METEOROLOGICAL ENVIRONMENT AND CLIMATE

8.1 INTRODUCTION

The Olympic Dam region is semi-arid, receiving an average annual rainfall of 167 mm and having an annual pan evaporation rate of around 3,000 mm. Temperature ranges from -6 °C to +48 °C. These climatic conditions are the primary drivers that influence the natural ecosystems and hydrogeology of the region. They also contribute to the level of potential impact and risk on the various disciplines assessed in the Draft EIS. For example, wind speed affects dust transfer, and rainfall intensity affects erosion risk and stormwater management.

This chapter details the climatic conditions of the areas relevant to the proposed expansion. It also discusses the potential effect that the proposed open pit and rock storage facility (RSF) may have on local and regional weather patterns. An overview of global climate change, including greenhouse gases, sea level rise and storm surge, is also provided, along with cross-references to the chapters of the Draft EIS where this information has been integrated into the project design and impact assessment.

8.2 ASSESSMENT METHODS

The climatic conditions of the project area were identified through desktop assessments of existing databases and discussions with relevant government agencies as listed in Table 8.1. A desktop assessment was also conducted to establish natural hazards and climate change relevant to the proposed expansion. Additional references are cited in the chapter whenever relevant.

Table 8.1 Climate data

Climate parameter	Data source	Collection period
Climate classification, based on temperature and humidity zones	Bureau of Meteorology (BOM) Climate Classification of Australia maps	1961–1990
Temperature, rainfall, humidity and evaporation	BOM official weather stations	1931–2007
Olympic Dam region wind speed and wind direction	BOM data supplemented by Olympic Dam automatic weather station	1993-2004 ¹
Seismic activity and risk mapping	Geosciences Australia and Australian Standard AS1170.4-1993	1840-2007
Historical flooding	BOM compilation of flooding events	1836-2004
Storm event including lightning ground flashes and annual thunder days	Commonwealth BOM National Climate Centre	1990–1999
Tropical cyclones	Commonwealth BOM National Climate Centre	1907–2008
Drought	Commonwealth BOM National Climate Centre	2007
Dust storms	BOM weather station observations	1949–2007
Fire	SA Country Fire Service	1997–2005

¹ 2004 is the most recent complete set of climate data due to lengthy weather station shutdowns in 2005. The automated weather station at Olympic Dam is no longer functional and is scheduled to be decommissioned.

8.3 CLIMATIC CONDITIONS

The Bureau of Meteorology has divided Australia into six main climatic zones on the basis of temperature and humidity (BOM 2006). Most of the study area, including Olympic Dam, Moomba, Port Augusta and Point Lowly, is within the 'hot dry zone with cool winter'. Adelaide (and Port Adelaide), are located within the 'temperate zone', and Darwin is located within the 'hot, humid summer, warm winter zone'.

Typical climatic conditions, including temperature, rainfall, humidity, evaporation, wind speed and direction for these three zones and for the major centres of the project area, are discussed below. Averages of temperature, rainfall and evaporation for the major centres of the project area are shown in Figure 8.1.

8.3.1 TEMPERATURE

Areas within the hot dry zone and temperate zone of South Australia are subject to hot summers and cool to mild winters. Temperatures are consistently higher in the north, with average monthly summer maximums reaching 36 °C at Roxby Downs, compared to 31 °C in Port Augusta and 27 °C in Adelaide. Conversely, minimum temperatures are slightly lower in the north, with average monthly winter minimums of 5 °C in Roxby Downs, compared to 7 °C in Adelaide.

In the hot and humid zone of the Northern Territory (i.e. where the Port of Darwin is located), temperatures are much more stable throughout the year. In fact, the average monthly maximum temperature (32 °C) is the same for the summer months as it is for the entire year. Minimum temperatures are generally much higher than in South Australia, with the average monthly winter minimums being 20 °C.

8.3.2 RAINFALL

Rainfall in the hot dry zone of South Australia is low, unpredictable and sporadic, with no seasonal pattern. Intense and usually short rainfalls can occur at any time of the year. Average annual rainfall at Roxby Downs is 167 mm and the average number of rain days is around 40 per year, although this can vary widely.

