Santos

Darwin LNG Annual Environmental Monitoring Report 2020

DLNG Annual Environmental Monitoring Report 2020

Santos

Licence Number:
EPL 217-02

Revision History

Revision	Date	Description	Preparer & Title	Reviewer & Title	Approver & Title
0	25 February 2020	Issued for Review	Jo-Anne Blunn Environmental Specialist	Leighton Randall Environmental Specialist	Beth English HSER Manager – Midstream

Authorisation and Certification

I [name and position below], 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.

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List of Symbols and Acronyms

Ag	Silver
AGI	Acid Gas Incinerator
AGV	Acid Gas Vent
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
As	Arsenic
ASS	Acid Sulphate Soils
BOD	Biological oxygen demand
BTEX	Benzene, ethyl-benzene, toluene, xylene
Cd	Cadmium
CH_4	Methane
Santos	Santos NA Darwin Pipeline Pty Ltd (Santos)
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPI/DAFF	Corrugated plate interceptor/dissolved air filtration flotation
Cr	Chromium
Cu	Copper
°C	Degrees Celsius
DHWQO	Darwin Harbour Water Quality Objectives
DLNG	Darwin liquefied natural gas facility
DO	Dissolved oxygen
DRP	Dissolved reactive phosphorous
EDI	Electrodeionisation
EMP	Environmental management plan
EPA	Environmental Protection Authority
EPP	Environmental Protection Policy
the Licence	Darwin LNG Environmental Protection Licence EPL217-02
Fe	Iron
FSANZ	Food Standards Australia New Zealand
g	Grams
GEL	Generally Expected Levels
GHG	Greenhouse gas
H_2S	Hydrogen Sulphide
Hg	Mercury
ISQG	Interim sediment quality guidelines
kg	Kilograms
kNm^3	Thousand normal cubic metres
L	Litres
LNG	Liquefied natural gas
LPG	Liquid petroleum gas
LOR	Limit of Reporting
m	Metre
m^3	Cubic metres
mg/dscm	milligrams / dry standard cubic meter.
mg/L	Milligrams per litre
MIL	Monitoring investigation limits
mL	Millilitres
mm	Millimetre
Mn	Manganese
Mol%	Mole % - a measure used to express gas compositions
MPN	Most probable number
MTPA	Million tonnes per annum
MZ	Mixing zone
N	Nitrogen
N_2O	Nitrous oxide
NATA	National Association of Testing Authorities
NEPM	National Environmental Protection Measure
NGER	National Greenhouse and Energy Reporting
NGGI	National greenhouse gas inventory
NGL	Natural gas liquids
Ni	Nickel
NO_x	Nitrogen oxides
NPI	National pollutant inventory
NRU	Nitrogen rejection unit
NSW	New South Wales
NT	Northern Territory of Australia
NTU	Nephelometric turbidity units
OEMP	Operations phase environmental management plan
ORP	Oxidation reduction potential
PAH	Polycyclic aromatic hydrocarbons
Pb	Lead
PIP	Performance Improvement Plan
PM_{10}	Particulate matter (with an aerodynamic diameter of less than 10µm)
ppm	Parts per million
PWC	Power and Water Corporation
RO	Reverse osmosis
SO_x	Sulphur oxides
SP	Sediment Pond
STP	Sanitary treatment plant
t	Tonnes
TN	Total nitrogen
TP	Total phosphorus
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
TSS	Total suspended solids
VOC	Volatile organic compounds
WMPC	NT Waste Management and Pollution Control Act
Zn	Zinc

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* 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 2019 and 31 December 2019. This report has been developed in line with Condition 81 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, 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
  - Greenhouse gas emissions.
- Discharges to land and surrounding environment, including:
  - Groundwater monitoring.

Monitoring results for each of these environmental monitoring programs is provided in this report. While not required by the Licence, Santos has also included monitoring information from greenhouse gas emissions from the DLNG facility.

Discharges to Water

- The irrigation discharge volume was lower in 2020 compared to previous years for various reasons; a trial relating to the boiler resulting in less contribution of boiler blowdown, maintenance on the irrigation holding tank T2903 and reduced personnel onsite in 2020 resulting in less contribution from the Sanitary Treatment Plant (STP).
- Speciated nutrients in irrigation discharge exceeded the Licence trigger values in 2020 resulting in a reportable non-conformance to the NT EPA. 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. The total nitrogen and total phosphorus results, which are better indicators of total nutrient load, did not exceed the Licence trigger values in 2020 and have a history of

compliance over the 2015-2020 monitoring period. A Licence amendment is proposed for 2021 to update the trigger values to better reflect the environmental risks.

- BOD and TSS exceeded the Licence trigger levels in late Q3 – Q4 2020 for irrigation discharge resulting in a reportable non-conformance to the NT EPA. This was due to a build up of biological material in the irrigation holding tank, corrugated plate interceptor/dissolved air filtration flotation (CPI DAFF) and STP. 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 Biological Oxygen Demand (BOD) and Total Suspended Solids (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.

- The jetty outfall discharge volume was the lowest annual discharge volume in the 2015-2020 period, primarily due to a reduction in losses from the steam system resulting in reduced demand for demineralisation water and the associated reject water production.

- Ammonium nitrogen and zinc are the key parameters of concern with concentrations in the jetty outfall discharge exceeding the Licence trigger value during the 2015-2020 period on a number of occasions. This did not trigger a reportable non-conformance to the NT EPA. With regards to the ammonium nitrogen, this is linked, in part, to the amine-based biocide used in the reverse osmosis plant. A biocide reduction trial was undertaken in 2019 which resulted in improvements to operational dosing practices which continued throughout 2020. This saw a temporary improvement in the effluent quality, however, ad hoc spikes in ammonium nitrogen continued.

  This is possibly due to improved performance of the electrodeionisation (EDI) cells in the demineralisation plant which were replaced at the end of 2019. A zero biocide dosing campaign is also being considered for Q1 2021. Likewise, the ad hoc spikes in zinc are likely due to concentration of low levels in the source water from the NT Power and Water Authority (POWA) through the demineralisation plant.

  The ammonium nitrogen and zinc exceedances did not trigger any reportable non-conformances to the NT EPA or translate to any Licence trigger value exceedances in the jetty outfall mixing zone in 2020. As such, the ammonium nitrogen and zinc are considered a low environmental risk.

- There were no occasions where the median concentration in the jetty outfall mixing zone exceeded both the reference site value and Licence trigger value for any other parameter, and as such there were no reportable non-conformances in 2020. The mixing zone 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.

- *E. coli* and turbidity exceeded the Licence trigger levels in Sediment Pond 1 and Sediment Pond 2 respectively resulting in reportable non-conformances to the NT EPA. The elevated concentrations can be attributed to the onset of the wet season and rainfall events carrying turbid water from the stormwater drainage network to the ponds and wildlife contributing faecal matter while sourcing freshwater from the ponds. These causes are primarily natural in original and not related to the operation of the DLNG facility.

- In 2020 there was an increasing trend in nutrients, microbiology and select heavy metal concentrations in the sediment pond discharge water quality. While higher than in 2019, the increasing trend is marginal with the 2020 averages for all parameters generally still meeting the Licence trigger values. The sources are also of natural origins, (ie vegetative matter and wildlife) rather than related to discharges from the DLNG facility. Zinc is the only exception to this and is a parameter of interest in sediments and biota downstream from Sediment Pond 1, thought to be linked to the greensands filter backwash discharge.

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.

- The results of the 2020 mangrove monitoring program indicate that mangrove forests around the DLNG facility remain in a stable, healthy condition. There is little evidence of anthropogenic impacts to mangroves, including from the sediment ponds, with most of the measured changes in mangrove health due to natural causes.
- Weak acid soluble concentrations of all metals analysed in sediments were below the ANZG (2018) DGV and GV-High trigger values at all sites except for the elevated zinc concentrations at site SP1 and SP1-A downstream of Sediment Pond 1. The scale of this influence appears to have been localised and confined to areas within the DLNG Approved Disturbance Boundary. In consideration of the broader mangrove metrics that demonstrate system health, the occurrence of these concentrations is considered low risk.
- Concentrations of metals in mudwhelks were below the Food Standards Australia New Zealand (FSANZ) Maximum Levels (ML) and Generally Expected Levels (GEL) guidelines for human consumption with the exception of copper which exceeded the GEL 90th percentile trigger value. This is assessed as not being linked to DLNG operations for the following reasons:
  - Biologically copper is essential for marine invertebrates and plays an important role in respiration and detectable concentrations can be present in molluscs from unpolluted waters (Peerzada, Eastbrook and Guinea, 1990).
  - Similar copper concentrations were recorded in a Darwin Harbour wide study and, more recently, from sampling undertaken in mangroves at Bladin Point control sites for the Ichthys LNG operations (CDM Smith, 2019).
  - Historic sediment pond discharge water quality data indicates a history of generally being near, and often below, the detection limits for copper.

Discharges to Air

- Monitoring of stack emissions sources at the DLNG facility indicated that 2020 results were compliant with the licence and generally consistent with historical data (2015-2020). The preventative actions implemented to reduce the risk of elevated boiler CO emissions in November 2019 have been effective with 2020 concentrations well below the Licence limits.
- The flaring emissions in 2020 were comparable with the 2019 emissions and overall there is a decreasing trend evident over the six-year period from 2015-2020 indicating a reduced risk to the environment.
- Venting from the nitrogen rejection unit (NRU) was higher than in 2019 but within the recorded ranges for the 2015-2020 period.
- Hot venting of acid gas occurred during 2020 due to planned shutdowns in June and August to conduct maintenance to the facility or acid gas incinerator (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 or AGI trips. The duration of these events was made as short as practicable.

- Results of the ambient air quality monitoring demonstrated that air quality was generally within the relevant NEPM, Air EPP and NSW EPA air quality standards and monitoring investigation limits (MIL) during the reporting period. This indicates that ambient air emissions fell within appropriate standards for human health in Darwin City and DLNG air emissions did not pose a risk of material or serious environmental harm to the flora, mangrove communities and terrestrial fauna in the Darwin air sheds.

  Elevated H_2S exceedances were recorded at the Santos network sites, however they are not considered to be attributable to DLNG emission sources. Elevated PM_{10} and $PM_{2.5}$ exceedances were recorded at the NT EPA network sites. These were derived from widespread dust events common in dry season conditions and are not considered to be attributable to DLNG emission sources.

- There is an overall decreasing trend in GHG emissions over the 2015-2020 reporting period due to reduced DLNG production rates resulting in less energy consumption. Santos implements a range of initiatives aimed at reducing the company's GHG emissions. The DLNG facility complies with GHG reporting requirements in Australia, including annual reporting to the Clean Energy Regulator under the National Greenhouse and Energy Reporting (NGER) scheme.

