



Darwin LNG

Annual Environmental Monitoring Report

1 January 2021 – 31 December 2021

EPL217-02

Date	Rev	Reason For Issue	Author	Checked	Approved
28/02/22	0	Final submission to NT EPA	LR	SI	PK

<Page intentionally left blank>

Table of Contents:

- 1.0 Executive Summary 1**
 - 1.1 Discharges to water 1
 - 1.2 Discharges to air 2
 - 1.3 Discharges to land and surrounding environment 3
- 2.0 Introduction..... 4**
 - 2.1 Overview 4
 - 2.2 NT EPA Licence 6
 - 2.2.1 Licence Performance Improvement Condition 7
 - 2.3 DLNG Environmental Monitoring 7
- 3.0 Monitoring Discharges to Water 10**
 - 3.1 Irrigation, Jetty Outfall and Sediment Pond Discharge Monitoring Program 10
 - 3.1.1 Monitoring Objective..... 14
 - 3.1.2 Monitoring Methods..... 14
 - 3.1.3 Monitoring Results – Irrigation Discharge 17
 - 3.1.4 Monitoring Results – Jetty Outfall 24
 - 3.1.5 Monitoring Results – Sediment Ponds 31
 - 3.1.6 Data Management and Quality Control..... 39
 - 3.1.7 Discussion and Interpretation of Results..... 39
 - 3.2 Mangrove Monitoring 40
 - 3.2.1 Monitoring Objectives..... 41
 - 3.2.2 Monitoring Methods..... 41
 - 3.2.3 Monitoring Results..... 45
- 4.0 Monitoring Discharges to Air 61**
 - 4.1 Stack Emissions Monitoring Program 63
 - 4.1.1 Monitoring Objectives..... 63
 - 4.1.2 Monitoring Methods..... 63
 - 4.1.3 Monitoring Results..... 63
 - 4.1.4 Data Management and Quality Control..... 80
 - 4.1.5 Discussion and Interpretation of Results..... 81
 - 4.2 Hydrocarbon Flaring and Venting 81
 - 4.2.1 Monitoring Objectives..... 81
 - 4.2.2 Monitoring Methods..... 81
 - 4.2.3 Monitoring Results..... 82
 - 4.2.4 Data Management and Quality Control..... 85
 - 4.2.5 Discussion and Interpretation of Results..... 86
 - 4.3 Ambient Air Monitoring..... 86
 - 4.3.1 Monitoring Objective..... 87
 - 4.3.2 NT EPA Network 87
 - 4.3.3 Data Capture 88

4.3.4	Meteorological Conditions	88
4.3.5	Nitrogen Dioxide (NO ₂).....	89
4.3.6	SO ₂	90
4.3.7	CO	92
4.3.8	PM ₁₀	92
4.3.9	PM _{2.5}	93
4.3.10	Hot Venting Periods	95
4.3.11	Discussion and interpretation of results	98
5.0	Monitoring discharges to Land and Surrounding Environment	99
5.1	Groundwater Monitoring Program.....	99
5.1.1	Monitoring Objectives.....	99
5.1.2	Monitoring Methods.....	99
5.1.3	Assessment Framework.....	100
5.1.4	Monitoring Results and Discussion	105
6.0	Certification.....	121
7.0	List of Symbols and Acronyms.....	122
8.0	References	123

Attachments:

Attachment A - Irrigation, Jetty Outfall and Sediment Pond data

Attachment B – Mangrove Data

Attachment C – Stack Emission Data

Attachment D – Groundwater Data

1.0 Executive Summary

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the Darwin Liquefied Natural Gas facility (DLNG) at Wickham Point, near Darwin, in the Northern Territory (NT) of Australia. DLNG receives dry natural gas from the Bayu-Undan field located in Timor-Leste offshore waters via a pipeline. The dry gas is liquefied, stored and exported from the DLNG facility.

As a facility producing over 500,000 tonnes of Liquefied natural gas (LNG) annually, DLNG is required by Schedule 2 of the NT Waste Management and Pollution Control Act 1998 to have an environmental licence (the Licence). The Licence requires Santos to provide an Annual Monitoring Report (this report). This report includes the environmental monitoring results in relation to the Licence for the period between 1 January 2021 and 31 December 2021. This report has been developed in line with Condition 84 of the Licence and the NT Environmental Protection Authority (EPA) Guideline for Reporting on Environmental Monitoring.

The Licence requires that Santos undertake a range of environmental monitoring programs in relation to the DLNG facility, including;

- Discharges to water
- Discharges to air, and
- Discharges to land and surrounding environment.

Monitoring results for each of these environmental monitoring programs are provided in this report.

1.1 Discharges to water

Total volume of irrigation water discharged was below the Licence limit and marginally less than for previous years. Long term data shows a declining trend since 2017. Water quality sampling of the irrigation discharge showed the licence trigger values were exceeded for BOD, TSS, pH, NH₃-N, PO₄-P, and Cu, two of these triggering notifications to the EPA. Many of these are considered to arise from biofilm within the irrigation holding tank. To address the above exceedances this the irrigation holding tank underwent a major deep clean in November 2021. Following the cleanout BOD, TSS and pH showed a trend back towards being within compliance limits.

The total volume of Jetty outfall water discharged was below the Licence limit and marginally less than previous years with a declining trend since 2016. Water quality parameters in the jetty outfall discharge during 2021 were generally within the Licence trigger values and consistent with or below the long term average. The exceptions were zinc and ammonium nitrogen (NH₃-N). These exceedances did not result in an exceedance in the jetty outfall mixing zone or trigger a reportable non-conformance to the NT EPA.

Field measurements for the discharge of all sediment ponds during 2021 were generally consistent with the long term average and were within the Licence trigger values with the following exceptions; NO₃-N, E.coli, and one instance of elevated total chromium. None of these events triggered a reportable non-conformance to the NT EPA with all other parameters being below the EPL licence limits.

Mangrove survey results for 2021 indicated that mangroves remain in good condition, with canopy cover characteristic of healthy mangrove assemblages. Examination of long-term trends in

canopy data demonstrate that mangrove health has remained stable or slightly improved during the 17 years since program commencement. Overall, defoliation index or tree condition recorded at each surveillance site showed minimal changes from the previous survey and that all changes recorded survey were naturally occurring. This confirms that the mangrove forests surrounding the DLNG site remain in a stable and healthy condition. The 2021 mangrove groundwater salinity results demonstrated consistency with previous monitoring since the baseline.

The extent of sediment deposition or accretion recorded long term has not been detrimental to mangrove health with small net differences at most sites reported in 2021. The sediment chemical results indicate sediments are predominantly un-influenced chemically by DLNG operations. Exceedances of sediment environmental criteria were limited to zinc at one site downstream of Sediment Pond 1 only. All sediment samples analysed in 2021 reported Total Recoverable Hydrocarbons (TRH) above the laboratory limit of reporting and at levels greater than the historical range. The cause behind these readings is unknown however it is highly unlikely to be a result of DLNG due to levels being similar across all sites including control sites.

Metal concentrations observed in the 2021 mudwheik samples were below the recommended guidelines for all metals except copper. The copper concentrations recorded in 2021 were consistent with historical data exceeding the trigger value at two sites. These exceedances are not considered to be linked to DLNG due to the broad distribution of the monitoring sites (including control sites) and pond discharge water quality data indicates a history of copper generally being near or below detection limits. Although detected in previous years, elevated zinc levels in mudwheiks were not recorded in 2021. Additionally, no relationship was observable with sediment Zinc concentrations. There was no evidence of any hydrocarbon contamination within the mudwheiks sampled.

Overall, the results of mangrove monitoring indicate that surface water discharged from the DLNG facility has not had a significant impact on mangrove sediment and biota surrounding the facility since post-commissioning monitoring began in 2006. In addition, the sediment ponds do not generally appear to be affected by algal blooms, odour issues, mortality or any other sources of contamination and spikes in water quality are of short duration. For these reasons, the discharge water quality from the sediment ponds is of low environmental risk or impact.

1.2 Discharges to air

During the reporting period, the total flaring volume from routine and non-routine sources was higher than the two previous years but within the range for the previous five years. The higher value for 2021 is due to several major events during the reporting period including the May Zero Rates Campaign and loading line repairs.

Nitrogen Rejection Unit venting was marginally above the historical range during 2021 due planned maintenance campaigns and the BOC Helium Plant outages.

During the 2021 reporting period, the total acid gas venting volume for planned and unplanned downtime was a similar to the volume for 2020. The total number of days for hot venting did not exceed the Licence limits. Stack testing showed that all emissions measured were compliant for 2021 except for an exceedance in Benzene concentrations in December 2021 for the acid gas vent. This exceedance is not a non-compliance with licence conditions as during this stack testing

event the waste gas stream was being treated by the acid gas incinerator and not being discharged via the acid gas vent.

Analysis of the NT EPA ambient air quality monitoring data from Palmerston, Stokes Hill and Winnellie shows that for the parameters analysed only PM₁₀ and PM_{2.5} exceeded the air NEPM standard. These exceedances are not attributed to DLNG operations.

The overall consistency with long-term data indicates the processes generating stack emissions are relatively stable and well understood. When considered in conjunction with the results of the ambient air monitoring program, the stack emissions are considered to present negligible environmental impact or risk.

1.3 Discharges to land and surrounding environment

Groundwater monitoring data shows that groundwater level elevations are mostly higher in 2021 than those measured for 2020. This is likely due to the significantly wetter wet season experienced for 2020/21

Statistical assessment comparing the groundwater and irrigation water parameters using the Mann Kendal analysis identified no correlation between the groundwater and irrigation water quality, therefore overall, the data collected from the 2021 groundwater monitoring events demonstrate that current irrigation practices present a low environmental risk.

2.0 Introduction

2.1 Overview

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the Darwin Liquefied Natural Gas facility (DLNG) at Wickham Point, near Darwin, in the Northern Territory (NT) of Australia. DLNG receives dry natural gas from the Bayu-Undan field located in Timor-Leste offshore waters via the 502 km long pipeline. The dry gas is liquefied, stored and exported from the DLNG facility. The upstream geographical limit of DLNG facility is defined as the beach valve of the Bayu-Darwin gas pipeline, located on Wickham Point. The downstream limit is the LNG loading arms at the jetty. The layout of the DLNG facility is shown in Figure 2-1

As a facility producing over 500,000 tonnes of LNG annually, DLNG is required by Schedule 2 of the *NT Waste Management and Pollution Control Act* (WMPC Act) to have an environmental licence. Santos holds licence number EPL217-02 (the Licence) in accordance with this requirement. The Licence was issued by the NT Environment Protection Authority (EPA). Further information on the Licence is provided in Section 2.2.

Condition 84 of the Licence requires Santos to provide an annual monitoring report. The annual monitoring report must be provided to the NT EPA by 1 March annually and relate to the previous period of 1 January to 31 December. This report includes the environmental monitoring results in relation to the Licence for the period between 1 January 2021 and 31 December 2021 (herein referred to as the reporting period).

As per the requirements of Condition 85 of the Licence, this report:

- Has been prepared in accordance with the requirements of the 'Guidelines for Reporting on Environmental Monitoring' (NT EPA 2016);
- Includes a tabulation of all monitoring data (refer to Attachments);
- Includes long-term trend analysis (at least three years) where suitable monitoring data are available;
- Includes an assessment of the environmental impact of the activity; and
- Includes analysis on the impacts of the operation of DLNG on ambient air quality.

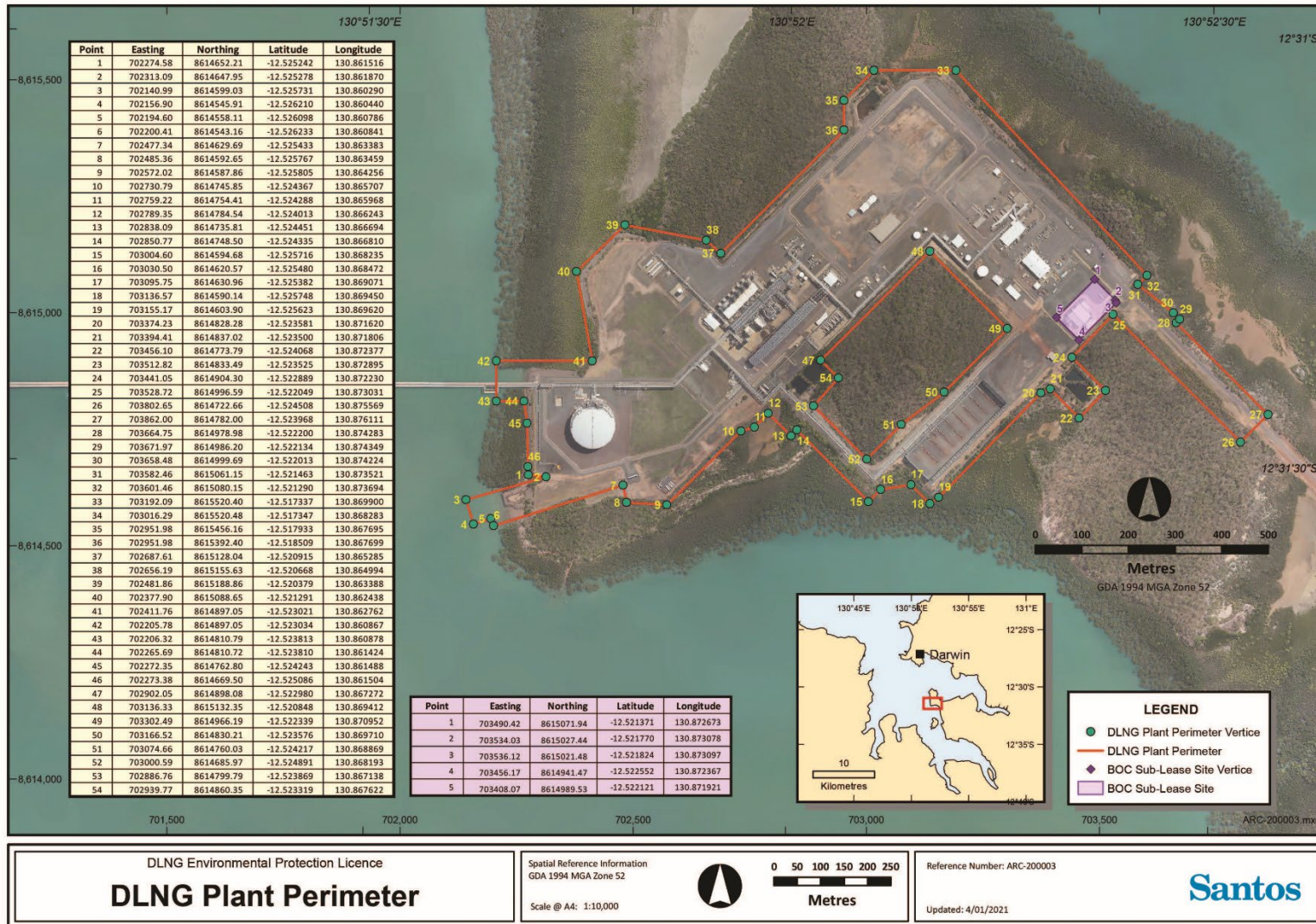


Figure 2-1 DLNG facility locality map

2.2 NT EPA Licence

The Licence commenced on 19 September 2017 and will expire on 18 September 2022. The boundary of the Licence is shown in Figure 2-1. The licence is also publicly available on the NT EPA website.

Monitoring conditions are outlined in the Licence in Condition 57 to 71. Requirements from the Licence monitoring conditions, along with reference to the section of the report in relation to the associated monitoring, are summarised in Table 2-1.

Table 2-1 Summary of monitoring-related Licence conditions and relevant sections of this report

Condition	Summary	Relevant sections within this report
General (Conditions 57 and 58)	<ul style="list-style-type: none"> Monitoring sample collection must provide for sample chain of custody documentation Monitoring equipment must measure the parameters of interest and results must be stored appropriately. 	<p>The sample collection points and monitoring equipment used are dependent on the discharge stream and parameters being monitored. Information relating to these conditions is included in each of the discharge monitoring sections:</p> <ul style="list-style-type: none"> Monitoring discharges to water (Section 3.0), Monitoring air discharges (Section 4.0), and Monitoring Discharges to Land and Surrounding Areas (Section 5.0).
Monitoring discharges to water (Conditions 59 to 65)	<p>Water Quality</p> <ul style="list-style-type: none"> Water quality monitoring must be in accordance with the conditions and tables appended to the Licence, which specify monitoring locations and parameters Water quality monitoring locations must be clearly labelled and able to be accessed Water quality sampling must be carried out in accordance with specified New South Wales (NSW) EPA methods. <p>Mangrove Monitoring</p> <ul style="list-style-type: none"> Mangrove monitoring must be in accordance with the tables appended to the Licence, which specify monitoring locations and parameters Revisions to the mangrove monitoring program must be reviewed by a suitably qualified 	<p>Water quality monitoring objectives, methods, results and discussion are presented in the following section:</p> <ul style="list-style-type: none"> Irrigation discharge – Section 3.1, Jetty outfall discharge and mixing zone – Section 3.1.4, and Sediment ponds 1, 2 and 3 discharge – Section 3.1.5. <p>Mangrove monitoring objectives, methods, results and discussion are presented in Section 3.2.</p>

	<p>professional and provided to the NT EPA</p> <ul style="list-style-type: none"> The NT EPA may require Santos to revise or amend and resubmit the mangrove monitoring program. 	
<p>Monitoring air discharges (Conditions 66 to 68)</p>	<ul style="list-style-type: none"> Air quality monitoring program must be in accordance with the tables appended to the Licence, which specify monitoring locations and parameters Air quality sampling and analysis must be carried out in accordance with specified NSW EPA methods Monitoring must be undertaken at least once per year under steady-state operational conditions. 	<p>Air quality monitoring is presented in Section 4.0, which includes results from these locations specified in the Licence:</p> <ul style="list-style-type: none"> Power generation turbines, Compressor turbines, AGI, Solvent regenerator reflux drum, and Boiler.
<p>Monitoring discharges to land and surrounding environment (Conditions 69 to 71)</p>	<ul style="list-style-type: none"> Maintain and implement the monitoring program in accordance with the tables appended to the Licence and the DLNG groundwater monitoring plan Groundwater sampling and analysis must be carried out in accordance with specified NSW EPA methods Sampling undertaken by a qualified sampler 	<p>Groundwater monitoring is presented in Section 5.1, which includes results from monitoring and control bores at the locations specified in the Licence.</p>

2.2.1 Licence Performance Improvement Condition

In accordance with Licence Conditions 90 and 91, Santos must prepare a Performance Improvement Plan (PIP) for managing wastewater discharge over time, so as to minimise the extent and impact of discharges to Darwin Harbour from the jetty outfall. The PIP was concluded in 2020 refer to the 2020 Annual Environmental Monitoring Report (Santos 2021) for more information.

2.3 DLNG Environmental Monitoring

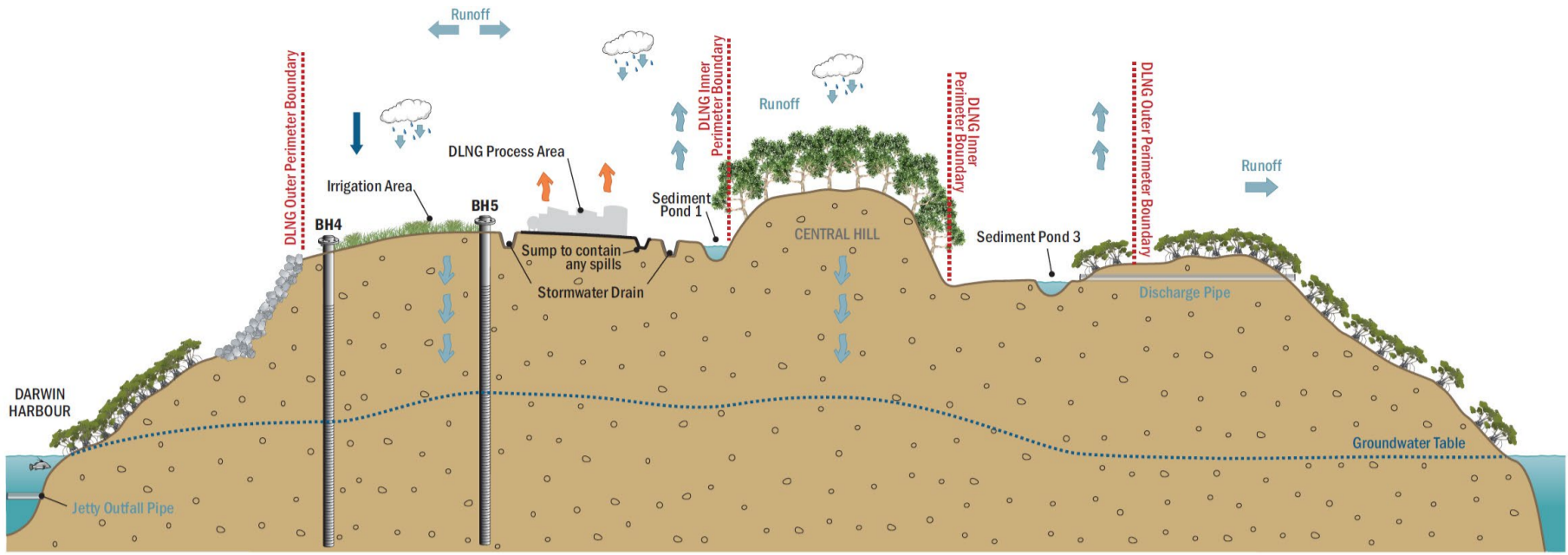
Several aspects of the operation of the DLNG facility may impact upon the environment. A conceptual model of the interactions of these aspects with the environment is provided in Figure 2-2 The Licence requires that Santos undertake environmental monitoring of these aspects and the environmental receptors that may be impacted. These are outlined in the DLNG facility Operations Environmental Management Plan (OEMP). The monitoring aspects include:

- Discharges to water, including:
 - Irrigation discharge monitoring;
 - Jetty outfall monitoring;
 - Sediment ponds monitoring; and

- Mangrove monitoring.
- Discharges to air, including:
 - Stack emission monitoring;
 - Ambient air quality monitoring;
 - Flaring and venting; and
- Discharges to land and surrounding environment, including:
 - Groundwater monitoring.

Santos has developed and implements routine monitoring programs to meet the requirements of the Licence.

The objectives, methods and results of these monitoring programs have been included in the relevant sections of this report.



NOTE:
Vertical Axis = SCALE EXAGGERATED
Horizontal Axis = NOT TO SCALE

LEGEND



Source	Emission or Discharge (Risk Factor)	Pathway	Receptor			
			Human Health and Community (Including Recreational Values)	Marine Waters (Darwin Harbour and Wetlands (Port Darwin))	Vegetation and Flora	Fauna
Stack emissions from operation of LNG processing and onsite power generation equipment Flaring – marine, ground and NGL flare Venting from operation of LNG processing equipment and acid gas venting Fugitive air emissions from storage tanks, and the operation of equipment and vehicles Failure, rupture, leaks or release from gas or HVAC systems Operation of LNG processing, onsite power generation equipment and marine vessel activities generating noise, heat and light emissions	Air pollutants and GHG emissions (as per EPL217) Air pollutants, GHG emissions and ozone depleting substances Noise, heat and light	Air	✓		✓	✓
Onsite irrigation of plant wastewater Discharge of reverse osmosis reject water via the jetty outfall Discharge of stormwater runoff (collected from hardstand areas and onsite stormwater drains) from the sedimentation ponds Accidental contamination of stormwater from overflow of process area spill containment Accidental hydrocarbon/chemical spills and unplanned releases (due to failure, rupture or leaks) from equipment, process area or jetty	Wastewater discharged (as per EPL217) Hydrocarbons and process chemicals Hydrocarbons, amine, LNG, process chemicals and hydraulic fluid	Surface water	✓	✓	✓	✓
Onsite irrigation of Plant wastewater Accidental hydrocarbon/chemical spill and unplanned release (due to failure, rupture or leaks) from equipment and process area	Wastewater discharged (as per EPL217) Hydrocarbons, process chemicals, diesel fuel and hydraulic fluid	Groundwater	✓	✓	✓	
Onsite irrigation of Plant wastewater Operation of LNG processing and onsite power generation equipment generating vibrations Discharge of stormwater runoff from stormwater drains Accidental hydrocarbon/chemical spill and unplanned release (due to failure, rupture or leaks) from equipment and process area Fire/explosion from operation of LNG processing and onsite power generation equipment Unauthorised access within the site perimeter Consumables and general waste generated from Plant operations	Wastewater discharged (as per EPL217) Ground vibrations Sediment Hydrocarbons, process chemicals, diesel fuel and hydraulic fluid Explosion, loss of vegetation and fauna Introduction and/or propagation of weeds, disturbance to vegetation Non-hazardous and hazardous solid and liquid waste	Land	✓	✓	✓	✓

Figure 2-2 DLNG environmental conceptual model

3.0 Monitoring Discharges to Water

Conditions 59 to 65 of the Licence outline requirements to monitor a range of liquid discharges, including:

- Irrigation discharge (Section 3.1)
- Jetty outfall discharge and mixing zone (Section 3.1)
- Sediment ponds discharge (Section 3.1). and
- Mangrove monitoring (Section 3.2).

The objectives, methods, analysis, and discussion of results for each of these monitoring programs are provided in the sections below.

3.1 Irrigation, Jetty Outfall and Sediment Pond Discharge Monitoring Program

As part of operations several water and wastewater streams are authorised to be discharged from the DLNG facility under EPL 217. Authorised discharge occurs via the irrigation field, the jetty outfall, and Sediment Ponds 1, 2 and 3. A schematic of processes associated with these water and wastewater streams are shown in Figure 3-1.

The irrigation discharge comprises several streams arising from the operation of DLNG:

- Treated wastewater from the Sanitary Treatment Plant (STP). The STP receives wastewater from bathroom and kitchen facilities. The STP utilises biological (e.g., activated sludge) and physical (e.g., filters, settlement) treatment to reduce the nutrient levels, biological oxygen demand and suspended solid levels in the treated sewage.
- Wastewater from the process area sumps which is treated by an oily water separator (Corrugated Plate Interceptor/Dissolved Air Filtration Flotation (CPI/DAFF) to remove hydrocarbons. The separated hydrocarbons are stored and disposed of offsite by a licenced waste contractor.
- Water from boiler blowdown and the turbine air humidifier system.

Each of these discharge streams are sent to the irrigation water holding tank and the combined stream is periodically discharged to the irrigation areas within DLNG shown in Figure 3-2.

The jetty outfall discharge comprises reject water from the Reverse Osmosis (RO) process, which uses water supplied by the Power and Water Corporation (PWC) as feed water. The jetty outfall pipe is shown in Figure 3-3. The estuarine waters of Darwin harbour surrounding the discharge pipe are sampled as part of the jetty outfall mixing zone monitoring program.

The sediment ponds are designed to allow for the collection of surface water runoff prior to release into the receiving environment. Sediment Ponds 1, 2 and 3 receive stormwater run-off. Sediment Pond 1 also receives backwash water from the greensand filter (part of the water RO plant). Overflow water from these ponds is passively discharged to Darwin Harbour. A typical view of a sediment pond is provided in Figure 3-4. Sediment Ponds are only sampled when they are actively discharging to the environment.

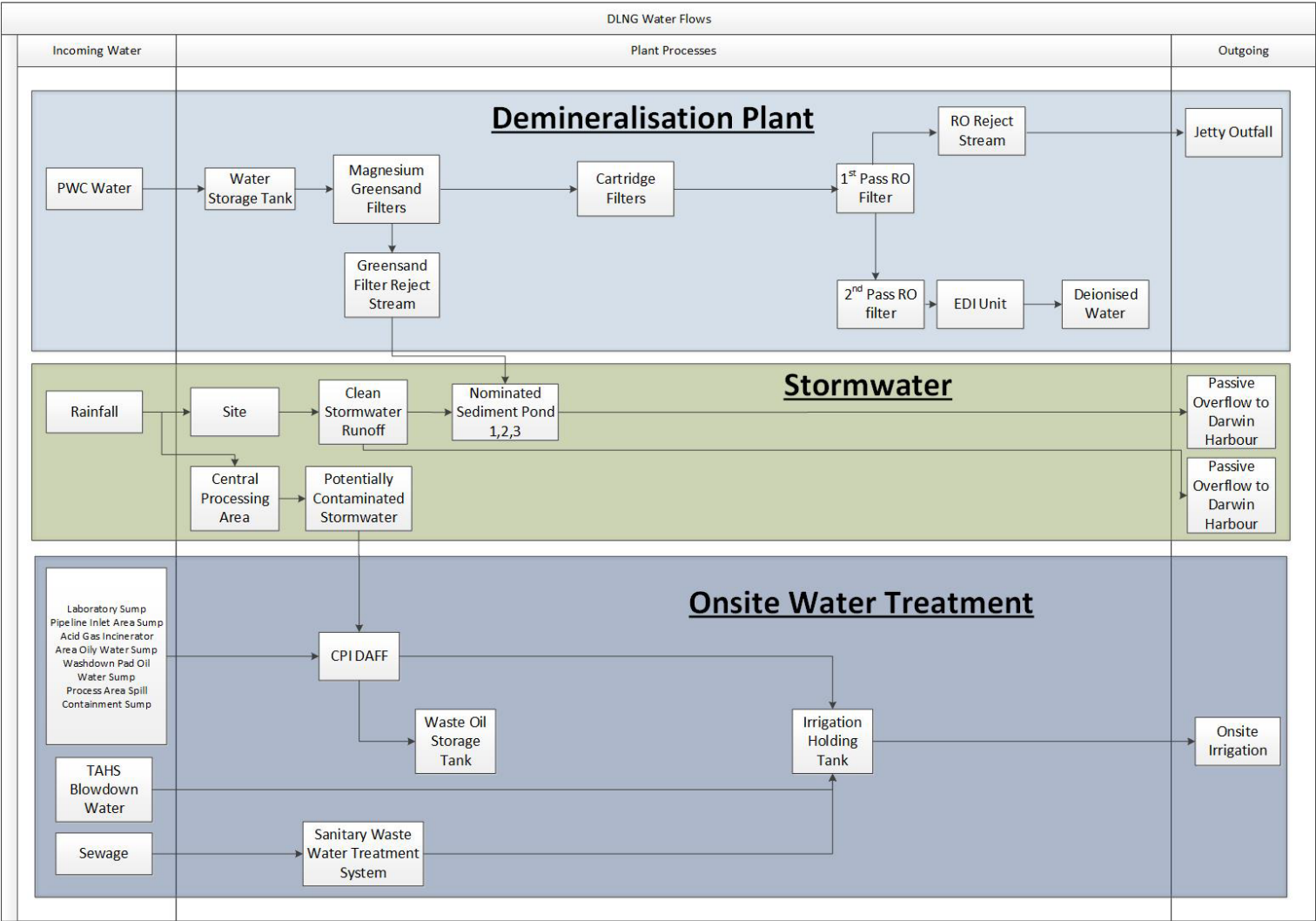


Figure 3-1 Schematic of water inputs, processes, and discharge points for the DLNG facility



Figure 3-2 Irrigation discharge area



Figure 3-3 DLNG jetty outfall pipe (Secured to Pylon)



Figure 3-4 DLNG sediment pond outflow sampling location

3.1.1 Monitoring Objective

The objectives of the irrigation, jetty outfall and sediment pond discharge monitoring programs are to:

- Characterise the quality of the discharge stream; and
- Assess compliance with the trigger values in the Licence (refer to Appendix B Table 2 within the licence).

Characterising the quality of the discharge stream allows Santos to identify the potential for the discharge stream to result in environmental impacts or risks. As outlined in the conceptual model of environmental aspects at DLNG (Figure 2-2), discharges may interact with groundwater and Darwin Harbour. The results of the irrigation, jetty outfall discharge and mixing zone and sediment pond discharge monitoring programs are also used to interpret results from other monitoring programs, such as the mangrove monitoring program (Section 3.2).

3.1.2 Monitoring Methods

Discharges to water locations are stipulated in the Licence. These locations are shown in Figure 3-5 and Figure 3-6. The coordinates, sampling frequencies and the discharge sources are provided within the Licence (Appendix B Table 1 and Table 2 and Condition 60, Table 2)

Samples are collected by DLNG laboratory staff or environmental consultants trained and experienced in the collection of water quality samples. The irrigation and jetty outfall discharge samples are collected via a sample valve along the discharge pipe within the plant, the sediment pond samples are collected at the overflow weir within the pond (Figure 3-4) and the jetty outfall mixing zone samples are collected via a vessel. The samples are then sent to analytical laboratories for analysis. All laboratories used maintain National Association of Testing Authorities (NATA) accreditation for the analyses being carried out.

Concentrations of the monitoring parameters are often very low and many sampling results are below the laboratory limit of reporting (LOR). Where analytical results indicated the concentration of an analyte was below the LOR, the analyte was assumed to be present at a concentration equal to the LOR. This approach is environmentally conservative.

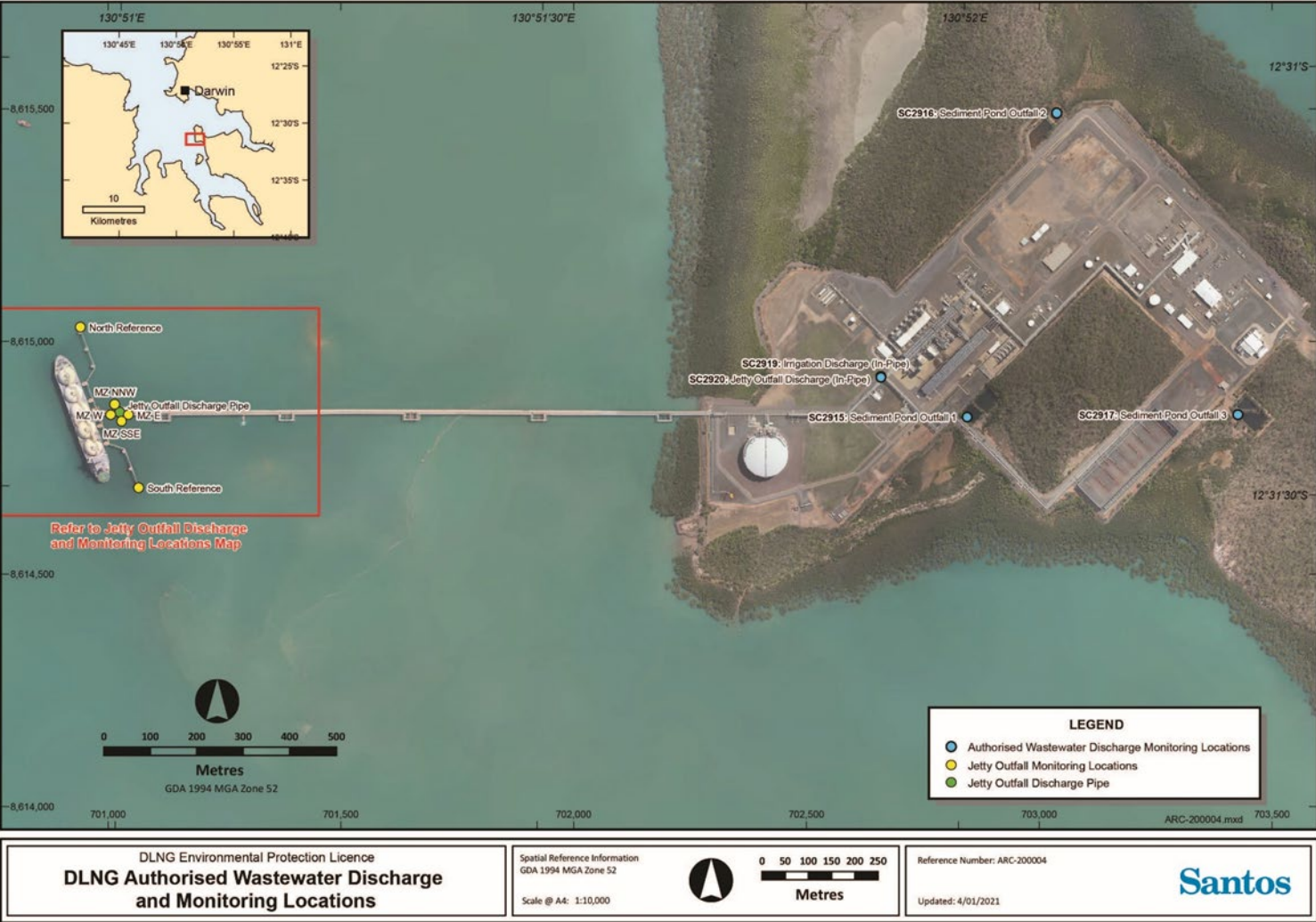


Figure 3-5 Map of authorised wastewater discharge locations

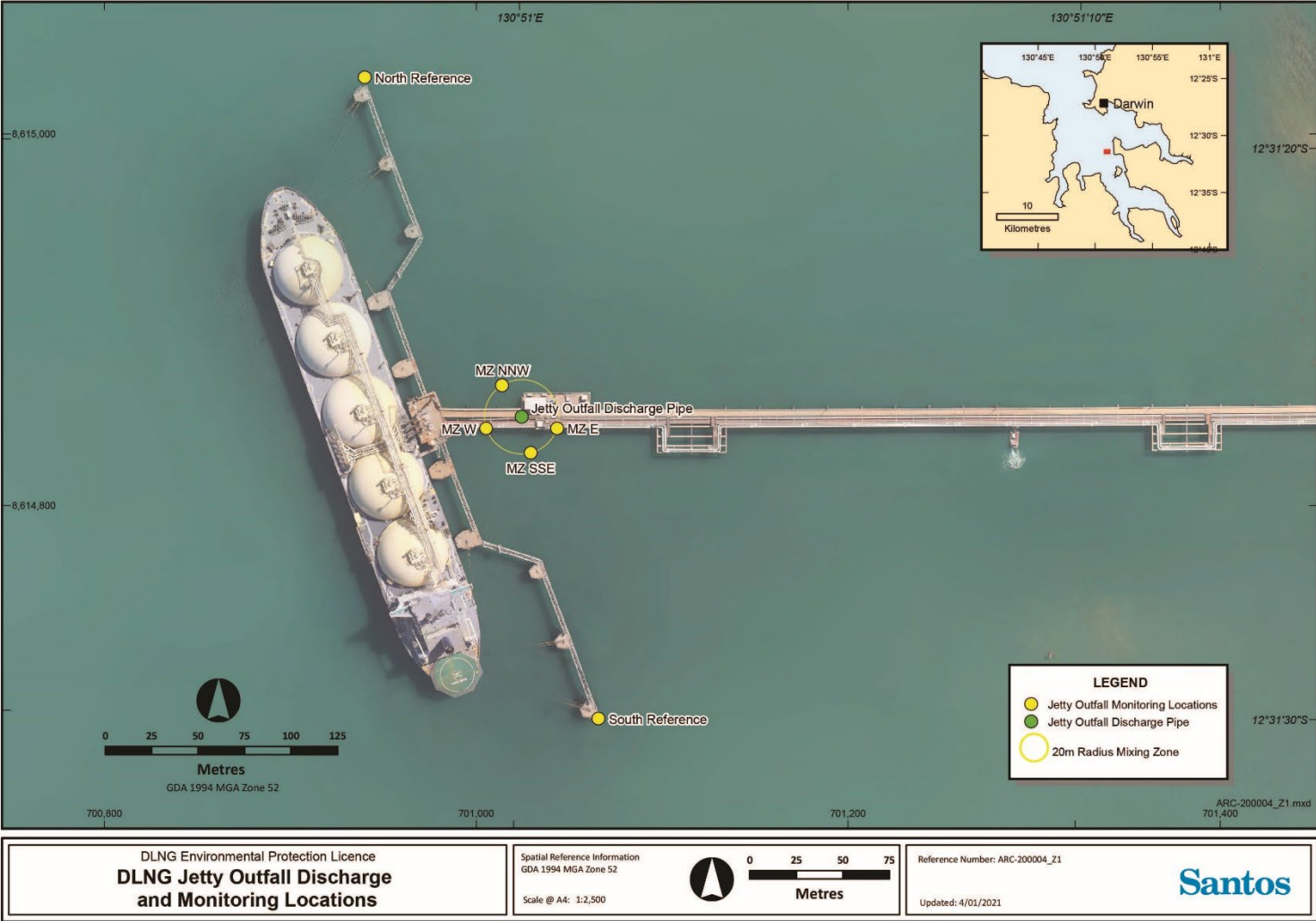


Figure 3-6 Map of jetty outfall discharge and monitoring locations

3.1.3 Monitoring Results – Irrigation Discharge

Volume Discharged

A total of 18,492 m³ was discharged to the irrigation area during the reporting period (Figure 3-7). This is approximately 71% of the 26 ML limit in EPL 217. This volume is comparable to 2020 and lower than 2016-2019 annual volumes.

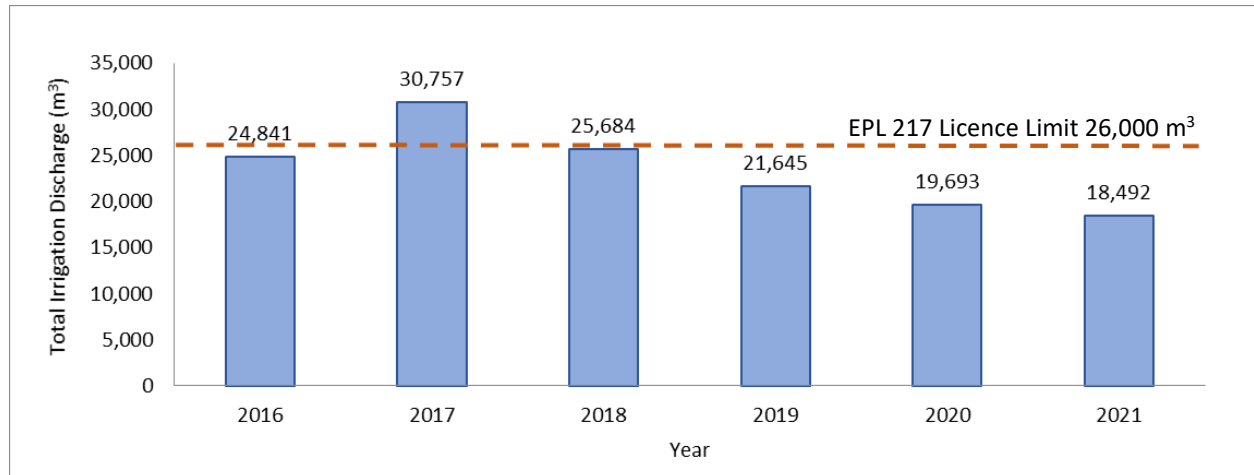


Figure 3-7 Water volumes discharged to the irrigation area

Discharge water quality results

A summary of the irrigation water quality results for 2021, long term trends from 2016-2021 and Licence trigger value exceedances are presented in Table 3-1 and discussed below.

The annual monitoring of environmental indicators was undertaken in March 2021 and the biannual indicators in November 2021. Voluntary monitoring has also been conducted for parameters of interest during 2021. The 2016-2021 dataset of both compliance and voluntary irrigation discharge water quality results is provided in Attachment A – Irrigation Discharge; values exceeding current Licence trigger values are bolded.

Key findings from a review of the irrigation discharge water quality results include:

- Biological oxygen demand (BOD) spiked above the Licence trigger value in September 2020 and remained in exceedance until November 2021 (up to 280 mg/L compared to a trigger value of 25 mg/L) (Figure 3-8). A reportable non-conformance was reported to the NT EPA on 12 November 2020. The exceedance is thought to be due to a build up over time of sludge in the bottom of the irrigation holding tank (T2903) and biofilm on the media filters and general tanks in the Corrugated Plate Interceptor/Dissolved Air Floatation (CPI DAF) Plant and to a lesser extent the STP. In response, during 2020 the irrigation tank (T2903) was drained to remove the build-up of sludge and the CPI DAF and STP media filters were serviced. However, elevated BOD concentrations in irrigation discharge continued into 2021; routine flushing, and biocide dosing was implemented with the irrigation holding tank then undergoing a major deep clean in November 2021. The data following the cleanout shows that BOD levels have improved.
- Total Suspended Solids (TSS) spiked above the trigger level in October 2020 (Figure 3-9). It remained higher than historical levels, but under the trigger limit for most of 2021

excluding one exceedances in March 2021 and again in October and November. The TSS result for December fell back to below the compliance trigger level following the deep clean of the Irrigation Holding Tank.

- The pH of the irrigation water fell outside the compliance trigger limit of 7 January 2021 and remained so for the majority of 2021 (Figure 3-10). This triggered a non-conformance with the licence following three consecutive results below Licence levels reported to the NT EPA on 7th April 2021. The pH levels returned to within compliance following the major cleanout of the irrigation holding tank.
- Ammonium nitrogen (NH₃-N) and dissolved reactive phosphorus (PO₄-P) exceeded the Licence trigger values in 2021 (Figure 3-11 and Figure 3-12). This triggered a non-conformance under the Licence to be reported to the NT EPA on 12 March 2021. Compared to the long term 2015 to 2020 average, the 2021 average concentrations for ammonium nitrogen and dissolved reactive phosphorus were lower. Given a significant wastewater source to the irrigation discharge stream is from the STP, nutrients are expected to be present and the current Licence trigger values for speciated nutrients are not considered to be appropriate indicators for sewerage. This is because they are based on the Darwin Harbour Water Quality Objectives (DHWQO) which do not reflect the receiving groundwater environment. It is noted that Nitrate and Nitrite which were above licence limits in 2020 remained within licence limits for 2021.
- Copper exceeded the Licence trigger value on two occasions in November and early December 2021 EPA (Figure 3-13). This did not trigger a reportable non-conformance and returned to below licence limits in the last sample taken on mid December 2021. The 2021 average concentration was slightly higher than the 2016-2020 long term.