Towards the south of South Australia, average annual rainfall increases and becomes more seasonal, falling predominantly during winter, with an average annual rainfall of 257 mm at Port Augusta and 450 mm at Adelaide Airport. Rainfall frequency is also higher, with an average of 71 rain days per year in Port Augusta and 121 per year in Adelaide. Average annual rainfall in the hot, humid zone is much higher than in South Australia. The long-term average rainfall for Darwin Airport is around 1,700 mm, more than 95% of which falls between October and April (see Figure 8.1). The long-term average January rainfall for Darwin is 419 mm, which is comparable to the average rainfall in Adelaide over a whole year. Winter in Darwin (June through August) is almost completely dry, with an average rainfall of only 3 mm. On average there are 112 rain days per year in Darwin.

Rainfall duration and intensity can affect stormwater patterns, flood immunity and soil erodiblity. The average recurrence interval (ARI) is a measure of the frequency of a rainfall event. Storm data based on the ARI are used to design the capacity of stormwater infrastructure and stormwater containment facilities (see Chapter 11, Surface Water, for further detail). Rainfall intensity data can also be used as a management tool. For example, to identify areas that may be affected by soil erosion following large storm events (see Chapter 10, Topography and Soils).

Table 8.2 summarises the ARI for rainfall events of five minutes, 24 hours and 72 hours in duration, and shows the volume of rain measured in millimetres per hour (mm/h) that would need to fall for each of the ARI events. The data varies only slightly across the project area in South Australia. Design rainfall intensities are marginally higher in the northern sections, which shows that these areas receive intense storms slightly more frequently than the southern areas.

To provide a context for these rainfall events, and to include Darwin, Table 8.3 presents the same data for Sydney, Melbourne, Brisbane and Darwin. The data show that rainfall intensities across the project area in South Australia are most similar to Melbourne, and considerably lower than Sydney, Brisbane and Darwin.

8.3.3 RELATIVE HUMIDITY

Relative humidity in South Australia is generally low. It is highest in winter and lowest in summer, and decreases from the coast to inland areas. Within the project area, the average annual relative humidity (as recorded at 3 pm) ranges from 27% in Moomba to 52% in Adelaide. Darwin has an average relative humidity of 54% and, in contrast to Adelaide's humidity pattern, it is highest in summer and lowest in winter. For the purpose of monthly comparison, the average relative humidity for Roxby Downs and Darwin in January is 17% and 70% respectively.

Table 8.2 Design rainfall intensities for project area locations in South Australia (mm/h)

Adelaide		Whyalla			Port Augusta			Olympic Dam				
AKI (Yr)	5 min	24 h	72 h	5 min	24 h	72 h	5 min	24 h	72 h	5 min	24 h	72 h
1	43	1.5	0.6	38	1.2	0.5	41	1.2	0.5	42	1.1	0.4
5	81	2.6	1.1	78	2.2	0.9	82	2.3	0.9	n.d.	2.3	n.d.
50	155	4.3	1.8	162	4.0	1.6	160	4.4	1.7	172	4.7	1.8
100	186	5.0	2.0	196	4.8	1.8	190	5.2	2.1	204	5.7	2.2



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		Sydney		Melbourne			Brisbane			Darwin		
AKI (yi)	5 min	24 h	72 h	5 min	24 h	72 h	5 min	24 h	72 h	5 min	24 h	72 h
1	103	4.2	2.0	47	1.9	0.9	117	4.1	2.0	150	4.8	2.2
5	166	7.0	3.3	87	3.1	1.4	191	7.1	3.4	228	7.7	3.9
50	245	10.9	5.2	157	4.9	2.3	290	11.7	5.5	331	11.9	6.5
100	270	12.2	5.8	183	5.5	2.6	324	13.3	6.3	366	13.4	7.4

Table 8.3 Design rainfall intensities for other Australian capital cities (mm/h)

8.3.4 EVAPORATION

Evaporation rates at Olympic Dam are high throughout the year, with an average annual of around 3,000 mm. The average evaporation rates greatly exceed the average rainfall each month and therefore no free water is present for most of the year. Based on annual averages, the evaporation rate at Olympic Dam is around 18 times greater than its rainfall.

