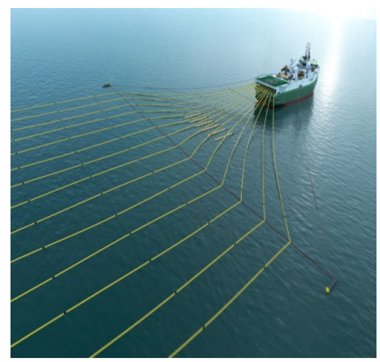
Polarcus UK Ltd

Environmental Assessment Eastern Newfoundland 2D/3D/4D Seismic Survey Program 2016 – 2022



Date: Feb. 28, 2017

Table of Contents

List of Figures

List of Tables

1 Introduction

Polarcus UK Ltd., is proposing to conduct two dimensional (2D), three dimensional (3D) and / or four dimensional (4D) seismic surveys in the Newfoundland Labrador Offshore Area (the Project). The Project area identified in Figure 1.1 is in Eastern Newfoundland. The project was scoped on the basis of Polarcus conducting seismic surveys over one or more years between 2016 and 2022. This document provides an Environmental Assessment of the Project during the 2016-2022 periods. However, the earliest that field work would take place, is May 2017.

The proposed Project will require authorizations from the Canada – Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), pursuant to:

- Section 138 (1)(b) of the Canada – Newfoundland and Labrador Atlantic Accord Implementation Act; and
- Section 134 (1)(b) of the Canada – Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act (Accord Acts).

The assessment has been planned, prepared and is being submitted in compliance with the associated requirements and processes of the C-NLOPB.

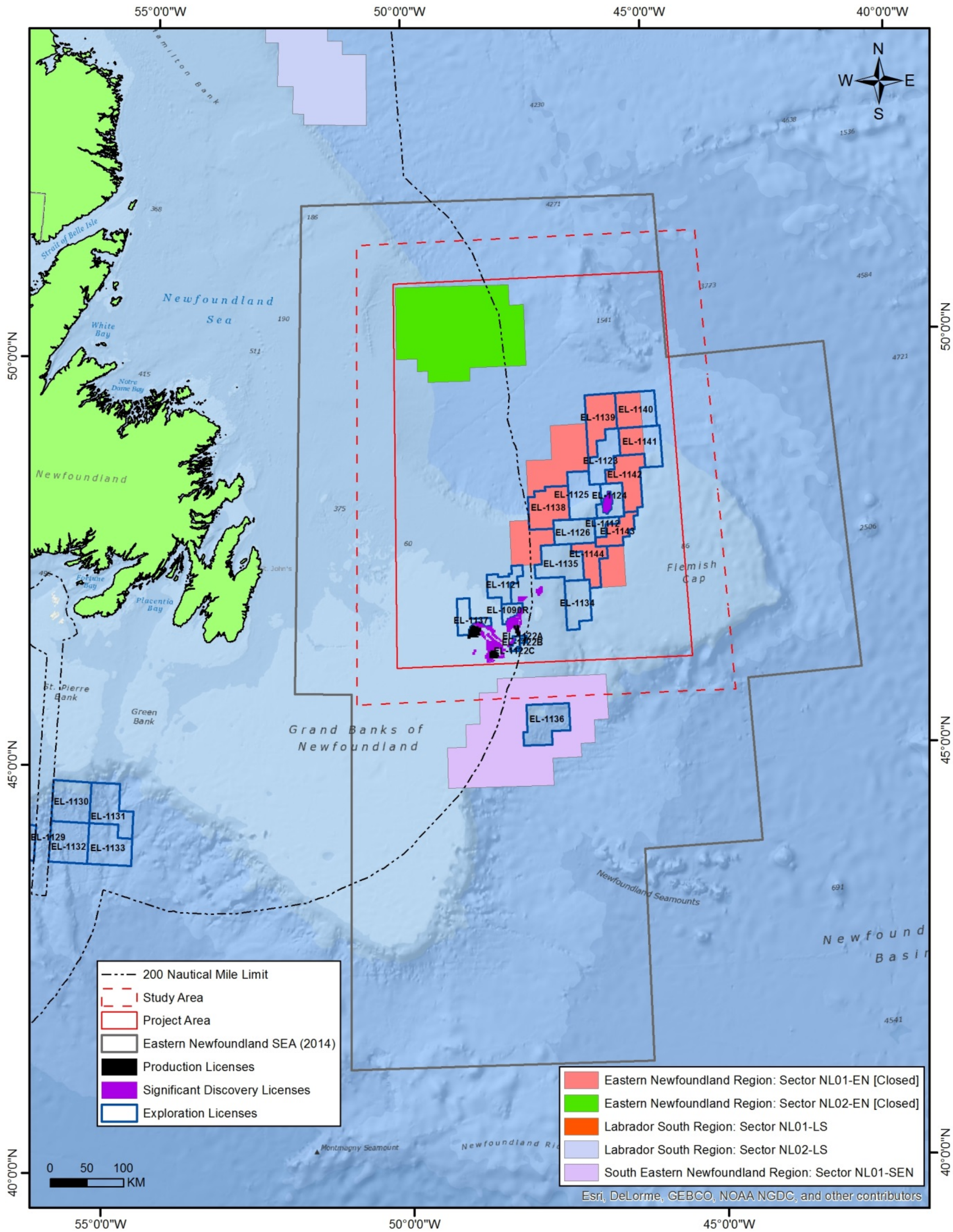


Figure 1.1. Eastern Newfoundland Project Area and Study Areas (2016-2022)

1.1 The Operator

Polarcus UK Ltd., (referred to hereafter as 'Polarcus') is an offshore geophysical company operating a fleet of seismic research vessels worldwide. The company has a strong environmental focus that aims to decrease emissions to both sea and air. In support of its commitment to the environment, all Polarcus vessels are certified to the highest rating of the DNV GL Triple-E standard reflective of leading maritime energy efficiency and environmental performance.

Polarcus provides worldwide seismic data acquisition services and Multi-Client library data as well as seismic data imaging to help energy companies find oil and gas reserves offshore.

The company was founded in 2008 in Dubai, UAE. Polarcus is registered in Canada.

Table 1.1. Project Proponent and Consultant Details

	Contact Name	**Contact Details**
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1.2 Regulatory Context and Relevant Legislation

An *Authorization to conduct a Geophysical Program* will be required from the C-NLOPB. The C-NLOPB is mandated by the Accord Acts. Pursuant to the Accord Acts, the C-NLOPB is responsible for seeking to identify the federal departments or agencies that may have expertise required in the completion of the assessment. Because seismic survey activities have the potential to affect fish and fish habitat, fisheries, marine-associated birds, marine mammals and sea turtles, Fisheries and Oceans Canada (DFO) and Environmental Canada (EC) are the agencies that have most involvement in the EA process. Legislation that is relevant to the environmental aspects of the Project includes:

- Canada-Newfoundland and Labrador Atlantic Accord Implementation Act, S.C. 1987, c.3;
- Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act, R.S.N.L. 1990, c. C-2;
- Oceans Act, S.C. 1996, c.31;
- Fisheries Act R.S.C.,1985, c. F-14;
- Navigation Protection Act, 2014;
- Canada Shipping Act, 2001;
- Migratory Birds Convention Act, 1994;
- Species at Risk Act (SARA) S.C. 2002, c.29; and
- Canadian Environmental Protection Act, 1999.

Polarcus will follow guidelines issued by the C-NLOPB, the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (C-NLOPB 2016), which include DFO's Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment. The Project will also consider other relevant advice received during the consultations for this Project.

- Oceans Canada (DFO);
- Environment Canada (EC);
- Natural Resources Canada;
- Transport Canada (TC);
- Parks Canada;
- Department of National Defense (DND);
- NL Department of Environmental and Conservation;
- NL Department of Fisheries and Aquaculture; and
- Canadian Association of Petroleum Producers (CAPP)

Polarcus will comply with all relevant provincial and federal legislation, regulations, acts and guidelines in the planning and conduct of its seismic exploration activities. The company has in place a Safety Management System that complies with the International Management Code (ISM). All Polarcus vessels hold a Safety Management Certificate (SMS) and the company holds a Document of Compliance (DOC) issued by DNV. The DOC ensures that the safety management system of the company has been audited and that it complies with the requirements of the International Management Code for the Safe Operation of Ships and for Pollution Prevention for Polarcus ships.

1.3 Canada-Newfoundland and Labrador Benefits

In full appreciation of the requirements of the Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland Labrador Act and the Canada-Newfoundland Atlantic Accord Implementation Act.

Polarcus will manage the seismic operations from St. John's, Newfoundland and Labrador. Polarcus agrees that first consideration will be given to personnel, support and other services that can be provided from within Newfoundland and Labrador, and to goods manufactured in Newfoundland and Labrador as long as the goods and services can be delivered at a high standard of Health, Safety and Environmental competency, are of high quality, and are competitive in terms of fair market price. All contractors and subcontractors working for Polarcus in Newfoundland and Labrador must also apply these principles in their operations.

1.4 Purpose and Structure of the Environmental Assessment Report

An Environmental Assessment (EA) is an important management tool for ensuring that the environmental hazards and impacts of any proposed operations are identified and evaluated during the planning phase and that appropriate mitigation measures are incorporated into the project design and implemented during the operations in the field.

The assessment is a risk management process, which comprises four main stages:

- characterization of the existing environment and identification of the environmental hazards associated with the activity;
- assessment of the magnitude and significance of the risks (the likelihood of the hazard and the severity of the impact);
- description of proposed control techniques to eliminate or lower the likelihood of the hazard or mitigate the severity of the impact; and
- development of plans and procedures to manage consequences of exceptional events.

For this offshore seismic acquisition project, environmental control measures are an essential part of the program design. The EA will assess the current environmental baseline, identify potential environmental effects resulting from project operations and develop mitigation measures and monitoring plans in line with industry best practice, as well as any additional commitments required by Polarcus internal standards.

The EA submission will be reviewed by the C-NLOPB and other applicable government departments and agencies and non-governmental organizations, as part of the process for gaining the necessary authorizations and approvals to allow the project to proceed.

The assessment has been planned and undertaken in accordance with the requirements of the C-NLOPB's review process, Polarcus internal standards, the final Scoping document (received February 3rd 2016) prepared by C-NLOPB and information received through liaison and consultation with government departments, agencies, private companies, non-governmental organizations and other key stakeholders. Table 1.2 illustrates where in the EA Report, the Scoping report factors have been considered.

Table 1.2. Requirements of C-NLOPB Scoping Document

Scoping Document 4. Factors to be Considered	**Section/Sections in EA Report that address requirement**
4.1 The purpose of the Project	2.3.1
4.2 The environmental effects of the Project, including those due to malfunctions or accidents that may occur in connection with the Project and any change to the Project that may be caused by the environment. Environmental effect is defined as: any change that the project may cause in the environment, including any such change on health and socio-economic conditions, on physical and cultural heritage, on the current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that	5.7 and 5.8

is of historical, archaeological, paleontological or architectural significance; and any change to the project that may be caused by the environment, whether any such change occurs within or outside Canada;	
4.3 Cumulative environmental effects of the Project that are likely to result from the project in combination with other projects or activities that have been or will be carried out;	6
4.4 The significance of the environmental effects described in 4.2 and 4.3;	5.7 and 5.8
4.5 Measures, including contingency and compensation measures as appropriate, that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the Project;	5.6
4.6 The significance of adverse environmental effects following the employment of mitigative measures, including the feasibility of additional or augmented mitigative measures; and	5.7 and 5.8
4.7 Report on consultations undertaken by Polarcus with interested other ocean users who may be affected by program activities and/or the general public respecting any of the matters described above. The One Ocean documents Fact Sheet for Non-One Ocean Petroleum Members and One Ocean Protocol for Consultation Meetings: Recommendations for the Fish and Petroleum Industries in Newfoundland and Labrador can assist in planning these consultations.	5.2 and Appendix C

1.4.1 Structure of the EA Report

This document has been prepared to provide the results of the EA in a clear, concise and well-organized manner. The EA Report is presented in the following sections each with their own table of contents:

Chapter 1 **Introduction:** Provides a background to the project, the company and consultants. Also included is a brief summary of the relevant legal and regulatory framework.