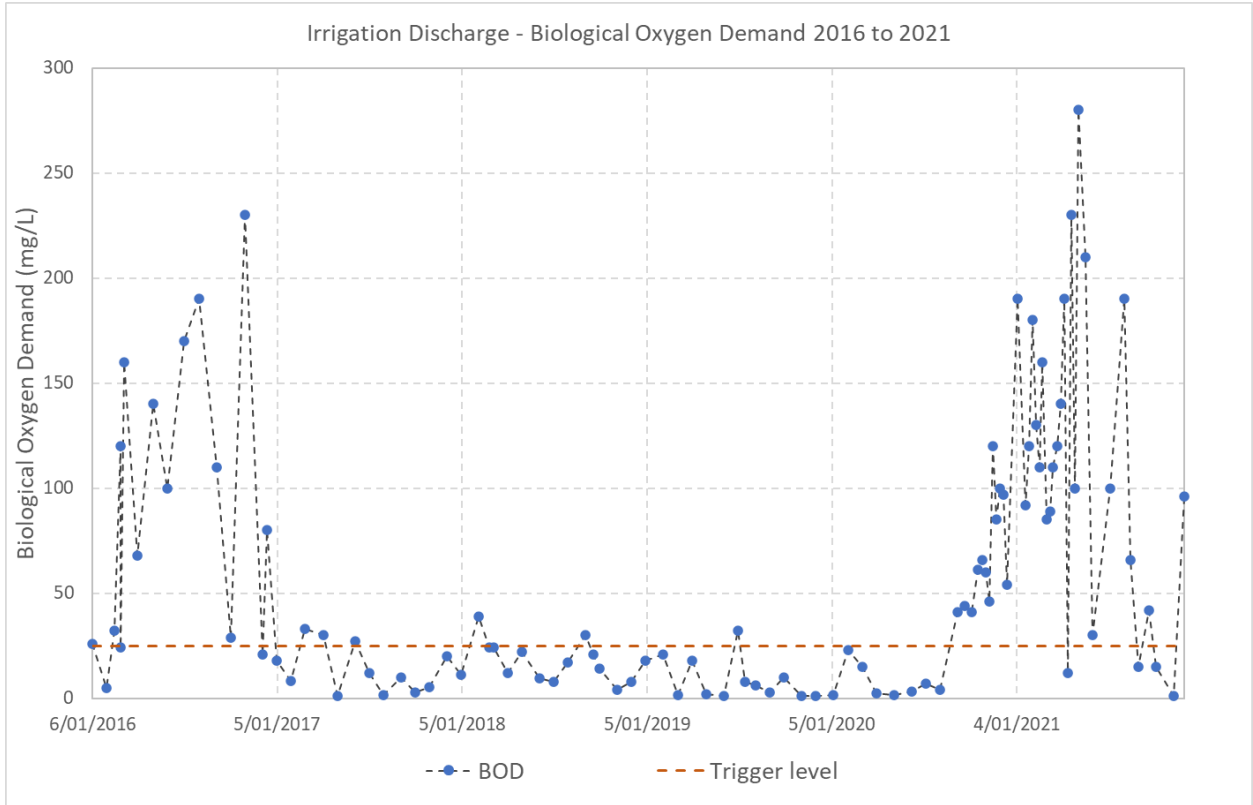


Figure 3-8 Irrigation discharge BOD concentrations 2016-2021

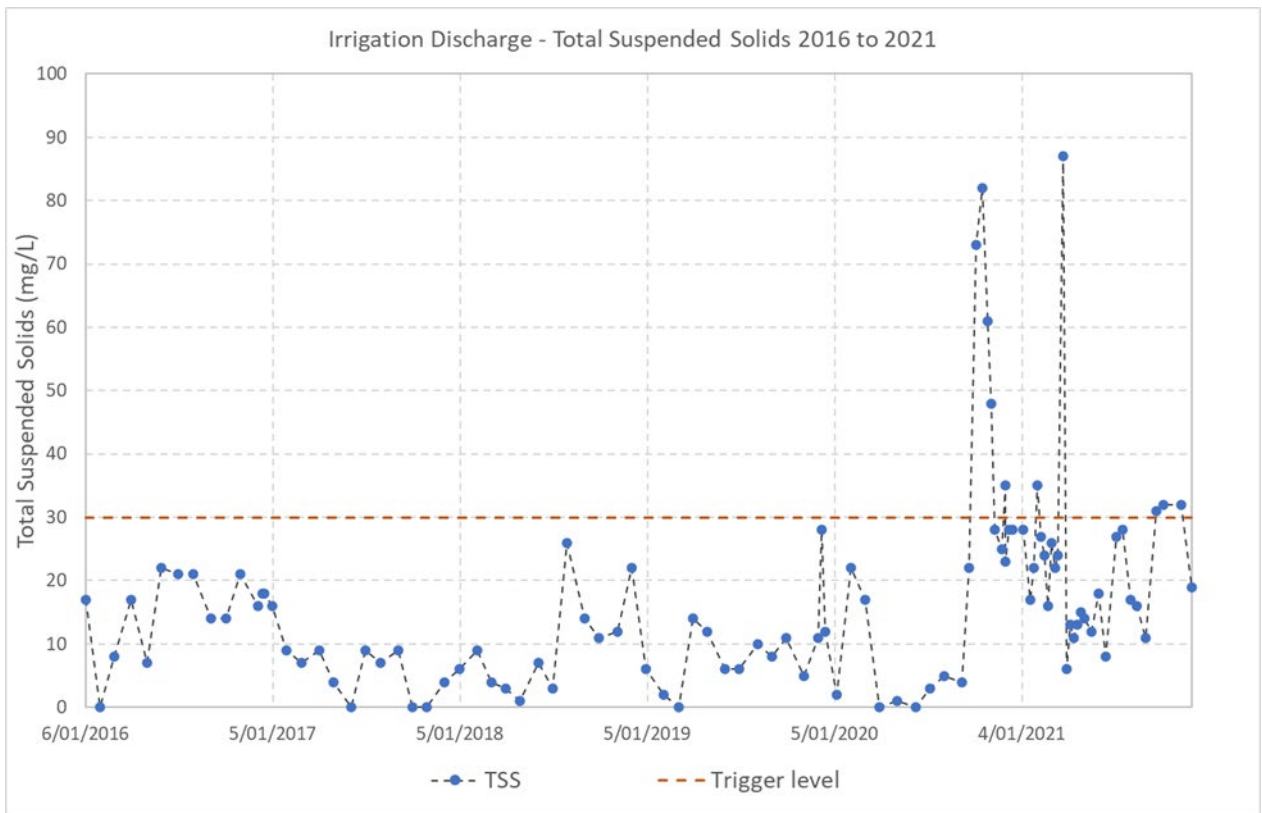


Figure 3-9 Irrigation discharge TSS concentrations 2016-2021

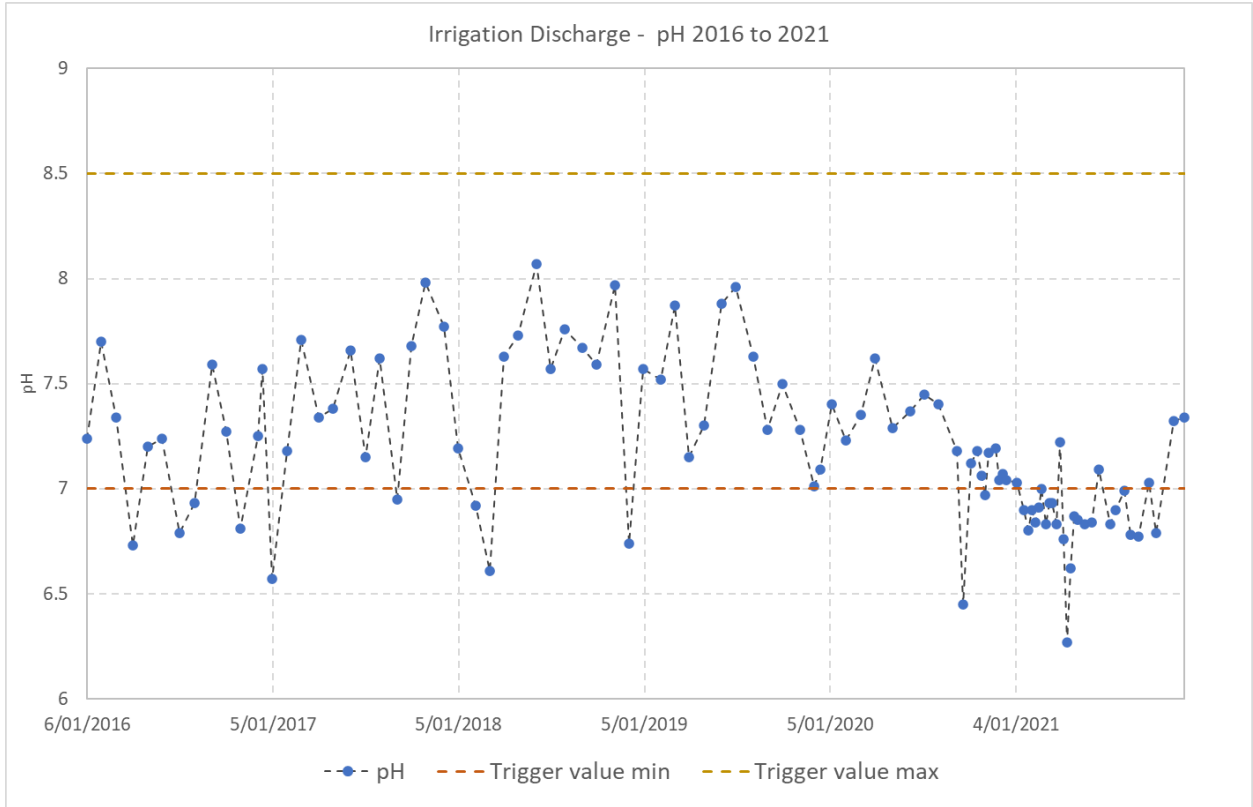


Figure 3-10 Irrigation Discharge pH 2016- 2021

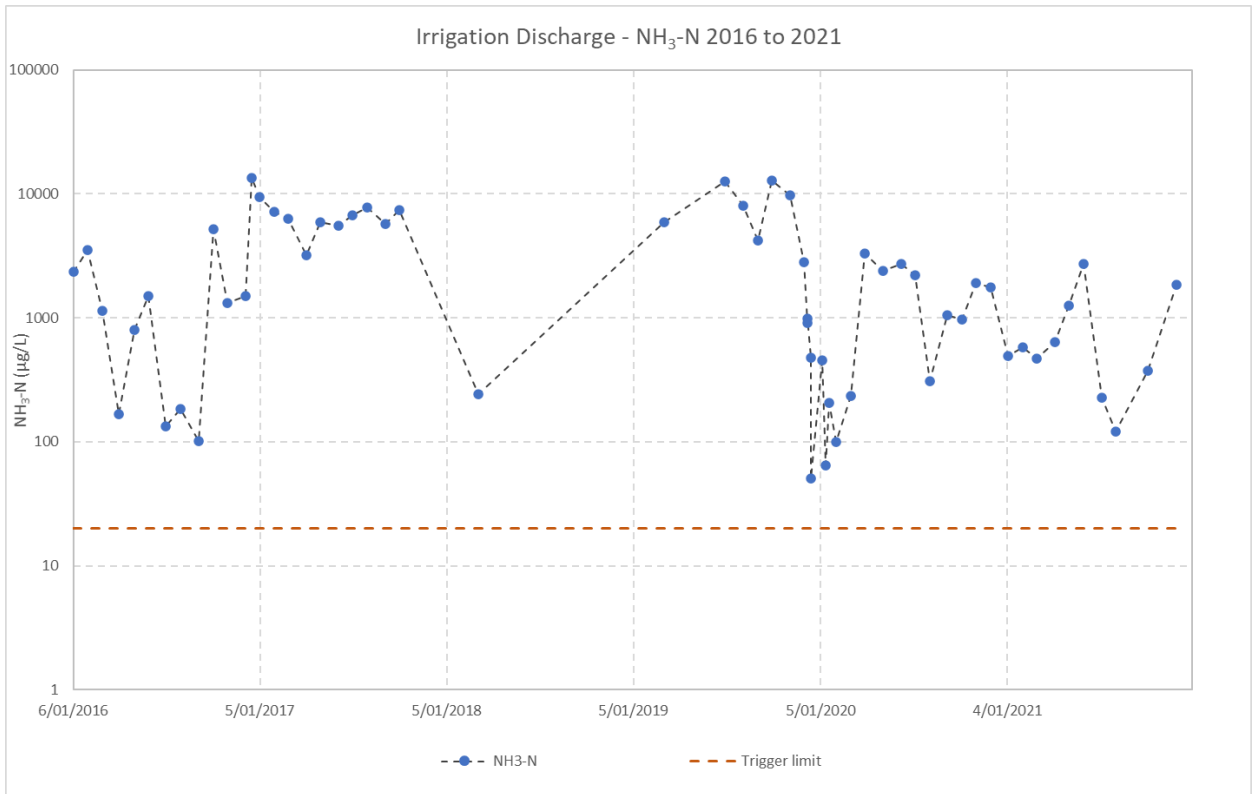


Figure 3-11 Irrigation Discharge NH₃-N 2016 - 2021

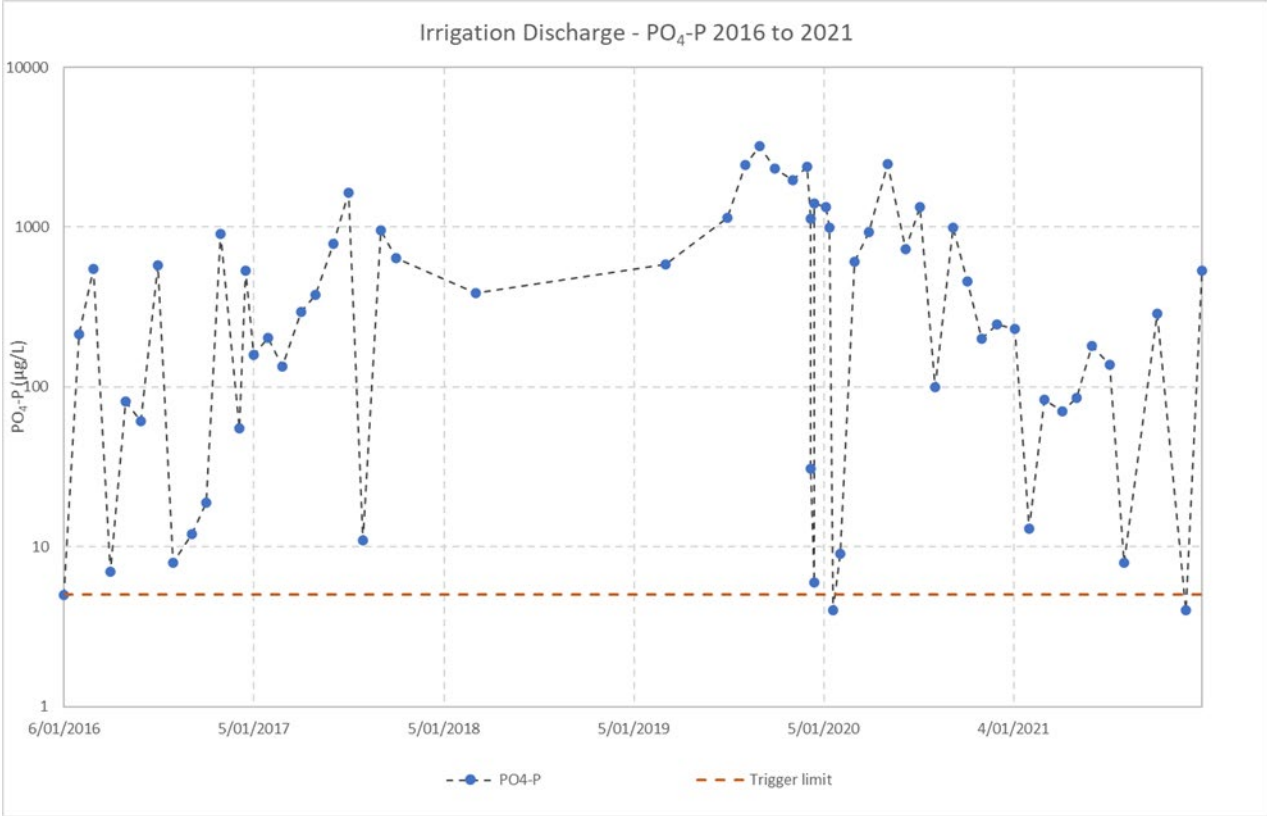


Figure 3-12 Irrigation discharge PO₄-P 2016 - 2021

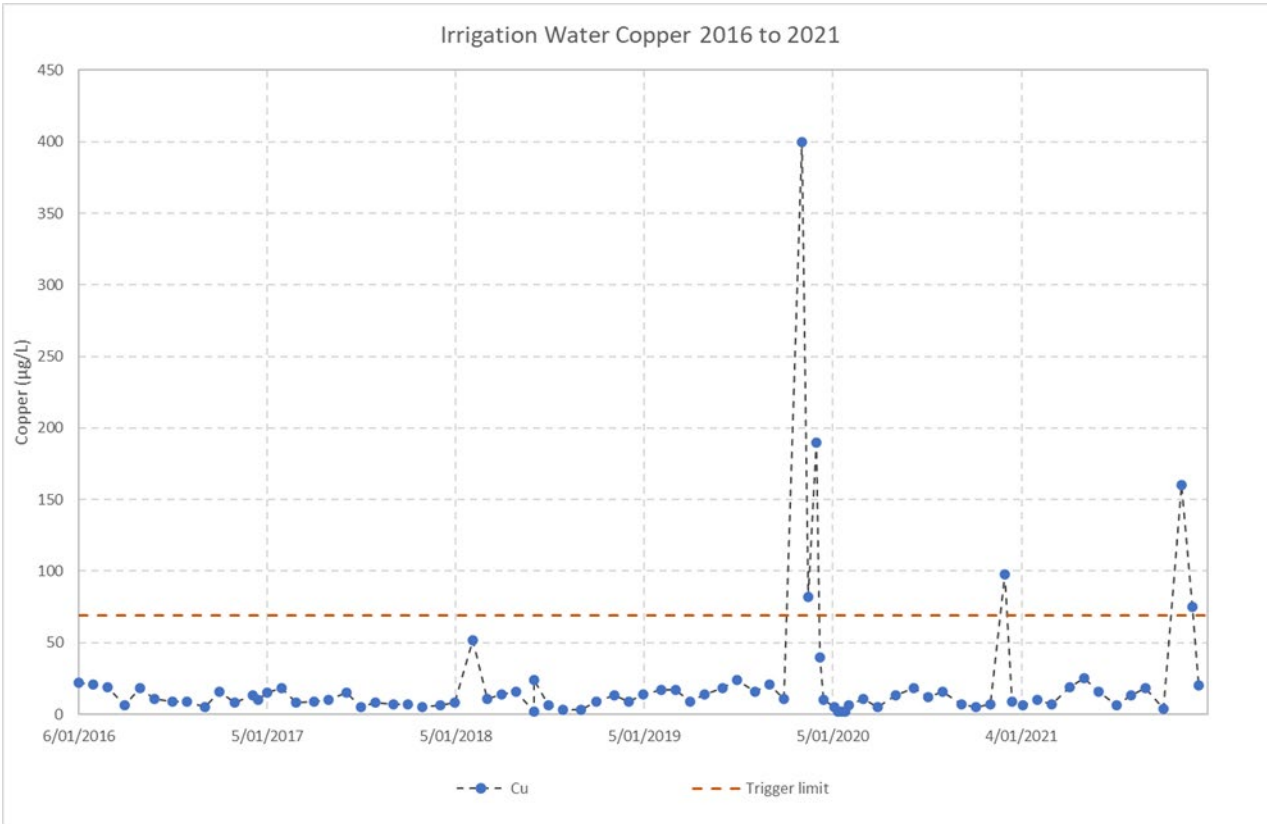


Figure 3-13 Irrigation discharge Copper concentrations 2016-2021

Table 3-1 Summary of irrigation water quality results

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Field Parameters							
pH	Monthly	7-8.5	7.34	6.27	6.90	7.20	No
Electrical conductivity(µs/cm)	Monthly	No trigger	859	158	288	243	N/A
TSS (mg/L)	Monthly	≤ 30	87.0	6.0	22.5	16.94	No
Turbidity (NTU)	Monthly	No trigger	35.6	11.0	18.4	13.1	N/A
DO (mg/L)	Monthly	No trigger	0.15	0.07	0.13	0.19	N/A
Temperature (°C)	Monthly	No trigger	39.7	32.0	36.2	36.2	N/A
Environmental Indicators							
Ammonium nitrogen (NH ₃ -N) (µg/L)	Annual	20	2,730	121	764	3106	Yes
Nitrate (NO ₃ -N) (µg/L)	Annual	17	70	<1	2.3	762	No
Nitrite (NO ₂ -N) (µg/L)	Annual	17	34	<1	2.3	89.34	No
DRP (PO ₄ -P) (µg/L)	Annual	5	287	4	96.4	635.1	Yes
Total Nitrogen (mg/L)	Annual	≤ 40	11.3	1.2	6.2	7.90	No
Total Phosphorous (mg/L)	Annual	≤ 10	1.6	0.4	0.75	1.36	No
Chlorophyll-a (µg/L)	Biannual	2	<1	<1	1	1	No
BOD (mg/L)	Monthly	≤ 25	280	<1	120.2	60.98	Yes
TRH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	0.96	No
<i>E. coli</i> (MPN/100 mL)	Biannual	≤ 75	10	<10	10	328.75	No
<i>Enterococci</i> (MPN/100 mL)	Biannual	50	<10	<10	N/A ^[2]	150.5	No
Metals & BTEX							
Arsenic (µg/L)	Annual	10	<1	<0.5	N/A ^[2]	N/A ^[2]	No
Cadmium (µg/L)	Monthly	3.2	<0.1	<0.1	N/A ^[2]	0.1	No
Chromium (µg/L)	Annual	10	<1	<0.5	N/A ^[2]	N/A ^[2]	No
Copper (µg/L)	Monthly	69	160	4	30	24	No
Iron (µg/L)	Annual	1,300	400	N/A ^[3]	N/A ^[3]	244	No

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Lead (µg/L)	Annual	10	<1	N/A ^[3]	N/A ^[3]	N/A ^[2]	No
Manganese (µg/L)	Annual	15,500	43	40	41	37	No
Mercury (µg/L)	Monthly	0.1	<0.1	<0.1	N/A ^[2]	N/A ^[2]	No
Nickel (µg/L)	Annual	290	<1	<0.05	N/A ^[2]	1.75	No
Silver (µg/L)	Annual	1.4	<1	N/A ^[2]	N/A ^[2,3]	N/A ^[1]	No
Zinc (µg/L)	Monthly	1,780	120	<5	24	22	No
BTEX (µg/L)	Monthly	700	4	<3	4	3.6	No

Note:

1. Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence
2. All results below LOR
3. Only one sample taken (annual requirement)

3.1.4 Monitoring Results – Jetty Outfall

Volume Discharged

A total of 31,877 m³ was discharged from the jetty outfall during the reporting period (Figure 3-14). This is approximately 52% of the Licence limit. This volume is slightly lower than 2020 and the lowest annual discharge volume in the five-year period from 2016-2021. This is primarily due to a reduction in losses from the steam system resulting in reduced demand for demineralisation water and the associated reject water production.

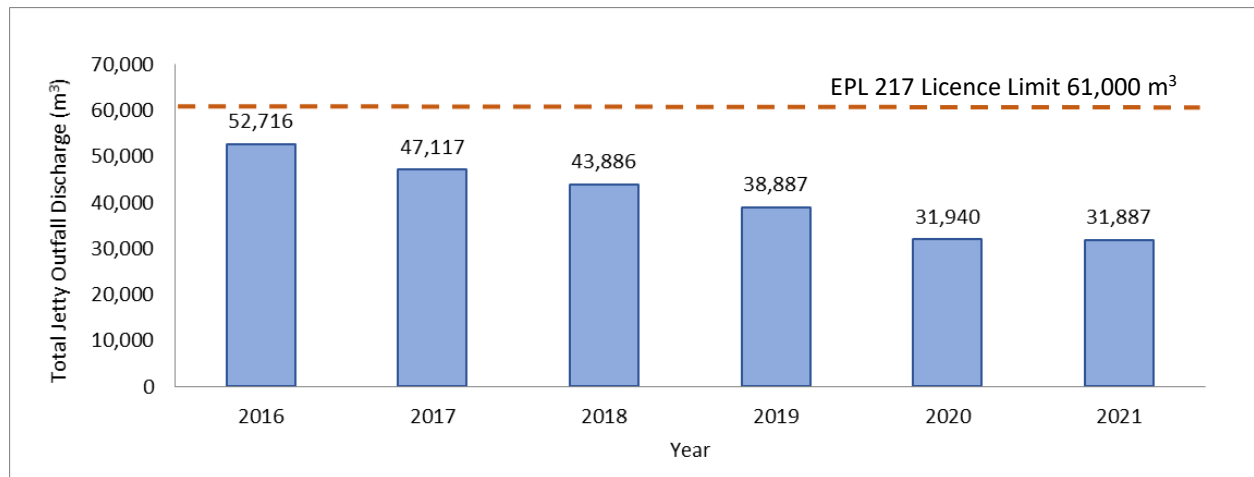


Figure 3-14 Water volumes discharged to jetty outfall

Discharge Water Quality Results

The annual monitoring of environmental indicators was undertaken in March 2021 and the biannual indicators in November 2021. Additionally, voluntary monitoring has also been conducted for parameters of interest during 2021. The 2015-2021 dataset of both compliance and voluntary jetty outfall discharge water quality results is provided in Attachment A – Jetty Outfall Discharge; values exceeding current Licence trigger values are bolded. It should be noted that an exceedance does not trigger a reportable non-conformance.

Key findings from a review of the jetty outfall discharge water quality results include:

- Field measurements of the jetty outfall discharge during 2021 were generally consistent with or below the 2016-2021 average and were within the Licence trigger values except for the following:
- Ammonium nitrogen (NH₃-N) exceeded the Licence trigger values on two occasions in 2021 (Figure 3-15). This did not result in an exceedance in the jetty outfall mixing zone or trigger a reportable non-conformance.

The source of ammonium nitrogen in the RO reject water was thought to be mostly attributable to the biocide dosing chemical injected in the Demineralisation Plant. A biocide reduction trial was initiated in Q2-3 2019 which progressively reduced the dosing concentration.

The ammonium nitrogen concentrations continued to be monitored more frequently than required under the Licence for the remainder 2021.

Despite the exceedances noted in select speciated nutrients, total nitrogen and total phosphorus were consistently well below the Licence trigger values in 2021.

- Metal concentrations in the jetty outfall discharge during 2021 were generally within the Licence trigger values, apart from zinc. Zinc exceeded the Licence trigger value on three occasions in the first half of 2021 before returning to complaint levels for the remainder of the year. (Figure 3-16). This did not result in an exceedance in the jetty outfall mixing zone or trigger a reportable non-conformance to the NT EPA and is likely due to concentration of low levels in the source water from the NT Power and Water Authority (POWA) through the demineralisation plant.
The remaining metals sampled were consistent with or below the 2016-2021 average.

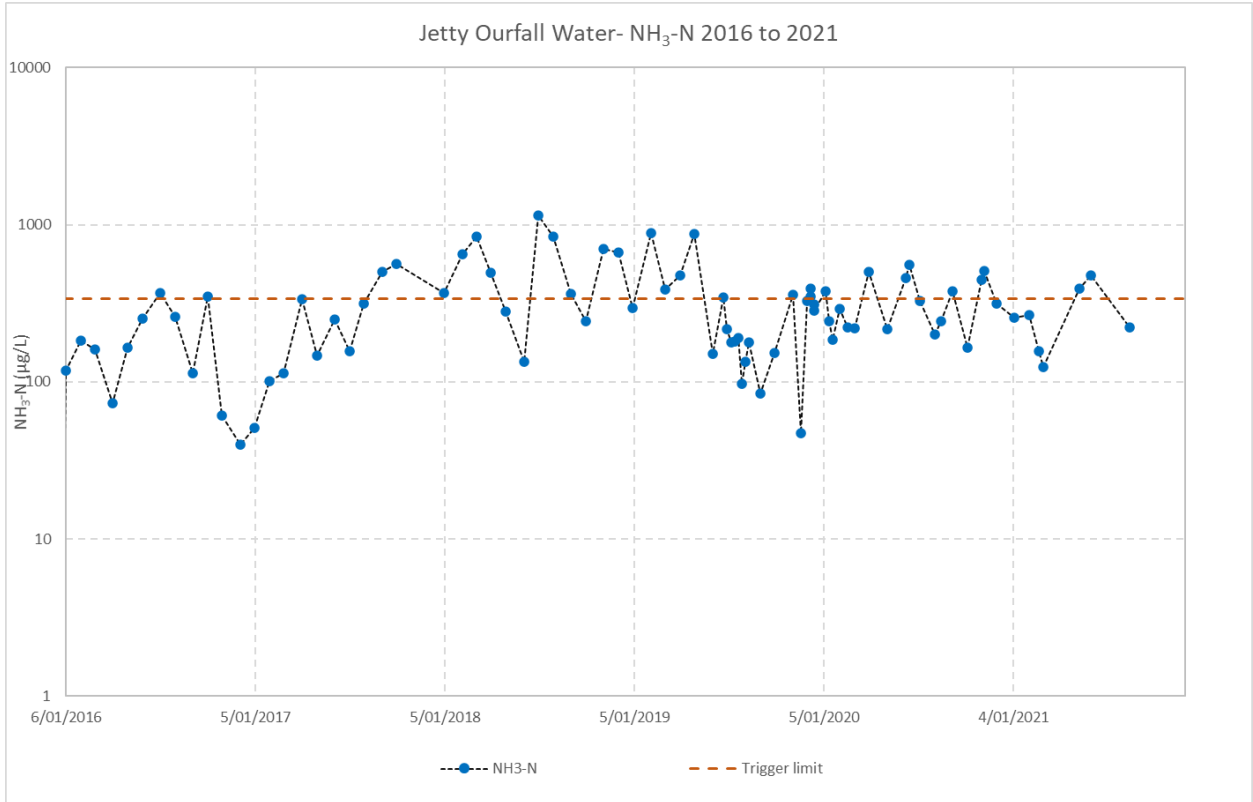


Figure 3-15 Jetty outfall discharge ammonium nitrogen (NH₃-N) concentrations 2016-2021

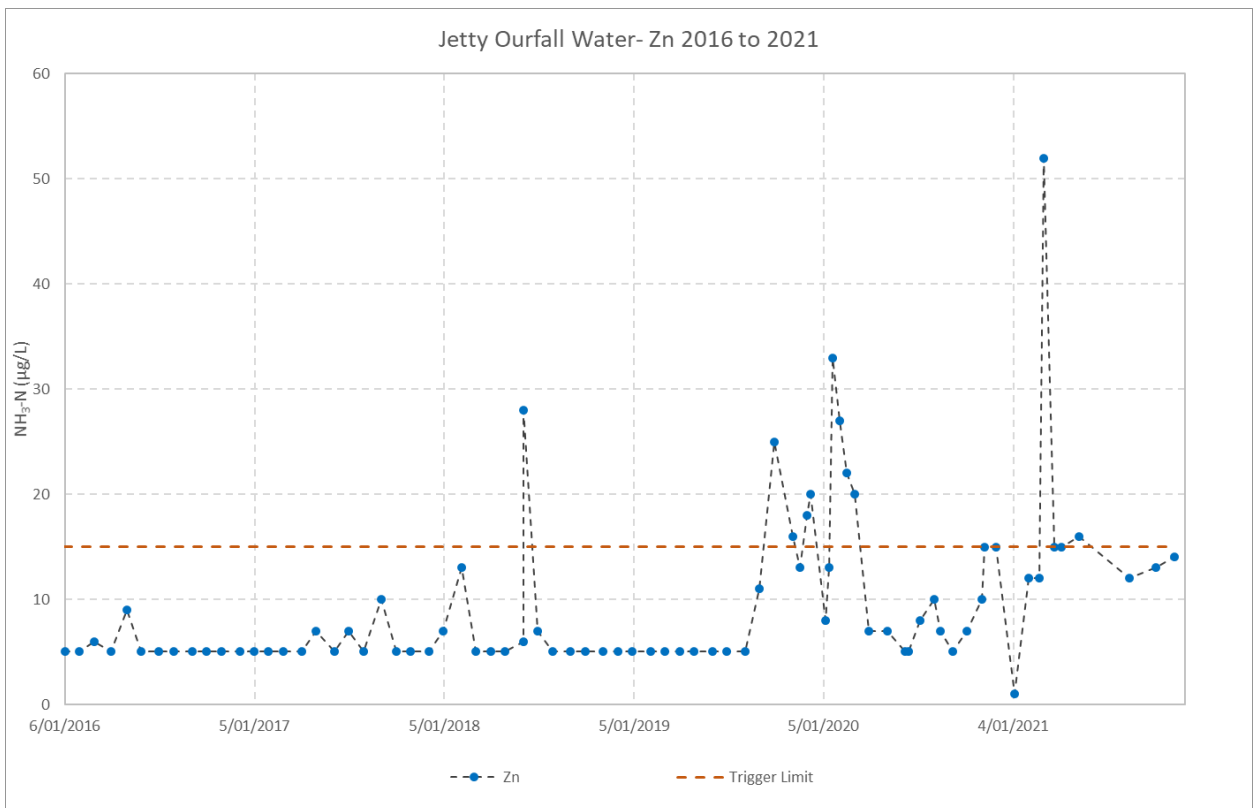


Figure 3-16 Jetty outfall discharge zinc concentrations 2016-2021

Table 3-2 Summary of 2021 jetty outfall discharge monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Field Parameters							
pH	Monthly	7-8.5	7.93	7.46	7.65	7.78	No
Electrical conductivity(µs/cm)	Monthly	No trigger	1,165	541	768	729	N/A
TSS (mg/L)	Monthly	≤ 30	7	0	0.62	0.35	No
Turbidity (NTU)	Monthly	20	1.17	0.29	0.76	1.23	No
DO (mg/L)	Monthly	No trigger	5.53	0.30	3.42	3.04	N/A
Temperature (°C)	Monthly	No trigger	35.2	30.5	33.1	32.7	N/A
Environmental Indicators							
Ammonium nitrogen (NH ₃ -N) (µg/L)	Annual	337	477	125	271	314	No
Nitrate (NO ₃ -N) (µg/L)	Annual	764	346	155	272	312	No
Nitrite (NO ₂ -N) (µg/L)	Annual	27	16	3	8	23	No
DRP (PO ₄ -P) (µg/L)	Annual	51	17	2	6.57	23.6	No
Total Nitrogen (mg/L)	Annual	≤ 40	2.82	0.97	1.42	1.73	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.12	0.01	0.03	0.07	No
BOD (mg/L)	Monthly	≤ 25	22.0	<1.0	6.76	6.37	No
TRH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
<i>E. coli</i> (MPN/100 mL)	Biannual	≤ 75	<10	N/A ^[2]	N/A ^[2]	N/A ^[1]	No
<i>Enterococci</i> (MPN/100 mL)	Biannual	50	<10	N/A ^[2]	N/A ^[2]	344 ^[3]	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	1	<1	1	1	N/A
Cadmium (µg/L)	Monthly	5.5	<0.05	<0.1	N/A ^[2]	N/A ^[2]	No
Chromium (µg/L)	Annual	4.4	<1	<1	N/A ^[2]	1.5 ^[3]	No
Copper (µg/L)	Monthly	3.0	2	<1	1.5	2.38	No
Iron (µg/L)	Annual	No trigger	82	26	55	191	N/A
Lead (µg/L)	Annual	4.4	<1	<1	N/A ^[2]	N/A ^[2]	No

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Manganese (µg/L)	Annual	No trigger	21	2	13	16	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.05	N/A ^[2]	N/A ^[2]	No
Nickel (µg/L)	Annual	70	6	2	2.7	3.7	No
Silver (µg/L)	Annual	1.4	<1	<1	N/A ^[2]	N/A ^[2]	No
Zinc (µg/L)	Monthly	16.0	52	12	18	14	No
BTEX (µg/L)	Monthly	700	<3	<3	N/A ^[2]	3.6	No

Notes:

1. Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence
2. All results below LOR.
3. Average based on a single detection.

Mixing Zone Water Quality Results

In August 2019, Condition 60 was added to the Licence via an officer driven licence amendment. This condition requires the 20 m mixing zone around the jetty outfall to be monitored quarterly and compared against the new jetty outfall mixing zone trigger values added to Appendix B Table 2 of the Licence.

The Licence is currently non-specific about how to assess results from the mixing zone sites against the reference sites in relation to select physicochemical parameters. In response, the following trigger value definitions have been developed to standardise comparison of mixing zone values and determination of compliance with the intent of the Licence. These nominated assessment criteria are calculated based on the reference value and are summarised in Table 3-3.

Table 3-3 Internal assessment criteria for physicochemical parameters

Parameter	Trigger Value (TV) – Relative to Upstream Reference Location
pH	If median of mixing zone (MZ) value is greater or less than + / - 0.5 units of the reference value
Oxidation Reduction Potential (ORP)	If median of MZ value is greater or less than + / - 5% of the reference value
Temperature	If median of MZ value is greater or less than + / - 1 °C of the reference value
Electrical Conductivity (EC)	If median of MZ value is greater or less than + / - 5% of the reference value
Total Suspended Solids (TSS)	If median of MZ value is greater than the reference value
Total Dissolved Solids (TDS)	If median of MZ value is greater than the reference value
Dissolved Oxygen (DO)	If median of MZ value is less than - 5 % saturation of the reference value
Biological Oxygen Demand (BOD)	If median of MZ value is greater than the reference value

A summary of results of the 2021 monitoring campaign undertaken by are presented in Table 3-4. The full 2021 dataset of the mixing zone water quality results is provided in Attachment A – Jetty Outfall Mixing Zone; values exceeding current Licence trigger values are bolded and/or shaded. The following is a summary of the Report provided in the quarterly Jetty outfall Monitoring Reports (CDM Smith 2021, a,b,c and d)

The key findings from a review of the jetty outfall mixing zone water quality results include:

- The median concentration in the mixing zone for various parameters exceeded the reference site concentration for various quarters in 2021; physicochemical parameters (pH, ORP, EC, and total dissolved solids, DO), nutrients (total nitrogen and nitrate) and metals (arsenic and manganese).
- The median concentration in the mixing zone exceeded the Licence trigger value for dissolved oxygen in Q1, Q2 and Q3 2021 and for pH in Q4.
- There were no reportable non-conformances in 2021.

Table 3-4 Summary of 2021 jetty outfall mixing zone monitoring results

Parameter	Units	EPL 217-02 Jetty Outfall Mixing Zone Trigger Values	Q1 2021		Q2 2021		Q3 2021		Q4 2021	
			North Reference (NORTHERN)	Median of Sites 1-3	North Reference (SOUTHERN)	Median of Sites 1-3	Southern Reference (SOUTHERN)	Median of Sites 1-3	North Reference (SOUTHERN)	Median of Sites 1-3
pH	pH units	7-8.5	6.59 (6.09-7.09)	7.78	7.85 (7.35-8.35)	7.61	6.42 (5.92-6.92)	6.55	7.86 (7.36-8.36)	7.97
ORP	mV	NA	146.3 (139.0-153.6)	117.7	86.6 (82.3-90.9)	94.4	234.1 (222.4-245.8)	223.1	60.9 (57.9-60.9)	55.3
Temperature	°C	NA	30.0 (29.0-31.0)	29.9	28.5 (27.5-29.5)	28.3	27.1 (26.1-28.1)	27.1	31.6 (30.6-32.6)	31.6
Electrical Conductivity	µs/cm	NA	50,556 (48,028-53,084)	38,557	49,460 (46,987-51,933)	49,899	53,616 (50,935-56,297))	53,560	50,500 (47,975-53,025)	47,600
Total Suspended Solids (TSS)	mg/L	≤10	LOR (<5)	<5	5	5	5	<5.0	<5	<5
Turbidity	NTU	20	2.0	2.4	1.6	1.1	2.6	2.2	3.9	4.5
Total Dissolved Solids (TDS)	mg/L	N/A	33,590	33,455	32,175	32,435	34,840	34,840.0	NR	NR
Dissolved Oxygen (DO)	%	80-100	35.0 (>33.3)	47.2	52.4 (>49.8)	49.9	96.0 (>91.2)	100.1	85.4 (<81.1)	91.0
Biological Oxygen Demand (BOD)	mg/L	NA	NR	NR	<2	<2.0	<2.0	<2.0	NR	NR
Total Nitrogen	mg/L	<0.27	0.106	0.111	0.078	0.068	0.104	0.077	0.158	0.158
Total Phosphorus (P)	mg/L	<0.02	LOR <0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ammonia	mg/L	<0.02	LOR <0.010	<0.010	<0.005	<0.005	<0.010	<0.010	<0.010	<0.010
Nitrate (NO ₃)	mg/L	0.7	0.007	0.004	<0.002	<0.002	0.002	0.003	0.024	0.024
Nitrite (NO ₂)	mg/L	NA	LOR <0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.003
Dissolved reactive phosphorus (PO ₄ -P)	mg/L	0.005	0.002	<0.001	0.008	0.002	<0.001	<0.001	0.002	0.002
Total Kjeldahl Nitrogen	mg/L	NA	-	-	-	-	-	-	-	-
Chlorophyll a	mg/L	<0.002	NT	NT	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
<i>Escherichia coli</i> (<i>E. coli</i>)	MPN /100mL	<200	<1	1	NT	NT	<1.0	<1.0	NT	NT
<i>Enterococci</i>	MPN /100mL	50	<10	<10	NT	NT	<10	<10	NT	NT
Arsenic ¹	µg/L	NA	1.2	1.2	NT	NT	1.3	1.4	NT	NT
Cadmium ¹	µg/L	5.5	LOR <0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium ¹	µg/L	4.4	LOR <0.5	<0.5	NT	NT	<0.5	<0.5	NT	NT
Copper ¹	µg/L	1.3	1	1	2	1	<1.0	<1.0	2	<1
Iron ¹	µg/L	NA	LOR <5.0	<5.0	NT	NT	<5.0	<5.0	NT	NT
Lead ¹	µg/L	4.4	LOR <0.2	<0.2	NT	NT	<0.2	<0.2	NT	NT
Manganese ¹	µg/L	NA	2	2.8	NT	NT	2	<0.5	NT	NT
Mercury ¹	µg/L	0.4	LOR <0.04	<0.04	NT	NT	<0.04	<0.04	NT	NT
Nickel ¹	µg/L	70	2	<0.5	1.2	0.6	11.7	<0.5	<0.5	<0.5
Silver ¹	µg/L	1.4	0.2	<0.1	NT	NT	0.1	<0.1	NT	NT
Zinc ¹	µg/L	15	13	<5	10	<5.0	40	<5.0	10	<5
BTEX	µg/L	700	LOR <1	<1	NT	NT	<1	<1.0	NT	NT
Total Recoverable Hydrocarbons (TRH)	mg/L	LOR (<0.1)	LOR <0.100	<0.100	NT	NT	<0.1	<0.10	NT	NT

Notes: NA indicates no Trigger Values available.

LOR indicates trigger value or detection below limit of reporting.

Yellow shading denotes values that exceed / are outside of the EPL 217-02 Jetty Outfall Mixing Zone Trigger Value.

Bold denotes values that exceed Reference Site Value.

Blue shading denotes medians that exceed the EPL 217-02 Jetty Outfall Mixing Zone Trigger Value and Reference Site Value

3.1.5 Monitoring Results – Sediment Ponds

Discharge Water Quality

A summary of the sediment water quality results for 2021 for Sediment Ponds 1-3, as well as the 2016-2021 trend and Licence trigger value exceedances are presented in Table 3-5, Table 3-6 and Table 3-7 and are discussed below.

Discharges from sediment ponds are affected primarily by the amount of rainfall except for Sediment Pond 1 which also receives greensands filter backwash discharge from the Demineralisation Plant year round. The following is a summary of the sediment pond discharge and sampling undertaken in 2021:

- SP1: Discharges occurred year round and monthly samples were collected with annual samples collected in March.
- SP2: Discharges occurred between February to March, then not again until wet season rains in November. The annual samples were collected in March.
- SP3: Discharges occurred between January to April, then not again until wet season rains in November. The annual samples were collected in March.

In addition to mandatory monitoring under the Licence, voluntary monitoring has also been conducted for parameters of interest during 2021. The 2016-2021 dataset of both compliance and voluntary sediment pond water quality results is provided in Attachment A – Sediment Ponds 1,2 and 3; values exceeding current Licence trigger values are bolded.

Key findings from a review of the sediment pond discharge water quality results include:

- Field measurements for the discharge of all sediment ponds during 2021 were generally consistent with the 2016-2021 average and were within the Licence trigger values with the following exceptions:
 - NO₃-N in Sediment Pond 1 on one occasion in November 2021 (Figure 3-17). This is likely due to the first flush of storm water into the pond following the dry season.
 - E. coli in Sediment Ponds 2 and 3 on two occasions in each (February and March for Sediment Pond 2 and January and February for Sediment Pond 3) Figure 3-18 and Figure 3-19.
 - One instance of elevated total chromium (Cr) in Sediment Pond 3 in early March 2021 (Figure 3-20). This is considered an anomalous result as historically total Cr has been below the limit of reporting. This returned to below the limit of reporting when resampled later the same month.
- None of these events triggered a reportable non-conformance to the NT EPA.
- All other parameters were below the EPL licence limits for 2021.

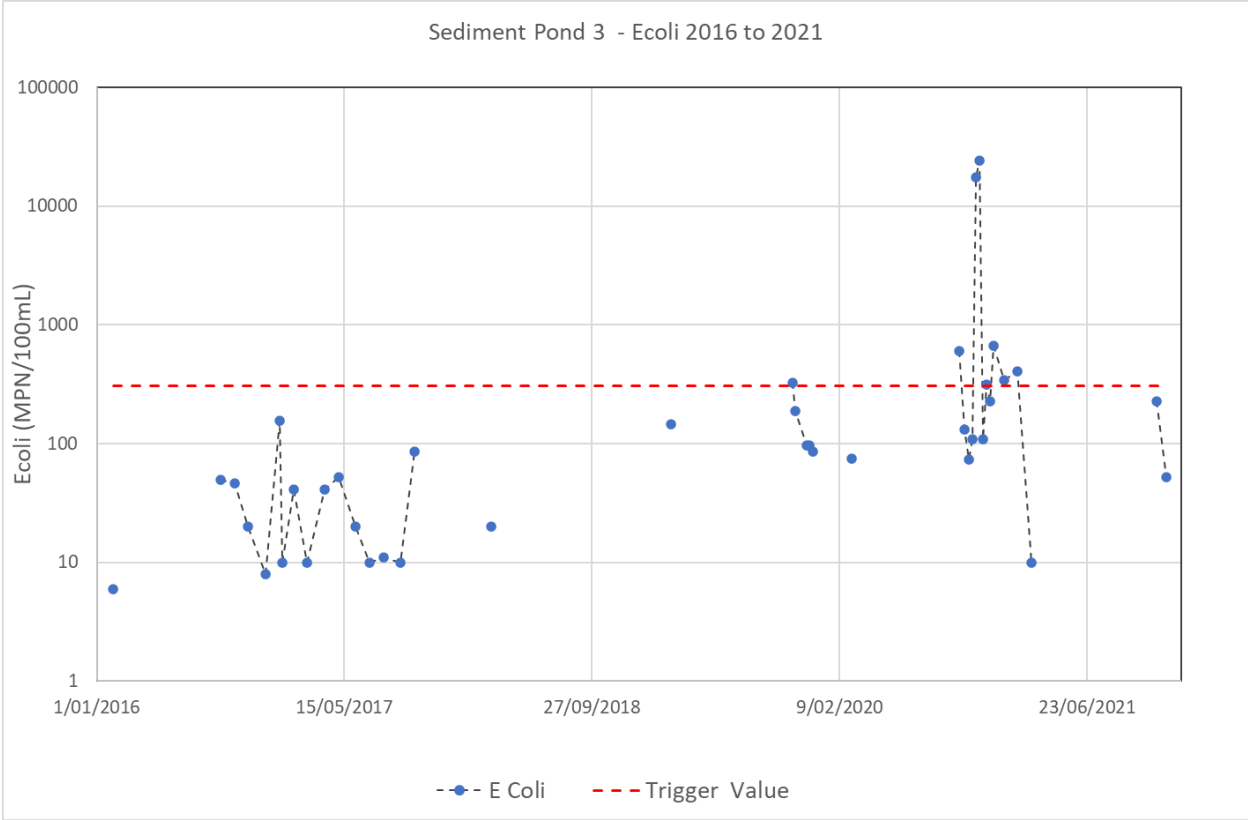


Figure 3-19 E. coli measured in the Sediment Pond 3 2016 - 2021



Figure 3-20 Total Chromium concentrations in Sed Pond 3 2016 - 2021

Table 3-5 Summary of 2021 Sediment Pond 1 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value ^[1]	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Field Parameters							
pH	Monthly	6-8.5	7.46	6.53	6.90	6.74	No
Electrical conductivity(µs/cm)	Monthly	No trigger	196	71	109	133	N/A
TSS (mg/L)	Monthly	≤ 75	7.00	0.00	1.00	0.43	No
Turbidity (NTU)	Monthly	28	6.91	1.28	2.74	2.03	No
DO (mg/L)	Monthly	No trigger	7.04	4.36	5.64	5.48	N/A
Temperature (°C)	Monthly	No trigger	31.0	23.2	27.3	28.9	N/A
Environmental Indicators							
Ammonium nitrogen (NH ₃ -N) (µg/L)	Annual	94	29	8	16	24	No
Nitrate (NO ₃ -N) (µg/L)	Annual	145	193	2	66	44	No
Nitrite (NO ₂ -N) (µg/L)	Annual	17	6	1	2.7	3	No
DRP (PO ₄ -P) (µg/L)	Annual	5	<1	<1	N/A ^[2]	4	No
Total Nitrogen (mg/L)	Annual	≤ 40	0.57	0.06	0.33	0.30	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.02	0.01	0.01	0.01	No
BOD (mg/L)	Monthly	≤ 25	2.7	1.0	1.9	2.03	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	N/A ^[2]	N/A ^[2]	No
<i>E. coli</i> (MPN/100 mL)	Biannual	≤ 305	75	10	31	67	No
<i>Enterococci</i> (MPN/100 mL)	Biannual	261	52	10	28	61	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<0.5	N/A ^[1]	N/A ^[1]	N/A
Cadmium (µg/L)	Monthly	5.5	0.2	<0.1	0.14	0.39	No
Chromium (µg/L)	Annual	4.4	<1	<0.5	N/A ^[2]	N/A ^[2]	No
Copper (µg/L)	Monthly	2.0	2	<1	2	1.67	No

Parameter	Monitoring Frequency	Licence Trigger Value ^[1]	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Iron (µg/L)	Annual	No trigger	120	110	115	175	N/A
Lead (µg/L)	Annual	4.4	<1	<0.2	N/A ^[2]	N/A ^[2]	No
Manganese (µg/L)	Annual	No trigger	300	80	190	422	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.1	N/A ^[2]	N/A ^[2]	No
Nickel (µg/L)	Annual	70	6	6	6	2.6	No
Silver (µg/L)	Annual	1.4	<1	<1	N/A ^[2]	N/A ^[2]	No
Zinc (µg/L)	Monthly	1,000	130	<5	45	106	No
BTEX (µg/L)	Monthly	700	<3	<2	N/A ^[2]	N/A ^[2]	No

Note:

1. Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.
2. No samples above LOR in the period.