Discharges to Land and Surrounding Environment

- No statistical correlation between groundwater and irrigation water quality has been detected, therefore overall, the data collected from the 2020 groundwater monitoring events demonstrate that current irrigation practices present a low environmental risk. The condition of the groundwater is considered in good health as determined by the 2015-2020 groundwater monitoring results.
- Ongoing monitoring is required to determine if there are any linkages for parameters with a limited dataset and investigations into groundwater levels and well integrity are ongoing.

1. INTRODUCTION

1.1 OVERVIEW

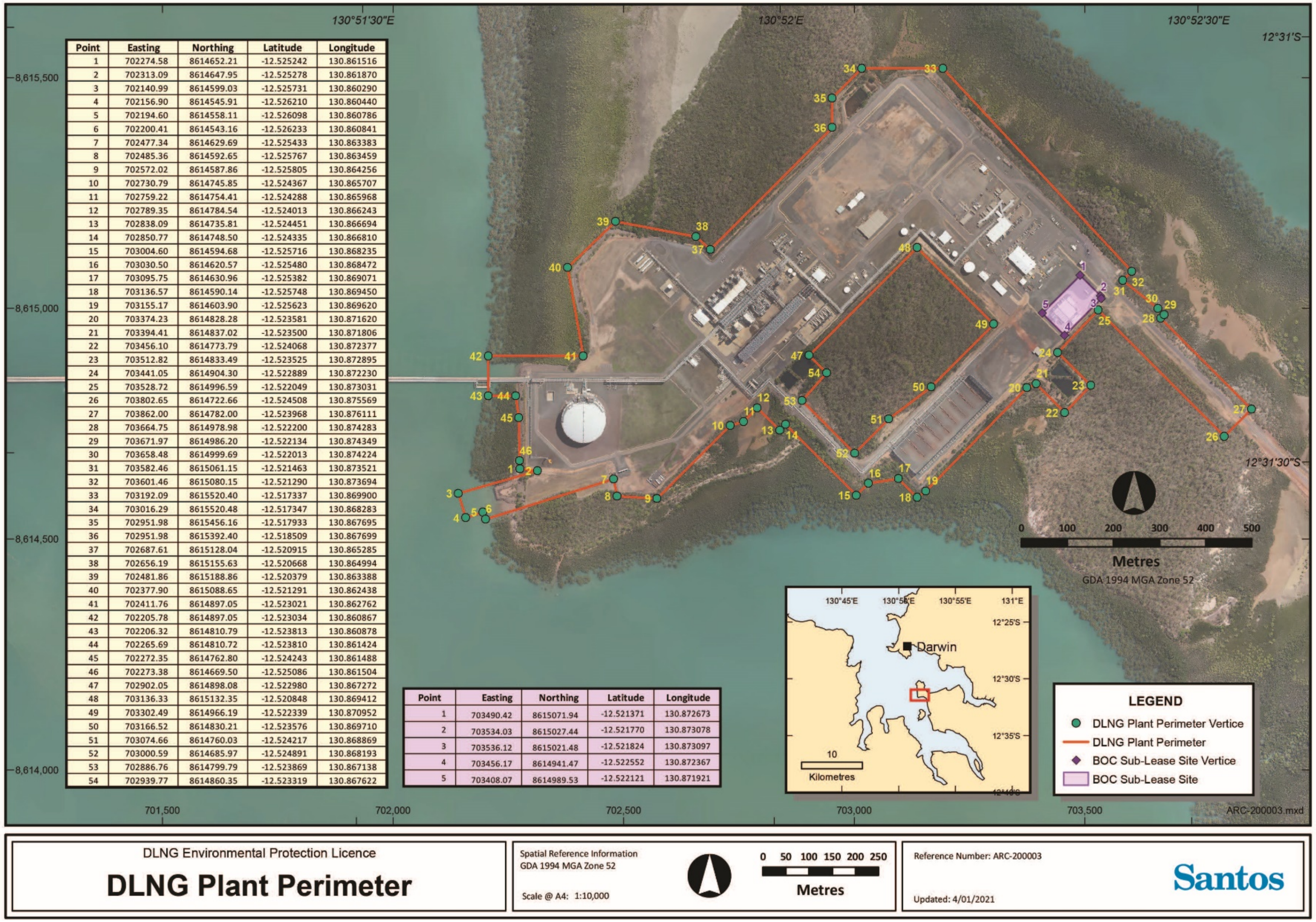
Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the Darwin Liquefied Natural Gas facility (DLNG) at Wickham Point, near Darwin, in the Northern Territory (NT) of Australia. DLNG receives dry natural gas from the Bayu-Undan field located in Timor-Leste offshore waters via the 502 km long 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 1-1**.

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 (herein referred to as 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 1.2**.

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 each year 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 2019 and 31 December 2019 (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.



Point	Easting	Northing	Latitude	Longitude
1	702274.58	8614652.21	-12.525242	130.861516
2	702313.09	8614647.95	-12.525278	130.861870
3	702140.99	8614599.03	-12.525731	130.860290
4	702156.90	8614545.91	-12.526210	130.860440
5	702194.60	8614558.11	-12.526098	130.860786
6	702200.41	8614543.16	-12.526233	130.860841
7	702477.34	8614629.69	-12.525433	130.863383
8	702485.36	8614592.65	-12.525767	130.863459
9	702572.02	8614587.86	-12.525805	130.864256
10	702730.79	8614745.85	-12.524367	130.865707
11	702759.22	8614754.41	-12.524288	130.865968
12	702789.35	8614784.54	-12.524013	130.866243
13	702838.09	8614735.81	-12.524451	130.866694
14	702850.77	8614748.50	-12.524335	130.866810
15	703004.60	8614594.68	-12.525716	130.868235
16	703030.50	8614620.57	-12.525480	130.868472
17	703095.75	8614630.96	-12.525382	130.869071
18	703136.57	8614590.14	-12.525748	130.869450
19	703155.17	8614603.90	-12.525623	130.869620
20	703374.23	8614828.28	-12.523581	130.871620
21	703394.41	8614837.02	-12.523500	130.871806
22	703456.10	8614773.79	-12.524068	130.872377
23	703512.82	8614833.49	-12.523525	130.872895
24	703441.05	8614904.30	-12.522889	130.872230
25	703528.72	8614996.59	-12.522049	130.873031
26	703802.65	8614722.66	-12.524508	130.875569
27	703862.00	8614782.00	-12.523968	130.876111
28	703664.75	8614978.98	-12.522200	130.874283
29	703671.97	8614986.20	-12.522134	130.874349
30	703658.48	8614999.69	-12.522013	130.874224
31	703582.46	8615061.15	-12.521463	130.873521
32	703601.46	8615080.15	-12.521290	130.873694
33	703192.09	8615520.40	-12.517337	130.869900
34	703016.29	8615520.48	-12.517347	130.868283
35	702951.98	8615456.16	-12.517933	130.867695
36	702951.98	8615392.40	-12.518509	130.867699
37	702687.61	8615128.04	-12.520915	130.865285
38	702656.19	8615155.63	-12.520668	130.864994
39	702481.86	8615188.86	-12.520379	130.863388
40	702377.90	8615088.65	-12.521291	130.862438
41	702411.76	8614897.05	-12.523021	130.862762
42	702205.78	8614897.05	-12.523034	130.860867
43	702206.32	8614810.79	-12.523813	130.860878
44	702265.69	8614810.72	-12.523810	130.861424
45	702272.35	8614762.80	-12.524243	130.861488
46	702273.38	8614669.50	-12.525086	130.861504
47	702902.05	8614898.08	-12.522980	130.867272
48	703136.33	8615132.35	-12.520848	130.869412
49	703302.49	8614966.19	-12.522339	130.870952
50	703166.52	8614830.21	-12.523576	130.869710
51	703074.66	8614760.03	-12.524217	130.868869
52	703000.59	8614685.97	-12.524891	130.868193
53	702886.76	8614799.79	-12.523869	130.867138
54	702939.77	8614860.35	-12.523319	130.867622

Point	Easting	Northing	Latitude	Longitude
1	703490.42	8615071.94	-12.521371	130.872673
2	703534.03	8615027.44	-12.521770	130.873078
3	703536.12	8615021.48	-12.521824	130.873097
4	703456.17	8614941.47	-12.522552	130.872367
5	703408.07	8614989.53	-12.522121	130.871921

Figure 1-1 Map of DLNG facility showing the boundaries of the Licence and bounding coordinates

1.2 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 1-1**. The licence is available on the NT EPA website at https://ntepa.nt.gov.au/your-business/public-registers/licenses-and-approvals-register/environment-protection-licences/hydrocarbons-gas/santos-na-darwin-pipeline-pty-ltd.

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 1-1**.

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

Conditions	Summary	Relevant Sections of this Report
General (Conditions 57 and 58)	• 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.	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: • Monitoring discharges to water (**Section 2**), • Monitoring air discharges (**Section 3**), and • Monitoring Discharges to Land and Surrounding Areas (**Section 4**).
Monitoring discharges to water (Conditions 59 to 65)	**Water Quality** • 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. **Mangrove Monitoring** • 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 professional and provided to the NT EPA • The NT EPA may require Santos to revise or amend and resubmit the mangrove monitoring program.	Water quality monitoring objectives, methods, results and discussion are presented in the following section: • Irrigation discharge – **Section 2**, • Jetty outfall discharge and mixing zone – **Section 2**, and • Sediment ponds 1, 2 and 3 discharge – **Section 2**. Mangrove monitoring objectives, methods, results and discussion are presented in **Section 12.2**.

Conditions	Summary	Relevant Sections of this Report
Monitoring air discharges (Conditions 66 to 68)	• 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.	Air quality monitoring is presented in **Section 3**, which includes results from these locations specified in the Licence: • Power generation turbines, • Compressor turbines, • AGI, • Solvent regenerator reflux drum, and • Boiler.
Monitoring discharges to land and surrounding environment (Conditions 69 to 71)	• 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	Groundwater monitoring is presented in **Section 4**, which includes results from monitoring and control bores at the locations specified in the Licence.

1.2.1 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 must include:

- An assessment of options to maximise the dilution of liquid discharges from the jetty outfall, including selection of a preferred option;
- An outline of the approach to discharge dispersion modelling to determine a mixing zone prior to installation;
- Timeframes for implementation, commissioning and reporting on improvements to the jetty outfall;
- Post-commissioning verification monitoring; and
- A receiving water monitoring program.

The Licence requires the PIP be submitted to the NT EPA for approval within six months of commencement of the Licence. The Licence also requires the PIP to be implemented within 12 months of being accepted by the NT EPA. Santos developed a PIP which was accepted by the NT EPA Board in November 2018.

The PIP is intended to define the water quality objectives and outline the steps and timelines to reduce the extents of influence of Jetty Outfall discharge to the Darwin Harbour. The PIP focusses on evaluation of modifications to the Jetty Outfall system, modelling to inform the potential change in extent of the mixing zone, and development of an infield monitoring program.

The PIP outlines that the current outfall configuration provides effective mixing with the receiving water. A field verification monitoring program was conducted in 2019.

