PROJECT SEA DRAGON
STAGE 1 LEGUNE GROW-OUT FACILITY
DRAFT ENVIRONMENTAL IMPACT STATEMENT

VOLUME 2 - ENVIRONMENTAL ASSESSMENT
CHAPTER 12 - CLIMATE CHANGE ASSESSMENT

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1 INTRODUCTION

This chapter presents the results of the climate change assessment undertaken by Water Technology (2016) for the Project Sea Dragon Stage 1 Legune Grow-out Facility (the Project or Project Area). It describes the projected annual emissions of greenhouse gases (GHG) as well as the risks to the Project from climate change impacts. Proposed GHG abatement measures, and mitigation measures to minimise the risk to the Project from climate change, are outlined.

1.1 TERMS OF REFERENCE ADDRESSED IN THIS CHAPTER

The Terms of Reference (ToR) addressed in this chapter, and the relevant sections in which they are addressed, are presented below in Table 1.

TABLE 1 TERMS OF REFERENCE

Section	Terms of Reference	Chapter Section
4.9.7	**Climate Change**	
	Provide an inventory of projected annual emissions for each relevant greenhouse gas, with total emissions expressed in 'CO2 equivalent' terms and a description of proposed greenhouse gas abatement measures.	Section 4.1 and Section 5.1
	Provide an assessment of risks to the Project from climate change impacts (e.g. increases in mean sea level, storm tides, waves and shoreline erosion).	Section 4.2
	Identify mitigation and adaptation measures to minimise risk to the Project from climate change impacts, particularly where there may be a significant impact to human safety or property.	Section 5.2

1.2 REGULATORY REQUIREMENTS, STANDARDS AND AGREEMENTS

The *Commonwealth National Greenhouse and Energy Reporting Act 2007* (NGER Act) introduced a single national framework for reporting and disseminating information about greenhouse gas emissions and energy use by corporations. The NGER Act makes registration and reporting mandatory for corporations whose energy production, energy use or greenhouse gas emissions meet specified thresholds. There are two types of thresholds for determining obligations to participate in the National Greenhouse and Energy Reporting Scheme:

- facilities which emit 25 kilotonnes (kt) or more of carbon dioxide equivalent (CO2-e), or produce or consume 100 tetrajoules (TJ) or more of energy
- corporations which emit 50 kt or more of CO2-e ,or produce or consume 200 TJ or more of energy.

Should the Project trigger these thresholds, the proponent will register and report all energy use and greenhouse gas emissions under the National Greenhouse and Energy Reporting Scheme.

2 METHODS

2.1 GREENHOUSE GAS ASSESSMENT

The GHG assessment covers Scope 1 emissions from construction (commencing July 2017) and 25 years of operations (late November 2019 to 2044). Financial modelling for the Project has assumed a nominal 25 year operating life. However, there is nothing in the proposed assets, facilities design, breeding program and operating plan which would prevent the business from continuing for a significantly longer period.

The calculation of GHG emissions for the Project was based on the methodology outlined in the National Greenhouse Accounts Factors (DoE 2015; NGA Factors). GHG emissions due to vegetation clearing were quantified using the Full Carbon Accounting Model (FullCAM).

2.2 CLIMATE CHANGE IMPACTS TO THE PROJECT

The assessment of climate change impacts to the Project involved a desktop review including:

- an extensive literature review to document the existing coastal environment within Joseph Bonaparte Gulf, the Keep River, the Victoria River, and the waterways around Legune Station. Legune Station is remote and thus previous detailed studies were limited, however, where available, data associated with physical oceanography including hydrodynamics, storm surges and waves was reviewed to inform the climate change assessment.
- a review of Climate Change in Australia Projections, Cluster Report – Monsoonal North (CSRIO 2015) which provides a summary of the climate change impacts that are currently projected around Legune Station.
- a review of 2012 Marine Report Card (CSIRO 2012) which includes an analysis of high accuracy sea levels across Australia collected as part of the Bureau of Meteorology's (BoM) Australian Baseline Sea Level Monitoring Program (AMSLMP).
- a review of Bureau of Meteorology Australian Climate Variability and Change- Timeseries graphs (BoM 2015).
- a review of Intergovernmental Panel on Climate Change (IPCC) 2014 Projected Sea Level Rise data.
- a review of The Engineers Australia Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering (Engineers Australia 2012).

To assist in characterising the physical coastal environment and to support the development and calibration of numerical models, a data collection program was undertaken. This program included the deployment of water level, wave, and water quality data loggers, and the collection of bathymetric data and current profiles.

A suite of numerical models including hydrodynamic, wave and transport models were developed to enable the simulation of the tides, waves, and extreme events on physical processes. Models were developed using the Danish Hydraulic Institute's (DHI) MIKE Modelling suite. Probabilistic storm tide modelling was completed for Legune Station by Systems Engineering Australia Pty Ltd (SEA 2016) to capture the generation and movement of tropical cyclones and oceanic processes over a wide region. SEA provided synthetic tropical cyclone track parameters which generate 50 and 100 year ARI (average recurrence interval) storm tide levels offshore of the sites (i.e. the combination of tidal water level and storm surge). A synthetic storm which generates a 1000-year ARI storm surge offshore of Legune was also modelled.

3 EXISTING ENVIRONMENT

3.1 TIDAL WATER LEVELS

3.1.1 Joseph Bonaparte Gulf

Joseph Bonaparte Gulf is a macro-tidal environment where astronomical tides circulate around a tidal node located offshore in the west of the Gulf. Tidal ranges around the tidal node are low and increase radially away from the tidal node.

The closest recognised tidal station to Legune is located at Pelican Island, approximately 50 km west of the site. The closest "Standard Port" tidal station is Cape Domett, located approximately 100 km north-northwest of Legune at the entrance to Cambridge Gulf. A Standard Port has a longer period of more reliable data than a secondary port. Tidal plane information for Pelican Island and Cape Domett are shown in Table 2.

