CHAPTER 7

PHYSICAL ENVIRONMENT

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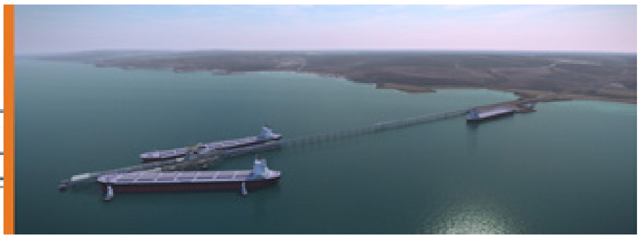

7 Physical Environment

This chapter details the existing physical environment of the Eyre Peninsula region including the meteorological environment, natural hazards, topography, soils and the marine environment. Predicted impacts of climate change on the physical environment of the region are also assessed. The terrestrial and marine ecological environments are described in further detail in Chapters 13 and 14 respectively.

7.1 Introduction

The Eyre Peninsula of South Australia has a Mediterranean-type climate with warm, dry summers and cool, wet winters. Typically, the southern Eyre Peninsula and coastal areas experience milder climatic conditions with increased rainfall, influenced by the proximity to the coast. Conversely, inland areas typically experience warmer, drier conditions. Mean annual rainfall across the region ranges from 250 mm in the central areas such as Wudinna to more than 400 mm in southern coastal areas. Topographically, the Peninsula is relatively flat with the majority of the landmass less than 150 m AHD, peaking at the Gawler Ranges north of Cleve at a height of just below 500 m AHD (Eyre Peninsula Natural Resources Management Board, 2009).

Climate is the primary influence upon natural ecosystems within the region. Climatic conditions also represent a major factor which influences the level of impact and risk for a number of the environmental aspects discussed in this EIS. For example, wind speed, direction and patterns influence dust and particulate matter transfer, whilst rainfall patterns dictate surface water run-off and therefore impact erosion and stormwater management.

The Hambidge Wilderness Protection Area, a significant patch of remnant indigenous vegetation dominated by mallee vegetation communities, is located to the southeast of the proposed mine site. Aside from Hambidge, the landscape adjacent to the CEIP Infrastructure consists predominantly of agricultural land, supporting only highly fragmented and degraded small patches of remnant vegetation which are generally restricted to dune crests. These patches generally provide only limited refuge for native fauna.

7.2 Assessment Methods

The physical environment relevant to the CEIP was identified through a desktop assessment of existing databases and information sources. A desktop assessment was also utilised to establish the natural hazards and climate change factors relevant to the development of the CEIP. Additional field data collected through various technical studies was also analysed. Key data sources are identified in Table 7-1.

Table 7-1 Data Sources

Parameter	Data Source	Collection Period
Mean maximum and minimum temperatures	Bureau of Meteorology (BOM) official weather stations	Various, maximum period of 1930-2013, minimum period of 1999-2012
Mean monthly rainfall	BOM official weather stations	
Relative humidity	BOM official weather stations	
Wind speed and direction	BOM official weather stations	Minimum of 1999-2010
Thunder days	BOM climatic averages mapping	1990-1999
Lightning flash density	BOM climatic averages mapping	1995-2002
Rainfall variability	BOM climatic averages mapping	1900-2003
Fire	SA Country Fire Service	1933-2013
Topography	Department of Environment, Water and Natural Resources	2012
Geology	Iron Road Geological/Geotechnical Investigations	2008-2014
Climate change	Department of Environment, Water and Natural Resources	2010
	Department of Climate Change	2009
	Intergovernmental Panel on Climate Change	2013

7.3 Existing Environmental Values

This section provides an overview of the existing environment surrounding the proposed CEIP Infrastructure sites in relation to the physical environment. Climatic conditions and natural hazards are discussed, as well as the topography and geology of the region.

7.3.1 Climate

The Bureau of Meteorology distinguishes Australia into six climate zones based on temperature and humidity. The Eyre Peninsula is located within the 'hot summer, cool winter' zone, as is the Adelaide Metropolitan area. Despite being located within the same climate zone, the Eyre Peninsula experiences significantly different weather patterns to Adelaide. Mean annual rainfall on the Eyre Peninsula ranges from 263 mm at inland areas such as Wudinna, to 381 mm at coastal locations such as Port Lincoln (BOM 2013). Comparatively, Adelaide typically receives a higher level of rainfall, with a mean of 543 mm per annum (BOM 2013). Differences in temperature are also noted when comparing locations on the Eyre Peninsula and Adelaide. Mean annual maximum and minimum temperatures at Adelaide range from 22.3°C to 12.2°C, compared to 25.1°C to 10.2°C at Wudinna and 23.5°C to 10.3°C at Kimba (BOM 2013). A comparison of mean monthly temperature and rainfall patterns between Adelaide and various locations on the Eyre Peninsula is provided in Figure 7-1.

Relative humidity in South Australia is generally very low. It is generally highest in winter and lowest in summer and is highest in coastal areas. Within the locality of the proposed CEIP Infrastructure, mean annual relative humidity (at 3 pm) is 48% at Cleve and 36% at Wudinna (BOM 2013).

Although the nearest weather station to the northern end of the infrastructure corridor is the Kyancutta station, hourly data is not available, with the next nearest station providing hourly data located at Wudinna. As such, the data recorded at the Wudinna station is preferred for providing a complete set of data at the northern end of the infrastructure corridor. All other stations utilised also provide hourly data which can be used as a comparison between meteorological conditions at the various locations.

7.3.2 Wind

The proposed CEIP Infrastructure extends from the east coast of the Eyre Peninsula near Port Neill to the central Peninsula at Wudinna where the proposed long-term employee village is to be located. At Wudinna, morning northerly winds are predominant in the winter, autumn and spring months, with strong south-easterly morning winds in summer months. Afternoon breezes are predominantly from the south in summer and autumn, the west in spring and from the northwest in winter. There is no existing wind monitoring station at Port Neill. The nearest coastal monitoring station is at Port Lincoln where morning wind direction is predominantly from the southeast in spring and northwest in winter. There is no prevailing morning wind direction in either summer or autumn. Afternoon winds at Port Lincoln are predominantly from the southeast in spring and autumn, northwest in winter and from the east in spring.