Evaporation rates in areas closer to Adelaide tend to be lower, particularly in winter. This is due to the higher rainfall and lower daily temperatures. In Adelaide, rainfall remains below its rate of evaporation with an average annual rainfall of 450 mm and an average annual evaporation rate around 1,900 mm (as measured at Adelaide Airport). The annual evaporation rates for Darwin (around 2,500 mm per year) are more consistent throughout the year due to smaller variations between summer and winter temperatures.

8.3.5 WIND AND ATMOSPHERIC STABILITY

Wind acts as a conduit for transporting dust and other airborne emissions, helping them travel far from their origins. Olympic Dam and Roxby Downs are dominated by southerly winds. Winds from the south-west to south-east accounted for more than 45% of all winds experienced in the 10 years from 1993 to 2004 (see Figure 8.2).

In the summer and autumn months, southerly winds are predominant. In spring, winds from the north-north-east and the north-east are more prevalent. During winter, winds from the north to north-east and from the south to south-west are predominant. Winter also has the highest number of calm days (average daily wind speeds being <0.5 m/s), followed by autumn, spring and summer. Wind speed and direction data are provided in Figure 8.2.

Atmospheric stability is measured using the Pasquill stability classes, which refers to the rate at which mixing and dispersion of pollutants occurs. The classes (A to F) are defined in Table 8.4. A stability of 'A' indicates conditions conducive to pollutant dispersion, and a stability of 'F' indicates poor dispersion of pollutants. The distribution of stability with time of day for the period 1993 to 2004 inclusive is described in Table 8.5. A review of this data shows that conditions conducive to pollutant dispersion (i.e. classes A–C) occur for about 32% of the day (most often between 1 pm and 5 pm), neutral conditions (i.e. class D) for about 43%, and conditions less favourable for pollutant dispersion (generally between 7 pm and 5 am) for 25% of the day.

Table 8.4 Pasquill atmospheric stability class definitions

Pasquill atmospheric stability class	Definition
А	Very unstable
В	Moderately unstable
С	Slightly unstable
D	Neutral
E	Slightly stable
F	Stable

Atmospheric inversion is a deviation from normal atmospheric conditions, and typically refers to an increase in temperature. Usually a temperature inversion occurs when the air temperature increases with height from the ground, instead of the other way around.

Atmospheric stability, inversion, wind speed and wind direction data have been used in air quality and acoustic modelling to predict the distribution and ground level concentrations of dust and emissions, noise contours, and their potential impacts on sensitive receivers (see Chapter 13, Greenhouse Gas and Air Quality, and Chapter 14, Noise and Vibration, for details). Hydrodynamic modelling, which is used to assess the potential effects of the proposed desalination plant at Point Lowly on the Upper Spencer Gulf marine environment, also uses wind data (see Chapter 16, Marine Environment, for details).

8.4 NATURAL HAZARDS

8.4.1 SEISMIC ACTIVITY

The magnitude of an earthquake is an estimate of the amount of energy it releases. Although earthquakes measuring less than 3.4 on the traditional Richter scale are generally not felt, they are recorded by seismographs. Earthquakes that measure 5.5 to 6.1 may cause slight building damage, and earthquakes of 6.2 to 6.9 may cause considerable building damage and houses to move on their foundations (Geoscience Australia 2006).

Adelaide has the highest earthquake hazard of all capital cities in Australia, although this risk is considered slight on a global scale (Atlas of South Australia 2006; Geoscience Australia 2006). The major seismic zone in South Australia occurs within the Adelaide Geosyncline (see Chapter 12, Groundwater, for further detail), extending from Kangaroo Island through the Mount Lofty Ranges and Flinders Ranges to Leigh Creek (Atlas of South Australia 2006).



Time of day	Pasquill atmospheric stability class									
	А	В	с	D	E	F				
1				1,750	1,077	1,076				
2				1,741	1,093	1,071				
3				1,718	1,083	1,104				
4				1,725	1,068	1,112				
5				1,671	1,092	1,142				
6	487	291	684	2,443						
7	472	300	731	2,402						
8	474	308	823	2,300						
9	448	369	1,031	2,057						
10	477	478	1,224	1,726						
11	590	556	1,271	1,488						
12	819	617	1,177	1,292						
13	1,048	673	1,037	1,147						
14	1,222	669	903	1,111						
15	1,260	672	883	1,090						
16	1,226	688	904	1,087						
17	1,127	678	1,011	1,089						
18	990	622	1,026	1,267						
19				1,984	816	1,105				
20				1,898	941	1,066				
21				1,788	1,045	1,072				
22				1,726	1,065	1,114				
23				1,644	1,097	1,164				
24				1,713	1,048	1,144				
Percentage	11	7	14	43	12	13				

