4 EXISTING ENVIRONMENT

This Chapter provides a description of the existing biophysical and socioeconomic environments that overlap and may interact with the proposed Project, including relevant components of the physical (geology, climate, oceanography, ice), biological (plankton, benthos, fish, marine birds, marine mammals, sea turtles) and socioeconomic (fisheries, other marine activities) environments.

In the EA, this overview of the existing environment is used as a basis for identifying potential environmental issues and interactions and required mitigation to avoid or reduce potential adverse environmental effects. It should also be noted that the description of the existing environment focuses primarily, but not exclusively, upon the identified VECs, and includes other aspects of the physical, biological and socioeconomic environments which are relevant as background and/or which have been specified in the Scoping Document for the EA.

4.1 Physical Environment

These sections give an overview description of relevant aspects of the physical environment of the EA Study Area, including its geology, bathymetry, climatology, oceanography and ice conditions.

4.1.1 Geology

The geology of the offshore area off Eastern and Southern Newfoundland is complex and dynamic, and the current bedrock and surficial characteristics of the Study Area have been shaped by various natural and human factors and processes over time. Their particular characteristics also make the area a prime candidate for GXT's basin span investigations, which look at the broad and deep structures at a basin scale to increase our knowledge about the region.

4.1.1.1 Bedrock and Surficial Geology

The Study Area, located on the eastern continental shelf, was formed during a time of tectonic rifting nearly 200 million years ago and is underlain by pre-rift basement rocks, mainly Mesozoic and lower Paleozoic late Precambrian formations (Figure 4.1, after Fader et al 1989). The southern margin of the Grand Banks is a transform margin that formed during the earliest rifting between North America and Africa (Piper 1991). It continued to be an active transform margin as the eastern margin experienced continental rifting between Iberia and North America. This rifting, combined with salt tectonics, created a complex series of Mesozoic rift basins that are separated by basement highs along the central to outer shelf. The Flemish Cap and Orphan Knoll are rifted horsts of continental basement on the outer continental margin (Piper 1991).

The Grand Banks off Southern and Eastern Newfoundland are a series of shallow outer banks separated by transverse troughs. They are separated from the coast by the deep Avalon Channel and its extension in the St. Pierre Channel, and by other irregular inner shelf basins (Fader and Piper 1990, in Piper et al 1990). The Avalon Channel is a deep trough parallel to the coastline off Southern Newfoundland and the Avalon Peninsula that is underlain by Paleozoic sediments (King et al 1986). The morphology of the southwest Newfoundland margin is highly incised by canyon and valley systems with numerous failure escarpments present on the modern slope

(Mosher and Piper 2007). The Fogo and Newfoundland Seamounts are located in the deeper waters of the Study Area along the southern and southeastern boundaries, respectively. Also in deeper water, the Laurentian Fan is positioned in the extreme southwestern portion of the Study Area and is the only prominent fan-like body on the continental rise (Fader and Piper 1990, in Piper et al 1990).

The continental shelves of Eastern Canada have similar morphological characteristics resulting from the glacial erosion of a previously fluvially-dominated landscape (Piper 1991). This glaciation produced a variety of glacial deposits, including sands and gravels, which are generally present as a veneer, basinal muds, muddy sands and gravels, glaciomarine sediments and glacial drift sediments. Within the Study Area, these deposits have been identified as classified as the Grand Banks Sand and Gravel, Placentia Clay, Adolphus Sand, Downing Silt and Grand Banks Drift, which are illustrated in Figure 4.2 (after Piper et al 1988).

The seabed in the Study Area is characterized by an assortment of features including iceberg scouring, sand ridges and waves, shell beds, pockmarks and seabed depressions of unknown origin (Cameron and Best 1985).

4.1.1.2 Seismicity

Canada's eastern continental margin is tectonically passive and seismicity is relatively rare throughout much of the region. Natural Resources Canada (2013a) estimates that approximately 450 earthquakes occur each year in Eastern Canada, with the majority having magnitudes between two and three. Earthquakes that affect the region typically occur in clusters and at depths ranging from near surface to 30 km. Seismicity generally occurs randomly along the Scotian and Grand Banks margins, except for a concentration of events in the greater Laurentian Channel area known as the Laurentian Slope Seismic Zone. The devastating Grand Banks earthquake of November 1929 (also known as the Laurentian Slope Earthquake) occurred in this seismic zone just 250 km south of Newfoundland and had a magnitude of 7.2. This earthquake triggered a large underwater slump, which severed a number of transatlantic cables and generated a tsunami that was recorded along the eastern seaboard as far south as South Carolina and across the Atlantic Ocean in Portugal (Natural Resources Canada 2011). Rare large earthquakes such as this are to be expected on the passive margins, likely concentrated along old basement lineaments (Keen et al 1990). The geologic record indicates that submarine landslides of similar size have occurred every 150 to 200 thousand years along the passive margin.

According to the National Earthquake Database (Natural Resources Canada 2013a) there have been 180 seismic events recorded within the boundaries of the Study Area between December 1985 and October 2013, as illustrated in Figure 4.3. The magnitudes of these events have been fairly low, ranging from 1.8 to 4.7 with an average magnitude of 3.1 and a median magnitude of 3.0. The vast majority of these 180 events were recorded within or in close proximity to the Laurentian Slope Seismic Zone, the most recent such event occurring on October 5, 2013 and having a magnitude of 3.1. The latest edition of the Seismic Hazard Map (Natural Resources Canada 2013b), indicates that portions of the Study Area have low to high seismic hazard.