Table 3-6 Summary of 2021 Sediment Pond 2 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value ^[1]	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Field Parameters							
pH	Monthly	6-8.5	6.66	6.56	6.63	6.62	No
Electrical conductivity(µs/cm)	Monthly	No trigger	109	68	90	205	N/A
TSS (mg/L)	Monthly	≤ 75	7.0	2.0	5.00	8.81	No
Turbidity (NTU)	Monthly	28	18	11	14	19	No
DO (mg/L)	Monthly	No trigger	6.34	5.05	5.8	5.44	N/A
Temperature (°C)	Monthly	No trigger	29.3	28.3	28.7	30.2	N/A
Environmental Indicators							
Ammonium nitrogen (NH ₃ -N) (µg/L)	Annual	94	29	7	18	80	No
Nitrate (NO ₃ -N) (µg/L)	Annual	145	115	8	61	169	No

Parameter	Monitoring Frequency	Licence Trigger Value ^[1]	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2016-2021)	2021 Reportable Non-Conformance ^[1]
Nitrite (NO ₂ -N) (µg/L)	Annual	17	4	2	3	6.6	No
DRP (PO ₄ -P) (µg/L)	Annual	5	1	<1	1	4.45	No
Total Nitrogen (mg/L)	Annual	≤ 40	0.36	0.20	0.28	1.07	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.015	0.01	0.01	0.02	No
BOD (mg/L)	Monthly	≤ 25	<1	<1	N/A	9.74	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
<i>E. coli</i> (MPN/100 mL)	Biannual	≤ 305	768	73	467	178	No
<i>Enterococci</i> (MPN/100 mL)	Biannual	261	120	86	101	211	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<1	N/A ^[2]	N/A ^[2]	N/A
Cadmium (µg/L)	Monthly	5.5	0.1	<0.1	0.1	0.2	No
Chromium (µg/L)	Annual	4.4	<1	<1	N/A ^[2]	N/A ^[2]	No
Copper (µg/L)	Monthly	2.0	2	1	1.3	1.9	No
Iron (µg/L)	Annual	No trigger	120	120	120	148	N/A
Lead (µg/L)	Annual	4.4	<1	<1	N/A ^[2]	N/A ^[2]	No
Manganese (µg/L)	Annual	No trigger	200	200	200	148	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.1	N/A ^[2]	N/A ^[2]	No
Nickel (µg/L)	Annual	70	<0.1	<1	N/A ^[2]	5	No
Silver (µg/L)	Annual	1.4	<1	<1	N/A ^[2]	N/A ^[2]	No
Zinc (µg/L)	Monthly	1,000	130	32	73	88	No
BTEX (µg/L)	Monthly	700	<3	<3	N/A ^[2]	N/A ^[2]	No

Note:

1. Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.
2. No samples above LOR in the period.

Table 3-7 Summary of 2021 Sediment Pond 3 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2015-2021)	2021 Reportable Non-Conformance ^[1]
Field Parameters							
pH	Monthly	6-8.5	7.28	6.58	6.89	7.07	No
Electrical conductivity(µs/cm)	Monthly	No trigger	141	76	105	151	N/A
TSS (mg/L)	Monthly	≤ 75	7	0	1.5	1.22	No
Turbidity (NTU)	Monthly	28	10.6	1.8	5.14	6.15	No
DO (mg/L)	Monthly	No trigger	8.95	6.5	7.25	6.07	N/A
Temperature (°C)	Monthly	No trigger	32.3	28.2	29.9	30.3	N/A
Environmental Indicators							
Ammonium nitrogen (NH ₃ -N) (µg/L)	Annual	94	19	8	12	24	No
Nitrate (NO ₃ -N) (µg/L)	Annual	145	48	1	17	69	No
Nitrite (NO ₂ -N) (µg/L)	Annual	17	3	<1	2	4	No
DRP (PO ₄ -P) (µg/L)	Annual	5	4	<1	4	7	No
Total Nitrogen (mg/L)	Annual	≤ 40	0.37	0.07	0.21	0.30	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.02	0.005	0.01	0.3	No
BOD (mg/L)	Monthly	≤ 25	1.1	<1.0	1.1	1.7	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
<i>E. coli</i> (MPN/100 mL)	Biannual	≤ 305	408	10	246	1,286	No
<i>Enterococci</i> (MPN/100 mL)	Biannual	261	41	<10	41	136	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<0.05	N/A ^[2]	1	N/A
Cadmium (µg/L)	Monthly	5.5	<0.1	<0.05	N/A ^[2]	0.4	No
Chromium (µg/L)	Annual	4.4	11	<0.05	11	11	No
Copper (µg/L)	Monthly	2.0	2	<1	2	2.5	No

Parameter	Monitoring Frequency	Licence Trigger Value	2021 Maximum	2021 Minimum	2021 Average	Long-term Average (2015-2021)	2021 Reportable Non-Conformance ^[1]
Iron (µg/L)	Annual	No trigger	520	180	350	220	N/A
Lead (µg/L)	Annual	4.4	<0.2	<1	N/A ^[2]	N/A ^[2]	No
Manganese (µg/L)	Annual	No trigger	48	0.5	24	70	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.1	N/A ^[2]	N/A ^[2]	No
Nickel (µg/L)	Annual	70	29	<0.5	29	8	No
Silver (µg/L)	Annual	1.4	<0.1	<0.1	N/A ^[2]	N/A ^[2]	No
Zinc (µg/L)	Monthly	1,000	48	2	22	98	No
BTEX (µg/L)	Monthly	700	<3	<2	N/A ^[2]	N/A ^[2]	No

Note:

1. Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.
2. No samples above LOR in the period.

3.1.6 Data Management and Quality Control

As outlined in Section 3.1.2, all samples are collected by DLNG laboratory staff or environmental consultants, who are trained and experienced in the sampling methodologies. All samples are analysed by laboratories with NATA accreditation for the analyses performed. The field parameters are an exception to this pH, DO, EC, TSS, turbidity, temperature all have short holding times, and hence are analysed by DLNG laboratory or with field meters.

Results are reviewed upon completion of analysis, and the data is recorded in the Santos database. Any results that are considered to be unreliable are investigated further and additional sampling undertaken if required.

3.1.7 Discussion and Interpretation of Results

Irrigation Area

In summary, there were two reportable non-conformances relating to the irrigation water during 2021, all of which were deemed to be of low risk and low impact to the environment:

- Speciated Nutrients above trigger levels - ammonium nitrogen ($\text{NH}_3\text{-N}$) and dissolved reactive phosphorus ($\text{PO}_4\text{-P}$). Groundwater monitoring results do not indicate any linkages between nutrient trends in irrigation water quality and groundwater quality. Accordingly, impacts to the receiving environment are likely to be negligible.
- Irrigation water contained pH concentrations below the Licence trigger value of 7-8.5 on the three consecutive occasions. The 2021 groundwater monitoring results do not indicate any linkages between pH trends in irrigation water quality and groundwater quality. Accordingly, impacts to the receiving environment are considered negligible. Additionally the irrigation holding tank underwent a deep clean in November 2021 following which the pH levels returned to within the EPL limits.
- BOD and TSS exceeded the Licence trigger levels in late Q3 – Q4 2020. TSS returned to within licence limits in 2021 except for a few isolated spikes. BOD continued to be above EPL limits during 2021 however values were generally lower following the cleanout of the irrigation holding tank and will continued to be monitored into 2022.
- As with other parameters mentioned above, pH licence exceedances are thought to be due to due to a build-up of biological material in the irrigation holding tank, CPI DAF and STP. Following the clean out of the tank in November pH levels returned to within the limits of the licence.

Based on the irrigation flow data, evapotranspiration rates, groundwater hydraulic head data and rainfall data, there is a low likelihood that the irrigation water applied has discharged to, or is impacting on the receiving environments, including groundwater and stormwater, either by surface or subsurface mechanisms. In addition, both BOD and TSS are not expected to cause groundwater quality issues given turbidity will be filtered through a soil profile and BOD is expected to be naturally high in the organic matter rich mangrove environment.

Jetty Outfall discharge and Mixing Zone

Metal concentrations in the jetty outfall discharge during 2021 were generally within the Licence trigger values, apart from zinc. Zinc exceeded the Licence trigger value on three occasions in the first half of 2021 before returning to complaint levels for the remainder of the year. This did not

result in an exceedance in the jetty outfall mixing zone or trigger a reportable non-conformance to the NT EPA and is likely due to concentration of low levels in the source water from the NT Power and Water Authority (POWA) through the demineralisation plant.

The remainder of metals were also consistent with or below the 2016-2021 average.

In summary, the results of the jetty outfall mixing zone sampling program were compliant with Condition 77. In addition, the dilutions generally met the reference site, Licence trigger or DHWQO trigger values, therefore the risk of environmental impact from the jetty outfall discharge is considered low.

Sediment Ponds 1,2&3

Overall in 2021 the monitoring results were consistent with data from previous years with the averages for all parameters meeting the licence triggers with the exception of E.Coli for Sediment Pond 2.

The nutrients in the sediment ponds are likely attributable to vegetative matter in the stormwater drainage network that leads to the sediment ponds as well as surrounding and within the sediment ponds. In addition, wildlife frequents the sediment ponds to source freshwater and contribute faecal matter which is expected to be the primary source for the microbiological spikes, as well as contributing to the nutrient concentrations. The spikes coincide with the onset of the wet season and rainfall events which is typical for tropical environments and is considered natural. The spikes are also typically of short duration.

In addition, field data shows that the sediment ponds do not generally appear to be affected by algal blooms, odour issues, mortality or any other sources of contamination. For these reasons, the discharge water quality from the sediment ponds is of low environmental risk or impact.

3.2 Mangrove Monitoring

There is mangrove habitat surrounding the DLNG facility, which is monitored to determine if there is any environmental impact from the operation of the facility. Condition 63 of the Licence requires Santos to undertake mangrove monitoring program. The requirements for this program are outlined in Appendix D of the Licence, and are summarised below:

- Mangrove health monitoring (including groundwater monitoring) – regular ongoing monitoring of indices related to mangrove health, such as:
 - Canopy density;
 - Tree density;
 - Species composition;
 - Defoliation index;
 - Changes in sediment height; and
 - Groundwater characteristics.
- Chemical monitoring – analysis of sediments and biota in mangrove habitats for hydrocarbon and heavy metal contamination, including:
 - Sediment particle size; and
 - Concentrations of metals and hydrocarbons in sediments and biota (mudwhelks).

The mangrove monitoring program is required to be undertaken annually.

CDM Smith, with the support of EcoScience, were commissioned by Santos to collect, review and interpret mangrove related data in accordance with the mangrove monitoring plan. The results of this analysis were provided in an annual mangrove monitoring report (CDM Smith, 2021e) and are summarised in this section.

3.2.1 Monitoring Objectives

The objective of the mangrove monitoring program is to identify and quantify potential impacts from the operation of the DLNG facility on the environment surrounding the facility. The monitoring program provides information on the health of this ecosystem. The information collected by the mangrove monitoring and chemical surveillance program is considered in conjunction with results from other monitoring programs implemented by Santos.

The mangrove monitoring and chemical surveillance program is also intended to maintain compliance with Condition 63 and Appendix D of the Licence.

3.2.2 Monitoring Methods

The annual mangrove monitoring was undertaken at the DLNG facility during August 2021. The methods used to undertake the monitoring are summarised in Table 3-8 and are in accordance with the Mangrove Surveillance and Chemical Monitoring Program outlined in Appendix D of the Licence. The sampling locations are shown in Figure 3-21 and Figure 3-22.

Table 3-8 Summary of 2021 mangrove monitoring and chemical surveillance methods

Element	Indicator	Method	Information Provided
Mangrove Monitoring			
Mangrove Health	Canopy cover	Densiometer readings of foliage or canopy cover	Quantitative estimates of mangrove canopy density used to determine changes in canopy cover over time
	Photo-monitoring	Comparison of photo-monitoring from current year with baseline imagery and previous years	Standardised set of photos used for comparison of forest health over time
	Tree condition	Defoliation index (score of health on scale of 0-5)	Visual assessment using standardised method of tree health used for comparison of forest health over time
	Tree density and species composition	Percentage species composition Tree density per hectare	Mangrove species richness, diversity and density measures used for comparison over time
	Resilience	Abundance of seedlings (<1 m) and saplings (<2 m) is ranked from 0 to 5	Assessment of the presence and abundance of mangrove seedlings and saplings as an indicator of forest health and potential for rapid regeneration
Groundwater monitoring	Water table depth	Water quality monitoring probes in monitoring bores	Data on groundwater quality (water table depth, TDS and pH) for comparison of water quality to

Element	Indicator	Method	Information Provided
	Total dissolved solids (TDS) pH		previous monitoring data and water quality standards
Sediment / erosion monitoring	Sediment levels	Measurements of sediment height taken from fixed reference post	Sediment height in relation to reference post for comparison over time
Chemical Monitoring			
Sediment characterisation	Particle size distribution (PDS)	Wet sieving Laser diffraction	Sediment particle size distribution for comparison over time
	Metal and hydrocarbon concentrations in sediments	Sediment samples for laboratory analysis	Concentrations of metals and hydrocarbons in sediments for comparison to previous monitoring data and sediment quality standards
Bioaccumulation	Metal and hydrocarbon concentrations in mudwhelks	Tissue samples for laboratory analysis	Concentrations of metals and hydrocarbons in mudwhelk tissue for comparison to previous monitoring data

The following changes have been made to the monitoring methods:

- During the August 2015 survey, two new sites (SS15A and SS16A) were established as replacement sites for SS15 and SS16 whose value had become limited due to location of plots within the flare dyke footprint during the construction phase. The new sites were selected to provide monitoring coverage in this area and were also located adjacent the outlet of discharge from Sedimentation Pond 1 (Figure 3-21).
- During monitoring surveys conducted between 2003 to 2017 canopy cover was measured using a standard densiometer. In 2017 and 2018 the Stickler's modified 17-point densiometer was trialled alongside the standard densiometer method. The 17 point densiometer has been widely adopted as the standard instrument in mangrove monitoring in Darwin Harbour since 2011. After reviewing the trial data and other benefits, this was adopted as the sole method for measuring canopy at DLNG since the 2019 mangrove surveillance monitoring campaign.
- Historically all photo monitoring has been undertaken using the corner post to centre method. During the 2018, 2019 and 2020 surveys a second set of photographs were undertaken using the centre to corner post method. This additional set of high-quality images will improve the ability to detect short-term and localised changes in mangroves, eliminate the redundancy of older, occasionally mis-matched photos and allow detailed visual monitoring of post-cyclone recovery and future changes in mangrove forest health.
- Three new chemical monitoring sites were installed during the 2020 program to help assess potential contamination downstream of Sediment Ponds 2 and 3 (SP2A – sediment only, SP3 – sediment only and SP3-A – sediment and biota). Biota is not typically present at SP2A and SP3.

Five new photo monitoring sites were installed at the pipeline crossing (PSC1) and downstream from the sediment ponds (SP1-A, SP1-B, SP2, SP3)

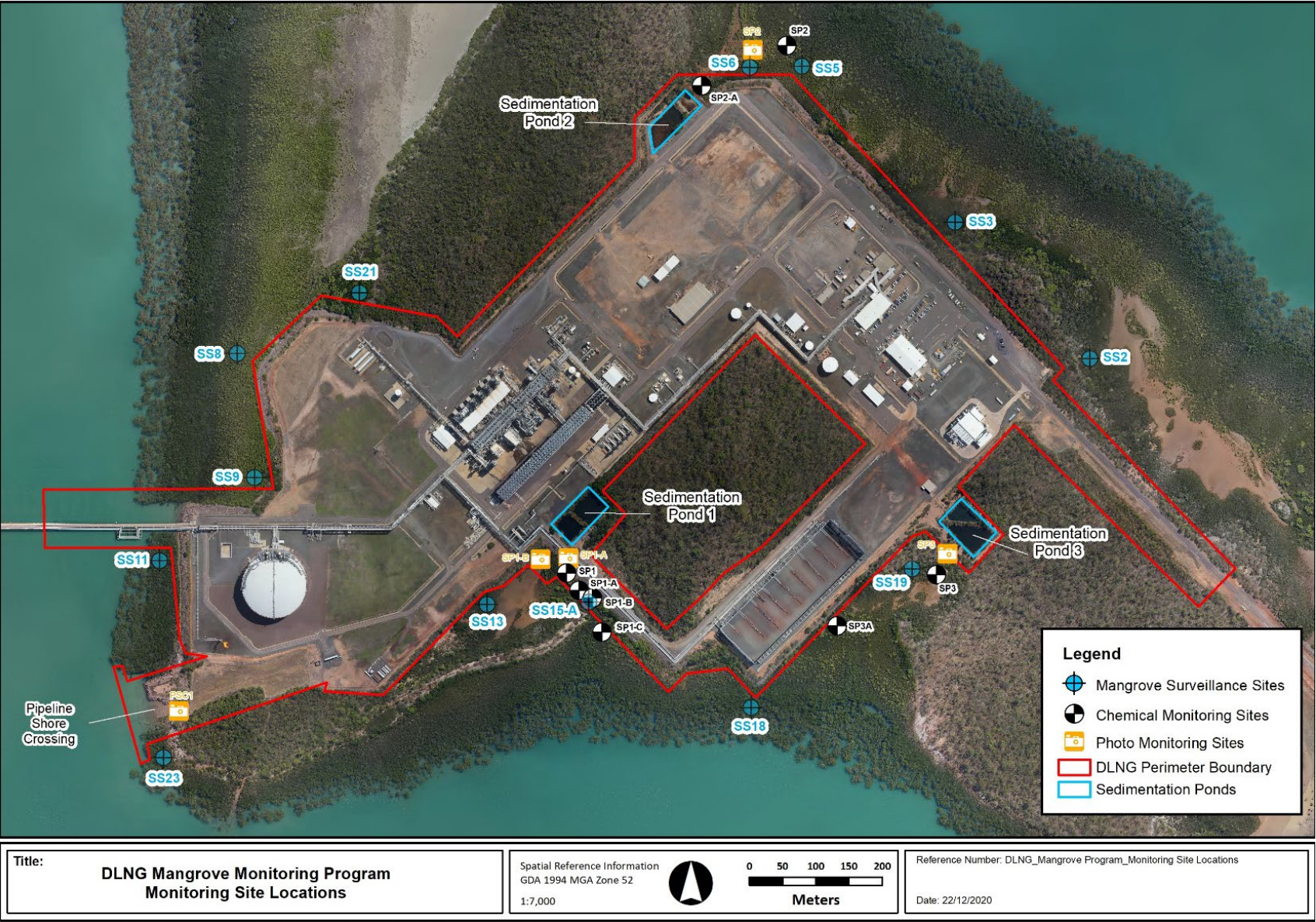


Figure 3-21 Location of sampling sites for the mangrove monitoring program

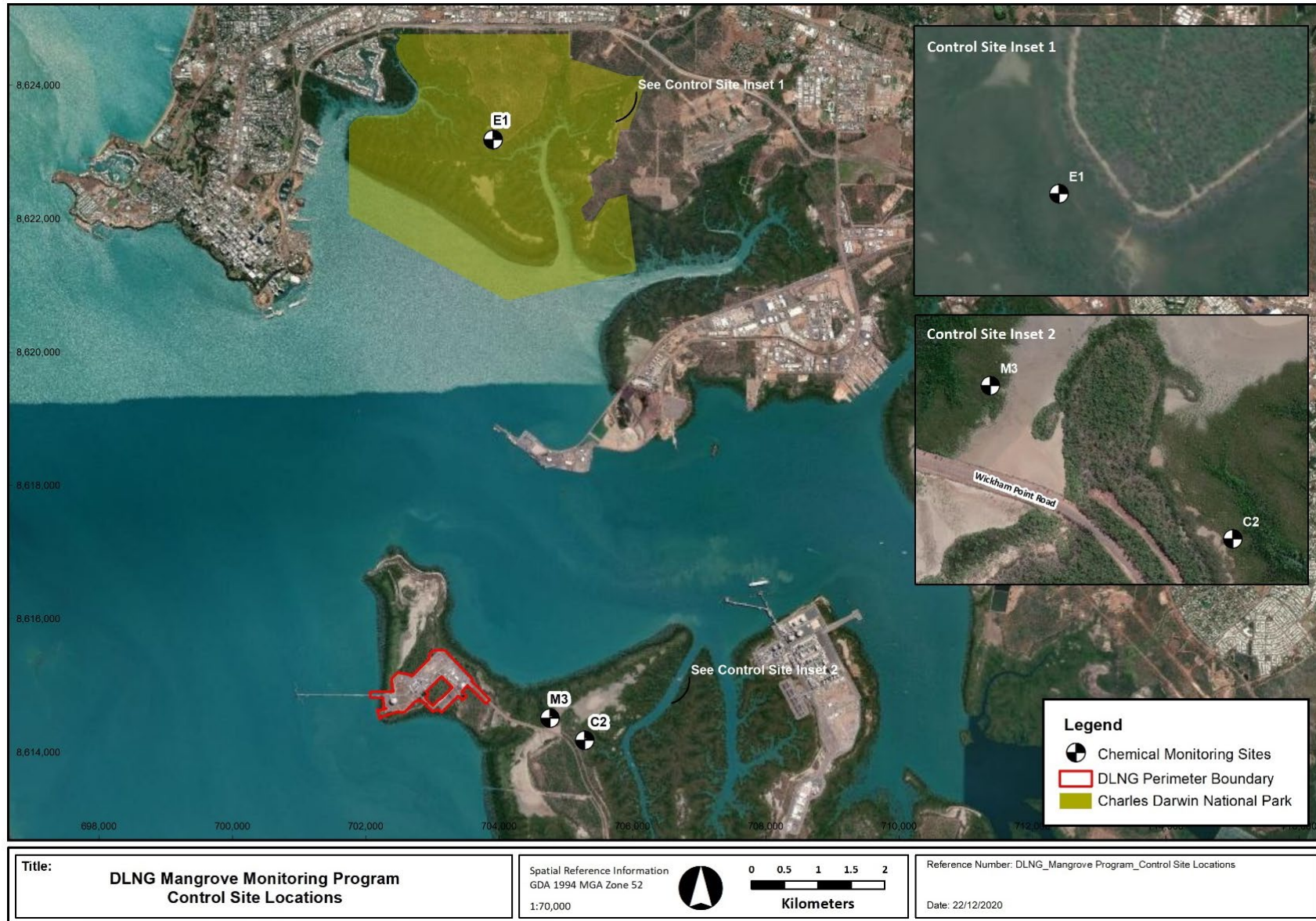


Figure 3-22 Location of control sites for the mangrove monitoring program

Mangrove monitoring sites around the DLNG facility represent several mangrove assemblages, which are distinguished by the degree of tidal inundation experienced as illustrated in the conceptual model (Metcalf, 2007) (Figure 3-23). DLNG monitoring sites are in the hinterland margin, tidal flat and tidal creek assemblages. Most sampling locations (11 of 23) are located in the most landward assemblage (hinterland margin), which typically abuts the DLNG facility boundary. The hinterland margin assemblage is dominated by mid-high *Ceriops australis* and *Lumnitzera racemosa* and in some areas this assemblage may be only 10 m in width. Three of the 23 surveillance sites occur within *Ceriops* forests of the tidal flat assemblage, which occurs slightly lower in the intertidal zone and are dominated by low *Ceriops australis*. Nine sites occur within forests dominated by *Rhizophora stylosa* (the tidal creek or *Rhizophora* zone) which typically occur further to seaward but are also associated with minor tidal channels draining the tidal flat.

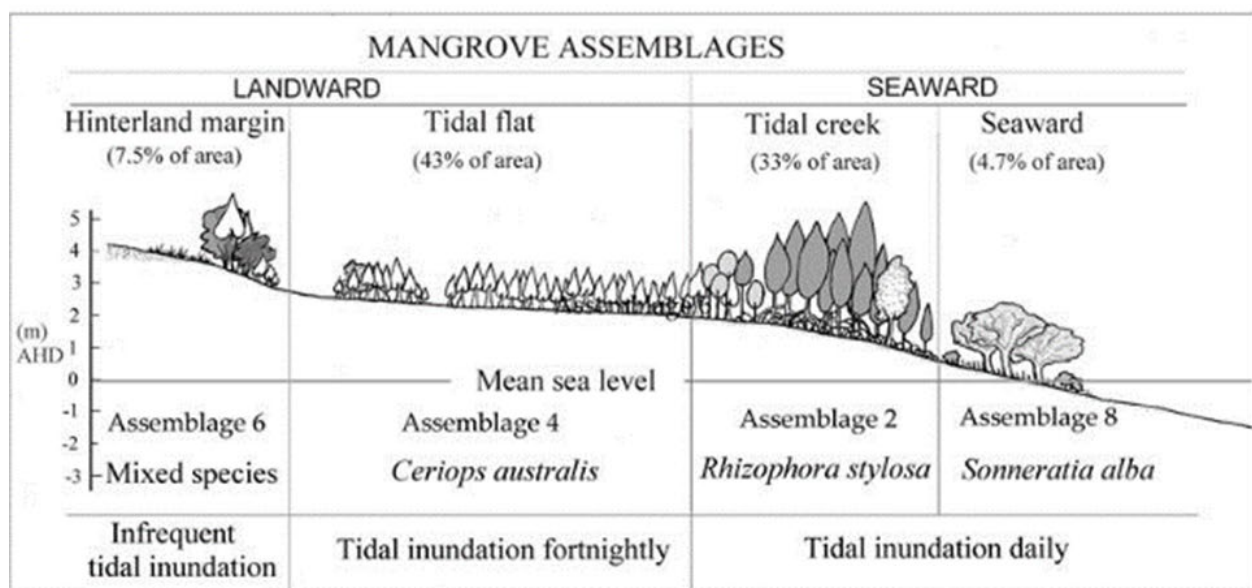


Figure 3-23 Conceptual model of the four main mangrove assemblages found within Darwin Harbour

3.2.3 Monitoring Results

A summary of the mangrove monitoring results is provided in the following sections with a dataset (2003-2021) provided in Attachment B.

Canopy Density

Canopy cover, which is determined by leaf growth and senescence, is sensitive to a wide range of environmental factors. Hence the density of the tree canopy is a useful gauge of forest condition and is typically a key indicator of mangrove health. During monitoring surveys conducted between 2003 and 2017 the canopy cover was measured using a standard densiometer. In 2017 and 2018, the Stickler's modified 17-point densiometer was trialled and is now the preferred and sole method since 2019.

From the 2021 monitoring event long-term changes in canopy cover (%) now incorporate the initial 2003-2004 baseline survey as well as the subsequent 2015 and 2017 baseline surveys. In contrast, all previous reports only examined long-term change between the initial 2003-2004 baseline survey and the most recent monitoring programme, omitting the additional sites SS15A

& SS16A established in 2015, and site SS06 which has only recently been included in canopy cover monitoring in 2017.

Changes in canopy cover data for each monitoring site is presented in Table 3-9. Key findings include:

- Survey results for 2021 indicated that mangroves remain in good condition, with canopy cover characteristic of healthy mangrove assemblages. Examination of long-term trends in canopy data demonstrate that mangrove health has remained stable or slightly improved during the 17 years since program commencement.
- Short and long-term assessment of percentage change in canopy cover indicated that change was well below trigger levels.
- Declines in canopy cover at sites SS03, SS10, SS11 and SS23 are considered to be most likely due to natural declines in mangrove health associated with localised forest senescence due to storm or lightning strike (SS03) and severe weather events (SS23).
- Notable increases in canopy cover since baseline at in upper Tidal flat and Hinterland margin habitats may be associated with increased inflows of freshwater near Sediment Ponds 2 and 3 respectively. These results may also be slightly exaggerated by apparent increases in low forests (2–4m in height) by use of the tripod-mounted 17-point densiometer which captures a greater portion of low-growing tree canopies. Increases in percentage change in canopy cover since baseline are regarded as positive changes and not of concern in terms of anthropogenic impacts to mangroves.

Table 3-9 Differences in mean canopy cover (%) between baseline (2003) and 2015-2021

Assemblage	Site	Standard Densiometer			17 Point Densiometer			
		2015	2016	2017	2018	2019	2020	2021
Hinterland margin	SS01	-1	1	1	6.3	6.5	4	6
	SS02	-2	4	3	9.1	8.2	7.9	7
	SS03	-18	-18	-16	-14.0	-16.2	-12.5	-11
	SS04	-2	-1	-1	2.1	2.5	2.9	3
	SS07	-2	-5	-7	5.9	-1.6	5	2
	SS09	-1	2	5	11.7	11.1	12.1	13
	SS13	1	2	3	7.2	6.3	8.2	9
	SS14	-4	-1	0	10.4	-0.1	0.5	2
	SS19	0	0	-1	28.3	18.5	17.8	11
	SS20	2	-7	-16	15.4	3.3	5.9	2
	SS21	1	0	0	1.2	3.1	2.3	4
Rhizophora forest	SS10	-3	-5	-5	-8.4	-6.8	-4.2	-2
	SS11	-6	-5	-8	-6.3	-6.5	-4.1	-3
	SS12	-2	-6	-3	1.0	2.1	2.9	4
	SS15A ^[2]	N/A	2	-3	13	9	9	7
	SS16A ^[2]	N/A	4	10	13	10	16	15
	SS17	-3	-2	-4	2.2	0.6	1.1	2
	SS18	-6	-4	-10	2.2	-3.6	-1.1	0
	SS22	-3	-3	-6	1.1	0.0	1.8	6

Assemblage	Site	Standard Densiometer			17 Point Densiometer			
		2015	2016	2017	2018	2019	2020	2021
	SS23	-1	-5	-5	-9.7	-14.2	-13.8	-14
<i>Ceriops</i> forest / tidal flat	SS05	8	8	14	40.6	35.7	37.2	33
	SS06 ^[2,3]	N/A	N/A	N/A	2	-8	4	1
	SS08	12	11	5	32.8	28.2	22.1	19

[1] N/A indicates data unavailable for previous years

[2] Surveillance sites SS15A & SS16A and SS06 which were established in 2015 and 2017 respectively: Mean change (%) calculated from the four subplots at each site.

[3] Change from Baseline data for SS06 is now derived from the 2017 Baseline survey 17-point densiometer data. NB: all previous reports displaying change were derived from the Standard densiometer method.

Photographic Monitoring

Photo-monitoring images are used as a reference and to monitor mangrove health by detection of any changes in forest structure, regeneration, species composition and physiognomy over time. Digital photographs were taken from the four corner posts of each of the 23 monitoring plots directed toward the centre of each plot, as well as from the centre outwards towards the four corner posts.

Key findings from the photographic monitoring results include:

- Photo-monitoring supplemented results for defoliation index and percentage canopy change, showing the following:
 - A decline in forest health at SS03 is associated with a sudden decrease in forest cover attributable to localised forest senescence from potential storm damage or lightning strike;
 - A change in community structure and species composition is evident at SS09, where the mid- and lower stratum layers have increased in density, becoming markedly thicker with low *Ceriops australis* trees becoming much more abundant than during baseline monitoring
 - A decline in density at SS23 (due to cyclone damage)
- Photo-monitoring during the 2021 survey demonstrated that no major negative changes in the health of mangroves surrounding the DLNG plant have occurred during the last year. Photo-monitoring results from this survey, and in previous surveys, indicate that in general, no major changes in mangrove forest structure, composition and physiognomy associated with DLNG plant construction and operation have occurred at surveillance sites since monitoring commenced.

Defoliation Index

To supplement canopy cover data and to provide a rapid assessment of forest health within each surveillance site, the health of the canopy, as indicated by the degree and extent of leaf loss (or defoliation) is estimated. To estimate defoliation index, the observer stands within the centre of each of the four 5 m x 5 m quadrants of the monitoring plot to assess tree health within the subplot. A ranked estimate of the cover of foliage (i.e. above and surrounding that central point), is derived from the mean of four visual assessments per plot.

Mean defoliation index data, averaged from four ranked estimates obtained from each site for the period 2016 and 2021 is presented in Table 3-10. Key findings were:

Overall, defoliation index or tree condition recorded at each surveillance site during the 2021 survey showed minimal changes from the previous survey. Overall defoliation index results combined with field observations show that all changes recorded during the 2021 survey were naturally occurring, confirming that the mangrove forests surrounding the DLNG site remain in a stable and healthy condition.

Table 3-10 Annual mean defoliation index data for 2016-2021

Assemblage	Site	2016	2017	2018	2019	2020	2021	Difference between 2020-2021
Hinterland margin	SS01	4.0	4.0	4.25	4.25	4.3	4.0	-0.3
	SS02	4.0	4.0	4.75	4.25	4.3	4.3	0.0
	SS03	3.5	3.5	2.0	2.5	2.5	2.5	0.0
	SS04	4.0	4.0	4.0	5.0	5.0	5.0	0.0
	SS07	4.0	4.0	3.5	4.0	3.5	3.5	0.0
	SS09	4.0	4.0	4.25	4.25	4.3	4.0	-0.3
	SS13	4.0	4.0	4.75	5.0	4.8	5.0	0.3
	SS14	4.0	4.0	4.25	4.0	4.0	3.8	-0.3
	SS19	4.0	4.0	2.75	3.0	3.0	2.8	-0.3
	SS20	4.0	4.0	3.0	3.0	3.0	2.8	-0.2
SS21	4.0	4.0	3.25	4.0	4.0	4.8	0.8	
<i>Rhizophora</i> forest	SS10	4.0	4.0	4.25	4.5	4.3	4.3	-0.3
	SS11	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS12	4.0	4.0	4.75	4.75	4.8	4.8	0.0
	SS15A	4.0	4.0	3.75	4.0	4.0	3.8	-0.2
	SS16A	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS17	4.0	4.0	4.25	4.25	4.3	4.3	0.0
	SS18	4.0	4.0	4.0	4.0	4.3	4.3	0.0
	SS22	4.0	4.0	4.5	4.25	4.0	4.0	0.0
SS23	4.0	4.0	3.25	3.5	3.3	3.3	0.0	
<i>Ceriops</i> forest / tidal flat	SS05	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS06	N/A	N/A	4.0	4.0	4.3	4.3	0.0
	SS08	4.0	4.0	4.25	4.0	4.0	4.0	0.0

Defoliation Index: 0 = Nil canopy; complete defoliation, 1 = <25% canopy, 2 = 25-50% canopy, 3 = 50-75% canopy, 4 = >75% canopy, 5 = complete full canopy.

Species Composition and Tree Density

The species composition and density of mangrove forests within each of the 23 surveillance monitoring sites was documented during program establishment in 2003 (URS, 2004). This data was recorded to provide a baseline for comparison of future change in mangrove health, forest structure and composition. Mangrove trees were defined in accordance with Brocklehurst and Edmeades (1996) as plants exceeding a height of 2 m and a diameter of 2 cm or more. Monitoring of tree density and species composition was conducted on a once-only data collection basis which may be repeated should any major change in forest health be detected, or at conclusion of the monitoring program.

Relative Ground Levels

Increased sedimentation rates have the potential to stress mangrove trees by burying or uncovering root systems. To understand sedimentation trends the relative mean sediment heights were surveyed from the top of each corner post at the surveillance sites. Net difference was then calculated to compare the sedimentation rate trend since baseline to each annual monitoring event. The last five years (2016 to 2021) net difference since baseline results are presented in Table 3-11 together with the change recorded between 2020 and 2021. For sites SS04, SS07, SS22 and SS23, where new posts were installed in 2018 post cyclone Marcus, a new baseline was set by establishing the difference between the 2017 height data and the newly established height in 2018 and subtracting this from the height data measured in 2019 and 2020.

A positive result, indicating a higher ground level, suggests a potential sediment deposition whilst a negative net difference indicates lower ground level and potentially sediment erosion. Figure 3-24 represents graphically the net difference since baseline to 2021 at all sites.

Key findings include:

- Comparison of the 2020 and 2021 sediment heights imply small net differences (i.e. <1 cm) at most sites.
- In the mangrove surrounding the DLNG plant, only net difference slightly greater than 2cm are observed. This slight net difference indicates a slight sedimentation deposition.
- Results revealed that sediment height net difference is greater in the Rhizophora dominated forests (-4.6 cm ± 6.8 SE), less in the Ceriops dominated forests (0.6 cm ± 4.1 SE) of the tidal flat assemblage and lesser in the hinterland margin (-1.1 cm ± 2.5 SE) There has been no indication of deterioration in the health of the mangroves subjected to sediment deposition rates of this magnitude.
- Comparison of changes since baseline (2003) indicated that sediment height has increased in the Rhizophora forests but has remained relatively stable in the Hinterland margin and Ceriops assemblage.
- Over the last 18 years most sites recorded a slight increase of ground level indicating small levels of accretion. Near to the jetty in the south-west of Wickham Point, sites from SS8 to SS12 show a higher level of accretion (13.3-27.8 cm). This is likely to be a natural sedimentation process due to exposure to tidal deposition.
- The extent of sediment deposition or accretion recorded from 2003 to 2021 monitoring has not been detrimental to mangrove health as indicated by the canopy cover data.

Table 3-11 Net difference in mean relative sediment height (cm) between baseline (2003) and 2016-2021

Assemblages	Site Number	2016	2017	2018	2019	2020	2021	Difference between 2020-2021
Hinterland margin	SS01	1.8	2.3	2.9	2.4	2.5	2.2	-0.3
	SS02	1.2	2.0	2.3	1.5	1.5	4.3	2.9
	SS03	1.7	1.9	1.1	2.1	2.2	1.4	-0.8
	SS04 ^[1]	0.3	0.3	0.1	1.4	1.6	1.1	-0.4
	SS07 ^[1]	-2.5	-3.0	-2.8	-2.8	-2.8	0.0	2.8
	SS09	12.7	12.9	16.8	15.8	15.9	16.0	0.1

	SS13	3.8	4.8	5.3	5.5	5.6	5.8	0.2
	SS14	2.7	2.7	2.5	1.8	2.2	3.4	1.2
	SS19	-0.2	0.6	0.2	0.1	0.1	0.5	0.4
	SS20	1.8	2.3	1.8	2.5	2.6	2.4	-0.2
	SS21	8.4	7.9	6.2	6.5	6.9	7.1	0.2
<i>Rhizopora</i> forest	SS10	11.5	13.6	21.0	24.9	27.5	27.8	0.3
	SS11	10.8	11	8.3	10.5	11.3	16.4	5.2
	SS12	10.6	12.6	13.8	13.9	14.6	15.4	0.8
	SS15A ^[2]	N/A	1.3	2.3	-4.1	-4.3	5.6	9.8
	SS16A ^[2]	N/A	0	1.0	0.4	0.3	3.2	2.9
	SS17	3.2	3.2	4.2	4.2	4.4	5.0	0.6
	SS18	7.1	7.1	9.5	9.1	8.9	9.9	1.0
	SS22 ^[1]	0.3	-0.3	0.5	0.5	0.5	1.6	1.1
	SS23 ^[1]	1.0	-0.5	1.3	-2.1	-1.0	-0.1	0.9
<i>Cerriops</i> forest / tidal flat	SS05	2.8	2.6	2.1	3.1	4.1	3.6	-0.5
	SS06	1.4	1.2	0.8	1.3	0.9	1.7	0.8
	SS08	8.9	10.1	11.1	11.4	11.6	13.3	1.7

Notes:

1 New corner posts were installed in 2018 after damages from cyclone Marcus. A new baseline was establish resulting in significant different data from the previous years.

2 Sites 15A and 16A were established in 2015

3 N/A indicates data unavailable

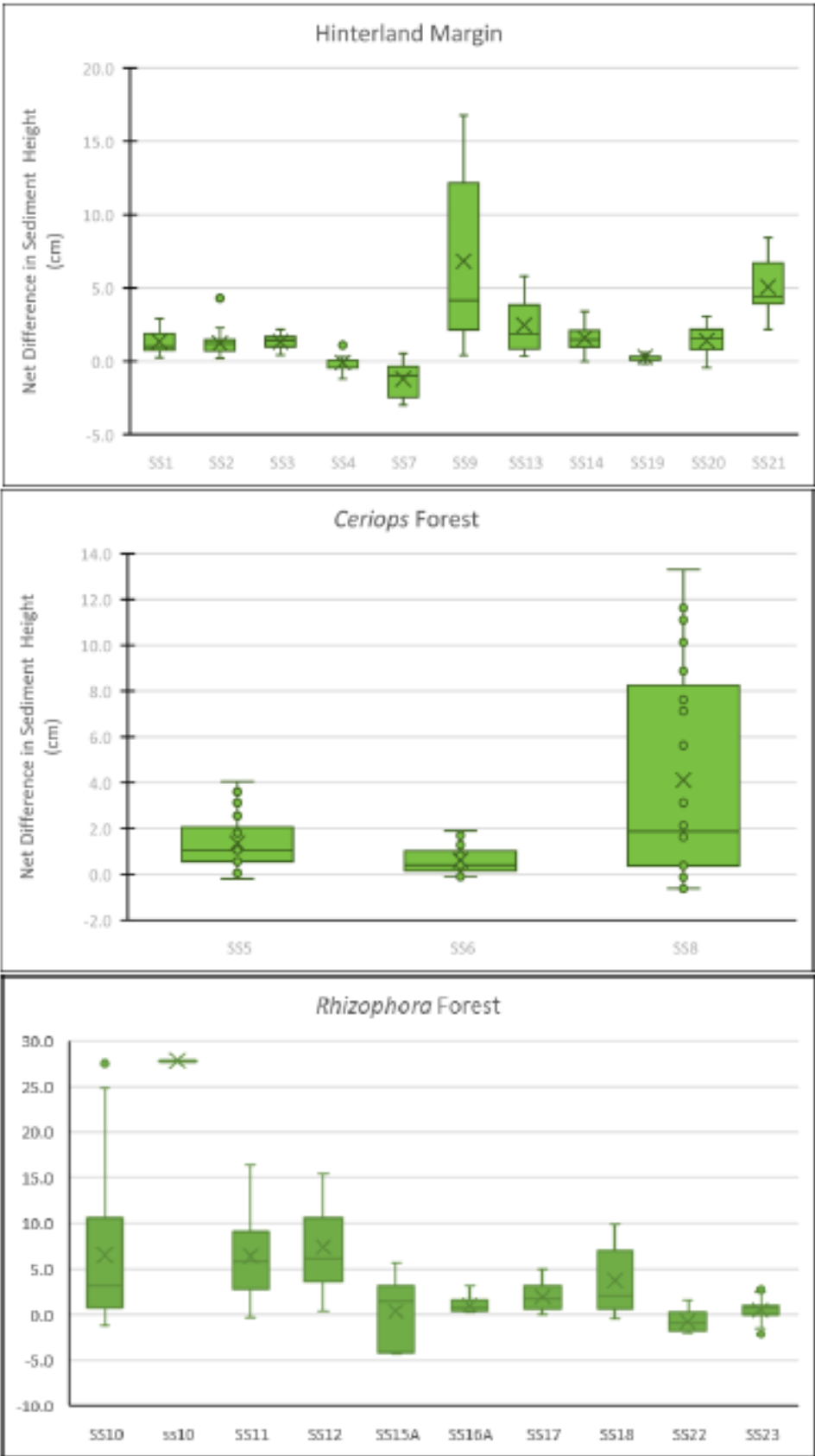


Figure 3-24 Change in sediment height distribution since baseline (2003 to 2021)

Groundwater

Groundwater monitoring is undertaken at sites potentially exposed to modification by freshwater input from the DLNG site, thus representing a potential impact to the mangrove health. A total of 15 shallow (<2m) groundwater monitoring bores were installed in the "hinterland fringe" mangrove zone and are monitoring for depth below ground level to the water table, salinity (TDS) and pH.

Groundwater monitoring results from hinterland monitoring sites from 2016 to 2021 are presented in Table 3-12. Boxplots of all monitoring results from baseline to 2021 are presented in (Figure 3-25). Key findings include:

- Between 2003 and 2006, groundwater monitoring conditions were analysed quarterly. During the wet seasons, salinity concentrations were lower and water levels were elevated closer to the ground surface by comparison with the dry season when salinity levels increase, and water was lower in the bores. This data demonstrates the seasonal variability of rainfall patterns between annual wet and dry seasons.
- Since the end of the construction phase in 2006, mangrove monitoring events have been undertaken only during the dry season and mostly coincided with neap tides. In 2021 mangrove monitoring was undertaken during elevated coefficient tides. Spring tides occurring in the days prior to the survey would have inundated the entire mangrove zone, including the hinterland fringe sites, therefore, only several sites (SS1, SS2 & SS20) were dry and could not be sampled.
- The 2021 salinity results demonstrated consistency with 2020 data and previous monitoring since baseline
- Comparison of salinity for the 12 sites over the last five years indicates there was minimal change.

Table 3-12 Groundwater salinity (TDS ‰) from hinterland mangrove monitoring sites from 2016 to 2021

Site No.	2016	2017	2018	2019	2020	2021	Salinity Range and Mean (‰) ^[2]
SS1	N/A	NC	NC	NC	NC	NC	50 (21-78)
SS2	NC	70	73	NC	65	NC	66 (56-73)
SS3	NC	69	67	68	66	64	66 (58-72)
SS4	NC	66	NC	NC	63	62	65 (61-70)
SS5	60	59	58	55	60	52	59 (48-66)
SS6	70	61	NC	NC	62	56	63 (56-71)
SS7	NC	48	NC	NC	45	42	45 (32-54)
SS9	67	70	72	70	60	68	68 (60-73)
SS13	NC	NC	24	NC	52	50	48 (24-61)
SS14	68	67	69	66	37	58	63 (37-71)
SS19	65	22	NC	NC	54	50	57 (22-67)
SS20	NC	NC	NC	NC	26	NC	56 (26-70)
SS21	NC	40	41	NC	41	22	36 (19-50)

Note: 1. "NC" indicates that sample/data was not collected due to lack of water in the bore
 2. Salinity range and mean data 2003 to 2021.

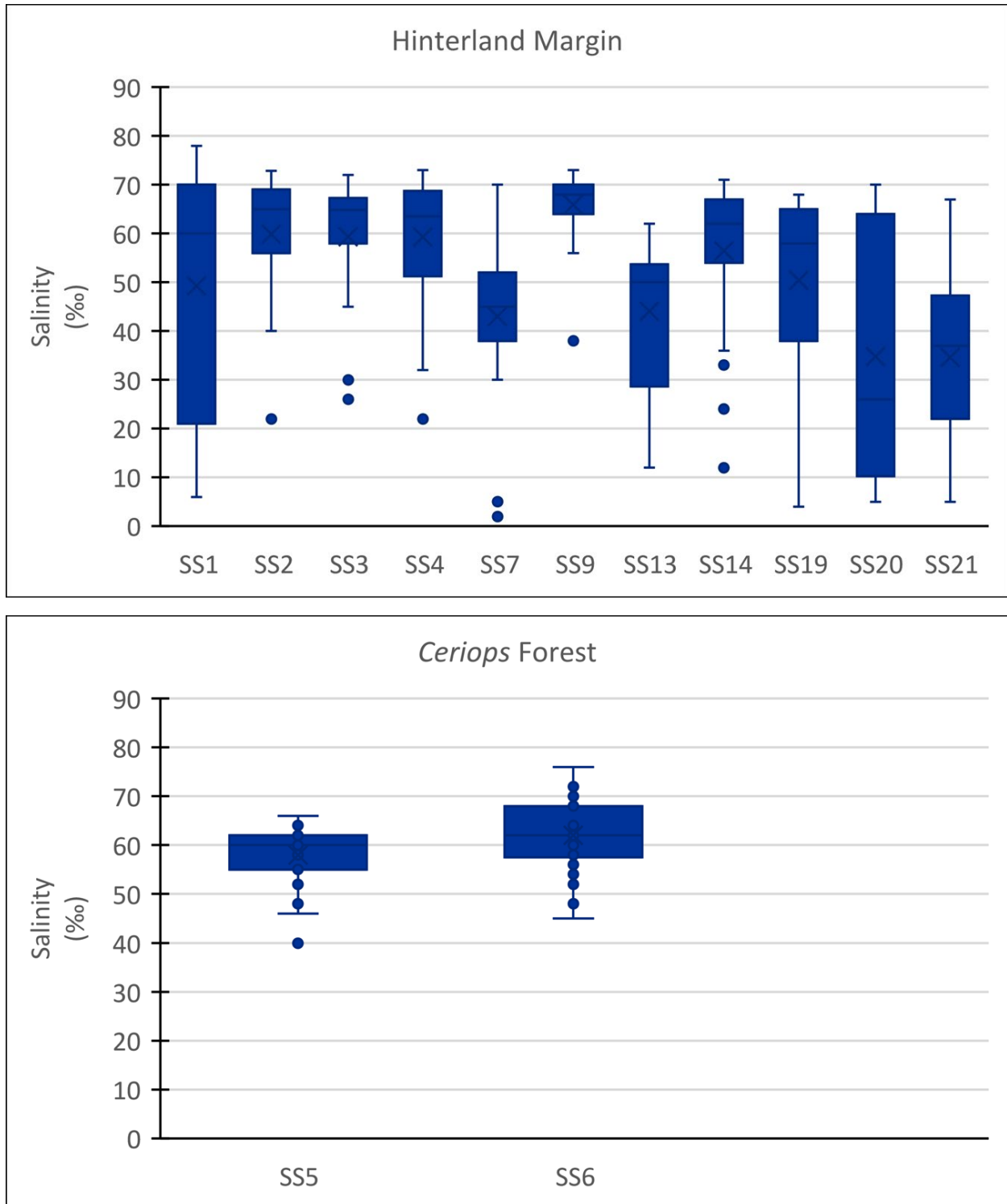


Figure 3-25 Boxplots of groundwater salinity (TDS %) for all monitoring periods (baseline to 2021)

Sediment

Mangrove ecosystems are known to act as physical and biogeochemical barriers to pollutant transport. Sediments in mangrove ecosystems are also reservoirs of heavy metals and hydrocarbons due to their physical and chemical properties. Mangrove sediments are anaerobic and reduced, as well as rich in sulphide and organic matter, properties which have strong influences on metal mobilisation and bioavailability (Silva et al. 1990; Clark et al. 1998).