The astronomical tide at both Pelican Island and Cape Domett is semi-diurnal (i.e. two high and two low tides daily) with a slight diurnal inequality which results in one higher tide and one lower tide per day. The mean spring tide range[1] (5.8 m) at Pelican Island is larger than Cape Domett (5.3 m), whilst the range between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) is slightly smaller (8.0 m compared to 8.1 m). This anomaly demonstrates the complex nature of the astronomical tides within Joseph Bonaparte Gulf which results from a combination of the tidal node and circulation of the tide, the funnelling of the tide into Joseph Bonaparte Gulf and Legune, and the funnelling of tides into the wide estuaries such as the Cambridge Gulf where Cape Domett is located.

TABLE 2 ASTRONOMICAL TIDAL PLANES (M AHD)

Location	Data source	HAT	MHWS	MHWN[2]	MLWN[3]	MLWS	LAT
Cape Domett	ANTT 2016	3.8	2.6	1.0	-1.0	-2.7	-4.2
Pelican Island	ANTT 2016	3.7	2.9	1.1	-1.1	-2.9	-4.3
Offshore Legune	Measured data	5.1	3.7	1.0	-1.0	-3.7	-5.3

3.1.2 Legune

An offshore water level logger was deployed for a 6 week period during September and October 2015 and again for 6 weeks between January 2016 and March 2016. Astronomical tidal constituents were obtained from the dataset and used to generate a tidal signal offshore from Legune. The tidal plane information, based on harmonic tidal constituents, is shown in Table 2.

The tide offshore from Legune is similar to that at Pelican Island - semi-diurnal with a slight diurnal inequality. The mean spring tide range is higher than Pelican Island at 7.4 m and as with Pelican Island there is significant difference between peak spring tidal ranges of around 1.0 m. The peak measured tidal range during October 2015 was in the order of 9 m.

[1] *Mean High Water Springs (MHWS) minus Mean Low Water Springs (MLWS)*
[2] *Mean High Water Neap*
[3] *Mean Low Water Neap*

The HAT of 5.1 m AHD noted in Table 2 is the predicted highest tide which could theoretically occur in a tidal epoch – a period of 18.6 years. Meteorological impacts such as storm surge and regional seasonal and inter-annual variability may result in a water level higher, or lower, than the HAT and the LAT respectively.

3.2 SEA LEVELS

In addition to tidal water level variations, longer term changes in water levels at the site will occur in response to local weather conditions including tropical cyclones, seasonal climatology and global climate forces. A summary of the period and magnitude of these changes is provided in Table 3 and described in more detail below. Tropical cyclones are discussed separately in the Climate and Local Meteorology chapter (Volume 2, Chapter 11).

TABLE 3 MAJOR PROCESSES IMPACTING SEA LEVEL VARIABILITY

Sea level driver	Period	Range
Astronomical Tide	0.5 – 1 day	8.0 – 9.0 m
Storm Surge	1 – 10 days	0.2 – 0.3 m
Seasonal/Monsoon	3 – 6 Months	0.2 – 0.3 m
El Niño-Southern Oscillation (ENSO)/ Indian Ocean Dipole (IOD)	Inter-annual	0.1 – 0.2 m

3.2.1 Storm Surge

Storm surge is the localised increase in water levels due to atmospheric and oceanographic conditions related to a storm event. An estimate of the non-tropical cyclone wind driven setup around Legune has been established. Analysis of the regional wind climate between October and February, when onshore conditions dominate, was used to establish the 99%, 90% and 75% wind speeds from the north through northwest. The water level set up values after 3 hours, which is considered conservative for these winds speeds, are shown in Table 4.

Wind setup increases as water is pushed into the Keep and Victoria Rivers and Forsyth Creek. Water levels at the intake and discharge points of Forsyth and Alligator Creeks peak 0.05 to 0.1 m higher than at the offshore point under the most extreme conditions. Further upstream, wind setup can lead to a peak water level increase of 0.2 m above mean sea levels. The modelling has been conducted using constant water levels at both mean sea level (0 m Australian Height Datum (AHD)) and also the offshore MHWS (mean high water spring; 3.7 m AHD) to provide extreme conditions. When considered in relation to the tidal range in excess of 9 m at Legune, wind driven setup is minor.

TABLE 4 POTENTIAL WIND INDUCED STORM SETUP OFFSHORE

Wind level	Wind speed and direction	Peak increase in mean sea level
99% Exceedance	7.2 m/s 322 deg	0.1
90% Exceedance	4.7 m/s 317 deg	< 0.1
75% Exceedance	4.2 m/s 317 deg	< 0.05

Atmospheric pressure variations can also cause increases to mean water levels. When considering pressure in isolation, a change in atmospheric pressure from 1000 hPa to 1010 hPa will cause (close to) a 10 cm decrease in water level. The range in atmospheric pressure in the region is steady at around 20 hPa throughout the year (BoM 2015). By extension, it can be assumed that atmospheric pressure would be expected to contribute as a maximum, a change in water level of 0.2 m during the passing of a front and associated change in pressure. As with the impact of wind on water levels, this potential change in water level is low relative to the high tidal range.

3.2.2 Seasonal Variability

Mean sea levels in the north of Australia are also influenced by monsoonal conditions and seasonal changes in atmospheric pressure, air temperature and wind conditions. Figure 1 shows the monthly difference of mean sea levels when compared to the long term average. The seasonal pattern is clearly evident with mean sea levels peaking during the wet season when atmospheric pressure and temperatures are high. The northwest monsoonal winds during this period also help to push water towards the coastline, increasing the elevated levels to around 0.1 m above the annual mean sea level during the monsoonal months. During the dry season months of June through October, winds are generally offshore (south and east) and the water (and air) temperatures are lower, reducing baroclinic impacts on water levels and mean sea levels are around 0.15 m below the annual average.