Figure 4.1 Overview of Bedrock Geology

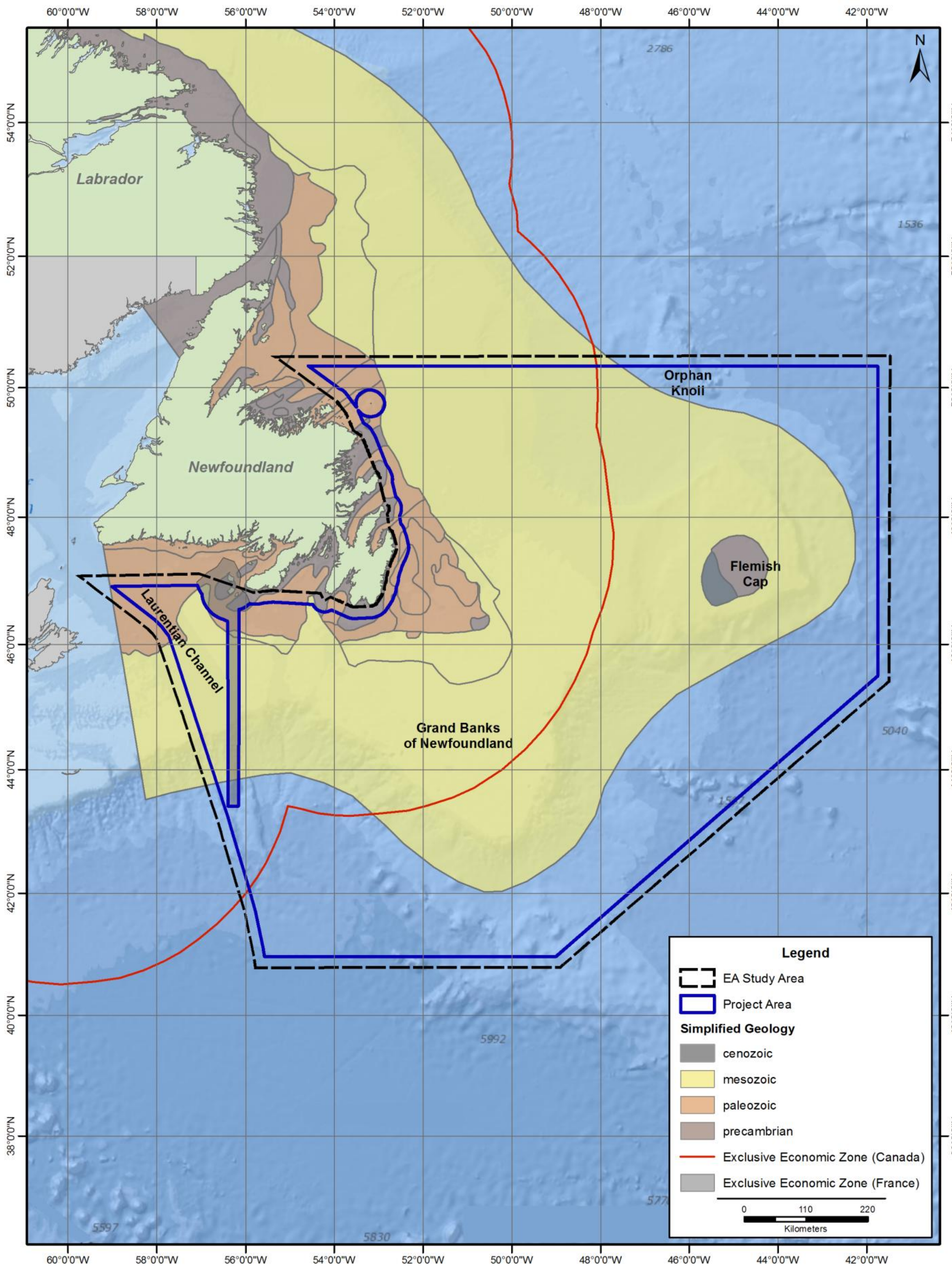


Figure 4.2 Overview of Surficial Geology

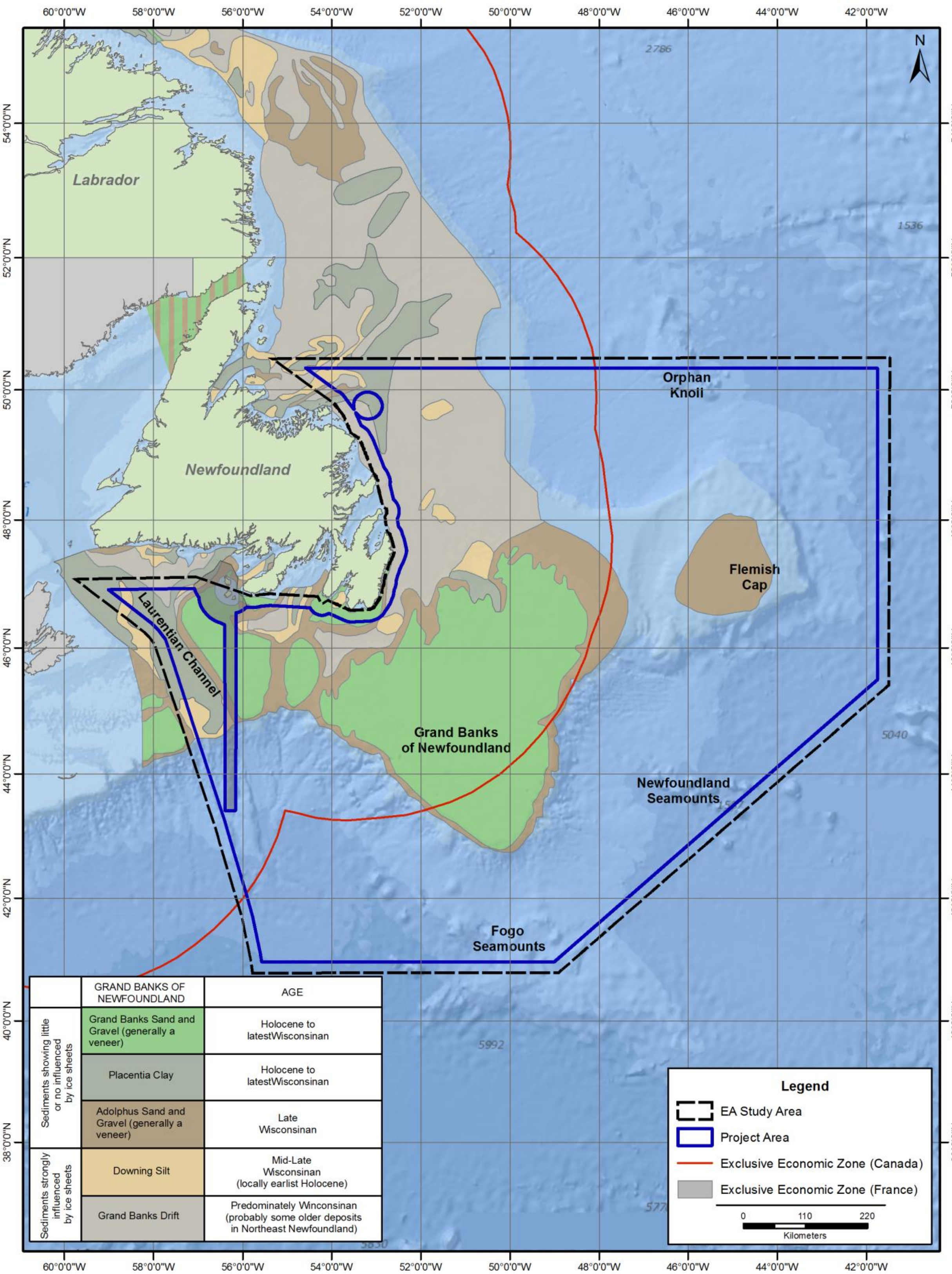
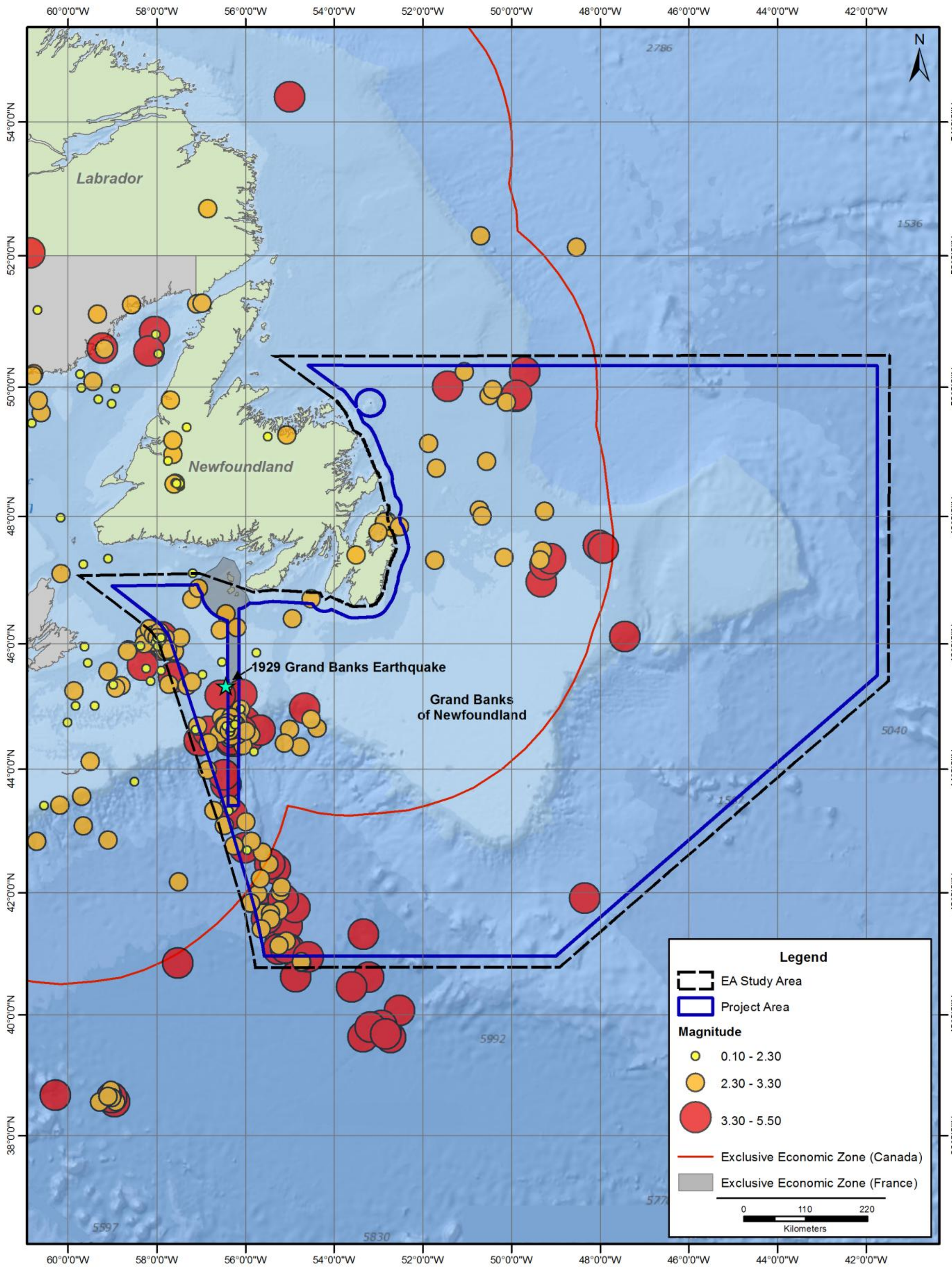