In addition, an officer driven Licence amendment was initiated in 2019 to include new conditions relating to a jetty outfall mixing zone monitoring program (conditions 60, 76 ad 77). Results of the PIP monitoring program and new jetty outfall mixing zone monitoring program are included in **Section 2.**

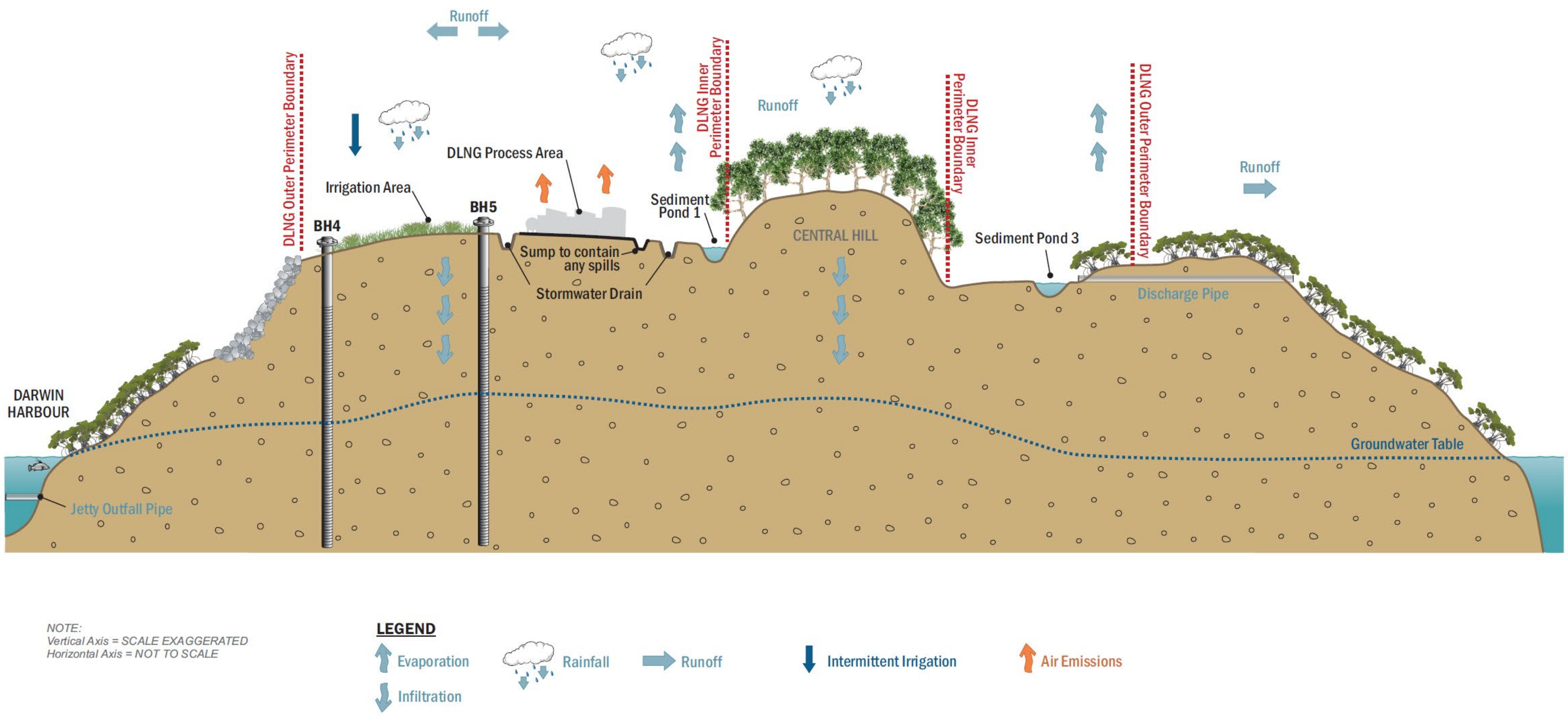
1.3 DLNG ENVIRONMENTAL MONITORING

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 1-2**. 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) and 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
  - Greenhouse gas emissions.
- Discharges to land and surrounding environment, including:
  - Groundwater monitoring.

Santos has developed and implements several routine monitoring programs to meet the requirements of the Licence. Santos has also included greenhouse gas (GHG) emissions monitoring (including flaring) within the report, although it is not required by the Licence.

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



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

Figure 1-2 Conceptual model of environmental aspects for DLNG

2. MONITORING DISCHARGES TO WATER

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

- Irrigation discharge (**Section 12.1**);
- Jetty outfall discharge and mixing zone (**Section 12.1**);
- Sediment ponds discharge (**Section 12.1**); and
- Mangrove monitoring (**Section 12.2**).

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

2.1 IRRIGATION, JETTY OUTFALL AND SEDIMENT POND DISCHARGE MONITORING PROGRAM

Several water and wastewater streams are discharged from the DLNG facility 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 2-1**.

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 2-2**.

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 2-3**. 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 2-4**. Sediment ponds are only sampled when they are actively discharging to the environment.

Santos

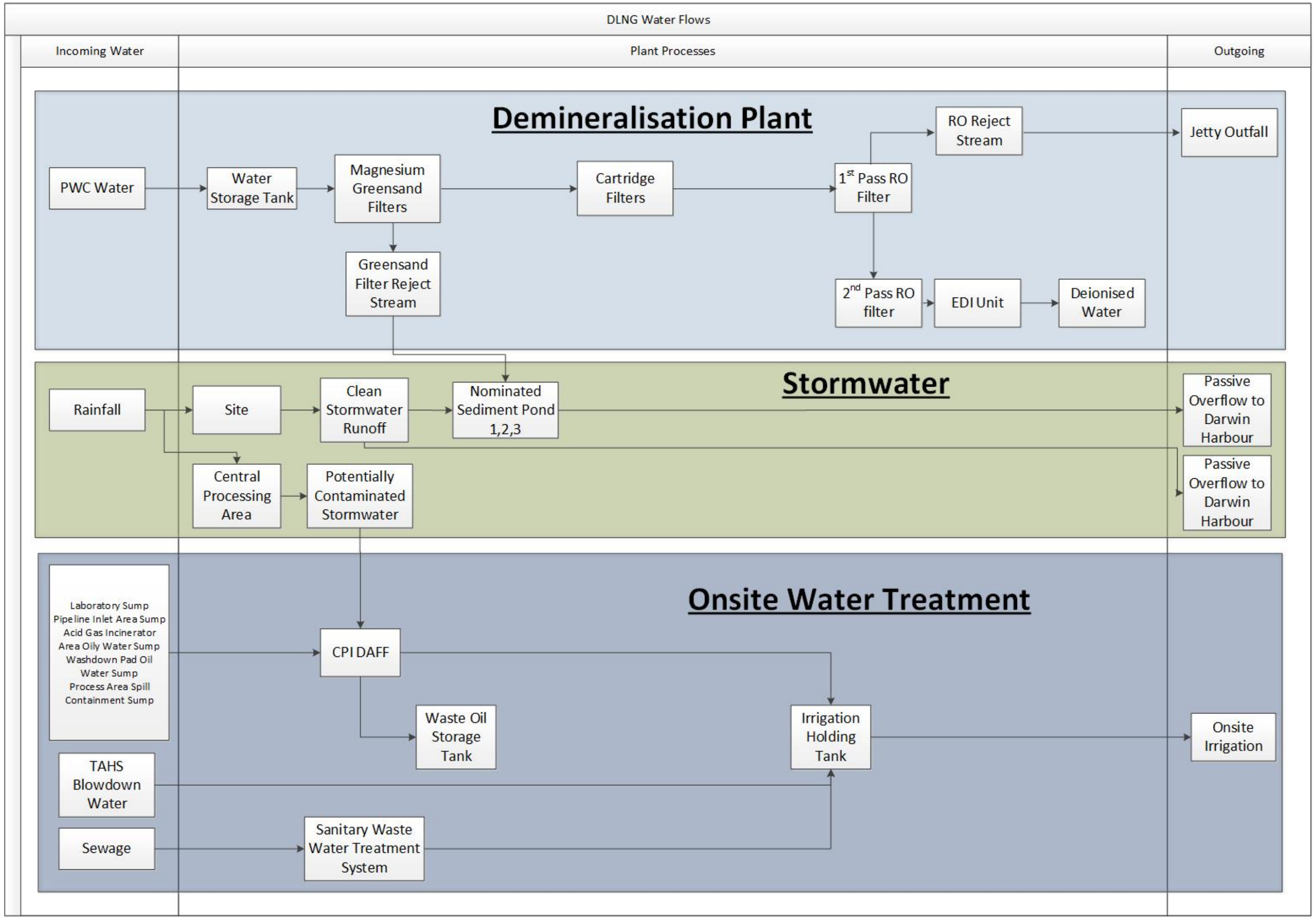


Figure 2-1 **Schematic of water inputs, processes and discharge points for the DLNG facility**

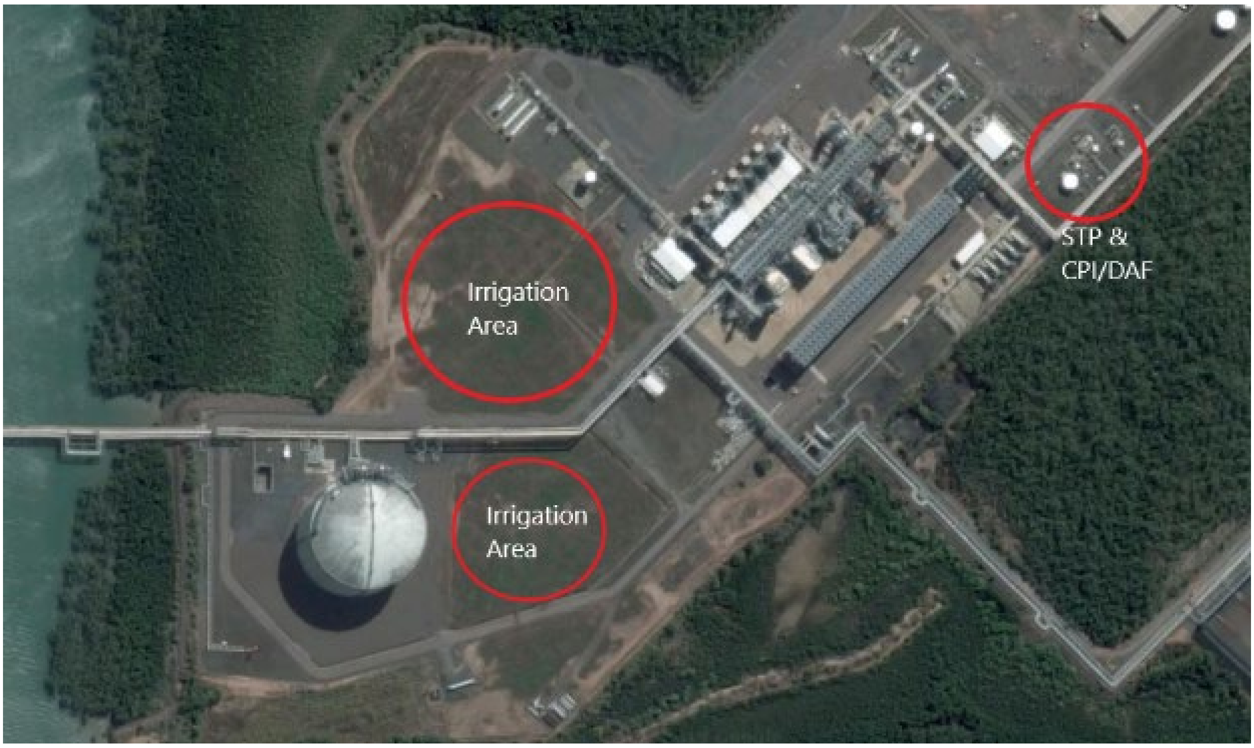


Figure 2-2 Irrigation discharge areas

Figure 2-3 DLNG jetty outfall pipe secured to pylon

Figure 2-4 DLNG sediment pond overflow sampling location

2.1.1 Monitoring Objectives

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).