Table 8.5 Atmospheric stability at Olympic Dam versus time of day (AWS data)

The highest magnitude earthquake recorded in the vicinity of the study area in South Australia occurred around 50 km northeast of Port Augusta in March 1939, measuring 5.8 on the Richter scale. During 2007, five earthquakes measuring more than 3.5 (which may be felt by some people) were recorded in South Australia, the closest to the study area occurring around 70 km north-east of Port Augusta (Geoscience Australia 2008). No earthquakes measuring more than 3.5 have occurred within 100 km of Olympic Dam.

Four earthquakes greater than 3.5 have been recorded within 100 km of Darwin. The largest, measuring 4.5 on the Richter scale, occurred in August 1986, and the most recent, with a magnitude of 3.6, occurred in December 2000 (Geoscience Australia 2008).

The effects of an earthquake will depend on its magnitude and on physical factors such as geology. Acceleration coefficients, which relate to the level of ground shaking that occurs following a seismic event, are used in engineering calculations to estimate the force exerted on built structures. At an acceleration coefficient of 0.1, poor-quality buildings would usually be damaged, while correctly designed and constructed buildings would not be affected (Standards Australia 1993). Contours of acceleration coefficients around Australia indicate that seismic events with acceleration coefficients of 0.09 could occur for the Olympic Dam and Darwin areas, and seismic events with accelerations coefficients of 0.11 could occur in the Point Lowly area (McCue et al. 1993). The probability of exceeding these figures is low, at 10% in 50 years.

Given that structures would be designed and built in accordance with the Australian Standards for Earthquake Actions (AS1170.4), the risk of these events causing environmental impact throughout the life of the project is considered to be low.

8.4.2 FLOODING AND STORM EVENTS

Flooding is a natural phenomenon in the arid lands of South Australia. Events range from localised, short-term surface ponding to widespread flooding that leads to major salt lakes being filled (see Plates 8.1 to 8.4). To maximise the benefit from such events, pastoralists often create small dams by connecting adjacent swales using drainage culverts. Up to two years' water supply can be stored from a large storm using this arrangement. Long-term storage of surface water is uncommon, because of very high evaporation rates and because silt builds up in dams when perennial vegetation dies (SAAL NRM Board 2006). Local



Plate 8.1 Unpredictable and sporadic rainfall events are often intense in nature and of short duration



Plate 8.3 Flooding of Coorley Creek in early 2007 – the creek had been dry since 1993



Plate 8.2 Short-term surface ponding from a storm event near Port Augusta

and regional flooding and the implications for stormwater management for the proposed expansion are discussed in Chapter 11, Surface Water.

Storm events can occur at any time of the year and are generally intense and of short duration. Thunderstorms occur infrequently in the southern areas of central Australia because the air, although often very hot, is generally drier.

The average annual lightning ground-flash density (see Plate 8.5), and days with thunder for the study area compared to Australian capital cities, is shown in Table 8.6 (BOM 2001 and BOM 2003a).



Plate 8.4 Lake Mary filled in early 2007 following heavy rainfall – the first time since 1989



Table 8.6 Lightning ground-flash density and thunder days (from north to south)

	Darwin	Brisbane	Olympic Dam to Whyalla	Sydney	Adelaide	Melbourne
Lightning ¹	3.0-4.0	2.0-3.0	0.5-1.0	1.0-2.0	0.0-0.5	0.5-1.0
Thunder days per year	80-100	25-30	10–15	20-25	10-15	10–15

¹ Average annual lightning ground-flash density (flash/km²/a).

8.4.3 TROPICAL CYCLONES AND STORM SURGE

Tropical cyclones are low-pressure systems that occur over warm waters in the tropics. They have well defined clockwise wind circulations, and the area surrounding the centre of the system experiences gale force winds (sustained winds of 63 km/h or greater, with gusts of more than 90 km/h) (BOM 2008).

