3.0 PHYSICAL ENVIRONMENT

The following sections provide an overview of the existing physical environment of the SEA Area. This description is based upon existing, readily available information gathered through a review of the published literature, unpublished reports, and other relevant information sources.

3.1 Sydney Basin Offshore Area Geology

Cape Breton Island has been a coal-mining area since the 1700s both on and offshore. Hydrocarbons are present in sandstones and along faults in mines and gas emerges at the sea floor along faults (Pascucci et al. 2000). The bedrock geology is primarily Pennsylvanian, except along the coastal section of the SEA Area, with isolated pockets of Tertiary-Pleistocene on the Burgeo Bank and in the Cabot Strait near Port aux Basques.

A large upper Paleozoic basin offshore Newfoundland is saucer-shaped and filled with 4 to 5 km of basinal fill. The SEA Area is composed of two lower-crustal blocks, the Avalon and the Central block (Pascucci et al. 2000). The geology of the SEA Area is summarized in Table 3.1. At the Earth's surface is the Pictou Group (approximately 1,000 m), consisting of red mudstone and sandstone. This overlies three formations in the Morien Group, from top to bottom: Sydney Mines, Waddens Cove, and Basal South Bar. The Sydney mines formation is approximately 1,000 m thick, consists of sandstone, grey and red mudstone, coals, limestone, and calcrete. The Waddens formation consists of red alluvial deposits and minor coal. Underneath that is the Basal South Bar formation, an 860-m thick, sandstone-dominated, braided-fluvial unit, containing minor coal. Both the Pictou Group and the Morien Group are part of the Upper Carboniferous succession. Underneath this is the Lower Carboniferous succession, which consists of three rock groups, from top to bottom: Mabou Group, Windsor Group, and Horton Group. The Mabou Group is approximately 100 m of lacrustine siliciclastic rocks, sulphate evaporate and limestone. The Windsor Group consists of marine and continental evaporate, carbonate and siliciclastic rocks, up to 1 km thick. The Horton Group is mainly alluvial conglomerate and sandstone, approximately 3 km or thicker. The Morien and Pictou Groups are at the surface over most of the basinal area (Gibling et al. 2002), so it is assumed that the surficial sediments are mudstone and sandstone.

Table 3.1 Geology of the Sydney Basin Offshore Area

Succession	Group	Layer name	Layer thickness (m)
Upper Carboniferous	Pictou	red mudstone (shale) and sandstone	1,000
	Morien: 1500 to 1800 total thickness	Sydney mines formation: sandstone, grey and red mudstone, coals, limestone, and calcrete	1,000
		Waddens Cove formation: red alluvial deposits, minor coal	approximately 100
		Basal South Bar formation: sandstone dominated, braided-fluvial unit, minor coal	860
Lower Carboniferous	Mabou	lacrustine siliciclastic rocks, sulphate evaporate, limestone	100
	Windsor	marine and continental evaporate, carbonate, and siliciclastic rocks	1,000
	Horton	mainly alluvial conglomerate and sandstone	3,000
Source: Gibling et al. 2002.			

The sediment offshore of Cape Breton Island has been well-studied. A 24-cm mudstone overlies a coal seam of the Morien Group off Cape Breton. This mudstone divides channel sandstone body into two sandstone units of 8.56 and 2.56 m, for the upper and lower layers, respectively. Sandstones in the Sydney Mines formation are fine-grained, and have a mean inter-granular porosity of 8.5 percent, and mean vertical permeability of 0.88 millidarcies.

Pennsylvanian sediments are comprised of conglomerate, sandstone, shale, coal and minor limestone (Fader et al. 1982). The sediments of the SEA Area (which occurs east of Cape Breton Island, beneath the Laurentian Channel) are a continuation of the coal-bearing strata that extends across the Laurentian Channel, from Cape Breton Island to within 9 to 19 km of the coast of insular Newfoundland (Fader et al. 1982).

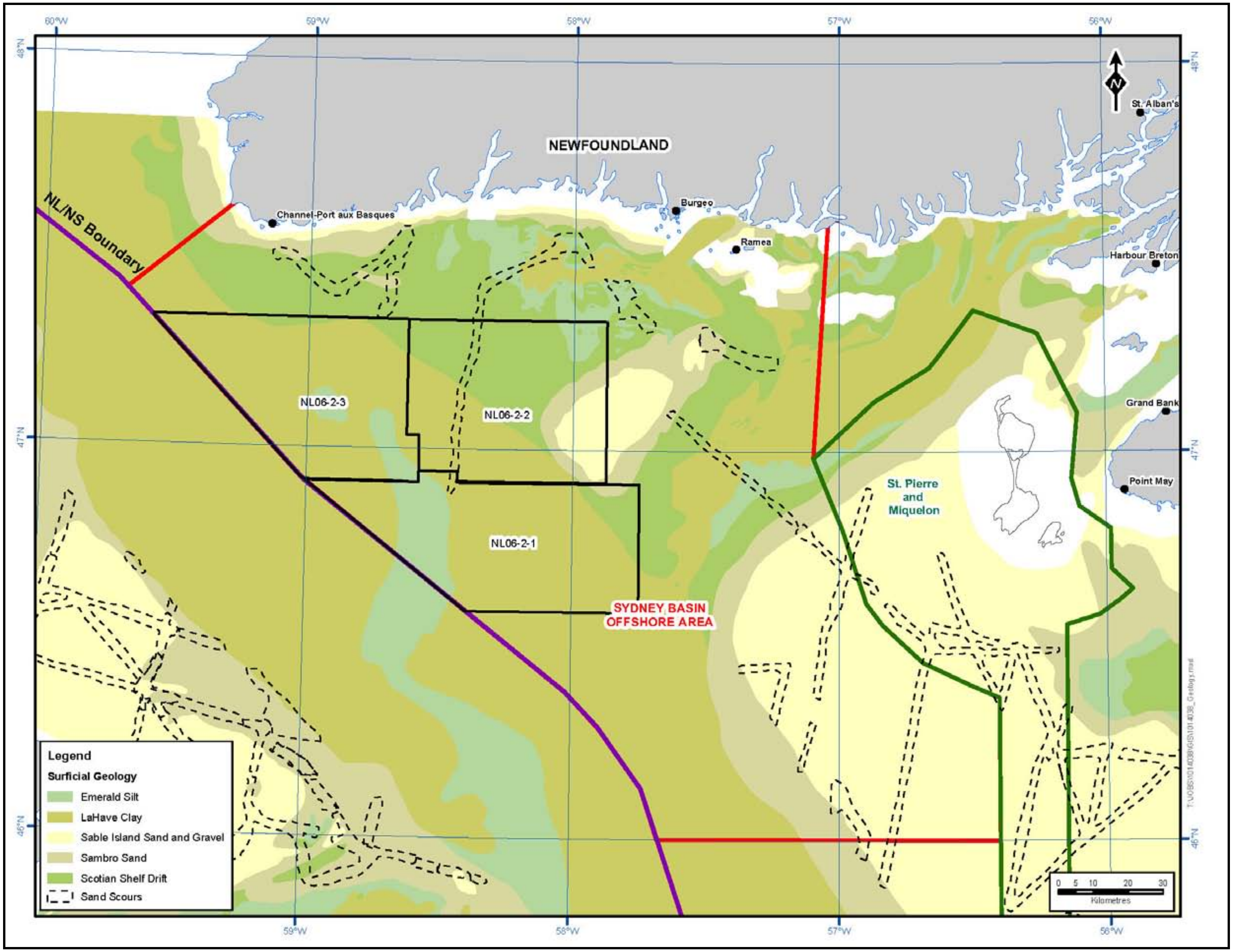
The edge of the Laurentian Channel is fringed with Sambro Sand, a dark, greyish-brown, fine to coarse grained sediment with some silt and clay-sized particles as illustrated in Figure 3.1. The Laurentian Channel seabed is comprised of LaHave Clay, a primarily clayey silt (marine mud). A portion of the Laurentian Channel is overlain with Emerald Silt, a proglacial clayey and muddy silt (Fader et al. 1982)

The Laurentian Channel, which runs through the SEA Area, is located along the Newfoundland Fracture Zone (Figure 3.2), which is regarded as the most seismically active portion of the Newfoundland Continental Shelf (Petro-Canada 1995). A number of earthquakes have been recorded in this area, most of which occurred in the Laurentian Slope Seismic Zone, located at the southern end of the channel. Most of the earthquakes are thought to be associated with the Glooscap Fault portion of the Newfoundland Fracture Zone (Seaconsult 1988, cited in Husky Oil 2000).