Chapter 2 **Project Description:** Describes the offshore operations associated with 2D, 3D (and 4D) seismic acquisition in the NLOA. This section also discusses the project alternatives.

Chapter 3 **Physical Environment**: Describes the background physical environmental characteristics in the study area.

Chapter 4 **Biological Environment**: Describes the background biological environmental characteristics in the study area

Chapter 5 **Assessment:** Defines the potential impacts from the project and the control measures to be implemented.

Chapter 6 **Cumulative Effects:** Summarizes the environmental effects of the Project that are likely to result from the project in combination with other projects or activities in the area.

Chapter 7	**Assessment Summary and Conclusions:** Provides a summary of the environmental effects of the project and conclusions of the assessment process.
Chapter 8	**References:** Lists the bibliographic material and data sources used in compiling the environmental assessment.

Table of Contents

List of Figures

List of Tables

2 Project Description

2.1 Introduction

The official name of the project is Polarcus Eastern Newfoundland Seismic Program 2016-2022. Polarcus has assessed conducting one or more 2D, 3D and/or 4D seismic surveys within its proposed Study Area (Figure 1.1), between 2016 and 2022. The first of these surveys would not actually take place until 1 May 2017. There is the possibility that Polarcus could conduct more than one survey in any given year. The timing of the surveys will be decided by circumstances and priorities assigned by Polarcus, weather conditions, contractor availability and regulatory approvals.

2.2 Spatial and Temporal Boundaries

The possible combinations of concurrent seismic survey types that may be conducted by Polarcus in any given year during 2017-2022 are any combination of 2D, 3D and 4D. For example: 2D plus 2D and 2D plus 3D and 3D-3D Spatial and Temporal Boundaries

The Study Area includes the Project Area plus a nominal 50 kilometre buffer around the Project Area to account for the propagation of seismic survey sound that could potentially affect marine biota (see Figure 1.1). The proposed Study Area is 308,384 square kilometres and the Project Area is 202,785 square kilometres. Just over half of the Project Area (57 percent) is located outside of Canada's Exclusive Economic Zone (EEZ; 200 nautical mile limit). Water depth within the Project Area ranges from 75 metres to > 4,000 metres. All project activities will take place within the Project Area.

The corner coordinates (decimal degrees, WGS84) of the extents of the Project Area are as follows:

Project Area 'Corner'	WGS84 (Decimal Degrees)	
	Latitude (°N)	Longitude (°W)
Northwest	51.04506	50.19496
Northeast	51.0478	44.95272
Southwest	46.32127	50.1959
Southeast	46.32257	44.95159

The "corner" coordinates (decimal degrees, WGS84) of the extents of the Study Area are as follows:

Study Area 'Corner'	WGS84 (Decimal Degrees)	
	Latitude (°N)	Longitude (°W)
Northwest	51.52525	50.9079
Northeast	51.52525	44.23973
Southwest	45.87144	50.9079
Southeast	45.87144	44.23973

The temporal boundary of the Project was originally set from 2016 to 2022 inclusive with seismic operations potentially occurring between May and November in any given year. The actual field work would not commence until 2017. The typical duration of a seismic survey in any given year is 90 to 120 days. The rationale for selection of the temporal boundary is to reflect the intended period of seismic operations between May and November. The rationale for selection of the spatial boundaries is to select the Project Area plus a nominal 50 kilometre buffer around the Project Area to account for the propagation of seismic survey sound that could potentially affect marine biota.

2.3 Project Overview

The proposed Project is a marine geophysical program that will include no more than 10,000 square kilometres of 3D seismic survey lines in 2017. Specific data acquisition plans for 2D, 3D and/or 4D surveys in subsequent years are not yet determined. The proponent may also collect gravity and magnetic data in any given year. The maximum annual amounts of 2D, 3D and 4D seismic surveying that would be conducted by Polarcus between 2017 and 2022 are 10,000km, 10,0000km2, and 10,000km2, respectively.

For the proposed 3D survey in 2017, the seismic survey vessel will be the Polarcus Amani or a similar vessel. The seismic survey vessel(s) used during subsequent 2D/3D/4D surveys are currently unknown; however they will be approved for operations in Canadian waters, and will be typical of the Polarcus fleet. Polarcus operates a fleet of seven purpose built seismic vessels.

The C-NLOPB's Geophysical, Geological, Environmental and Geotechnical Program Guidelines (*C-NLOPB,* 2016 will be used as the basis for the marine mammal seabird monitoring and mitigation program for seismic surveys. The C-NLOPB guidelines contain recommended planning, mitigation and reporting measures for marine seismic surveys in the Newfoundland offshore area (*see Appendix 2 of C-NLOPB, 2016*). Dedicated Marine Mammal and Seabird Observers (MMSOs) will monitor for marine mammals and sea turtles, and implement mitigation measures as appropriate.

The airgun array will be ramped up, and ramp ups will be delayed if a marine mammal or sea turtle is detected within the appropriate safety zone (minimum of 500 metres as noted in Fisheries and Oceans Canada Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (*Fisheries and Oceans Canada, 2007*). The airgun array will shut down any time an Endangered or Threatened (as listed on Schedule 1 of SARA) marine mammal or sea turtle is detected within the safety zone. These measures are designed to minimize disturbances to marine life, particularly marine mammals and species considered at risk under the SARA. In addition, the MMSOs will conduct seabird surveys during the project period; the Survey method will follow the Eastern Canada Seabirds at Sea (ECSAS) Standardized Protocol for Pelagic Seabird Surveys from Moving and Stationary Platforms (Gjerdrum C., 2012). One of the MMSOs will check the decks for stranded birds and dead birds each day, with close attention to dark and protected areas under machinery. Deckhands will be instructed to alert the MMSO on duty if stranded birds were found. If stranded birds were recovered and released it would follow the handling methods devised by Williams and Chardine (Chardine, 1999). Any dead birds will to be disposed of at sea. A Fisheries Liaison Officer (FLO) will be onboard the seismic vessel and / or the supply vessel to ensure implementation of communication procedures intended to minimize conflict with the commercial fishery.

To help with monitoring the fishing activities and avoiding potential conflicts with Polarcus seismic operations, Polarcus will work with DFO to obtain access to VMS (i.e., Vessel Monitoring System) data by DFO showing fishing vessels' distribution in and near the project.

2.3.1 Rationale and Objectives

The objective of the Project is to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. Existing data in the area does not provide sufficient quality or coverage to serve the energy companies in their exploration, development and production activities. Acquisition of more 2D, 3D and /or 4D seismic data is required to provide images of higher resolution and quality that will reduce the possibility of unnecessary drilling activity.

2.3.2 Project Scheduling

Seismic surveys will be conducted between 1 May and 30 November of any year, from 2017 until 2022. If the scope of work includes activity occurring simultaneously in close proximity to other marine installations or structures or other vessels, information will be submitted to demonstrate that activities ongoing in the field will be properly coordinated and that affected parties have agreed documented protocols to manage the coordination of activities.

2.3.3 Site Plan

The specific plan for acquisition has not been finalized, however no more than 10,000 square kilometres of 3D seismic data will be acquired in any given year. The average survey line length is estimated to be approximately 100 kilometres. The Operator also intends to collect gravity and magnetic data.

Supply and Support Vessel

There will be two additional vessels for the 2D/3D/4D projects. A supply vessel will be utilized to supply the seismic vessel where necessary. The support vessel will be used to scout ahead of the seismic vessel for fishing vessels and gear, as well as for hazards such as ice and floating debris. The supply vessel will be utilized to supply the seismic vessel when necessary.

Crew Change

Crew changes will be conducted dock to dock, vessel to vessel (an approved passenger craft) or via helicopter depending on logistics determined at the time of the project and approved by the C-NLOPB.

Shorebase

Polarcus will have a shore representative based in St. John’s for the duration of the project. No new shore base facilities will be established as part of the project.

2.3.4 Personnel

Personnel onboard the seismic vessel will include technical crew and maritime crew. The typical Polarcus fleet of vessels accommodates approximately 60 personnel. All crew will have the required certifications for offshore Newfoundland and Labrador for working under the C-NLOPB’s jurisdiction. There will be MMSOs and at least one FLO onboard for the duration of the project.

2.3.5 Gravity and Magnetic Survey

Gravity and magnetic surveying involves measuring the Earth's gravitational and magnetic fields using highly sensitive instruments. These Potential Field measurements can be made on the Earth surface, both on land and the sea bottom, from ships or from aircraft. The data from the surveys are processed in a number of ways but usually produce some form of anomaly value, i.e. a variation from what would normally be expected at that point. These gravity and magnetic anomalies can be attributed to variations in the Earth's crust and are a major asset in mineral and hydrocarbon exploration, as well as furthering our understanding of the deeper Earth structure and processes.

Polarcus will collect gravity and magnetic data as part of the seismic acquisition program using gravity and magnetic sensors located on the vessel. The survey vessel may also passively collect and record gravity and magnetic data at the same time as the seismic survey and will have an echosounder for depth soundings. Given that gravity and magnetic data will be obtained passively as part of the proposed survey program through the installation of the recording equipment on the seismic vessel, and because the planned use of this apparatus does not have environmental emissions or interactions associated with it, these data collection devices have been assessed as part of the potential project interactions but are not listed as separate project activities in the environmental interactions table (see Section 5.5.1).

2.3.6 Seismic Survey Background

Seismic surveys are conducted to identify sub-surface geological structures that might contain trapped hydrocarbon deposits. All seismic surveys require the following equipment:

- Acoustic source;
- Acoustic detection equipment.

Offshore seismic surveys are conducted using high pressure air supplied to the seismic source from compressors onboard the seismic survey vessel. The source is charged with the high pressure air before being electrically triggered. When the source is triggered, the high pressure air is discharged into the surrounding water through ports in the side of the source (Figure 2.1). The released air from these ports forms a bubble which initially expands and subsequently collapses through an oscillation period. The initial expansion and collapse provides the main acoustic impulse (P-wave) into the water column. The P-waves are then reflected back from the subsurface geological layers at varying time intervals dependent on the physical properties of the strata.

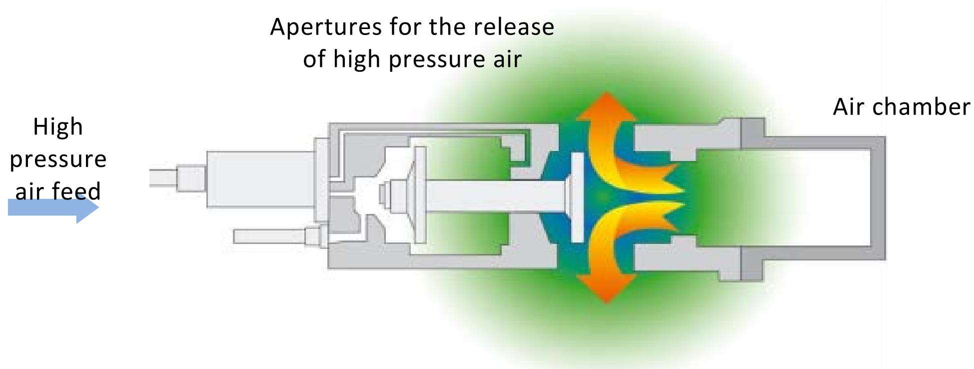

Figure 2.1. Example Acoustic Energy Source (OGP, 2004)

The acoustic signal is detected by seismic streamers. These are towed behind the vessel to detect the reflected energy that travels from the seismic source, through the water column, down through the geological formations and back to the surface. The streamers convert the pressure signals into electrical signals which are transmitted along the streamer to the survey vessel.