Figure 4.3 Earthquake Epicentres (1984-2013)



4.1.2 Bathymetry

The EA Study Area covers a large expanse of the Northwest Atlantic Ocean, extending approximately 1,000 km north to south and 1,300 km west to east. The Study Area boundary furthest to the east-southeast is about 870 km east of St. John's, while the western boundary is about 100 km northeast of Cape Breton and 100 km southeast of the Cabot Strait. The general bathymetry of the Study Area and surrounding region is shown in Figures 4.4 and 4.5.

The key bathymetric features of the western portion of the Study Area south of Newfoundland are the Laurentian Channel, which runs in a northwest-southeast direction with water depths of 400 to 450 m, and, the St. Pierre Bank which rises to the northeast to depths of about 50 m or less. The central portion of the Study Area contains the Grand Banks, a region with average depths of about 75 m which extend to about 350 km east of St. John's to the 200 m depth contour and then a farther 50 km to the 1,000 m depth contour, as well as the Flemish Pass which has depths of almost 1,300 m. On the eastern side, water depths rise again to the Flemish Cap, a large bathymetric feature of about 50,000 km^2 with depths rising back up about 130 m.

The banks extend also to the north and south. To the south, at the Tail of the Banks comprise numerous canyons which run down off the continental slope into the Newfoundland Basin and deep ocean with depths of 2,000 to 4,000 m. The Southeast Shoal, with depths of about 40 to 50 m, lies about 75 to 125 km to the north of the tail.

The Sackville Spur extends the nose of the Grand Banks at depths of up to 1000 m about 450 km east-northeast from the western boundary of the Study Area. The Grand Banks extend north to the Northeast Newfoundland Shelf, with depths generally of 200 to 300 m. Northeast of the shelf lies the Orphan Basin, with water depths ranging from about 1,200 m at the edge of the continental shelf to as deep as 3,500 m. The Labrador Basin and deep ocean lie farther offshore to the north and east of the Orphan Basin and Flemish Cap, with depths of 3,000 to over 4,000 m.