Sediment sampling was undertaken at 14 sites (refer to Figure 3-21 & Figure 3-22). Sediment samples were analysed for particle size and metals (cadmium, chromium, copper, iron, manganese, nickel, lead and zinc).

Metal concentrations in sediment samples were compared against the ANZG (2018) sediment guideline values. ANZG (2018) provide two sediment quality guideline values, the 'DGV' (Default Guideline Value) and 'GV-high' values. The DGVs indicate the concentrations below which there is a low risk of unacceptable effects occurring, and should be used, with other lines of evidence, to protect aquatic ecosystems. In contrast, the 'upper' guideline values (GV-high) provide an indication of concentrations at which you might expect to observe toxicity-related adverse effects. As such, the GV-high value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems. The ANZG (2018) guidelines therefore provide values which can be used to assess whether contaminant concentrations at the sites are likely to have adverse impacts on the biotic communities at those sites.

The 2021 results were compared with historical data and relevant criteria. Key findings include:

- During the 2021 monitoring six out of the eleven chemical monitoring sites adjacent to the Darwin LNG facility recorded a greater amount of fine material (clay and silt) than coarse material (gravel and sand). There was no clear distinction between sediment grain size between the impact and reference monitoring sites.
- The sediment results of metals indicate sediments are predominantly un-influenced chemically by DLNG operations. Exceedances of default sediment environmental criteria were limited to zinc at one site downstream of Sediment Pond 1 only.
- Concentrations of zinc derived from the acid soluble metals analysis exceeded the ANZG (2018) DGV value (200 mg/kg) at site SP1 (210 mg/kg) (Table 3-13 and Figure 3-26). Previous annual monitoring has recorded elevated levels of total zinc downstream from Sedimentation Pond 1 (sites SP1, SP1-A and SP1-B) since 2006, except for the period 2013, 2014, 2015 and 2017. Sediment analysis has moved from total metal analysis to acid soluble metals analysis only in 2020 as this represents the biologically available fraction.
- The proximity to the pond and decreasing concentrations of zinc with distance indicate that some form of anthropogenic influence in the area immediately downstream of Sedimentation Pond 1. The scale of this influence appears to have been localised and confined to areas within the DLNG Approved Disturbance Boundary. This influence appears to be variable with historical data showing higher zinc concentration at SP1 or SP1-A. However, historical zinc concentration data for Sediment Pond 1 water includes the dissolved fraction only and is insufficient to assess discharge loads from this point source. Dissolved zinc discharge concentrations between 2020 and 2021 range from <5 µg/L to 360 µg/L. Exceedances in weak acid extractable zinc concentrations were observed only in 2020 and 2021 and it is not possible at this point in time to correlate water quality from the pond and downstream sediment trends.
- The ANZG state that the GV-high value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems. They recommend using multiple lines of evidence as part of the weight-of-evidence process to better assess the risk to a sediment ecosystem if a DGV is exceeded or even

where toxicant concentrations in the sediment are trending towards the DGV. Assessments of toxicity may also be refined by assessing the organic carbon content. Using this assessment process, the occurrence of the zinc concentrations is considered low risk based on the following conclusions:

- No consistent increasing trends;
- The extent of elevated concentrations appear small and localised;
- The environmental exposure is limited; and
- The broader mangrove metrics demonstrate system health.

It should be noted that monitoring is ongoing, and that further assessment may be warranted in the future.

- Santos have undertaken multiple investigations to identify the potential operational sources of zinc. The investigations identified that sediments from the greensand filter backwash discharge may be the primary cause. This is because it contains zinc which can be mobilised through physical and chemical processes. This discharge is approved under the Licence to discharge to the stormwater network which generally reports to Sediment Pond 1 (on occasion it is diverted to Sediment Pond 3).
- Corrective actions have and are continuing to be implemented with a focus on removal of sediment from the stormwater drain adjacent the greensand filter backwash discharge. Corrective actions have included:
 - In 2016, the drainage channel discharging into the sedimentation pond 1 was cleaned out to remove built up sediments and associated metals.
 - In 2017, water that usually discharged to the Sedimentation Pond 1 was temporarily re-diverted to Sedimentation Pond 3. This was to enable Sedimentation Pond 1 to be emptied and the sediment removed. In addition to these works, the Sedimentation Pond 1 galvanised iron culvert was replaced by stainless steel to eliminate this as a potential zinc source.
 - In 2018, 2019, 2020 and 2021 the drainage channel discharging into the Sedimentation Pond 1 was cleaned out again to remove built up sediments and associated metals.
 - In 2019-2020 a review of management options was undertaken. The outcome resulted in budget allocation to design and implement a treatment system on the greensands filter backwash discharge to remove the sediment load in 2021. This scope is planned for completion in 2022.
- Historically hydrocarbons in sediments have been detected. However, in more recent years (2012-2020) levels have been below laboratory limits of reporting. During the 2021 mangrove monitoring program all sediment samples reported Total Recoverable Hydrocarbons (TRH) above the laboratory limit of reporting (Table 3-14) and at levels an order of magnitude greater than the historical range. Silica-gel clean-up was run on the samples to confirm levels reflected mineral hydrocarbons and not naturally occurring organic sources. The cause behind these higher readings is unknown however it is highly unlikely that they are a result of DLNG as levels were similar across all sites (i.e. no gradient from a local source point) and all three control sites also recorded elevated TPH concentrations.

Table 3-13 Weak acid Zinc concentrations in mangrove sediments (mg/kg dry weight) 2018-2021

Location	Site	2018	2019	2020	2021
ANZG (2018) DGV (Default Guideline Value)		200			
ANZG (2018) GV-high		410			
Wickham Pt	LG1	2	27	27	12
	LG2	3	18	30	17
	LG3	1	13	11	11
	SP1	170	33	520	210
	SP1-A	170	48	340	98
	SP1-B	73	64	13	51
	SP1-C	3	27	9	16
	SP2	9	30	64	37
	SP2-A	ND	ND	100	140
	SP3	ND	ND	46	70
	SP3-A	ND	ND	13	9
Control Site	M3	11	24	35	18
	E1	15	15	4	6
	C2	4.6	6	6	5

Note: ND means no data collected. Bold data means it has met or exceeded an ISQG trigger Value

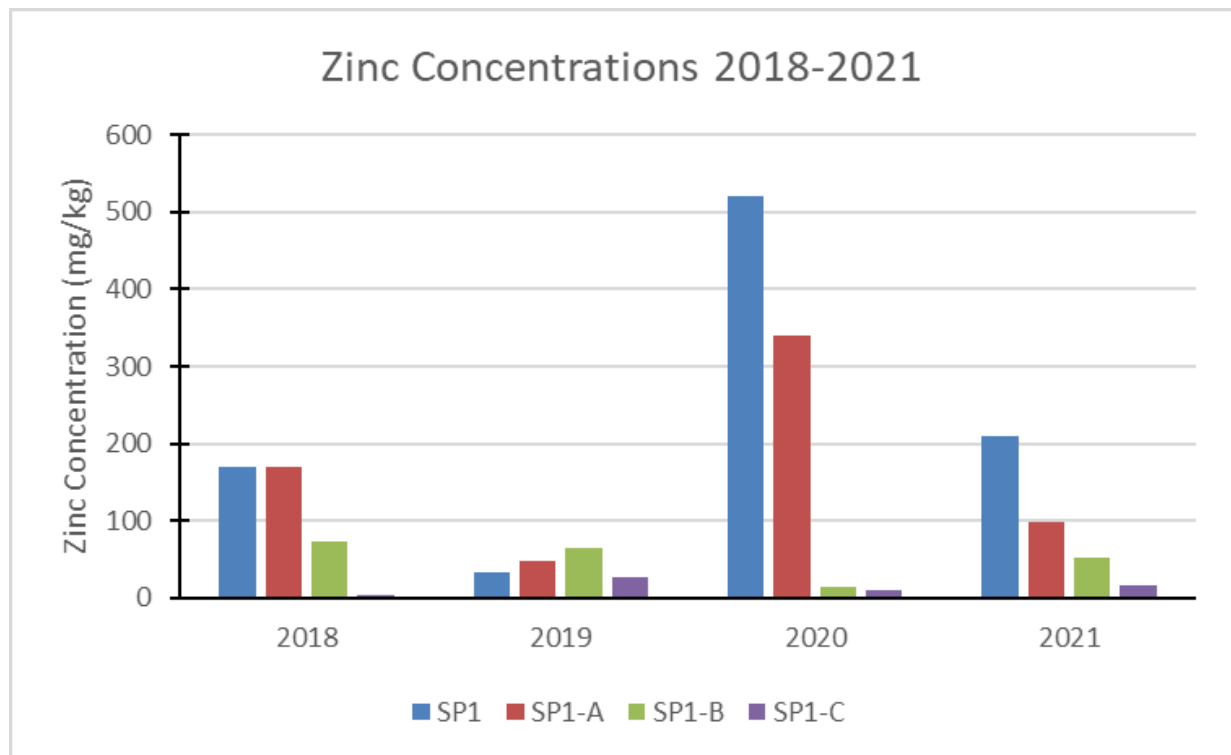


Figure 3-26 Weak acid soluble zinc concentrations at sites located downstream to Sediment Pond 1 SP1 (23 m), SP1-A (60 m), SP1-B (80 m) and SP1-C (120 m) (2018 to 2021)

Table 3-14 Hydrocarbons Concentrations in Sediments at all Sites since 2006 to 2021

TPH in sediments (mg/kg)																		
LOR		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.2
DGV		N/G																
GV-High		N/G																
Location	Site	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Wickham Pt	LG1	<0.1	65	82	28	5.5	28	<0.1	<2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	150	
Wickham Pt	LG2	<0.1	25	52	22	<0.1	7.7	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	42	
Wickham Pt	LG3	<0.1	41	73	7.4	26	28	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	170	
Wickham Pt	SP1	ND	ND	53	1.2	<0.1	26	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	120	
Wickham Pt	SP1-A	ND	85	54	1.9	66	4.6	<0.1	<2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	160	
Wickham Pt	SP1-B	<0.1	31	45	23	4.6	72	<0.1	<2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	160	
Wickham Pt	SP1-C	ND	88	46	21	8.8	27	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	150	
Wickham Pt	SP2	<0.1	63	48	8.1	<0.1	12	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	96	
Wickham Pt	SP2-A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.2	58	
Wickham Pt	SP3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.2	110	
Wickham Pt	SP3-A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.2	100	
Control Site	M3	<0.1	94	100	10	20	21	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	220	
Control Site	E1	<0.1	54	43	<0.1	22	20	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	120	
Control Site	C2	ND	ND	ND	ND	ND	ND	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	150	

N/G" indicates no guidelines; "ND" indicates no data

Bioaccumulation

Biota analysis allows an assessment of bioavailability of specific elements in sediments and water which may be influenced by site activities. *Telescopium telescopium* or mudwhelks are an appropriate organism to assess bioavailability of sediments and pore waters. This is because they are benthic feeders and have limited mobility between areas and hence are likely to ingest surface contaminants representative of an area.

Mudwhelks were collected from a total of twelve sites (refer to Figure 3-21 & Figure 3-22) and tested for moisture, lipids, metals and hydrocarbons and compared against the Food Standards Australia New Zealand (FSANZ 2005) guidelines. The FSANZ (2005) criteria for molluscs provides maximum levels (MLs) for contaminants to not be exceeded in the specified food items. Generally Expected Levels (GELs) have been introduced to maintain the lowest achievable levels of contaminants in food. GELs were derived from analysis of uncontaminated samples of various foods, with the 90th percentile representing the value below which 90% of the values fell. It should be emphasised that the criteria levels relate to potential human health risk and do not imply that the health of the molluscs would be adversely affected at metal concentrations exceeding these levels.

Key findings include:

- Metal concentrations observed in the 2021 mudwhelk samples were below the recommended FSANZ ML and GEL for all metals except copper. Copper exceeded the GEL 90th percentile (30 mg/kg) at LG1 (38 mg/kg) and LG2 (39.52 mg/kg) and was elevated but below the GEL at SP1, SP1-B and all three control sites (M3, E1 and C2).
- The copper concentrations in mudwhelks recorded in 2021 are consistent with historical data and the range of previous studies undertaken in Darwin Harbour with concentrations exceeding the trigger value (GEL 90th percentile) at two sites (LG1, LG2) (Table 3-15). Since monitoring commenced in 2006, copper concentrations exceeding the GEL have been regularly recorded at various sites. This is not considered to be contamination linked to DLNG operations for two reasons: firstly the distribution within the mudwhelks is broad across the monitoring sites including control sites and secondly, pond discharge water quality data indicates a history of generally being near or below detection limits for copper (noting that this data is limited to the dissolved fraction). Biologically available copper is essential for marine invertebrates and plays an important role in respiration and, as a result, detectable concentrations can be present in molluscs from unpolluted waters.
- Previous years have recorded elevated zinc concentrations in mudwhelks and seen some relationship between levels in sediments and mudwhelks. In 2021, there were no elevated zinc levels in mudwhelks recorded and no relationship was observable with sediment concentrations.
- There was no evidence of any hydrocarbon contamination within the mangrove sediments and mudwhelks sampled. TPH concentrations at all the sites were below detection limit of reporting.

Table 3-15 Metal concentrations in mudwhelks in 2021

Location	Site	Metal Concentrations (mg/kg wet weight)							
		Cd	Cr	Cu	Fe	Mn	Pb	Ni	Zn
FSANZ Maximum		2	N/G	N/G	N/G	N/G	N/G	N/G	N/G
GEL 90 th Percentile		N/G	N/G	30	N/G	N/G	N/G	N/G	290
Wickham Pt	LG1	0.06	0.63	37.98	54.86	35.87	0.63	1.27	25.32
	LG2	<0.1	0.49	39.52	61.75	3.46	0.49	0.49	16.80
	LG3	<0.1	0.51	13.26	51.00	8.42	<1	0.51	12.75
	SP1	<0.1	0.24	26.84	51.24	10.25	0.49	0.24	16.59
	SP1-A	0.08	0.41	17.14	75.48	14.28	0.61	0.61	24.48
	SP1-B	<0.1	0.38	26.88	34.56	24.96	0.38	0.38	16.13
	SP1-C	<0.1	<1	20.05	27.43	5.70	0.42	0.84	12.03
	SP2	<0.1	0.44	14.08	26.40	10.12	<1	0.44	13.86
	SP3-A	<0.1	0.52	11.14	25.90	12.43	<1	0.78	10.88
Control Site	M3	0.11	0.56	18.60	63.24	10.04	0.74	0.37	12.83
	E1	<0.1	0.39	25.09	52.11	2.90	0.39	0.77	15.25
	C2	<0.1	1.32	29.04	76.56	8.71	0.79	0.26	10.56

Note: Exceedances are highlighted in bold. Results of <1 denote where the dry weight concentrations were below the limit of reporting therefore wet weight concentrations could not be calculated.

N/G indicated no guideline

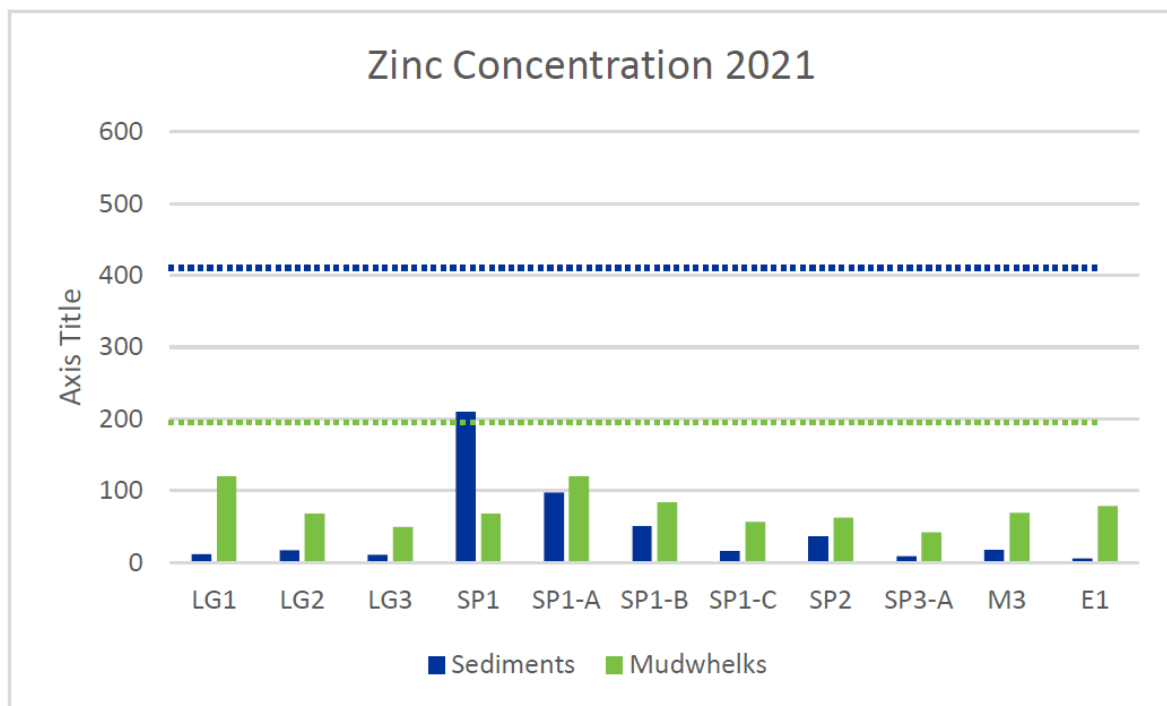


Figure 3-27 Zinc concentrations for biota and sediment in 2021

Data Management and Quality Control

Mangrove monitoring data and chemical analysis samples were collected by qualified professional environmental consultants who followed standard QA/QC procedures. The data validation procedure employed in the assessment of the field and laboratory QA/QC data showed the field and laboratory results to be representative of the conditions at the sample locations at the time of sampling and that the analytical data can be relied upon

Discussion and Interpretation of Results

Canopy cover and defoliation index monitoring indicated that the mangroves surrounding DLNG remain in a healthy and stable condition with no significant deterioration in plant health detected. Where notable declines were observed these were due to natural events (past cyclones and natural senescence) and not associated with DLNG activities. Increases in cover were noted in the hinterland sites. This may be due to possible freshwater inflows or sea level rise. Long term results show no canopy declines greater than 20% since baseline. Forest resilience monitoring showed only minor changes in 2021 with the most pronounced changes at the mid to upper tidal zone with an increase in abundance. Photo monitoring showed that the forest structure and composition has remained stable for the majority of the sites with some gradual change observed and damage from past cyclones still evident. Changes in Sediment heights were consistent at most sites with previous years monitoring and there was no evidence of substantial erosion or sedimentation that has the potential to affect mangrove health.

Metal results in sediments indicate concentrations of Zinc exceed ANZIG (2018) DGV value (200mg/kg) at SP1 (210mg/kg) and have risen in SP2-A. The proximity to the sediment ponds and the decreasing values with distance indicate some form of anthropogenic influence however the influence appears to be localised and confined to the areas within the DLNG Approved Disturbance Boundary. There was evidence of elevated levels of possible hydrocarbon contamination at sediment sites across the DLNG as-well as the control sites, indicating it is highly unlikely linked to activities at the facility.

Copper concentrations in mudwhelks has exceeded the trigger values at two sites at Wickham Point in 2021 and had regularly been reported at various sites since monitoring commenced in 2006. This is not considered to be contamination linked to DLNG due to it being found in a broad distribution of sites including the control sites and secondly the pond discharge is generally near or below the limit of detection for Copper. There was no evidence of any hydrocarbon contamination within mudwhelks sampled.

Overall the results of mangrove monitoring indicate that surface water discharged from the DLNG facility has not had a significant impact on mangrove sediment and biota surrounding the facility since post-commissioning monitoring began in 2006. In addition, the sediment ponds do not generally appear to be affected by algal blooms, odour issues, mortality or any other sources of contamination and spikes in water quality are of short duration. For these reasons, the discharge water quality from the sediment ponds is of low environmental risk or impact.

4.0 Monitoring Discharges to Air

Conditions 44 to 52 of the Licence permits Santos to discharge emissions to air from the following sources:

- Stack emissions from the power generation turbines, compressor turbines, acid gas incinerator and process boiler (Section 4.1); and
- Hydrocarbon flaring and venting (Section 4.2).

In addition, Condition 53 relates to ambient air quality and Conditions 66 to 68 of the Licence outline requirements to monitor air emissions.

The following section is also included in relation to monitoring discharges to air:

- Ambient air quality monitoring program (Section 4.3);

The objectives, methods, analysis, and discussion of results for each of these monitoring programs are provided in the sections below.

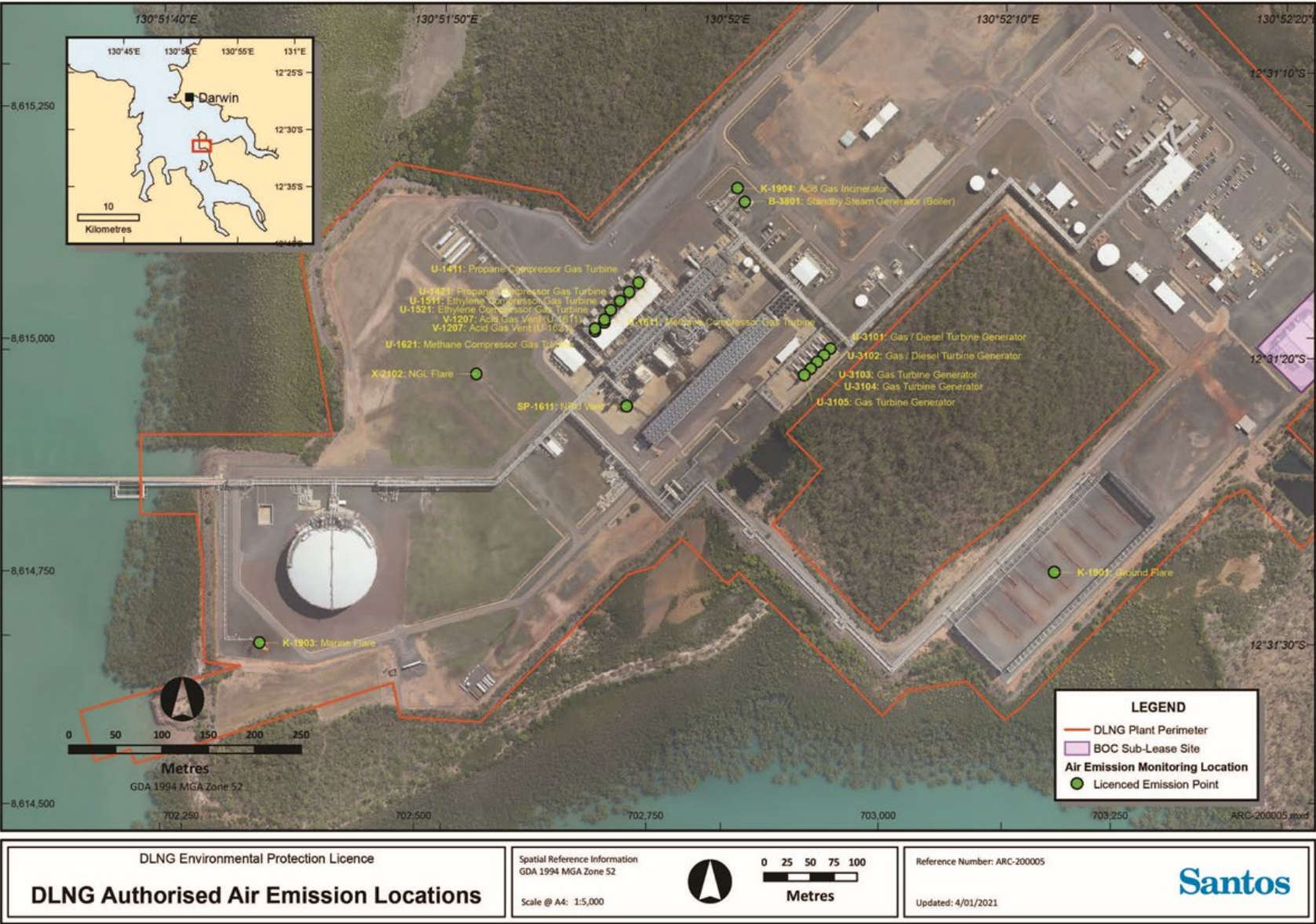


Figure 4-1 Map of emissions to air locations permitted by the Licence

4.1 Stack Emissions Monitoring Program

Most of the emissions from the DLNG facility are from point sources, such as exhaust stacks. These stacks are a source of atmospheric pollutants, which are regulated under the Licence. The Licence specifies the locations of stack emissions that are permitted, the concentrations of pollutants that are allowed, the mass emission rates for pollutants and the frequency at which these must be monitored.

4.1.1 Monitoring Objectives

The objective of the stack emission monitoring program is to quantify the mass emission rates and concentrations of potential atmospheric pollutants at the point of emission. These results are considered in conjunction with other atmospheric monitoring programs, such as the ambient air quality monitoring program (Section 3.3). The monitoring program is also intended to ensure compliance with Conditions 66 to 68 of the Licence.

4.1.2 Monitoring Methods

The Licence requires stack sampling to be completed in accordance with NSW EPA document *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*. Santos has developed a stack emissions monitoring program, which is implemented by a specialist contractor in accordance with the approved methods stipulated by the Licence.

The required locations, parameters and frequency of monitoring is outlined in Appendix B Table 3 of the Licence. Stack emissions monitoring was undertaken in 2019 in accordance with these requirements. The locations are shown in Figure 4-1.

Biannual testing of the power generation turbines, compressor turbines and boiler stack emissions was undertaken in June and November/December 2021. Quarterly testing of AGI and solvent regenerator reflux drum was undertaken in March, June, September and November/December 2021. Stack Testing was undertaken by external consultants and reported in a quarterly basis (Ektimo 2021a,b and c and Ektimo 2022). The results of these reports are summarised in the following sections.

4.1.3 Monitoring Results

A summary of the stack emissions monitoring results, since commencement of the revised Licence emissions conditions in September 2017, is provided in the following sections. The historical dataset is provided in Attachment C.

Power Generation Turbines

Comparison of the maximum emission concentrations and emission rates for each operating unit show:

- Compliant nitrogen oxides (NO_x) mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-2);
- Compliant carbon monoxide (CO) mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-3); and
- Compliant sulphur dioxide (SO₂) mass emissions rates and concentration for 2021 and overall for the 2016-2021 period. All results were below the LOR in 2021 (Figure 4-4).

Variability in NO_x and CO mass emissions rates and concentrations between each unit occurred due to different operation requirements and tuning of the management system. The results were aligned with vendor-specified measurement units for expected NO_x and CO emissions concentrations for the respective units. The low SO₂ concentrations can be attributed to low H₂S concentrations in the feed gas.

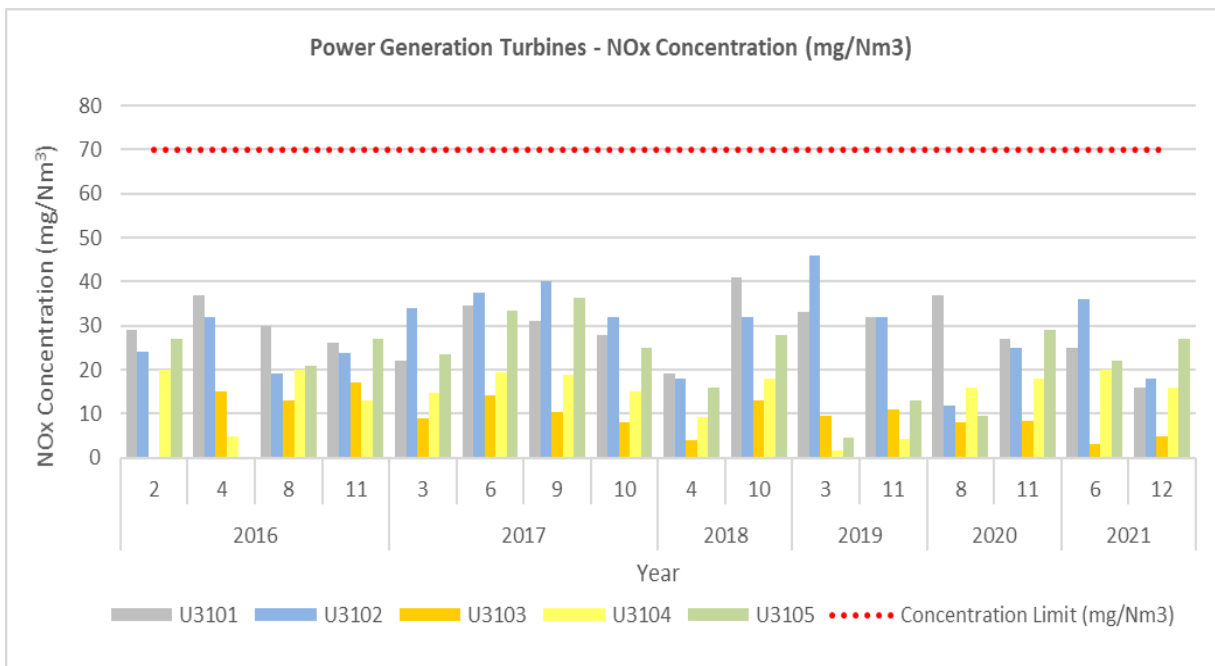
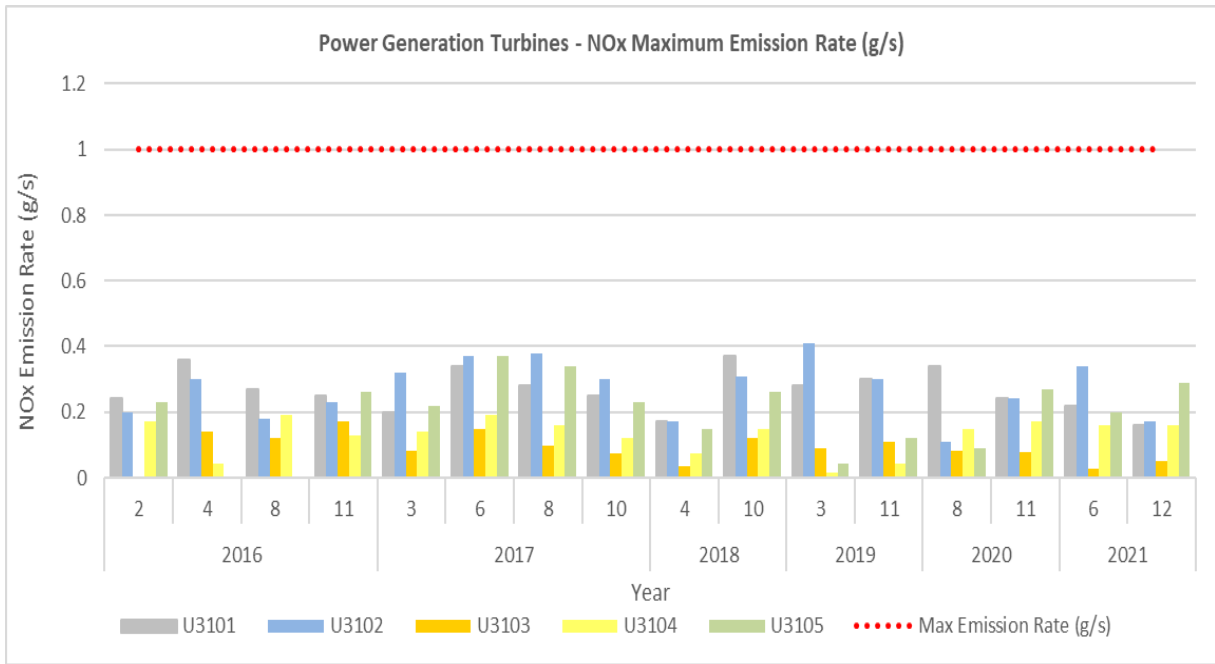


Figure 4-2 Power generation turbines NO_x emissions from 2016-2021

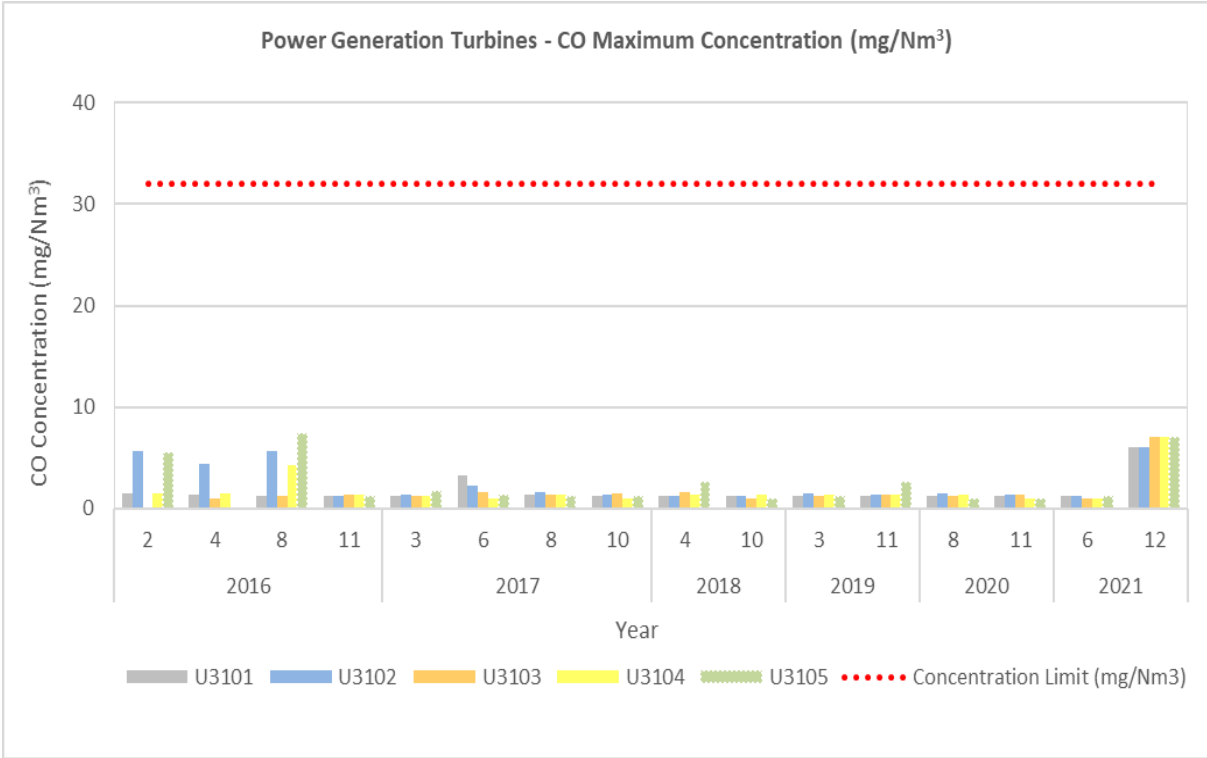
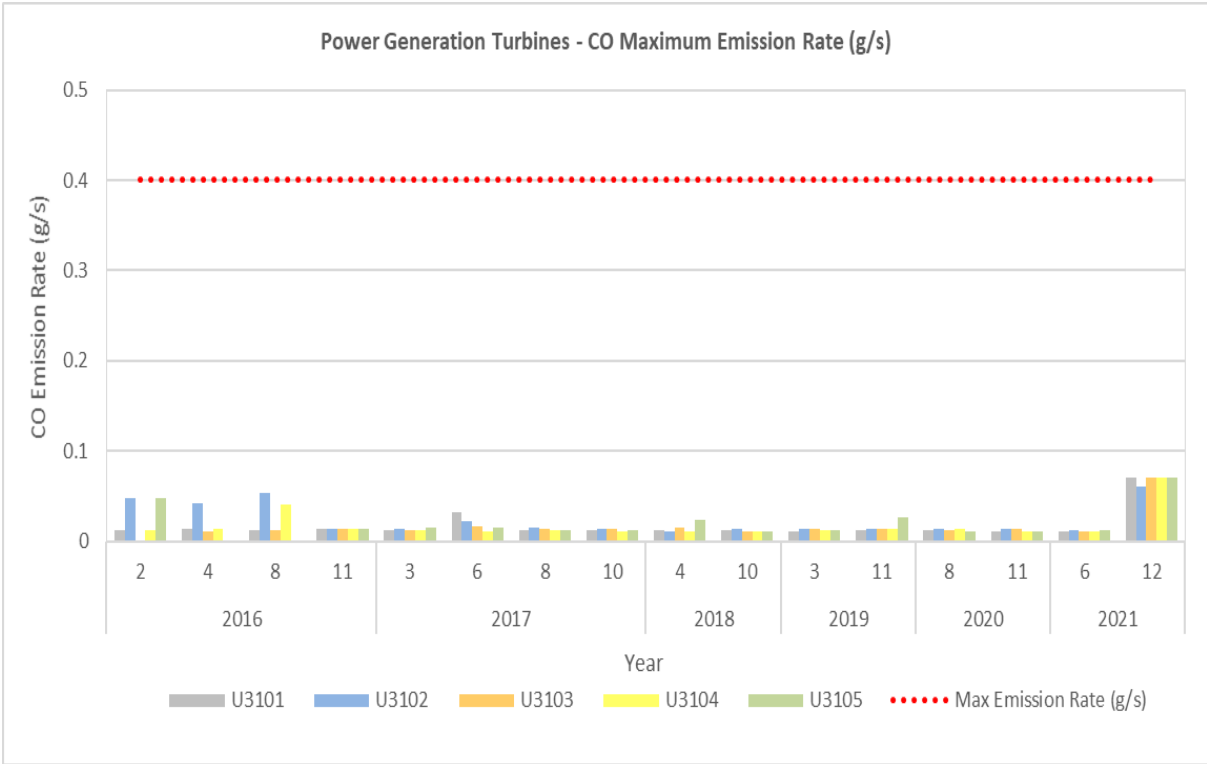


Figure 4-3 Power generation turbines CO emissions from 2016-2021

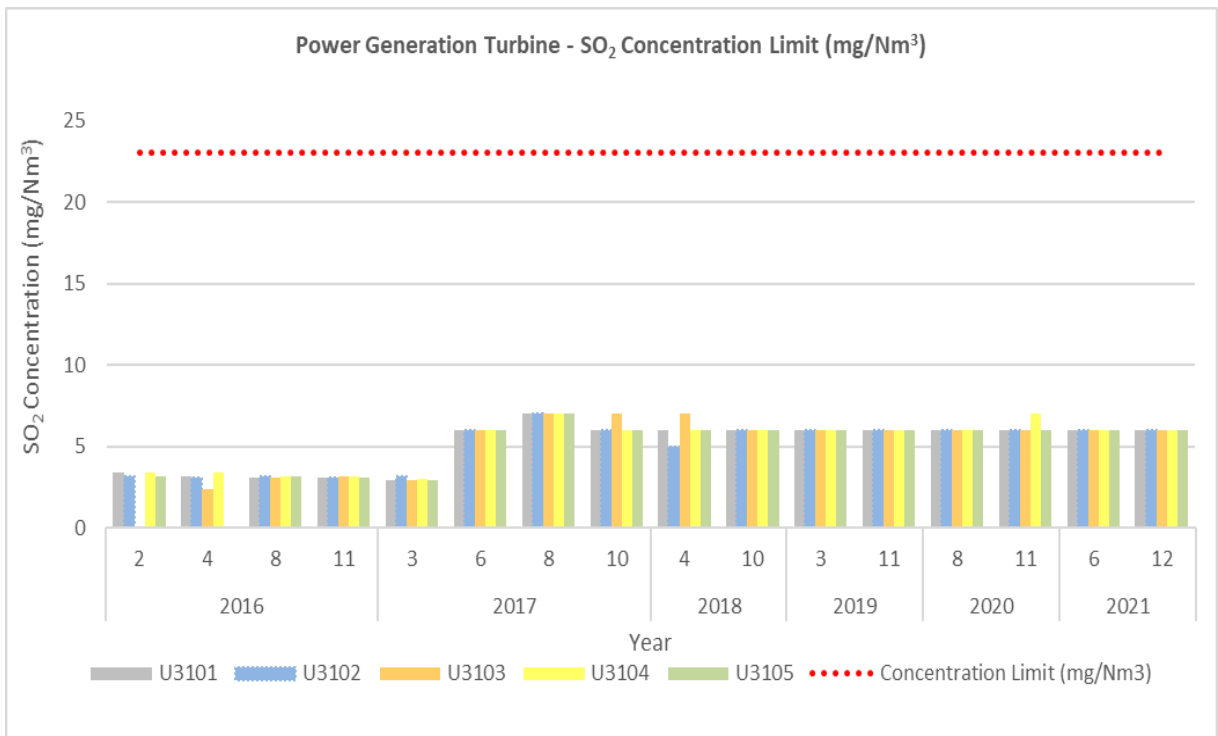
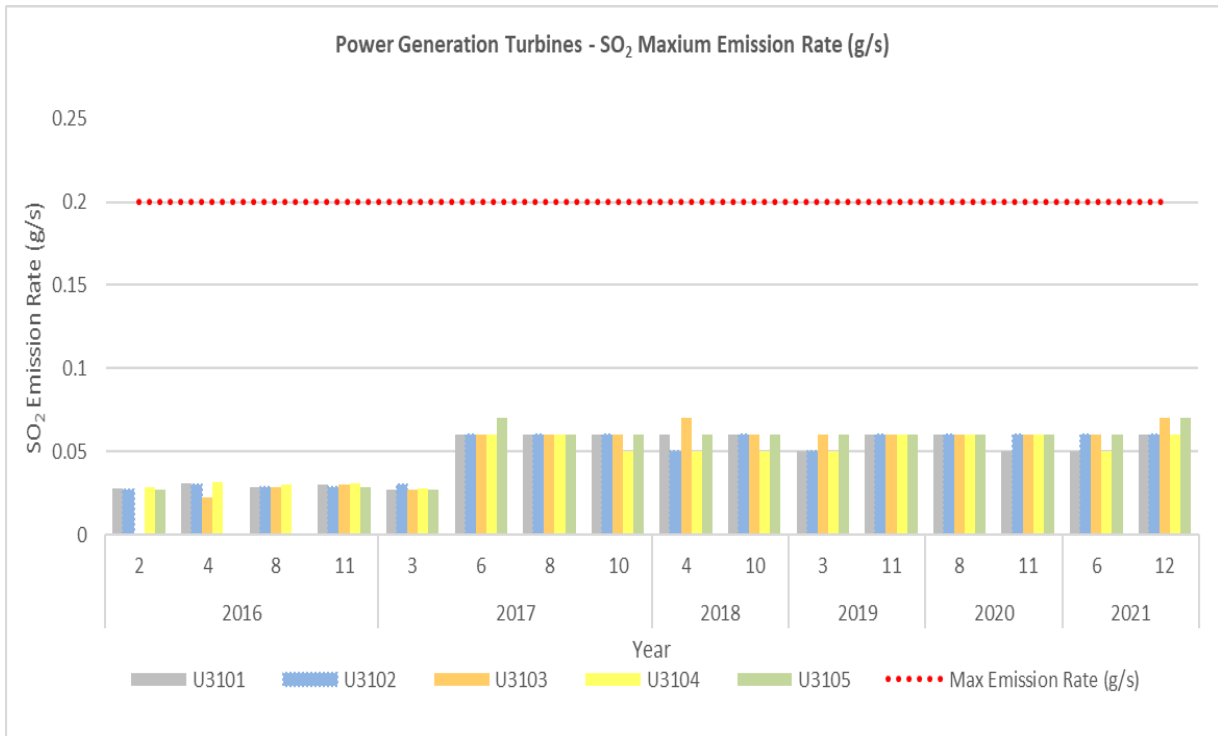


Figure 4-4 Power generation turbines SO₂ emissions from 2015-2021

Compressor Turbines

Comparison of mass emissions rates and concentrations for compressor turbines shows the following observations:

- Compliant NO_x mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-5);
- Compliant CO mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-6); and
- Compliant SO₂ mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-7).

NO_x emissions from compressor turbines are controlled by water injection, to optional set-points of 25, 50 or 68 parts per million (ppm), plus an incremental controller. During the reporting period, NO_x suppression settings on the compressor turbine units were set at 68 ppm and as a result there is efficient scrubbing of NO_x in the gas stream.

