| Pipeline augment transport framework | 1 | 0 | **1** |
| Mid-east explosion | 1 | 0 | **1** |
| Failure of the US Dollar | 1 | 0 | **1** |
| Russia takes back part Bering Strait from Alaska | 0 | 1 | **1** |
| Ship size is not constrained | 0 | 0 | **0** |
| Rapid technological change in drilling | 0 | 0 | **0** |
| Possibility of war amongst Arctic countries | 0 | 0 | **0** |
| Power of aboriginal peoples in the region | 0 | 0 | **0** |
| Negative effect of pollution control | 0 | 0 | **0** |
| Endangered species | 0 | 0 | **0** |
| Safety of alternative routes | 0 | 0 | **0** |
| What comes after the container? | 0 | 0 | **0** |
| All future ships are ice-breaking ships | 0 | 0 | **0** |
| One large cruise ship to the Arctic | 0 | 0 | **0** |
| Resumption of Arctic arms race | 0 | 0 | **0** |
| Nuclear powered ships | 0 | 0 | **0** |
| Changing fishery patterns | 0 | 0 | **0** |
| Effect loss of permafrost on oil and gas development | 0 | 0 | **0** |
| Extreme tourism | 0 | 0 | **0** |
| Missile defense | 0 | 0 | **0** |
| Geography of trans-shipment hubs | 0 | 0 | **0** |
| Gov policy accelerates/decelerates regional development | 0 | 0 | **0** |
| Timing of land-navigation versus sea-navigation | 0 | 0 | **0** |
| Proliferation of aqua culture | 0 | 0 | **0** |

| | | | |
|---|---|---|---|
| Invasive species | 0 | 0 | **0** |
| Federate Republic of the Inuit | 0 | 0 | **0** |
| Depopulation of the Russian north | 0 | 0 | **0** |
| Global development of alternative energy | 0 | 0 | **0** |
| Massive land-based development in support of oil & gas | 0 | 0 | **0** |
| Availability of personnel to develop (labor supply) | 0 | 0 | **0** |
| Rise of virtual tourism (boomers stay home!) | 0 | 0 | **0** |
| Unilateral control of the Arctic Ocean by the Arctic states | 0 | 0 | **0** |
| Increasing communications of local communities | 0 | 0 | **0** |
| Creation of new communities and support infrastructure | 0 | 0 | **0** |
| Multi-lateral agreement w/18 nations (e.g. Antarctic treaty) | 0 | 0 | **0** |
| Capricious political agreements | 0 | 0 | **0** |
| Political confusion due to climate variability | 0 | 0 | **0** |
| Piracy | 0 | 0 | **0** |
| Modifying melting point of ice | 0 | 0 | **0** |
| Political instability vs. open ocean | 0 | 0 | **0** |
| Availability of low temperature steel | 0 | 0 | **0** |
| Temporary or migrant communities | 0 | 0 | **0** |
| New submarine technology | 0 | 0 | **0** |
| Robotic shipping | 0 | 0 | **0** |
| Better predictive models | 0 | 0 | **0** |
| Arctic as thoroughfare for blimp transport | 0 | 0 | **0** |
| Resettlement of coastal communities due to climate change | 0 | 0 | **0** |
| Improved technology for discovering sea ice | 0 | 0 | **0** |
| Need for search and rescue capability | 0 | 0 | **0** |
| Sub-sea completion of O&G extraction independent of ice | 0 | 0 | **0** |
| Rogue shipping companies test the ocean | 0 | 0 | **0** |
| Navigation neutrality | 0 | 0 | **0** |
| Tactical navigation aids | 0 | 0 | **0** |
| Break-up of the Russian Federation | 0 | 0 | **0** |
| Oil spill clean up in broken ice | 0 | 0 | **0** |
| Trans-Eurasian rail and pipeline | 0 | 0 | **0** |
| Canadian break-up | 0 | 0 | **0** |
| Investments in other shipping routes | 0 | 0 | **0** |
| American isolationism | 0 | 0 | **0** |
| Chinese hegemonic world | 0 | 0 | **0** |
| International small pox epidemic | 0 | 0 | **0** |
| Global nationalization of natural resources | 0 | 0 | **0** |
| Africa of new center of production | 0 | 0 | **0** |
| Undue influence of EU in Arctic affairs | 0 | 0 | **0** |
| Involving indigenous in economic benefits | 0 | 0 | **0** |
| Resource “Haves” and ”Have-Nots” | 0 | 0 | **0** |

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This document describes the results of Phase 2 – Part 1 of the Analysis of Marine Traffic (AMT) Project, conducted under contract W7714-093795. The purpose of this Part is to scope out the various factors that can influence maritime traffic patterns in the Canadian Arctic to the year 2020. The patterns of interest are categorized by ship type, activity type, and location (spatial patterns of the routes). The results will serve as the foundation for the variables included in Phase 2 – Part 2 of the project, during which traffic projections will be modeled. The method was to conduct a thorough survey of the literature, determine what key factors affect current and projected traffic patterns, and identify what sources of information can be used to establish a base case, low case, and high case for each factor. Furthermore, information on current and forecasted ice conditions is summarized, such as the extent, seasonality, and type of ice that will affect accessibility of the various northern routes. All these factors are organized into a framework that will provide structure for developing the traffic forecasting model. The report recommends factors that are the most important to include, and discusses limitations of the information presented.

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Arctic
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Climate change
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