Figure 4.4 Key Bathymetric Features

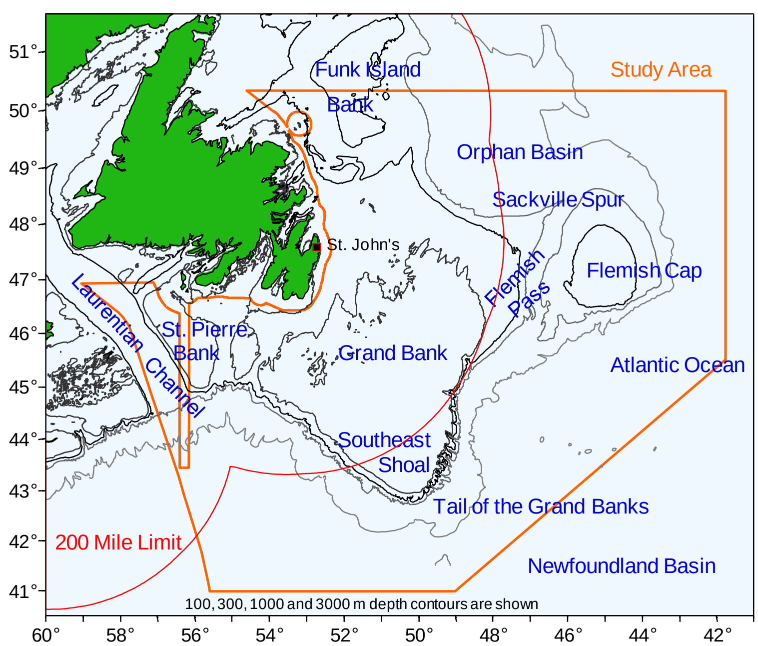
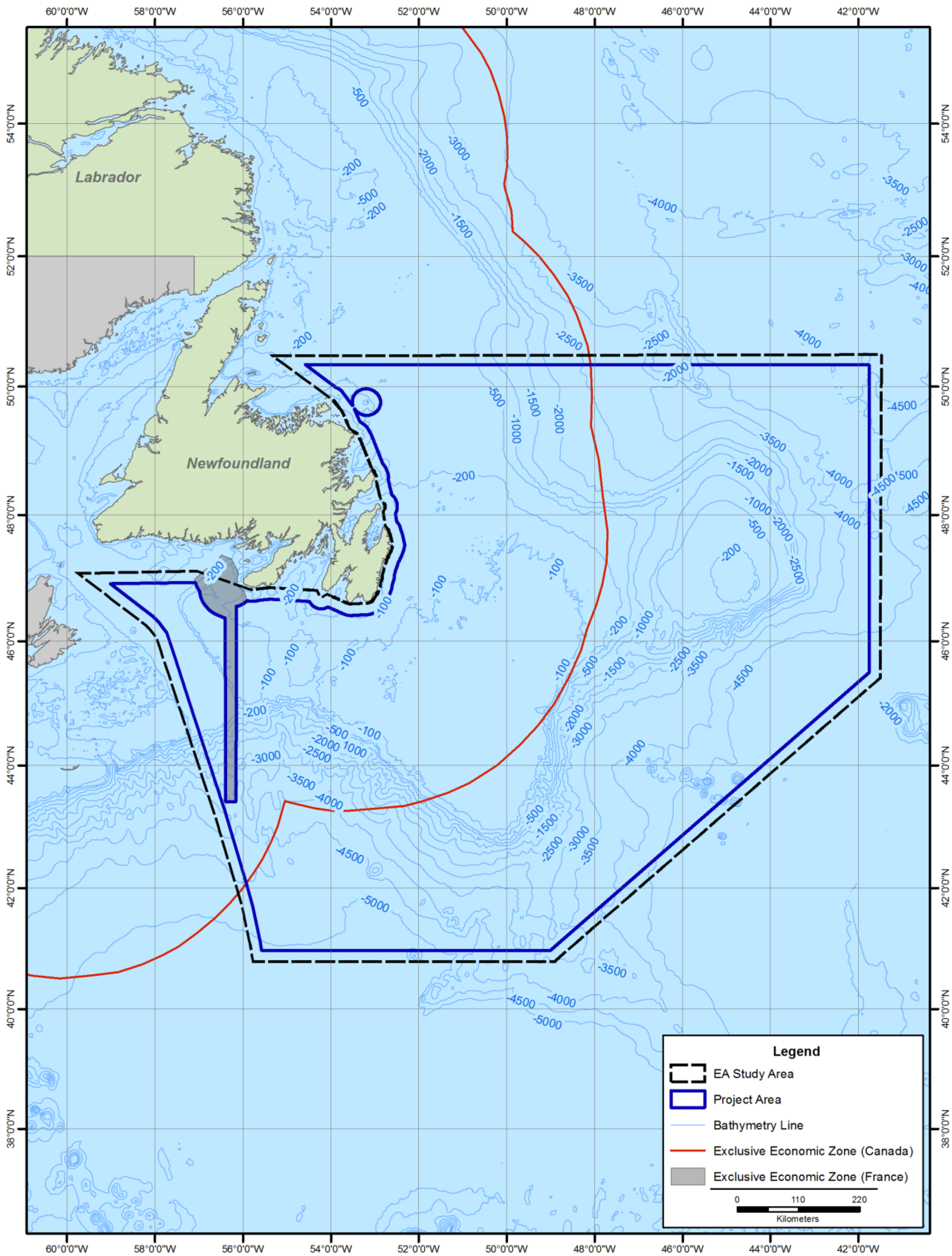


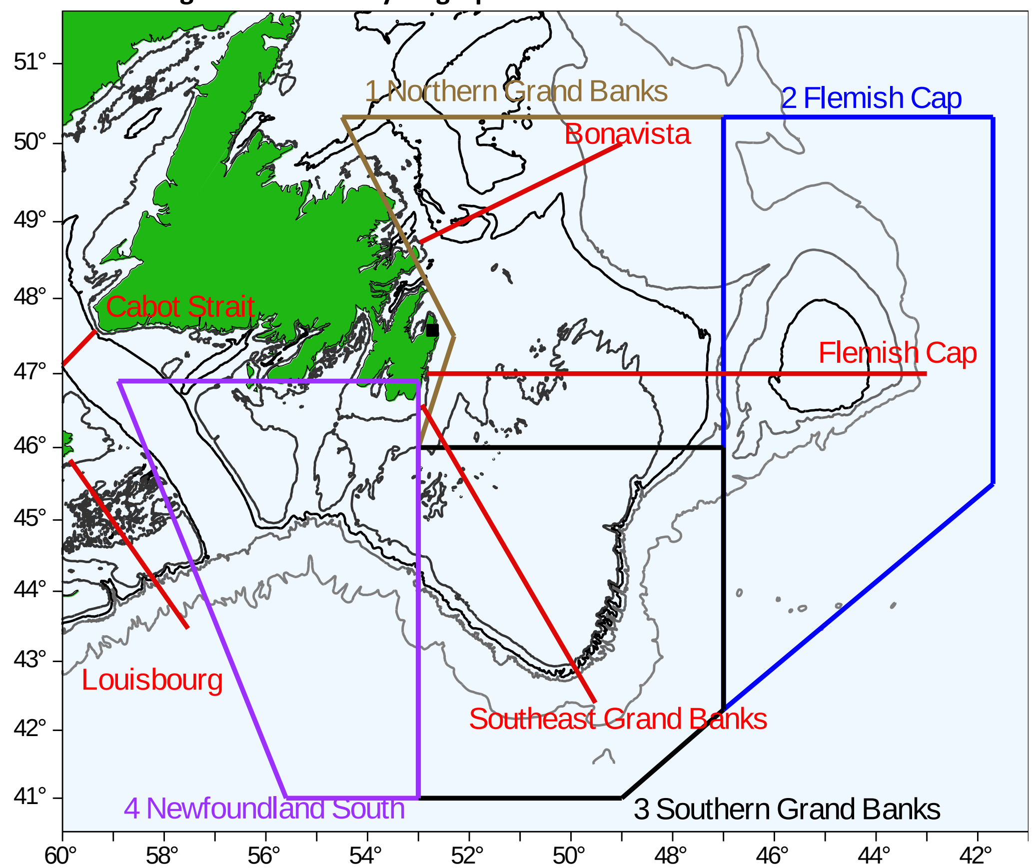
Figure 4.5 General Bathymetry of the Study Area



4.1.3 Climatology

The International Comprehensive Ocean-Atmosphere Data Set (NCAR 2014, Woodruff et al 1998, Worley et al 2005, Woodruff et al 2005) represents the most extensive available database of observations of atmospheric and sea conditions relevant for the Study Area. The dataset consists of global marine (ship and rig) data observations spanning the years 1911 to present, compiled by the National Centre for Atmospheric Research (NCAR). As illustrated in Figure 4.6, four regions were defined for the Study Area, and these were used to query the ICOADS for 1960 to 2013 and assemble statistics of meteorological and marine conditions across this region.