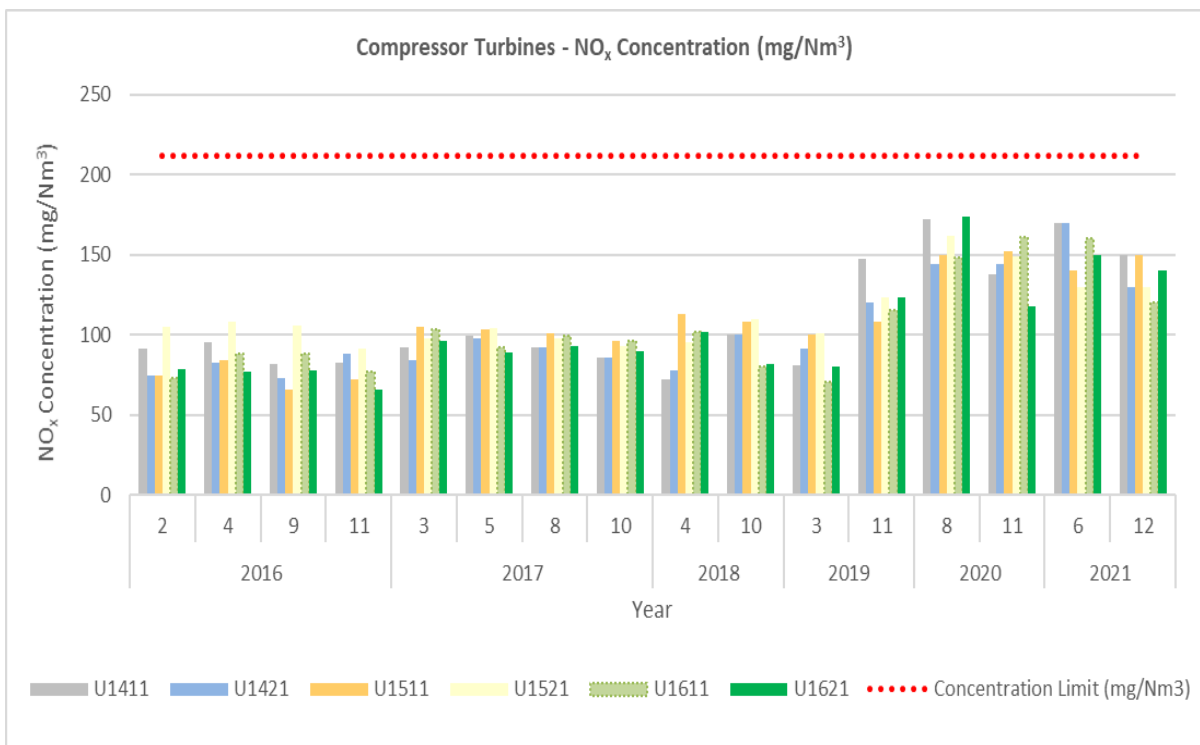
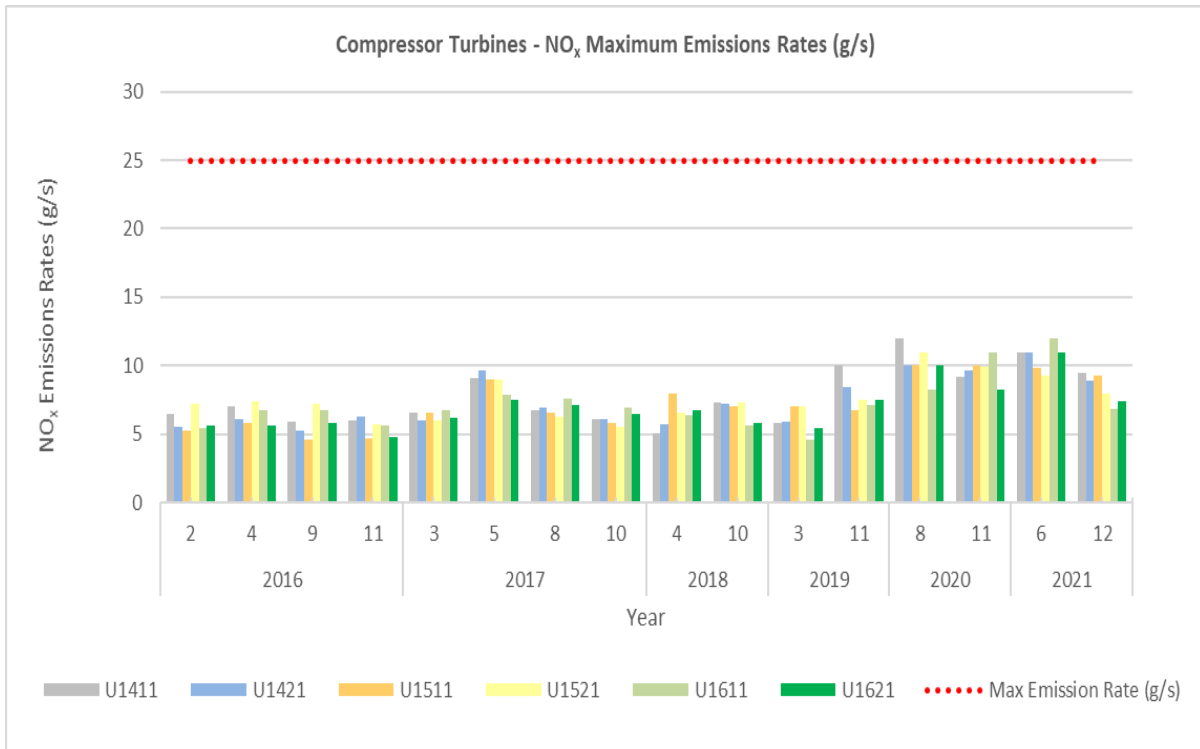


Figure 4-5 Compressor gas turbine NO_x emissions 2016-2021

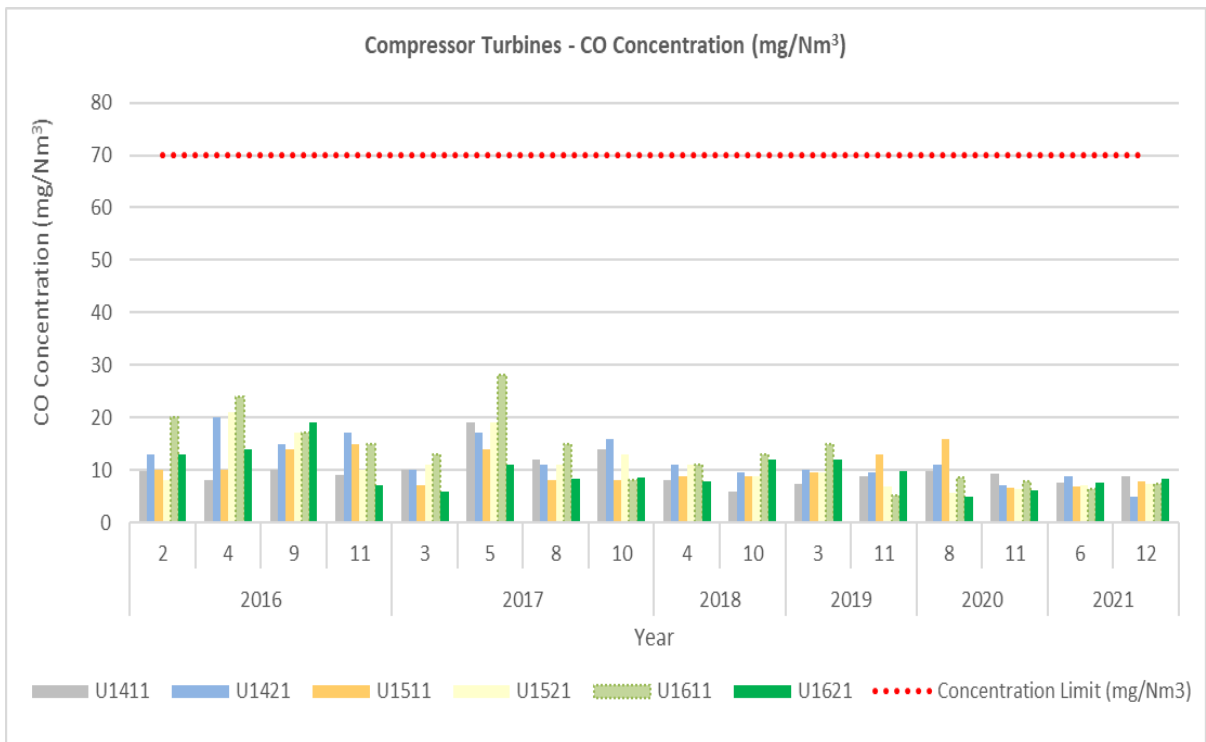
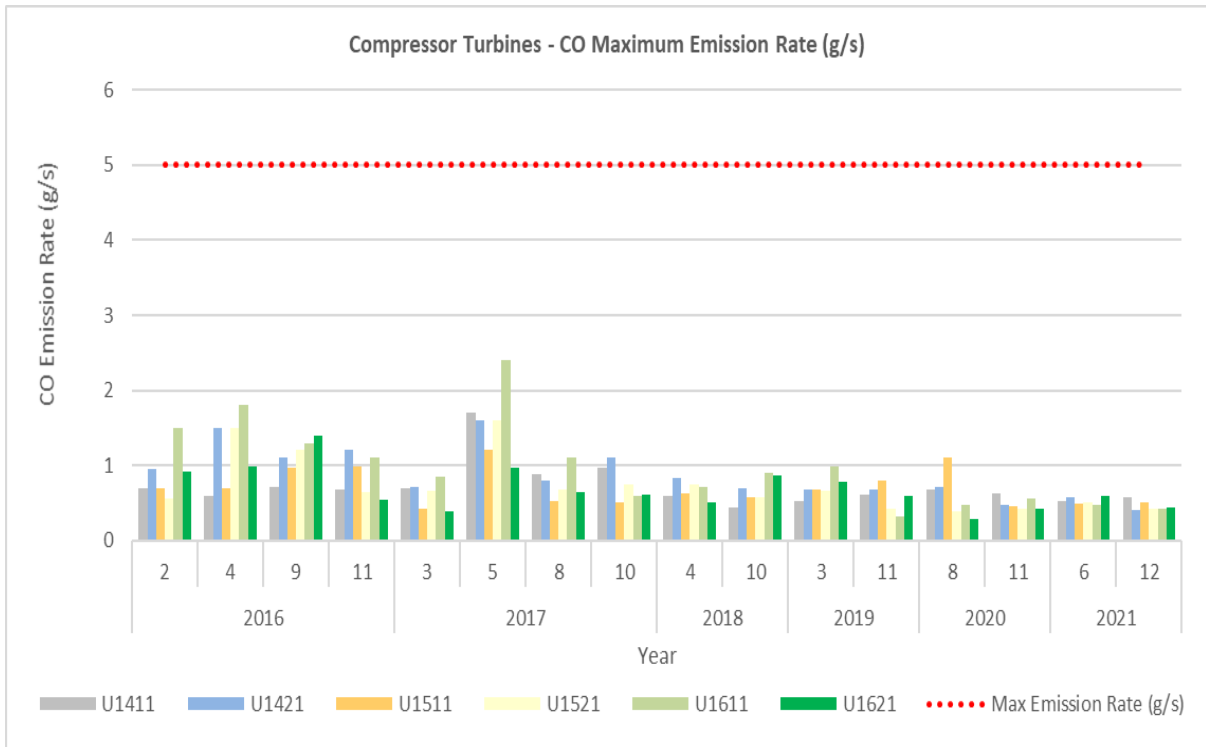


Figure 4-6 Compressor gas turbine CO emissions 2016-2021

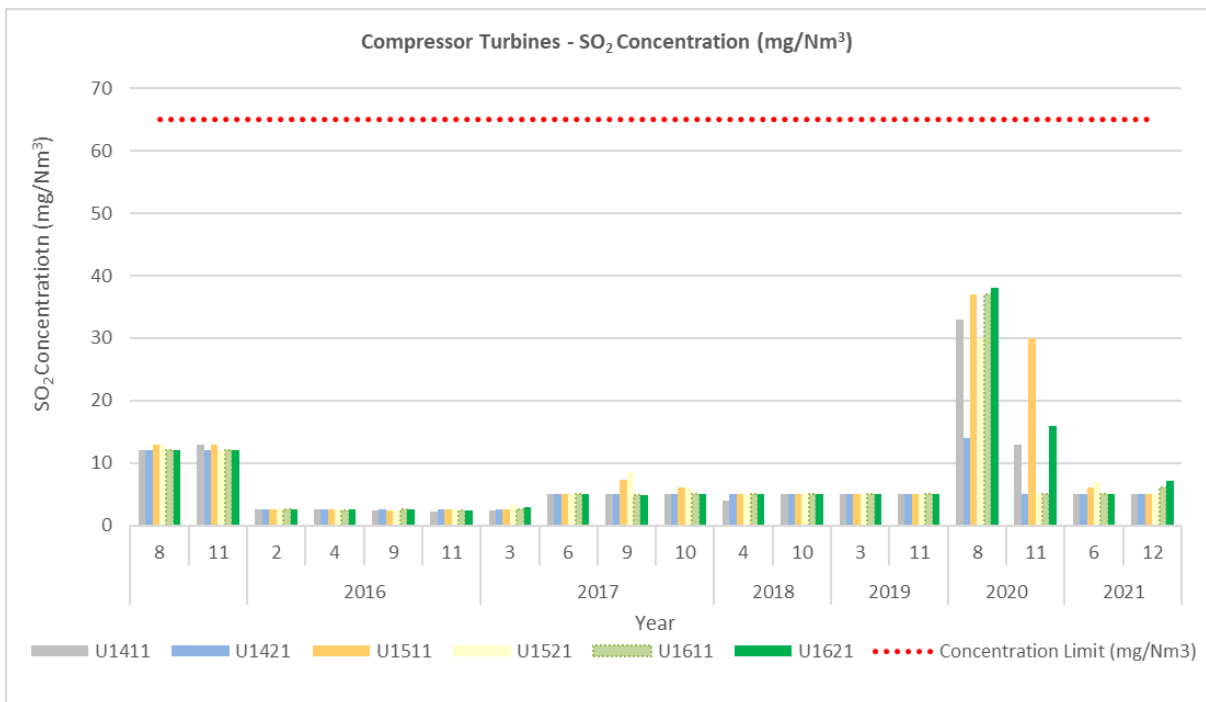
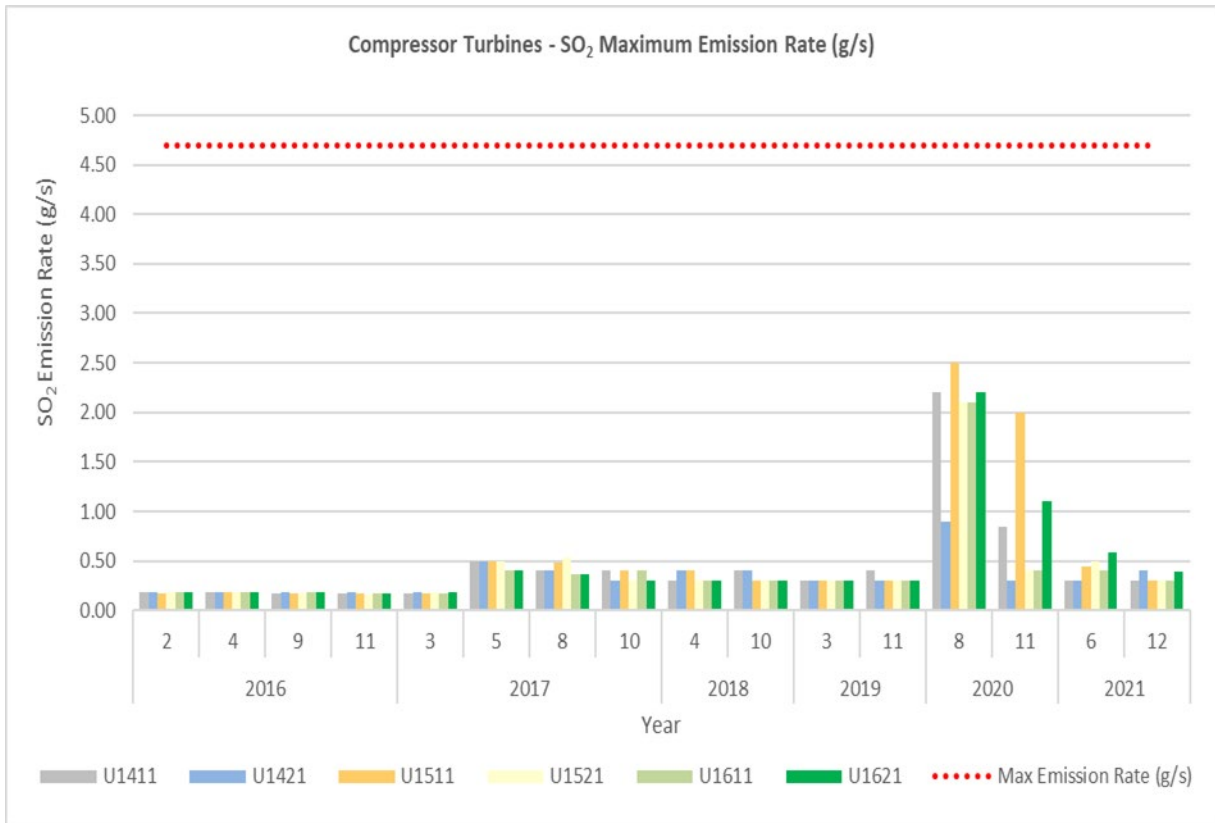


Figure 4-7 Compressor gas turbine SO₂ emissions 2016-2021

Acid Gas Incinerator

The AGI was the primary disposal method for acid gas in 2021 since the hot vent trial was suspended in Q3 2019.

Comparison of mass emissions rates and concentrations for the AGI shows the following observations:

- Compliant NO_x mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-8);
- Compliant CO mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-9);
- Compliant SO₂ mass emissions rates and concentrations for 2021 and for overall for the 2016-2021 period (Figure 4-10); and
- Compliant hydrogen sulphide (H₂S) mass emissions rates and concentrations for 2021 and overall for the 2017-2021 period (Figure 4-11).

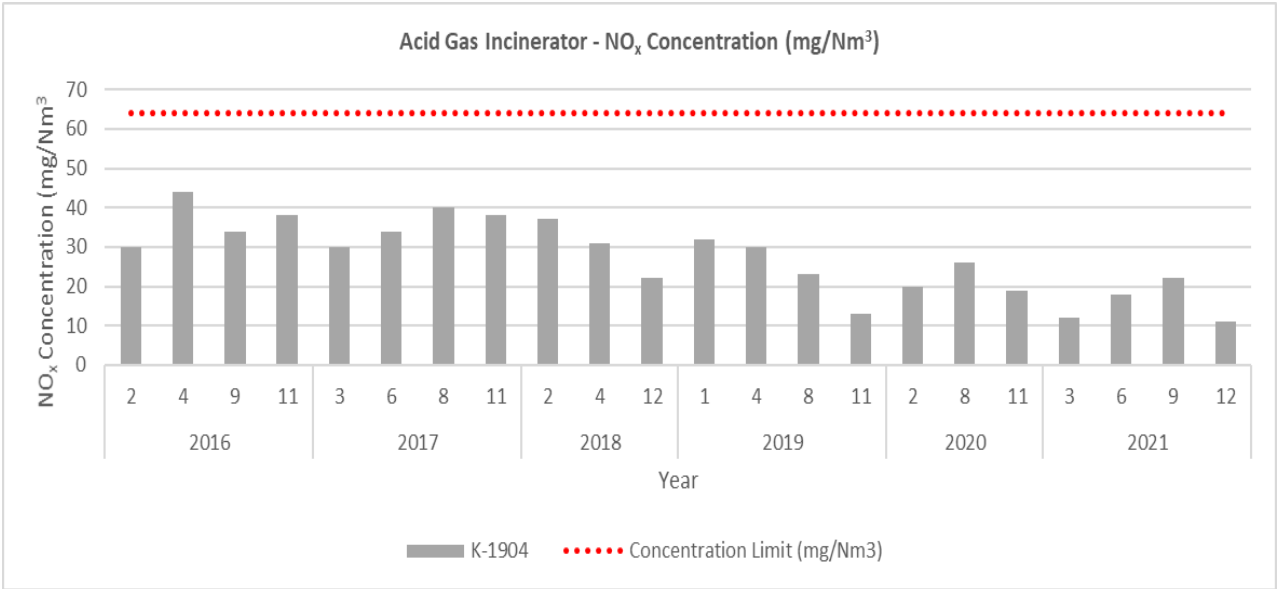
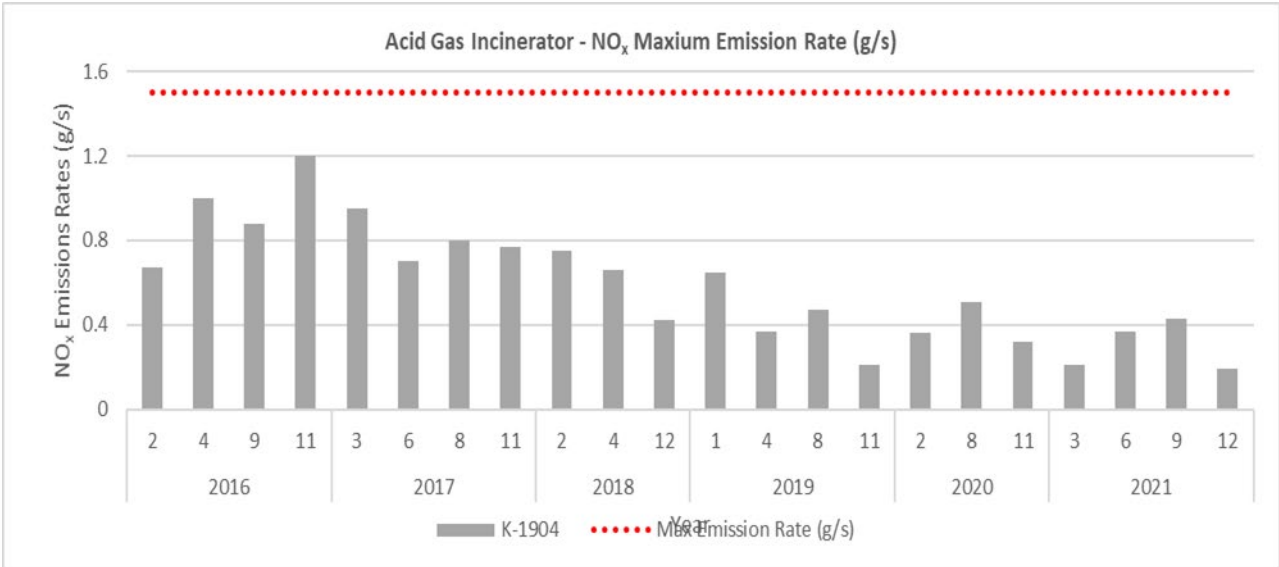


Figure 4-8 AGI NO_x emissions 2016-2021

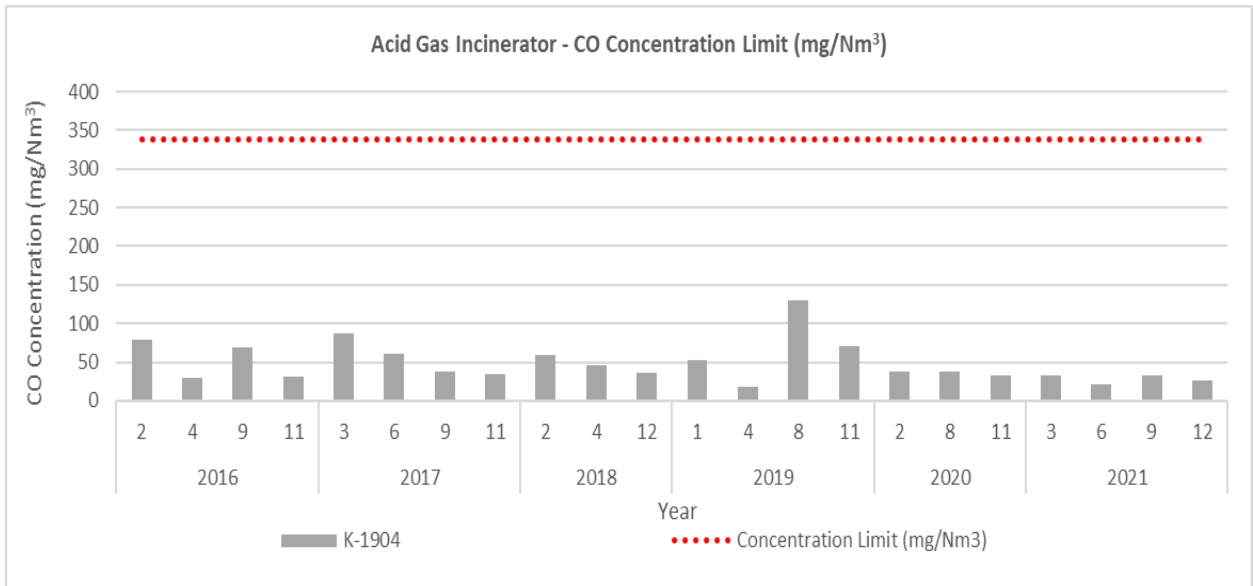
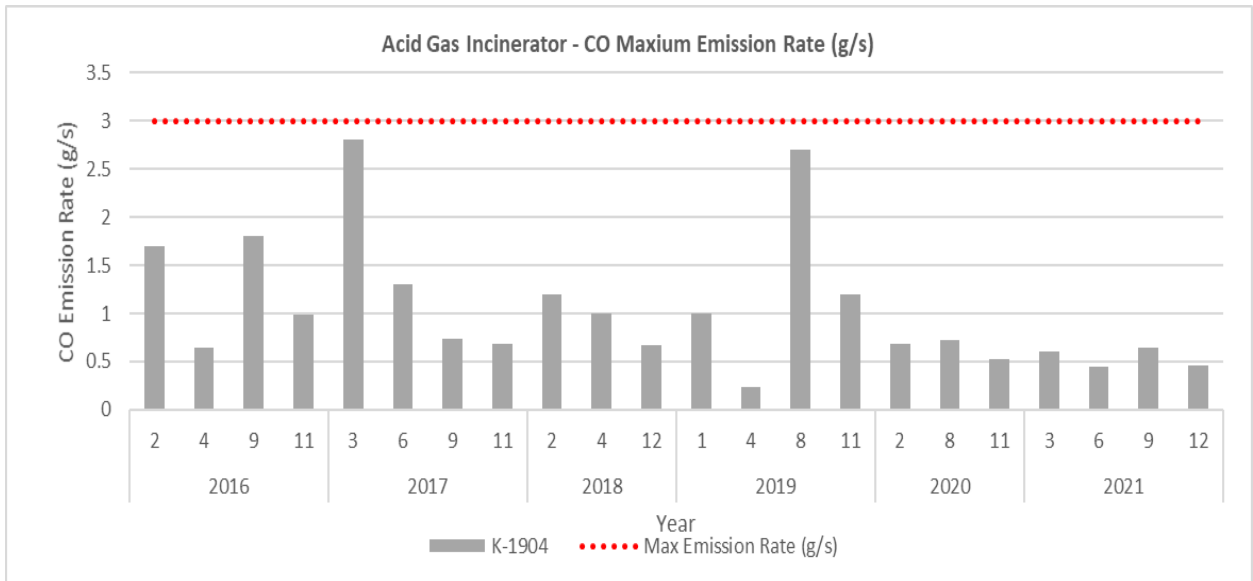


Figure 4-9 AGI CO emissions 2016-2021

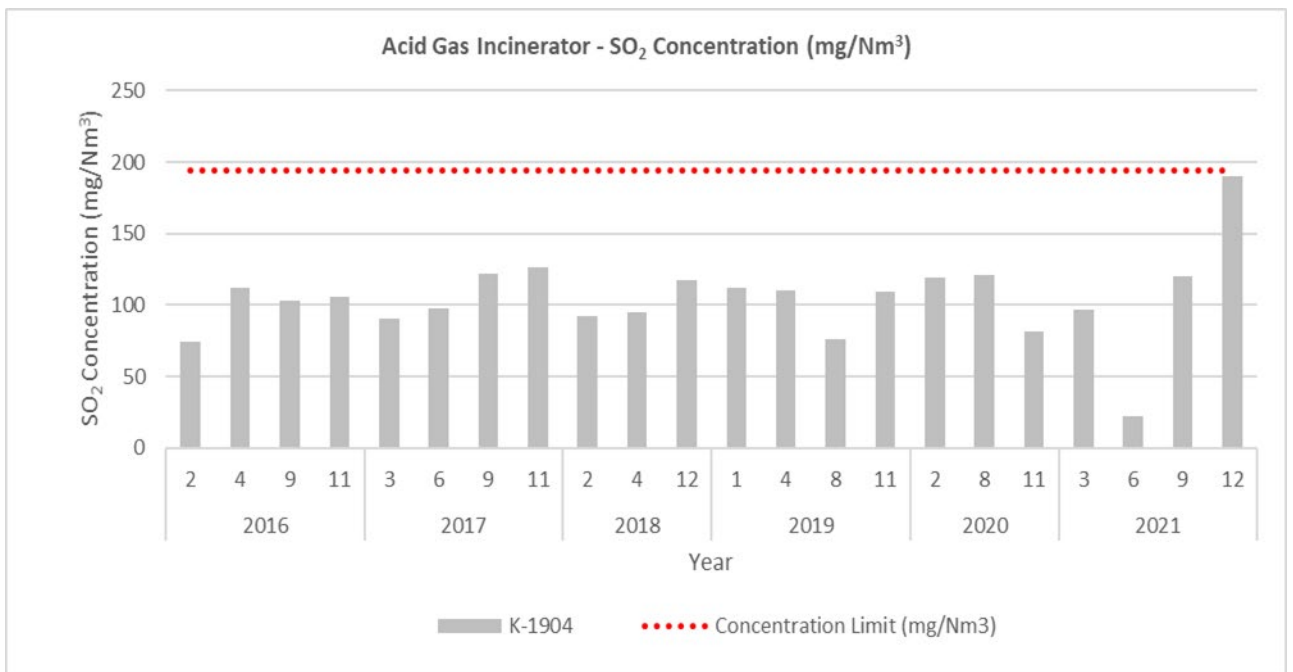
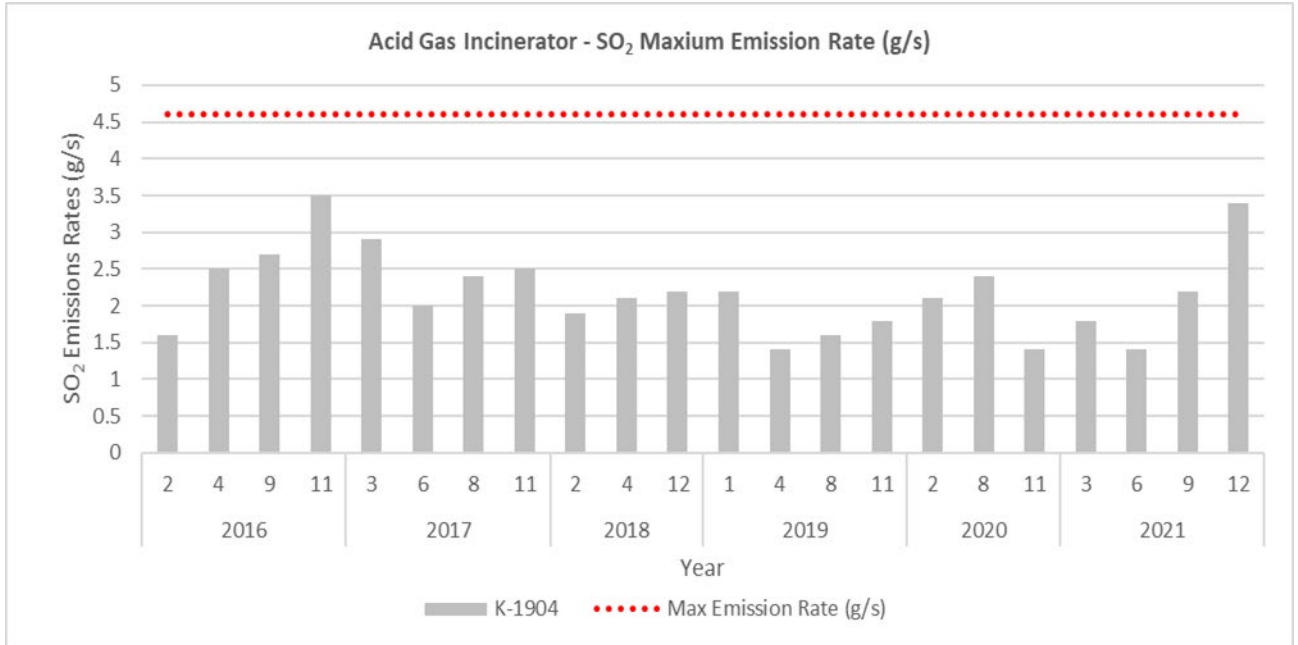


Figure 4-10 AGI SO₂ emissions 2016-2021

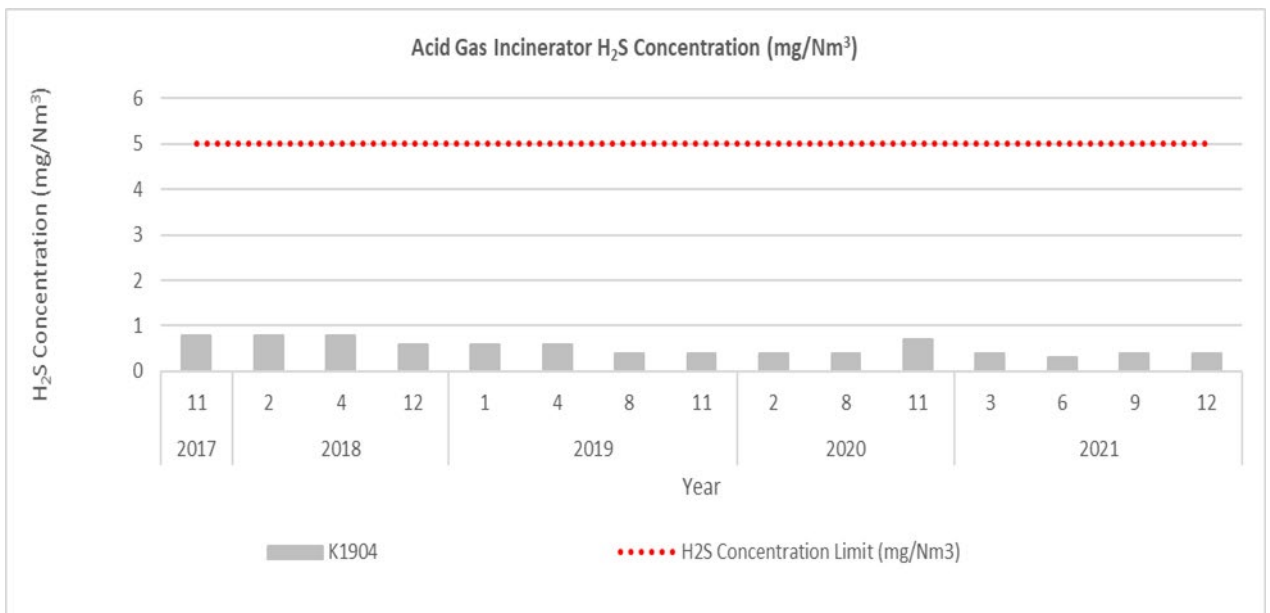
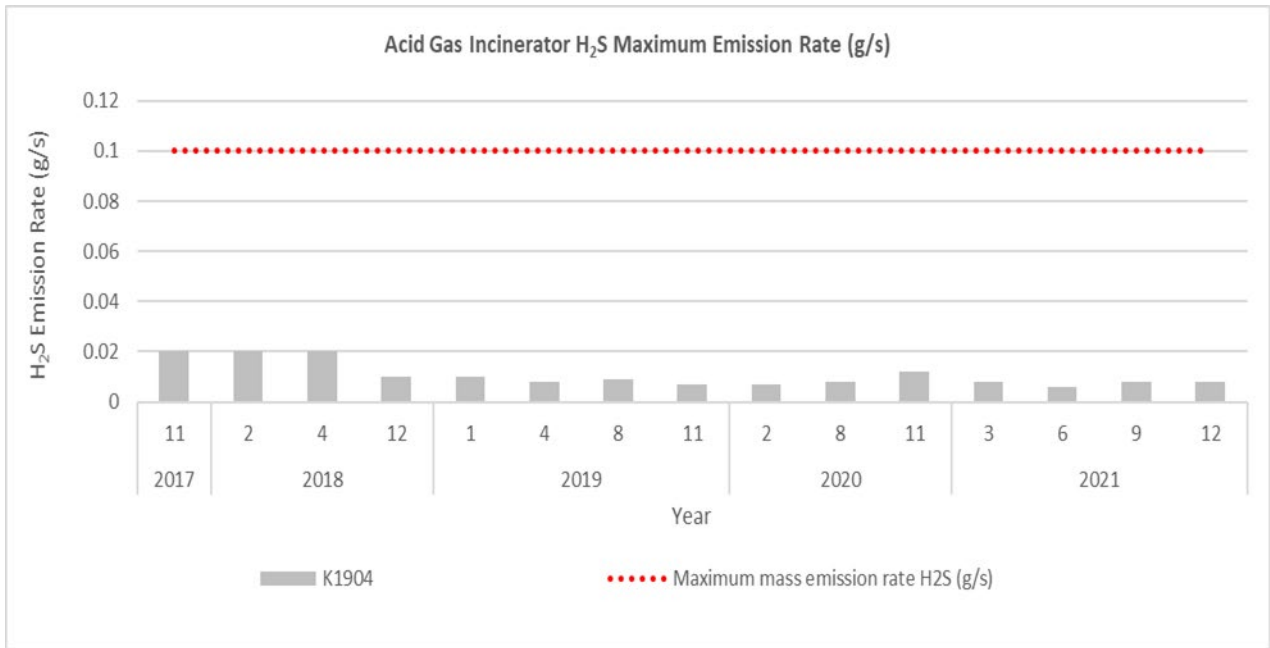


Figure 4-11 AGI H₂S emissions Q4 2017-2021

Process Boiler

Comparison of mass emissions rates and concentrations for process boiler shows the following observations:

- Compliant NO_x mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-12).
- Compliant CO mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period with the exception of an isolated spike recorded in November 2019 (Figure 4-13).
- Compliant SO₂ mass emissions rates and concentrations for 2021 and overall for the 2016-2021 period (Figure 4-14).

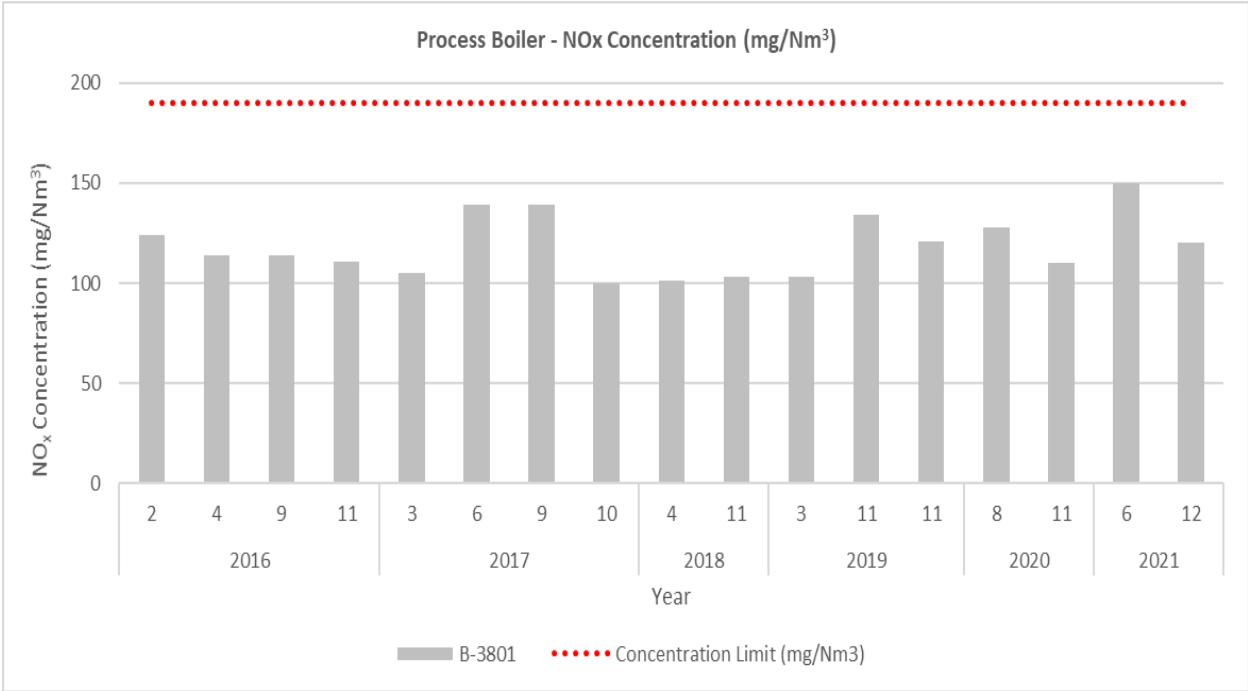
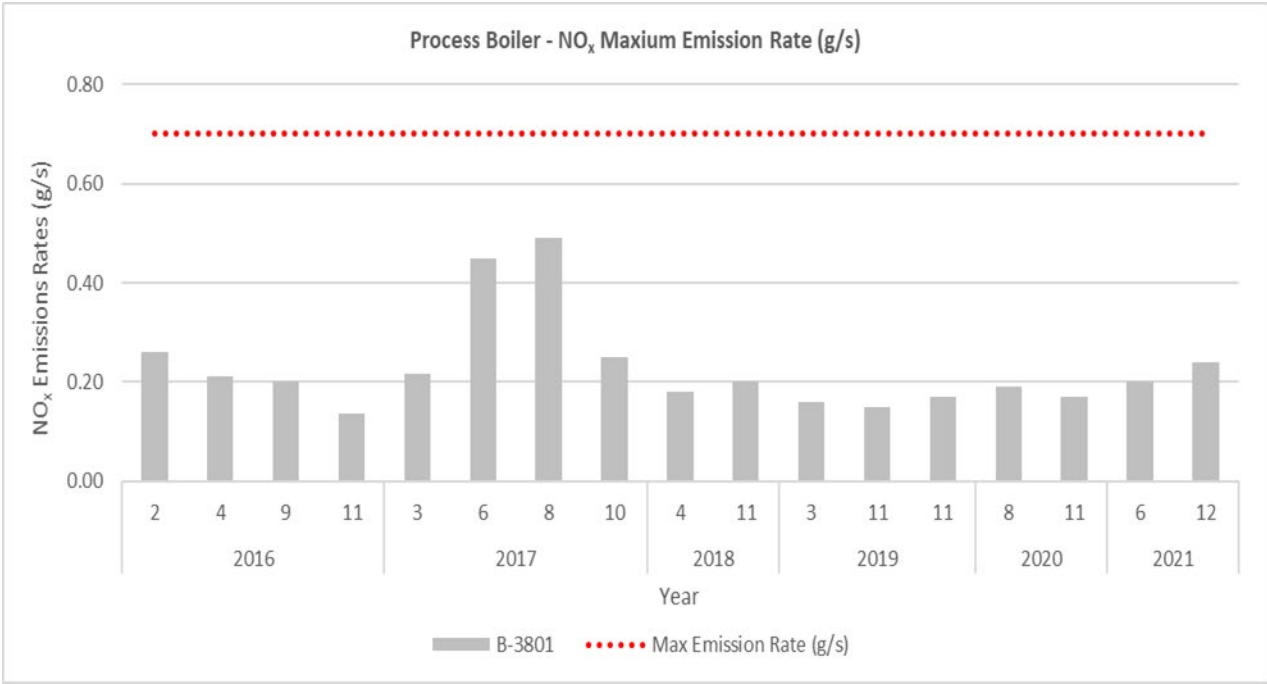


Figure 4-12 Process boiler NO_x emissions 2016-2021

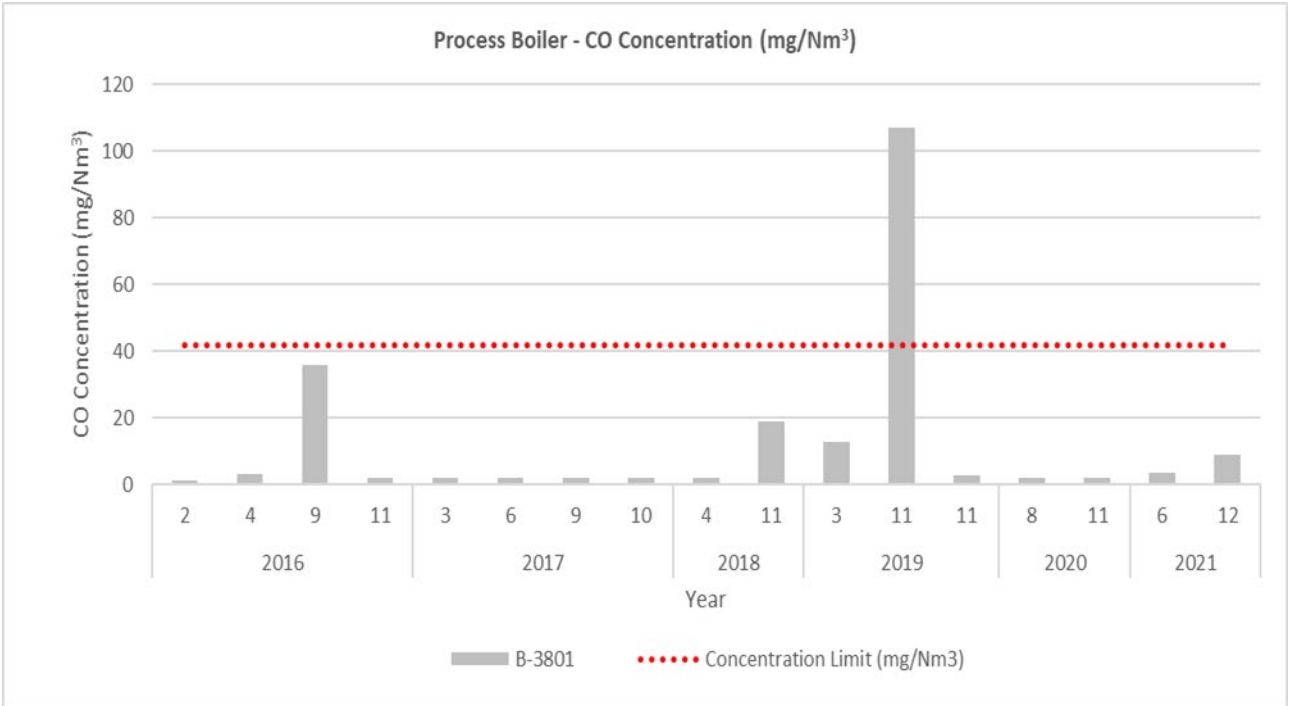
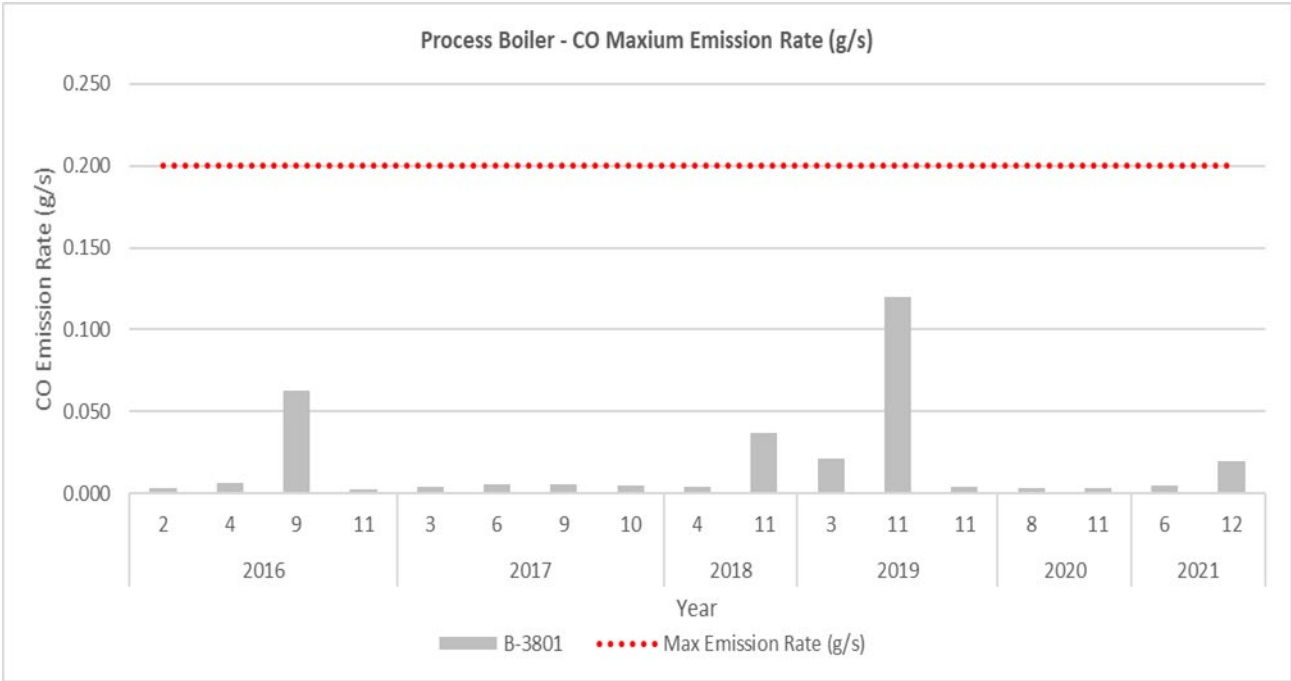


Figure 4-13 Process boiler CO emissions 2016-2021

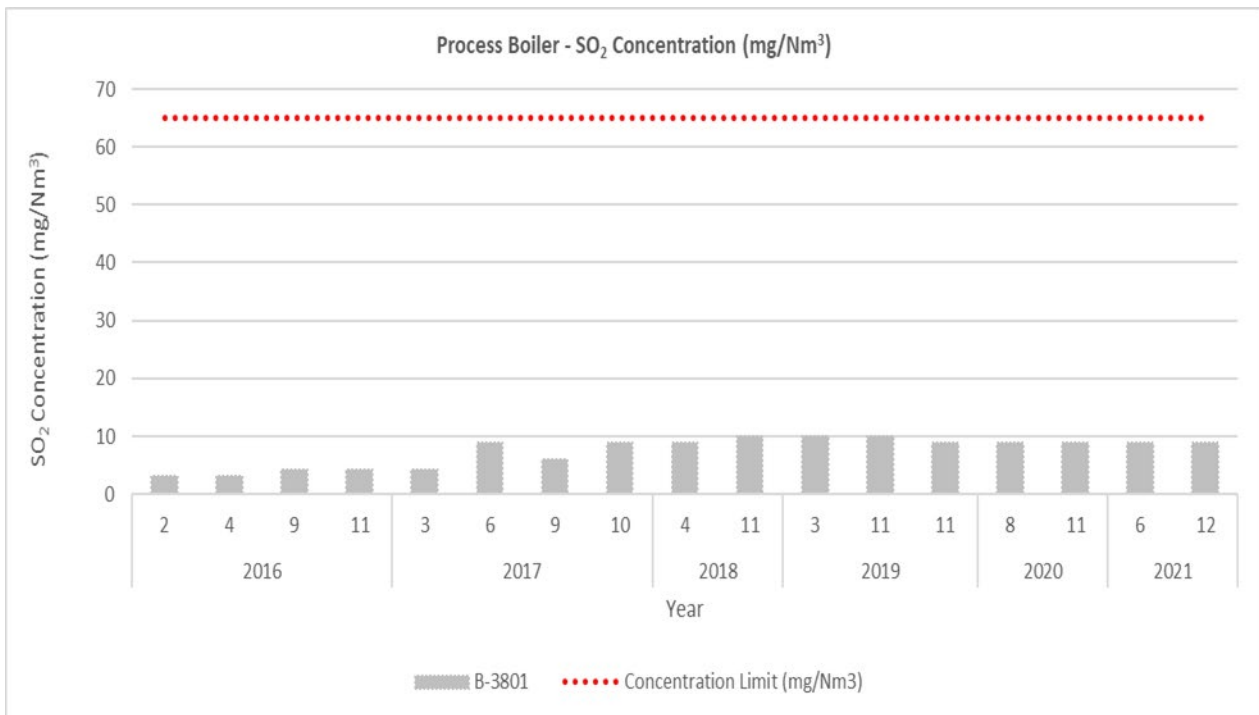
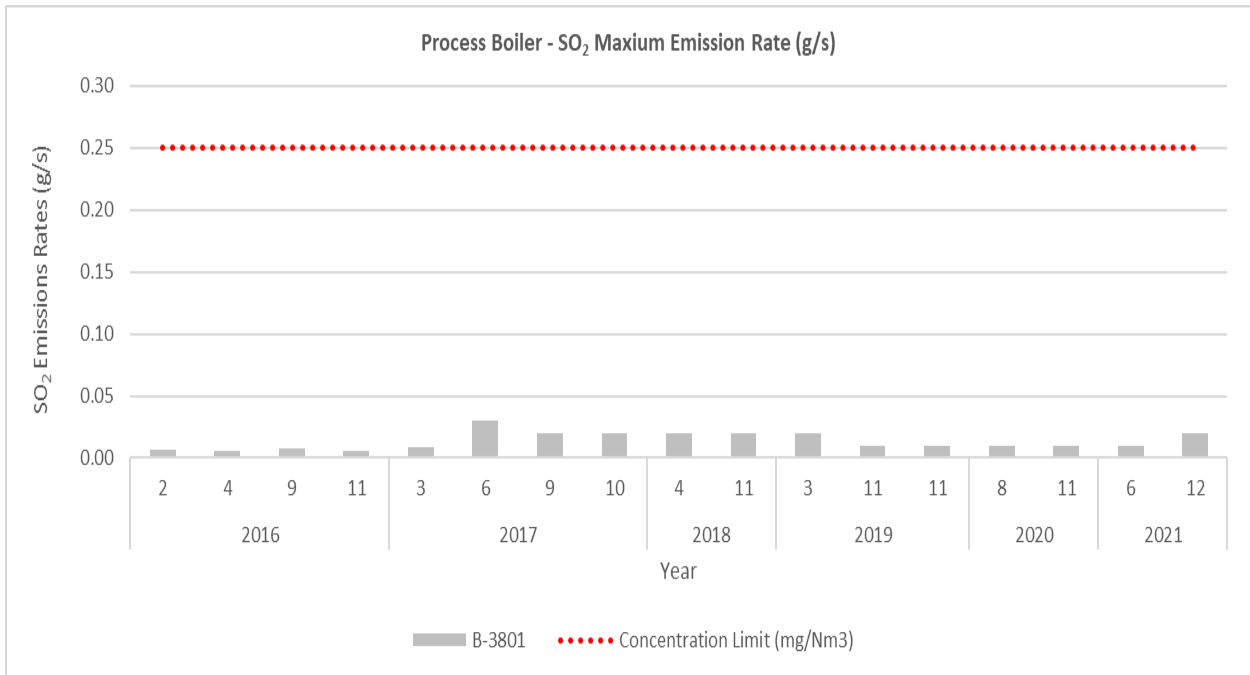


Figure 4-14 Process boiler SO₂ emissions 2016-2021

4.1.4 Data Management and Quality Control

All samples collected by the stack emissions monitoring specialist (Ektimo) complied with the NSW Approved Methods for the Sampling and Analysis of Air Pollutants. Ektimo is accredited by NATA for the sampling and analysis of air pollutants from industrial sources. Unless otherwise stated test methods used are accredited with NATA.