Roses of wind direction versus wind speed measured at 9am and 3pm at Wudinna and Port Lincoln are depicted in Figure 7-2, Figure 7-3, Figure 7-4 and Figure 7-5 (BOM 2012 & BOM 2012a).

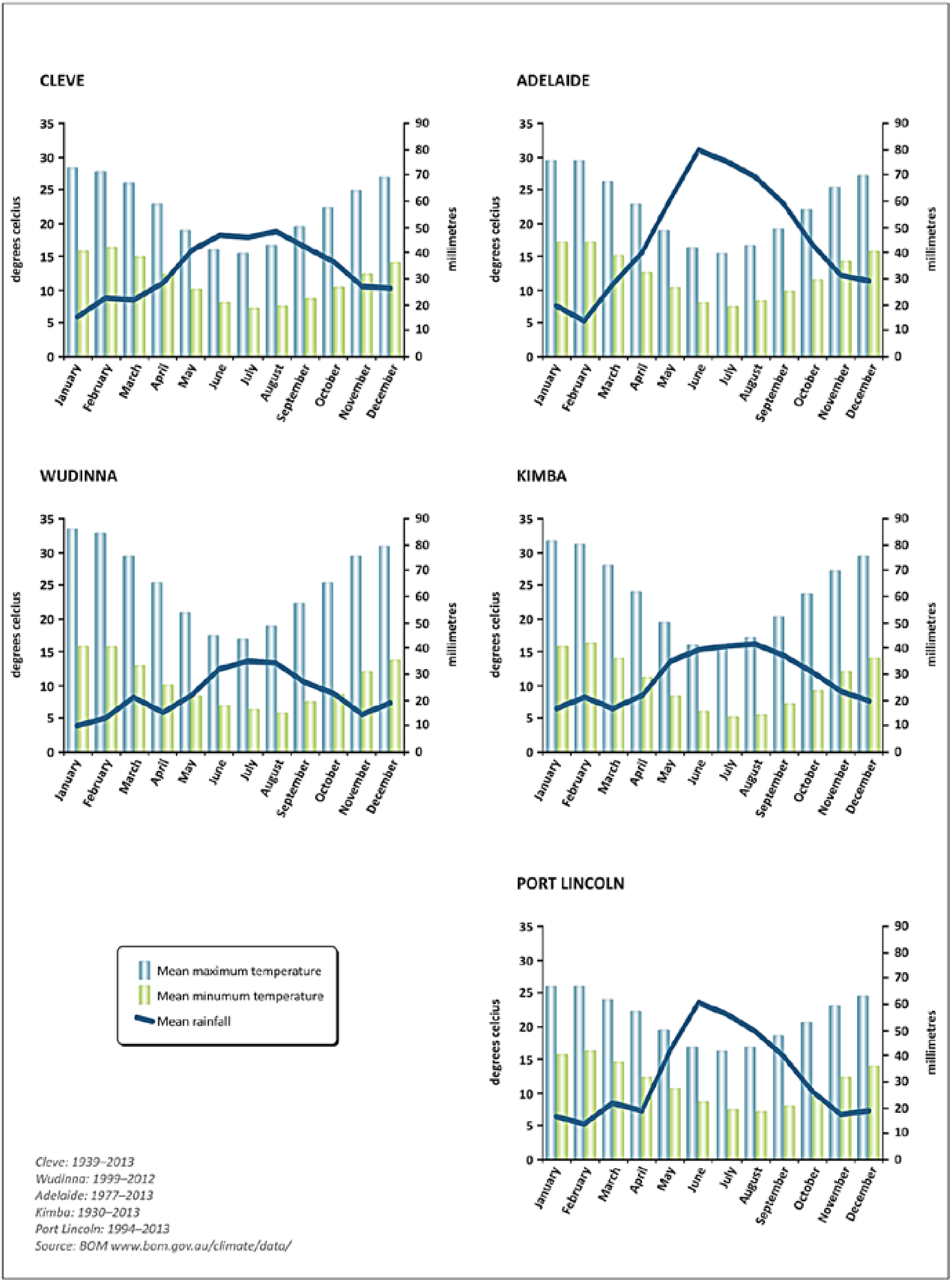