Characterising the quality of the discharge stream allows Santos to identify the potential for the discharges stream to result in environmental impacts or risks. As outlined in the conceptual model of environmental aspects at DLNG (**Figure 1-2**), 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 of use in interpreting results from other monitoring programs, such as the mangrove monitoring program (**Section 12.2**).

2.1.2 Monitoring Methods

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

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 2-4**) 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.

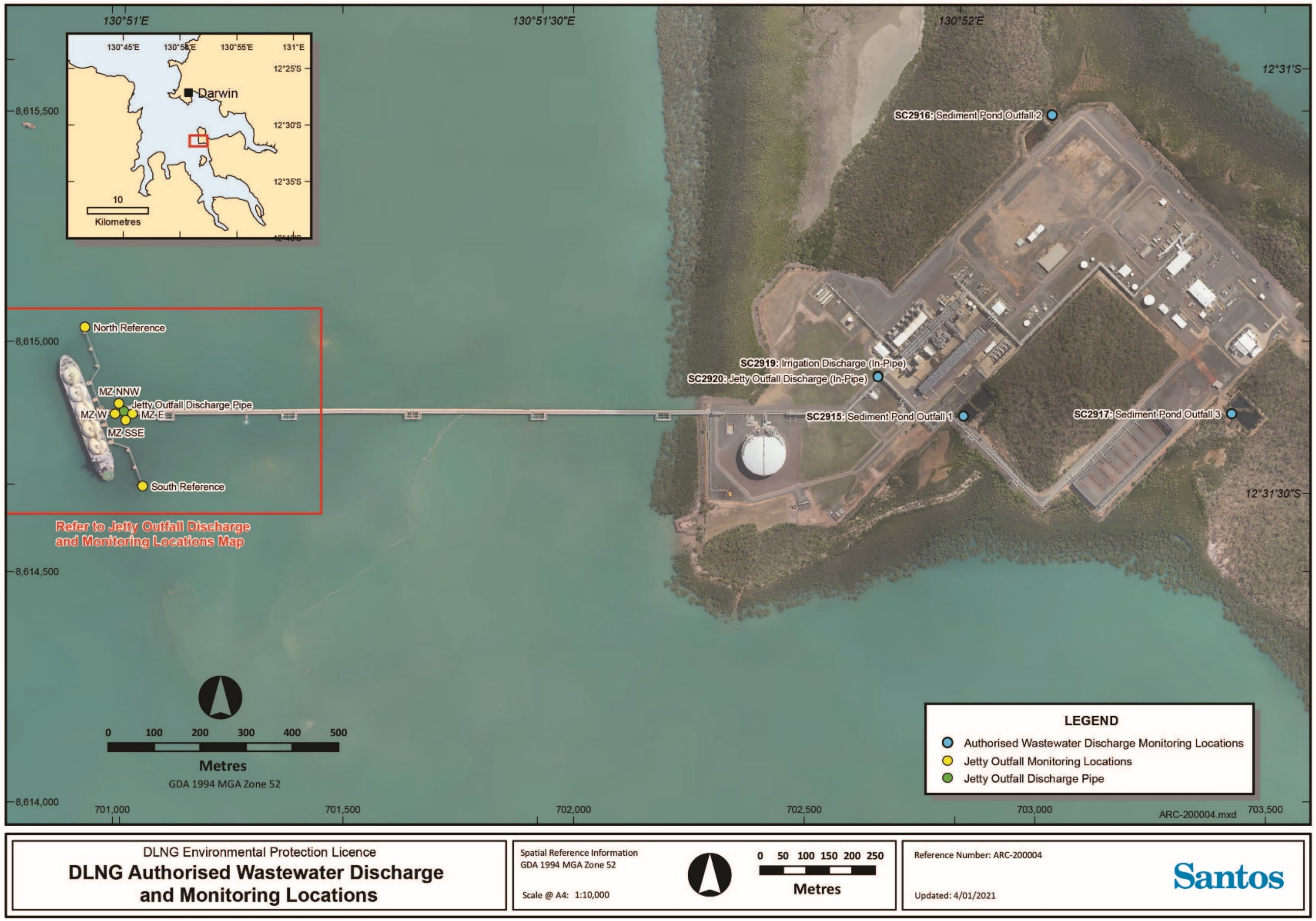


Figure 2-5 Map of authorised wastewater discharge and monitoring locations

Figure 2-6 Map of jetty outfall discharge and monitoring locations

2.1.3 Monitoring Results

2.1.3.1 Irrigation Discharge Monitoring

2.1.3.2 Volume Discharged

A total of 19,693 m^3 was discharged to the irrigation area during 2020 (**Figure 2-7**). This was marginally lower than 2016-2019 annual volumes due to a combination of the following:

- Reduced contribution from boiler blowdown during a boiler fuel reduction trial in 2020;
- Clean out of the irrigation holding tank T2903 in November 2002 resulting in wastewater being temporarily stored in an isotainer and removed offsite; and
- Reduced personnel onsite in 2020 resulting in less input from the STP.

The significant reduction from 2015 to 2016 was due to a historical over reporting error. Review of the treated effluent holding tank size identified that reported irrigation discharge volumes were inclusive of RO reject volumes discharged to the jetty outfall. Irrigation discharge volumes were updated to better reflect the treated effluent holding tank volume on site.

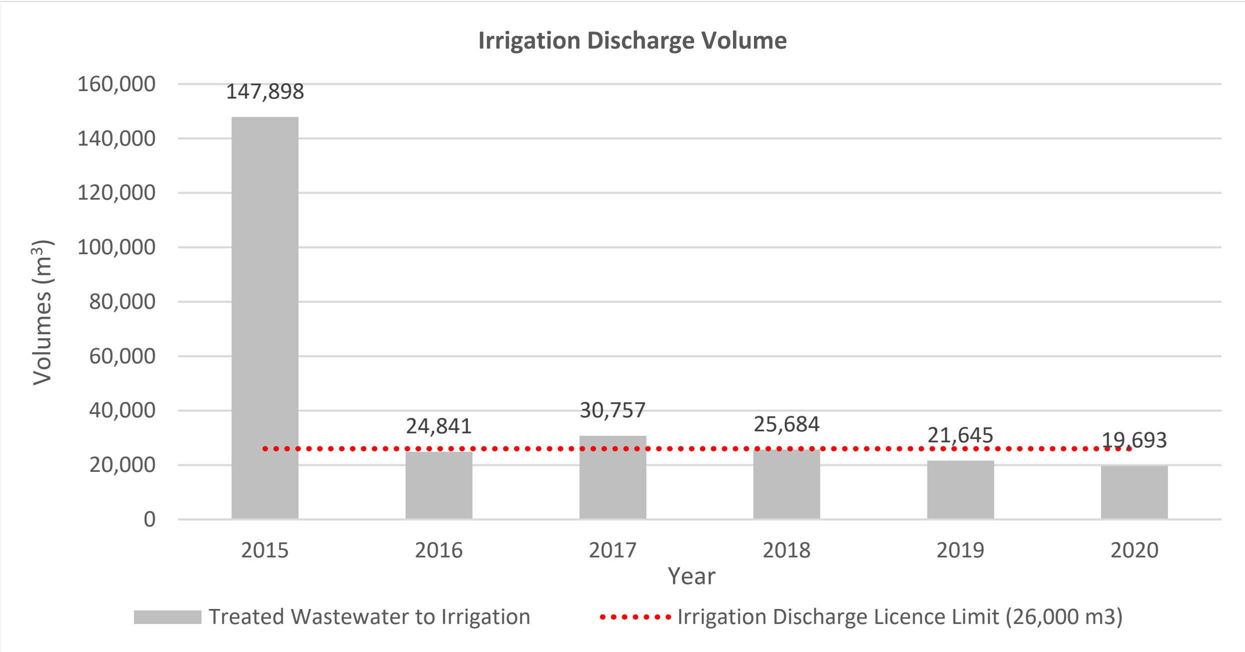


Figure 2-7 Water volumes discharged to irrigation field 2015-2020

2.1.3.3 Discharge Water Quality Results

A summary of the irrigation water quality results for 2020, long term trends from 2015-2020 and Licence trigger value exceedances are presented in **Table 2-1** and discussed below.

The annual monitoring of environmental indicators was undertaken in March 2020 and the biannual indicators in October 2020 and voluntary monitoring has also been conducted for parameters of interest during 2020. The 2015-2020 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 and remained in exceedance for the remainder of 2020 (range of 41-120 mg/L compared to a trigger value of 25 mg/L) (**Figure 2-8**). This triggered a reportable non-conformance and was reported to the NT EPA on 12 November 2020. The exceedance was 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, the irrigation tank (T2903) was drained to remove the build-up of sludge and the CPI DAF and STP media filters were serviced.

  Elevated BOD concentrations in irrigation discharge continued to be an ongoing issue entering into 2021; routine flushing and biocide dosing is being implemented along with additional monitoring to trend the BOD concentrations back into compliance.

- Field measurements of the irrigation discharge during 2020 were generally consistent with the 2015-2020 long term average and were within the Licence trigger values with the exception of two marginally low pH results and a trend of increased total suspended solids (TSS) in Q4 2020 (**Figure 2-9**). The TSS concentrations triggered a reportable non-conformance and was reported to the NT EPA on 2 December 2020. The root cause of the elevated levels is related to BOD exceedances discussed above. After corrective maintenance activities were completed in November 2020 and the residue in the pipework had time to flush through, the TSS concentrations returned to compliant levels in December 2020.