The largest earthquake (magnitude of 7.2, with aftershocks having magnitudes as high as 6.0) occurred in November 1929. A large tsunami (seismic sea-wave) generated from the earthquake resulted in considerable destruction and loss of life on Newfoundland’s Burin Peninsula (Trifunac et al. 2002). The approximate locations of the epicentres for a number of historic earthquakes (1929 to 1980) are illustrated in Figure 3.2 (Mobil Oil 1985; Petro-Canada 1995). Past seismic events are not well documented for the offshore, particularly for earthquakes with magnitudes of less than 5.0 (Seaconsult 1988, in Petro-Canada 1995).

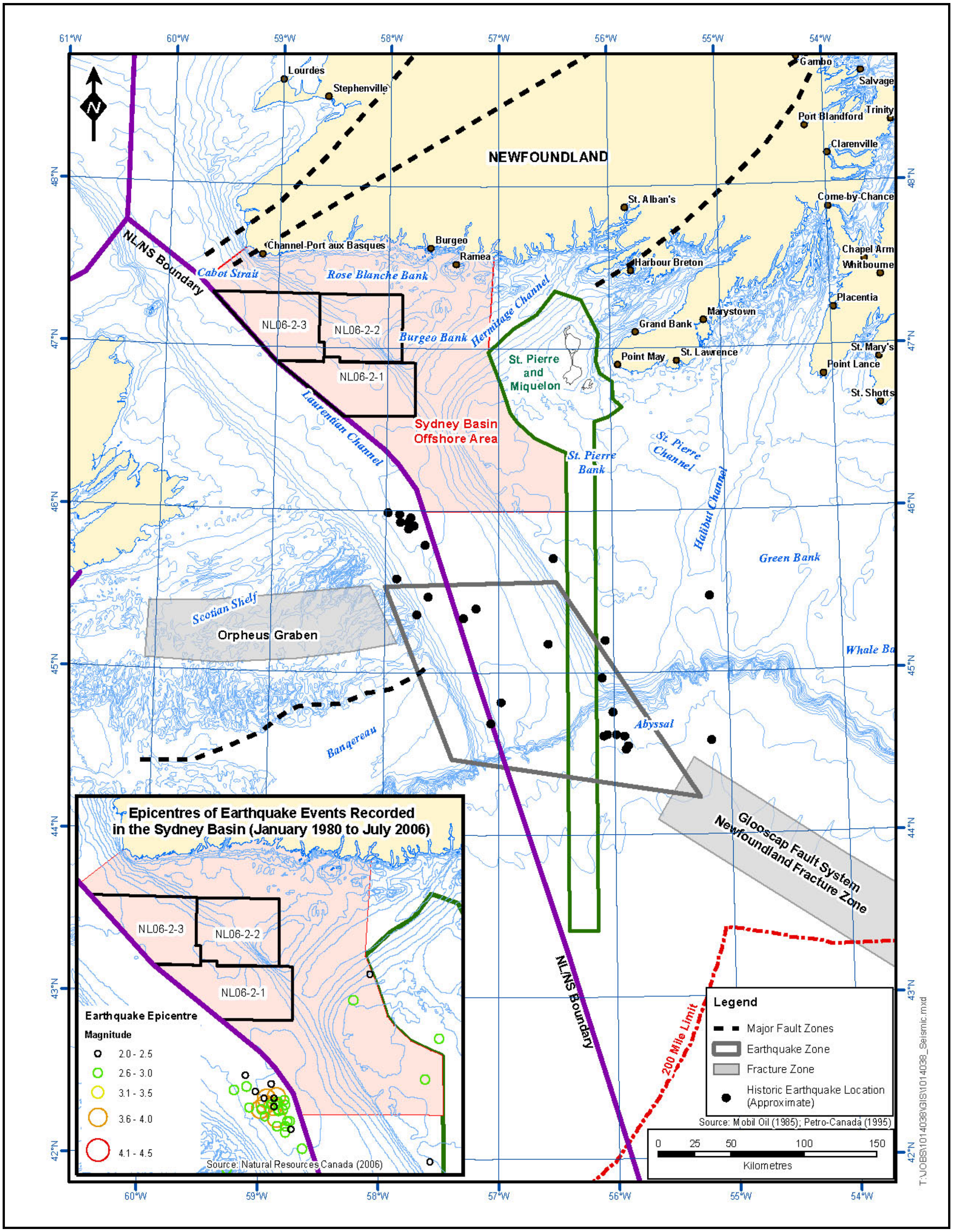
Earthquake information for the period 1980 to present is available from the National Earthquake Database (Natural Resources Canada 2006). The approximate locations of the epicentres for those recorded within the Sydney Basin are illustrated in Figure 3.2. From January 1980 to July 2003, there were 53 events recorded within the boundaries of the SEA Area (Natural Resources Canada 2006). However, the magnitudes of these earthquake events have been relatively low, ranging from 2.0 to 4.5, with an average magnitude of 2.88. The most recent event occurred on February 3, 2006 (having a magnitude of 2.8). As illustrated in Figure 3.2, the epicentres of the majority of these recorded events were in the west-central portion of the SEA Area (see Appendix C for additional information on the dataset).

Figure 3.1 Marine Geology in the Strategic Environmental Assessment Area



Source: Fader et al. 1982.

Figure 3.2 Seismicity in the Strategic Environmental Assessment Area



3.1.1 Coastal Geomorphology

The bedrock geology of the southwest coast is primarily pre-Pennsylvanian (acoustic basement (undifferentiated), includes Pre-Cambrian to Devonian volcanic, sedimentary, high grade metamorphic and granite rocks; it may locally contain some younger sedimentary and volcanic rocks) and are the oldest rocks in the SEA Area.

3.2 Bathymetry

The key features of the SEA Area are the Laurentian Channel, which traverses the SEA Area in a northwest-southeast direction (Figure 3.3). Channel water depth in the SEA Area is 400 m, with some areas within the three exploration leases 450 m deep. Two important fishing areas in the SEA Area are the Rose Blanche (water depth is approximately 125 to 150 m) and Burgeo (water depth is approximately 100 m, minimum 70 m) Banks. The Burgeo Bank is adjacent to the Hermitage Channel, which branches off the Laurentian Channel and has a water depth of approximately 250 to 350 m and an average width of 37 km.

3.3 Climatology

Wind and wave climate summaries are presented based on hindcasts available from Environment Canada's Meteorological Service of Canada (formerly the Atmospheric Environment Service (AES)). The best available source of wind and wave information for estimation of normal and extreme waves is the AES40 North Atlantic Wind and Wave Climatology.