In Australia, most cyclones occur in the tropics along the northwestern, northern and north-eastern coasts between December and April. On average, 10 tropical cyclones develop in the Australian region each year and six cross the coast (BOM 2008). Darwin is located in the tropical cyclone risk area, with an average annual number of cyclones of 0.2 to 0.4 (see Figure 8.3). Table 8.7 details some of the cyclones that have occurred in the northern region. South Australia is not in a tropical cyclone risk area.

Tropical cyclones are dangerous because they produce destructive winds, heavy rainfall and flooding that can cause inundation of low-lying areas. Potentially, the most destructive phenomenon associated with tropical cyclones that reach land is the storm surge. Storm surge is the rise of sea level above the normal water level along a shore, caused by strong on-shore winds and/or reduced atmospheric pressure. The surge height is the difference between the observed water level and the predicted tide level. If the surge occurs at the same time as a high tide then the area inundated can be quite extensive, particularly along low-lying coastlines. The largest storm surge in Australia was around 15 m, recorded during Cyclone Mahina in Far North Queensland in 1899 (BOM 2008).

Infrastructure constructed in tropical cyclone risk areas (i.e. Port of Darwin facilities) would be built to the appropriate Australian standards. Appropriate design criteria and a detailed risk management and cyclone response plan would be developed.

8.4.4 DROUGHT

Drought is a natural hazard common to many parts of Australia, including the project area. Although the incidence of drought across Australia has no identifiable pattern, the risk of drought in any given area can be inferred from the index of rainfall variability. This is a measure of the likelihood of annual rainfall differing from the long-term average. Areas of high variability are more likely to experience periods of drought or extreme rainfall (Atlas of South Australia 2006).

The rainfall variability in South Australia generally increases from the coast to inland areas. It ranges from low to moderate in the south of the state (including Adelaide), to moderate to high in the vicinity of Olympic Dam. The average annual rainfall variability for the project area compared to Australian capital cities is shown in Table 8.8 (BOM 2003b).

8.4.5 DUST STORMS

Dust storms are a common meteorological phenomenon in dry, arid and semi-arid regions of Australia. Although they are usually restricted to inland areas, they may affect coastal regions in times of severe drought. The storms form a blanket of wind-blown dust over a large area, usually as a result of convection currents created by intense heating of the ground.

Dust storm frequency increases in years of drought and in arid and temperate areas during summer months. The average frequency of dust storms for the project area is shown in Table 8.9. A photograph of a heavy dust storm, which occurred in Roxby Downs during December 2005, is shown on Plate 8.6.

8.4.6 FIRE

South Australia's dry climatic conditions cause frequent bushfires. In general, the incidence of bushfires, scrub and grass fires is higher in the hotter months. In the sparsely vegetated arid regions, bushfires are more often associated with the growth of ephemeral grasses following significant rainfall events, and their subsequent dieback as dry conditions return.

Tropical cyclone	Location (approximate) in relation to Darwin	Date	Maximum severity category	Estimated maximum wind gusts (km/h)
Helen	130 km south-west	January 2008	2	130
Monica	300 km east	April 2006	5	360
Ingrid	110 km north	March 2005	3	185
Thelma	<200 km north-west	December 1998	5	320
Tracy	0 km	December 1974	4	>217

Table 8.7 Northern region cyclone history¹

¹ Sourced from BOM 2008.

Table 8.8 Average annual rainfall variability (from north to south)¹

	Darwin	Brisbane	Olympic Dam	Port Augusta to Whyalla	Sydney	Adelaide	Melbourne
Index of rainfall variability	Low to moderate	Low to moderate	Moderate to high	Moderate	Low to moderate	Low to moderate	Low

¹ Based on data from 1900 to 2003.



Table 8.9 Average dust storm frequency¹

		5		Auciarac	Darwin
Dust storms per year 2	2	1	~0.4	0.6	0.5

¹ Sourced from Middleton (1984).



To help control bushfires and protect lives and property, restrictions are imposed on the lighting of fires during a designated fire danger season. Annual fire restrictions are in place for the North West and North East Pastoral Districts (Olympic Dam and Moomba) from 15 October to 31 March, for Flinders District (Port Augusta) and Eastern Eyre Peninsula District (Point Lowly) from 15 October to 15 April and in the Adelaide metropolitan area from 1 November to 30 April.