Figure 4.6 ICOADS Regions and DFO Hydrographic Sections

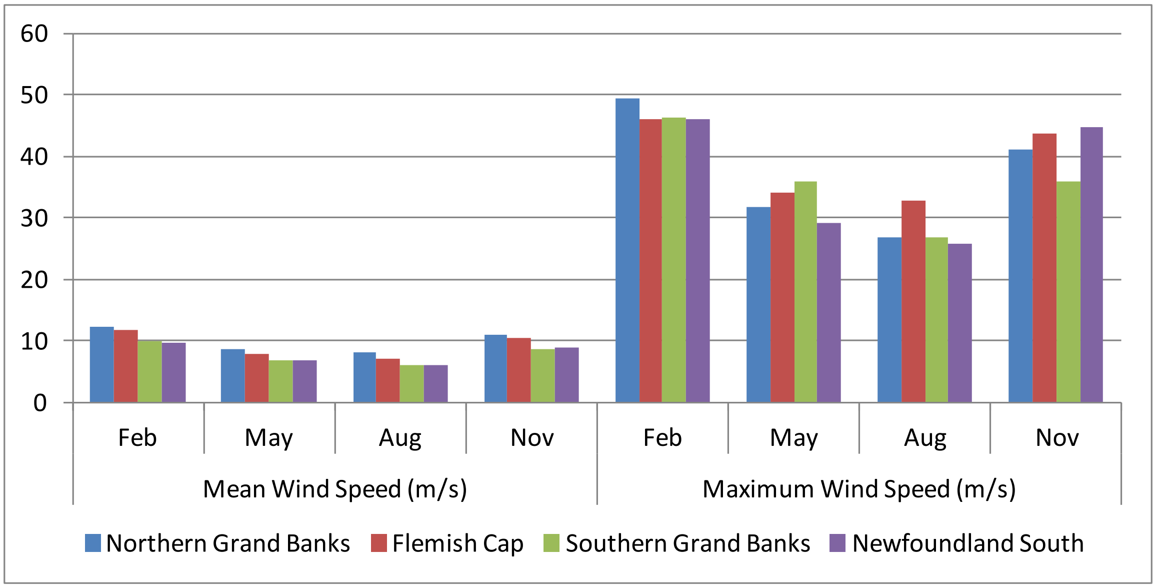


4.1.3.1 Wind

The prevailing winds over the Study Area are from the west to northwest in winter and from the southwest in summer. Extreme wind gusts greater than 100 knots (51 m/s) have been measured in winter and in association with tropical and post-tropical weather systems. The frequency of gales (34 to 40 knots, 17 to 21 m/s) in January is 10-15 percent over most of the area, 15-20 percent for northern parts of the Northern Grand Banks and southwest of the Island of Newfoundland, and as high as 20-30 percent for northeastern portions of the Flemish Cap region. The frequency of gales in July is two percent or less for most of the Study Area, greater than two percent over the Flemish Cap. Many storm systems are still strengthening as they pass through the area; as a result winds over the northeast are on average stronger than those over the southwest (Bowyer 1995).

Figure 4.7 summarizes seasonal monthly mean and maximum wind speeds for the four ICOADS regions that comprise the Study Area.

Figure 4.7 Wind Speeds



4.1.3.2 Air Temperature

Air temperatures in the Study Area overall are coolest in February or January and warmest from July through September for all regions. Table 4.1 presents minimum, maximum and seasonal monthly and annual mean air temperatures for the four regions that comprise the Study Area. Air temperatures are coldest for the Northern Grand Banks, the annual mean being 3°C cooler than the next coldest region and almost 2°C colder in February. The Southern Grand Banks experiences the warmest temperatures annually and in the summer and fall.

Table 4.1 Air Temperature

Air Temperature (°C)	Northern Grand Banks	Flemish Cap	Southern Grand Banks	Newfoundland South
Minimum	-23.9	-13.0	-13.0	-18.6
Mean: Feb	-0.6	3.9	3.7	1.2
Mean: May	4.0	8.4	8.2	7.0
Mean: Aug	13.9	16.0	18.8	17.7
Mean: Nov	4.9	9.2	9.7	8.0
Mean: Annual	5.7	9.2	10.4	8.9
Maximum	24.0	30.0	32.5	33.0

4.1.3.3 Precipitation

Rain can occur at any time of year throughout the EA Study Area and is most likely to occur with southerly or southwesterly winds. Snow and freezing rain are possible any time from October through May, and snow can accompany winds of any direction. Freezing rain is most common with easterly or northeasterly winds. Freezing drizzle frequently persists for days in the spring along the East Coast of Newfoundland. In July the frequency of precipitation over most of the Study Area is five percent and slightly higher at 10 percent for the northwest and northeast. In January, precipitation occurs 20 to 30 percent over most of the Study Area, and is slightly higher at 30 to 40 percent south of the Island of Newfoundland and to the northeast over the Orphan Basin and Flemish Cap (Bowyer 1995).

4.1.3.4 Visibility

In general, visibility is the best in fall and winter and most frequently restricted in summer and spring. Visibility is least favourable for the Northern Grand Banks ICOADS region, and most favourable for the Southern Grand Banks region. Table 4.2 summarizes conditions based on the ICOADS dataset, with visibility classes defined as very poor (< 0.5 km), poor (0.5 to 2 km), fair (2 to 10 km) and good (> 10 km).

Table 4.2 Visibility

Visibility	Northern Grand Banks	Flemish Cap	Southern Grand Banks	Newfoundland South
Fair or Good	51% in Jul to 88% in Oct, Dec, Jan	66% in Jul to 93% in Oct to Feb	64% in July to 91% in Oct, Dec, and Jan	75% in Jun and Jul to 90% or better Sep through Mar
Poor or Very Poor	12-15% in winter to 49% in Jul	7% in winter to 34% in Jul	one third of the time in Jun and Jul to 9 to 11% in fall and winter	25% in Jun and Jul to 5-10% from Sep through March