Figure 7-1 Climatic Conditions

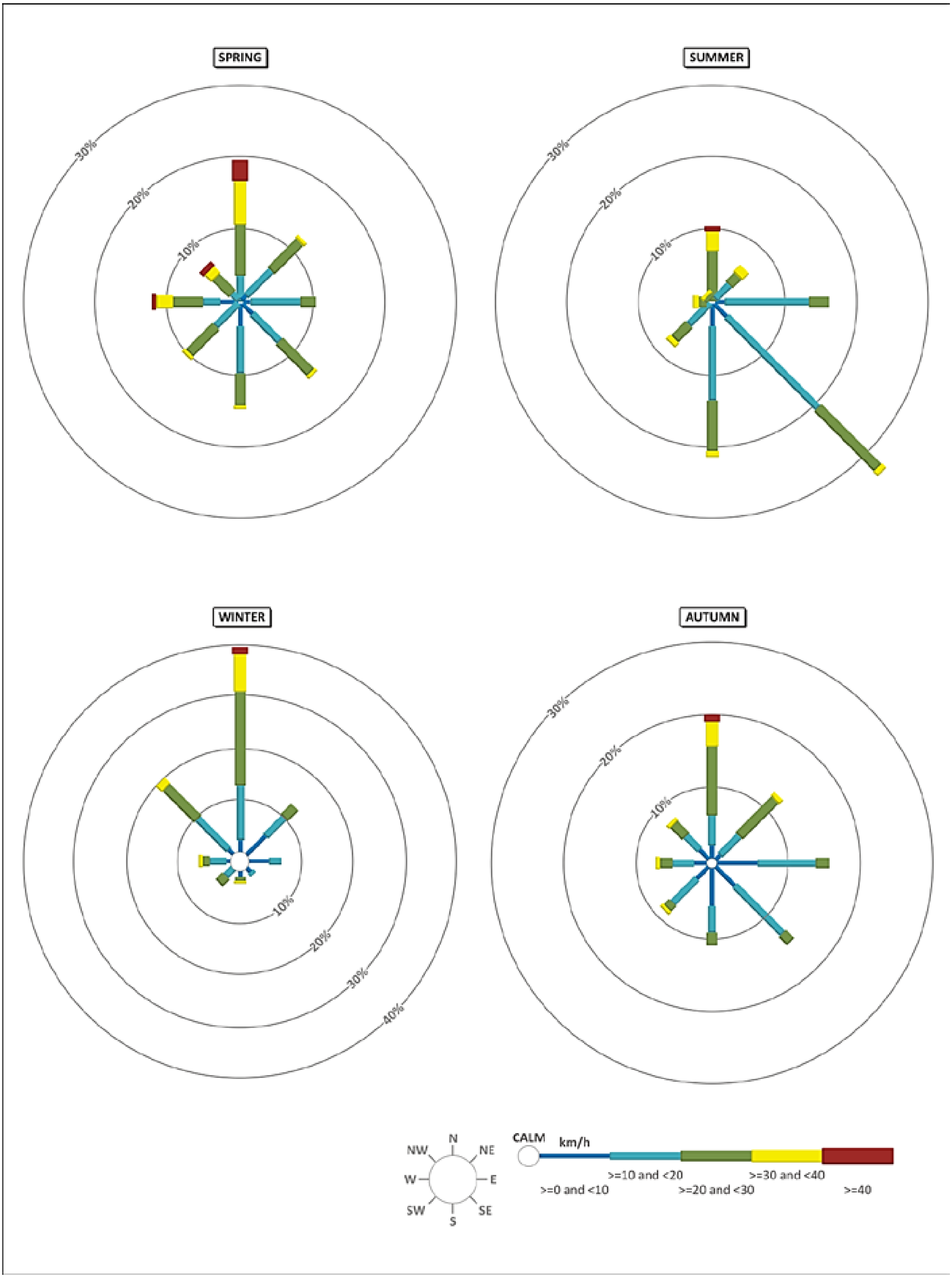

Figure 7-2 Seasonal Wind Roses (9am Wudinna)

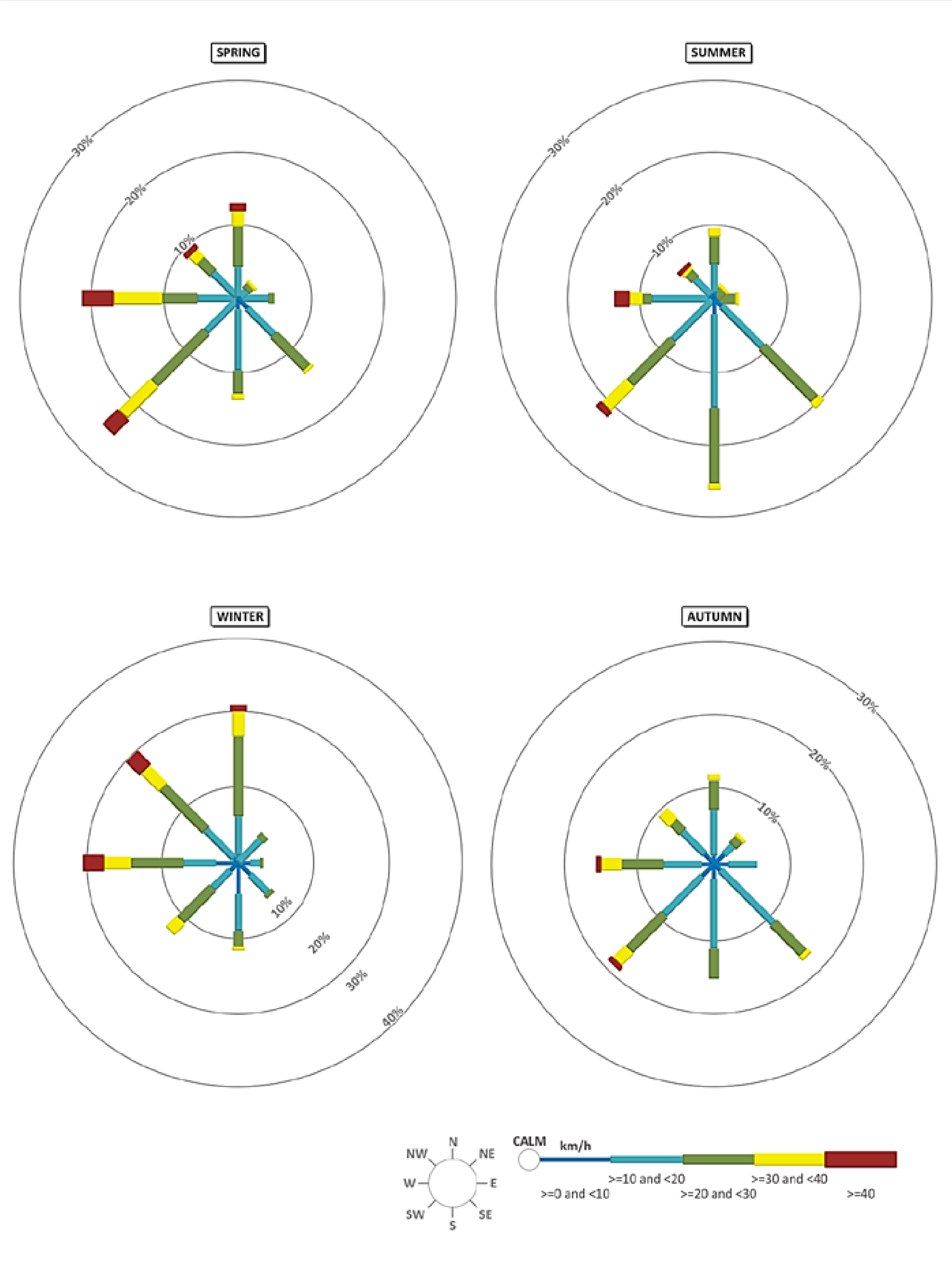

Figure 7-3 Seasonal Wind Roses (3pm Wudinna)