8.5 CHANGES TO THE METEOROLOGICAL ENVIRONMENT

As part of the Draft EIS, Pacific Air Environment completed a study of the potential for the proposed expansion to affect meteorological conditions (such as wind patterns and temperature) due to the construction of the RSF, tailing storage facility (TSF) and the open pit (see Chapter 13, Greenhouse Gas and Air Quality, for details). Climate modelling was used to predict the potential effects at a national (i.e. Australia-wide), regional (>10 km) and local (<10 km) scale. No significant changes in weather are predicted at distances of more than 10 km from the mine site. Within 5–10 km from the pit, the average temperature, wind speed and rainfall are also unlikely to be affected. The modelling suggests, however, that some minor changes to wind direction and relative humidity may occur when the open pit and RSF are well developed (i.e. in the later stages of the proposed expansion). Close to the mine site (<5 km), the RSF and open pit are likely to affect airflow patterns, with some forced upward and downward flow along the RSF edges, and a potential for convergence of airflow into the pit. As rock temperatures naturally increase with depth, the air temperature within the pit is predicted to increase with depth by an estimated 1 °C per 100 m.

Air flow and wind patterns are important factors in predicting the fate of dust and other airborne emissions. Because of this, results of the local climate study have been considered in the air quality modelling (see Chapter 13). High temperatures in the pit may also affect the occupational health and safety of mine workers. Potential impacts and management measures for this are discussed in Chapter 22, Health and Safety.

8.6 CLIMATE CHANGE

8.6.1 CLIMATE CHANGE DATA AND PREDICTIONS

Scientists have concluded that human-caused increases in greenhouse gas (GHG) emissions are enhancing the natural greenhouse effect. Human activities, especially the burning of fossil fuels, clearing of forests and changing of land use, have been the major causes of global warming and climate change in recent decades (DEH 2005).

In 2004, the Intergovernmental Panel on Climate Change (IPCC) warned that increasingly, observations are showing that the planet is warming and the climate is changing. The Working Group II report, *Impacts, Adaptation and Vulnerability* (IPCC 2007) from the recent Fourth IPCC Assessment Report, confirms that these predictions are now occurring in Australia. A summary of the climate change predictions and warnings of relevance to Australia are as follows (IPCC 2007):

- There has been a warming of the lower atmosphere and upper ocean.
- The uptake of anthropogenic carbon by the ocean since 1750 has resulted in a slight increase in acidity, an average decrease of 0.1 units. During the 21st century, a further increase in acidity is expected with a reduction in pH between 0.14 and 0.35 units.
- An increase in global average precipitation has been observed in many regions from 1900 to 2005, although it appears highly variable. An increase in the density and duration of droughts has been observed globally and is predicted to continue.
- Most of the global warming observed over the past 50 years is attributable to human activities. Several greenhouse gases occur naturally within the environment. Increases in atmospheric conditions over the past 250 years can be attributed to human activity.
- By 2100, it is estimated that global average temperatures may rise 2.4 °C to 6.4 °C and global sea level may rise 26–59 cm, relative to 1980 levels, if greenhouse gas emissions continue at current levels.
- By 2100, current predictions estimate that sea levels may rise 18–59 cm above those in 2000. The predictions for Australia, however, are subject to regional modifications that could potentially result in a change in sea level of up to ± 25% of the estimated figure.
- By 2020, it is estimated that in Australia, within 800 km of the coast, the temperature is likely to increase by between 0.1 °C and 1.3 °C above 1990 temperature levels. The temperature increase is predicted to range from 0.3 °C to 3.4 °C by 2050 and from 0.4 °C to 6.7 °C by 2080.
- A decrease in annual rainfall is considered likely across the majority of southern and sub-tropical Australia. Increases in extreme daily rainfall events are also considered likely.
- The projected change in annual average rainfall for Central Australia ranges between ± 5% by 2020, ± 13% by 2050 and ± 27% by 2080.