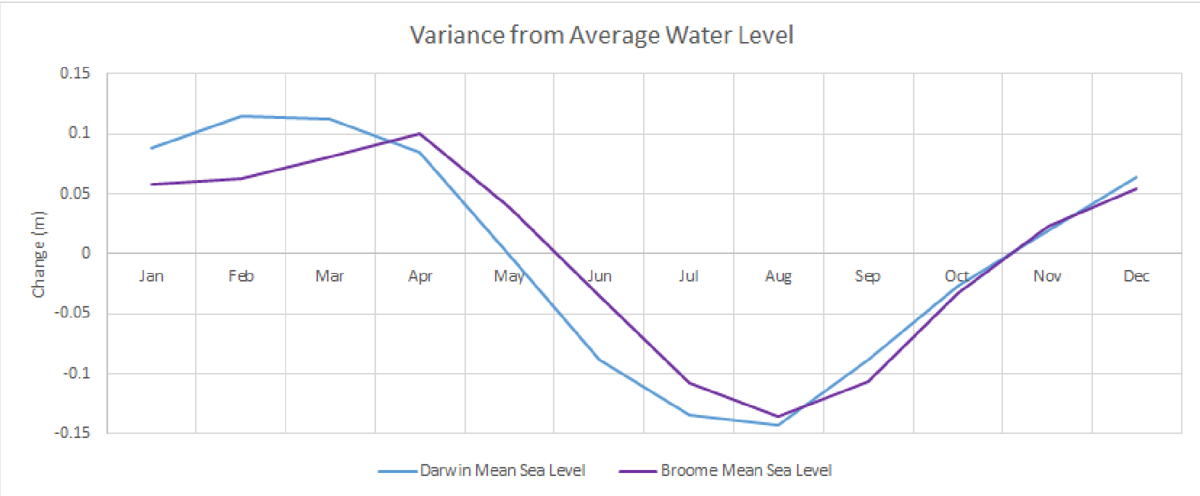

FIGURE 1 SEASONAL VARIATION OF MEAN SEA LEVEL AT DARWIN AND BROOME

3.2.3 Inter-annual Variation

Global weather systems lead to an inter-annual variation in water levels which can cancel out or exacerbate the seasonal change. The north of Australia is impacted by both the El Niño Southern Oscillation and processes in the Pacific Ocean. The main regional flow path is from the Pacific Ocean through South-East Asia to the Indian Ocean. During an El Niño period, sea surface heights in the western Pacific are lower than normal which also results in lower than normal sea surface heights across northern Australia. Conversely, during periods of La Niña, water levels are higher than average in the western Pacific and across northern Australia.

Figure 2 shows the variation of annual sea level anomalies based on measured data at Broome and Darwin. The yellow line represents the Southern Oscillation Index (SOI) where levels above zero represent periods of La Niña and below the line are representative of El Niño. Figure 2 illustrates that regional water level anomalies around Legune Station are influenced by the SOI with annual average water levels following a similar pattern to the fluctuation between La Niña and El Niño. During a prolonged period of La Niña, such as during the period 1998 – 2001, regional water levels can be on average 0.1 m higher than average whilst during a strong El Niño as was present in 2015, regional water levels can be greater than 0.1 m below the long term average.

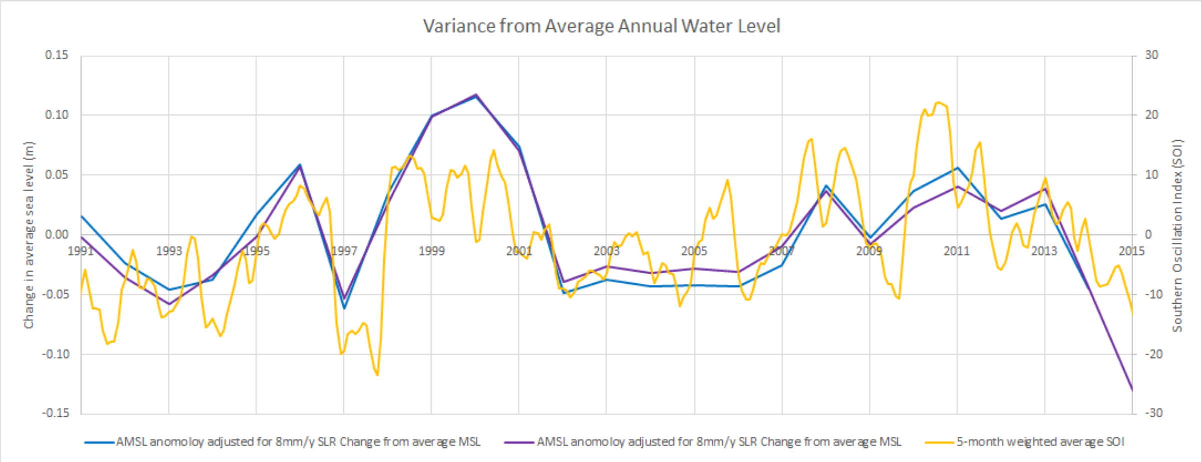

FIGURE 2 ANNUAL VARIATION OF MEAN SEA LEVEL AT DARWIN AND BROOME

4 ASSESSMENT OF POTENTIAL IMPACTS

4.1 GREENHOUSE GAS ASSESSMENT

The major sources of Scope 1 emissions from the Project during construction and operation are outlined in Table 5. Relevant GHG include carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O).