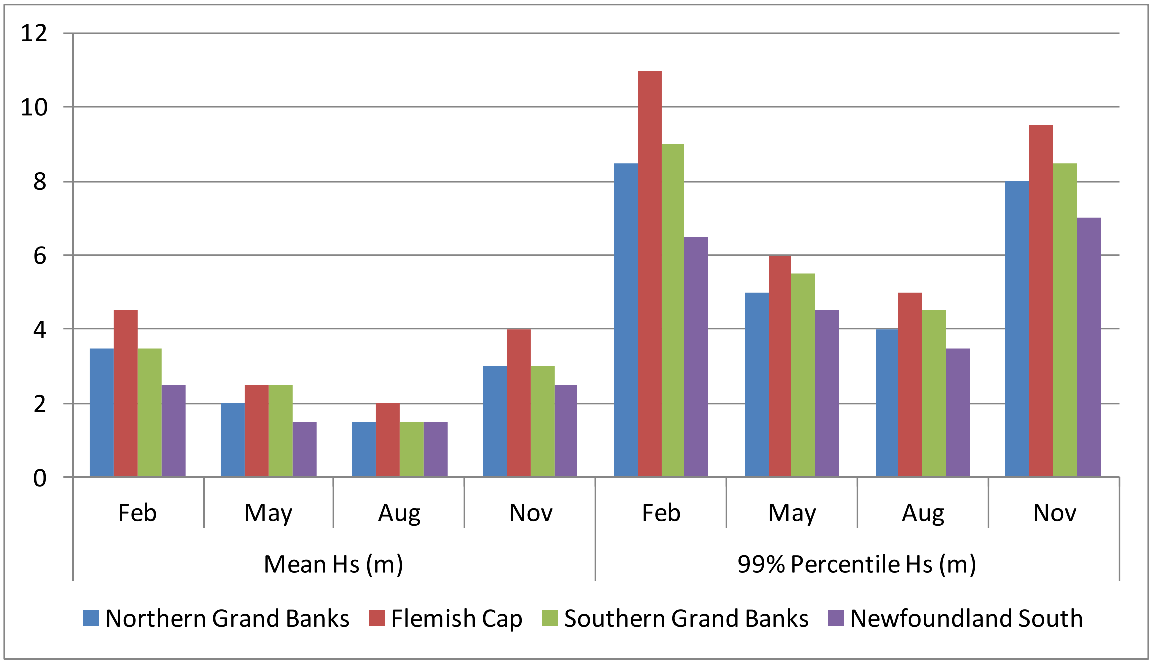
4.1.4 Oceanography

As described above, the ICOADS (1960 to 2013) datasets and other sources were used to provide an overview summary of oceanographic conditions across the Study Area, based on each of the subregions shown in Figure 4.6 above.

4.1.4.1 Waves

A summary of regional wave conditions as reported in the MSC50 hindcast climatology (Oceanweather 2011), for the period 1955 to 2004, is presented in Figure 4.8 for the four ICOADS regions that comprise the Study Area. Seasonal monthly mean and maximum significant wave height (Hs), estimated to the nearest 0.5 m are reported. The largest seas are seen farthest offshore, namely for the Flemish Cap and Southern Grand Banks regions described here. Mean significant wave heights in spring and summer (May and August) range from 1.5 to 2.5 m, and in fall and winter (November and February) range from 2.5 to 4.5 m. The 99th percentile values of significant wave height range from approximately 4 to 6 m in May and August to 7 to 9.5 m in November and 6.5 to 11 m in February.

Figure 4.8 Significant Wave Height



4.1.4.2 Ocean Currents

The circulation of the Study Area, which includes the continental shelf waters off Eastern Canada, is dominated by a generally southward flow of the cold Labrador Current and its 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. The current's inshore branch tends to flow mainly in the Avalon Channel along the coast of the Avalon Peninsula but may sometimes also spread further on the Grand Banks.

In the western regions south of Newfoundland, the general circulation consists of modified Labrador Current waters, the inshore branch of which flows through the Avalon Channel and around Cape Race. This branch then divides into two parts, one flowing to the west around the north of St. Pierre Bank, and the other flowing to the south between the south of St. Pierre Bank and Green Bank. This southern branch then joins a part of the offshore branch that has flowed around the Tail of the Grand Bank, westward along the continental slope to the Laurentian Channel and goes up into the Gulf of St Lawrence (Colbourne and Murphy 2008). In the southwestern portions of the Study Area, the Gulf Stream flows to the east south of the Tail of the Grand Banks

The offshore branch of the Labrador Current flows over the upper Continental Slope at depth, and through the Flemish Pass has average speeds of approximately 40 cm/s. Over parts of the Grand Banks with water depths less than 100 m, the mean currents are generally weak (< 10 cm/s) and flow southward, dominated by wind-induced and tidal current variability.

4.1.4.3 Seawater Properties (Temperature, Salinity)

Summaries of winter and summer sea temperature and salinity derived from DFO's Climatology for the Newfoundland Shelf (DFO 2012a) are provided in Tables 4.3 and 4.4. Four geographic areas have been selected to characterize the conditions for EA Study Area, although it is noted these cover only a portion of the Newfoundland Shelf:

- Area 30 (NE Newfoundland Shelf, depth=600 m) for Northern Grand Banks;
- Area 36 (Flemish Cap, W Slope, depth=1000 m) for Flemish Cap;
- Area 52 (SE Grand Bank, depth=1000 m) for Southern Grand Banks; and
- Area 65 (Laurentian Channel, depth=500 m) for Newfoundland South

Average sea surface temperatures generally range from about -1°C to 3°C in February and from about 10°C to 16°C in summer, whereas mean near-bottom sea temperatures generally range from 3°C to 5°C year-round.

Average sea surface salinities range from about 32 psu in the western portion of the Study Area to almost 34 psu to the northeast. Although Table 4.4 shows near-bottom salinities above 34 psu, this accounts for the deep waters in those regions. Over the shallower banks of the region (e.g., St. Pierre Bank and Grand Bank), near-bottom salinities typically range from approximately 32 to 33 psu in winter and 32.7 to 33.3 psu in summer.

Table 4.3 Sea Temperature

Mean Sea Temperature (°C)	Northern Grand Banks	Flemish Cap	Southern Grand Banks	Newfoundland South
Feb: Surface	-1.1	3.1	1.3	0.2
Feb: Mid-Depth	2.2	4.1	0.8	6.3
Feb: Near-Bottom	3.2	3.8	-	4.6
Aug: Surface	10.8	12.4	16.1	16.0
Aug: Mid-Depth	2.8	4.1	3.0	6.0
Aug: Near-Bottom	3.7	4.0	-	5.0

Table 4.4 Salinity

Mean Salinity (psu)	Northern Grand Banks	Flemish Cap	Southern Grand Banks	Newfoundland South
Feb: Surface	33.2	33.9	32.8	32.1
Feb: Mid-Depth	34.2	34.9	33.3	34.6
Feb: Near-Bottom	34.6	34.9	-	34.9
Aug: Surface	31.8	33.0	32.3	31.5
Aug: Mid-Depth	34.6	34.9	34.7	34.6
Aug: Near-Bottom	34.9	34.9	-	34.9

4.1.5 Ice Conditions

Portions of the Study Area are subject to seasonal intrusions of se ice and icebergs, as well as vessel icing during particular meteorological conditions and events.

4.1.5.1 Sea Ice

The Sea Ice Climatic Atlas for the East Coast 1981-2010 (CIS 2011) reports how frequently sea ice is present, its concentration when present, and its predominant ice type and hence thickness. In the northwest portion of the Study Area, sea ice can be present as early as the first week of January. By the week of February 12, sea ice is present two of every three years; from the end of April through mid- to late-May (Figure 4.9) sea ice may be expected from one in every three to two in every three years. From mid-June to the first week or two of July there is a 1 to 15 percent chance sea ice will be present, though over much smaller areas just to the northwest.