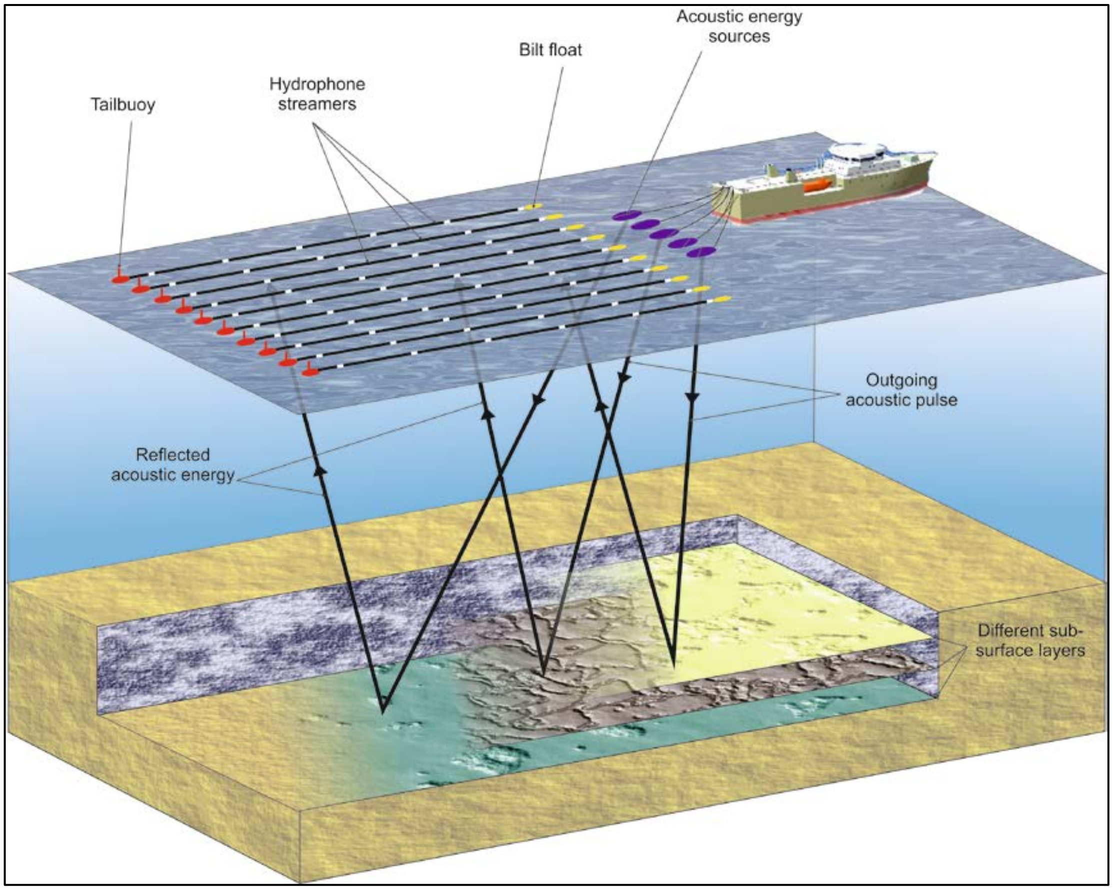

Figure 2.2. Example of a Typical 3D Seismic Survey Setup

A marine seismic survey is usually designed based on a grid pattern of lines, along each of which are 'shot points', where the sound is released, and are typically acquired as shown in (Figure 2.2), with a "race-track" pattern being employed. This allows adjacent sail lines to be recorded in the same direction whilst reducing the time needed to turn the vessel in the opposite direction.

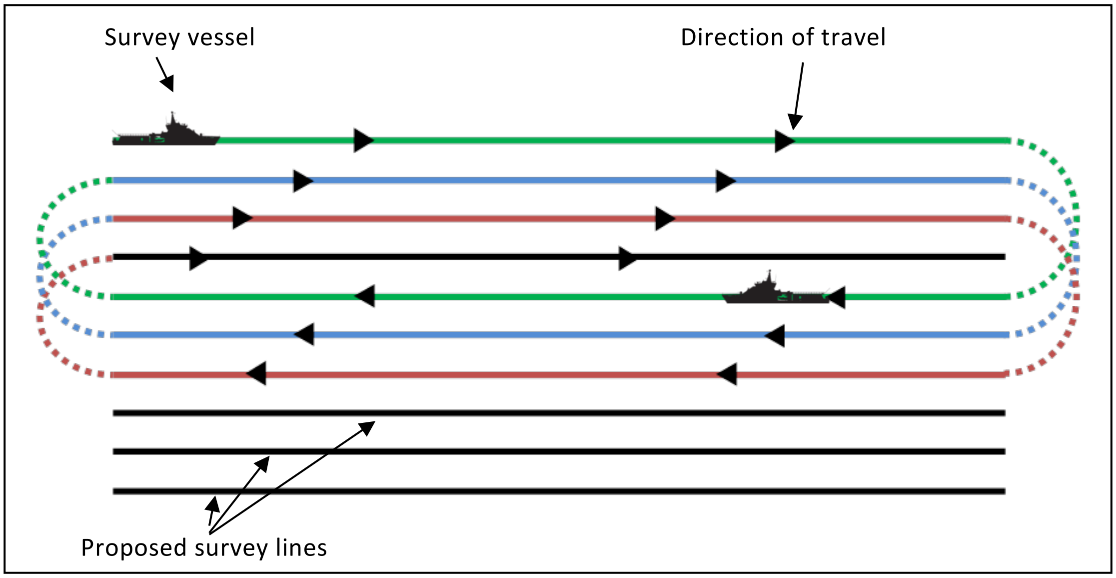

Figure 2.3. Example of a Typical Seismic Survey Line Plan

Survey Types

2D Seismic Survey

In 2D operations, a single seismic streamer is towed behind a survey vessel together with a single acoustic source. The reflections from the subsurface geology are assumed to lie directly below the vessel track line. This provides an image in two dimensions (horizontal and vertical) (Figure 2.3 and Table 2.1).

3D Seismic Survey

During 3D seismic surveys the survey vessel tows multiple streamers and uses multiple acoustic sources to acquire the data. This provides a 3D volume of data, rather than the strips of data acquired during the 2D surveys. This data volume means that lines, planes, slices or 'probes' can be extracted in any orientation, with nominally consistent data processing characteristics. 3D surveys also tend to cover specific areas, with known geological targets that have been identified from previous 2D exploration data.

The general aim of 3D surveys is to achieve a higher degree of spatial resolution and to obtain a more reliable image of the subsurface geology than is achievable by 2D surveys (*Mjelde, 2006*). Seismic surveys may also be differentiated by the density of measurements made over a given area. 3D surveys have a much denser number of measurements than 2D surveys (*OGP, 2011*).

Fundamentally, however, the greatest benefit of 3D resides in its spatial resolving power both in terms of absolute spatial resolution and relative accuracy in image. Features such as fault systems can now be mapped in much more detail than was possible with 2D seismic data (*Davies et al., 2004*).

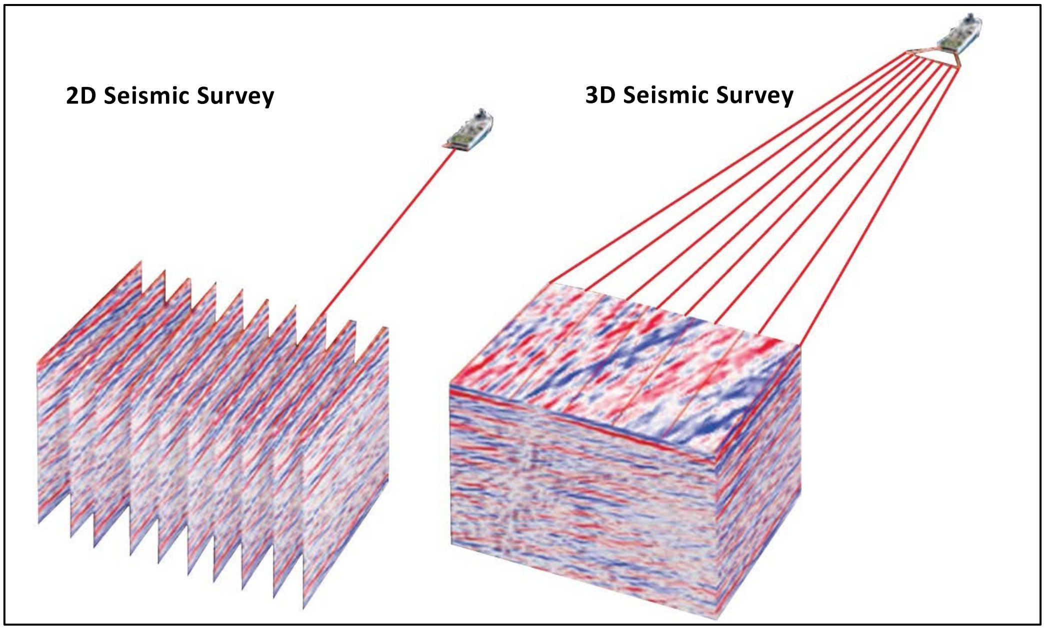

Figure 2.4. Differences in Data Collection between 2D and 3D Seismic Surveys

4D Seismic Survey

4D or time-lapse 3D seismic surveys use the same survey layout, acoustic source and technical specifications as a 3D seismic survey. 4D surveys require a much higher specification for positioning of all in sea equipment. The 4D element means that survey data is acquired repeatedly over the same area over a number of months or years. As a result of the repeated surveys, there is a high level of data density across the survey area because there are multiple data points at any given location. 4D surveys have a higher data density than 3D surveys (*OGP, 2011*).

The purpose of this project is to obtain images of how the reservoir hydrocarbons are changing over time. This information is used by geoscientists and reservoir engineers to maximize production and hydrocarbon recovery from the field.

Table 2.1. Differences between 2D, 3D and 4D Seismic Surveys

	2D Seismic Survey	**3D Seismic Survey**	**4D / Time-Lapse 3D**
Output	Vertical slices or strips of data	A 3D volume of data	As per 3D but repeated over the same area
Common mid point	Line	Area	
Streamers	Use a single streamer	Use multiple streamers	
Source	Single source	Multiple source	

2.3.7 Seismic Vessel

Any seismic vessel used will comply with the applicable regulations under the Canada Shipping Act, 2001 (*CSA, 2001*) and applicable International Maritime Organization (IMO) Standards. In addition, the operations will comply with provisions under the Maritime Occupational and Health Regulations pursuant to Part II of the Canada Labour Code. In 2017, Polarcus will use either the Polarcus Amani or similar vessel from the Polarcus Fleet. Delivered in 2012, Polarcus Amani is an ultra-modern, super high ice class, 14 streamer 3D/4D seismic vessel. Built to the ULSTEIN SX134 design and incorporating the innovative ULSTEIN X-BOW® hull, the vessel combines the latest developments in maritime systems with the most advanced seismic technology commercially available. The vessel is also amongst the most environmentally sound seismic vessels in the market with diesel-electric propulsion, high specification catalytic convertors to reduce harmful exhaust emissions, double hull and regulatory-exceeding advanced ballast water treatment / bilge water cleaning systems. The vessel complies with the stringent DNV CLEAN DESIGN notation.