- Speciated nutrients (ammonium nitrogen, nitrate, nitrite and dissolved reactive phosphorus) exceeded the Licence trigger values in 2020, however only ammonium nitrogen and dissolved reactive phosphorus triggered a reportable incident under the Licence. This was reported to the NT EPA on 25 March 2020 (235 ug/L compared to a trigger value of 20 ug/L for ammonium nitrogen and 931 ug/L compared to a trigger value of 5 ug/L for dissolved reactive phosphorus) (**Figure 2-10**). Compared to the long term 2015 to 2020 average, the 2020 average concentrations for ammonium nitrogen and dissolved reactive phosphorus were lower and the nitrate and nitrite were higher indicating a variable trend.

  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. The total nitrogen and total phosphorus results, which are better indicators of total nutrient load, did not exceed the Licence trigger values in 2020 (**Figure 2-11**).

- Chlorophyll-a results were within the range of the 2015-2020 long term average and were within the Licence trigger values in 2020.

- Copper exceeded the Licence trigger value on one occasion in December 2020. This did not trigger a reportable non-conformance to the NT EPA (**Figure 2-12**). The 2020 average concentration was less than the 2015-2020 long term average and the elevated copper results from Q4 2019 were an isolated event not repeated in 2020, indicating a reduction in risk.

  All other metals were below the Licence trigger values in 2020 and within historical ranges for the 2015 to 2020 period.

- Hydrocarbons (total recoverable hydrocarbons (TRH) and Benzene, ethyl-benzene, toluene, xylene (BTEX)) were below the Licence trigger values in 2020 and generally were below the LOR. This is consistent with historical data.

- *Enterococci* exceeded the Licence trigger value on one occasion in November 2020. This did not trigger a reportable non-conformance to the NT EPA (**Figure 2-13**). Spikes are related to short term effluent quality issues in the CPI DAF or STP and generally return to compliant concentrations within 1-2 weeks. Overall, in 2020, *E. coli* and *Enterococci* concentrations were within the historical ranges for the 2015 to 2020 period and showed a reducing trend in 2020.

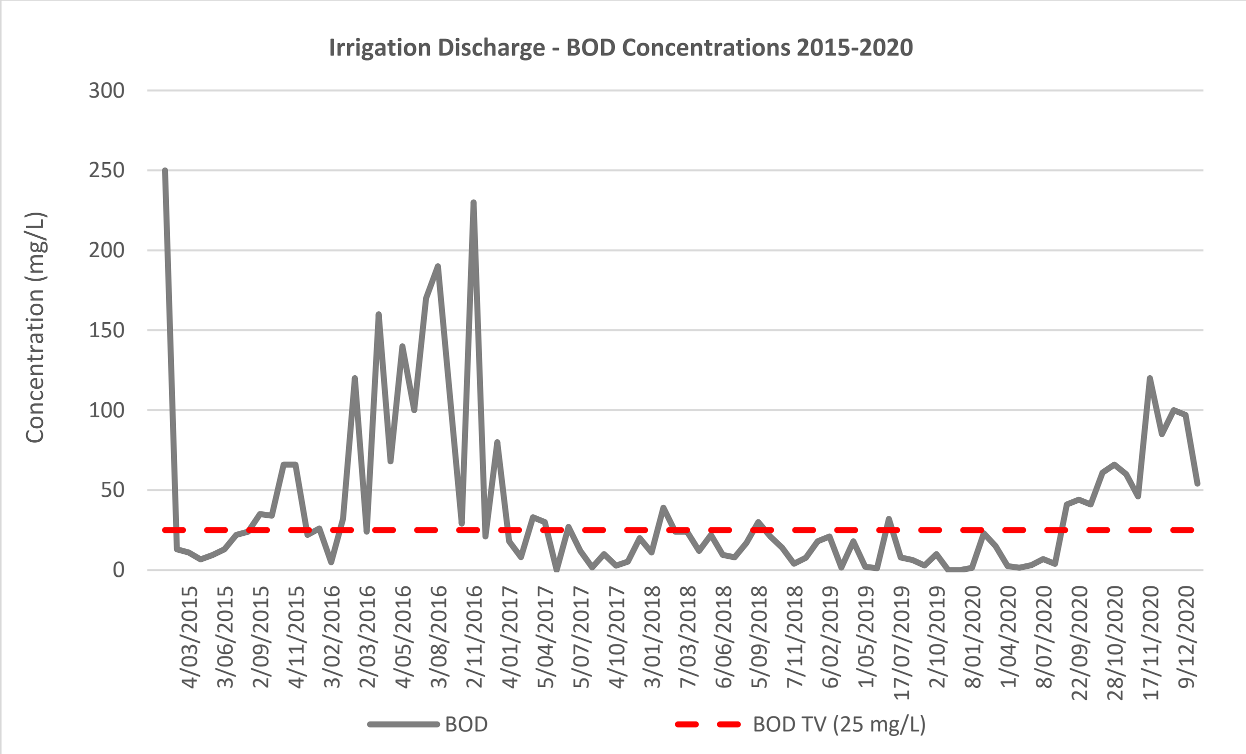


Figure 2-8 Irrigation discharge BOD concentrations (2015-2020)

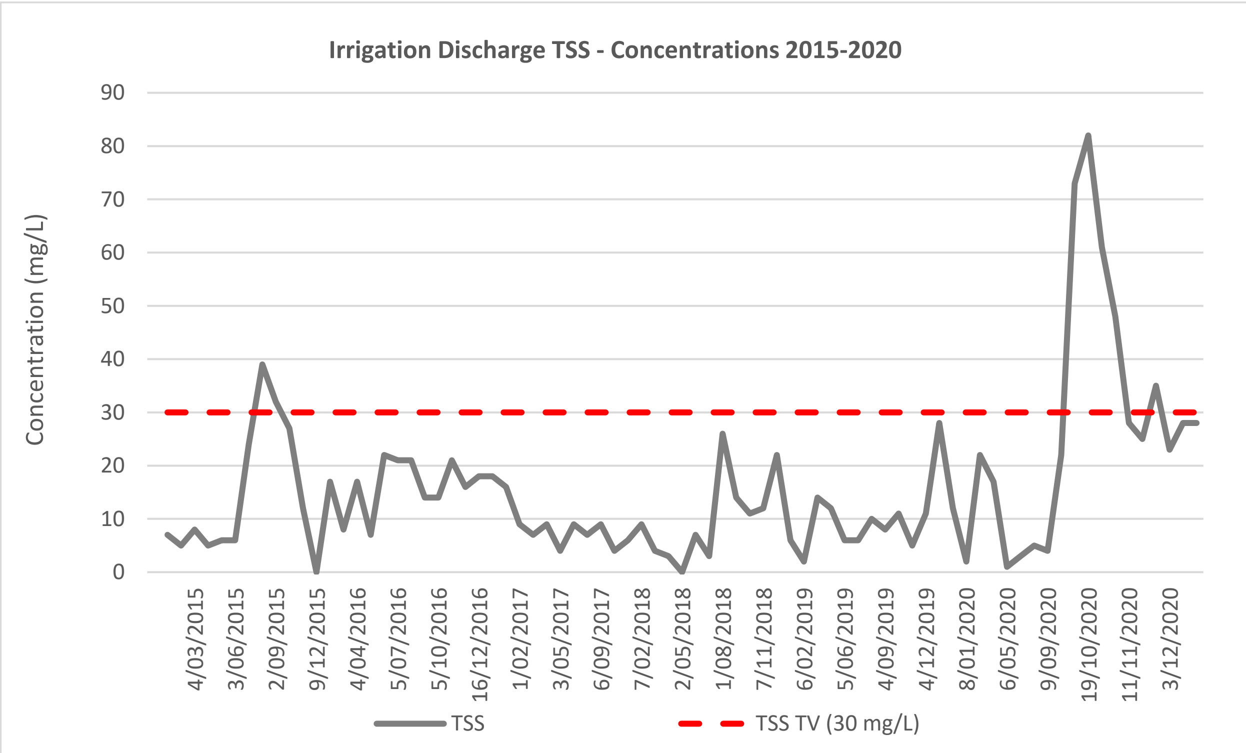


Figure 2-9 Irrigation discharge TSS concentrations (2015-2020)

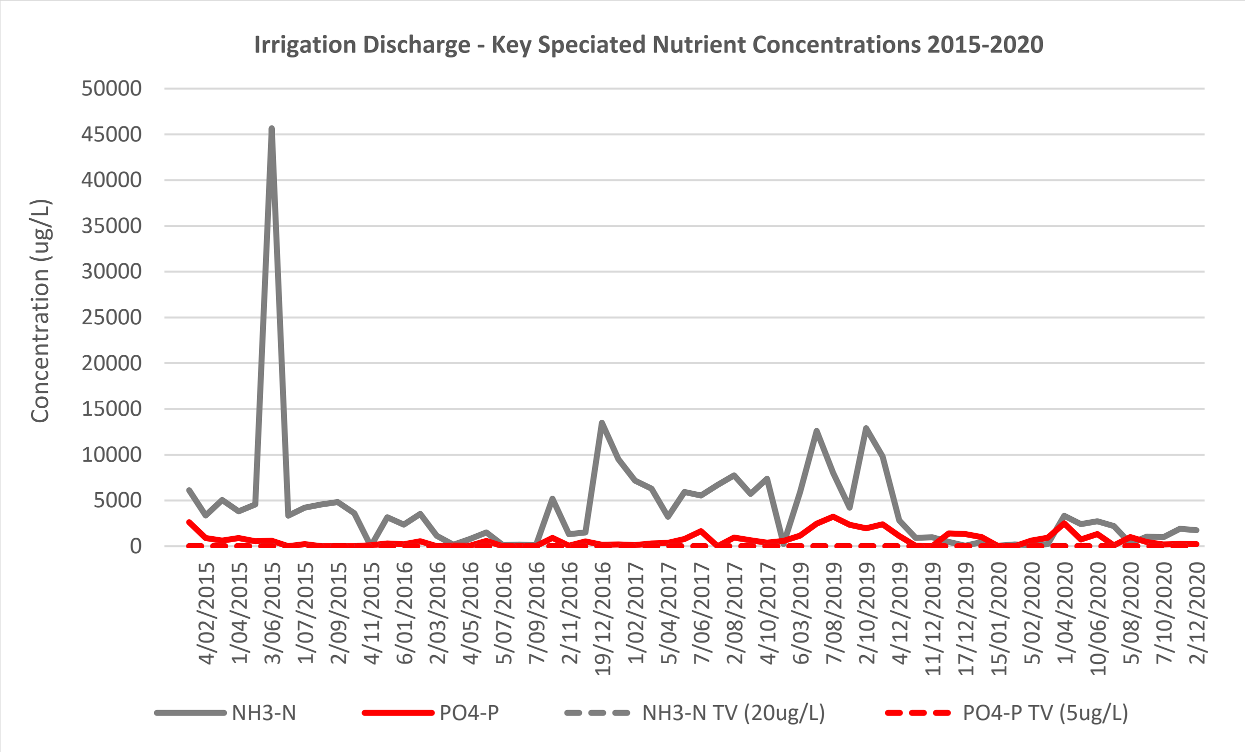


Figure 2-10 Irrigation discharge speciated nutrient concentrations (2015-2020)