TABLE 5 MAJOR SOURCES OF GHG EMISSIONS

Emissions source	Relevant GHG
Construction	
Clearing of vegetation to establish general construction laydown areas, ponds and channels etc.	CO2
Use of diesel in generators, earthmoving equipment and other vehicles and machinery	CO2, CH4, N2O
Onsite landfill facility (including putrescible waste and biosolids from wastewater treatment)	CH4
Onsite wastewater treatment plants	CH4
Operations	
Use of diesel – in on-farm vehicles and transport of feed, fuel and harvested prawns to and from Legune, and in onsite power station used to power onsite equipment and infrastructure (i.e. grow-out pond aerators, pumps and buildings)	CO2, CH4, N2O
Onsite landfill facility (including putrescible waste and biosolids from wastewater treatment)	CH4
Onsite wastewater treatment plants	CH4
Onsite stockpiling of pond sludge and IRFP sediment	CH4

Total GHG emissions associated with the Project were estimated to be approximately 2,018,104 t CO2-e[4], with 201,465 t CO2-e and 1,816,639 t CO2-e attributed to construction and operations, respectively. Annual estimated emissions for each major emissions source is provided in Table 6. Emissions related to the combustion of diesel was the largest source of emissions for both construction and operations (Figure 3 and Figure 4), estimated at 82% and 74%, respectively.

Based on the latest National GHG Inventory data, in 2014, Australia's total GHG emissions were 525,202,270 t CO2-e and the Northern Territory's total emissions were 12,439,890 t CO2-e (DoE 2014). The Project's estimated average annual emissions (72,075 t CO2-e) equate to approximately 0.01% and 0.58% of total 2014 emissions for Australia and the Northern Territory, respectively. The current facility threshold for determining an obligation under the NGER Act is:

- 25 kt or more of greenhouse gases (CO2-e) (scope 1 and scope 2 emissions) or
- production of 100TJ or more of energy or
- consumption of 100 TJ or more of energy.

The Project's estimated average annual emissions exceed the 25 kt threshold.

[4] *Carbon dioxide equivalent is the standard unit for measuring carbon footprints.*

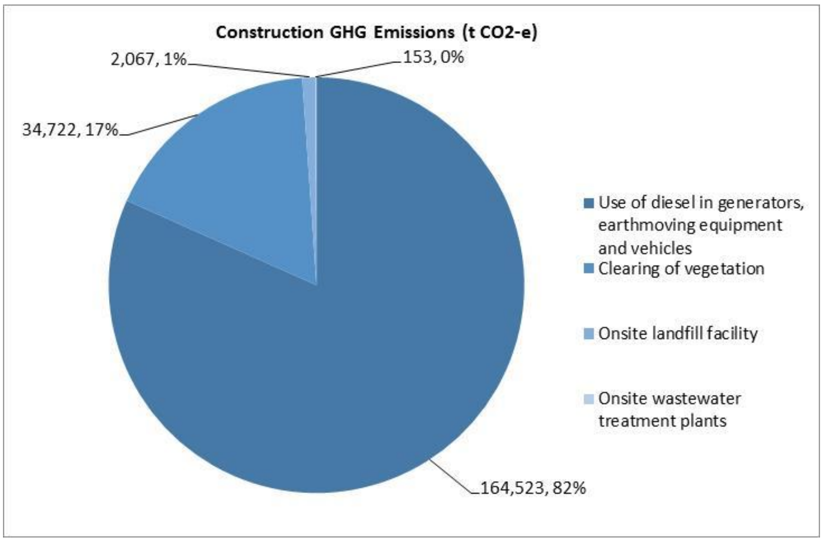

FIGURE 3 GHG EMISSIONS AND EMISSION SOURCES ASSOCIATED WITH CONSTRUCTION

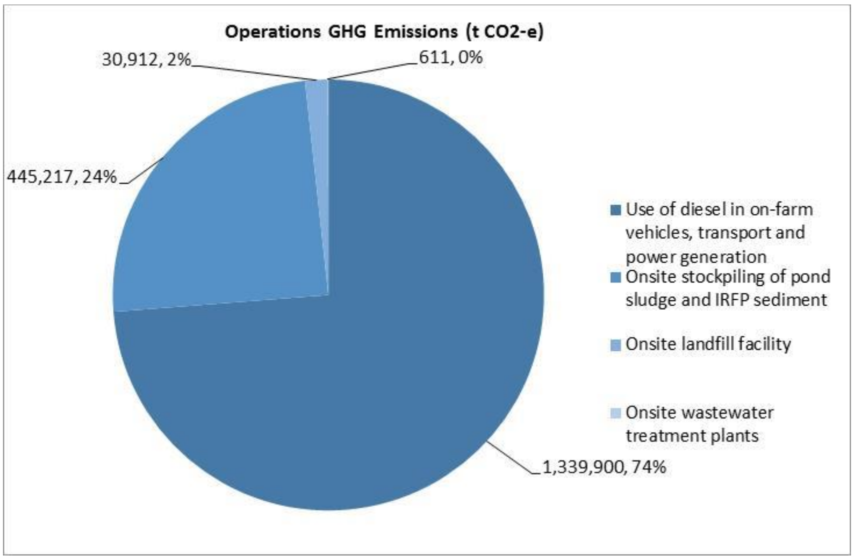

FIGURE 4 GHG EMISSIONS AND EMISSION SOURCES ASSOCIATED WITH OPERATION

TABLE 6 ANNUAL ESTIMATED GHG EMISSIONS (T CO2-E)

Year	Combustion of diesel	Pond waste and IFRP sediment	Landfill	Onsite wastewater treatment	Vegetation clearing	Annual Total (t)
2017	36,561	0	0	33	34,722	71,315
2018	73,121	0	563	65	0	73,750
2019	68,107	0	1,504	55	0	69,667
2020	53,065	1,652	1,946	24	0	56,688
2021	53,065	7,714	1,680	24	0	62,484