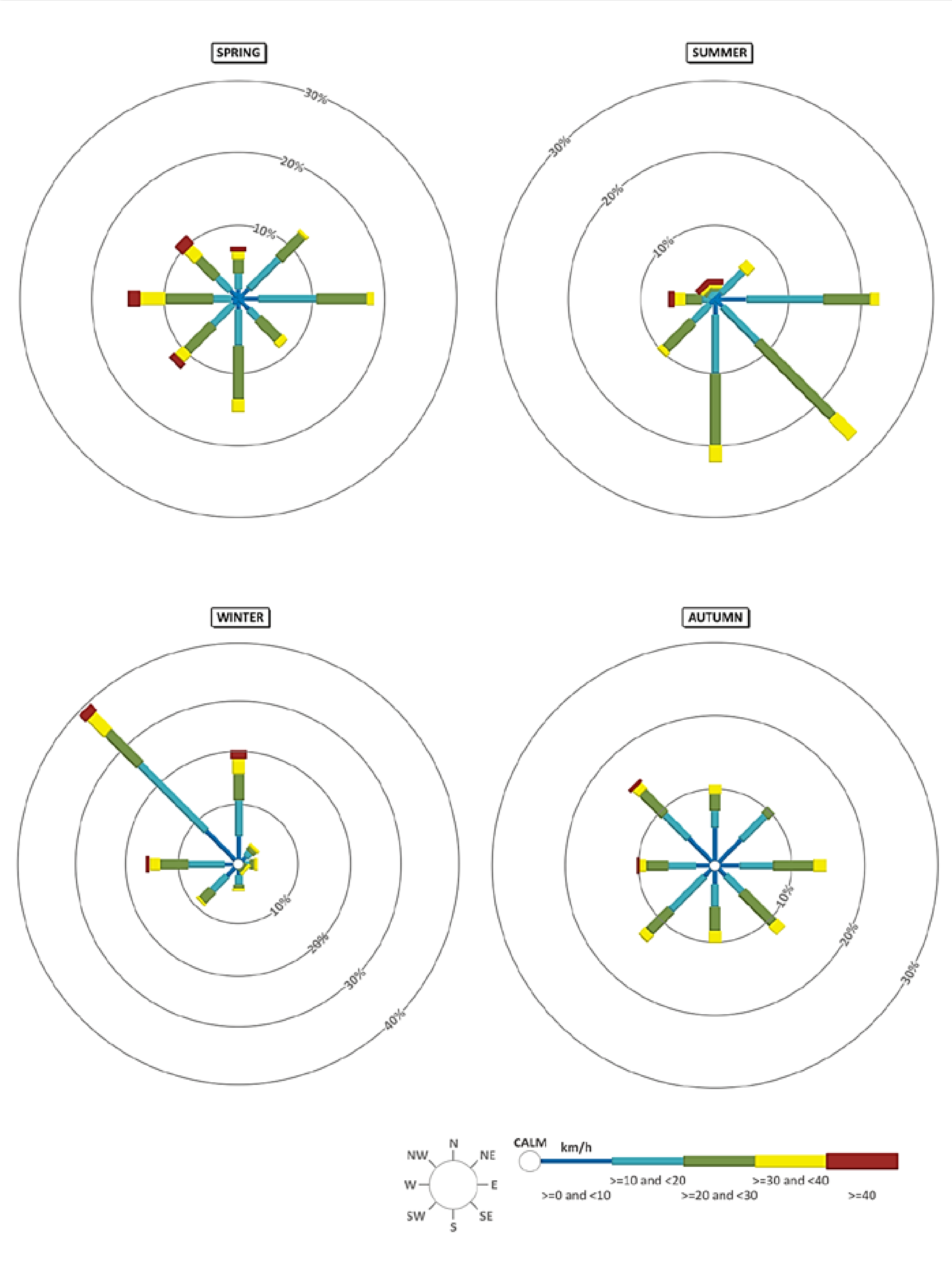

Figure 7-4 Seasonal Wind Roses (9am Port Lincoln)