The Amani is 92 metres long, 21 metres wide, and has a maximum draft of 7.5 metres. The vessel has accommodations for 60 crew and a maximum cruising speed of 17 knots. Typical seismic surveying speed is 4.5 to 5 knots. For future surveys during 2017 to 2022, vessel specifications will be provided once the vessels have been identified.

2.3.8 Seismic Source Parameters

In 2017, the seismic source array to be deployed will consist of one of three options described below and shown in Figure 2.5 including:

- a dual-source, 4240 cu in array, comprised of two arrays consisting of three-gunstrings each;
- a triple-source, 3090 cu in array, comprised of three arrays consisting of two-gunstrings each; or
- a penta-source, 3090 cu in array, comprised of three arrays consisting of two-gunstrings each and configured in the source controller such that different gun-strings are grouped together for each discrete shotpoint, representing five-sources.

In every case, the source will operate at towed depths between six and nine meters at a nominal operating pressure of 2,000 psi.

The 4240 cu in array will exhibit peak-to-peak pressures of 404 bar-metres (equivalent to approximately 272 dB re 1 µPa @1m).

The 3090 cu in array will exhibit peak-to-peak pressures of 256 bar-metres (equivalent to approximately 268 dB re 1 µPa @1m).

The triple and penta sources described above are collectively referred to as Polarcus XArray™ configurations. The XArray™ triple and penta source configurations are an innovative Polarcus development providing increased cross-line sampling density for any selected streamer separation. When paired with wide streamer separations, the use of the lower volume triple or penta source arrays will result in reduced survey duration and noise in the environment.

The maximum energy source for projects in 2018-2022 will be 4,240.

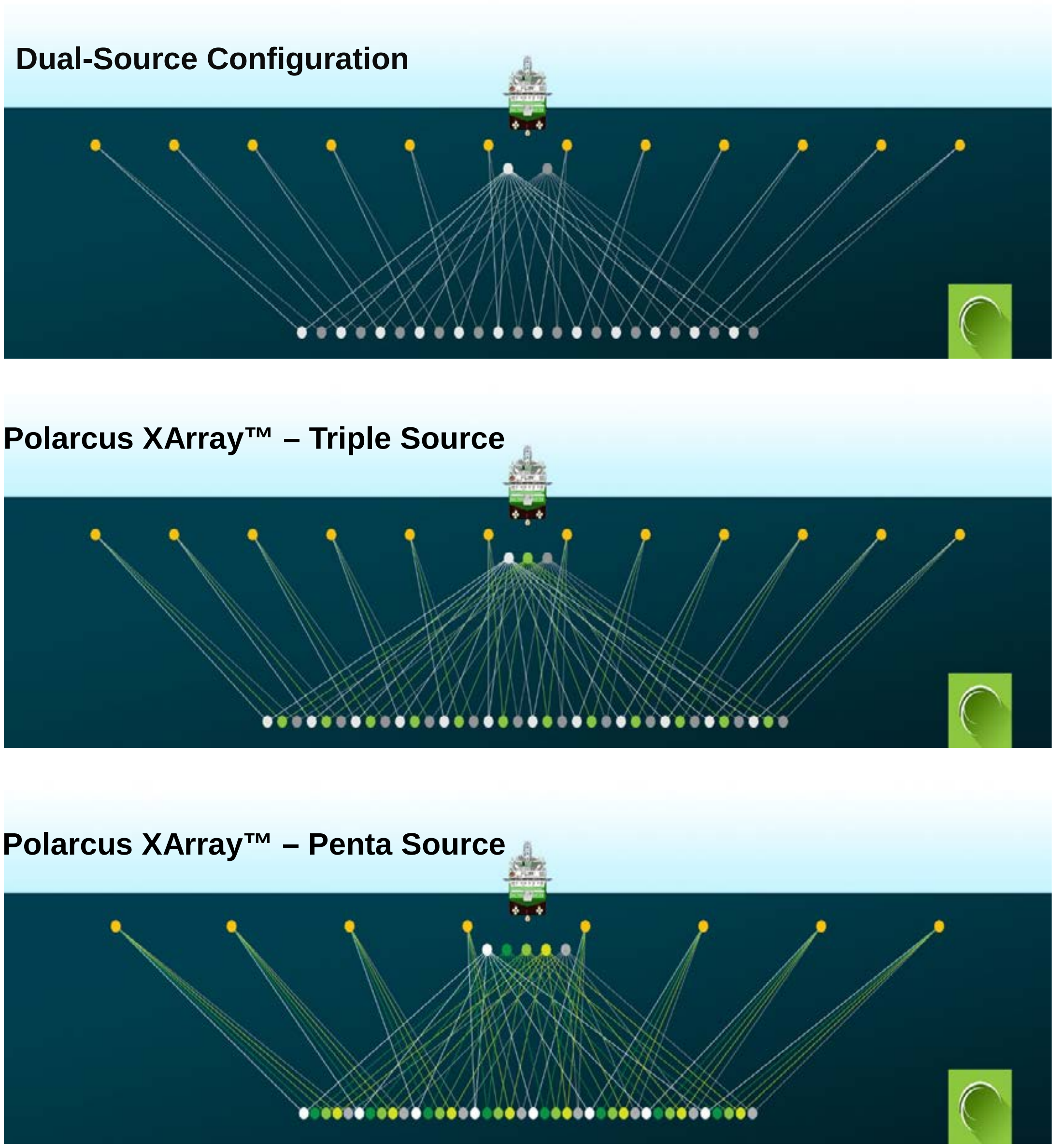

Figure 2.5. Polarcus Seismic Vessel Source Arrangement

2.3.9 Seismic Streamers

In 2017, the 3D seismic survey vessel will tow up to 14 multiple solid streamers that are 8,000-10,000 metres each in length at a depth of 9 to 25 metres. Spacing between the streamers will depend upon the source configuration used (triple or penta) but will be between 62.5 metres and 150 metres. The Polarcus XArray™ streamer configuration offers increased streamer separation over conventional dual source configuration which is beneficial to the environment as it reduces the number of streamers needed and therefore reduces the footprint of the survey. The Polarcus XArray™ triple source will, with a 12x150 metres streamer configuration achieve the same cross line sampling density as a conventional dual source with a 12x100 metres streamer configuration but with 50% improved operational efficiency. This improvement in efficiency minimizes the time the survey vessel will spend surveying and therefore reduces the impact on the environment.

In subsequent 2D, 3D and/or 4D seismic surveys (2017-2022), streamer equipment specifications will be provided when program design is complete. The solid streamers will be deployed at depths ranging from 9 to 25 metres. As many as 14 streamers may be towed during a 3D or 4D seismic survey.

The maximum streamer length for future years (2018-2022) will be 12,000m.

2.4 Potential Environmental Emissions and their Management

2.4.1 Underwater Noise

Noise will be generated both above (from the survey and support vessel engines) and below the sea surface (from the seismic energy source). Offshore seismic surveys are conducted using high pressure air supplied to the seismic source from compressors onboard the seismic survey vessel. The source is charged with the high pressure air before being electrically triggered. When the source is triggered, the high pressure air is discharged into the surrounding water through ports in the side of the source. The released air from these ports forms a bubble which initially expands and subsequently collapses through an oscillation period. The initial expansion and collapse provides the main acoustic impulse (P-wave) into the water column. The P-waves are then reflected back from the subsurface geological layers at varying time intervals dependent on the physical properties of the strata.

Underwater noise has the potential to impact fauna in the area, particularly some fish species and cetaceans, modifying their behaviour patterns (changes in swimming and breathing patterns and the masking of communication between marine mammals). More significantly and in extreme cases, the pressure waves associated with noise can inflict physical harm and possibly be lethal. A number of scientific terms are used in order to accurately describe noise. These have been defined in Table 2.2.

Table 2.2. Noise Terminology Glossary as Applicable to Underwater Acoustics (Southall et al., 2016; NDE, 2016; UNSW, 2016, The Engineering Toolbox, 2016)

Key term	Definition
Attenuation	Decrease in intensity (loudness) of a sound.
Decibel (dB)	Logarithmic unit commonly used to quantify the intensity (loudness) of a sound. Decibels are a ratio between the pressure of an event and a pressure of reference. The pressure of reference for underwater sounds is usually 1 µPa, whereas airborne sounds are usually referenced to 20 µPa. Therefore underwater sound measurements are commonly expressed in “dB re 1µPa”.
Fr0equency	Number of cycles of a sound wave per second measured in units of hertz, or Hz. Various species of marine mammals and fish hear sounds within certain ranges of frequencies. When sounds produced by anthropogenic sources fall within their range of hearing, a potential for harassment exists. If a sound is loud enough, even though it is outside the hearing frequency range, it sometimes can still be detected by the organism and can cause

Key term	Definition
	injury if it is extremely loud.
Masking	Interference from sound sources that reduces the ability of organisms to detect or locate sounds of interest.
Non Pulse Noise	Single or multiple discrete acoustic events of a similar decibel level within 24 hours (no variation greater than 3dB re 1µPa). E.g. vessel/ aircraft passes.
Multiple Pulse Noise	Multiple acoustic events within a 24 hour period that have a difference of more than 3 dB re 1µPa between the impulse sound level and background noise level. E.g. sequential sound source as used for seismic surveys or piling strikes.
Hearing Threshold	Minimum intensity / loudness where an organism with unaffected hearing can hear a sound.
Threshold Shift	Increase (worsening) in the threshold of hearing for an ear at a specified frequency. This can take two forms: Temporary Threshold Shift (TTS): describes a temporary increase in threshold that occurs during or shortly after exposure to high noise levels. This can last from a few minutes, to hours or days. Permanent Threshold Shift (PTS): describes how prolonged or repeated exposure to high levels of sound accelerates the normal process of permanent gradual hearing deterioration with age.

In terms of the different categories and metrics of anthropogenic sounds in the ocean, Southall *et al.,* (2007) identified three types of sound; single pulse, multiple pulse and non-pulse. According to this classification, it is anticipated that the dominant sound sources from the proposed activity will be:

- Survey and support and supply vessels: a non-pulse sound source;
- 3D Seismic Survey: a multiple pulse sound source.

Noise Emissions

The main sources of noise from the proposed survey program are the acoustic energy sources towed by the survey vessel and general vessel (survey, supply and support operations.

Seismic Survey (Multi-Pulse Noise)

The noise emitted during the seismic survey will primarily originate from the acoustic energy sources. Onboard machinery and propeller noise will contribute a negligible amount to the acoustic transmissions from the survey. The number of acoustic energy sources provides the greatest influence on the array sound emission strength. A well-designed array maximizes the proportion of the energy directed downwards (in the direction of interest) and minimizes 'wastage' to the sides; effectively maximizing the directivity.

The noise from the acoustic source will be emitted below the water surface. The noise generated by these processes tends to be of low frequency in the range of <1 to 250 hertz, meaning that it will attenuate less and will travel further from its source, when compared to a high frequency sound.

Underwater noise levels associated with the acoustic noise source are estimated at 246 dB re 1 μPa (*OGP, 2011*). This value has been used in a simple spherical spreading model provided Figure 2.6.