Year	Combustion of diesel	Pond waste and IFRP sediment	Landfill	Onsite wastewater treatment	Vegetation clearing	Annual Total (t)
2022	53,065	11,777	1,501	24	0	66,368
2023	53,065	14,502	1,382	24	0	68,974
2024	53,065	16,327	1,301	24	0	70,718
2025	53,065	17,551	1,248	24	0	71,889
2026	53,065	18,372	1,211	24	0	72,673
2027	53,065	18,922	1,187	24	0	73,199
2028	53,065	19,290	1,171	24	0	73,551
2029	53,065	19,537	1,160	24	0	73,787
2030	53,065	19,703	1,153	24	0	73,946
2031	53,065	19,814	1,148	24	0	74,052
2032	53,065	19,888	1,145	24	0	74,123
2033	53,065	19,938	1,143	24	0	74,171
2034	53,065	19,972	1,141	24	0	74,203
2035	53,065	19,994	1,140	24	0	74,224
2036	53,065	20,009	1,140	24	0	74,239
2037	53,065	20,019	1,139	24	0	74,248
2038	53,065	20,025	1,139	24	0	74,254
2039	53,065	20,030	1,139	24	0	74,259
2040	53,065	20,033	1,138	24	0	74,261
2041	53,065	20,035	1,138	24	0	74,263
2042	53,065	20,037	1,138	24	0	74,265
2043	53,065	20,038	1,138	24	0	74,266
2044	53,065	20,038	1,138	24	0	74,266
TOTAL	**1,504,423**	**445,217**	**32,979**	**763**	**34,722**	**2,018,104**

4.2 CLIMATE CHANGE ASSESSMENT

4.2.1 Impacts of Climate Change on Meteorological Conditions

The predicted impacts of climate change on meteorological conditions are well documented. The 2015 Commonwealth Scientific and Industrial Research Organisation (CSIRO) report "Climate Change in Australia Projections, Cluster Report – Monsoonal North" (CSRIO 2015) provides a summary of the impacts that are currently projected around Legune. The key points are summarised below.

4.2.1.1 Temperature

Air temperatures within the monsoonal northwest have increased linearly by an average 0.9°C over the last century. Daytime temperatures have increased by slightly more at 1.0°C during the period. Global models predict that temperatures in the north will increase by an additional 0.5-1.3°C above 1986-2005 average levels by the year 2030 depending on the modelled emission scenario. By 2090, the projected increase in temperature rises to 1.3°C to as much as 5.1°C on 1986-2005 levels.

Along with the increase in average temperatures, the number of hot days (i.e. above 35°C) is predicted to increase from an average of 11 days per year under current conditions to between 25 and 74 days by 2030 and between 54 and 211 days per year by 2090.

4.2.1.2 Evaporation

As would be expected given increases in average temperature and the number of hot days, the rate of surface evaporation in northern Australia is likely to increase in the future. The magnitude of this increase relies on a number of climatic conditions and there is low confidence by CSIRO in the estimates of evaporation magnitude.

4.2.1.3 Rainfall

The monsoonal environment of northern Australia, and the strong influence of the ENSO on annual climate variation results in no clear trend on which to base the projected impact of climate change on rainfall patterns or totals around Legune. However, it is generally considered that rainfall will become more intense and maximum daily rainfall totals will increase in the future.

4.2.1.4 Wind Conditions

Global models do not provide a consistent understanding of wind conditions into the future, however, the general consensus is that there is likely to be some small increase in wind speed during the monsoonal and trade wind seasons with more variability of speed and direction predicted for the transitional seasons.

4.2.2 Impacts of Climate Change on Oceanographic Conditions

4.2.2.1 Water Levels

The Bureau of Meteorology has been collecting high accuracy sea levels across Australia since the early 1990s as part of the Australian Baseline Sea Level Monitoring Program. Analysis of this data by CSIRO as part of the 2012 Marine Report Card (CSIRO 2012) indicated that measured sea levels around the northern coast of Australia have risen at a rate of approximately 8 mm/year in the period between 1993 and 2012, well above the global average of 3 mm/year. The rate of sea level rise (Sea Surface Height Trend or SSH) based on the BoM data and data derived from satellite altimeter data measuring offshore changes is shown in Figure 5 (CSIRO 2012). More recent estimates of long term sea level rise provided by the BoM indicate the rate could currently be in the order of 6.4 mm/year.

The rate of global sea level rise is predicted to increase into the future, with projected global sea level rise of between 0.12 m and 0.35 m by 2065 and between 0.16 m and 0.55 m by 2090 (CSIRO 2012). CSIRO (2015) provides an estimated increase of 0.06 to 0.17 m by the year 2030 above 0.28 – 0.85 m across northern Australia by the year 2090.

The increasing mean sea levels will result in a corresponding increase in the tidal planes presented in Table 2 and the level of MHWS offshore of Legune Station may rise from 3.7 m AHD currently to between 4.0 m and 4.5 m AHD by 2090. These increases will increase the extent of inundation across the tidal floodplain at spring high water.