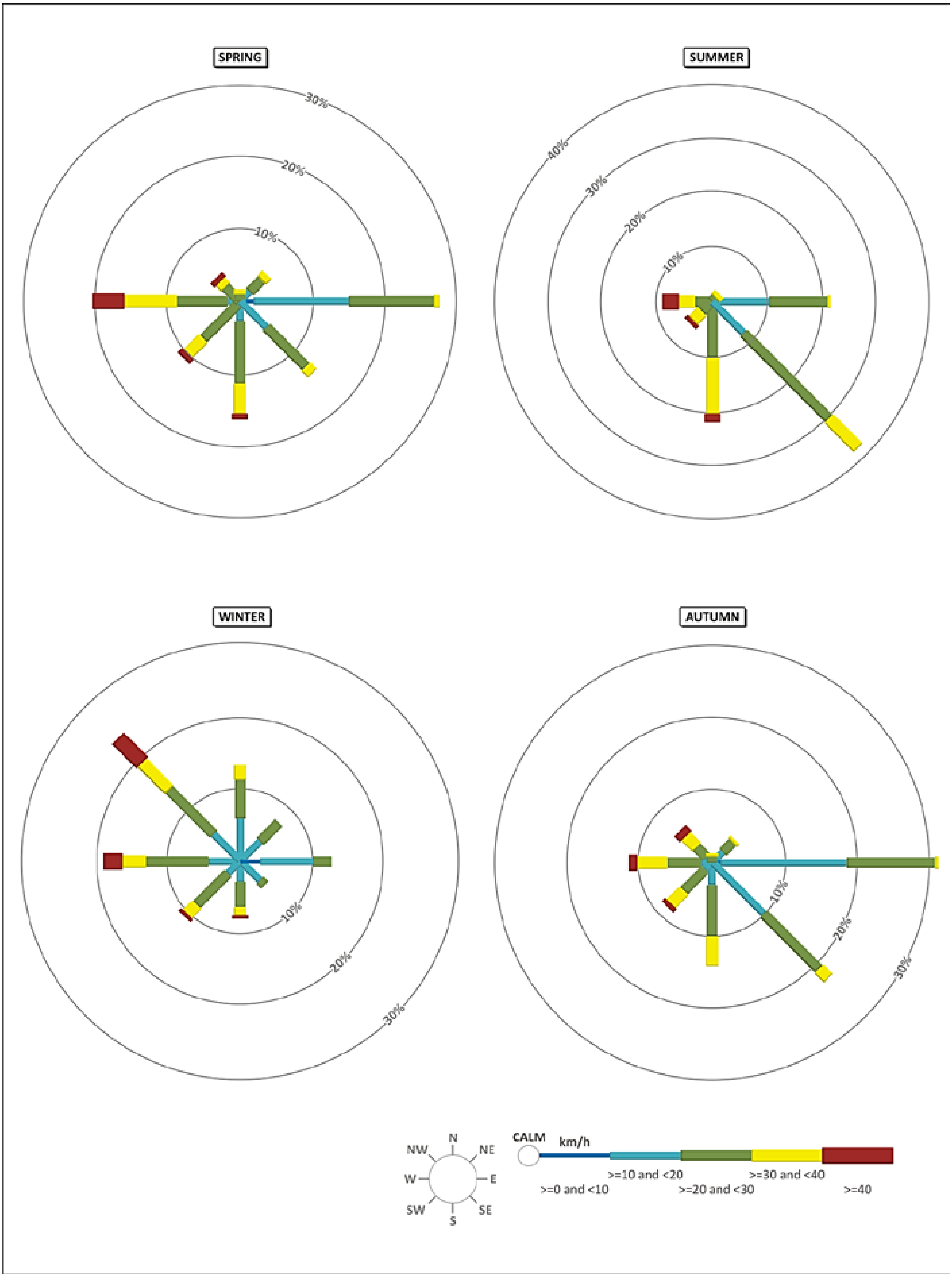

Figure 7-5 Seasonal Wind Roses (3pm Port Lincoln)

7.3.3 Natural Hazards

The following section identifies natural hazards that may affect construction and operation of the CEIP Infrastructure.

Storm Events

The Eyre Peninsula region experiences few severe storm events. On average, five to ten days of thunder are observed on the Peninsula each year (BOM 2013a). Similarly, a low density of total lightning flashes is observed on the Peninsula with an average of 0-1 flashes per square kilometre each year (BOM 2013a). South Australia and the Eyre Peninsula are unaffected by tropical cyclones with an average of zero cyclones per annum (BOM 2013b).

Drought

Drought hazards in Australia have no identifiable pattern however, the risk of drought in any given area is directly associated with the index of rainfall variability. The index of rainfall variability indicates how rainfall will vary in a given location from year to year (BOM 2013c). The majority of coastal areas in Australia exhibit lower variability, which means the rainfall will tend to be relatively consistent from one year to the next. Conversely, areas in central Australia tend to have high rainfall variability, meaning rainfall is likely to be irregular from one year to the next. The Eyre Peninsula is bisected by Goyder's Line which identifies land in South Australia which receives more than 30 cm of rain annually and is able to support sustainable agriculture. Goyder's line runs from approximately Arno Bay, northwest to approximately Ceduna (State Library of South Australia 2014). In recent times, severe rainfall deficiencies have been observed across much of the Eyre Peninsula and the CEIP project area, as depicted in Figure 7-6 (BOM 2014a).