Emissions were calculated using Santos Plant Operating process data, a system which complies with data management standards and requirements to ensure quality and reliability of data.

4.1.5 Discussion and Interpretation of Results

Monitoring of stack emissions sources at the DLNG facility indicated that 2021 results were compliant with the Licence and generally within range of recent historical data (2015-2021).

The overall consistency with long-term data indicates the processes generating stack emissions are relatively stable and well understood. When considered in conjunction with the results of the ambient air monitoring program (Section 4.3), which showed low levels of stack emission pollutants attributable to DLNG beyond the facility boundary, the stack emissions are considered to present little environmental impact or risk.

4.2 Hydrocarbon Flaring and Venting

Hydrocarbon flaring and venting is an unavoidable activity and is required to operate the DLNG facility in a safe manner. Santos seeks to reduce the volume of hydrocarbons flared where practicable and implements flare targets for the DLNG facility. Methane is a much more potent GHG than Carbon Dioxide (CO₂), although methane has a shorter average residence time in the atmosphere. Hence, flaring of hydrocarbons to convert methane to CO₂ is the preferred disposal method.

The nitrogen stream from the DLNG facility contains a commercially viable amount of helium, and the nitrogen stream removed from the liquefaction process is sent to an off-site helium extraction plant. Venting of nitrogen from the nitrogen rejection unit (NRU) occurs during routine operations where the helium extraction plant is unable to receive the nitrogen gas stream (e.g. during maintenance, when the DLNG stream exceeds the helium plant's capacity, etc.).

As part of a historic planned shutdown the acid gas cold vent pipework was removed and replaced with the hot vent pipework, which results in the acid gas stream being comingled with the compressor exhaust emissions to increase plume buoyance and mixing. Small quantities of acid gas are hot vented on occasions when the AGI is unavailable (e.g. AGI or plant trip)

4.2.1 Monitoring Objectives

The objective of the flaring and venting monitoring program is to understand the amounts of emissions associated with these activities. This information is used to quantify the atmospheric emissions and inform reporting to the NT EPA. The information is analysed in conjunction with other monitoring programs, such as the ambient air monitoring program. The monitoring is also intended to ensure compliance with the conditions of the Licence.

4.2.2 Monitoring Methods

Measurements of volumes of gas sent to the flares, NRU and acid gas vent are calculated based on metering of gas flows within the DLNG facility.

4.2.3 Monitoring Results

Flaring

During the reporting period, the total flaring volume from routine and non-routine sources was 20,943 kNm³ (Figure 4-15). The flaring volume was higher than in 2020. The higher value for 2021 is due to several major events during the reporting period including the May Zero Rates Campaign and loading line repairs. Over the six-year period, excluding 2018 and 2021, the flaring volume has generally reduced. The following has contributed to recent reductions in flaring in recent years:

- Three offline compressor turbines not flowing primary seal gas to flare;
- Flaring during ship loading minimised;
- Reduced ethylene and propane to flare due to the ethylene purifier being online; and
- Reduction in off-specification natural gas liquids (NGL) to flare.

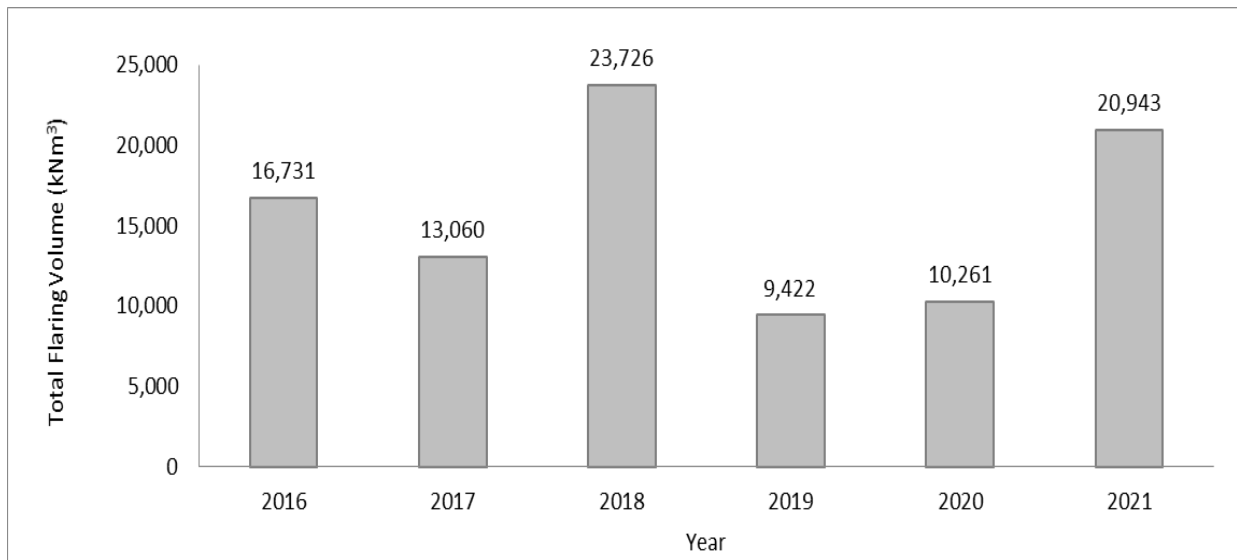


Figure 4-15 Annual flaring volumes (2016-2021)

Nitrogen Rejection Vent

During the reporting period, the total venting from the NRU was 77.3 kNm³ (Figure 4-16). NRU venting was marginally above the historical range recorded following commissioning of the Helium Plant in 2011 but was higher than in 2021 due to the following reasons:

- Maintenance campaign conducted in May 2021 which required venting during shutdown and start-up of the facility;
- BOC Helium Plant outages resulting in venting.

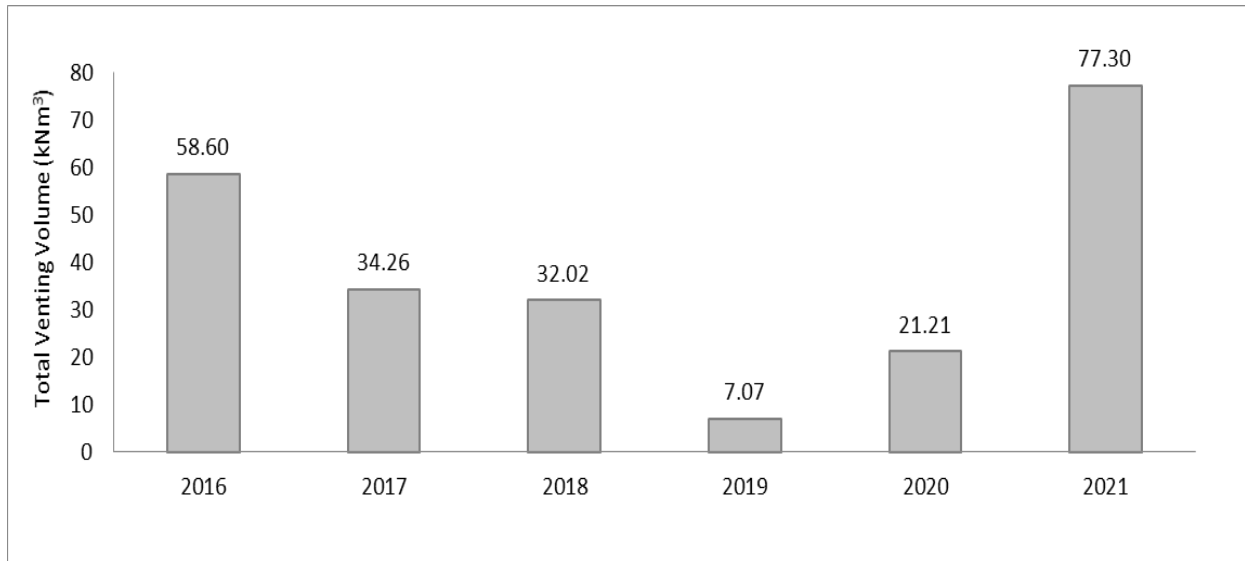


Figure 4-16 DLNG annual NRU venting volumes (2016-2021)

Acid Gas Vent

During the reporting period, the total acid gas venting volume for planned and unplanned downtime was 10,979 kNm³ (Figure 4-17), similar to the volume for 2020. Acid gas was vented due to planned repair and maintenance for a total duration of 16.5 days in 2021. The duration of trips or unplanned maintenance in 2021 was 8.68 days, bringing the annual total venting duration to 25.18 days.

Santos was compliant with Condition 51 which states that the acid gas incinerator is not to be in repair and maintenance for more than 28 days at any one time and no more than 55 days per year.

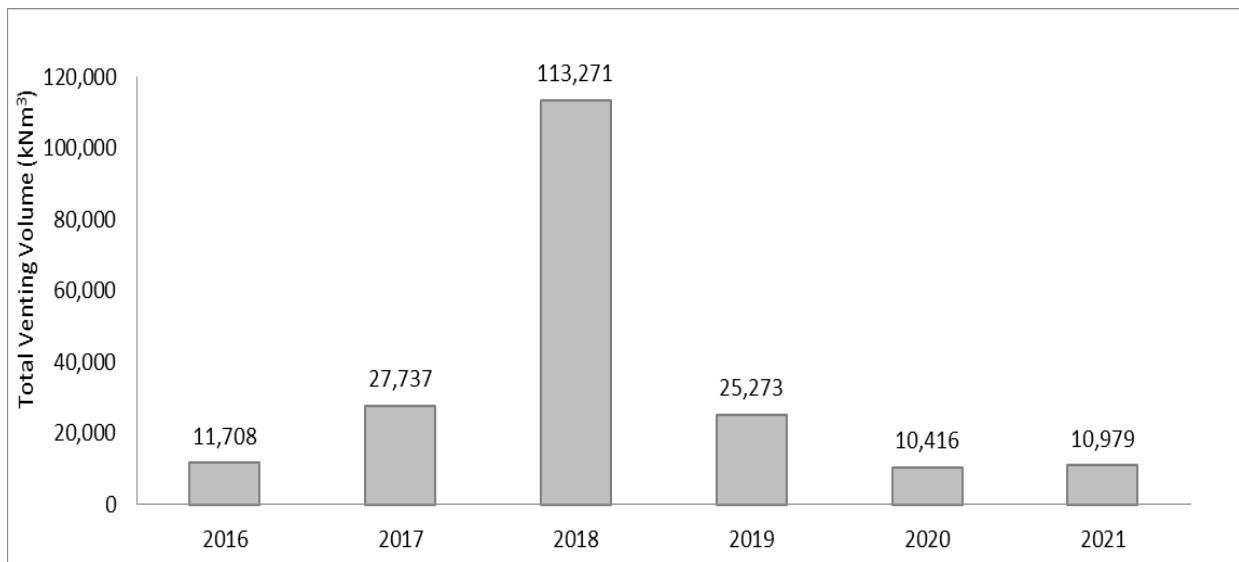


Figure 4-17 DLNG annual acid gas venting volumes (2016-2021)

Quarterly sampling of the AGV was initiated in Q4 2017 following a licence amendment that included this new monitoring condition in September 2017. Comparison of mass emissions rates and concentrations for the AGV shows the following observations:

- Compliant H₂S mass emissions rates and concentrations for 2021 and overall for the Q4 2017-2021 period with the exception of a minor concentration exceedance in October 2018 (Figure 4-18); and
- Compliant benzene mass emissions rates and concentrations for 2021 except for an exceedance in December 2021. During this stack testing event, the waste gas stream was being treated by the acid gas incinerator and not being discharged via the acid gas vent. Overall, the 2017-2021 period has been compliant except for an exceedance in April 2019 and elevated levels at the Licence limit in November 2019 (Figure 4-19). During each of these historical stack testing occasions the waste gas stream was being treated via the acid gas incinerator and was not discharged via the acid gas vent.

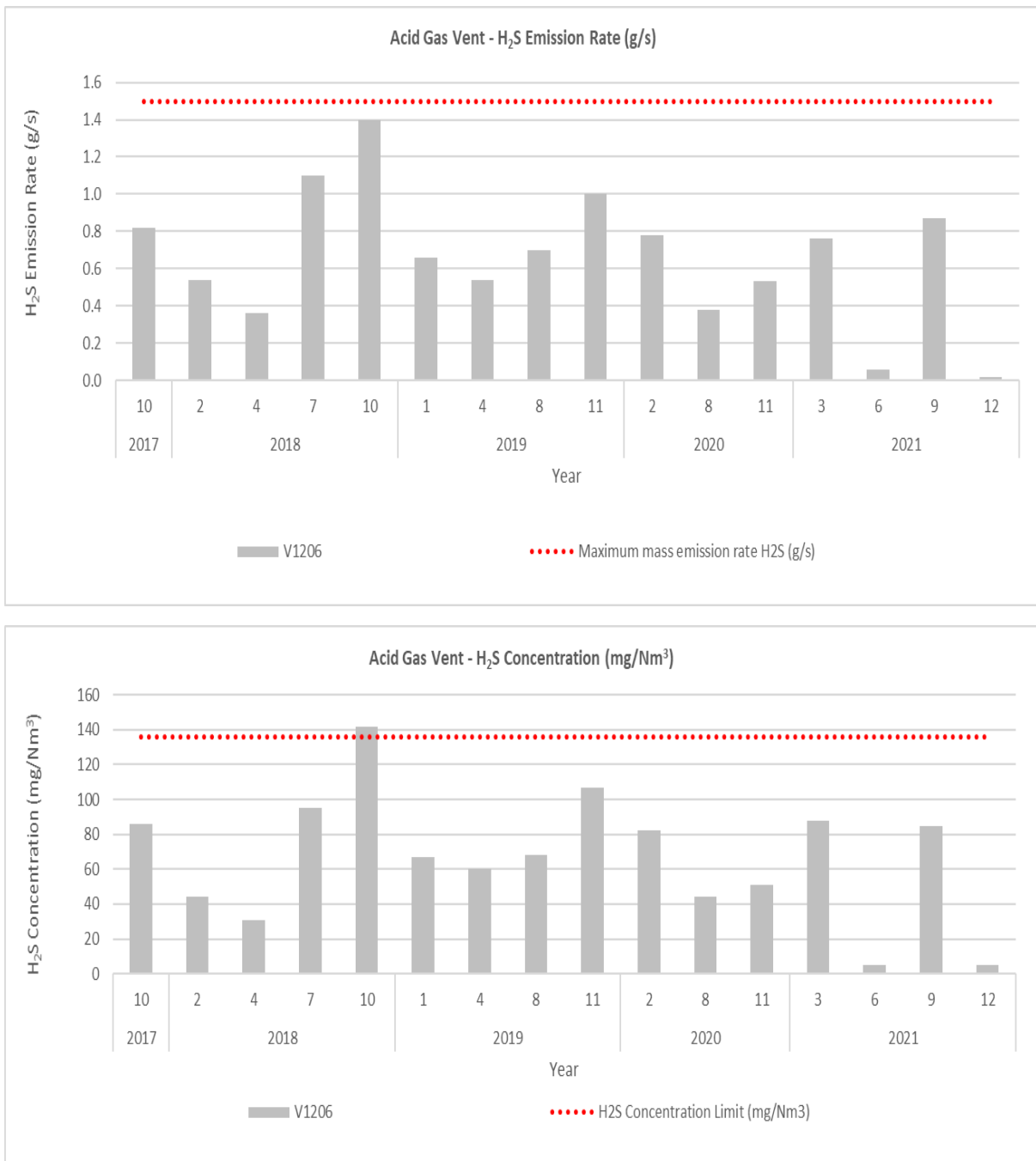


Figure 4-18 AGV H₂S emissions Q4 2017-2021

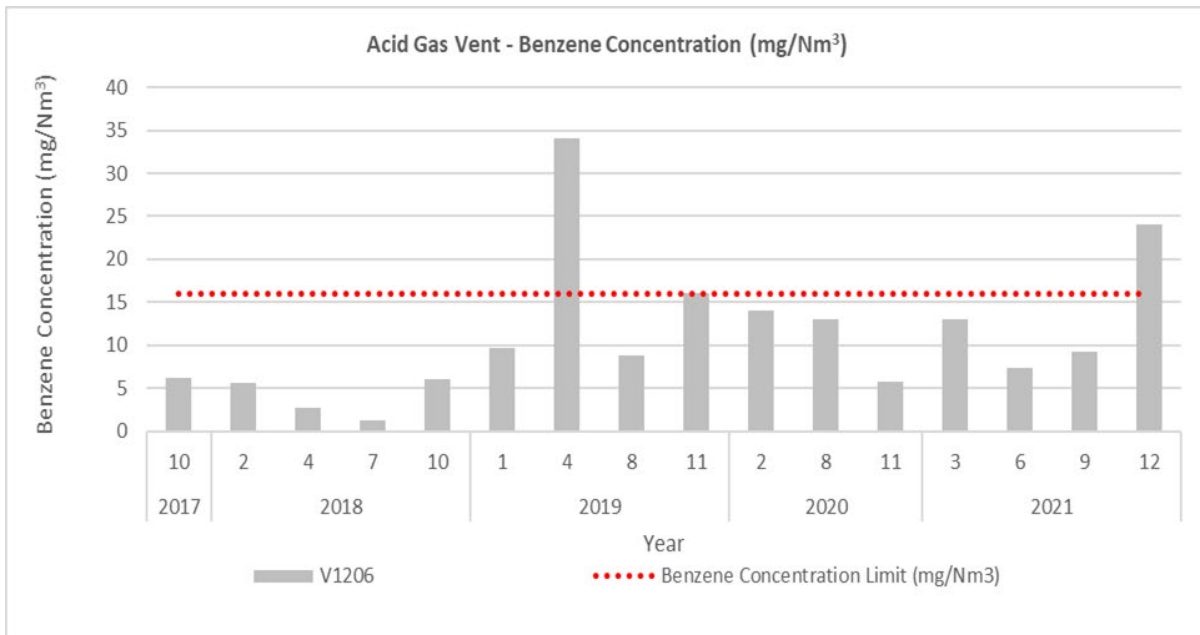
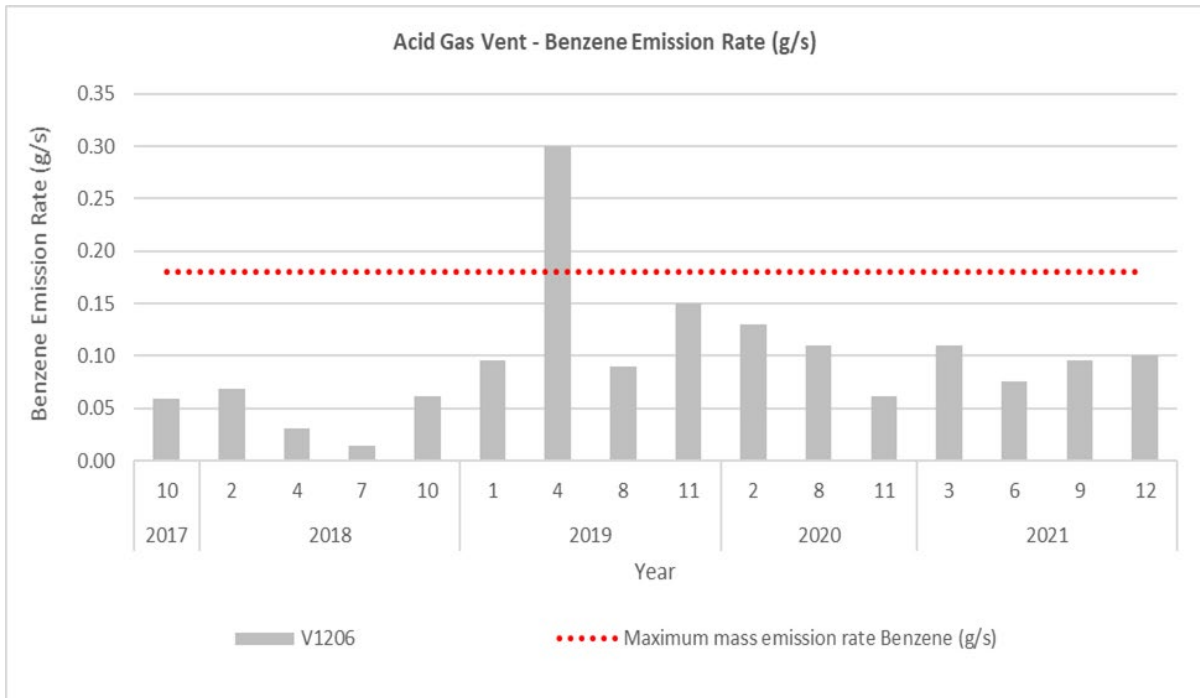


Figure 4-19 AGV benzene emissions Q4 2017-2021

4.2.4 Data Management and Quality Control

Hydrocarbon flaring and venting volumes were calculated using Santos plant operating process data system. This system is routinely monitoring as part of the operation of the DLNG facility and is considered reliable.

4.2.5 Discussion and Interpretation of Results

The 2021 Acid gas venting emissions were comparable to 2020 and lower than the preceding periods. The NRU and flaring volumes were greater than the previous year with the NRU being slightly above the range for the previous five years. With the exception of 2021 for NRU and flaring, overall there is a decreasing trend evident over the five-year period from 2016-2021 indicating a reduced risk to the environment.

Stack testing of the AGV indicated that the mass emissions rates and concentrations of acid gas were compliant with the Licence limits except for Benzene in Q4 2021 however the gas was being treated by the AGI at the time of sampling.

Hot venting of acid gas occurred during 2021 due to planned shutdowns in May and October to conduct maintenance to the facility or AGI. The total number of days for hot venting did not exceed the Licence limits. In addition, acid gas was also hot vented during unplanned events such as process trips of the AGI. These events were reported to the NT EPA and the duration of these events was made as short as practicable.

Overall, the flaring and venting volumes in 2021 presents a negligible environmental risk or impact as supported by ambient air monitoring data of the Darwin airshed. Refer to Section 4.3 for more information on ambient air quality monitoring results.

4.3 Ambient Air Monitoring

As outlined in the summary of the 2021 stack emissions monitoring program results (Section 4.1), the DLNG facility has air emissions points permitted by the Licence. While the stack emissions monitoring program provides information on the amounts of atmospheric releases from these authorised discharge points, it does not provide information on their potential impacts in the airshed around the DLNG facility. To address this, Santos has developed, and implements, an ambient air quality monitoring program.

Ecotech Pty Ltd was commissioned by Santos to design, establish and implement an ambient air monitoring program for the DLNG facility over an 18-month period starting March 2016. This included the establishment of three monitoring sites managed by Santos. Once this data was collected, the scope of the ambient air monitoring was reduced in September 2017 to focus on analytes of interest, notably benzene and H₂S for the hot vent trial permitted by Appendix C of the Licence.

The ambient air monitoring program was scaled back to focus on data available from the three NT EPA managed stations only from March 2020 onwards. This was due the suspension of the hot venting trial in November 2019, coupled with a history of compliance with the relevant air quality standards demonstrating low environmental risk. The Santos monitoring stations are not mandatory under EPL 217-02.

Katestone was commissioned by Santos to collate, review and interpret the ambient air monitoring data from NT EPA managed stations (Katestone, 2022). The results of this are summarised in this section.

4.3.1 Monitoring Objective

The ambient air quality monitoring program aims to obtain robust data that accurately monitors the Darwin City and DLNG air sheds to determine the impact, if any, from DLNG air emissions. The data from the ambient air monitoring program is considered in conjunction with the stack emissions monitoring program and the operational activities at the DLNG facility.

The ambient air monitoring program was also intended to provide information for the DLNG acid gas Hot Vent Trial that is permitted by Appendix C of the Licence. The trial has since been cancelled 2019 and the Santos ambient air stations were decommissioned in early 2020.

4.3.2 NT EPA Network

NT EPA maintain their own network of three stations with the program evolving over the years. These are Stokes Hill near Darwin city, Winnellie along the Stuart Highway, and Palmerston. These monitoring sites are shown in Figure 4-20 and detailed in Table 4-1.

All three sites currently monitor particulate matter (PM₁₀ and PM_{2.5}), CO, oxides of nitrogen (NO_x, NO and NO₂), SO₂ and meteorological parameters. This dataset is available on the public NT Air Quality Network website and is included within the ambient air quality discussion.

In general, the primary air pollutant in Darwin and Palmerston is particulate matter in smoke from distant and local vegetation burning during the dry season. Other air pollutants CO, NO₂ and SO₂ all occur at very low levels compared to large cities in other parts of Australia, while O₃ occurs at moderate levels, typically due to natural processes.



Figure 4-20 Ambient air quality monitoring station locations

Table 4-1 NT EPA ambient air monitoring network

Site description		Palmerston	Stokes Hill	Winnellie
Geographical coordinates	Latitude	130.94848	130.8506	130.89326
	Longitude	-12.50776	-12.46702	-12.42443
Classification		Residential	Industrial	Generally Representative Upper Bound
Meteorology				
Wind speed		✓	✓	✓
Wind direction		✓	✓	✓
Pollutants				
NO, NO ₂ , NO _x		✓	✓	✓
SO ₂		✓	✓	✓
O ₃		✓	✓	✓
CO		✓	✓	✓
PM ₁₀ , PM _{2.5}		✓	✓	✓

4.3.3 Data Capture

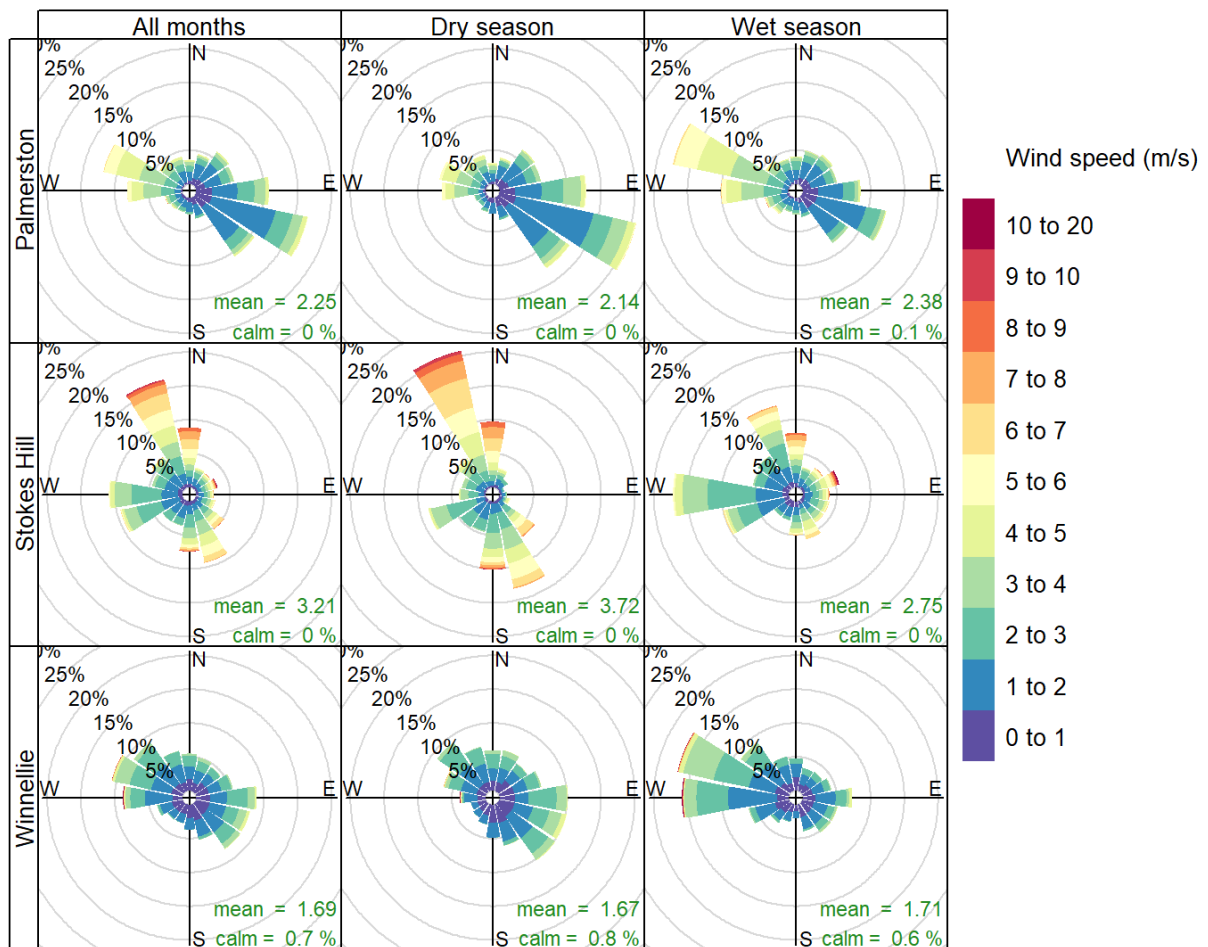
The ambient air quality monitoring network data were downloaded via the public NT Air Quality Network website by Katestone as hourly averages for all air pollutants and meteorological parameters. This data is automatically collected and may not have undergone preliminary quality checks or data ratification. The lack of data ratification is obvious in the concentration data for some pollutants, and it is not possible for Katestone to carry out this data ratification as it requires specific calibration data that is not published. Hence, while Katestone has sought to remove anomalous values from the dataset, the underlying data quality remains very poor in some cases.

Data at each monitoring site was compared with relevant air quality standards.

4.3.4 Meteorological Conditions

Meteorological conditions play an important role in the dispersion of air pollutants from their point of emission. The NT EPA ambient air monitoring network measures wind speed and wind direction at the three monitoring sites and indicate the following (Figure 4-21):

- The predominant winds in the region are from the east-southeast and west-northwest, based on Palmerston and Winnellie; northerly and southerly winds are uncommon at both sites
- Wind direction at these sites generally shifts from predominantly easterly in the Dry season (May to October) to predominantly westerly in the Wet season (November to April)
- The Stokes Hill data show a very different pattern, and one which is very different to previous years, which perhaps suggests instrument error.



Frequency of counts by wind direction (%)

Figure 4-21 2021 wind rose for the NT EPA monitoring sites

4.3.5 Nitrogen Dioxide (NO₂)

A summary of NO₂ concentrations measured by the NT EPA monitoring network is presented in timeseries are shown in Figure 4-22. The results show that:

- 1-hour average concentrations of NO₂ were below the Air NEPM standard of 0.08 ppm
- Annual average concentrations of NO₂ were well below the Air NEPM standard of 0.015 ppm
- Concentrations of NO₂ complied with the relevant Air NEPM standards at all monitoring sites, reaching at most 80% of the standards.

The large spike in concentrations in mid-August in Figure 4-22 looks potentially anomalous, but closer investigation shows a spike over several hours on 14 August 2021 for several pollutants (namely NO₂, SO₂, CO, PM_{2.5} and PM₁₀), with concentrations being elevated throughout this day and the following day (15 August 2021). This could potentially represent instrument error, although all the instruments failing at the same time seems unlikely, unless due to an electrical issue or potentially a problem with the datalogger. Regardless, no similar spike in concentrations has been observed since this period.

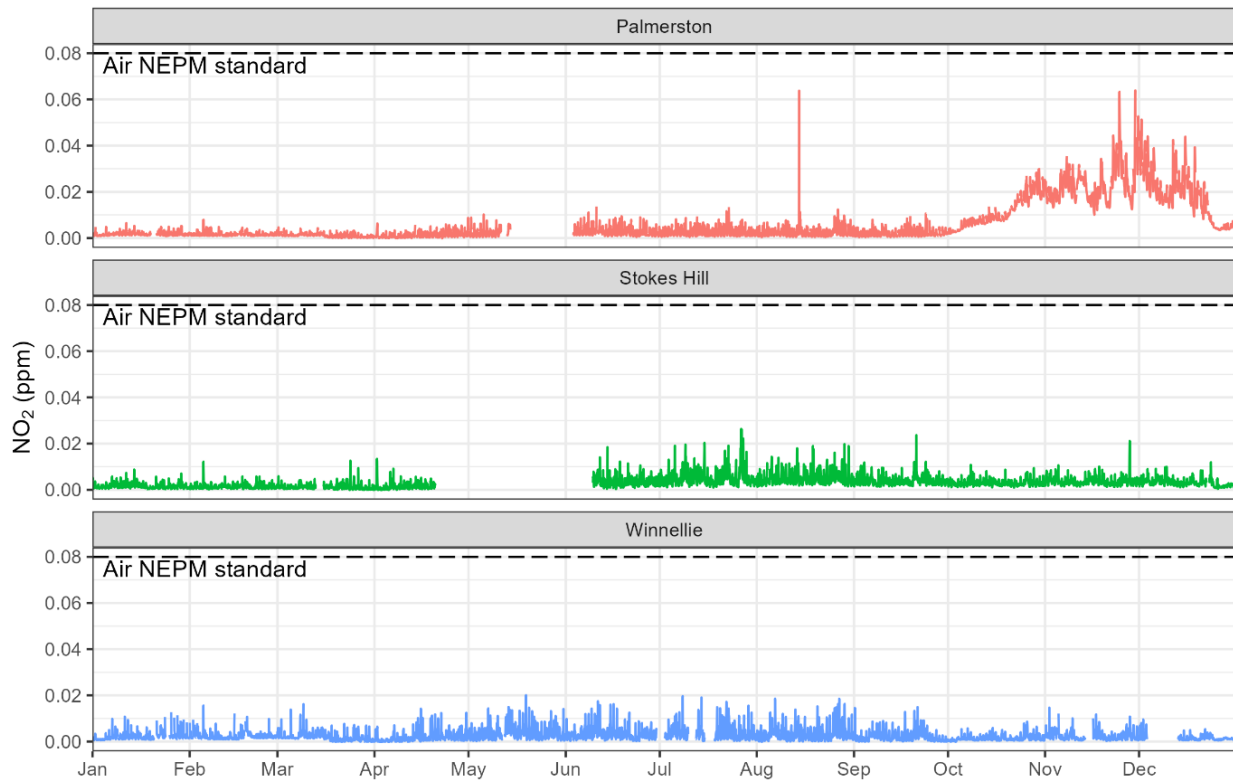


Figure 4-22 1-hour average concentrations of NO₂ measured by the NT EPA monitoring network 2021

4.3.6 SO₂

Summaries of SO₂ concentrations measured by the NT EPA monitoring network are presented in in Figure 4-22 and Figure 4-23. The results show that:

- 1-hour average concentrations of SO₂ were well below the Air NEPM standard of 0.10 ppm
- 24-hour average concentrations of SO₂ were well below the Air NEPM standard of 0.02 ppm
- Concentrations of SO₂ complied with the relevant Air NEPM standards at all monitoring sites, reaching at most 43% of the standards.

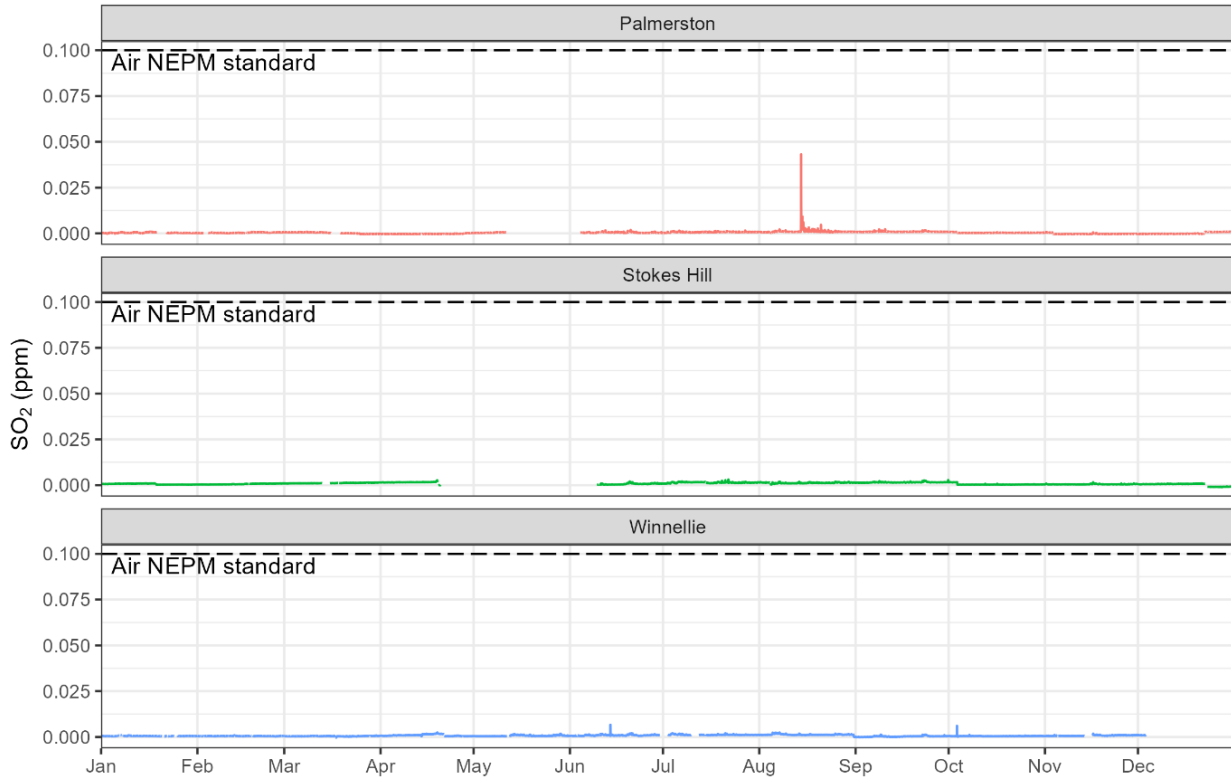


Figure 4-23 Timeseries of 1-hour average SO₂ concentrations (ppm) measured by the NT EPA monitoring network (January 2021 to December 2021)

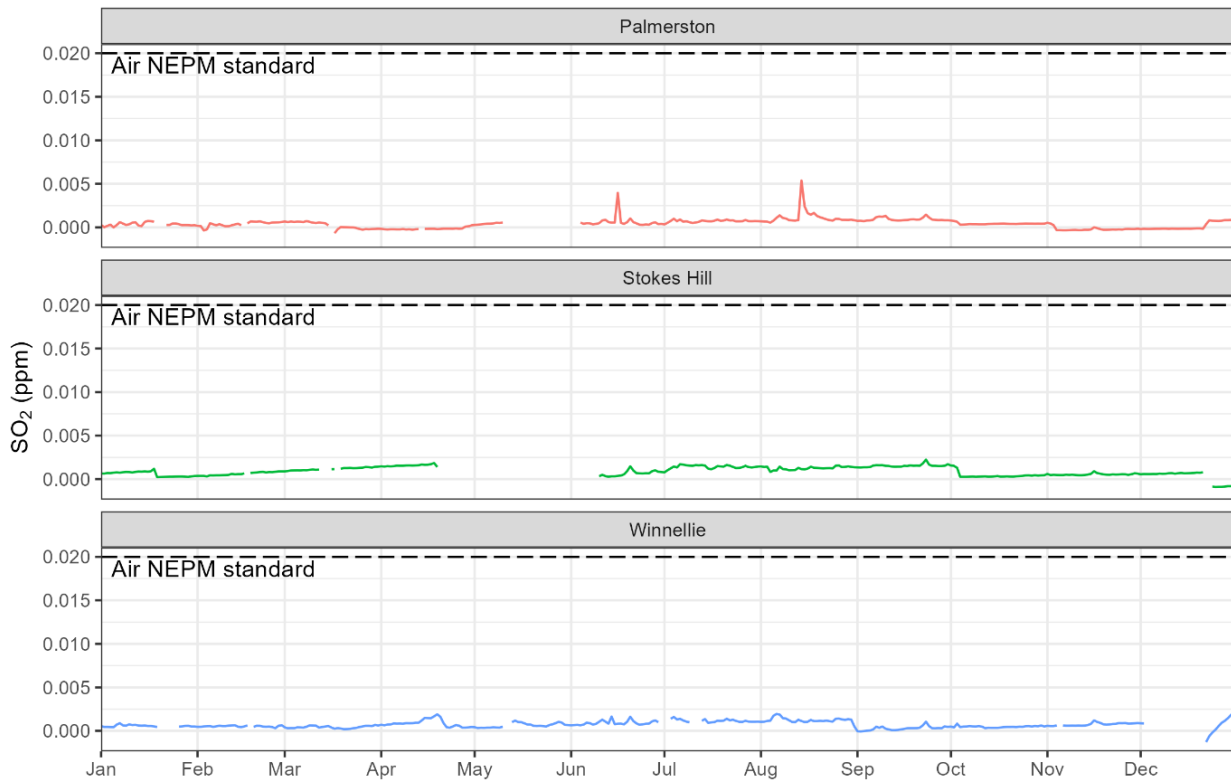


Figure 4-24 Timeseries of 24-hour average SO₂ concentrations (ppm) measured by the NT EPA monitoring network (January 2021 to December 2021)

4.3.7 CO

A summary of CO concentrations measured by the NT EPA monitoring network is presented in the timeseries are shown in Figure 4-25. The results show that 8-hour rolling average concentrations of CO were well below the Air NEPM standard of 9.0 ppm.

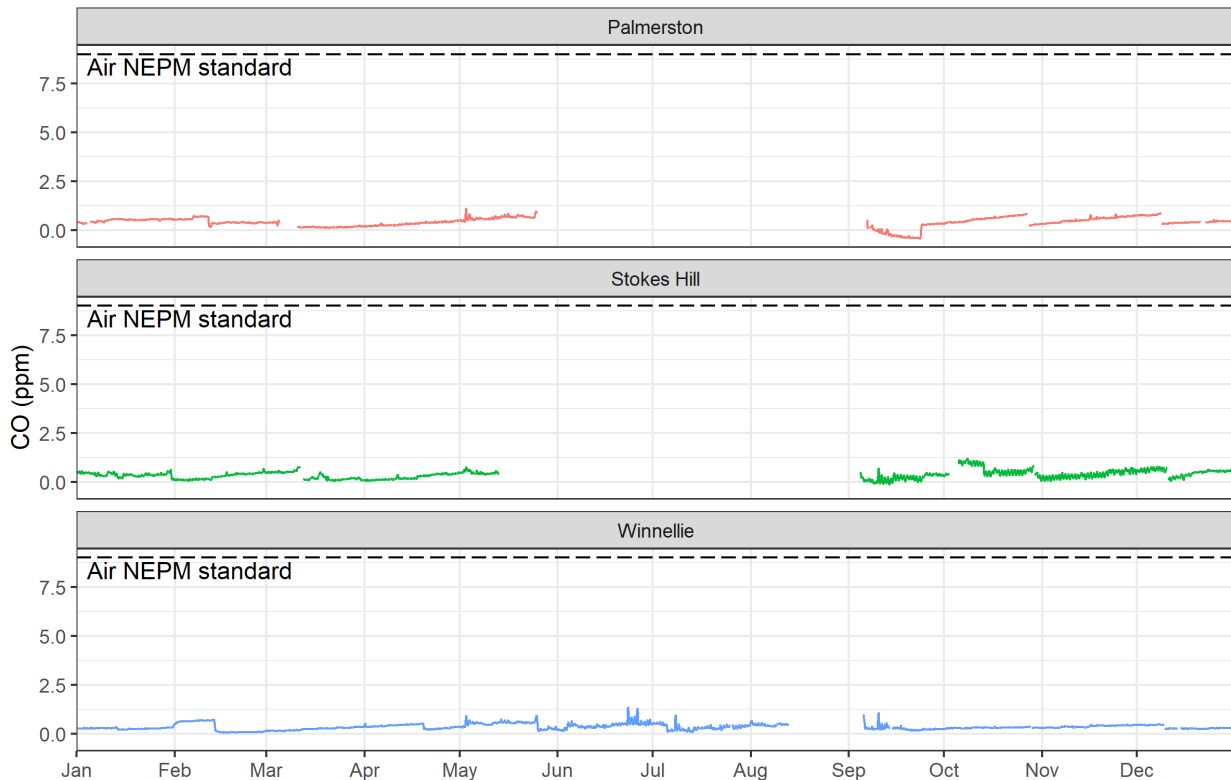


Figure 4-25 Timeseries of 8-hour rolling average CO concentrations (ppm) measured by the NT EPA monitoring network (January 2021 to December 2021)

4.3.8 PM₁₀

A summary of PM₁₀ concentrations measured by the NT EPA monitoring network is presented in the timeseries are shown in Figure 4-26. The results show that:

- Annual average concentrations of PM₁₀ complied with the Air NEPM standard of 25 µg/m³
- 24-hour average concentrations of PM₁₀ exceeded the Air NEPM standard of 50 µg/m³ at all three sites, on a total of eight occasions across the three sites.

Table 4-3 shows that all sites recorded relatively high concentrations on these days, which in some cases is likely indicative of a widespread dust event. Consistent with this is the fact that the exceedances occurred during the Dry season (May to October), when natural dust events are common. However, the elevated concentrations at Palmerston on 14 and 15 August 2021 do not look to be a result of a widespread dust event. Concentrations at Palmerston on these days are discussed further in Section 4.3.6.

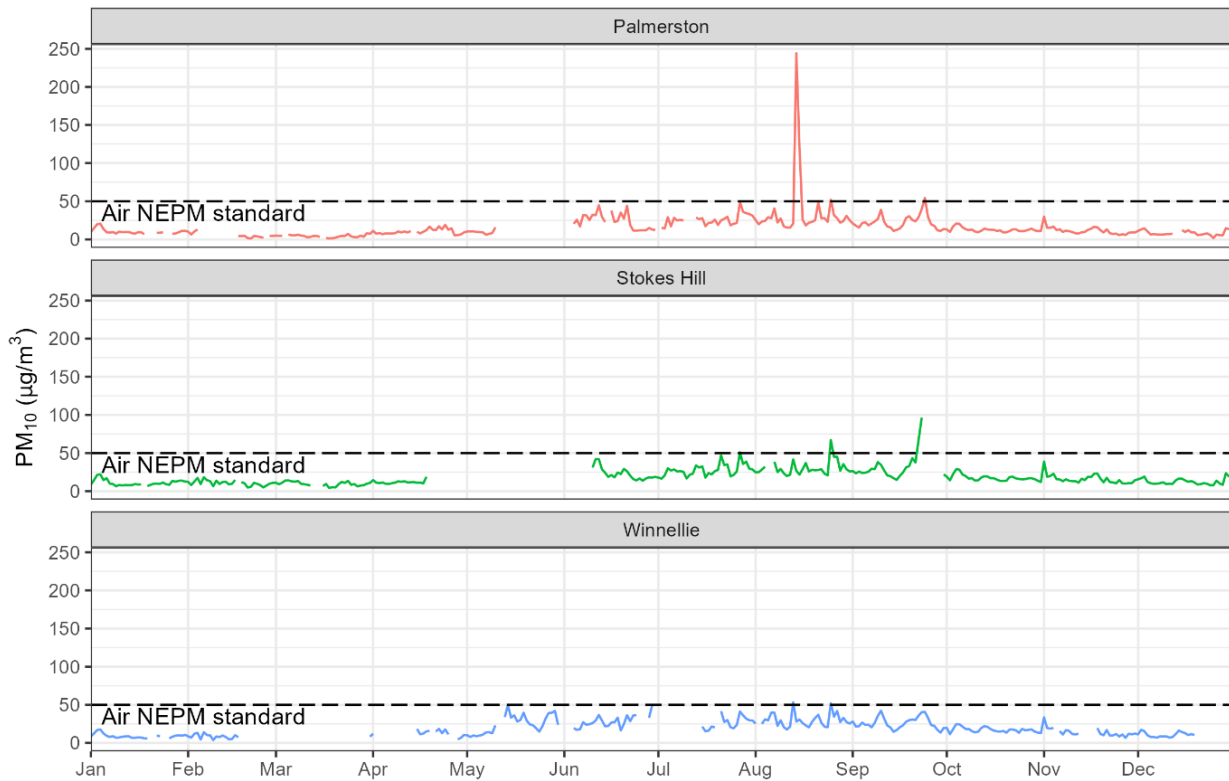


Figure 4-26 Timeseries of 24-hour average PM_{10} concentrations ($\mu g/m^3$) measured by the NT EPA monitoring network (January 2021 to December 2021)

Table 4-2 24-hour average PM_{10} concentrations ($\mu g/m^3$) measured by the NT EPA monitoring network on exceedance days (January 2021 to December 2021)

Date	24-hour average PM_{10} concentration ($\mu g/m^3$)		
	Palmerston	Stokes Hill	Winnellie
27 July 2021	49.0	50.9	41.2
13 August 2021	20.8	41.6	53.2
14 August 2021	244.1	26.6	28.0
15 August 2021	119.9	21.7	30.6
25 August 2021	51.8	66.9	52.0
22 September 2021	29.1	67.4	35.9
23 September 2021	39.9	96.5	40.4
24 September 2021	54.2	-	40.8

4.3.9 $PM_{2.5}$

A summary of $PM_{2.5}$ concentrations measured by the NT EPA monitoring network is presented in the timeseries are shown in Figure 4-27. The results show that:

- Annual average concentrations of $PM_{2.5}$ at Stokes Hill complied with the Air NEPM standard of $8 \mu g/m^3$; concentrations at Palmerston and Winnellie did not
- 24-hour average concentrations of $PM_{2.5}$ exceeded the Air NEPM standard of $25 \mu g/m^3$ on 34 occasions.