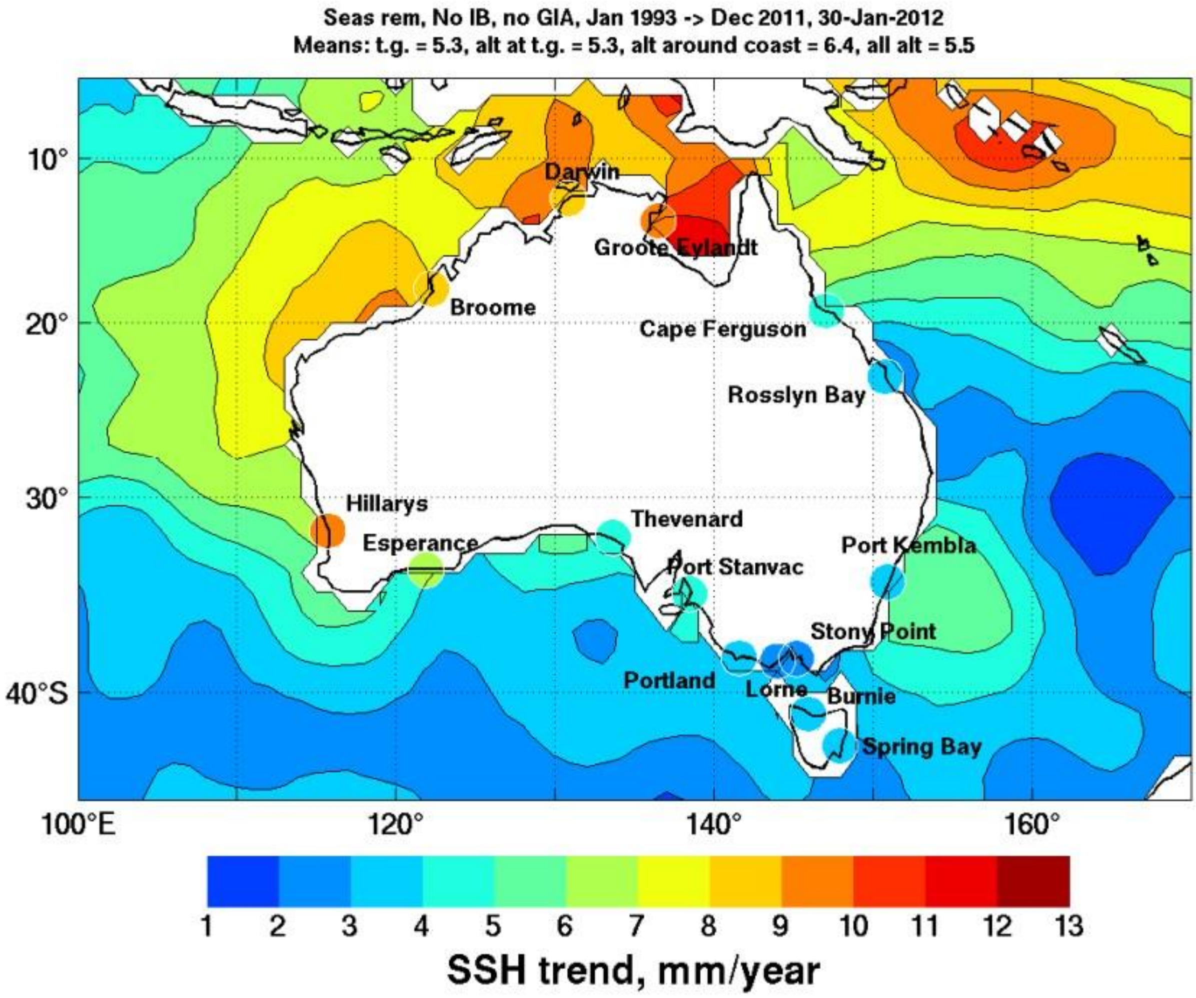

FIGURE 5 RATE OF SEA LEVEL RISE AROUND AUSTRALIA BASED ON CSIRO 2012

4.2.2.2 Water Temperature

The Bureau of Meteorology analysis of annual sea surface temperature data indicates that surface temperatures are rising at a rate of 0.04 – 0.08°C per decade (BoM 2015). CSIRO (2015) also details predicted changes to sea surface temperature in the north of Australia, with sea surface temperature expected to increase with the increasing global temperatures by a range of 0.4 - 1.1°C by 2030 at Darwin. Temperature projections beyond the year 2030 are less certain and the range of projected temperature change increases to 0.3 to 4.1°C by the year 2090.

4.2.2.3 Waves

Changes to wind conditions around Legune may have minor impact on non-cyclonic wave conditions around the site, however, regular wind generated waves are generally small and have minor impact on the site.

4.2.3 Impact of Climate Change on Tropical Cyclones

The impact of climate change on cyclone frequency and intensity is complicated, as many oceanographic and meteorologic conditions combine to provide optimum conditions for cyclone generation. CSIRO (2015) indicated that there was medium confidence in predicting that there would be less frequent, but more intense, cyclones in the future.

It is more likely that the frequency and duration of ENSO cycles will have a greater impact on the number and intensity of cyclones with the average annual number of cyclones in Joseph Bonaparte Gulf increasing from 0.2 to 0.4-0.6 between El Niño and El Nina.

4.2.4 Impacts of Climate Change on the Project

To assess the potential impact of climate change on the coastal environment and the Project's coastal infrastructure, a risk assessment methodology has been adopted. The main steps of the risk assessment process were:

- Identification of the relevant threats associated with climate change to the coastal environment.
- Determination of the aspects of the development that could potentially be exposed to these threats.
- Assessment of the overall risk of this exposure.

4.2.4.1 Threat Identification

Relevant climate change impacts on the physical processes operating on the coastal environment are considered to be:

- sea level rise
- tropical cyclone intensity and frequency.

Sea Level Rise

As noted in Section 4.2.2.1, the most recent estimates of long term sea level rise provided by the BoM indicate the rate could currently be in the order of 6.4 mm/year. As presented in Table 7, based on sea level rise of 6.4 mm/year, sea levels could be expected to rise above present day levels by 0.09 m by the year 2030 and 0.35 m by the year 2070.

This rate of global sea level rise is predicted to increase into the future. CSIRO (2012) project global sea level rise of between 0.12 m and 0.35 m by 2065 and between 0.16 m and 0.55 m by 2090 (Table 7).