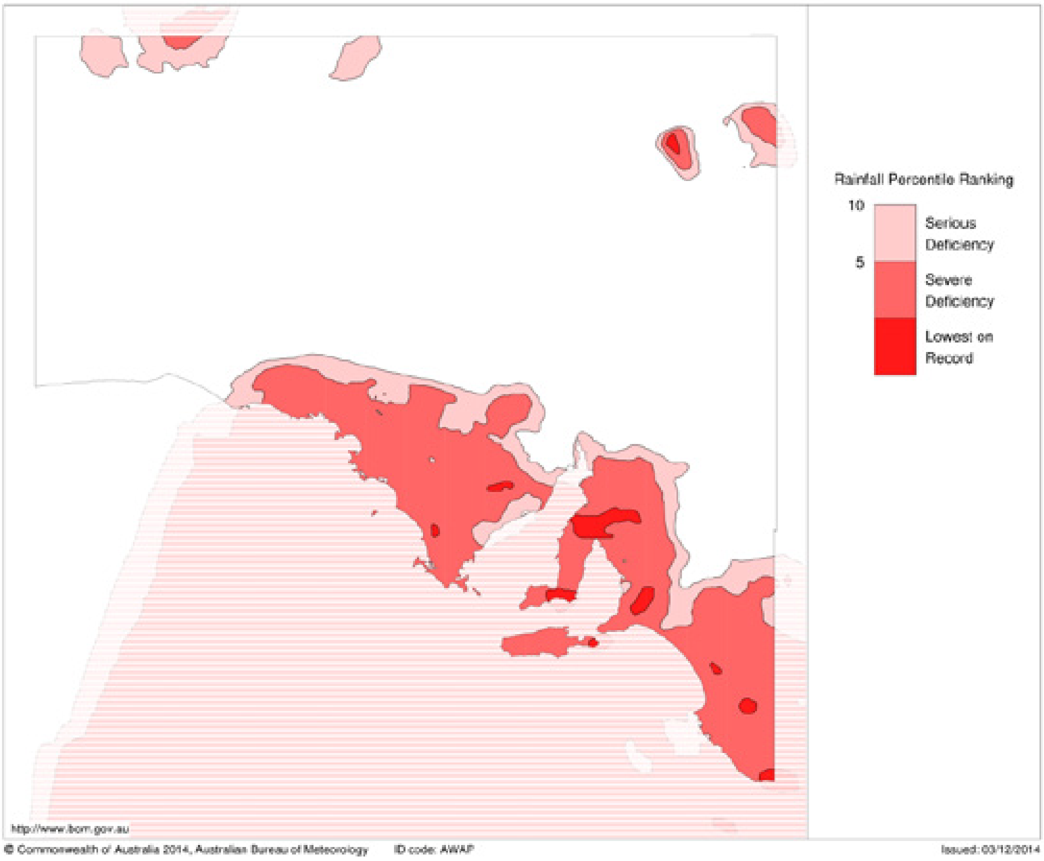

Figure 7-6 South Australian Rainfall Deficiency 1 September to 30 November 2014

Fire

South Australia's climatic conditions provide an ideal environment for frequent bushfires. Typically, incidences of bushfire are more frequent in dry summer conditions. To protect people and property, fire bans are implemented annually during high risk months. Fire bans within the Eastern Eyre Peninsula, Lower Eyre Peninsula and West Coast districts (the location of the CEIP) were applied from 1 November to 30 April during the 2013-14 fire danger season (CFS, 2014). Remnant vegetation coverage on the Eyre Peninsula is patchy, predominantly limited to designated conservation areas, with the majority of the region cleared for agricultural purposes. As such, there are predominantly low fuel loads, resulting in quick burning grass fires in the agricultural regions.

Historically, South Australia can expect serious fires within the State in six or seven years out of ten (CFS 2014a). A summary of known historically significant fires on the Eyre Peninsula is provided in Table 7-2 (CFS, 2014a).

Table 7-2 Historically Significant Fire Events on Eyre Peninsula

Date	Location	Area Affected
1933-34	Eyre Peninsula	Unknown
1938-39	Eyre Peninsula	Unknown
1943-44	Eyre Peninsula	Unknown
1953	Hincks Wilderness Protection Area	30,000 Ha
1959	Hincks Wilderness Protection Area	31,000 Ha
1959	Wudinna	76,000 Ha
1965	Hambidge Wilderness Protection Area	15,000 Ha
1967	Lincoln National Park	7,000 Ha
1968-69	Murdinga	8,000 Ha
1972	Eyre Peninsula	13,000 Ha
1975	Hincks Wilderness Protection Area	13,000 Ha
1977	Hincks Wilderness Protection Area	15,000 Ha
1980	Sheoak Hill Conservation Park	10,000 Ha
1983	Hincks Wilderness Protection Area	28,000 Ha
1990	Munyaroo	12,000 Ha
1991	Coffin Bay	10,000 Ha
2000	Hambidge Wilderness Protection Area	25,000 Ha
February 2001	Tulka	14,000 Ha
2002	Gawler Ranges	15,000 Ha
January 2005	Wangary	78,000 Ha
2005	Pinkawillinie Conservation Reserve	35,000 Ha
January 2009	Port Lincoln (Proper Bay)	252 Ha
December 2009	Port Lincoln	650 Ha
2012	Coomunga	6,000 Ha
2012	Tulka	5,000 Ha
January 2014	Ceduna (Yumburra Conservation Park)	46,000 Ha

7.3.4 Topography

The central Eyre Peninsula is dominated by sand dune covered plains. Isolated peaks such as Darke Range and Caralue Bluff are visible from the CEIP Infrastructure, with elevation typically increasing northeast of Darke Peak and north of Wudinna. The gentle, undulating topography (Plate 7-1 and Plate 7-2) continues to the northeast of the Peninsula, with several areas of higher elevation near Cowell. To the south, the Lincoln Uplands run along the east coast, with the Marble Range along the west coast. Coastal areas are predominantly undulating dunes with an average height of approximately 7 m (Department for Water, 2011a). Within the footprint of the proposed CEIP Infrastructure, the topography ranges from approximately 5 m AHD at the coast near Port Neill to approximately 175 m AHD in the farmland areas surrounding Darke Range (Plate 7-3 and Plate 7-4). The topography of the Eyre Peninsula and project area is depicted in Figure 7-7.