The AES40 grid points for the South Coast of Newfoundland and the SEA Area are shown in Figure 3.4. There are six selected grid points spanning the SEA Area that were used to describe wind conditions within the SEA Area (circled in green on Figure 3.4). Two grid points, 5683 and 5540 have location information described thereby providing area context for the grid locations used in the description of wind conditions for the SEA Area. Grid point 5683 is approximately 65 km east of Port Aux Basques, 50 km west of Burgeo, 177 km to St. Pierre and 200 km to Cape Breton. Grid point 5540 at the South is approximately 195 km south east of Port Aux Basques, 148 km south of Burgeo, 106 km southwest of St. Pierre and 175 km east of Cape Breton.

Figure 3.3 Marine Physiography in the Strategic Environmental Assessment Area

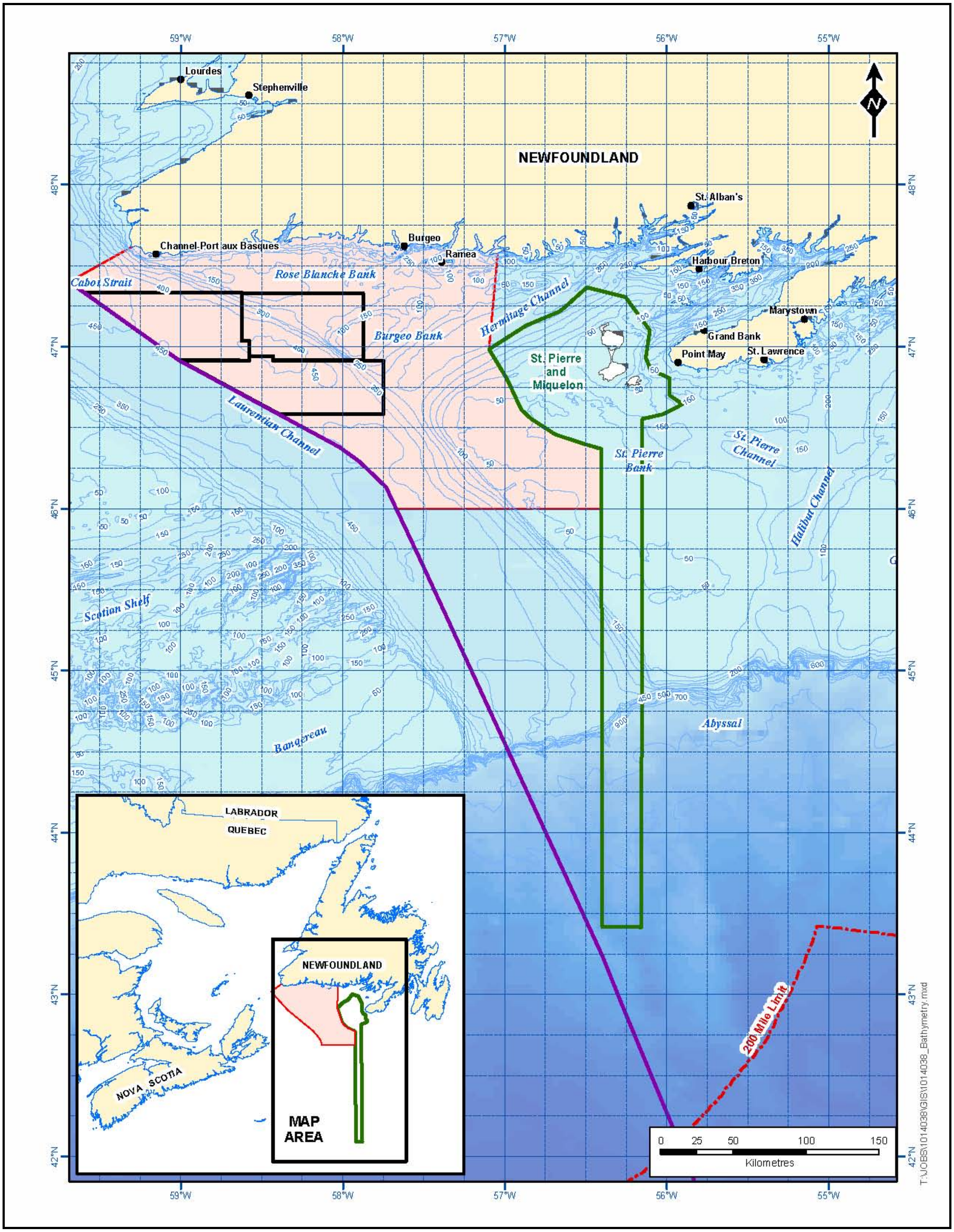
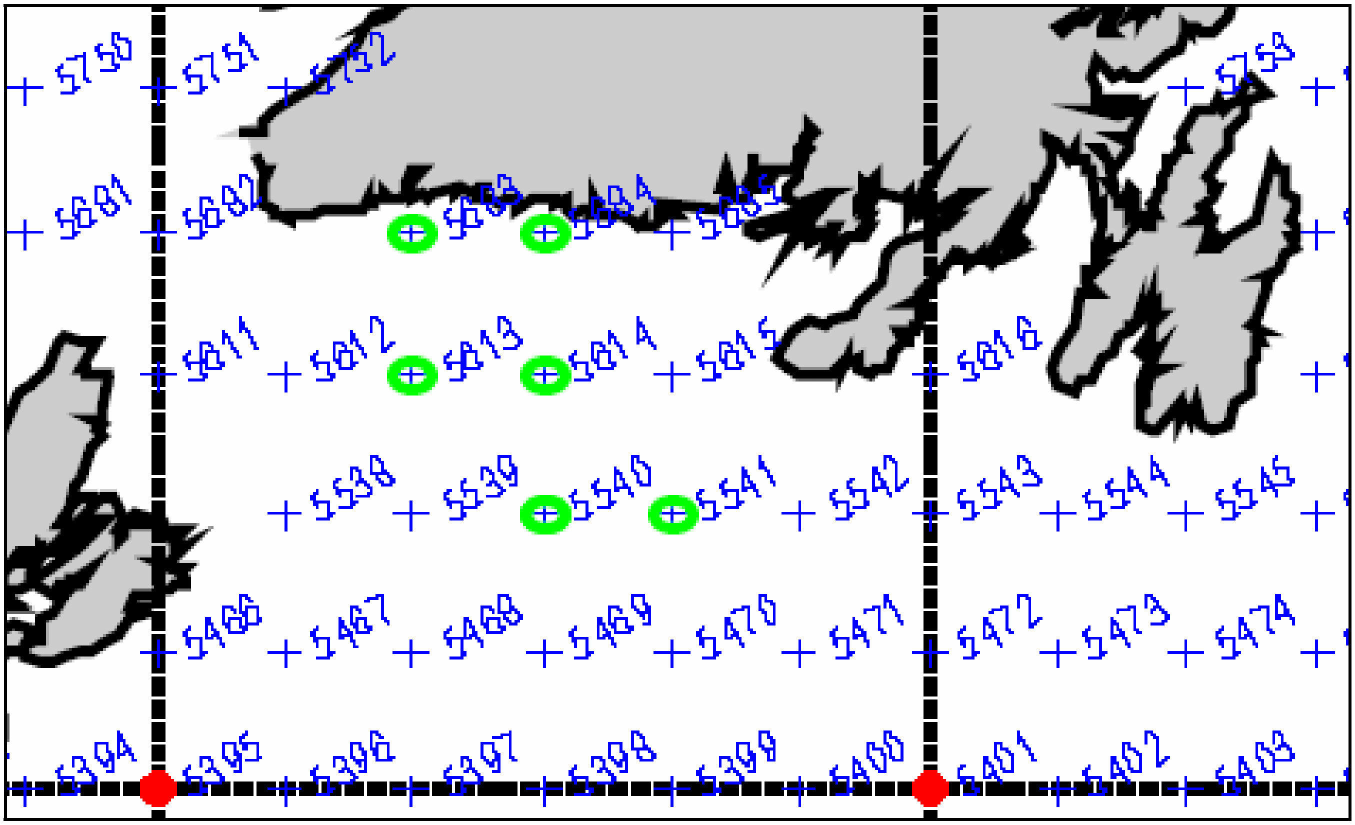