Table 4-4 shows that almost all of the exceedances occurred during the Dry season (May to October), when natural dust events are common, and such events are likely to be the cause of most of the exceedances.

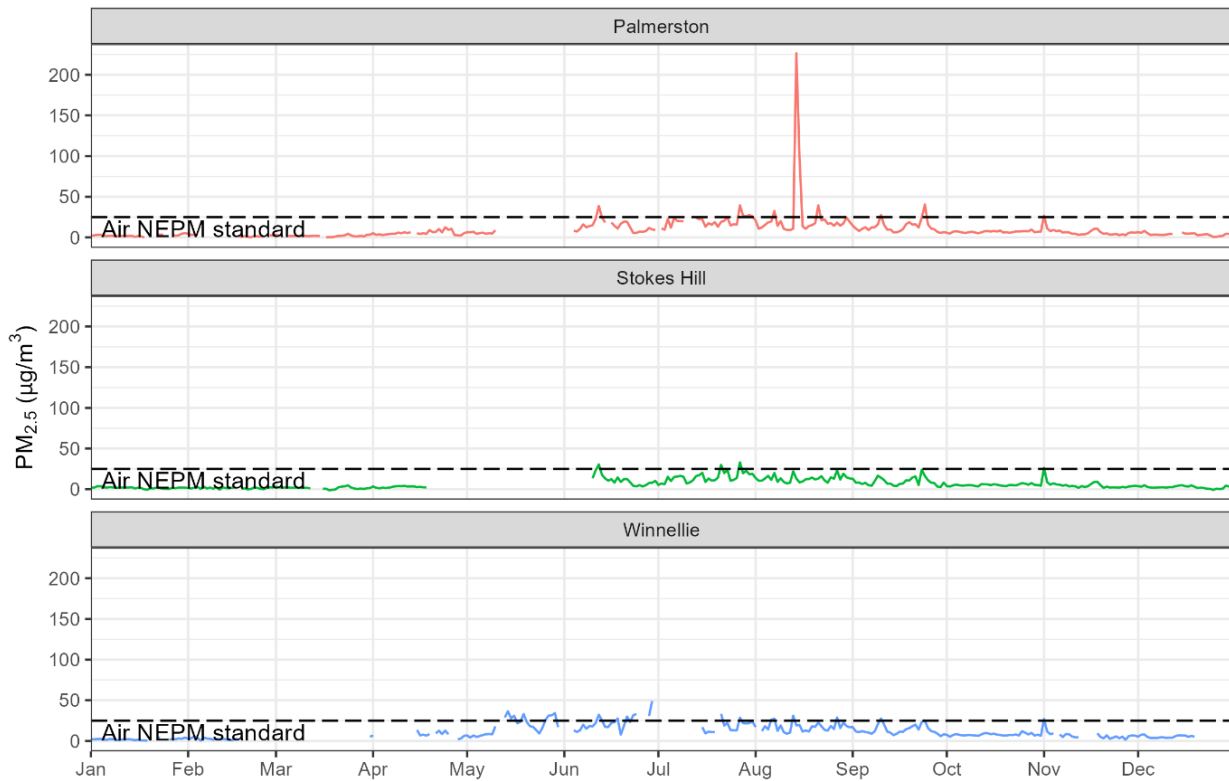


Figure 4-27 Timeseries of 24-hour average $PM_{2.5}$ concentrations ($\mu\text{g}/\text{m}^3$) measured by the NT EPA monitoring network (January 2021 to December 2021)

Table 4-3 24-hour average $PM_{2.5}$ concentrations ($\mu\text{g}/\text{m}^3$) measured by the NT EPA monitoring network on exceedance days (January 2021 to December 2021)

Date	24-hour average $PM_{2.5}$ concentration ($\mu\text{g}/\text{m}^3$)		
	Palmerston	Stokes Hill	Winnellie
13 May 2021	-	-	28.9
14 May 2021	-	-	36.5
15 May 2021	-	-	27.9
16 May 2021	-	-	30.9
19 May 2021	-	-	33.2
26 May 2021	-	-	25.9
27 May 2021	-	-	31.3
28 May 2021	-	-	31.6
29 May 2021	-	-	34.4
12 June 2021	38.7	30.4	32.3
13 June 2021	24.6	17.7	25.1
18 June 2021	10.9	14.5	27.6
21 June 2021	19.2	12.5	30.0
23 June 2021	5.4	4.2	31.7
24 June 2021	5.6	3.6	33.2
26 June 2021	6.9	3.4	29.8
28 June 2021	11.6	7.6	30.6
29 June 2021	9.9	7.8	49.0

Date	24-hour average PM _{2.5} concentration (µg/m ³)		
	Palmerston	Stokes Hill	Winnellie
21 July 2021	19.2	30.0	33.4
27 July 2021	39.5	33.0	28.7
28 July 2021	26.8	19.5	22.0
29 July 2021	26.0	22.7	21.5
30 July 2021	27.4	18.4	22.1
31 July 2021	25.9	18.9	23.8
6 August 2021	19.5	11.5	26.1
7 August 2021	32.6	19.9	27.4
13 August 2021	10.8	22.0	31.1
14 August 2021	226.4	13.1	19.2
15 August 2021	98.7	8.4	19.7
21 August 2021	39.4	13.1	22.6
27 August 2021	18.2	23.2	28.9
10 September 2021	27.6	14.1	27.6
24 September 2021	40.5	16.3	25.0
1 November 2021	26.8	26.2	27.0

4.3.10 Hot Venting Periods

Table 4-5 provides details of the hot venting conducted during 2021 and corresponding ambient air quality events.

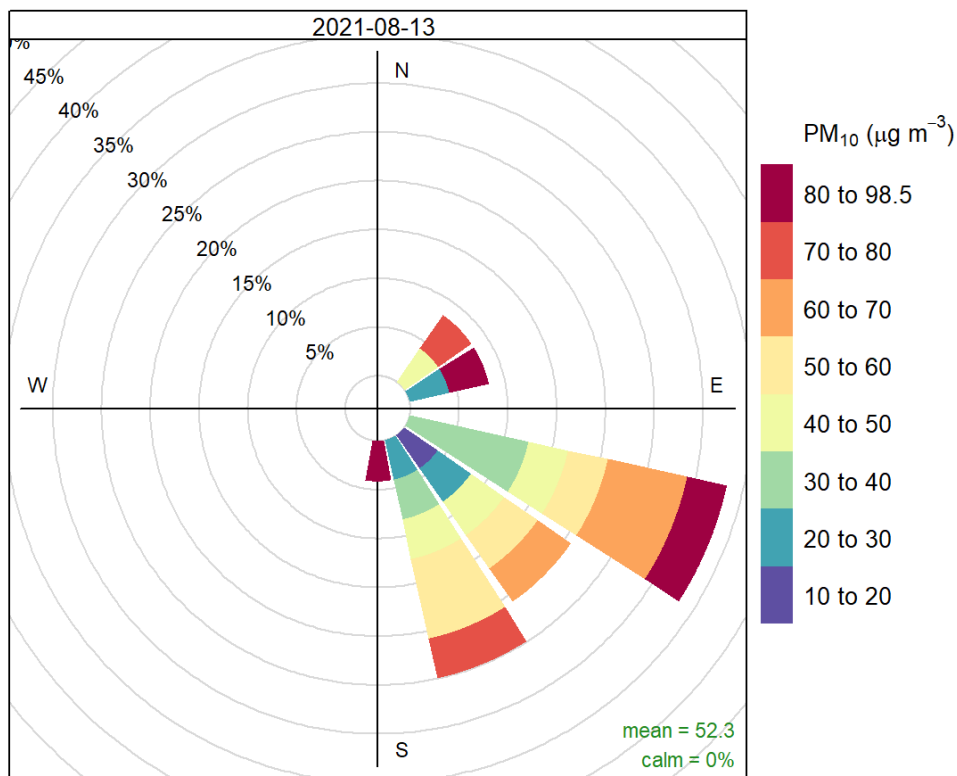
Table 4-4 Hot Venting Periods and Ambient Air quality events (January 2021 to December 2021)

Start Date/time	End Date/Time	Duration (Days)	Volume discharged (kNm ³)	Type	Ambient Air Quality Events
7/02/2021 17:35	9/02/2021 19:45	2.09	1,888	Unplanned	No exceedances
15/05/2021 10:33	25/05/2021 2:46	9.68	588	Planned	Exceedance of 24-hour average PM _{2.5} at Winnellie (15, 16 and 19 May 2021)
30/05/2021 23:33	31/05/2021 22:50	0.97	180	Unplanned	Exceedance of 24-hour average PM _{2.5} at Palmerston and Winnellie (30 May 2021)
3/06/2021 20:01	5/06/2021 11:42	1.65	863	Unplanned	No exceedances
28/07/2021 13:06	28/07/2021 14:39	0.06	23	Unplanned	Exceedance of 24-hour average PM _{2.5} at Palmerston (28 July 2021)
11/08/2021 17:35	12/08/2021 2:30	0.37	70	Unplanned	No exceedances
12/08/2021 13:38	13/08/2021 2:30	0.54	116	Unplanned	Exceedances of 24-hour average PM _{2.5} and PM ₁₀ at Winnellie (13 August 2021)
28/09/2021 16:00	30/09/2021 1:35	1.4	268	Unplanned	No exceedances
30/09/2021 9:35	30/09/2021 16:05	0.27			
5/10/2021 13:50	5/10/2021 16:35	0.11	62	Unplanned	No exceedances
6/10/2021 7:46	13/10/2021 4:10	6.85	5,487	Planned	No exceedances
7/11/2021 4:10	7/11/2021 21:30	0.72	424	Unplanned	No exceedances
8/11/2021 18:50	9/11/2021 12:11	0.49	440	Unplanned	No exceedances

While four periods of hot venting at the DLNG facility aligned with exceedances of the particulate matter standards, hot venting is not associated with significant emissions of particulate matter. Furthermore, as is shown in Figure 4-28, Figure 4-29 and Figure 4-30, the monitors were not downwind of DLNG at these times. Specifically:

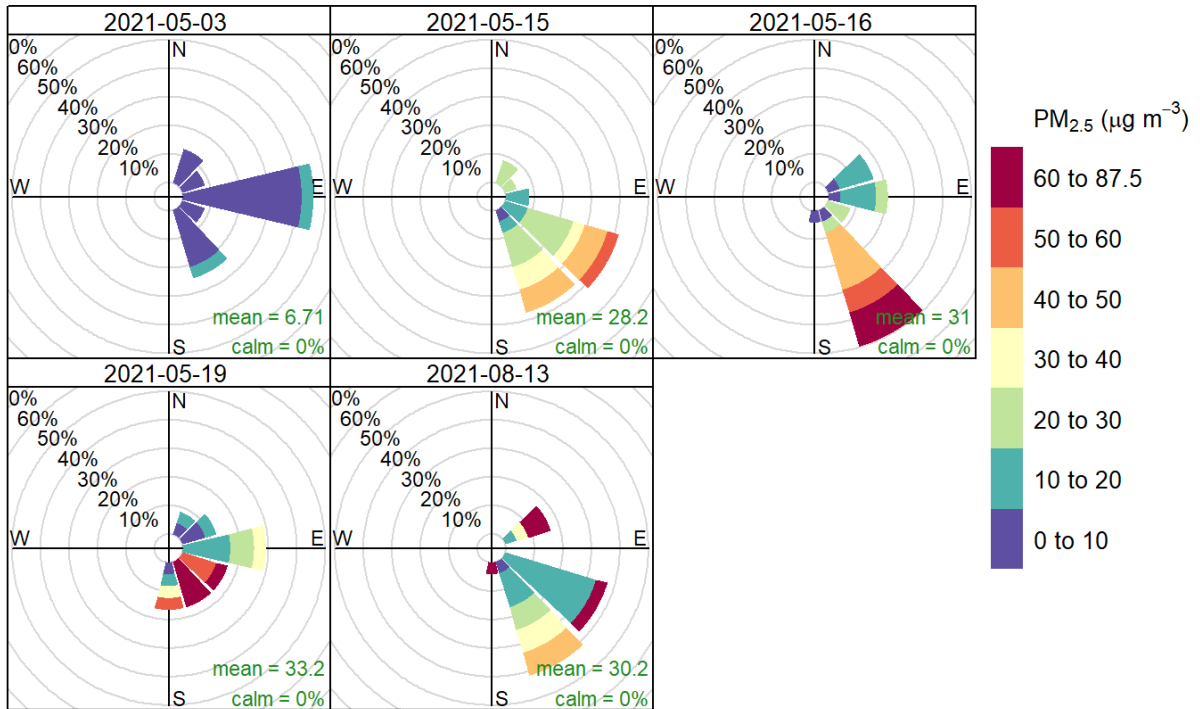
- Winnellie is to the north-northeast of DLNG and would be downwind under south-southwesterly winds; exceedances of the PM_{2.5} and PM₁₀ standards only occurred during easterly and south-easterly winds when the monitor would not have been downwind of the facility and would thus have been unaffected by its emissions.
- Palmerston is to the east of DLNG and would be downwind under westerly winds; exceedances of the PM_{2.5} standard occurred during easterly winds when the monitor would have been upwind of the facility and unaffected by its emissions.

It is, therefore, highly unlikely that any of the exceedances of the Air NEPM standards were caused by DLNG operations.



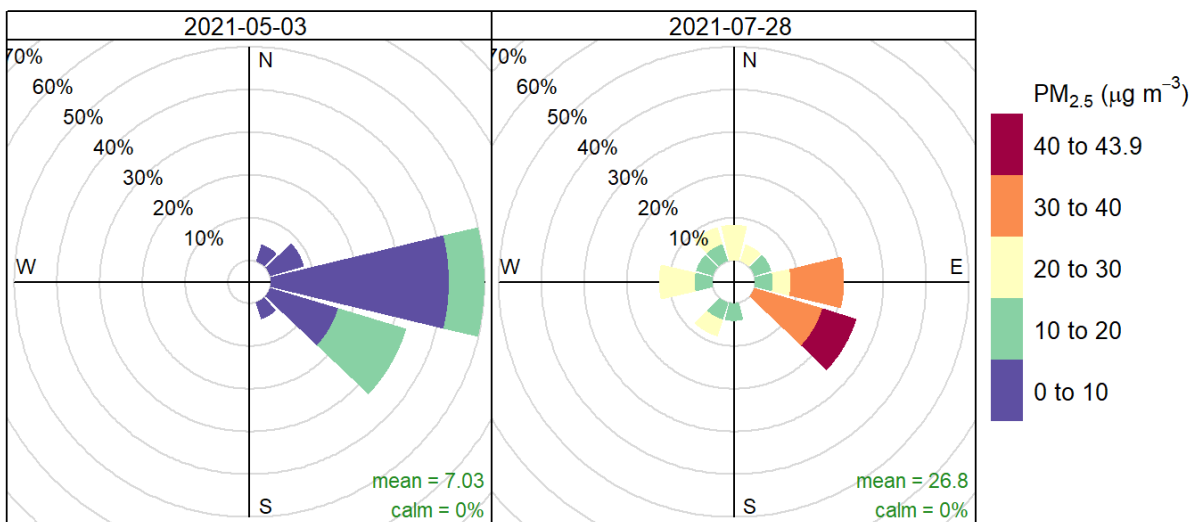
Frequency of counts by wind direction (%)

Figure 4-28 Distribution of 1-hour average PM₁₀ concentrations measured at Winnellie on days with 24-hour average concentrations above the Air NEPM standard and on which hot venting occurred



Frequency of counts by wind direction (%)

Figure 4-29 Distribution of 1-hour average PM_{2.5} concentrations measured at Winnellie on days with 24-hour average concentrations above the Air NEPM standard and on which hot venting occurred



Frequency of counts by wind direction (%)

Figure 4-30 Distribution of 1-hour average PM_{2.5} concentrations measured at Palmerston on days with 24-hour average concentrations above the Air NEPM standard and on which hot venting occurred

4.3.11 Discussion and interpretation of results

Analysis of the NT EPA ambient air quality monitoring data from Palmerston, Stokes Hill and Winnellie shows:

- The NT EPA monitoring network achieved a minimum of 75% valid data capture annually for all relevant pollutants except PM₁₀ and PM_{2.5} at Winnellie. Low data capture in several months resulted in data capture rates of 74.6% for these pollutants at Winnellie.
- Concentrations of NO₂ complied with the relevant Air NEPM standards at all monitoring sites, reaching at most 80% of the standards.
- Concentrations of SO₂ complied with the relevant Air NEPM standards at all monitoring sites, reaching at most 43% of the standards.
- Concentrations of CO complied with the relevant Air NEPM standard at all monitoring sites, reaching at most 47% of the standard.
- Annual average concentrations of PM₁₀ complied with the Air NEPM standard of 25 µg/m³.
- 24-hour average concentrations of PM₁₀ exceeded the Air NEPM standard of 50 µg/m³ on eight occasions.
- Annual average concentrations of PM_{2.5} complied with the Air NEPM standard of 8 µg/m³.
- 24-hour average concentrations of PM_{2.5} exceeded the Air NEPM standard of 25 µg/m³ on 34 occasions.
- No exceedances of the Air NEPM standards for PM₁₀ and PM_{2.5} were attributed to hot venting periods at DLNG; all exceedances that occurred during hot venting periods occurred at times when the monitors were not downwind of the facility.

5.0 Monitoring discharges to Land and Surrounding Environment

5.1 Groundwater Monitoring Program

Treated wastewater is discharged to the irrigation area at DLNG, which have the potential to permeate into the local groundwater. Santos has developed and implements a groundwater monitoring plan for the DLNG facility. This program is intended to monitor groundwater characteristics in the vicinity of the DLNG facility. The groundwater monitoring plan is a requirement of the Licence and was previously submitted to, and approved by, the NT EPA.

CDM Smith was commissioned by Santos to collect, review and interpret groundwater quality data in accordance with the groundwater monitoring plan. The results of this analysis was provided in an annual groundwater monitoring report (CDM Smith, 2021f), the results of which are summarised in this section.

5.1.1 Monitoring Objectives

The objective of groundwater monitoring at the DLNG facility is to determine the presence and concentration of potential contaminants from the facility that may be present in the groundwater. Groundwater flows may lead to any contaminants being transported away from the DLNG facility, potentially resulting in downstream impacts to the environment.

Additionally, the groundwater monitoring plan is intended to ensure compliance with the groundwater-related monitoring requirements of the Licence (Conditions 66 to 68).

5.1.2 Monitoring Methods

Groundwater samples were taken by qualified personnel from a network of seven monitoring bores (Figure 5-1). Six monitoring bores are located within the Irrigation Area inside the boundary of the DLNG facility and a control bore is located to the east of the DLNG facility outside the operations footprint. The locations and sampling frequency of the monitoring bores is provided in Table 5-1; the bores are shown in Figure 5-1.

Each bore has geological characteristics that potentially influence the groundwater conditions observed, including proximity to coastal/tidal influences, water retention/flow capacity and strata chemistry. BH6 encountered significantly different strata from the other boreholes. A review of historical maps pre-dating the DLNG facility suggests that BH6 was the only borehole not located on the phyllite headland that underlies most of the infrastructure and was instead positioned over a small former bay/inlet where natural clay and laterite deposits predominated.

Two groundwater monitoring events were undertaken during the reporting period to capture wet and dry seasonality (April 2021 and August 2021). Groundwater analysis was completed for physical parameters, major ions, TPH and dissolved metals listed in the DLNG Groundwater Monitoring Plan. Groundwater standing water levels were also measured in field.

Samples were collected following stabilisation of the field parameters (water level, temperature, pH, conductivity and ORP) and stored in bottles and vials supplied by the laboratory. Duplicates, triplicates and a field blank were collected at a rate of one per sample event (one per seven) for quality assurance purposes.

Table 5-1 Groundwater monitoring bore locations

Bore	Location (Decimal Degrees)	Monitoring Frequency
BH1	12.52388 °S 130.8753 °E	Biannually
BH2	12.52099 °S 130.8635 °E	Biannually
BH3	12.52204 LS 130.8637 °E	Biannually
BH4	12.52316 °S 130.8628 °E	Biannually
BH5	12.52424 °S 130.8638 °E	Biannually
BH6	12.52455 °S 130.8641 °E	Biannually
BH7	12.52558 °S 130.8641 °E	Biannually

5.1.3 Assessment Framework

Under the DLNG Groundwater Monitoring Plan, no groundwater specific water quality objectives are nominated or are specified in the Licence. Therefore, to assess environmental risk a tiered assessment framework has been developed and includes the following three steps:

- Step 1 – Irrigation discharge quality assessment: comparison of the irrigation discharge (monthly 2020 and 2021 and 2021 annual average) against the EPL 217-02 Table 2 of Appendix B, the modelled ammonium nitrogen trigger value and the irrigation discharge historical (2009-2019) 80th percentile.
- Step 2 – Groundwater quality trend assessment: evaluate change in groundwater from historical conditions by analysing trends within each bore. This level of assessment includes a comparison of the 2021 groundwater quality against the DHWQO, the modelled ammonium nitrogen trigger value and the groundwater historical (2015-2019) 80th percentile.
- Step 3 – Environmental risk assessment: analyse trends and correlations between each bore and the irrigation discharge. This level of assessment includes statistics and further assessment to confirm potential environmental risk from the irrigation discharge.

A highly conservative trigger value of 9.0 mg/L for ammonium nitrogen in groundwater applied at the groundwater network boundary was developed using a spreadsheet fate and transport model (CDM Smith, 2019). The model uses the Ogata Banks calculation, and allows for the determination of the maximum concentration of ammonium nitrogen to meet the DHWQO if discharged to the harbour based on distance and time travelled and the subsequent dispersion and degradation of ammonium nitrogen.

The assessment framework is illustrated in Figure 5-2 and the investigation trigger values for compliance and the assessment of impacts to groundwater are represented in Table 5-2 and Table 5-3.

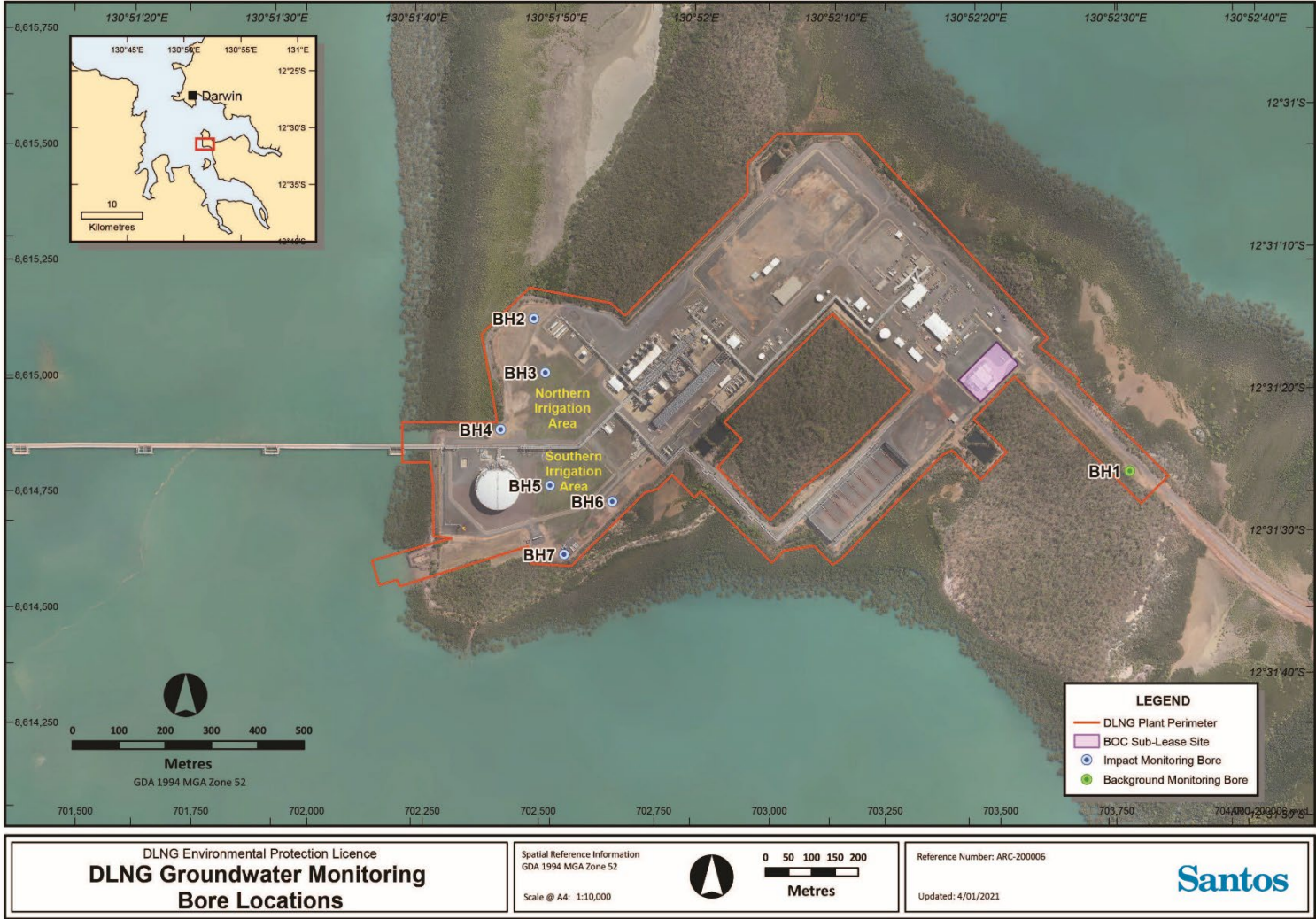


Figure 5-1 Groundwater monitoring program bore locations

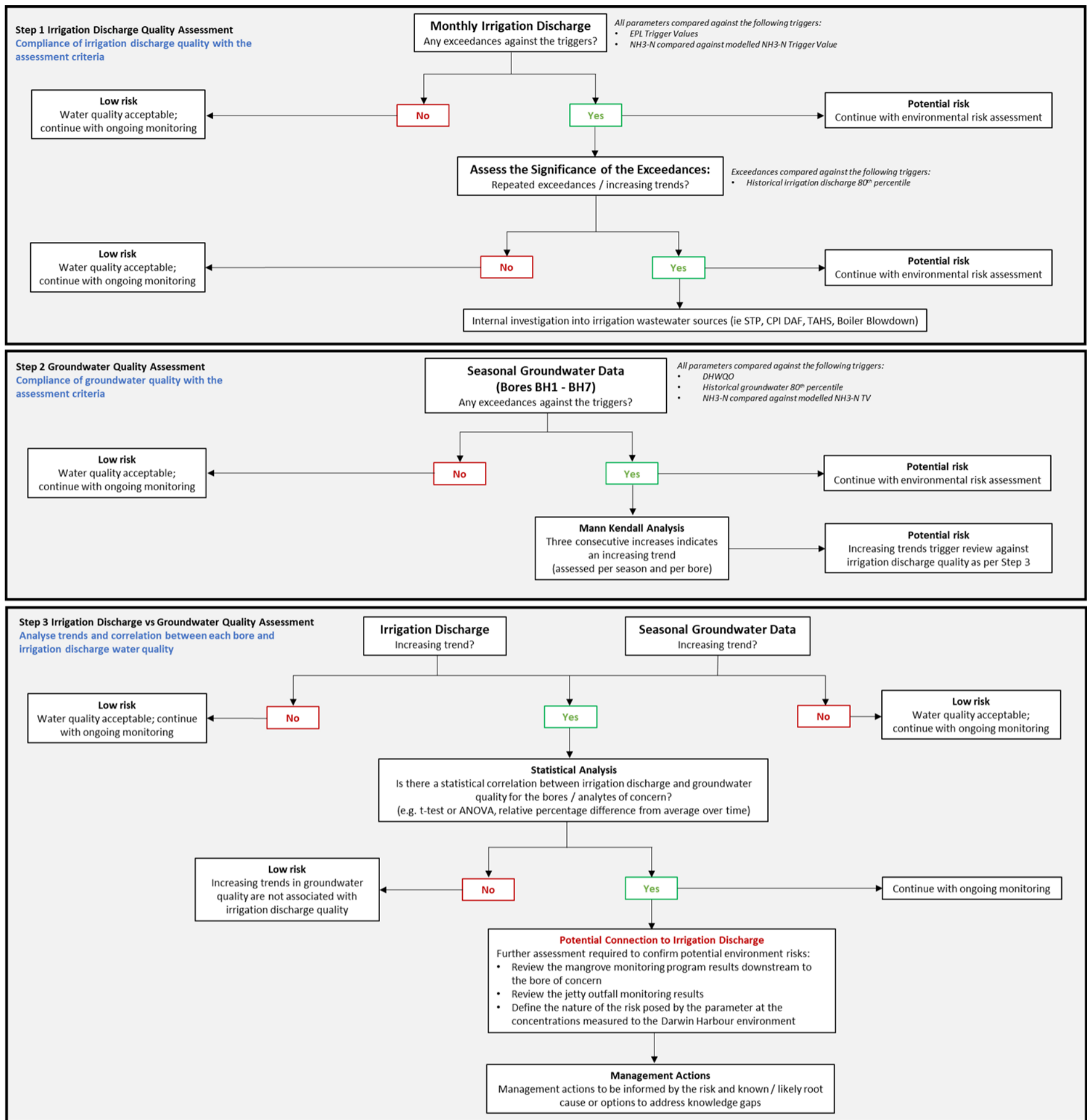


Figure 5-2 Assessment framework of impact to groundwater from irrigation discharge

Table 5-2 Assessment for irrigation discharge

Parameter	Units	EPL 217-02 Irrigation Discharge TV	Modelled TV	Historical 80 th Percentile (2009-2019)
pH	pH units	7-8.5 ¹	N/A	7.0-7.84
Total Dissolved Solids (TDS)	mg/L	<750 ¹	N/A	<182.2
Total Suspended Solids (TSS)	mg/L	≤30 ¹	N/A	<14.0
Total Nitrogen (TN)	mg/L	≤40 ¹	N/A	<13.40
Total Phosphorus (TP)	mg/L	≤10 ¹	N/A	<2.16
Ammonium nitrogen (NH ₄ -N)	mg/L	<0.02 ¹	<9.0	<6.882
Nitrate (NO ₃)	mg/L	<0.017 ¹	N/A	<2.126
Nitrite (NO ₂)	mg/L	<0.017 ¹	N/A	<0.163
Dissolved reactive phosphorus (PO ₄ -P)	mg/L	<0.005 ¹	N/A	<1.326
<i>E. coli</i>	MNP/100ml	≤75	N/A	<16.80
<i>Enterococci</i>	MNP/100ml	50	N/A	<41.00
Biological Oxygen Demand	mg/L	25	N/A	<26.00
Arsenic ³	µg/L	<10 ²	N/A	<1.0
Cadmium ³	µg/L	<3.2 ²	N/A	<0.1
Chromium ³	µg/L	<10 ²	N/A	<1.0
Copper ³	µg/L	<69 ²	N/A	<41.4
Iron ³	µg/L	1,300 ²	N/A	<268.0
Lead ³	µg/L	<10 ²	N/A	<1.0
Manganese ³	µg/L	15,500 ²	N/A	<42.0
Mercury ³	µg/L	<0.1 ²	N/A	<0.1
Nickel ³	µg/L	<290 ²	N/A	<2.0
Zinc ³	µg/L	<1,780 ²	N/A	<25.8
Silver ³	µg/L	<1.4 ²	N/A	<1.0
BTEX	µg/L	<700 ¹	N/A	<3.0
Total Petroleum Hydrocarbons (TPH)	mg/L	<6 ¹	N/A	<1

Note 1: Derived from Northern Territory Government (NTG, 2010) Water Quality Objectives for the Darwin Harbour Region – Background Document as well as the Australian and New Zealand Environment Conservation Council (ANZECC/ARMCANZ, 2000) Australian and New Zealand Guidelines for Marine and Freshwater quality guideline document for metals.

Note 2: Interim Trigger Values from EPL 217-02 developed by using the 80th percentile value of the current groundwater reference well (BH1) dataset, which comprises of 16 data points including 11 consecutive data points collected as part of the development of the final site specific trigger values.

Note 3: Represents dissolved fraction.

Note 4: pH assessment based on 20th and 80th percentile

Table 5-3 Assessment for groundwater quality – Darwin harbour water quality objectives and groundwater historical 80th percentile trigger values

Parameters	Units	DHWQO ₁	Modelled Trigger Values	80th percentile 2015-2020 Wet and Dry Season ⁵													
				BH1	BH1	BH2	BH2	BH3	BH3	BH4	BH4	BH5	BH5	BH6	BH6	BH7	BH7
pH (Field)	-	7-8.5	N/A	4.13 ² 4.51	4.22 ² 5.14	6.40 ² 6.54	6.30 ² 6.53	4.40 ² 5.76	4.62 ² 5.95	4.31 ² 5.19	4.09 ² 5.50	6.13 ² 6.63	5.71 ² 6.46	5.07 ² 5.31	5.35 ² 5.55	6.01 ² 6.14	6.09 ² 6.27
Dissolved Oxygen (Field)	%	80-100	N/A	63.81	60.85	50.68	33.32	55.96	31.50	50.15	38.38	79.02	60.42	45.10	24.10	52.27	27.37
Total Suspended Solids (TSS)	mg/L	<10	N/A	7,976.0	571.8	7,264	6,300.0	16,540.0	7,342.0	17,184.0	2,632.0	14,048.0	13,740.0	2,644.8	3,796.0	34,280.0	1,660.0
Total Nitrogen	mg/L	<0.27	N/A	2.040	1.020	26.80 0	30.240	1.140	4.320	2.020	0.620	2.860	2.860	0.780	1.100	5.960	5.840
Ammonia as N (NH ₃ -N)	mg/L	<0.02	<9	0.640	0.180	27.30 0	23.640	0.430	0.382	0.034	0.039	0.100	0.100	0.396	0.676	3.420	3.204
Nitrate as N (NO ₃) ³	mg/L	<0.02 ³	N/A	0.638	0.478	0.02	0.022	0.024	0.934	0.03	0.034	1.088	1.672	0.038	0.034	0.050	0.040
Reactive phosphorus (PO ₄ -P)	mg/L	<0.005	N/A	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
Total Phosphorus (TP)	mg/L	<0.02	N/A	1.348	0.30	0.962	1.674	4.108	2.396	2.038	0.464	0.48	0.972	0.092	0.176	0.81	0.134
<i>E. coli</i>	MNP/100ml	≤200	N/A	2	2	2	2	2	22	2	2	2	2	2	2	2	2
<i>Enterococci</i>	MNP/100ml	≤50	N/A	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cadmium ⁴	mg/L	<0.0055	N/A	0.0033	0.0006	0.0012	0.001	0.0001	0.0002	0.0001	0.0001	0.0002	0.0002	0.0011	0.0004	0.0002	0.0001
Chromium (III) ⁴	mg/L	<0.0274	N/A	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Chromium (VI) ⁴	mg/L	<0.0044	N/A	0.028	0.01	0.028	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.018	0.010	0.010
Copper ⁴	mg/L	<0.0013	N/A	0.077	0.006	0.01	0.013	0.004	0.008	0.005	0.01	0.001	0.001	0.003	0.002	0.001	0.001
Lead ⁴	mg/L	<0.0044	N/A	0.011	0.001	0.010	0.010	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001
Mercury ⁴	mg/L	<0.0004	N/A	0.0003	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel ⁴	mg/L	<0.07	N/A	0.289	0.054	0.017	0.027	0.010	0.009	0.003	0.002	0.018	0.035	0.014	0.007	0.01	0.004
Zinc ⁴	mg/L	<0.015	N/A	1.684	0.573	0.050	0.426	0.043	0.129	0.069	0.056	0.021	0.131	0.030	0.435	0.016	0.164
Silver ⁴	mg/L	<0.0014	N/A	0.010	0.001	0.010	0.010	0.001	0.001	0.001	0.001	0.001	0.046	0.001	0.006	0.001	0.005
Benzene	mg/L	<0.700	N/A	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1: DHWQO Trigger Values for marine and estuarine systems - Mid estuary.

Note 2: 20th percentile applied only for pH.

Note 3: No DHWQO trigger value is determined for Nitrite (NO₂-N), however NO_x (nitrite + nitrate) in the groundwater is mainly composed of nitrate. The trigger value for NO_x was used for NO₃-N.

Note 4: Represents dissolved fraction.

Note 5: Grey shaded cells indicate the wet seasons data from 2015 to 2019. Yellow shaded cells indicate the dry season data from 2015 to 2019.

5.1.4 Monitoring Results and Discussion

The results of the 2021 groundwater monitoring program are discussed in the following sections with the 2016-2021 groundwater quality dataset provided in Attachment D.

Groundwater Level and Flow Direction

The standing water level (SWL) was measured in the field for each bore by recording the depth to groundwater from the top of the PVC casing. Groundwater elevation was then corrected to mAHD using survey data.

Groundwater levels were also monitored using three data loggers:

- May 2020 to April 2021 – monitoring wells BH4, BH5 and BH6.
- April 2021 to August 2021 – monitoring wells BH1, BH3 and BH5.

Key findings from groundwater level data includes:

- The groundwater elevations are mostly higher in 2021 than those measured for 2020. This is likely due to the significantly wetter wet season experienced for 2020/21 (40% higher than the 2019/20 season). However, as with previous years; there is a distinct seasonal trend in response to the wet and dry season, with significantly higher groundwater levels during the wet season (Figure 5-3). During the wet season, a groundwater mound forms under the area of irrigation and groundwater flows radially away from these areas eventually discharging to Darwin Harbour. The mound then dissipates during the dry season. The rise and fall of groundwater levels appears to be predominantly influenced by rainfall driven recharge and not irrigation which occurs all year round. The rainfall induced mounding is likely due to the irrigation area having no substantial vegetation on it allowing direct infiltration into the ground during the wet season as opposed to the surrounding areas.

This is further supported by the groundwater data loggers; the limited variation and delay in water level response suggests limited mixing and tidal effects of groundwater within the irrigation field. This is an important insight and confirms there is minimal tidal flushing effect and that the dominant feature remains seasonal recharge in the wet season and groundwater recession in the dry season. This suggests that wet season period presents a higher risk for flushing of contaminants to the Darwin Harbour noting that there are also increases in dilution potential.

- Hydrograph records for Bore BH3 indicate that the groundwater level may be responding to entry of surface water, particularly during the wet season, and as such may not fully represent groundwater quality. Investigations into groundwater levels and well integrity are ongoing.

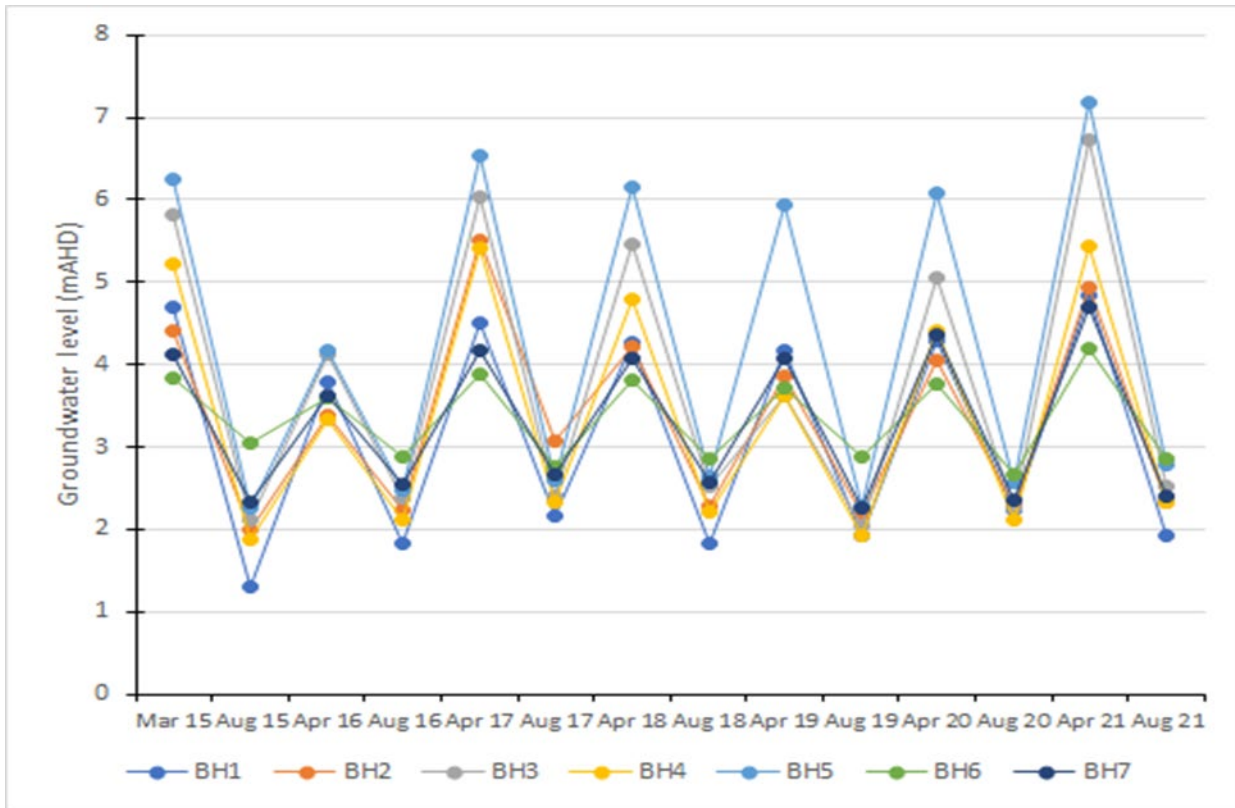


Figure 5-3 Groundwater elevations

Groundwater Quality Field Parameters

In addition to visual and olfactory observations, the following parameters were observed or measured for all bores: electrical conductivity, pH, redox potential and dissolved oxygen. Key findings from groundwater field parameters include:

- The field parameters during the 2021 monitoring event are generally consistent with the previous records with the following main observations:
- **pH:** all bores excluding BH7 continue to display a reducing trend in pH with BH6 showing a largest variation. These results are likely to be related with Acid Sulphate Soils (ASS) impact (ERM, 2019) resulting in an overall increase in metal concentrations in these bores. The source of these changes remains unknown but are not considered to be related with the DLNG operations including the irrigation discharge.
- **Electrical Conductivity (EC):** A decreasing trend was observed for all wells during the wet and dry season. The variations in EC observed in the 2016-2021 groundwater dataset appear to be linked to the geochemistry, transmissivity and relative location of each well to the perimeter of site and therefore saline influences. Wells located either within or near to the Irrigation Area demonstrate lower electrical conductivity levels.
- **Oxidation Reduction Potential (ORP):** Oxidation reduction potential (ORP) ranges from -62.8. mV (BH7) to 265.6 mV (BH1) during the 2021 groundwater monitoring events. ORP at wells BH2 and BH7 tend to be predominantly negative and share the same trend over time, with the exception of BH7 since August 2019. All other wells tend to have a positive ORP.
- **Dissolved Oxygen (DO):** DO in groundwater ranges from 19.0 % (BH3) to 44.0 % (BH5) during the 2021 groundwater monitoring events, indicating varying aerobic conditions

across the site. DO concentrations in all monitoring wells measured during the 2021 dry seasons show an upward trend from the dry season in 2010 and a downward trend overall when compared against the readings taken in August 2015.

Graphs illustrating the historical field water quality measurements for all in-situ parameters are provided in Figure 5-4.

Visual and olfactory observations were recorded during the purging and groundwater sampling program. Apart from BH2 and BH7, no odours or sheens were recorded. A sulphur odour commonly associated with estuarine and marine anoxic saturated zones was noted in the purged groundwater from BH2 and BH7 which are located within coastal boundaries. These observations are consistent with previous monitoring events, noting that BH1 and BH3 has in the past reported a sulphur smell.

The results of field water quality measurements for the 2021 monitoring program were compared against the DHWQO TV (Table 5-4) and the groundwater historical 80th percentile (Table 5-5). When compared against the assessment framework, pH and dissolved oxygen conditions of groundwater exceeded the DHWQO TV and all parameters exceeded the groundwater historical 80th percentile at various bores.