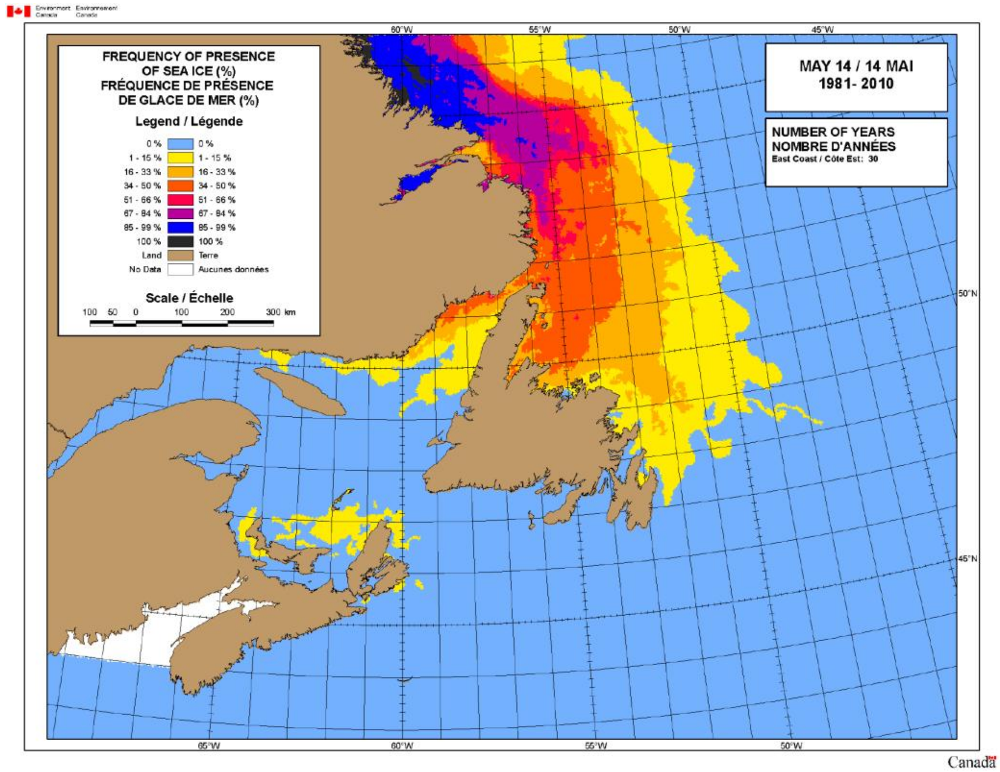
The frequency of presence of sea ice for the western portion of the Study Area south of Newfoundland is 16 to 33 percent by the end of January and is most likely to occur about the second week of March, being present then from 50 to 66 percent of the time. By the third week of April the frequency of presence has dropped to 15 percent or less and by the end of April sea ice is normally absent from the western portion of the Study Area.

Sea ice generally appears in the eastern portion of the Study Area, from 16 to 33 percent of the time as far south as 48°N and as far west as 49°W by the end of January and reaches its furthest extent east and south in March and the early part of April, reaching to 45°N and 49°W about one every six years. Closer to shore, sea ice is more frequent being present for example mid-March for 67 to 84 percent of the time at 49°N, northeast of the Bonavista Peninsula, and as far east as 51°W. By the end of April, ice may be seen east of the Avalon Peninsula and in patches on the Grand Banks from one to 15 percent of the time, from 16 to 33 percent of the time off the northeast coast, and ice free south of the island.

As illustrated in the companion Figure 4.10 below, for the second week of May ice concentrations (when ice is present) may be as low as 1/10 to 3/10 in pockets near the coast and farther offshore to the east. Concentrations as high as 9/10 to 9+/10 may also be experienced in small patches in the northwest portion of the Study Area and farther offshore to the east. Larger areas of 7/10 to 8/10 concentration are encountered northeast of the Avalon and Bonavista Peninsulas and as far as the Orphan Basin.

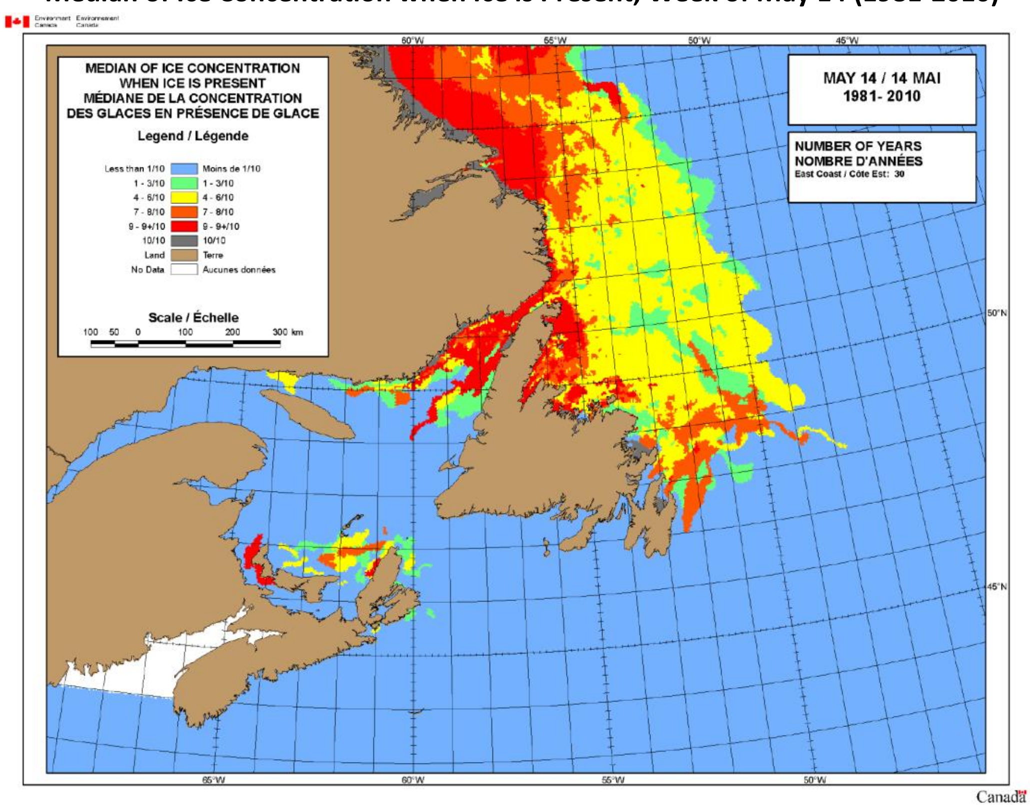
The median of predominant ice type when ice is present in January ranges from new ice of thickness 10 cm or less to grey-white ice of thickness 10-30 cm. Thin first year ice sea ice (30-70 cm) is present by mid-February over regions farthest offshore. By mid-March, the median of sea ice present over the Study Area is thin first year with patches of medium first-year ice (70-120 cm). Thick first year ice (greater than 120 cm) is commonly the median of the predominant ice type from mid-April to the end of May. Old ice (namely, that which has survived at least one summer’s melt) appears from late May through June as the predominant sea ice type when ice is present in several areas east of Newfoundland.