Figure 3.4 AES40 North Atlantic Wave Climatology Gridpoints



(Source: http://www.oceanweather.com/metocean/aes40/AES40-Grid-Images.pdf)
Selected Grid Points for the Strategic Environmental Assessment Area are highlighted

3.3.1 Wind Conditions

Given the area of interest being relatively large, six AES40 nodes (Figures 3.4 and 3.5) were considered to make some comparisons and justify a good representation. Yearly wind directional distribution roses are presented in Figure 3.5 and monthly mean (over the 48 years of data) and maximum wind speed are presented in Figure 3.6. The two southern-most grid points 5540 and 5541 are shown in red. Grid points 5683 and 5684 to the north are shown in blue, while the two middle grid points 5613 and 5614 are shown in green.

The mean wind frequency direction and amplitude are similar for the six grid points or nodes. Yearly mean frequency roses are pretty much the same and only a maximum of 1 m/s difference is seen between the mean speed of extreme nodes, in winter. As a general overview, nodes situated more to the northwest offshore exhibit, on average, slightly stronger wind (nodes 5613 and 5540) than the northern ones situated near the coast (nodes 5683 and 5684).

The differences of maximum wind speed are more pronounced, with differences reaching up to 6 m/s for some nodes in spring and summer, but staying on the same order or magnitude with stronger winds offshore northwest and weaker in the north. The 5541 node maximum peak of July is associated with Tropical Storm Ana in 1985.

Therefore, in terms of representing monthly percentage of wind speed by direction, one node is believed to be adequate taking in account the preceding brief discussion.

Grid point 5614 was deemed to be representative of the area and its results are represented in Figure 3.7 and Table 3.2.

Figure 3.5 Yearly Directional Distribution of Wind Speed per Grid Point for the Strategic Environmental Assessment Area

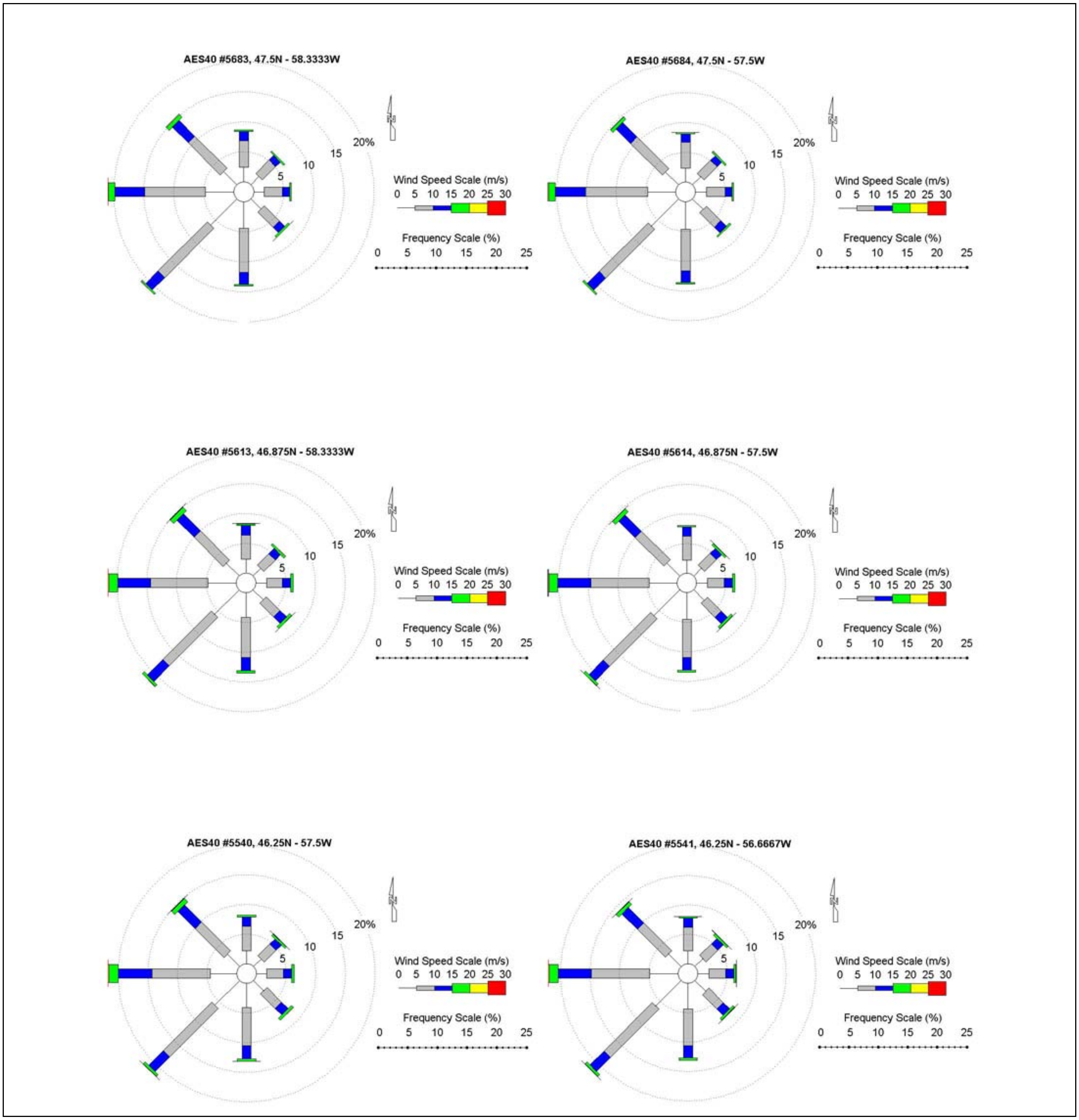
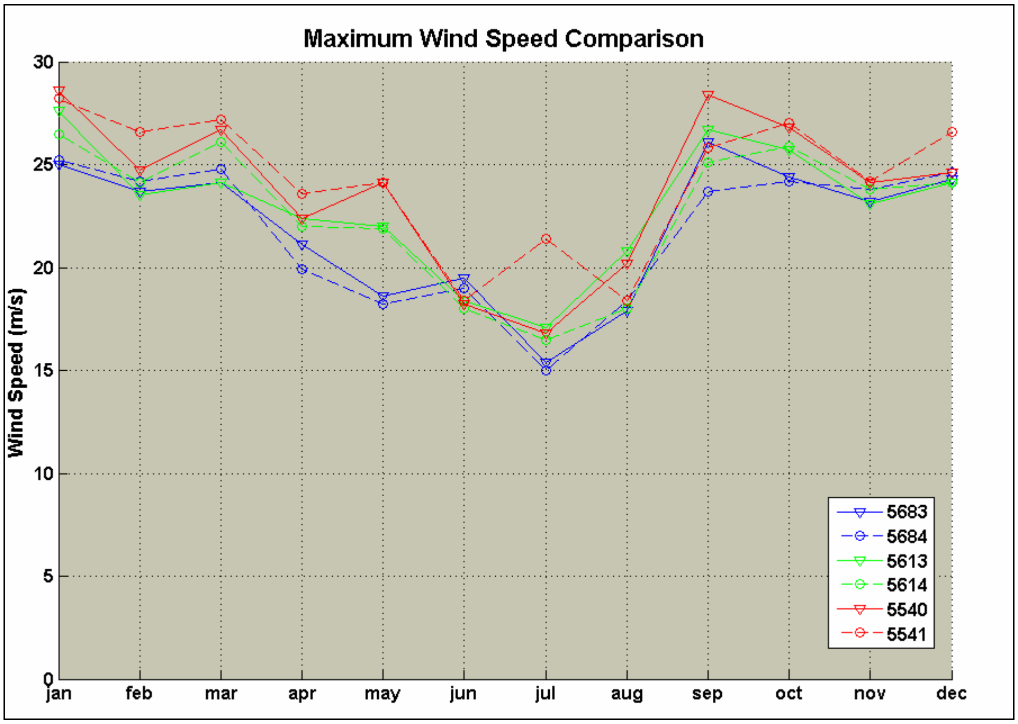