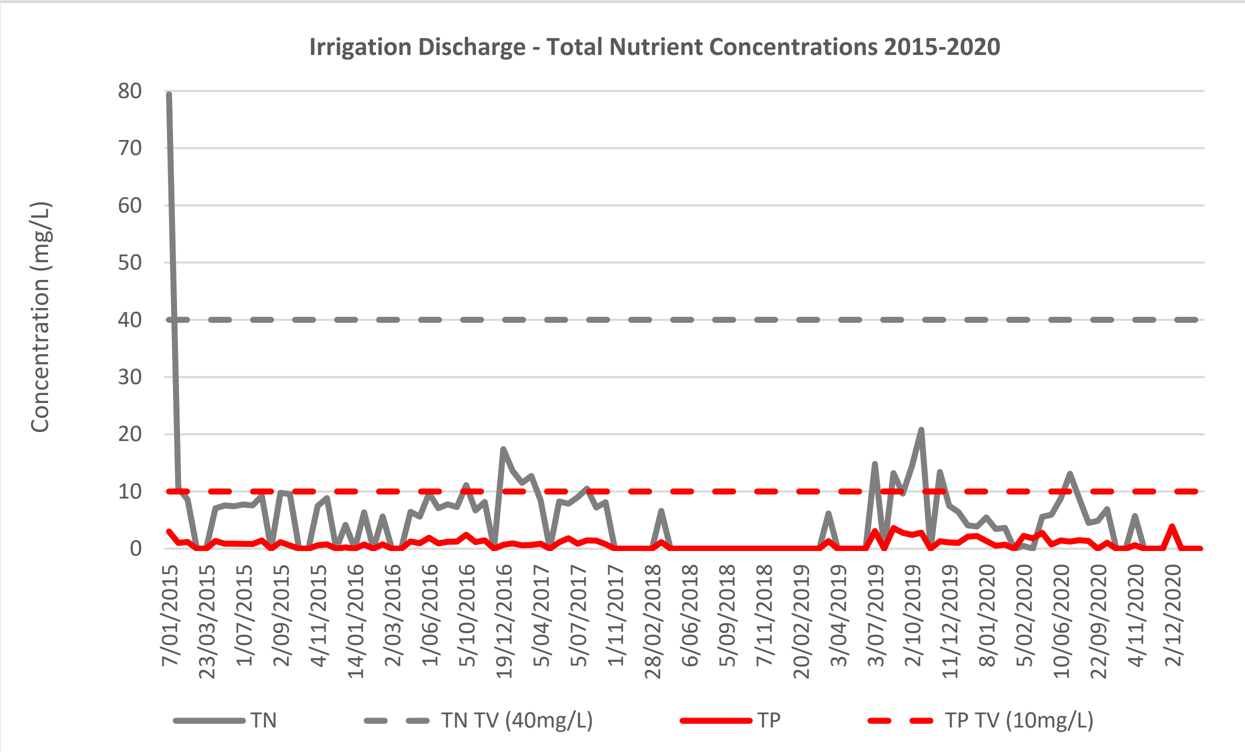


Figure 2-11 Irrigation discharge total nutrient concentrations (2015-2020)

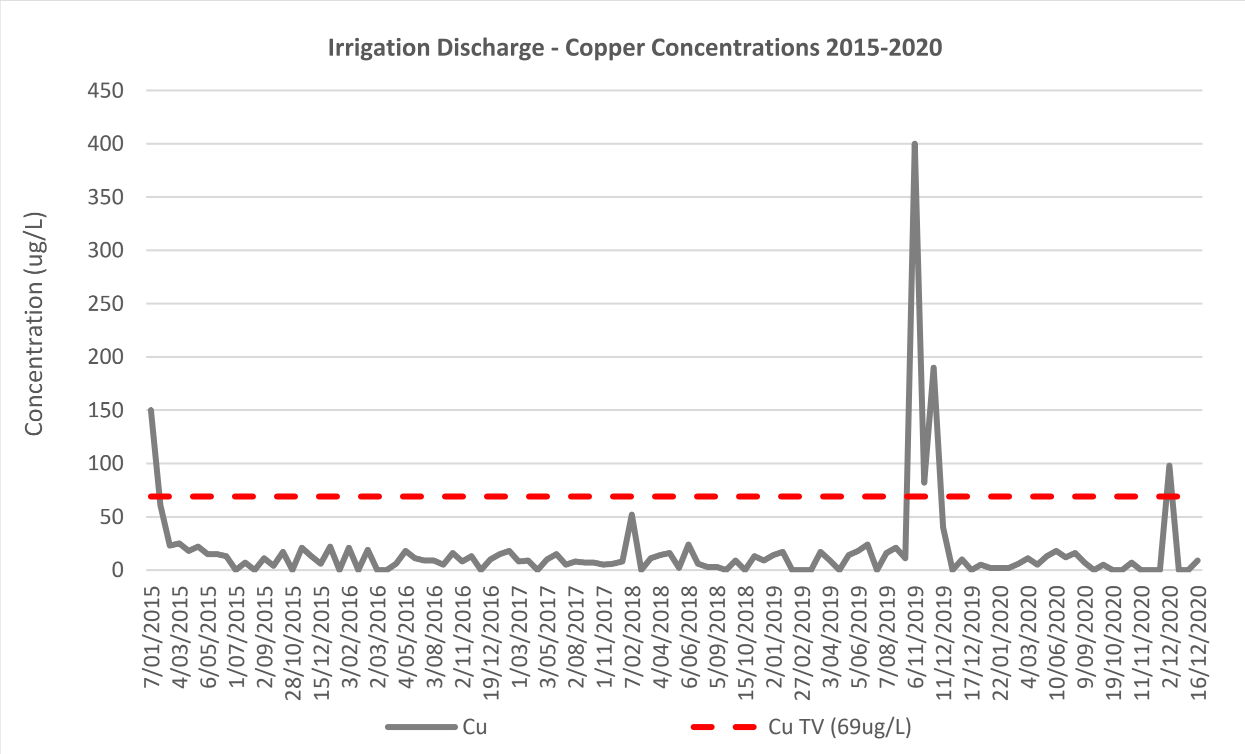


Figure 2-12 Irrigation discharge copper concentrations (2015-2020)

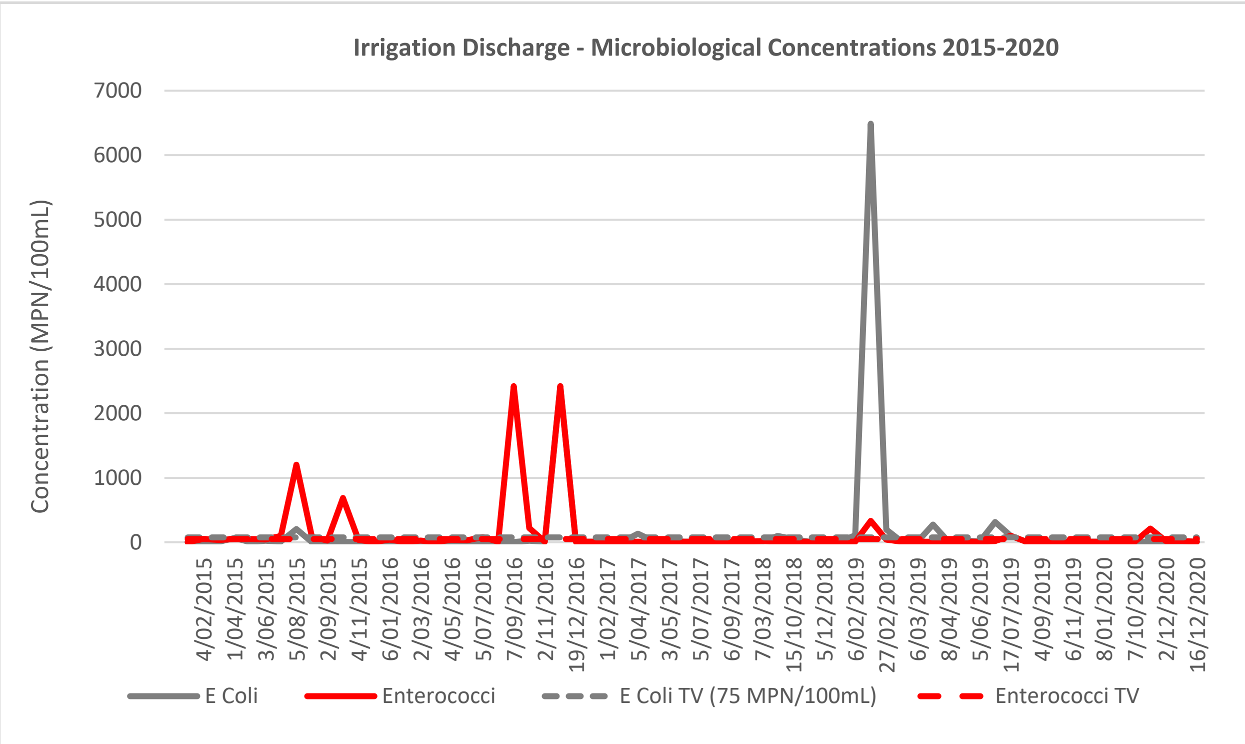


Figure 2-13 Irrigation discharge microbiological concentrations (2015-2020)

Table 2-1 Summary of 2020 irrigation water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Field Parameters							
pH	Monthly	7-8.5	7.62	6.45	7.19	7.34	No
Electrical conductivity(µs/cm)	Monthly	No trigger	401	206	262	239	N/A
TSS (mg/L)	Monthly	≤ 30	82	0	25	14	**Yes**
Turbidity (NTU)	Monthly	No trigger	21.10	1.92	10.89	12.50	N/A
DO (mg/L)	Monthly	No trigger	0.15	0.05	0.12	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	3,330	65	1,267	4,284	**Yes**
Nitrate (NO_3-N) (µg/L)	Annual	17	6,890	<1	1,341	567	No
Nitrite (NO_2-N) (µg/L)	Annual	17	1,670	<1	156	71	No
DRP (PO_4-P) (µg/L)	Annual	5	2,500	4	667	691	**Yes**
Total Nitrogen (mg/L)	Annual	≤ 40	13.10	0.50	5.79	9.41	No
Total Phosphorous (mg/L)	Annual	≤ 10	3.91	0.52	1.52	1.39	No
Chlorophyll-a (µg/L)	Biannual	2	1	<1	1	1	No
BOD (mg/L)	Monthly	≤ 25	120.0	1.4	43.6	39.6	**Yes**
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	0.71	No
E. coli (MPN/100 mL)	Biannual	≤ 75	10	<10	10	166	No
Enterococci (MPN/100 mL)	Biannual	50	213	<10	42	133	No
Metals & BTEX							
Arsenic (µg/L)	Annual	10	<1	<1	<1	1	No
Cadmium (µg/L)	Monthly	3.2	<0.1	<0.1	<0.1	0.1	No
Chromium (µg/L)	Annual	10	<1	<1	<1	1	No
Copper (µg/L)	Monthly	69	98	2	14	23	No

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Iron (µg/L)	Annual	1,300	320	120	212	227	No
Lead (µg/L)	Annual	10	<1	<1	<1	2	No
Manganese (µg/L)	Annual	15,500	40	20	29	35	No
Mercury (µg/L)	Monthly	0.1	<0.1	<0.05	<0.1	0.1	No
Nickel (µg/L)	Annual	290	<1	<1	<1	1	No
Silver (µg/L)	Annual	1.4	<1	<1	<1	1	No
Zinc (µg/L)	Monthly	1,780	34	<5	13	18	No
BTEX (µg/L)	Monthly	700	3	<4	<3	3	No

* Note: Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.