The Intergovernmental Panel on Climate Change (IPCC) is the authoritative source on projections of future sea-level rise due to climate change. Table 7 displays the IPCC sea level rise projections, relative to late 20th century mean sea levels, for the A1FI (fossil fuel intensive) high emission scenario.

TABLE 7 IPCC 2014 PROJECTED SEA LEVEL RISE

Scenario	2030 (m)	2070 (m)	2100 (m)
Existing rate 6.4 mm/yr	0.09	0.35	0.54
CSIRO (2012)		Year 2065: 0.12 – 0.35	Year 2090: 0.16 - 0.55
IPCC (2014)	0.18	0.42	0.82

The main impacts associated with an increase in mean sea level within Joseph Bonaparte Gulf around Legune Station are considered to be:

- shoreline recession
- increase in storm tide elevations.

Tropical Cyclone Intensity and Frequency

As previously discussed, there is considerable debate regarding the projected impact of climate change on tropical cyclones. The Engineers Australia 'Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering' suggests that whilst there is "*no evidence that (globally) tropical cyclones are getting stronger, or are becoming more frequent or producing greater rainfall*", there is the opportunity that peak winds during a tropical cyclone may increase by 11% by the year 2100, and that rainfall associated with a tropical cyclone may increase by 20% by 2100 (Engineers Australia 2012).

The storm tide assessment carried out by SEA (2016) considered the effects of climate change on sea level rise and assessed potential storm tide levels under the assumption of an elevated water level and a 5% increase in maximum wind speed. The predicted storm tides for a number of return periods under 2060 conditions offshore from Legune Station are provided in Figure 6 and indicate the 100 year offshore storm tide water level may approach 6.0 m by 2060. In comparison, based on 2015 conditions, during a 100 year ARI event storm tide water levels in Forsyth Creek and Victoria River may approach 5.4 m.

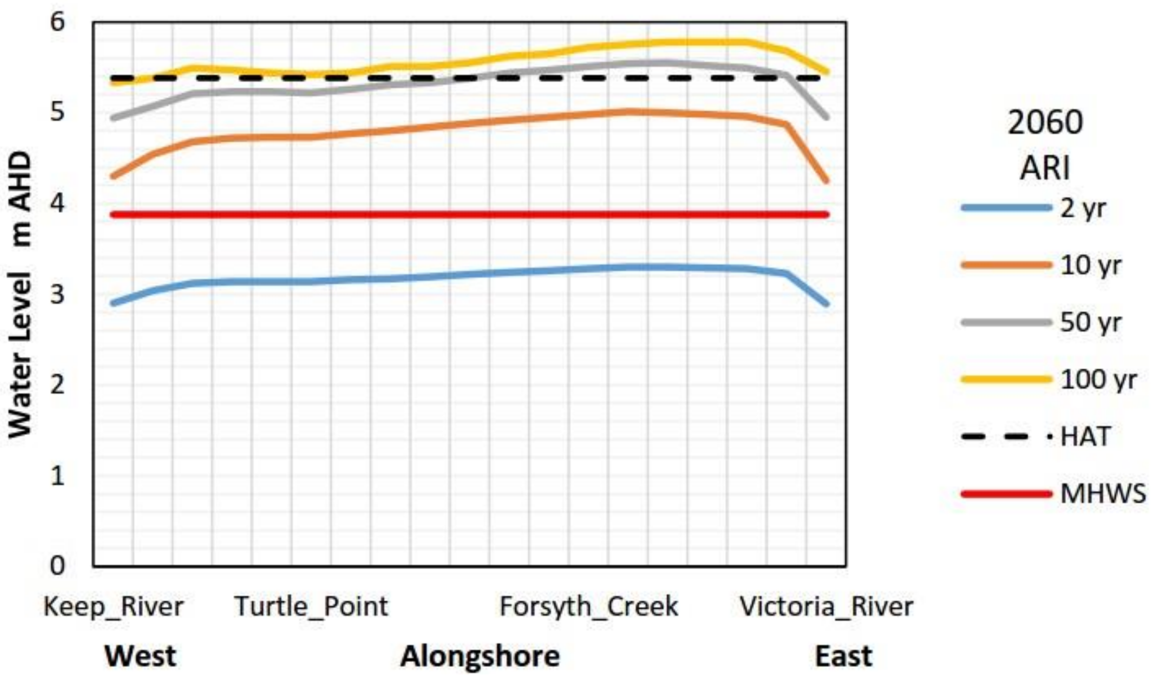

FIGURE 6 PREDICTED STORM TIDE LEVELS

The main potential impacts associated with increases in tropical cyclone intensity are considered to be:

- higher maximum wind speeds generating larger waves and associated wave set-up on the coastline
- higher maximum wind speeds and lower central pressures generating larger storm surges.

4.2.4.2 Exposure to Risk

The main components of the Project that are exposed to the threats presented above are considered to be:

- intake and discharge infrastructure
- land based facilities.

The threats and consequences to these Project components are presented below.

Intake and Discharge Infrastructure

Threats

The intake and discharge infrastructure are vulnerable to potential changes to the shoreline through increased inundation or coastal erosion due to increases in mean sea level, storm tides and wave action. Higher wave energy could result due to deeper water during storm events which may impact the bed more than present conditions.

Consequences

Channel and bank erosion at the seawater intake facility on Forsyth Creek has previously been identified as a risk, with average existing bank erosion of up to 15 m per year. Increasing sea levels will lead to more frequent inundation and consequential wave and current erosion on the upper portion of the bank along Forsyth Creek. This could lead to an increased rate of erosion of the bank and a reduction of the period before the shore cuts landward beyond the proposed piled structure. Erosion of the shoreline to this extent would require costly and frequent movement of the intake pipes and could also cause production delays.