- In parts of South Australia, the intensity of the daily rainfall event (1-in-20-year daily rainfall event) is likely to increase by up to 10% by 2030.
- Water balance models indicate a likely reduction in both soil moisture and run-off across the majority of Australia. For the period 2021 to 2050, a decline in run-off of 6% to 8% is predicted across the majority of eastern Australia and 14% across south-western Australia.
- Modelling the occurrence of droughts (1-in-10-year soil moisture deficit) demonstrated that up to 20% more droughts are likely to occur over the majority of Australia by 2030, and up to 80% more droughts by 2070 in southwestern Australia.
- By 2030, water security problems resulting from a continued decrease in precipitation and an increase in evaporation are predicted to intensify in southern and eastern Australia.
- The risk that extreme event design criteria for major infrastructure will be exceeded is considered very likely to occur in Australia by 2030. This includes failure of flood plain protection and urban drainage/sewerage, increased storm and fire damage and more heatwaves. It is predicted that the increase in heatwaves will contribute to a greater number of blackouts and more heat-related deaths.
- A decline in species migration resulting from a loss and/or change of habitat is considered likely to occur, although the effect depends on the species' ability to adapt to climate change.

Increased atmospheric concentrations of carbon dioxide (CO_2) and other GHG emissions have been measured. Based on National Oceanic and Atmospheric Administration data, the atmospheric concentration of CO_2 has risen to a 2007 average of 384 parts per million (ppm) (NOAA 2008). This is a 21% increase in CO_2 from the 1959 average recorded at the Mauna Loa observatory in Hawaii, which provides the longest continuous instrumental measurement of CO_2 levels. If GHG and aerosol emissions were held constant at 2005 levels, CO_2 and equivalent gas (CO_2 -e) concentrations would rise to 531 ppm by 2100. The predicted temperature increase of this CO_2 -e level is 2 °C (Hare and Meinshausen 2004).

The IPCC, United Nations Convention on Biological Diversity and the Council of the European Union consider that a global average surface temperature rise above 2 °C is likely to have critical and irreversible climate change effects. To avoid the 2 °C temperature rise, atmospheric concentrations of CO_2 -e need to stabilise at 400–450 ppm (Hare and Meinshausen 2004). To achieve this with reasonable certainty, GHG emissions need to be cut by at least 30% of the 1990 levels by 2050 (Hare and Meinshausen 2004). Net greenhouse gas emissions, as reported in the *National Greenhouse Gas Inventory 2005* (Australian Greenhouse Office 2007), were 2.2% above the 1990 levels. Between 1910 and 2004, Australia's average maximum temperature has increased by 0.6 °C and the average minimum temperature has increased by 1.2 °C. Most of these changes have occurred since 1950 (IPCC 2007). The IPCC (2007) states that since 1950, the temperature in Australia has increased by between 0.4 °C and 0.7 °C. Heatwaves and frosts occur more frequently, and the amount of rainfall in southern and eastern Australia has decreased.

A significant degree of climate change across Australia now seems inevitable, and is likely to become more apparent during the latter half of this century (Suppiah et al. 2006). Changes are expected in climate averages and in the magnitude and frequency of climate extremes. Suppiah and others (2006) and CSIRO (2002) suggest that long-term planning should not be based on the assumption that future climate statistics and resources will be the same as they were over the last century. Climate change will have an impact on water supply, flooding, sea level and storm surges.

The assessment of GHG generation as a result of the proposed expansion is discussed in Chapter 13, Greenhouse Gas and Air Quality. The implications of global climate change are discussed wherever relevant throughout the Draft EIS.

8.6.2 SEA LEVEL RISE

Rising sea levels can be caused by the melting of land-based ice, such as glaciers and ice sheets, and from elevated land and atmospheric temperatures (i.e. global warming) transferring heat to the oceans and causing water to expand (NOVA 2006). Current predictions suggest that sea levels may rise between 18-59 cm (relative to 2000 levels) by 2100 (IPCC 2007). For Australia, however, these predictions are subject to regional modifications which could potentially result in a change in sea level of up to \pm 25% of the estimated figure. For the Olympic Dam expansion, the areas that may be affected by rising sea levels include the coastal desalination plant, landing facility and port facilities.

Reducing the potential impact on infrastructure can be achieved by siting the infrastructure at sufficient elevations so that it is not affected by a rise in sea level. The location of the desalination plant at Point Lowly is likely to be at an elevation of more than 25 m AHD, which is well above predicted sea levels. Potential rises in sea level, however, would be considered in the detailed design of the intake pumping station facility. Because the landing facility and port facilities would be closer to natural sea level, designs have accounted for predicted sea level rise and storm surge.