Figure 4.9 Frequency of Presence of Sea Ice (%),Week of May 14 (1981-2010)



Source: CIS (2011)

Figure 4.10 Median of Ice Concentration when Ice is Present, Week of May 14 (1981-2010)



Source: CIS (2011)

4.1.5.2 Icebergs

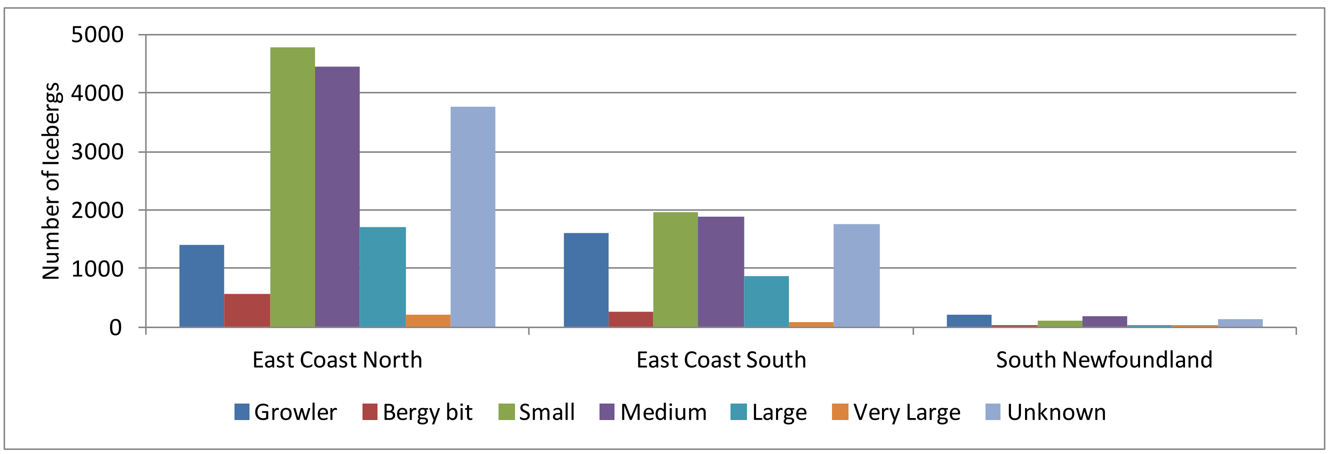
A summary of iceberg sightings from the comprehensive NRC-PERD Iceberg Sighting Database (NRC 2013) for the years 1983 to 2012 is presented below for three sub-regions covering the Study Area:

- East Coast North: 47 to 50.33°N, 53 to 41.75°W;
- East Coast South: 41 to 47°N, 53 to 41.75°W; and
- South Newfoundland: 41 to 47°N, 53 to 41.75°W

The iceberg sightings are from various sources including industry, aircraft and ship, and include radar, visual and measured observations. Statistics are reported here for first iceberg sightings (excluding any re-sightings of the same iceberg), and include size classes ranging from growlers (less than 1 m in height, less than 5 m in length and mass about 500 t) to very large icebergs (50 to 100 m in height, 100 to 200 m in length and mass about 5 tonnes). Icebergs of unknown size are also reported. These criteria yield 26,023 icebergs.

As illustrated in Figure 4.11, the majority of icebergs are first observed in the East Coast North sub-region: almost 16,900 over the past 30 years, compared with 8,400 for the East Coast South, and just 700 for South Newfoundland, which have either drifted around the Avalon Peninsula or entered from the Cabot Strait to the west. Of the 20,362 icebergs for which size is known, 20 percent are growlers or bergy bits, 66 percent are small or medium, 13 percent are large, and just over one percent are very large.

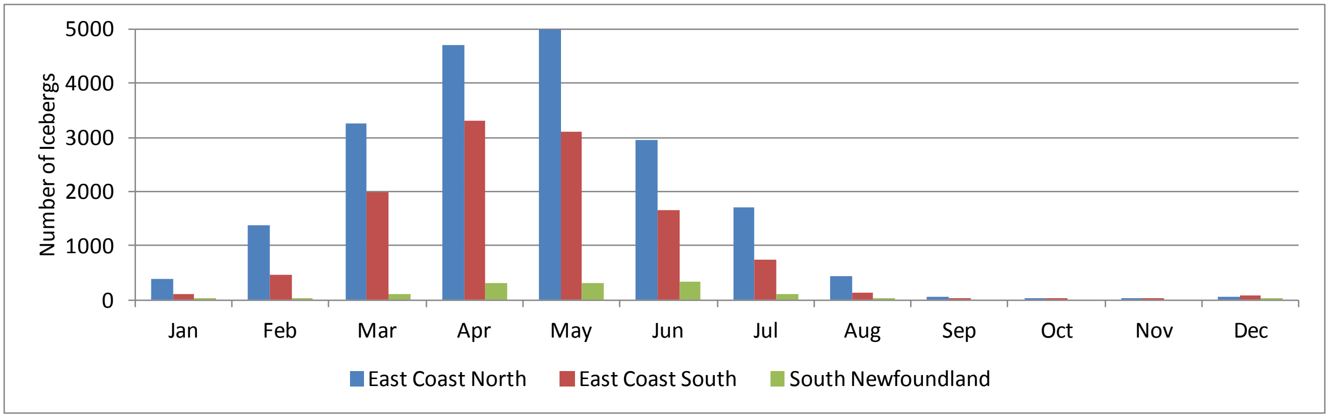
Figure 4.11 Iceberg Sightings in the Study Area by Size Category (1983-2012)



Source: Data from NRC (2013)

The iceberg season for the Study Area traditionally lasts from January through August, with 85 percent of first sightings during March through June (Figure 4.12). There have been five sightings as late as August (a large iceberg 18 August 1991) in the South Newfoundland sub-region, while icebergs have been sighted as late as December. Each ice season is different: the number of icebergs reported annually for the East Coast North ranges from zero in 2005 and 2006 to 2,027 in 1998 and averages 563. For the East Coast South, just over 1,000 icebergs were sighted in both 1990 and 1991: the annual average is 281. For the South Newfoundland sub-region, about 15 icebergs might be expected in any given year.

Figure 4.12 Iceberg Sightings in the Study Area by Month (1983-2012)



Source: Data from NRC (2013)

4.1.5.3 Vessel Icing

Vessel icing, most frequently from freezing spray, is a marine condition that can hinder and limit shipboard activities, increase a vessel's weight and alter its centre of gravity. Freezing spray is most likely to occur from November through April. Air temperatures must be lower than -2°C to produce freezing spray in salt water. Icing conditions are worsened with colder temperatures, high winds and large waves. For example, at a temperature of -5°C, icing potential is light for wind speeds of about 10 to 25 knots (19 to 46 km/h), moderate from 25 to 40 knots, heavy for 40 to 60 knots, and very heavy for winds greater than 60 knots. Heavy icing can be experienced at wind speeds as low as 18 knots (33 km/h) when air temperatures are as cold as -15°C (Bowyer 1995). The potential for vessel icing varies over the Study Area, being the greatest in the northwest off the northeast coast of Newfoundland and in the west, just south of the island. In January the potential for moderate icing or worse is about 20 percent of the time; to the south and eastern portions of the EA Study Area the potential in January is five percent or less.