Survey, Support and Guard Vessel Noise (Non Pulse Noise)

The noise characteristics and level of various vessels that will be present in the field over time can vary between 130 and 182 dB re 1μPa (*Simmonds et al., 2003; Richardson et al., 1995; Senior et al., 2008*). The particular activity being conducted by the vessel also greatly influences the noise characteristics, for example, if it is idle, in a holding position using bow thrusters, or accelerating. Small commercial vessels (e.g. support vessels) have been recorded producing noise levels between 170 and 180 dB re 1μPa (*Senior et al., 2008*). For comparison purpose, smaller coastal and recreational vessels have typically produce noise between 140 and 170 dB re 1μPa with higher noise levels produced by faster moving vessels (*Hunt, 2007*).

Noise Modelling

The main concerns associated with acoustic emissions from seismic surveys are the potential for impacts on plankton, fish and shellfish, commercial fisheries, marine mammals and marine turtles. The potential for effects on these marine receptors is dependent on the magnitude of the sound and its frequency.

It is important to note that the magnitude of the sound manifests itself as pressure, i.e. force acting over a given area. It is expressed in terms of 'sound levels', which use a logarithmic scale of the ratio of the measured pressure to a reference pressure (decibels (dB)).

The pressure of a seismic pulse diminishes with increasing distance from the source. Most of the loss is due to "spherical spreading" of the expanding wave front with sound levels decreasing rapidly with distance from the source. Depending on the propagation conditions, the attenuation is between three and six decibels per doubling of distance (*Swan et al., 1994*). However, after the initial period of rapid attenuation, the noise levels decrease more slowly and the signal may be above background levels for several tens of kilometres or more (*Swan et al., 1994*). The bathymetry of an area can be an important influence on sound propagation, the bathymetry of the Study Area is such that the spherical spreading model can be utilised as an indication of what may happen to seismic noise generated.

Spherical spreading and the sound level attenuation curve can be expressed as the following equation:

Received pressure[1] = (Source pressure measured at one metre) – (20 log R)

The results of the noise modelling of the attenuation of the sound levels produced by the acoustic source and operational vessel noise are provided in Figure 2.6. These attenuation curves are compared against threshold criteria of environmental effects in the Section 5.

[1] Where: Source pressure is: either 246 dB re 1μPa (acoustic energy source) or 180 (operational vessel noise). R = range to receiver (m).

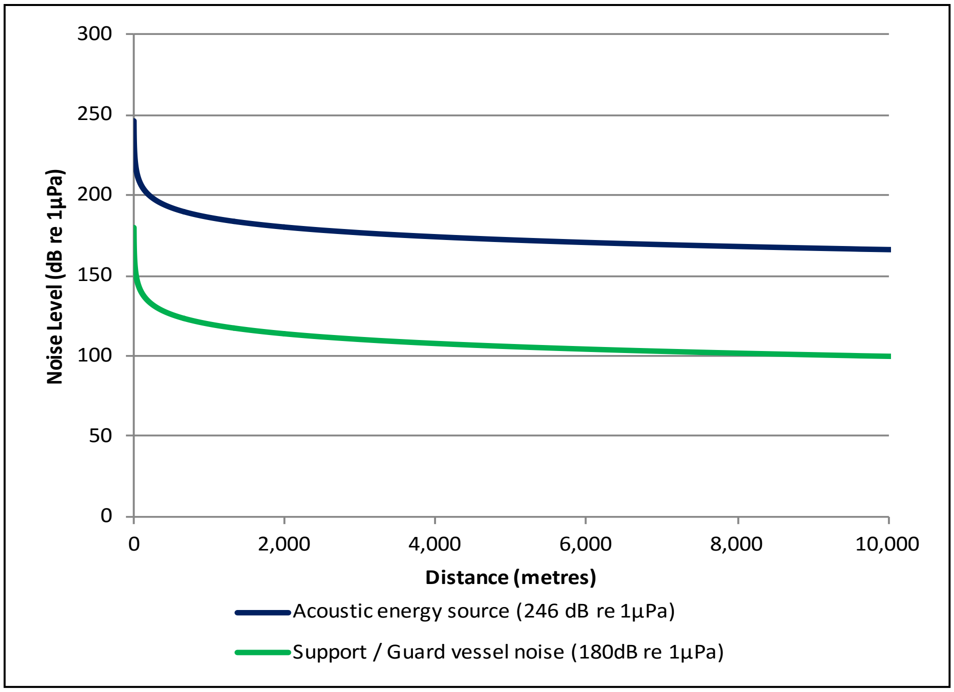

Figure 2.6. Sound Decay Curves for the Acoustic Energy Source and Operational Vessel Noise (Based on Spherical Spreading)

DFO's "*Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*" specifies the mitigation measures that must be met during the planning and conduct of marine seismic surveys, in order to avoid or minimize effects on marine biota.

Project mitigations will include dedicated MMSOs who will monitor for marine mammals and sea turtles and implement mitigation measures as appropriate. The airgun array will be ramped up, and ramp ups will be delayed if a marine mammal or sea turtle is detected within the appropriate safety zone (minimum of 500 metres). The airgun array will be shut down any time an Endangered or Threatened (as listed on Schedule 1 of the Species at Risk Act (SARA)) marine mammal or sea turtle is detected within the safety zone.

A Fisheries Liaison Officer (FLO) will be on board the seismic vessel to ensure implementation of communication procedures intended to minimize conflict with the commercial fishery.

These and other measures are discussed in further detail and considered in the environmental effects assessment that follows (Section 5).

2.4.2 Solid Waste Management

Waste management will be consistent with industry best practices in Offshore Newfoundland and Labrador. Polarcus follows MARPOL 73/78 Annex IV: Pollution by Sewage from Ships, and Annex V: Pollution by Garbage from Ships. Polarcus procedures and practices related to recycling and/or repurposing of waste streams will be in effect. Waste oil from the vessels will be burned on-board in approved incinerators. The shipboard incinerators will have been examined and tested in accordance with the requirements for shipboard incinerators IMO Res. MEPC 76(40) for disposing of ships-generated waste appended to the Guideline for the implementation of Annex V of MARPOL 73/78.

2.4.3 Potential Liquid Discharges

Grey and black water includes all wash water and sewage effluent generated by the crew accommodations, laundry and cafeteria. All grey and black water will be managed in accordance with applicable requirements under MARPOL and the Canada Shipping Act.

If discharges of bilge and ballast water are necessary, all such discharges will be conducted in accordance with regulatory requirements described under MARPOL and the Canada Shipping Act.

The Polarcus seismic vessel will operate the Alfa Laval Pure Ballast water management system which is 100% chemical free and eliminates all invasive species from the ballast water.

2.4.4 Atmospheric Emissions

Air Emissions will be those associated with standard operations for marine vessels, including the seismic vessel and the Support/Guard and supply vessels. Polarcus follows MARPOL 73/78 Annex VI: Regulations for the Prevention of Air Pollution from Ships. Air emissions reporting will be performed using a Polarcus developed, DNV GL certified emissions tracking tool and when feasible to do so, operational adjustments will be made to minimize airborne emissions impact and improve overall environmental performance. Certified emissions statistics will be made available following any project.

2.4.5 Accidental Events

In the unlikely event of an accidental spill during the project, the measures outlined in Polarcus Shipboard Oil Pollution Emergency Plan (SOPEPs) will be implemented. The SOPEP will be provided to the C-NLOPB. Polarcus will be registered with Eastern Canadian Response Corporation (ECRC) for the duration of the program in Canada. Polarcus will have an overarching Emergency Response Plan in place which will be implemented in the event of an accidental release.

2.4.6 Environmental Management

Polarcus ensures its environmental footprint is minimized by managing all their operations responsibly through a process of measuring, monitoring and continuous improvement. Information relating to how Polarcus manage their operations with minimal impact to the Environment is presented in Appendix B.

The EA outlines Polarcus environmental management system (Appendix B) and its components, including, but not limited to:

- Pollution prevention policies and procedures – see Section 5.6.6;
- Fisheries liaison / interaction policies and procedures – see Section 5.6.2;
- Program for compensation of affected parties – see Section 5.6.4 and
- Emergency response plans – see Section 5.6.6.

2.4.7 Cumulative Effects

As described in Section 5.4 of the Scoping document the assessment of cumulative effects is presented in Section 6 and is consistent with the principles described in the February 1999 CEAA "Cumulative Effects Assessment Practitioners' Guide" and in the November 2007 CEAA operational policy statement "Addressing Cumulative Environmental Effects under the Canadian Environmental Assessment Act". Consideration has been given to the environmental effects that are likely to result from the proposed project in combination with other projects or activities that have been or will be carried out. These include, but are not limited to: proposed oil and gas activities under EA review (listed on the C-NLOPB Public registry at www.cnlopb.ca); other geophysical activities; fishing activities; and marine transportation.

Table of Contents

List of Figures

List of Tables

3 Physical Environment

The physical environment of the Eastern Newfoundland Offshore area is described in the Eastern Newfoundland Offshore Area Strategic Environmental Assessment (SEA) (*AMEC, 2014*). The Study Area (denoted by a dashed red line in Figure 3.1) includes Orphan Basin, Flemish Cap, and Northern Grand Banks (Figure 3.1). This chapter provides an updated summary of the meteorological and oceanographic characteristics within the Study Area in order to provide the basis for assessing the effects of the physical environment on the project.

In order to characterize the distinctive environments of the Orphan Basin, Flemish Cap and Northern Grand Banks, graphically and statistically, data from the International Comprehensive Ocean-Atmospheric Data Set (ICOADS) was segregated per regions shown in Figure 3.1. For clarity, the colours green, blue and red, for Orphan Basin, Flemish Cap, and Northern Grand Banks, respectively, correspond to the colours in the statistical graphs on Figures 3.2, 3.3, 3.4, and 3.6.

Table 3.1 below demonstrates where updated baseline data has been included in this report.

Table 3.1. Baseline Data Updated Since the Eastern Newfoundland SEA (August, 2014).

Data	Eastern Newfoundland SEA (August, 2014)	Polarcus Project-Based EIA	Data Source
Climatology	1950-2012	1960-2015	ICOADS
Oceanography	1950-2012	1960-2015	ICOADS

3.1 Bathymetry

The bathymetry of the Study Area is a consideration during impact assessment of the seismic program, since it has an important influence on sound propagation. It also has a strong correlation to the location of fishing activities which may interact with the acquisition.

As described in the Offshore Newfoundland SEA, the *Physical Environment* Study Area is characterized by a variety of seabed features such as iceberg scouring, sand ridges, sand waves, shell beds, and seabed depressions. Notable topographic highs in the SEA Area are the Central Ridge, Flemish Cap and Orphan Knoll. The Flemish Cap is a large, isolated submarine knoll approximately 600 kilometres east of Newfoundland and represents the most easterly extension of North American continental crust (*King and Fader, 1985*). The Flemish Cap consists of a central core of Hadrynian rocks, including granodiorites, granites, dacites and a sequence of Mesozoic to Cenozoic aged sediments (*King et al., 1986*).

The west-central portion of the Study Area contains the Grand Banks. Average depths are approximately 75 metres within this region. The Grand Banks extend from the western boundary of the SEA Area east to the 1,000 metre depth contour and the Flemish Pass with depths of almost 1,300 metres. On the eastern side of the Study Area, depths rise to the Flemish Cap up to about 130 metres (*C-NLOPB, 2014*).

The Sackville Spur extends north of the Northeast Newfoundland Shelf with depths of approximately 200 to 300 metres. The Orphan Basin lies north of the Northeast Newfoundland shelf. Depths in the Orphan Basin increase from about 1,200 metres at the edge of the continental shelf to 3,500 metres at its deepest point (*C-NLOPB, 2014*).