2.1.3.4 Jetty Outfall Monitoring

2.1.3.5 Volume Discharged

A total of 31,940 m^3 was discharged from the jetty outfall during 2020 (**Figure 2-14**). This was the lowest annual discharge volume in the six-year period from 2015-2020, primarily due to a reduction in losses from the steam system resulting in reduced demand for demineralisation water and the associated reject water production.

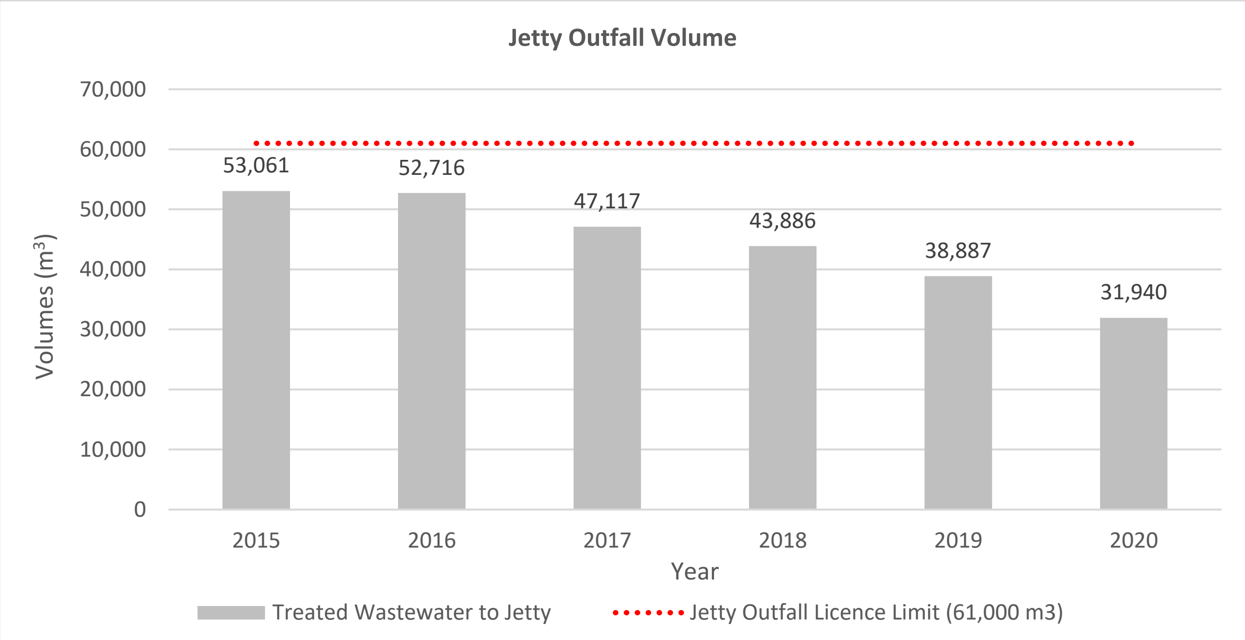


Figure 2-14 Water volumes discharged to jetty outfall

2.1.3.6 Discharge Water Quality Results

A summary of the jetty outfall discharge water quality results for 2020, as well as the long-term trend from 2015-2020 and Licence trigger value exceedances are presented in **Table 2-2** and discussed below.

The annual monitoring of environmental indicators was undertaken in March 2019 and the biannual indicators in October 2020 and voluntary monitoring has also been conducted for parameters of interest during 2020. The 2015-2020 dataset of both compliance and voluntary jetty outfall discharge water quality results is provided in **Attachment B – 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 2020 were generally consistent with or below the 2015-2020 average and were within the Licence trigger values with the exception of one elevated pH result in April 2020. This did not trigger a reportable non-conformance to the NT EPA.
- Speciated nutrients (ammonium nitrogen) exceeded the Licence trigger values on multiple occasions in 2020 and dissolved reactive phosphorus exceeded the Licence trigger value on a single occasion in 2020 (**Figure 2-15**). This did not result in an exceedance in the jetty

outfall mixing zone or trigger a reportable non-conformance to the NT EPA.

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. Weekly samples were collected and results indicated that the ammonium nitrogen concentrations reduced significantly with reduced dosing rates. As a result, the operational procedures were updated with the lower dosing rate for ongoing environmental benefit.

The ammonium nitrogen concentrations continued to be monitored more frequently than required under the Licence for the remainder of 2019 with results indicating consistently low ammonium nitrogen until November 2019. The trend of ad hoc spikes continued throughout 2020 despite the lower biocide dosing rate but did not trigger a reportable non-conformance under the Licence.

The concentrations are possibly due to improved performance of the electrodeionisation (EDI) cells in the demineralisation plant which were replaced at the end of 2019. A zero biocide dosing campaign is also being considered for Q1 2021.

Despite the exceedances noted in select speciated nutrients, total nitrogen and total phosphorus were consistently below the Licence trigger values in 2020. The 2020 averages for all nutrients, including ammonium nitrogen, were less than the long term 2015-2020 average indicating an overall decreasing trend.

- BOD was within the Licence trigger value in 2020 and within the 2015-2020 average.
- Metal concentrations in the jetty outfall discharge during 2020 were generally within the Licence trigger values, apart from zinc. Zinc exceeded the Licence trigger value on multiple occasions in Q1 2020 before returning to complaint levels for the remainder of 2020 (**Figure 2-16**). 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 remainder of metals were also consistent with or below the 2015-2020 averages with the exception of manganese and nickel which were above the historical average but still well below Licence trigger levels were applicable. Given the jetty mixing zone water quality did not indicate any exceedances for metals, these isolated spikes or relative increase in concentrations are not considered to present an environmental risk.
- Hydrocarbons (TRH and BTEX) were below Licence trigger values in 2020 and below the LOR. This is consistent with historical data which demonstrates long term trends where hydrocarbon concentrations are generally below detection limits.
- *E. coli* and *Enterococci* were below the LOR and within the Licence trigger value in 2020. This is consistent with historical data which demonstrates long term trends where microbiological concentrations are generally below detection limits.

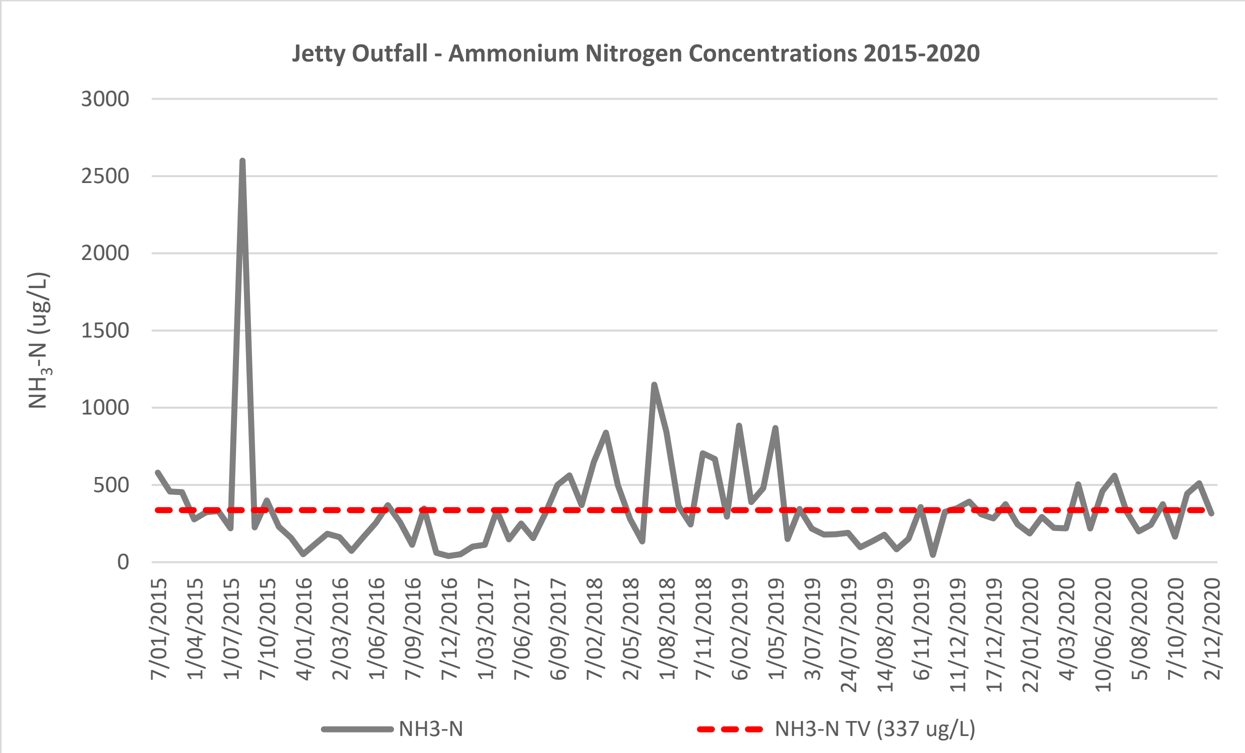


Figure 2-15 Jetty outfall discharge ammonium nitrogen concentrations (2015-2020)