Figure 3.6 Mean and Maximum Monthly Wind Speed by Grid Point



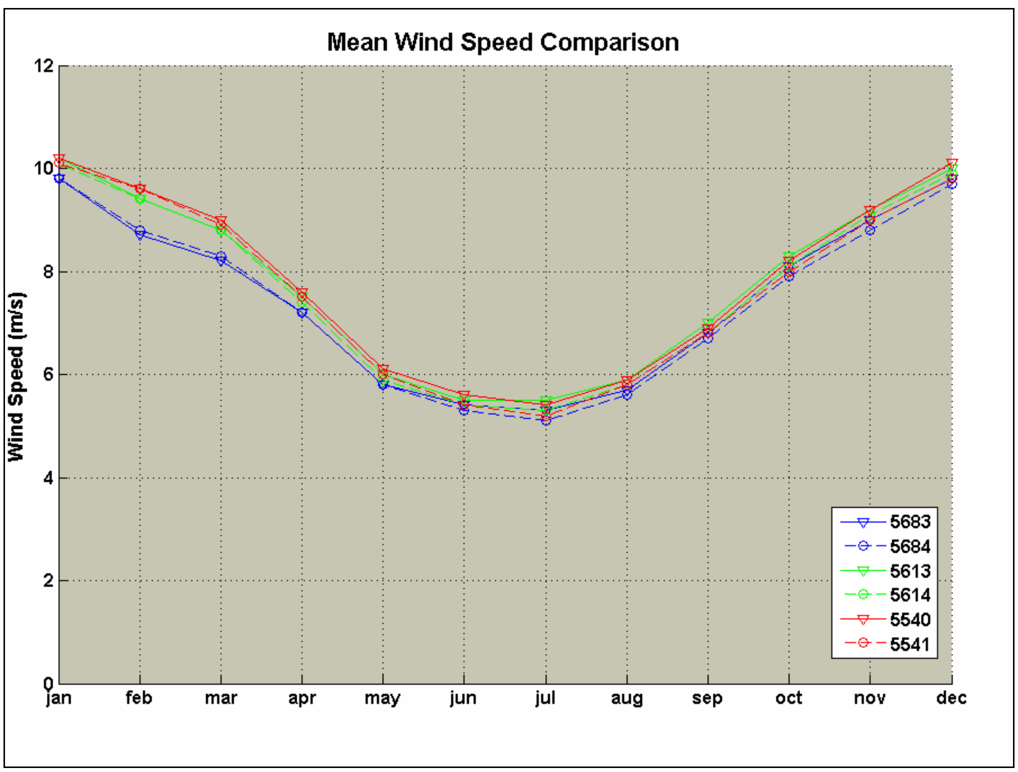


Figure 3.7 Monthly Directional Distribution of Wind Speeds for AES40 Grid Point 5614