3.2 Climatology

Climatology controls the operating window for seismic vessels, and impacts all aspects of operations including safety, gear deployment and recovery apparatus, refuelling operations, personnel transfers, and effectiveness of proposed mitigation.

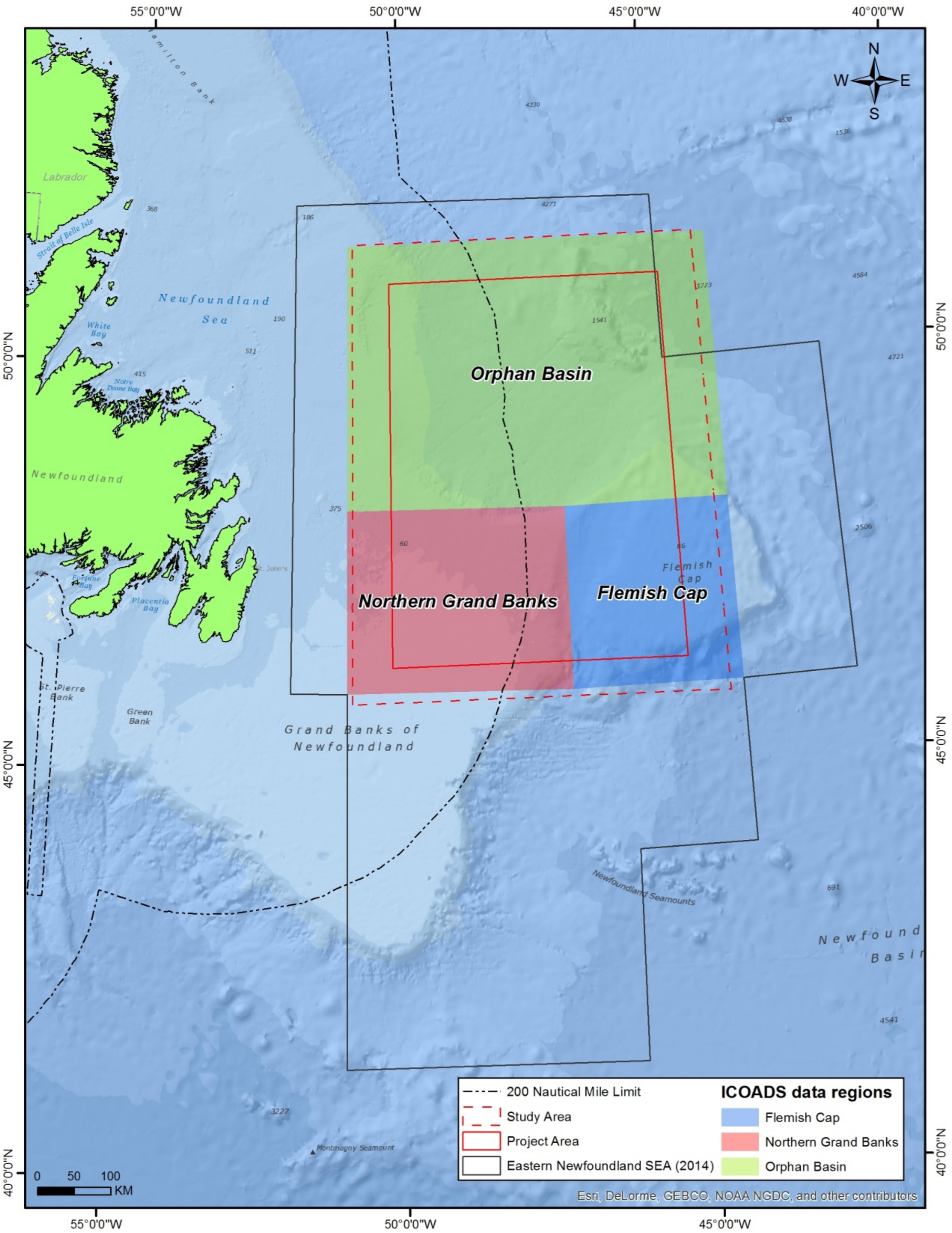

Figure 3.1. ICOADS Data Regions

It is therefore vital to understand the baseline climatic conditions within an area when planning and assessing a seismic acquisition program.

3.2.1 Air Temperature

The proposed study Area overlaps the Orphan Basin, the Flemish Cap, and Grand Bank regions. Within the Flemish Cap region, air temperature values exhibit strong seasonal variations, with mean temperatures ranging from 1.5 degrees Celsius in February to 13.5 degrees Celsius in August. The coldest observed air temperature on record (-12 degrees Celsius) was in January, while during the summer months the coldest observed temperatures were around 3 degrees Celsius in August (Figure 3.2) (data from *NCDC et al., 2016*).

Across the Orphan Basin, the air temperature values exhibit strong seasonal variations, with mean temperatures ranging from 0.8 degrees Celsius in February to 11.7 degrees Celsius in August. The coldest observed air temperature on record (-20.5 degrees Celsius) was in February, while during the summer months the coldest observed temperatures were around 1.8 degrees Celsius in June (Figure 3.2) (data from *NCDC et al., 2016*)

Mean temperatures across the Grand Banks region range from -0.5 degrees Celsius in February to 13.7 degrees Celsius in August. The coldest observed air temperature on record (-13.5 degrees Celsius) was in February, while during the summer months the coldest observed temperatures were around 4.4 degrees Celsius in June (Figure 3.2) (data from *NCDC et al., 2016*).

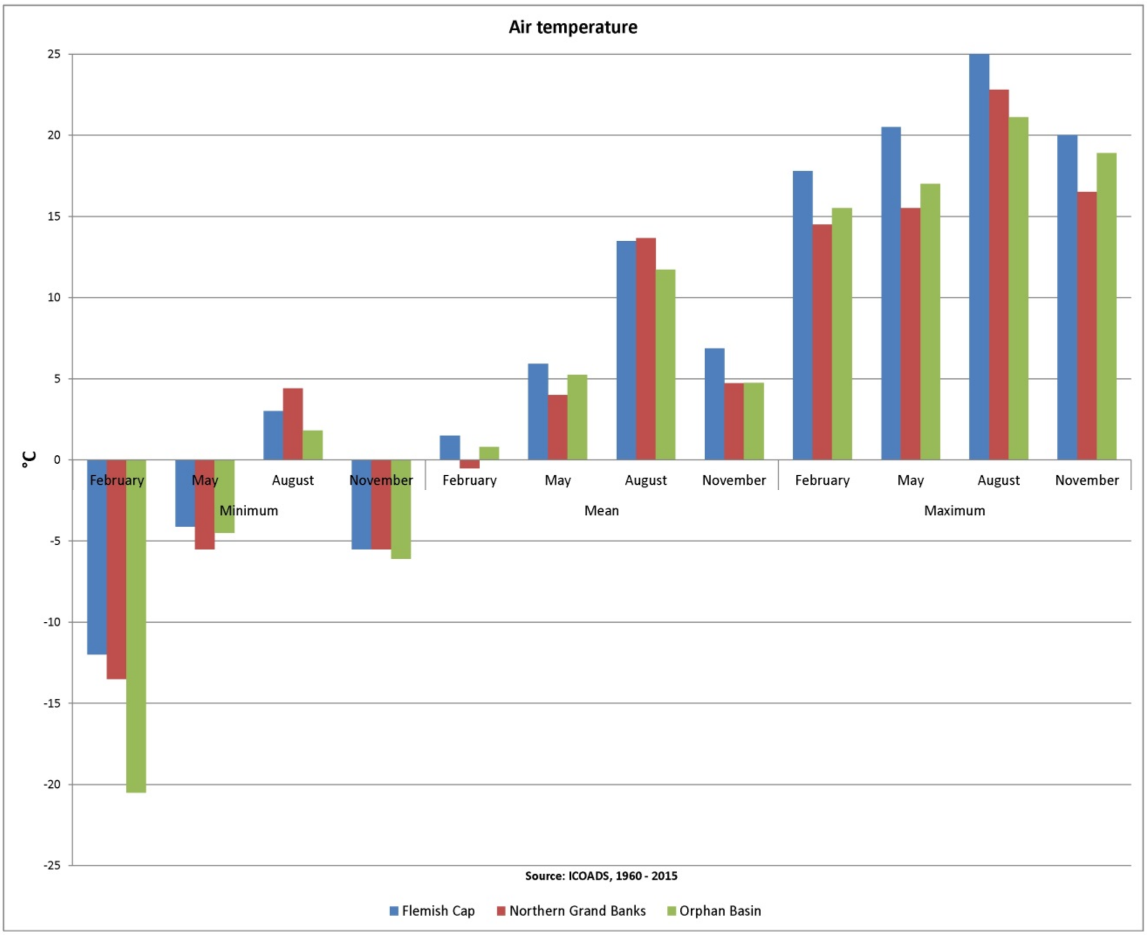

Figure 3.2. Air Temperature within the Study Area (min mean and maximum) for ICOADS Regions (NCDC, 1960 – 2015)

3.2.2 Wind

Wind speed is an important characteristic of the physical environment that can directly affect project activities. High winds result in dangerous or disruptive sea states which can shut down operations and put the vessel in weather standby mode.

Within the Study Area, mean wind speeds in February (when conditions are generally least favourable) range from approximately 11.2 metres per second in the northwest portion of the Study Area to 12.9 metres per second in the Northern Grand Banks region. During the summer months (June to August) mean wind speeds of 6.6 to 8.8 metres per second are recorded across the entire Eastern Newfoundland SEA Area *(ICOADS, 1960-2015)* (Figure 3.3).

Across the Flemish Cap region, the prevailing winds during most of the year are from a westerly (24.2 percent of the time annually) or south-westerly (20.8 percent of the time annually) direction. Westerly and north-westerly winds are generally most frequent during the period from October to April, while south-westerly and westerly winds are most frequent during the warmer months from June to September. Sustained hurricane force winds (stronger than 32.9 metres per second) occur in December when the maximum wind speed is 35.8 metres per second (*C-NLOPB, 2014)*.

In the Orphan Basin region, the prevailing winds annually are from a south-westerly (20.3 percent), westerly (20.1 percent) or north-westerly (16.4 percent) direction, depending on the time of the year. As with the Flemish Cap region, westerly and north-westerly winds are dominant during the period from November to March, while south-westerly and southerly winds are more frequent during the warmer months from May to September. Sustained hurricane force winds (stronger than 32.9 metres per second) occur in the Orphan Basin sub-region in February where the maximum wind speed is 36 metres per second (*C-NLOPB, 2014)*.

In the Grand Banks region, the prevailing winds annually are from a south-westerly (22.7 percent) or westerly (20.0 percent) direction. Westerly winds are dominant during the period from October to March, while south-westerly winds are most frequent from April to September. Storm force winds, in the range from 24.7 to 32.4 metres per second, occur in all months except May through July (*C-NLOPB, 2014)*.