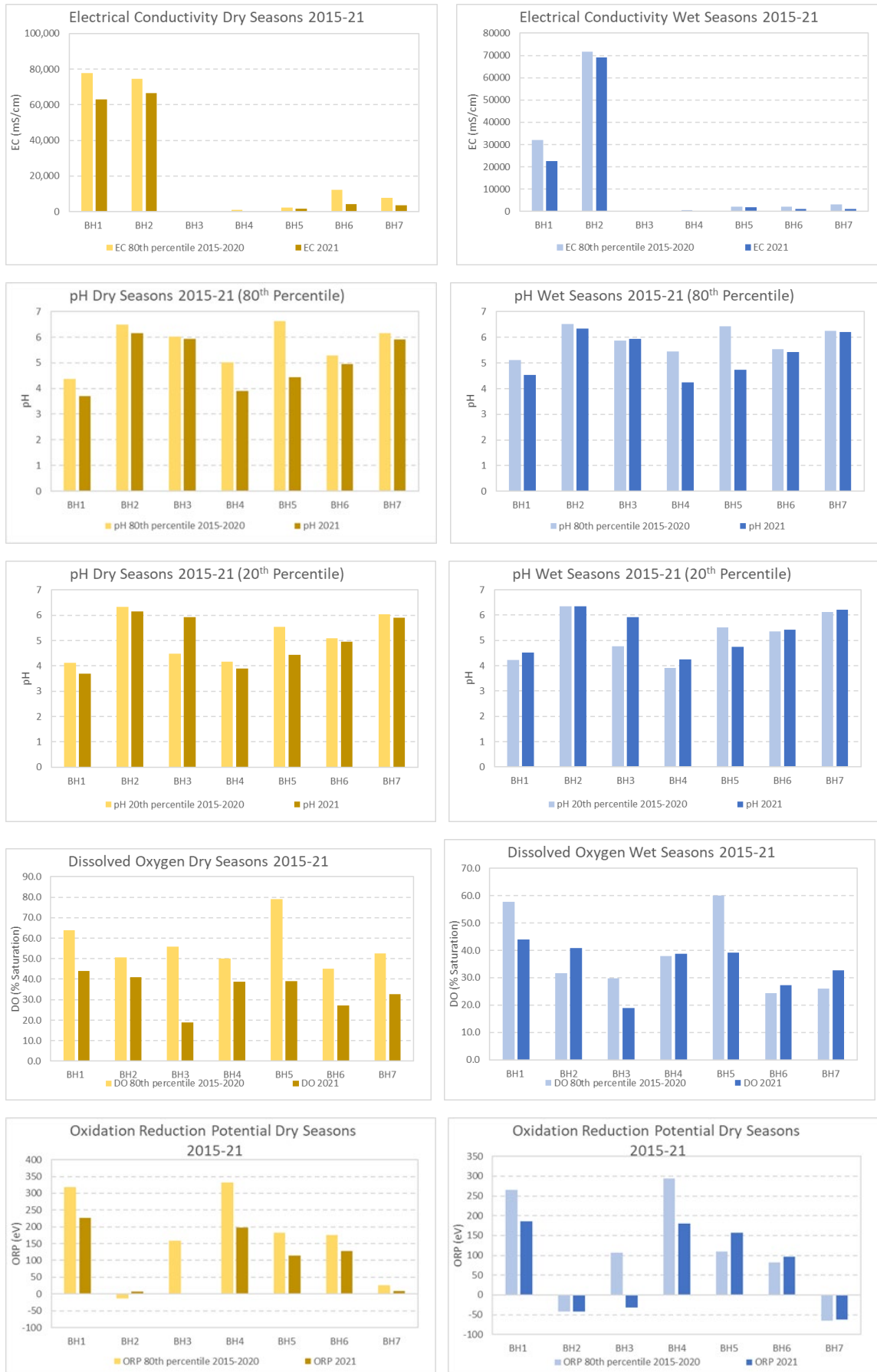


Figure 5-4 Field groundwater parameter trends

Table 5-4 Field groundwater parameter

Monitoring Bore	Date	EC (µS/cm)	pH	Redox Potential (mV)	Temperature	DO (% Saturation)
DHWQO		NA	7-8.5	NA	NA	80-100 %
BH1	23/04/2021	22,665	4.53	185.8	31.0	38.4
	18/08/2021	62,930	3.7	226.6	31.1	44.0
BH2	07/04/2021	68,992	6.35	-42.7	31.6	20.8
	11/08/2021	66,379	6.15	7.0	31.9	40.9
BH3	23/04/2021	177.4	5.93	-31.4	29.6	26.6
	10/08/2021	209.8	5.93	-1	29.3	19.0
BH4	07/04/2021	398.9	4.24	180.1	32.5	23.8
	11/08/2021	381.8	3.9	198.2	32.4	38.7
BH5	06/04/2021	1,737	4.74	157.2	29.4	40.1
	11/08/2021	1,503	4.44	114	28.1	39.1
BH6	06/04/2021	1,074	5.42	96.8	32.9	20.5
	11/08/2021	4,154	4.95	127.3	32.8	27.2
BH7	06/04/2021	1,172	6.21	-62.8	32.1	23.8
	11/08/2021	3,704	5.91	9.3	31.2	32.8

Table 5-5 Water quality measurements wet and dry seasons 2015-2021 compared against groundwater historical 80th Percentiles

Wet Seasons 2015-2020										
Parameters	EC 80th percentile	EC	pH 20th percentile	pH Unit	pH 80th percentile	pH Unit	ORP 80th percentile	ORP	DO 80th percentile	Oxygen
	2015-2020	2021	2015-2020	2021	2015-2020	2021	2015-2020	2021	2015-2020	2021
Unit	(µS/cm)		pH Unit		pH Unit		mV		% Saturation	
BH1	32017	22,665	4.23	4.53	5.11	4.53	264.7	185.8	57.7	38.4
BH2	71706	68,992	6.34	6.35	6.53	6.35	-41.4	-42.7	31.6	20.8
BH3	245.5	177.4	4.78	5.93	5.88	5.93	107	-31.4	29.7	26.6
BH4	474	398.9	3.92	4.24	5.45	4.24	294.6	180.1	38.0	23.8
BH5	2050	1,737	5.52	4.74	6.43	4.74	108.8	157.2	60.0	40.1
BH6	2220	1,074	5.36	5.42	5.53	5.42	82.4	96.8	24.4	20.5
BH7	3213	1,172	6.13	6.21	6.25	6.21	-64.4	-62.8	26.0	23.8
Dry Seasons 2015-2020										
Parameters	EC 80th percentile	EC	pH 20th percentile	pH Unit	pH 80th percentile	pH Unit	ORP 80th percentile	ORP	DO 80th percentile	Oxygen
	2015-2020	2021	2015-2020	2021	2015-2020	2021	2015-2020	2021	2015-2020	2021
Unit	(µS/cm)		pH Unit		pH Unit		mV		% Saturation	
BH1	77,671	62,930	4.12	3.7	4.38	3.7	318.8	226.6	63.8	44
BH2	74,520	66,379	6.33	6.15	6.49	6.15	-13	7	50.7	40.9
BH3	340	209.8	4.49	5.93	6.03	5.93	158.9	-1	56.0	19
BH4	903	381.8	4.16	3.9	5.01	3.9	333	198.2	50.2	38.7
BH5	2,280	1,503	5.55	4.44	6.62	4.44	182	114	79.0	39.1
BH6	12,409	4,154	5.09	4.95	5.28	4.95	176.4	127.3	45.1	27.2
BH7	7,817	3,704	6.03	5.91	6.15	5.91	25.7	9.3	52.6	32.8

Groundwater Quality Laboratory Results

The analytical results for the 2021 biannual groundwater monitoring are presented below in line with the assessment framework outlined in Section 5.1.3.

Step 1: Irrigation Discharge Quality Assessment

Key findings from a review of the irrigation discharge water quality against the assessment framework include:

Irrigation discharge exceeded the assessment criteria for September 2020 to August 2021 (Licence trigger value for irrigation discharge, modelled trigger value and irrigation discharge historical 80th percentiles) for the following analytes and the results are summarised in Table 5-6 and Table 5-7:

- Electrical Conductivity was above the 80th Percentile for the dry season at four events in late 2020 and three times in 2021 there were no exceedances for the wet season 2021
- Total Suspended Solids exceeded the historical 80th Percentile from September 2020 through to Late March 2021 and then again from June through to September 2021 excluding on result. There were also seven exceedances of the EPL licence for the period.
- Ammonia as N did not exceed the historical 80th percentile however it exceeded the EPL Licence limits for all events in the period.
- pH was not recorded above the historical 80th percentile trigger values during the period however was outside the EPL Licence limits for 22 monitoring events mainly during 2021.
- Nitrate (as N) exceeded the compliance limit for one event in December 2020,
- Reactive Phosphorus as P exceeded the EPL compliance limit for all events in the period
- Phosphorus total (P2O5) exceeded the 80th percentile for one event in December 2020
- BOD Exceeded both the 80th Percentile and the EPL licence triggers for all events during the period.
- Copper exceeded both the EPL limit and the historical 80th percentile for one event in December 2020.
- Enterococci Exceeded both the EPL Licence trigger and 80th percentile for one event in November 2020
- Toluene exceeded the historical 80th Percentile for three events from September 2020 through to early January 2021.
- Turbidity exceeded the historical 80th percentile for two events in October 2020 and three events from May to August 2021. There were no exceedances within the wet season.
- Xylene Total exceeded the historical 80th percentile for October and November 2020. It was below the LOR for all other events.

Irrigation discharge water quality is discussed in further detail in Section 3.1.3.

Table 5-6 Step 1: Summary of irrigation discharge exceedances against the assessment criteria from September 2020-August 2021

Date Sampled / Analyte	Electrical Conductivity	Total Suspended Solids	Ammonia as N	pH	Nitrate (as N)	Reactive Phosphorus as P	Phosphorus total (P2O5)	BOD	Copper	Enterococci	Toluene	Turbidity	Xylene Total
Units	uS/cm	mg/L	mg/L	Units	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	µg/L	NTU	µg/L
EPL 217-02		30	0.02	7 - 8.5	0.017	0.005	10	25	0.069	50			
Modelled TV			9										
80 th percentile	272.8	14	6.264	7.8	2.402	2.34	1.742	24.8	0.04	41	0.5	15.98	1.5

Dry Season													
9/09/2020	288	4	1.06	7.18	<0.001	0.455	1.35	41	0.007	-	1.2	6.96	<1.5
22/09/2020	282	22	-	6.45	-	-	-	44	-	-	-	15.1	-
7/10/2020	257	73	0.975	7.12	0.002	0.201	1.06	41	0.005	10	0.6	21.1	1.6
19/10/2020	401	82	-	7.18	-	-	-	61	-	-	-	-	-
28/10/2020	275	61	-	7.06	-	-	-	66	-	-	-	21	-
Wet Season													
4/11/2020	251	48	1.91	6.97	<0.001	0.245	0.635	60	0.007	-	<0.5	15.6	3.5
11/11/2020	258	28	-	7.17	-	-	-	46	-	-	-	11	-
17/11/2020	-	-	-	-	-	-	-	120	-	213	-	-	-
25/11/2020	254	25	-	7.19	-	-	-	85	-	-	-	15.9	-
2/12/2020	233	35	1.76	7.04	0.024	0.232	3.91	100	0.098	20	<0.5	11.2	<1.5
3/12/2020	-	23	-	-	-	-	-	-	-	-	-	-	-
9/12/2020	228	28	-	7.07	-	-	-	97	-	20	-	13.8	-
16/12/2020	241	28	-	7.04	-	-	-	54	0.009	10	-	12.1	-
6/01/2021	222	28	0.496	7.03	0.002	0.013	0.445	190	0.006	<10	1	14.4	<1
20/01/2021	194	17	-	6.9	-	-	-	92	-	-	-	-	-
27/01/2021	173	22	-	6.8	-	-	-	120	-	-	-	-	-
3/02/2021	210	35	0.578	6.9	0.002	0.083	0.67	180	0.01	-	<0.5	15.6	<1.5
10/02/2021	-	27	-	6.84	-	-	-	130	-	-	-	-	-
17/02/2021	-	24	-	6.91	-	-	-	110	-	-	-	-	-
23/02/2021	-	16	-	7	-	-	-	160	-	-	-	-	-
3/03/2021	-	26	0.466	6.83	0.002	0.07	0.41	85	0.007	<10	<0.5	13.2	<1.5
10/03/2021	-	22	-	6.93	-	-	-	89	-	-	-	-	-
15/03/2021	-	24	-	6.93	-	-	-	110	-	-	-	-	-
24/03/2021	-	87	-	6.83	-	-	-	120	-	-	-	-	-
31/03/2021	-	6	-	7.22	-	-	-	140	-	-	-	-	-
7/04/2021	205	13	0.641	6.76	0.002	0.086	0.56	190	0.019	-	<2.5	12.3	<7.5
14/04/2021	-	11	-	6.27	-	-	-	-	-	-	-	-	-
21/04/2021	-	13	-	6.62	-	-	-	-	-	-	-	-	-
Dry Season													
5/05/2021	315	14	1.25	6.85	0.004	180	0.74	280	0.025	-	<0.5	18.1	<1.5
19/05/2021	-	12	-	6.83	-	-	-	210	-	-	-	-	-
2/06/2021	276	18	2.73	6.84	0.002	137	1.64	30	0.016	-	<0.5	24.4	<1
16/06/2021	-	8	-	7.09	-	-	-	-	-	-	-	-	-
7/07/2021	159	27	0.226	6.83	<0.001	8	0.36	100	0.006	-	<0.5	12.7	<1
19/07/2021	-	28	-	6.9	-	-	-	-	-	-	-	-	-
4/08/2021	387	17	0.121	6.99	0.002	287	1.56	190	0.013	-	<0.5	19.4	<1
16/08/2021	-	16	-	6.78	-	-	-	66	-	-	-	-	-

Notes
 Grey text denotes value less than LOR
 Blue cells denote concentrations exceeds the EPL 217-02 TV
 Red text denotes values exceeds the historical 80th percentile of groundwater based on data since 2015 to 2020

Step 1 Irrigation Water Assessment
Compliance of Irrigation Water against:

- EPL 217-02
- Modelled NH₃-N TV
- Irrigation Water Historical 80th percentile



Irrigation Water (Sep 2020 – April 2020) VS EPL 217-02/ Modelled NH ₃ -N TV		Irrigation Water (Sep 2020 – August 2021) VS Irrigation Water Historical 80 th percentile (Oct 2009 – Aug 2020)					
Cu	pH	Enterococci	BOD	NH ₃ -N	NO ₃ -N*	P2O5	TSS
1 Event > EPL 217-02	13 Events > EPL 217-02	1 Event > EPL 217-02	20 Events > EPL 217-02	6 Events > EPL 217-02	1 Event > EPL 217-02	0 Events > EPL 217-02	4 Events > EPL 217-02
0 Events > EPL 217-02	9 Events > EPL 217-02	0 Events > EPL 217-02	11 Events > EPL 217-02	6 Events > EPL 217-02	0 Events > EPL 217-02	0 Events > EPL 217-02	3 Events > EPL 217-02
				0 Events > Modelled NH ₃ -N TV			
				0 Events > Modelled NH ₃ -N TV			
1 Event > 80 th percentile	0 Events > 80 th percentile	1 Event > 80 th percentile	20 Events > 80 th percentile	0 Events > 80 th percentile	0 Events > 80 th percentile	1 Event > 80 th percentile	18 Events > 80 th percentile
0 Events > 80 th percentile	0 Events > 80 th percentile	0 Events > 80 th percentile	11 Events > 80 th percentile	0 Events > 80 th percentile	0 Events > 80 th percentile	0 Events > 80 th percentile	9 Events > 80 th percentile

* No DHWQO trigger value is determined for Nitrite (NO₂-N), however NO_x (nitrite + nitrate) in the groundwater is mainly composed of nitrate. The trigger value for NO_x was used for NO₃-N.
 * Wet season = November to April, Dry season = May to October

Table 5-7 Summary of Step 1 results: Irrigation discharge water quality compared against the assessment criteria

Step 2: Groundwater Quality Trend

All groundwater parameters for samples collected during the 2021 GMEs (the period of record) have been compared against the groundwater assessment criteria (i.e. the DHWQO, modelled ammonia TV and the seasonal historical 80th percentile of each monitoring well). A total of 34 parameters fail the assessment criteria over the period of record including 14 parameters which exceed the DHWQOs, one well (BH2) which exceeds the modelled ammonia TV and 32 parameters which exceed the historical 80th percentile (2015 – 2020) during the 2021 GMEs.

Table 5-9 summarises where exceedances have been recorded against the DHWQO, modelled ammonia TV and/or the historical 80th percentiles. Note, parameters which do not exceed a TV or 80th percentile have been excluded. An illustration of the Step 2 risk assessment process is provided in Figure 5-5; for ease of interpretation, only those parameters which exceed both the DHWQO and modelled TV/80th percentile have been included in this figure.

Field parameters

Upon sampling of each monitoring well at the DLNG site, field parameters including electrical conductivity (EC), pH, oxidation reduction potential (ORP) and dissolved oxygen (DO) have been measured as a preliminary step to laboratory analysis. When compared against the groundwater assessment criteria the following can be concluded:

- pH (field) exceeds the DHWQOs in all wells for both wet and dry seasons.
- Temperature (BH2 Wet/Dry, BH1 Dry, BH4 Dry), redox potential (BH5 Wet, BH6 Wet, BH7 Wet, BH2 Dry) and pH (BH3 Wet) exceed the historical 80th percentile.
- No breach of the assessment criteria is noted for DO, EC and ORP.

The variations in EC observed throughout the groundwater monitoring network appear to be linked to the geochemistry, transmissivity and relative location of each well to the perimeter of site and therefore saline influences. Wells located either within or near to the Irrigation Area demonstrate lower electrical conductivity levels than those located within closer proximity to the harbour.

Microbiology

Elevated levels of Enterococci were detected within BH3 during the 2021 GMEs and triggered exceedance of the historic 80th percentile as well as the DHWQO (≤ 200 E.coli / 100 mL and ≤ 50 Enterococci / 100 mL).

The sample round conducted on 7 April 2021 returned concentrations of Enterococci and E.coli measuring 24,196 and 3,255 MPN/100mL at BH3 and <10 and 20 MPN/100mL at BH1 respectively. Due to the abnormally high readings, BH1 and BH3 were resampled on 23 April 2021 and returned concentrations below the LOR for E.coli at both monitoring wells. However, the resampled laboratory results reported persistent Enterococci concentrations in BH3 which exceeded the 80th percentile and DHWQO.

Following the August GME, one well (BH3) was resampled on 23 August 2021 after detection of elevated Enterococci measuring 17,329 MPN/100mL was initially recorded. As per the procedure undertaken during the April GME, the well was re-sampled and the sample was sent for re-analysis with concentrations of Enterococci notably decreasing to 3,255 MPN/100mL following the resampling event. No exceedances of E.coli occurred during the August GME.

Nutrients

The following nutrients failed the assessment criteria during the 2021 GMEs:

- Ammonia (BH1 Wet/Dry, BH2 Dry, BH3 Wet/Dry, BH4 Dry, BH5 Wet/Dry, BH6 Wet/Dry, BH7 Wet/Dry), nitrate (BH1 Wet/Dry, BH3 Wet, BH5 Wet/Dry), nitrite (BH1 Wet/Dry, BH3 Wet, BH5 Wet/Dry), reactive phosphorus (BH1 Dry, BH2 Wet, BH4 Wet/Dry, BH5 Wet/Dry), total nitrogen (BH1 Wet/Dry, BH2 Wet/Dry, BH3 Wet/Dry, BH5 Wet/Dry, BH6 Dry, BH7 Wet/Dry) and total phosphorus (BH1 – BH7 Wet/Dry) when compared against the DHWQO.
- Total phosphorus (BH6 Wet, BH7 Wet) Nitrate (BH5 Wet/Dry), nitrite (BH5 Wet/Dry), total nitrogen (BH3 Dry, BH5 Wet) and Total Kjeldahl Nitrogen (TKN) (BH3 Dry, BH6 Wet) when compared against the historical 80th percentile.
- Ammonia (BH2 Wet/Dry) when compared against the modelled ammonia TV.

Additional testing of nutrients using ultra-trace methods has been undertaken to ensure LORs remain below DHWQOs. Some LORs, however, were raised for a number of nutrients during the 2021 GMEs including nitrate, nitrite, nitrate and nitrite (NO_x-N), TKN and reactive phosphorus. Due to the LOR increases, some parameters exceed their respective DHWQO and are therefore, unable to be assessed within the risk assessment framework. Such parameters include nitrate and nitrite (NO_x-N) (BH5 Dry, BH7 Wet/Dry) and reactive phosphorus (BH2 Dry).

Petroleum Hydrocarbons

TRH, Total Petroleum Hydrocarbons (TPH), Benzene, Toluene, Ethylene, Xylene and Naphthalene (BTEXN) register below the LOR during the 2021 GMEs which is consistent with historical data.

Metals

The following metals failed the assessment criteria during the 2021 GMEs:

- Chromium (III + VI) (BH5 Wet), copper (BH1 Dry, BH3 Wet, BH5 Wet/Dry), nickel (BH1 Dry, BH5 Wet/Dry) and zinc (BH1 Wet/Dry, BH4 Wet/Dry, BH5 Wet/Dry) when compared against the DHWQO.
- Aluminium (BH4 Wet, BH5 Wet/Dry), arsenic (BH2 Dry, BH3 Wet, BH7 Wet), chromium (III + VI) (BH1 Wet, BH5 Wet, BH6 Wet), iron (BH2 Dry, BH4 Wet/Dry, BH5 Wet), lead (BH4 Wet), manganese (BH3 Dry, BH5 Wet/Dry, BH6 Wet), nickel (BH4 Wet/Dry, BH5 Wet/Dry), trivalent chromium (BH5 Wet) and zinc (BH4 Wet/Dry, BH5 Wet) when compared against the historical 80th percentile.

Due to high levels of TDS in BH1 and BH2 monitoring wells, the LOR of some heavy metals, namely trivalent and hexavalent chromium have been raised by the laboratory following the April and August 2021 GMEs respectively.

Although most of the LOR values remain below the assessment criteria, hexavalent chromium cannot be assessed in this framework as the LORs prior to April 2020 were above the assessment criteria (0.0044 mg/L) for most samples, meaning there aren't enough data points of this parameter to establish a trend. The LOR has been increased to 0.001 mg/L for samples measured following the April 2020 GME.

The Mann Kendall results for the parameters showing an increasing trend are presented in Table 5-8. In total, 15 groundwater parameters show an increasing trend from the data collected between April 2015 to August 2021.

The MK analysis identified a total of seven (7) parameters with an increasing trend including cadmium (BH5) and nickel (BH5) for the wet season and bicarbonate alkalinity (BH3), total alkalinity (BH3), copper (BH1), nickel (BH4), pH (BH3) and temperate (BH2) for the dry season. A decreasing trend is observed for pH (lab) which shows four consecutive decreases in a row at BH5 during the past four wet seasons.

No trend has been derived from the MK analysis for eight (8) parameters including ionic balance (BH2), manganese (BH2) and potassium (BH3) during the wet season and electrical conductivity (EC) (BH2), field redox (BH2), iron (BH4), temperate (BH2) and field TDS (BH2) during the dry season, despite these parameters having increased four consecutive times over their respective seasons. The 2020 results suggested the reason the MK analysis returned a 'non detect' trend might be due to the limited number of data points within each seasonal dataset rather than the MK analysis returning a 'no trend' result. Verification of the 2021 results following the MK analysis, however, demonstrates the seasonal dataset for almost all parameters (excluding silver, dissolved oxygen, E. coli and Enterococci) is now statistically significant with enough data points for the MK analysis to calculate a trend.

Table 5-8 2021 Tier Assessment Summary for Groundwater Parameters with an Increasing ^[1] Trend

Season	Parameter (Mg/L)	Location	Min	Max	Mann Kendal Trend	General Trend ^[2]	DHWQO	80 th Percentile
Wet Season	Cadmium	BH5	0.0001	0.00042	Increasing	Variable	Below Criteria	Above Criteria
	Ionic Balance (%)	BH2	1.4	8.59	No Trend	4 Increasing	No Criteria	Above Criteria
	Manganese	BH2	5.72	97.3	No Trend	4 Increasing	No Criteria	Below Criteria
	Nickel	BH5	0.001	0.254	Increasing	4 Increasing	Above Criteria	Above Criteria
	Potassium	BH3	1	7.3	No Trend	4 Increasing	No Criteria	Above Criteria
	Temperate (Field)	BH2	30.8	32.4	No Trend	4 Increasing	No Criteria	Above Criteria
Dry Season	Alkalinity (Bicarbonate)	BH3	1	46	Increasing	Variable	No Criteria	Above Criteria
	Alkalinity (total)	BH3	1	46	Increasing	Variable	No Criteria	Above Criteria
	Copper	BH1	0.013	0.089	Increasing	Variable	Above Criteria	Below Criteria
	EC (field) (µS/cm)	BH2	45,608	74,700	No Trend	4 Increasing	No Criteria	Below Criteria
	Field Redox (mV)	BH2	-75.5	7	No Trend	4 Increasing	No Criteria	Above Criteria
	Iron	BH4	0.11	1.79	No Trend	4 Increasing	No Criteria	Above Criteria
	Nickel	BH5	0.001	0.104	No Trend	4 Increasing	Above Criteria	Above Criteria
		BH4	0.002	0.0077	Increasing	Variable	Below Criteria	Above Criteria
	Nitrogen (Total)	BH5	0.91	3.1	No Trend	4 Increasing	Above Criteria	Below Criteria
	pH (Lab)	BH3	4.23	6.55	Increasing	Variable	Below Range	Above Range
		BH5	5.5	7.34	Decreasing	4 Decreasing	Below Range	Below Range
	TDS (Field)	BH2	29,640	48,295	No Trend	4 Increasing	No Criteria	Below Criteria
Temperate (Field)	BH2	28.9	31.9	Increasing	4 Increasing	No Criteria	Above Criteria	

Notes:

1. Decreasing and increasing trend for pH
2. Variable trend denotes not four consecutive increasing results

Table 5-9 Step 2 – Summary of Groundwater Exceedances from the April and August 2021 GMEs

Sample ID	Sampled Date	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (total) as CaCO3	Ammonia as N	Aluminium (filtered)	Arsenic (filtered)	Cadmium (filtered)	Chromium (III+VI) (filtered)	Copper (filtered)	Lead (filtered)	Manganese (filtered)	Nickel (filtered)	Zinc (filtered)	Iron (filtered)	Chromium (Trivalent) (filtered)	Temp (Field)	Redox Potential (Field)	Enterococci	pH (Field)	Anions Total	Cations Total	Ionic Balance	Magnesium (filtered)	Potassium (filtered)	Nitrate (as N)	Nitrite + Nitrate as N	Dissolved Oxygen	pH (Lab)	Reactive Phosphorus as P (filtered)	Sulfate as SO4 - Turbidimetric (filtered)	Total Suspended Solids	Kjeldahl Nitrogen Total	TDS	Nitrogen (Total)	Phosphorus (total)	
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	oC	mV	MPN /100mL	-	meq/L	meq/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
DHWQO				0.02				0.0044	0.0013	0.0044		0.07	0.015				50	7-8.5							0.02	0.02		7-8.5	0.005		10				0.27	0.02
Modelled TV				9																																

Wet Season																																			
BH1	7/04/2021	7	7	0.025	0.026	<0.0002	0.00006	0.0032	0.0006	0.0002	1.66	0.008	0.04	0.096	0.002	31	185.8	<10	4.53	18.5	18.2	0.79	42	14	0.032	0.032	4.7	5.94	0.004	113	776	0.25	1250	0.28	0.205
80th Percentile		10	10	10	0.368	0.002	0.0006	0.001	0.008	0.001	5.57	0.06	0.386	1.1	0.01	31.3	264.7	2	5.11	174	223	9.74	400	60	0.44	0.36	6.7	5.7	0.018	733	735	0.68	21629.4	1	0.41
BH2	7/04/2021	205	205	13.8	0.005	0.0331	-	0.0024	<0.001	0.0004	84.6	0.0128	0.007	7.07	<0.010#1	31.6	-42.7	<10	6.35	384	456	8.59	928	252	0.017	0.017	6.6	7.25	0.014	893	758	15.4	24100	15.4	0.061
80th Percentile		645	645	19.8	3.316	0.12	0.001	0.01	0.025	0.01	95	0.025	0.058	45.7	0.01	31.5	-41.4	2	6.53	765	871	4.962	1890	477	0.03	0.05	4.6	7.19	0.018	3280	3760	21.3	48843	21.3	1.5
BH3	7/04/2021	24	24	0.284	0.072	0.0073	<0.00005	0.0003	0.0023	0.0008	0.118	0.0008	0.007	0.654	<0.001	29.6	-31.4	5,630	5.93	1.05	0.98	-	3	7	0.034	0.044	4	6.31	0.003	10	4,790	1.97	323	2.01	0.759
80th Percentile		28	28	28	0.282	0.006	0.0002	0.001	0.008	0.001	0.17	0.008	0.034	0.79	0.01	30	107	20	5.88	1.57	1.5	70.718	4	5	0.38	0.236	5.9	6.4	0.026	12	6940	3.68	119.24	4	1.76
BH4	7/04/2021	<1	<1	0.012	0.852	0.004	<0.00005	0.0006	0.0009	0.0017	0.218	0.0039	0.029	1.14	<0.001	32.5	180.1	<10	4.24	3.19	3.03	2.52	9	5	0.004	0.004	4.3	4.52	0.008	38	538	0.03	236	0.03	0.076
80th Percentile		20	20	20	0.81	0.008	0.0001	0.001	0.007	0.001	0.27	0.002	0.018	0.76	0.01	33.1	294.6	2	5.45	2.94	3.08	4.098	10	4	0.03	0.05	6.7	5.7	0.018	31	1850	0.44	289.9	0.6	0.37
BH5	6/04/2021	2	2	0.052	0.26	0.0009	0.00042	0.0914	0.0094	0.0004	14.5	0.254	0.187	0.564	0.085	29.4	157.2	<10	4.74	16.4	14.4	6.44	25	2	2.91	2.91	6.7	5.5	0.018	82	434	0.6	978	3.51	0.156
80th Percentile		99	99	99	0.14	0.002	0.0002	0.001	0.001	0.001	7.43	0.045	0.083	0.23	0.01	30.6	108.8	2	6.43	16.8	14.1	14.796	43	6	2.36	2.376	5.2	6.78	0.018	74	13600	0.86	1152.9	3.1	0.61
BH6	6/04/2021	14	14	0.409	0.013	0.0012	0.00005	0.002	<0.0005	0.0003	10.2	0.0036	0.01	4.83	0.002	32.9	96.8	<10	5.42	10.6	8.76	9.44	22	7	0.008	0.008	5.9	5.88	0.003	121	1,960	0.92	632	0.93	0.55
80th Percentile		33	33	33	0.074	0.002	0.0002	0.001	0.002	0.001	7.5	0.006	0.019	14.9	0.01	34.2	82.4	2	5.53	10.7	10.2	3.45	120	21	0.02	0.038	5.4	6.1	0.018	146	3100	0.76	1150.6	1.1	0.1
BH7	6/04/2021	60	60	2.17	0.014	0.0023	<0.00005	0.0009	<0.0005	<0.0001	30.2	0.0012	0.002	22.9	<0.001	32.1	-62.8	<10	6.21	10.8	9.82	4.74	24	10	<0.020#1	<0.020#1	4.2	6.32	0.002	151	65	1.98	607	1.98	0.272
80th Percentile		87	87	87	0.018	0.001	0.0001	0.001	0.001	0.001	58	0.004	0.008	65.9	0.01	33.3	-64.4	2	6.25	14.6	13	6.162	66	22	0.04	0.042	5.1	6.58	0.018	176	1200	3.32	1249.3	3.8	0.08
Dry Season																																			
BH1	10/08/2021	<1	<1	0.031	1.56	0.0049	0.0024	<0.0005	0.071	0.0021	12.8	0.227	1.05	0.407	<0.010#1	31.1	226.6	<10	3.7	676	698	1.59	1630	237	0.359	0.359	10.6	4.24	0.039	3080	183	0.15	45100	0.51	0.124
80th Percentile		20	20	0.6	1.788	0.01	0.0032	0.01	0.082	0.01	16.3	0.29	1.63	1.18	0.01	30.8	318.8	NA	4.38	574	651	8.334	2300	430	0.59	0.452	8.34	5.3	0.06	3050	7600	2	47749	2	0.9
BH2	11/08/2021	693	693	11.2	0.013	0.0515	<0.0002	<0.0005	<0.001	0.0007	27	0.0084	<0.005	4.73	<0.010#1	31.9	7	<10	6.15	677	709	2.27	1440	410	<0.002	<0.002	6.5	7.03	<0.010#1	2470	9040	15.5	47600	15.5	0.457
80th Percentile		629	629	27.3	0.1	0.016	0.001	0.01	0.01	0.01	39.5	0.017	0.05	3.49	0.01	30.7	-13	2	6.49	552	641	10.51	1830	510	0.02	0.026	8.84	7.48	0.06	1140	7100	27	45819	27.9	0.77
BH3	10/08/2021	46	46	1.62	<0.005	0.0186	<0.00005	<0.0002	0.0006	<0.0001	0.192	<0.0005	0.002	0.092	<0.001	29.3	-1	3255	5.93	1.63	1.82	-	6	7	<0.002	<0.002	8.4	6.24	0.005	7	1830	4.96	228	4.96	0.977
80th Percentile		35	35	0.38	0.504	0.032	0.0001	0.001	0.003	0.001	0.152	0.007	0.033	8.65	0.01	29.3	158.9	10	6.03	1.72	1.52	2.152	4	4	0.04	0.044	7.4	6.1	0.06	10	15600	1.06	163.8	1.1	3.97
BH4	10/08/2021	3	3	0.027	0.331	0.005	<0.00005	<0.0002	0.0009	0.001	0.21	0.0041	0.032	1.79	<0.001	32.4	198.2	<10	3.9	3.06	2.92	2.27	8	4	<0.002	<0.002	7.7	5.11	0.006	33	2560	0.04	237	0.04	0.038
80th Percentile		20	20	0.02	0.4224	0.01	0.0001	0.001	0.0054	0.001	0.28	0.004	0.134	1.04	0.01	32.3	333	10	5.01	3.19	3.22	1.718	11	4.7	0.03	0.038	7.34	5.37	0.06	42	9480	1.26	281.1	1.8	1.66
BH5	11/08/2021	<1	<1	0.032	0.224	0.0008	0.00028	0.001	0.0076	0.0002	8.48	0.104	0.154	<0.002	<0.001	28.1	114	<10	4.44	12.5	11.8	3.19	20	2	1.47	1.47	7.9	4.62	0.012	75	245	<0.05#1	782	1.5	0.082
80th Percentile		66	66	0.09	0.1152	0.003	0.0003	0.001	0.001	0.001	7.63	0.056	0.072	0.05	0.01	29.6	182	1	6.62	13	11.2	6.172	26	4	1.36	1.09	7.42	7.03	0.06	59	5860	1.18	1277.9	2.8	0.38
BH6	11/08/2021	17	17	0.149	0.012	0.0014	0.00012	<0.0002	0.001	0.0003	4.18	0.0067	0.014	7.95	<0.001	32.8	127.3	<10	4.95	23.8	27	6.34	57	14	<0.020#1	<0.020#1	6.4	5.64	<0.001	195	290	0.21	1490	0.21	0.083
80th Percentile		20	20	0.38	0.05	0.003	0.0011	0.001	0.0049	0.002	6.41	0.013	0.038	13.6	0.01	33.5	176.4	NA	5.28	29.8	35.3	17.38	370	46	0.05	0.05	7.42	5.96	0.06	222	956	0.58	5358.6	0.7	0.09
BH7	11/08/2021	59	59	2.09	<0.005	0.0047	0.00005	<0.0002	<0.0005	<0.0001	34.8	0.0045	0.007	15.5	<0.001	31.2	9.3	<10	5.91	53.4	46.3	7.14	95	38	<0.020#1	<0.020#1	8	6.15	0.01	342	256	1.62	3410	1.62	0.065
80th Percentile		69	69	3.4	0.014	0.007	0.0002	0.001	0.001	0.001	65	0.01	0.014	36.3	0.01	31.2	25.7	2	6.15	45.2	45.9	4.32	197	66	0.05	0.044	7.58	6.53	0.06	114	34000	5.12	4501	5.9	0.71

Step 2 Analyse trend within each well
Environmental risk assessment

Inputs Results Wet Season Dry Season

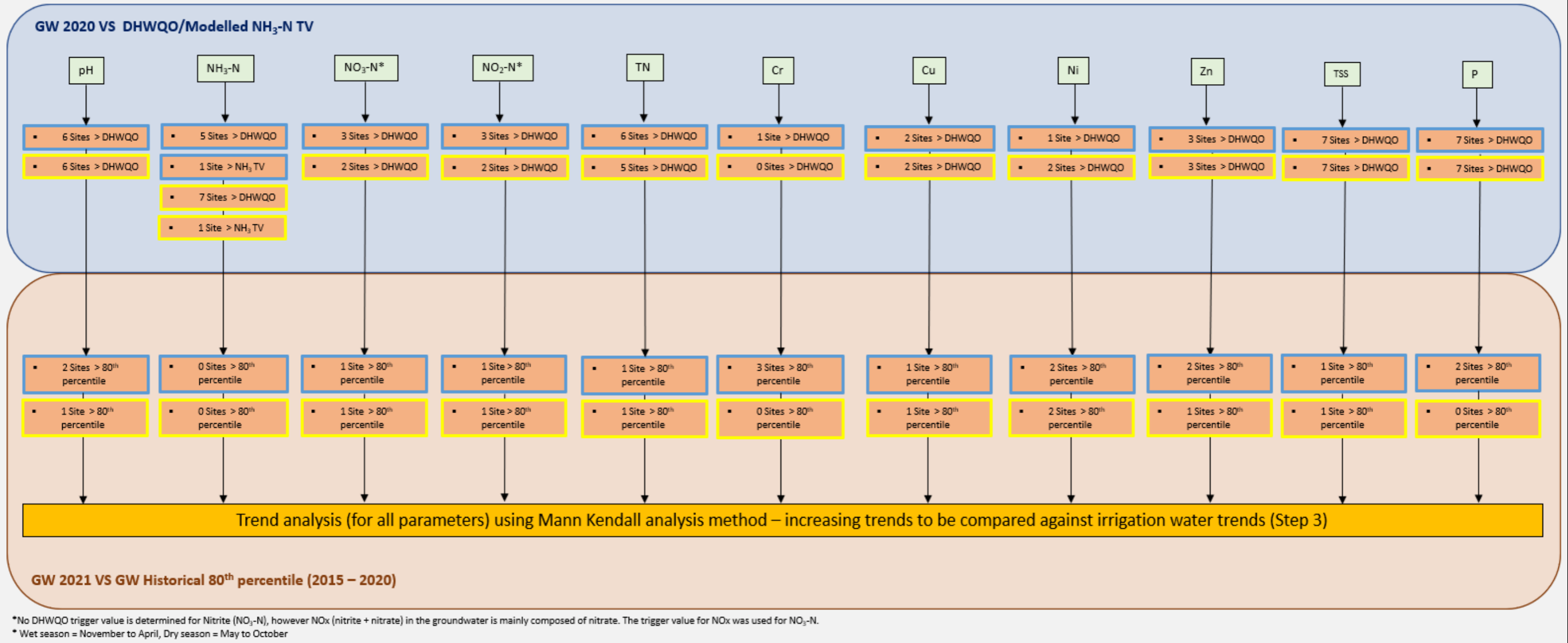


Figure 5-5 Summary of Step 2 Results: 2021 Groundwater Compared Against the DHWQO, Modelled NH₃-N and Groundwater Historical 80th percentiles (2015-2020)

Step 3: Environmental Risk Assessment: Correlation Between Groundwater and Irrigation Discharge

A total of 24 parameters from the irrigation water and groundwater show an increasing trend identified by either a MK trend or as four consecutive GME increases (Table 5-10). However, the analysis found no increasing trend (as a MK trend) exists for parameters shared between the irrigation water and the groundwater. Therefore, and in accordance with the risk assessment framework, no further statistical assessment was undertaken.

No MK trend for E. coli or Enterococci has been identified within groundwater despite notable exceedances over both 2021 GMEs and an increasing MK trend within the irrigation water. A review of the MK analysis results indicate there is insufficient microbiology data for the MK analysis to calculate a trend, and as such, these bacteria cannot yet be assessed by the framework. Monitoring of microbiology in groundwater began in 2019 and further sample data is required for the seasonal datasets to be statistically robust.

Copper concentrations within BH1 during the dry season continue to show an increasing MK trend despite a decreasing trend of copper in irrigation water. It should be noted, BH1 is located outside of the irrigation area where influence from irrigation activities is considered unlikely.

Table 5-10 2021 Tier Assessment Summary for Irrigation and Groundwater Parameters with An Increasing Trend

Parameter (Mg/L)	Location	Season	Min	Max	Mann Kendal Trend	General Trend ^[1]	DHWQO	EPL-217-02	80 th Percentile
Alkalinity (Bicarbonate)	BH3	Dry Season	1	46	Increasing	Variable	No Criteria	-	Above Criteria
Alkalinity (total)	BH3	Dry Season	1	46	Increasing	Variable	No Criteria	-	Above Criteria
BOD	Irrigation Water	-	1	280	Increasing	Variable	-	Above Criteria	Above Criteria
Cadmium	BH5	Wet Season	0.0001	0.00042	Increasing	Variable	No Criteria	-	Above Criteria
Chloride	Irrigation Water	-	12.898	64.386	Increasing	Variable	-	No recent value	No recent value
Copper	BH1	Dry Season	0.013	0.089	Increasing	Variable	No Criteria	-	Below Criteria
E. Coli	Irrigation Water	-	0	24196	Increasing	Variable	-	Below LOR & Below Criteria	Below LOR & Below Criteria
EC (field)	BH2	Dry Season	45608	74700	No Trend	4 Increasing	No Criteria	-	Below Criteria
Enterococci	Irrigation Water	-	1	2420	Increasing	Variable	-	Above Criteria	Above Criteria
Field Redox	BH2	Dry Season	-75.5	7	No Trend	4 Increasing	No Criteria	-	Above Criteria
Ionic Balance	BH2	Wet Season	1.4	8.59	No Trend	4 Increasing	No Criteria	-	Above Criteria
Iron	Irrigation Water	-	0.025	3.6	Increasing	Variable	-	No recent value	No recent value
	BH4	Dry Season	0.11	1.79	No Trend	4 Increasing	No Criteria	-	Above Criteria
Kjeldahl Nitrogen Total	Irrigation Water	-	0.67	79.3	Increasing	4 Decreasing	-	No recent value	No recent value
Manganese	BH2	Wet Season	5.72	97.3	No Trend	4 Increasing	No Criteria	-	Below Criteria
Nickel	BH5	Dry Season	0.001	0.104	No Trend	4 Increasing	No Criteria	-	Above Criteria
	BH5	Wet Season	0.001	0.254	Increasing	4 Increasing	No Criteria	-	Above Criteria
	BH4	Dry Season	0.002	0.0077	Increasing	Variable	No Criteria	-	Above Criteria
Nitrogen (Total)	BH5	Dry Season	0.91	3.1	No Trend	4 Increasing	No Criteria	-	Below Criteria
pH (Lab)	BH3	Dry Season	4.23	6.55	Increasing	Variable	No Criteria	-	Above Range
	BH5	Wet Season	5.5	7.34	Decreasing	4 Decreasing	Below Range	-	Below Range
	Irrigation Water	-	5.7	8.41	Decreasing	Variable	-	Below Range	Below Range
Potassium	BH3	Wet Season	1	7.3	No Trend	4 Increasing	No Criteria	-	Above Criteria
	Irrigation Water	-	1.971	17.7	Increasing	Variable	-	No Criteria	No recent value
Sodium	Irrigation Water	-	3.379	27.225	Increasing	4 Increasing	-	No Criteria	No recent value
TDS (Field)	BH2	Dry Season	29640	48295	No Trend	4 Increasing	No Criteria	-	Below Criteria
Temperature (Field)	BH2	Wet Season	30.8	32.4	No Trend	4 Increasing	No Criteria	-	Above Criteria
	BH2	Dry Season	28.9	31.9	Increasing	4 Increasing	No Criteria	-	Above Criteria
TDS (Lab)	Irrigation Water	-	3.31	878	Increasing	Variable	-	No Criteria	No recent value
TSS	Irrigation Water	-	0	120	Increasing	Variable	-	Above Criteria	Above Criteria
Turbidity	Irrigation Water	-	0.37	62.8	Increasing	Variable	-	No Criteria	Above Criteria

Data Management and Quality Control

Groundwater samples were collected by qualified professional environmental consultants who followed standard quality control procedures. The data validation procedure employed in the assessment of the field and laboratory quality control data showed the field and laboratory results to be representative of the conditions at the sample locations at the time of sampling. While there were some exceedances in quality assurance targets noted it is possible that this was the result of variability in groundwater from within the monitoring wells due to the use of a bailer for groundwater sampling and not the result of laboratory inaccuracy. Therefore, it is concluded that overall the quality of the field and laboratory data produced is reliable for the purposes of this groundwater assessment.

Conclusions

Statistical assessment comparing the groundwater and irrigation water parameters using the Mann Kendal analysis (Step 3) identified no correlation between the groundwater and irrigation water quality, therefore overall, the data collected from the 2021 groundwater monitoring events demonstrate that current irrigation practices present a low environmental risk.

6.0 Certification

I Peter Kirkpatrick, Production - Manager DLNG, have reviewed this report and I confirm that to the best of my knowledge and ability all the information provided in the report is true and accurate.

7.0 List of Symbols and Acronyms

Ag	Silver	m ³	Cubic metres
AGI	Acid Gas Incinerator	mg/L	Milligrams per litre
AGV	Acid Gas Vent	mL	Millilitres
ANZECC	Australian and New Zealand Environment and Conservation Council	mm	Millimetre
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand	Mn	Manganese
As	Arsenic	Mol%	Mole % - a measure used to express gas compositions
ASS	Acid Sulphate Soils	MPN	Most probable number
BOD	Biological oxygen demand	MTPA	Million tonnes per annum
BTEX	Benzene, ethyl-benzene, toluene, xylene	MZ	Mixing zone
Cd	Cadmium	N	Nitrogen
CH ₄	Methane	N ₂ O	Nitrous oxide
Santos	Santos NA Darwin Pipeline Pty Ltd (Santos)	NATA	National Association of Testing Authorities
CO	Carbon monoxide	NEPM	National Environmental Protection Measure
CO ₂	Carbon dioxide	NGL	Natural gas liquids
CO _{2e}	Carbon dioxide equivalent	Ni	Nickel
CPI/DAFF	Corrugated plate interceptor/dissolved air filtration flotation	NO _x	Nitrogen oxides
Cr	Chromium	NRU	Nitrogen rejection unit
Cu	Copper	NSW	New South Wales
°C	Degrees Celsius	NT	Northern Territory of Australia
DHWQO	Darwin Harbour Water Quality Objectives	NTU	Nephelometric turbidity units
DLNG	Darwin liquefied natural gas facility	OEMP	Operations phase environmental management plan
DO	Dissolved oxygen	ORP	Oxidation reduction potential
DRP	Dissolved reactive phosphorous	PAH	Polycyclic aromatic hydrocarbons
EMP	Environmental management plan	Pb	Lead
EPA	Environmental Protection Authority	PIP	Performance Improvement Plan
the	Darwin LNG Environmental	PM _{2.5}	Particulate matter (with an aerodynamic diameter of less than 2.5 µm)
Licence	Protection Licence EPL217-02	PM ₁₀	Particulate matter (with an aerodynamic diameter of less than 10µm)
Fe	Iron	ppm	Parts per million
FSANZ	Food Standards Australia New Zealand	PWC	Power and Water Corporation
g	Grams	RO	Reverse osmosis
GEL	Generally Expected Levels	SO _x	Sulphur oxides
GHG	Greenhouse gas	SP	Sediment Pond
H ₂ S	Hydrogen Sulphide	STP	Sanitary treatment plant
Hg	Mercury	t	Tonnes
ISQG	Interim sediment quality guidelines	TN	Total nitrogen
kg	Kilograms	TP	Total phosphorus
kNm ³	Thousand normal cubic metres	TDS	Total dissolved solids
L	Litres	TPH	Total petroleum hydrocarbons
LNG	Liquefied natural gas	TRH	Total recoverable hydrocarbons
LPG	Liquid petroleum gas	TSS	Total suspended solids
LOR	Limit of Reporting	VOC	Volatile organic compounds
m	Metre	WMPC	NT Waste Management and Pollution Control Act
		Zn	Zinc

8.0 References

- Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. ANZECC & ARMCANZ, Canberra.
- Brocklehurst, P. and Edmeades, B., 1996. The Mangrove Communities of Darwin Harbour. Technical Report No. R96/7. Department of Lands, Planning and Environment, Darwin.
- CDM Smith, 2019. Darwin LNG Ammonia Fate and Transport Modelling, CDM Smith, Perth.
- CDM Smith, 2021 a DLNG Jetty Outfall Quarterly Monitoring Report –Q1 2021
- CDM Smith, 2021 b DLNG Jetty Outfall Quarterly Monitoring Report –Q2 2021
- CDM Smith, 2021 c DLNG Jetty Outfall Quarterly Monitoring Report –Q3 2021
- CDM Smith, 2021 d DLNG Jetty Outfall Quarterly Monitoring Report –Q4 2021
- CDM Smith, 2021e. Darwin LNG Mangrove Monitoring 2021 Annual Report. CDM Smith, Darwin.
- CDM Smith, 2021f. Darwin LNG Groundwater Interpretive Report 2021. CDM Smith, Darwin.
- Clark, M.W., McConchie, D., Lewis, D.W., Saenger, P., 1998. Redox stratification and heavy metal partitioning in Avicennia-dominated mangrove sediments: a geochemical model.
- Ektimo, 2021a. Emission Testing – DLNG, Quarter 1, 2021 Santos NA Darwin Pipeline Pty Ltd (DLNG). Ektimo, west Leederville WA
- Ektimo, 2021b. Emission Testing – DLNG, Quarter 2, 2021 Santos NA Darwin Pipeline Pty Ltd (DLNG). Ektimo, west Leederville WA
- Ektimo, 2021c. Emission Testing – DLNG, Quarter 3, 2021 Santos NA Darwin Pipeline Pty Ltd (DLNG). Ektimo, west Leederville WA
- Ektimo, 2022. Emission Testing – DLNG, Quarter 4, 2021 Santos NA Darwin Pipeline Pty Ltd (DLNG). Ektimo, west Leederville WA
- ERM, 2019. Groundwater Solute Trend Assessment, ERM, Perth.
- Katestone, 2022. Darwin LNG Annual Ambient Air Quality Monitoring Report 2020. Katestone, Brisbane.
- Metcalfe, K., 2007. The Biological Diversity, Recovery from Disturbance and Rehabilitation of Mangroves, Darwin Harbour, NT. Doctoral thesis, Charles Darwin University, Darwin.
- New South Wales Environmental Protection Authority, 2006. Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales. Department of Environment and Conservation NSW, Sydney.
- Northern Territory Environmental Protection Authority, 2016. Guidelines for Reporting on Environmental Monitoring. Environmental Protection Authority, Darwin.
- Peerzada, N., Eastbrook, C. and Guinea, M., 1990. Heavy metal concentration in Telescopium from Darwin Harbour, NT, Australia. Marine Pollution Bulletin 21(6): 307-308.
- Santos, 2021. Darwin LNG Annual Environmental Monitoring Report 2020

Silva, C.A.R., Lacerda, L.D., Rezende, C.E., 1990. Heavy Metal Reservoirs in a Red Mangrove Forest. *Biotropica* 22, 339–345.

URS, 2004. Darwin LNG Plant Mangrove Monitoring Programme 2003-04 Annual Report - Results of Mangrove Mapping; Surveillance and Groundwater Monitoring: and Sedimentation/Erosion Monitoring. URS Australia, Perth.



Attachment A - Irrigation, Jetty Outfall and Sediment Pond data



Attachment B – Mangrove Data



Attachment C – Stack Emission Data



Attachment D – Groundwater Data