Strategies (such as constructing levees or sea walls) may need to be investigated in the future to protect existing infrastructure such as port facilities (<5 m AHD). If these measures are deemed insufficient, it may be necessary to relocate existing infrastructure in the future. This would be an issue not only for the BHP Billiton port facilities, but for the majority of the Port Adelaide area and the Port of Darwin.

8.6.3 TROPICAL CYCLONES AND STORM SURGE

Trends in tropical cyclone activity in the Australian region show that although the total number of cyclones has decreased in recent decades, the number of stronger cyclones (minimum central pressure less than 970 hPa) has not declined (BOM 2008).

Predictions of the future occurrence and intensity of tropical cyclones in the Australian region due to global climate change vary. Two studies discussed in the CSIRO report *Climate Change in Australia* (CSIRO 2007) predict that there will be no significant change in the number of cyclones, while other research from CSIRO (2007) shows a decrease in the number of cyclones. Each of the above studies predicts an increase in the frequency of severe (category 3–5) cyclones.

As discussed in Section 8.3.6, infrastructure constructed in tropical cyclone risk areas (i.e. Port of Darwin facilities) would be built to appropriate standards and a detailed risk management and cyclone response plan would be developed. Both the detailed design and risk management plan would consider the implications of climate change on tropical cyclone and storm surge magnitude and frequency.

South Australia is not in a tropical cyclone risk area, but coastal areas can still be affected by storm surge. Storm surges have a low probability in South Australia and planning guidelines for coastal development are set by the 100-year average recurrence interval (ARI) water level rather than by storm surge levels. The proposed desalination plant would be located at an elevation of more than 25 m AHD (i.e. well above the 100-year ARI level) and therefore would not be affected by storm surge. Storm surges would not affect the proposed outfall and intake pipes for the desalination plant either because they would be placed on the sea bed rather than being secured to a jetty structure. The sump associated with the intake pipe and the landing facility (see Chapter 5, Description of the Proposed Expansion, Section 5.7.4 and Section 5.9.5) would be constructed near the seashore. Sea level rise and storm surge predictions are being considered in determining the siting and detailed design of these structures.

8.6.4 RAINFALL, SURFACE WATER RUN-OFF AND DROUGHT

The annual average rainfall may increase or decrease across Australia depending on location, with a decreasing trend likely over southern and sub-tropical Australia (IPCC 2007). The projected change in annual average rainfall for Central Australia varies from \pm 5% by 2020, \pm 13% by 2050 and \pm 27% by 2080 (IPCC 2007). Where there is a minor increase or decrease in average rainfall it is considered likely that there will be an increase in the extreme daily rainfall. It is estimated that in parts of South Australia, the intensity of the 1-in-20 year daily rainfall event is likely to increase by up to 10%. Water balance models, including projected changes in rainfall and evaporation, indicate a likely reduction in both soil moisture and run-off across most of Australia (IPCC 2007). For the period 2021 to 2050, the predicted decline in run-off varies between 6% and 8% across most of eastern Australia and 14% across south-western Australia.

The occurrence of droughts (which have been defined as a 1-in-10 year soil moisture deficit) over most of Australia is estimated to increase by up to 20% by 2030 and up to 80% by 2070 in south-western Australia.

For the proposed expansion, rainfall variation is most relevant to the site's water balance and the sizing of the TSF cells. Additional design controls to accommodate higher intensity rainfall events for structures have been included. For example, an additional 0.5 m of freeboard has been included in the TSF design to accommodate the possibility of higher intensity rainfall events (see Chapter 5, Description of the Proposed Expansion, Section 5.5.6). Further assessment of the risks associated with higher intensity storm events on the TSF is presented in Chapter 26, Hazard and Risk, and the potential for climate change to affect salinity in Upper Spencer Gulf is discussed in Chapter 16, Marine Environment. The effects of climate change on groundwater recharge has also been included in sensitivity analysis for the regional groundwater model (see Appendix K6).

8.6.5 **BUSHFIRES**

As droughts are expected to occur more frequently in Australia, the fire danger will increase, and the length of the fire season is likely to be extended. The increase in fire danger is potentially associated with a shorter interval between fires, increased fire intensity and spread. The IPCC predicts that the frequency of very high and extreme fire danger days is expected to increase by 4% to 25% by 2020 and 15% to 70% by 2050 (IPCC 2007).