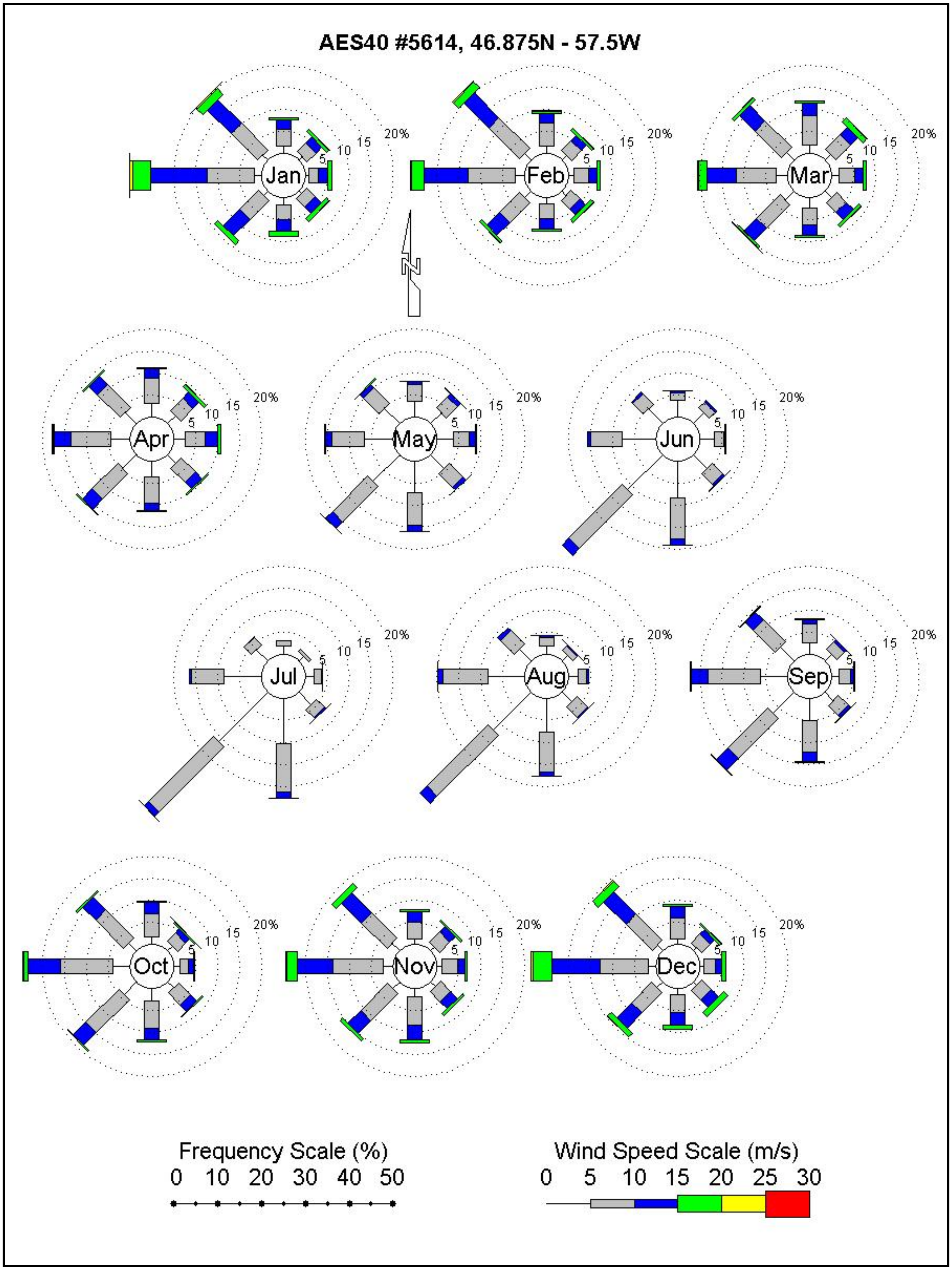


Table 3.2 Monthly Mean and Maximum Wind Statistics

Wind parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean hourly speed (1-hour average at height of 10m) (m/s)	10.1	9.4	8.8	7.4	5.9	5.4	5.3	5.8	6.8	8.1	9.1	9.9	7.7
Most frequent Direction (from)	W	W	W	W	SW	SW	SW	SW	SW	W	W	W	W
Maximum hourly speed (m/s)	26.5	24.1	26.1	22.0	21.9	18.0	16.5	18.0	25.1	25.9	23.8	24.1	26.5
Direction of maximum hourly speed (from)	NW	NW	SW	E	NE	E	SW	S	SE	NE	N	W	NW
Source: AES40, Grid Point 5614.													

The wind roses of Figure 3.7 show that the wind in this area occurs mostly from the west-northwest during the winter time (November to March), whereas it is predominantly from the southwest during the summer (June to August). In between (April-May and September-October), a transitional regime is taking place giving wind from roughly every direction during spring and mostly from the southwest to west during fall.

While the AES40 database provides a good general picture of conditions for the offshore SEA Area, it is relevant to note as well historical data available from coastal stations at Port aux Basques and Burgeo, which span the South Coast along the northern portion of the SEA Area. These data are represented in the Environment Canada 1971 to 2000 Canadian Climate Normals. As the complete data sets can be ordered from Environment Canada for any additional analyses or presentations, it is suggested that these be considered in project-specific environmental assessments. Several of the normal statistics for these coastal stations and for offshore are provided in Table 3.3.

Table 3.3 Comparison of South Coast Wind Measurements

Parameter	Port aux Basques	Burgeo	AES40 (5614)
Spring-Summer			
Mean wind speed (m/s)	4.9 (Aug)	4.4 (Aug)	5.3 (Jul)
Maximum wind speed (m/s)	20.6 (Jun-Aug)	19.2 (Jul)	16.5 (Jul)
Most frequent direction (from)	E	E	SW
Fall-Winter			
Mean wind speed (m/s)	9.0 (Jan)	7.9 (Jan)	10.1 (Jan)
Maximum wind speed (m/s)	33.3 (Feb)	35.8 (Jan)	26.5 (Dec, Jan)
Most frequent direction (from)	W	W	W

In addition, the climate normals report extreme wind gusts of 161 km/h (87 knots or 45 m/s). Note that the climate normals are likely 2-minute or 10-minute average winds, which will be slightly larger than the 1-hour means from the AES40. Conversely, overwater winds (AES40) will be larger than corresponding winds overland.

Another factor that should be borne in mind for applying any of these data is their measurement or representation for a 10 m elevation. Overwater wind speed is a function of height above the surface and is dependent upon the averaging time interval used in estimating or measuring the mean. Various logarithmic or power law scalings based on elevation and averaging time interval exist than can be applied to relate these different wind speed measurements and estimates.

For the South Coast, local effects are also a consideration, where, for example, convergence of land and sea winds may create stronger bands of wind near the shore than are seen offshore. Funnelling with increased wind speed effects can also be a consideration due to the many narrow steep-sided bays that indent the coastline. There is a more frequent occurrence of easterly winds along the coast compared with offshore in spring and summer. One effect producing this in the spring is blocking of southerly winds: mild southerly winds push cooler air against the hills along the coast, and in turn ride up over the trapped cooler air. The resulting difference in air pressure between the two air masses yields an easterly flow along the coast (Bowyer 1995).

An additional source of information is the MSC buoy 44255 deployed since late July 1998 at a Northeast Burgeo Bank location 47°17'N, 57°21'W in a depth of 185 m, approximately midway between the two northern AES40 grid points 5683, 5684. This buoy reports hourly significant and maximum wave height, peak period, wind speed and direction, gust wind speed, atmospheric pressure, and air and sea surface temperatures. These data are available online from the DFO Marine Environmental Data Service and should be investigated for any project-specific environmental assessment conducted in the SEA Area.

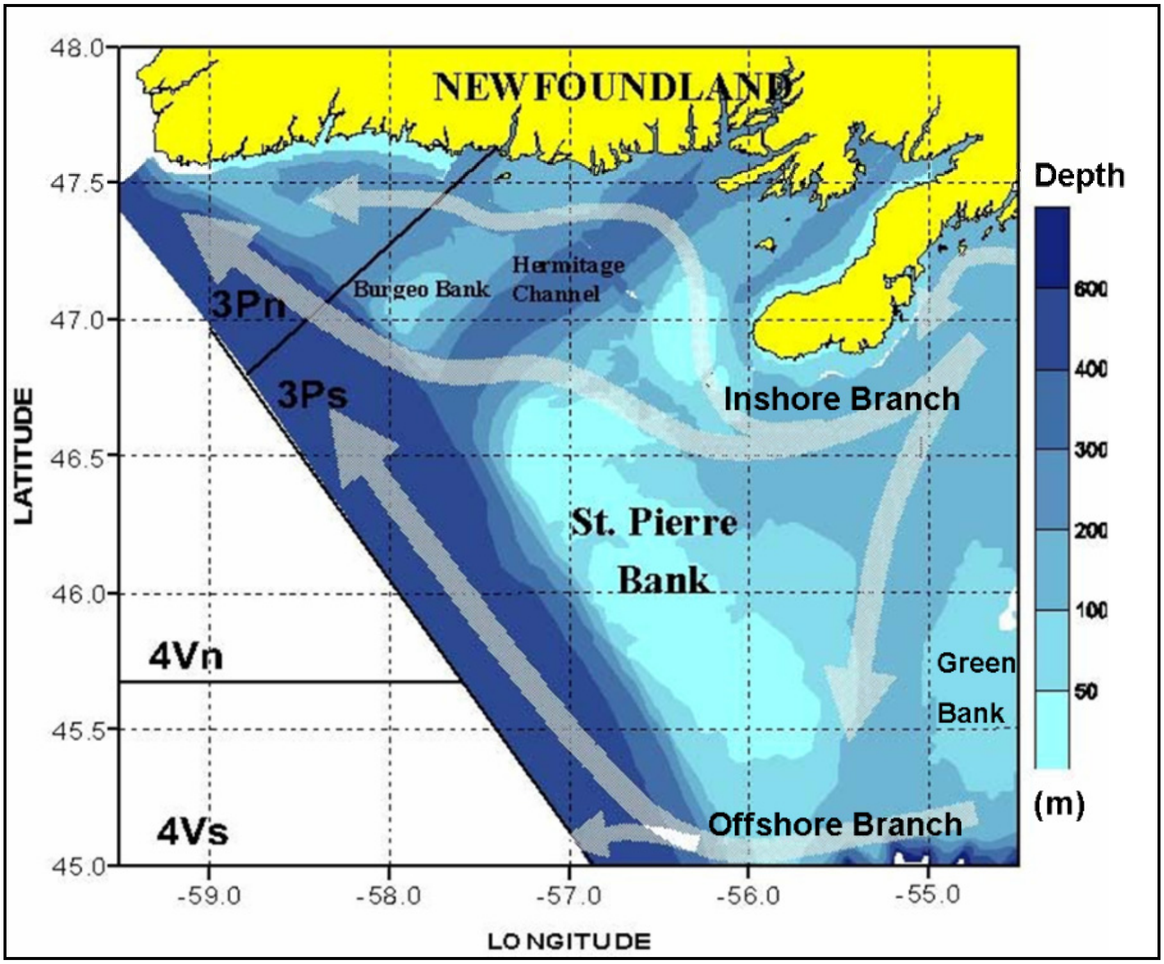
3.3.2 General Circulation

The circulation of the Continental Shelf waters off eastern Canada is dominated by a general southward flow; from Hudson Strait to the Grand Banks, the waters are transported south by the Labrador Current (DFO 1997).