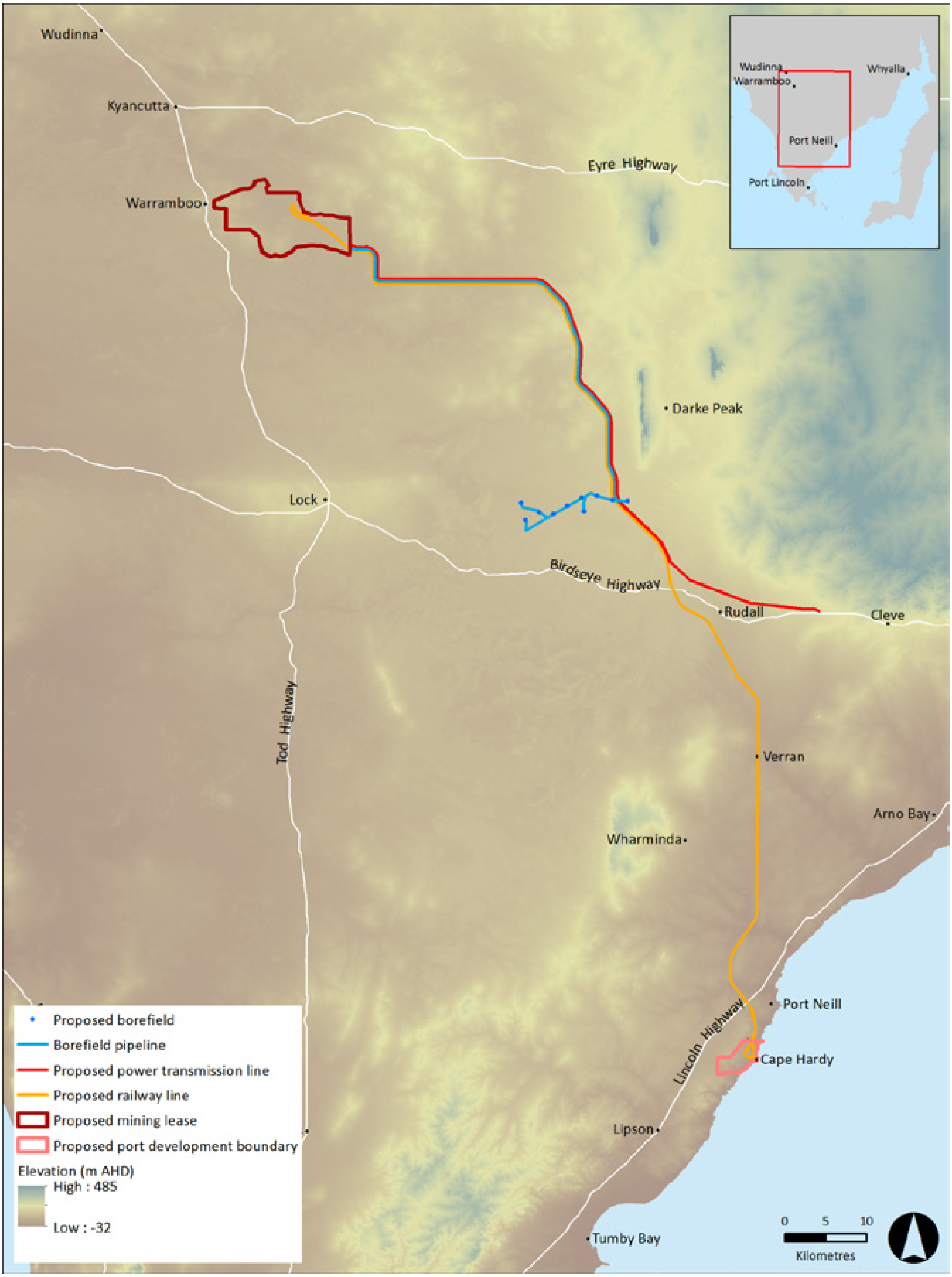

Figure 7-7 Topography of Project Area

Plate 7-1 Farmland North of Hambidge Wilderness Protection Area (April 2014)

Plate 7-2 Farmland at Proposed Port Site (April 2014)

Plate 7-3 Darke Range (April 2014)

Plate 7-4 View from Darke Range towards Hambidge Wilderness Protection Area (April 2014)

7.3.5 Soils and Geology

The geological characteristics and soil types of the CEIP Infrastructure site were determined during geotechnical investigations in 2012 and 2013 (SKM 2012, SKM 2014 and SKM 2014a). Field investigations were supplemented with publically available geological information where required. Core samples gathered during the geotechnical investigations are shown in Plate 7-5. The core samples depicted were taken from near the crossing point of the infrastructure corridor and the Lincoln Highway, approximately 1 km apart. The core samples demonstrate variations in geology that can occur across a small region of the CEIP Infrastructure site.

Port Site

The geotechnical investigations revealed that the proposed port site is characterised by a thin to moderate layer of soil deposits between 1 m and 9 m thick overlying a weathered bedrock zone of sandy gravel (nominally 2 m thick), above strong gabbro and gneiss metamorphic rock to a maximum depth of 30 m.

The soils consist predominantly of alluvial deposits of clayey to gravelly sand with sandy clay encountered in the deeper areas located in the centre of the site.

Bedrock or weathered rock was revealed between approximately 1 m and 9 m below ground level across the port site. Bedrock was encountered at shallow depths (<5 m below ground level) in the northern portion of the site and deeper soil-rock interfaces were encountered in the south-eastern portion of the site.

Infrastructure Corridor

The geological sequences along the rail corridor from the port site to near the proposed mining lease boundary were investigated and identified to include dune sands, alluvial deposits, calcrete and bedrock. The infrastructure corridor was split into segments, grouping the geological characteristics based on distance from the port site as follows:

- 0 to 4 km from the port site: 0 to 3 m of interlayered medium dense sand and firm to stiff sandy clay and clay, 3 to 5 m sandy gravel (weathered rock) underlain by strong gabbro/gneiss bedrock.
- 4 to 20 km from the port site: 0 to 8 m or more of interlayered sand and sandy clay underlain by interlayered sand, clay and sand and gravel over 30 m thick in some areas such as watercourse crossings.
- 20 to 64 km from the port site: predominantly sand (clayey, gravelly and silty in places) and clay in excess of 15 m thick with near surface calcrete underlain by sandstone encountered in areas more than 48 km from the port site.
- 64 km from the port site to the mine site: interlayered sand and clay (with gravel) to 9 m with calcrete (hard clay consistency) to 20 m or deeper with some weak sandstone at depth.

Plate 7-5 Core Samples from Geotechnical Investigations near Lincoln Highway

7.3.6 Marine

The marine environment surrounding the port site is considered to be a relatively sheltered system with very low to moderate wave energy, primarily driven by tidal currents. Tides are predominantly semi-diurnal with two high and low tides each day. A tidal gauge was deployed off the coast of Cape Hardy for a period of 34 days and tidal planes are presented in Table 7-3.

Table 7-3 Cape Hardy Tidal Planes

Tidal Level	Levels Relative to Chart Datum (mCD)
Highest Astronomical Tide	2.25
Mean High Water Springs	1.82
Mean High Water Neap	1.30
Mean Sea Level	1.08
Mean Low Water Neap	0.86
Mean Low Water Springs	0.34
Lowest Astronomical Tide	0.06
Chart Datum	0.00

Water temperatures at the port site were recorded over a two month period and varied from around 23°C to 21°C near the surface and 22.5°C to 20.5°C at depth. Due to a lack of freshwater inputs and high rates of evaporation, salinity is typically high in the Spencer Gulf, particularly in the upper regions. Salinity levels at the port site were recorded at five locations and ranged between 36 and 38 psu, compared to 35 psu in open waters off the South Australian coast (BOM 2014b). The sub-tidal topography at the port site is generally consistent and free of navigational hazards such as rocky reefs. The 20 m depth contour (required to accommodate Capesize vessels) is approximately 1,200 m offshore.