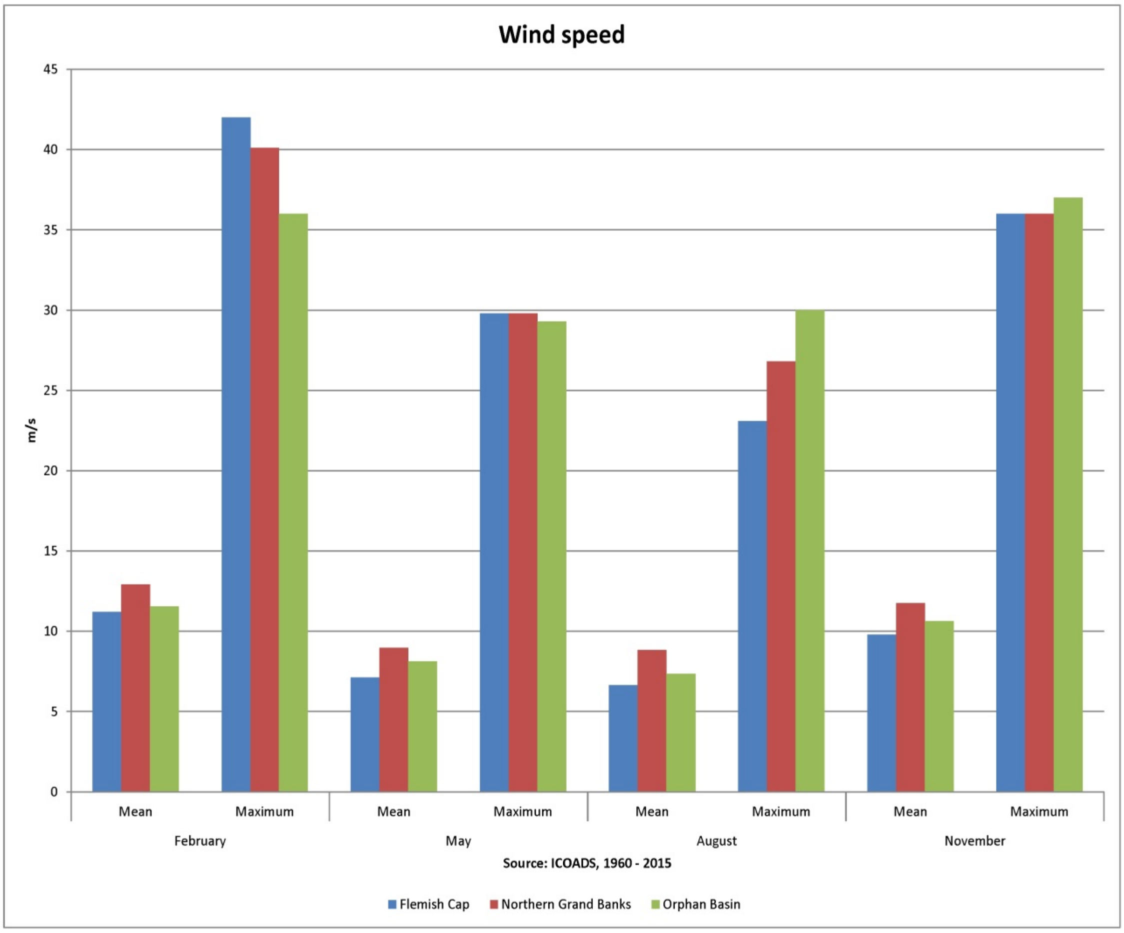

Figure 3.3. Wind Speeds (mean and maximum) for ICOADS Regions (1960 – 2015)

3.2.3 Precipitation and Visibility

Visibility impacts the safety of operations as well as the ability to apply effective visual monitoring and associated mitigation measures.

Within the Flemish Cap region, the monthly frequency of rainfall is lowest between May and August, with maximum rainfall occurring in November. Peak snowfall occurs in January and February, with minimum snow frequency occurring from May to August. Freezing rain and drizzle are relatively infrequent within the Flemish Cap region, occurring less than one percent of the time during any given month (*ICOADS, 1960 - 2015*) (Table 3.2).

Within the Orphan Basin area, the monthly frequency of rainfall is lowest in February and August, with maximum rain frequency occurring during November. Peak snowfall occurs in February, with minimum snow frequency occurring from May to August. Freezing rain and drizzle are relatively infrequent within the Orphan Basin region, with the maximum frequency (1.06%) occurring during February (*ICOADS, 1960-2015*) (Table 3.2).

Within the Grand Banks region, the monthly frequency of rainfall is lowest in February and August, with maximum rain frequency occurring in November. Peak snowfall occurs during February, with minimum snow frequency occurring from May to August. Freezing rain and drizzle are relatively infrequent within the Northern Grand Banks region, occurring less than one percent of the time during any given month (*ICOADS, 1960-2015*) (Table 3.2).

Table 3.2. Precipitation with the Study Area (ICOADS, 1960 – 2015)

Precipitation Type	Percentage Occurrence		
	Flemish Cap	Northern Grand Banks	Orphan Basin
Rain	***Percentage Occurrence***		
Feb	10.65	7.23	9.11
May	9.16	9.95	10.57
Aug	9.30	7.91	9.78
Nov	13.88	12.48	18.36
Snow	***Percentage Occurrence***		
Feb	10.65	12.85	22.99
May	1.08	0.93	1.19
Aug	0.00	0.04	0.00
Nov	2.56	2.14	4.62
Freezing Rain / Drizzle	***Percentage Occurrence***		
Feb	0.27	0.81	1.06
May	0.13	0.12	0.00
Aug	0.00	0.01	0.00
Nov	0.00	0.11	0.00

The Study Area has some of the highest occurrence rates of marine fog in North America (*C-NLOPB, 2014)*. Advection fog is formed when warm moist air flows over a cold surface such as the cold Northwest Atlantic Ocean, and can persist for days or weeks. Fog and visibility conditions and seasonal variability are expected to vary across the Study Area, along with air temperatures and precipitation rates.

Within the Flemish Cap region, good or fair visibility combined occur 81.9 percent of the time annually. Good visibility (greater than 10 kilometres) is most frequent during November and February, and least frequent in May. Visibility is poorest in August (*ICOADS, 1960-2015*).

Across the Orphan Basin region, good or fair visibility combined occur 84.5 percent of the time annually. Good visibility (greater than 10 kilometres) is most frequent during November, and least frequent in August. Visibility is poorest in August and throughout the summer.

For the Grand Banks region, good or fair visibility combined occur 76.7 percent of the time annually. Good visibility (greater than 10 kilometres) is most frequent during November, and least frequent in May. Visibility is poorest in the spring and summer, especially during August (Figure 3.4) (Table 3.3).

Table 3.3. Visibility with the Study Area (ICOADS, 1960 – 2015)

Region	Very Poor (<0.5km)	Poor (0.5–2km)	Fair (2-10km)	Good (>km)
Flemish Cap	*Percentage Occurrence*			
Feb	0.88	7.03	46.75	45.33
May	5.08	19.56	36.25	39.10
Aug	8.74	19.78	29.59	41.89
Nov	1.99	7.26	45.45	45.30
Northern Grand Banks	*Percentage Occurrence*			
Feb	3.88	11.93	43.77	40.42
May	12.10	21.09	35.23	31.58
Aug	12.26	15.64	33.05	39.05
Nov	3.75	8.86	37.44	49.95
Orphan Basin	*Percentage Occurrence*			
Feb	1.09	8.66	50.95	39.29
May	4.34	12.28	42.54	40.83
Aug	6.99	17.09	37.19	38.73
Nov	0.94	7.76	46.11	45.19

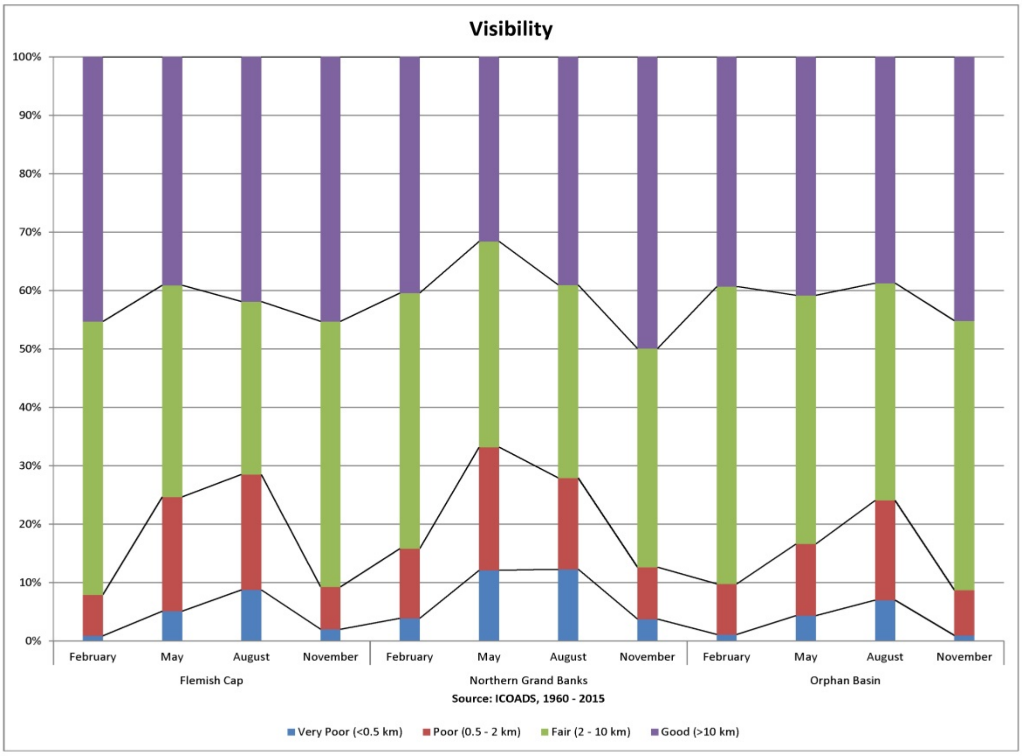

Figure 3.4. Visibility for ICOADS Regions (1960 – 2015)

3.2.4 Storms

Hurricanes making landfall in Newfoundland and Labrador are relatively rare occurrences. Tropical systems, whether they are weakened hurricanes, tropical storms or post-tropical (extra tropical) storms, do however affect portions of the province and the marine offshore once or twice each year on average. Tropical systems can affect Newfoundland anytime during the Atlantic hurricane season (June 1 to November 30), but most activity generally occurs in the fall season (September and October) (Figure 3.5). In January 2016, a hurricane occurred in the Atlantic during January, resulting in large waves off the coast of Newfoundland. This was a rare weather system and the first January hurricane in the region since 1938 (*CBC News, 2016*).