In the SEA Area, the general circulation consists of modified Labrador Current Water, 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 (splitting along both sides of the Burgeo Bank) around the north of St. Pierre Bank and the other flows to the south between the south of St. Pierre Bank and Green Bank (Figure 3.8). This southern branch then joins a part of the offshore branch that has flowed around the tail of the Grand Banks, westward along the continental slope to the Laurentian Channel and goes up into the Gulf of St Lawrence (Colbourne and Murphy 2005).

The waters between the Gulf and the Atlantic Ocean are primarily exchanged at the Cabot Strait. This leads to particularly strong and rather complex current streams; one branch (Labrador origin) is flowing in, and another (Gaspé current origin) is flowing out of the Gulf. The inflow branch concerns the eastern part of the Strait, whereas the outflow occupies the west part. The outflow is larger than the inflow and occupies approximately 66 percent of the width, but the inflow is spread more deeply. The strength of these two branches is seasonal, but globally, the outflow is slightly stronger than the inflow, with approximately 1 Sv in winter and 0.8 Sv in summer (for an inflow of approximately 0.7 Sv year-around). The mean speed of these flows is high and can reach up to 45 cm/s for the outflow in fall (20 cm/s for the inflow in winter and summer) (Han et al. 1999).

Figure 3.8 General Oceanic Circulation in the Strategic Environmental Assessment Area



Source: Colbourne and Murphy 2005.

3.3.3 Tides

Tidal currents can be relatively strong is this area, especially on the banks. Analyses have been done using the DFO WebTide model (Dupond et al. 2002) for the year 2006 at different strategic points (Figure 3.9) and the results are presented in Table 3.4 and Figure 3.10 shows the magnitude of the east-west and north-south components of the current at each location noted in the upper left of each graph panel (scale is -0.4 to 0.4 m/s).

Figure 3.9 Tidal Prediction Locations

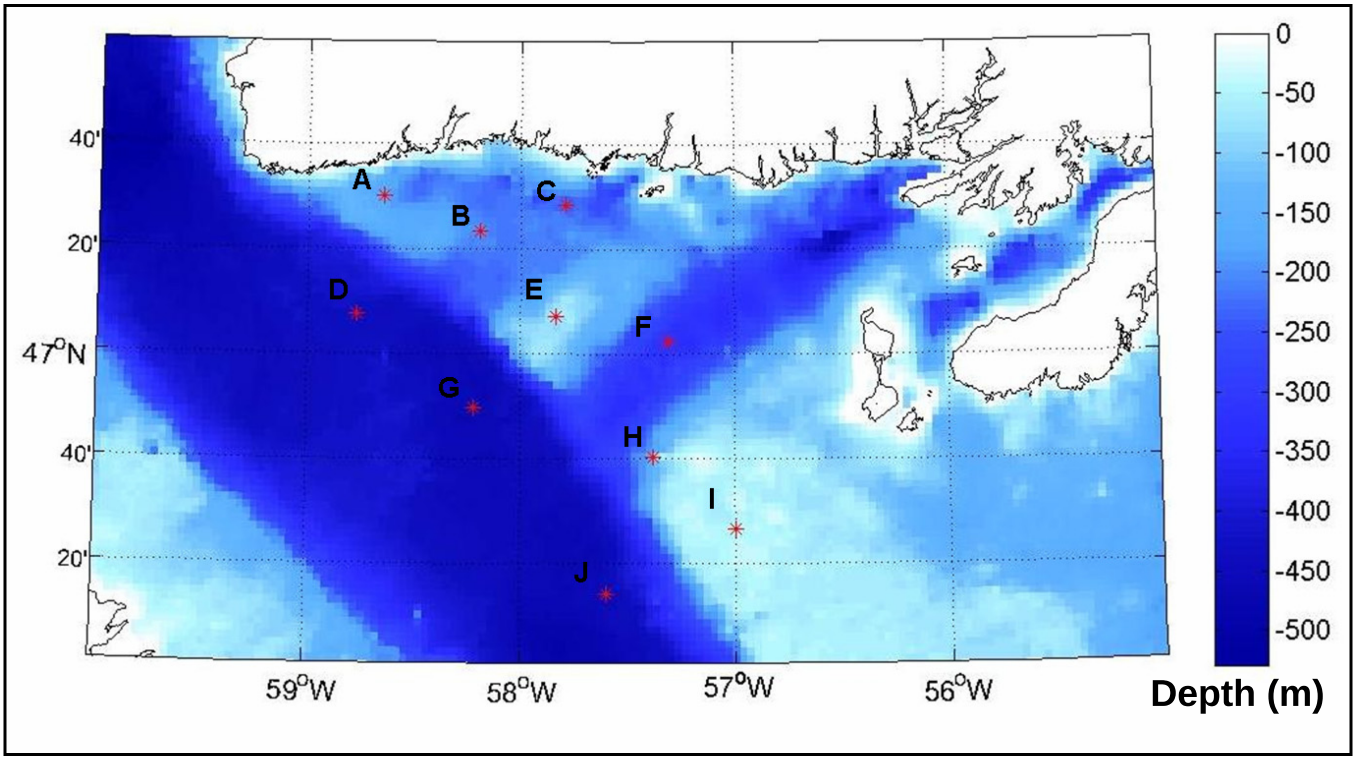


Table 3.4 Tidal Ellipses Major, Minor Axis and Depth for Selected Locations

Site	Latitude	Longitude	major-axis (m/s)	minor-axis (m/s)	Depth (m)
A	47°30'	58°39'	0.24	0.03	177
B	47°23'	58°11'	0.16	0.02	205
C	47°28'	57°47'	0.19	0.03	233
D	47°07'	58°46'	0.18	0.07	432
E	47°47'	57°50'	0.26	0.13	65
F	47°02'	57°18'	0.13	0.07	318
G	46°49'	58°10'	0.12	0.08	464
H	46°40'	57°25'	0.18	0.10	89
I	46°24'	56°59'	0.38	0.36	47
J	46°14'	57°36'	0.09	0.03	436

Tidal currents vary greatly from one site to another in the SEA Area. As seen in the Table 3.4 results, and following the theory, these differences are mainly due to the change of bathymetry, where the shallower waters result in stronger currents. Another interesting feature is the change in shape of the ellipses, also due to the change in bathymetry; in areas on the slopes (of the banks or the coast), the ellipses tend to get flatter, indicating flow is mostly parallel to a channel or a coast. The steeper the slope, the more elongated the tidal ellipse.