Wave data recorded at Cape Hardy indicated that the site is exposed to both ocean swell and wind generated sea waves. Swell wave energy typically approaches the port site from a south-south-east direction. Wind generated waves usually occur during south-easterly storm events.

Physical conditions in the marine environment are discussed in further detail in Chapter 14.

7.4 Projected Environmental Values

The following section discusses the potential outcomes of climate change on the physical environment of the Eyre Peninsula. Climate change is defined as a change in the state of the climate, identifiable by changes in the mean and/or the variability of its properties and persists for an extended period (IPCC 2013).

7.4.1 Climate Change Predictions

Table 7-4 summarises the climate change projections for the Eyre Peninsula Region by 2030 and 2070 based on medium level emission scenarios (Department of Environment and Natural Resources 2010). It can be noted that under the most likely scenario (50th percentile), mean annual temperatures are projected to increase from current levels by 0.8°C in 2030 and 1.75°C in 2070. Also of note, predicted mean annual rainfall is anticipated to decrease from current levels by 3.5% by 2030 and 15% by 2070 and evapotranspiration is projected to increase by 3% by 2030 and 6% by 2070 (Department of Environment and Natural Resources 2010).

Table 7-4 Climate Change Predictions for Eyre Peninsula

Variable	Season	2030			2070		
		10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Temperature °C	Annual	+0.5	+0.8	+1.3	+1.25	+1.75	+2.75
	Summer	+0.5	+0.8	+1.3	+1.25	+1.75	+2.75
	Autumn	+0.5	+0.8	+1.3	+1.25	+1.75	+2.75
	Winter	+0.5	+0.8	+1.3	+1.25	+1.75	+2.75
	Spring	+0.5	+0.8	+1.3	+1.25	+1.75	+2.75
Rainfall %	Annual	-15	-3.5	0	-30	-15	0
	Summer	-15	-3.5	+7.5	-30	-7.5	+15
	Autumn	-15	-3.5	+7.5	-30	-7.5	+15
	Winter	-15	-7.5	0	-30	-15	0
	Spring	-15	-7.5	0	-30	-15	0
Potential Evapotranspiration %	Annual	0	+3.0	+3.0	0	+6.0	+10.0
	Summer	0	0	+3.0	0	+6.0	+10.0
	Autumn	0	+3.0	+6.0	+3.0	+6.0	+14.0
	Winter	0	+6.0	+10.0	+6.0	+10.0	+18.0
	Spring	0	0	+3.0	-3.0	+3.0	+6.0
Relative Humidity %	Annual	-1.5	0	0	-2.5	-0.75	0
	Summer	-0.75	0	0	-1.5	-0.75	+0.75
	Autumn	-1.5	0	+0.75	-2.5	0	+1.5
	Winter	-1.5	0	0	-3.5	-0.75	+1.5
	Spring	-1.5	-0.75	0	-3.5	-1.5	0
Wind Speed %	Annual	-3.5	0	+3.5	-7.5	0	+7.5
	Summer	0	3.5	+7.5	-3.5	+3.5	+17.5
	Autumn	-7.5	0	+3.5	-12.5	0	+12.5
	Winter	-7.5	-3.5	+3.5	-17.5	-7.5	+7.5
	Spring	-7.5	0	+3.5	-17.5	-3.5	+7.5

Sea Level Rise

Alternative scenarios for predicted changes in sea level relative to 1990 levels in Australia were identified by the Department of Climate Change and Energy Efficiency (Department of Climate Change, 2009). The regional rate of risk for the Eyre Peninsula is not known; therefore the risk associated with projected sea level rise for the Australian Coast has been used in the preparation of this EIS. The projected scenarios for sea level rise are depicted in Table 7-5.

Table 7-5 Projected Sea Level Rise (Relative to 1990 Levels)

Year	Low Scenario[1]	Medium Scenario[2]	High Scenario[3]
2030	0.132 m	0.146 m	0.2 m
2070	0.333 m	0.471 m	0.7 m
2100	0.496 m	0.819 m	1.1 m

[1] Sea level rise that is likely to be unavoidable based on current climate change scenarios
[2] Sea level rise based on current greenhouse gas emissions and observations
[3] Sea level rise associated with more recent information on sheet dynamics

Although the proposed CEIP mine has a life of 25 years, the proposed port is anticipated to continue beyond this time servicing other exporters. As such, sea level rise projections out to 2100 are considered relevant to future operations. It can be observed that under the medium scenario, sea levels in Australia are anticipated to increase by 0.146 m by 2030 and up to 0.819 m by 2100. The impacts of sea level rise may be further exacerbated as a result of storm surge events and wave patterns. Design of the port, in particular the height of the jetty, has incorporated an allowance for sea level rise as discussed in Chapter 4.

Rainfall and Surface Water

A decreasing trend of average annual rainfall is predicted over southern Australia (Intergovernmental Panel on Climate Change 2013). In addition, an increase in extreme daily rainfall is projected. In some parts of South Australia an increase of up to 10% in intensity of 1 in 20 year daily rainfall events is likely. The projected fall in average annual rainfall in the Eyre Peninsula region is 0-15% by 2020, 0-40% by 2050 and 0-80% by 2080.

As a result of changing rainfall patterns, surface water runoff is predicted to decline up to 14% across south-western Australia. Similarly, the occurrence of droughts in south-western Australia is anticipated to increase up to 20% by 2030 and up to 80% by 2070.

Fire

As the frequency of droughts increases in Australia as a result of increased temperatures and decreased rainfall, fire danger will increase and the length of fire danger seasons are likely to be extended. An increase in fire danger is likely to be associated with a reduced interval between fires, increased fire intensity, a decrease in fire extinguishments and faster fire spread. It is projected that the frequency of very high and extreme fire danger days will increase by between 2% and 30% by 2020 and between 5% and 100% by 2050 (Intergovernmental Panel on Climate Change 2013).

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