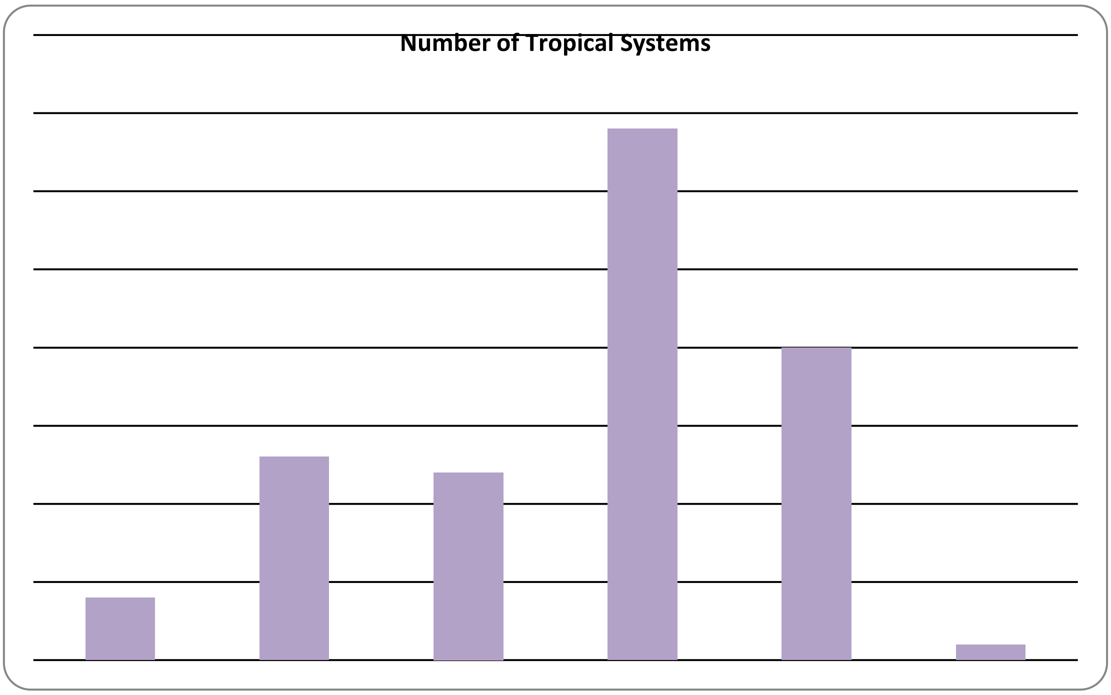

Figure 3.5. Frequency of Tropical Systems Affecting Newfoundland and Labrador (ICOADS, 1960 – 2015)

3.3 Oceanography

3.3.1 Waves

Wave conditions can potentially affect seismic acquisition programs since operations can be shut down due to wave height or swell. Due to the spatial and inter-annual variability in ice cover and other conditions throughout the SEA Study Area, the wave climate varies across the Eastern Newfoundland region, particularly during the winter period, with ice presence as a modifying variable for wave climate statistics at specific locations. Based on 55 years of data from the MSC50 wind and wave hindcast dataset, the mean wave heights in February ranges from about 2.5 to 4.25 metres in the SEA Study Area (Figure 3.6). Inspection of the corresponding August map shows corresponding mean wave heights in the 1.25 to 1.5 metre range uniformly across the entire SEA Study Area.

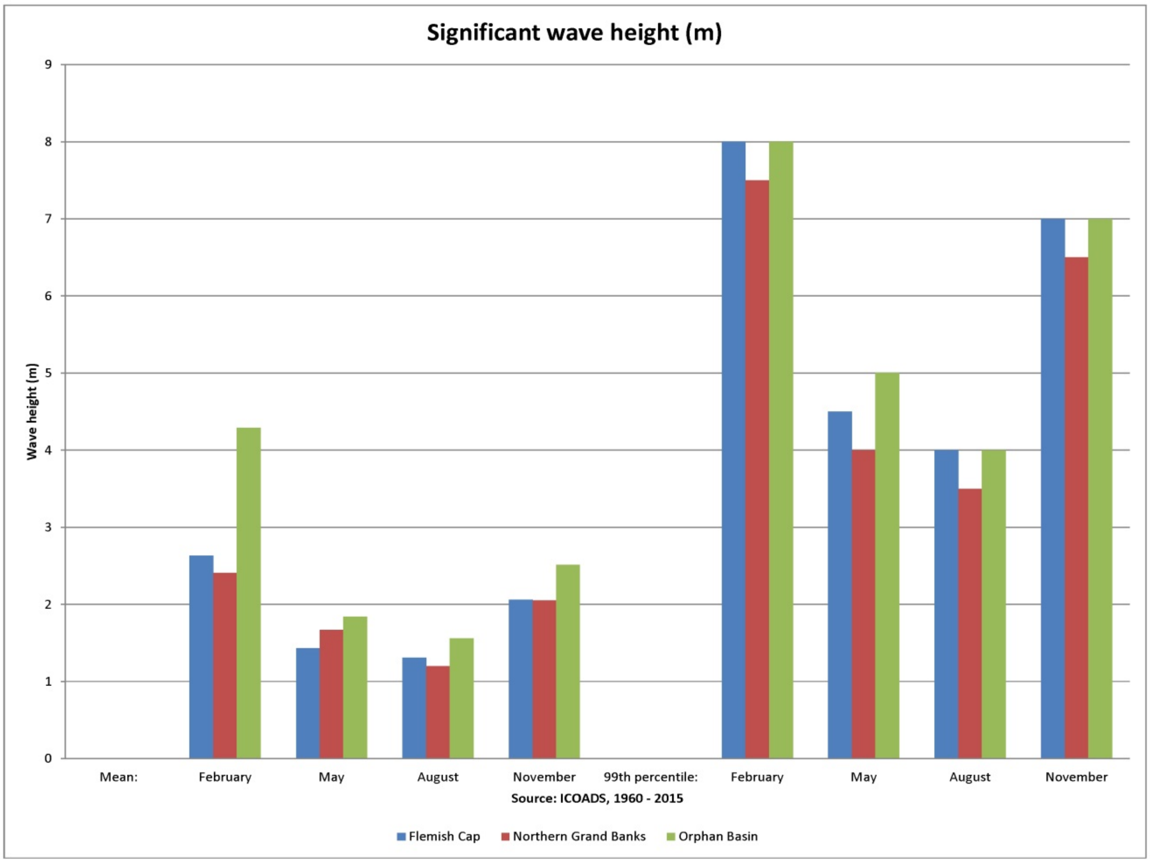

Figure 3.6. Significant Wave Height in the SEA Study Area (ICOADS, 1960 – 2015)

3.3.2 Currents

The cold, northerly Labrador Current dominates the general circulation over the Eastern Newfoundland Offshore Area. The Labrador Current is divided into two streams: an inshore branch that flows along the coast on the continental shelf and an offshore branch that flows along the outer edge of the Grand Banks *(C-NLOPB, 2014)*.

The flow in the offshore stream is characteristically stronger than in the inshore stream. When it reaches Hamilton Bank (northwest of the Orphan Basin), the inshore branch of the Labrador Current typically has an average speed of approximately 0.15 metres per second, carrying approximately 15 percent of the total transport. The offshore Labrador Current (which remains bathymetrically trapped over the upper Continental Slope) has average speeds of approximately 0.40 metres per second *(C-NLOPB, 2014)*.

According to the Ocean Data Inventory (ODI) database (*Gregory, 2004; DFO, 2013a*), maximum current speeds range from a mean of 0.1 metres per second (in the north-west in depths greater than 1,000 metres) to a maximum of 2.1 metres per second (in the south-west in depths up to 100 metres).

3.3.3 Seawater Properties

Seawater properties are a critical factor to the operation of towed streamers and in all aspects of sounds propagation. The sea surface temperatures south of Newfoundland typically reach their peak in late September, allowing tropical weather systems (weakened hurricanes, tropical storms or post-tropical storms) that approach from the south to maintain their strength as they track towards Newfoundland *(C-NLOPB, 2014)*.

The temperature statistics exhibit considerable seasonal variability, particularly in the upper part of the water column, while the monthly mean salinity values are comparatively more stable throughout the year (32 to 35 practical salinity units (psu)). The Flemish Cap experiences a sea surface temperature range of 3.4 to 12.8 degrees Celsius, the Grand Banks ranges between -0.1 and 13.8. The Orphan Basin experiences the coldest sea surface temperatures of between -1.1 degrees Celsius (February) and 10.8 degrees Celsius (August) *(DFO, 2012a).*

3.4 Ice Conditions

Ice conditions are an important component of the physical environment, directly affecting the safety of offshore operations and navigation, as well as accessibility and timings of offshore surveys.

3.4.1 Sea Ice

A large variability in sea ice conditions is experienced offshore Newfoundland from year to year. The ice season for the Orphan Basin and Grand Bank sub-regions may last for as long as 14 weeks from the third week of January to the third week of April. At the Grand Bank location, there is a greater likelihood of sea ice being present from mid to late February to mid-March. The Flemish Cap region might not experience ice until the second or third week of March, and then typically for just one or two weeks, and once every six years or less frequent *(C-NLOPB, 2014)*.

Ice thicknesses generally decrease further to the south in February and March. For the Grand Banks area, young ice is more frequent than first-year ice in February. The ice that is encountered later in the year at Orphan Basin is thick first-year ice. Within the Flemish Cap region, the ice is predominantly 70 centimetres in thickness or less (*CIS, 2011*).

3.4.2 Icebergs

The West Greenland and Labrador Currents move icebergs southwards along the Davis Strait, along the coast of Labrador, to the northern bays of Newfoundland, and into the Study Area. The greatest numbers of icebergs are seen in both the northern and southern halves of the Orphan Basin and in the Northern Grand Banks, with the three sub-regions accounting for 72 percent of the total number of icebergs observed. Very large icebergs have not been observed as frequently in the Flemish Pass North compared with the other regions of the Study Area (Figure 3.6) (*CIS, 2011*).

The majority of the icebergs (95 percent) have been observed from February through July across the Study Area. Icebergs have been rarely reported outside these times of year for the eastern and southern portions of the SEA Study Area. Icebergs have been most frequently observed in March for the Flemish Cap South, April for the Grand Banks South and Tail of the Banks, May for the Orphan Basin South, Flemish Cap North, and Grand Banks North, and July for the Orphan Basin North (*CIS, 2011*).

In addition to icebergs ranging in size from growlers to very large, ice islands have also been experienced historically in the Arctic and off the coasts of Labrador and Newfoundland. The NRC-PERD iceberg sighting database reports 358 ice islands (346 ice island size and 12 island shape entries) from 1889 to 2012. Recent record includes six ice islands from the 1950s, 11 in 2011 (10 in July, one in August) and one in March 2012. However, none of the ice islands recorded was observed in the Study Area (*CIS, 2011*).

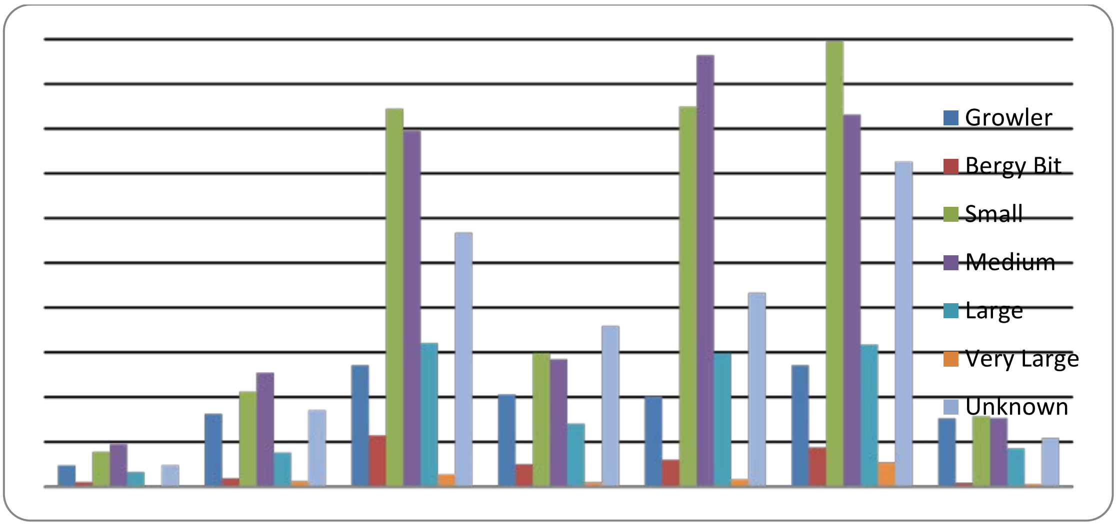

Figure 3.7. Iceberg Numbers Recorded across the Study Area (NRC-PERD Iceberg Sighting Database (1889 to 2012))