Figure 3.10 Tidal Predictions for the Strategic Environmental Assessment Area

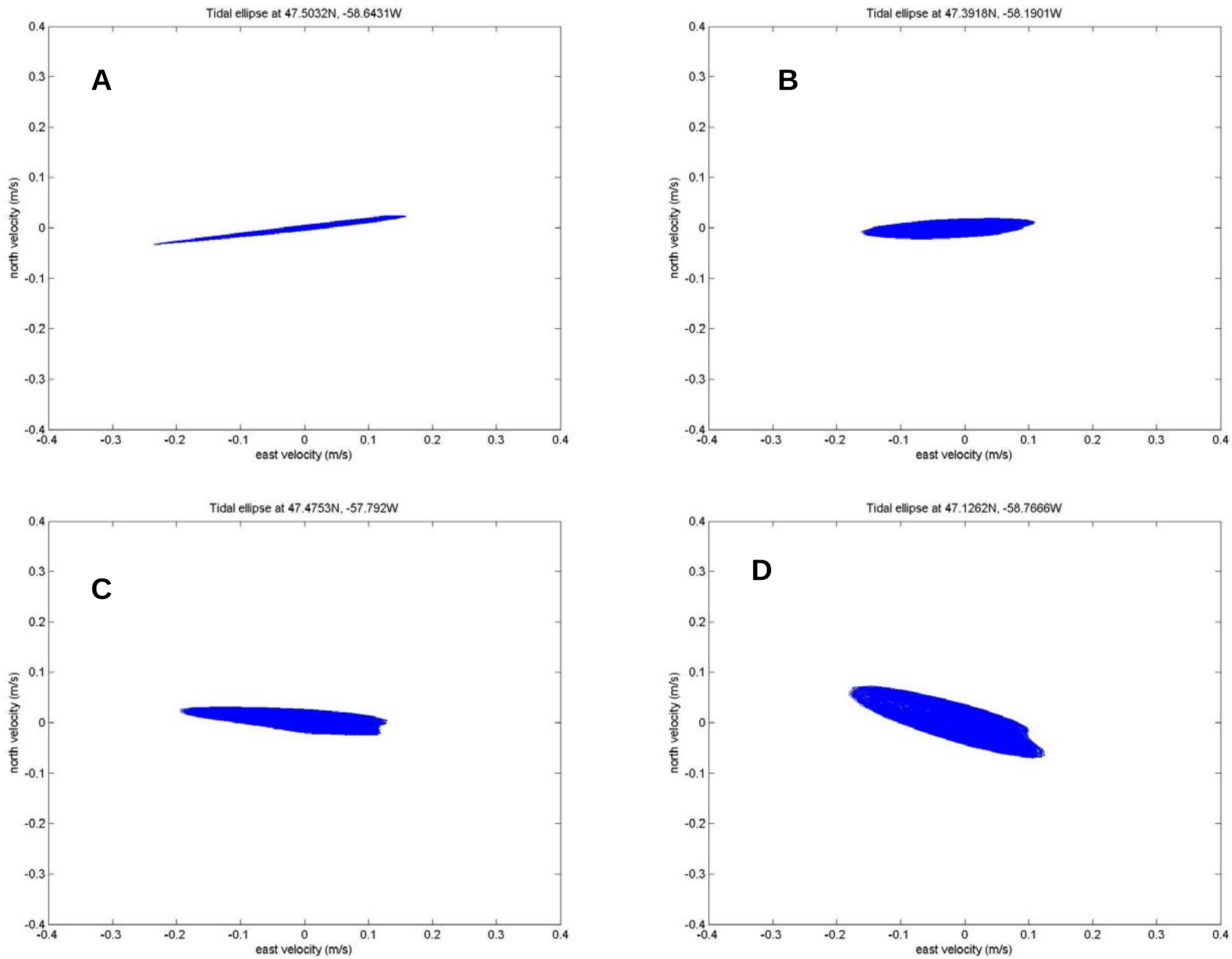


Figure 3.10 Tidal Predictions for the Strategic Environmental Assessment Area (cont'd)

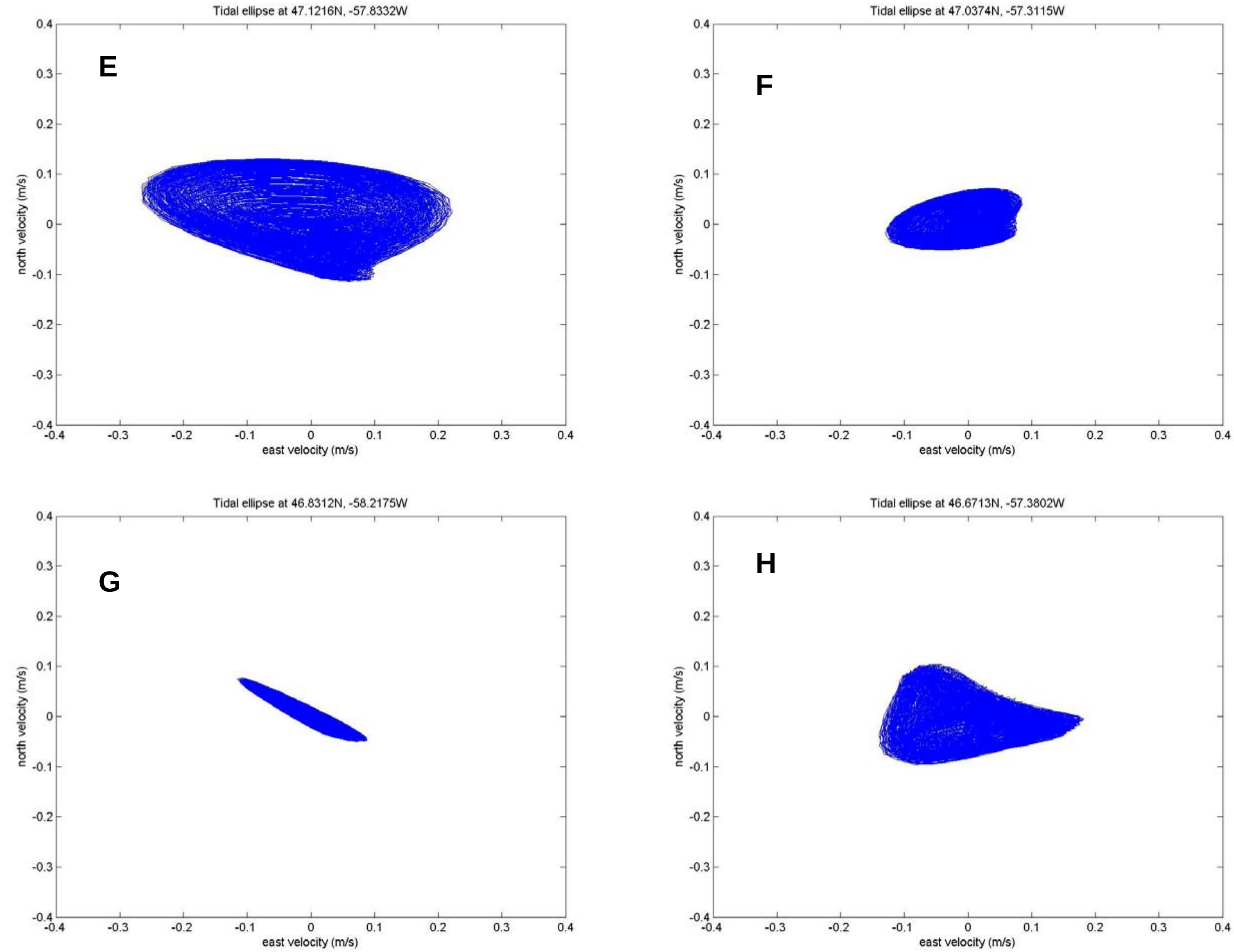


Figure 3.10 Tidal Predictions for the Strategic Environmental Assessment Area (cont'd)