Conditions at the proposed Alligator Creek discharge may similarly be impacted by rising sea levels by exposing the upper portion of the bank to more frequent inundation and potentially greater erosion through more frequent current and wave action. Increased erosion of the bank around the discharge facility could lead to increased terminal scour around the ends of the discharge rock blanket, and greater infrastructure to protect the weir and the environmental protection zone could be required.

Land Based Facilities

Threats

Facilities associated with the Project adjacent to or near the existing coastline and on the tidal floodplain (i.e. farms and channels) could potentially be exposed to threats associated with shoreline recession. The proposed footprint is primarily located above the supra-tidal floodplain at an elevation above 4.5 m AHD.

Whilst the buffer between the existing coastal shoreline and the facility is greater than 10 km, tidal channels intersect the floodplain in some areas, particularly on the northern edge of the development footprint. The predicted 0.09 - 0.18 m increase in mean sea level over the next 20 years will result in more frequent inundation of these supra-tidal floodplains and will increase the tidal prism of the local tidal channels. The channels may then become wider and more prominent and erosion adjacent to the footprint may occur.

The predicted 2060 extreme storm tide level of 6.0 m AHD may result in inundation across a wide area of Legune Station. The peak of inundation will be limited to the high tide period, however, it may be accompanied by strong wind conditions. Small waves along the boundary of the site could result in localised erosion of farm infrastructure and access to the site may be restricted.

Consequences

Increased inundation of the tidal floodplain and increased erosion of the tidal channels to the north of the site could result in erosion of the farm bunds and a loss of production time, leading to profit loss and additional costs associated with restoring damage caused by erosion.

The consequences of inundation by extreme storm tides also include costs associated with damage to infrastructure along with potential interruption of production and associated loss of production costs.

5 MITIGATION AND MONITORING

5.1 GREENHOUSE GAS EMISSIONS

5.1.1 Abatement Measures

Impacts of the Project on GHG emissions have been avoided or minimised where possible through the planning and design process. Abatement measures to be implemented include:

- limiting vegetation cleared areas and, where possible, revegetation of cleared areas upon completion of construction works
- where possible, providing beneficial use of stockpiled waste from the ponds and IFRP e.g. erosion control, assisting vegetation of the embankments on channels and ponds, construction of new berms
- reducing energy use and conserving fuel through the use of energy efficient lighting and equipment use, correctly rated pumps and motors
- optimising the use of renewable energy (e.g. solar)
- optimising construction activities and transport logistics to reduce the number of trips required, and therefore fuel consumption
- use of more efficient plant and vehicles
- developing a fuel management strategy
- developing a waste management strategy to minimise the amount of waste going to the landfill.

5.1.2 Complying With NGERS

As presented in Section 4.1, the Project's estimated average annual emissions exceed the 25 kt threshold. Therefore, the proponent will comply with the requirements of the NGER Act, including all record keeping and reporting obligations.

5.2 CLIMATE CHANGE IMPACTS TO THE PROJECT

Climate change impacts to the Project will be mitigated through the design and operation of the facilities as outlined below:

- The seawater intake structure is designed to allow the intake pipes to be shifted with the movement of the channel as the bank continues to erode in a southerly direction. The piled structure is proposed to extend around 130 m landward of the current bank position.
- Structural design of the intake piles and bedding will consider the potential for increased wave conditions into the future, including potentially locating pumps at a level high enough to avoid being impacted by large waves.
- The discharge outlet comprises a 100 m weir which controls the effluent discharge rate into Alligator Creek. This weir structure will be setback nominally 30 m from the bank of the creek to allow for the existing bank erosion rates at that location (in the order of 2-4 m per year). This setback distance will provide between 10 and 30 years erosion buffer. Downstream of the outlet, the effluent will be conveyed to the creek across a rock blanket. This rock blanket limits erosion of the floodplain surface.

- Sufficient setback will be provided which will extend the design life of structures.
- Design will ensure adequate scour protection is provided to piles, discharge and intake structures near the banks.
- Designing scour protection of the bunds around the farm and the intake channels to control potential future ensure potential future erosion will be controlled.

Monitoring and continual assessment of bank and channel changes, and the effectiveness of the mitigation measures described above, will be undertaken to respond and adapt to the changing conditions into the future.

6 COMMITMENTS

Based on the outcomes of this GHG and climate change assessment the proponent commits to:

- Implementing the abatement measures listed in Section 5.1.1.
- Complying with the requirements of the NGER Act, including all record keeping and reporting obligations.
- Designing and operating the facility to minimise the risks to the Project from climate change impacts as outlined in Section 5.2.

7 CONCLUSIONS

Impacts of the Project on GHG emissions have been avoided or minimised where possible through the planning and design process. The Project's estimated average annual GHG emissions (72,075 t CO2-e) equate to approximately 0.01% and 0.58% of total 2014 emissions for Australia and the Northern Territory, respectively. The annual emissions exceed the 25 kt threshold listed in the NGER Act. Accordingly, the proponent will comply with the requirements of the NGER Act, including all record keeping and reporting obligations.

The key threats to the Project from climate change are sea level rise and increases in tropical cyclone intensity and frequency. These climate change impacts are likely to result in:

- shoreline recession
- increase in storm tide elevations
- higher maximum wind speeds generating larger waves and associated wave set-up on the coastline
- higher maximum wind speeds and lower central pressures generating larger storm surges.

The Project components at risk from climate change impacts include the intake and discharge infrastructure and the land based facilities situated on the estuarine-deltaic plain (i.e. the farms and channels). These risks will be mitigated through the design of the facility, including the shifting of the intake structure with the movement of the channel, set back of discharge weir 30 m from the bank, installation of the rock blanket to convey effluent to Alligator Creek and scour protection of the farm bunds and infrastructure near to the banks. Monitoring and continual assessment of bank and channel changes, and the effectiveness of the mitigation measures, will be undertaken to respond and adapt to the changing conditions into the future.