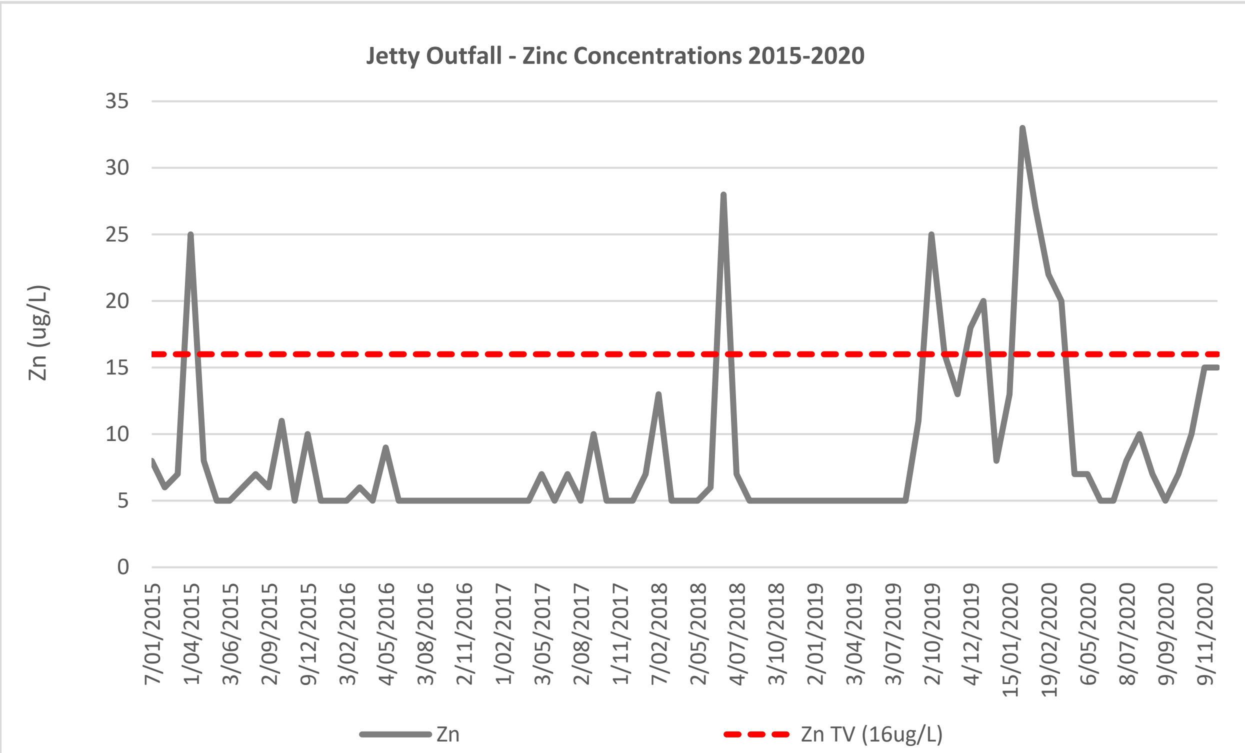


Figure 2-16 Jetty outfall discharge zinc concentrations (2015-2020)

Table 2-2 Summary of 2020 jetty outfall discharge monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Field Parameters							
pH	Monthly	7-8.5	9.10	7.34	7.73	7.81	No
Electrical conductivity(µs/cm)	Monthly	No trigger	902	561	763	723	N/A
TSS (mg/L)	Monthly	≤ 30	1	0	0.38	0.35	No
Turbidity (NTU)	Monthly	20	1.87	0.26	0.91	1.42	No
DO (mg/L)	Monthly	No trigger	5.25	0.60	2.95	2.83	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	560	165	326	346	No
Nitrate (NO_3-N) (µg/L)	Annual	764	466	112	244	288	No
Nitrite (NO_2-N) (µg/L)	Annual	27	27	3	13	23	No
DRP (PO_4-P) (µg/L)	Annual	51	100	2	19	95	No
Total Nitrogen (mg/L)	Annual	≤ 40	1.88	0.99	1.42	1.84	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.74	0.01	0.09	0.44	No
BOD (mg/L)	Monthly	≤ 25	10.0	<1.0	4.4	5.4	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
E. coli (MPN/100 mL)	Biannual	≤ 75	<10	<10	<10	<5	No
Enterococci (MPN/100 mL)	Biannual	50	<10	<10	<10	20	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<1	<1	<1	N/A
Cadmium (µg/L)	Monthly	5.5	<0.1	<0.1	<0.1	<0.1	No
Chromium (µg/L)	Annual	4.4	<1	<1	<1	1	No
Copper (µg/L)	Monthly	3.0	1	<1	1	1	No
Iron (µg/L)	Annual	No trigger	95	19	55	333	N/A

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Lead (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Manganese (µg/L)	Annual	No trigger	210	3	47	20	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.05	<0.1	<0.1	No
Nickel (µg/L)	Annual	70	18	2	7	4	No
Silver (µg/L)	Annual	1.4	<1	<1	<1	<1	No
Zinc (µg/L)	Monthly	16.0	33	5	12	9	No
BTEX (µg/L)	Monthly	700	<4	<3	<3	<3	No

* Note: Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.

2.1.3.7 *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 (refer to **Figure 2-6**).

The Licence is currently non-specific with regard to 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 2-3**.

Table 2-3 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

Quarterly sampling commenced in July 2019 continued throughout 2020. The results are presented in **Table 2-4**. The 2020 dataset of the mixing zone water quality results is provided in **Attachment B – Jetty Outfall Mixing Zone**; values exceeding current Licence trigger values are bolded and/or shaded.

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 2020; physiochemical parameters (pH, ORP and total dissolved solids), nutrients (total nitrogen, nitrate and total kieldahl nitrogen) and metals (arsenic and manganese).
- The median concentration in the mixing zone exceeded the Licence trigger value for dissolved oxygen in Q1 and 3 2020 and for zinc in Q4 2020.
- There were no occasions where the median concentration in the mixing zone exceeded both the reference site value and Licence trigger value, and as such there were no reportable non-conformances in 2020.
- Levels of *chlorophyll-a*, microbiological constituents and hydrocarbons were detected below the limit of reporting and do not represent an environmental risk.

Table 2-4 Summary of 2020 jetty outfall mixing zone monitoring results

Parameter	Units	EPL 217-02 Jetty Outfall Mixing Zone Trigger Values	Q1 2020		Q2 2020		Q3 2020		Q4 2020	
			Southern Reference (SOUTHERN)	Median of Sites 1-3	North Reference (NORTHERN)	Median of Sites 1-3	Southern Reference (SOUTHERN)	Median of Sites 1-3	North Reference (NORTHERN)	Median of Sites 1-3
pH	pH units	7-8.5	7.2 (6.7-7.7)	7.15	7.72 (7.22-8.22)	7.83	7.7 (7.2-8.2)	7.97	6.58 (6.08-7.08)	**7.74**
ORP	mV	NA	45.6 (43.32-47.88)	**69.7**	80.6 (76.6-84.6)	**64.2**	140.5 (133.5-147.5)	**100.4**	141.7 (134.6-148.8)	**8.5**
Temperature	°C	NA	30.8 (29.8-31.8)	30.9	27.1 (26.1-28.1)	27.4	27.9 (26.9-28.9)	28	31.3 (30.3-32.3)	31.1
Electrical Conductivity	µs/cm	NA	50,556 (48,028-53,084)	50,672	53,111 (50,455-55,767)	53,084	53,701 (51,016-56,386)	54,769	54,454 (51,731-57,177)	54,445
Total Suspended Solids (TSS)	mg/L	≤10	LOR (<5)	<5	10	6	<5	**5**	<52	<5
Turbidity	NTU	20	4.4	4.2	0.7	0.7	1.3	1.3	2.7	1.6
Total Dissolved Solids (TDS)	mg/L	N/A	32,890	**32,955**	34,515	34,515	34,970.0	**35,685**	35400	35,380
Dissolved Oxygen (DO)	%	80-100	48.4 (<45.98)	72.3	73.8 (<70.1)	83.3	37.5 (<35.6)	57.6	84.4 (<80.2)	83.6
Biological Oxygen Demand (BOD)	mg/L	NA	<2	<2	<2	<2	22	<2	<22	<2
Total Nitrogen	mg/L	<0.27	LOR <0.005	0.079	0.067	**0.090**	0.113	0.074	0.120	0.105
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 <0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.010	<0.010
Nitrate (NO_3)	mg/L	0.7	0.01	**0.012**	0.003	0.003	0.006	0.006	0.005	**0.008**
Nitrite (NO_2)	mg/L	NA	LOR <0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved reactive phosphorus (PO_4-P)	mg/L	0.005	0.002	0.002	<0.001	<0.001	0.003	0.002	0.002	0.002
Total Kjeldahl Nitrogen	mg/L	NA	0.075	0.069	0.064	**0.088**	-	-	-	-
Chlorophyll a	mg/L	<0.002	LOR <0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Escherichia coli (E. coli)	MPN /100mL	<200	LOR <1	<1	<1	<1	<1	<1	<1	<1
Enterococci	MPN /100mL	50	LOR <1	<1	<10	<10	<10	<10	<10	<10
Arsenic[1]	µg/L	NA	1.2	**1.3**	1.8	1.6	1.5	**1.6**	1.6	1.6
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	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Copper[1]	µg/L	1.3	LOR <1	<1	<1	<1	1	<1	<1	<1
Iron[1]	µg/L	NA	8	<5	<5	<5	<5	<5	<5	<5
Lead[1]	µg/L	4.4	LOR <0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese[1]	µg/L	NA	1.0	**1.1**	0.9	0.9	1.4	1.4	1.0	0.6
Mercury[1]	µg/L	0.4	LOR <0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Nickel[1]	µg/L	70	0.8	0.5	<0.5	0.5	11.7	1.2	30.4	1.5
Silver[1]	µg/L	1.4	LOR <0.1	<0.1	0.2	0.1	0.1	<0.1	<0.1	<0.1
Zinc[1]	µg/L	15	LOR <5	<5	<5	<5	40	<5	38.0	17.0
BTEX	µg/L	700	LOR <1	<1	<1	<1	<1	<1	<1	<1
Total Recoverable Hydrocarbons (TRH)	mg/L	LOR (<0.1)	LOR <0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Note 1: Represents dissolved fraction.

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.

2.1.3.8 Sediment Ponds Monitoring

2.1.3.9 Discharge Water Quality Results

A summary of the sediment water quality results for 2020 for Sediment Ponds 1-3, as well as the 2015-2020 trend and Licence trigger value exceedances are presented in **Table 2-5, Table 2-6** and **Table 2-7** and are discussed below.

Discharges from sediment ponds are affected primarily by the amount of rainfall with the exception of 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 2020:

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

In addition to mandatory monitoring under the Licence, voluntary monitoring has also been conducted for parameters of interest during 2020. The 2015-2020 dataset of both compliance and voluntary sediment pond water quality results is provided in **Attachment B – Sediment Ponds 1-3**; 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 2020 were generally consistent with the 2015-2020 average and were within the Licence trigger values with the following exceptions:
  - Turbidity in both Sediment Pond 2 and 3 exceeded the Licence trigger value on two sampling occasions in October (both ponds) and December (Sediment Pond 2 only). This triggered a reportable non-conformance against the Licence for Sediment Pond 2 only (92.70 NTU compared to a trigger value of 28 NTU) and reported to the NT EPA on 13 October 2020.
- Speciated nutrients (ammonium nitrogen, nitrate, nitrite and dissolved reactive phosphorus exceeded the Licence trigger values on multiple occasions in 2020 as detailed below and in **Figure 2-17, Figure 2-18, Figure 2-19** and **Figure 2-20.** Total nutrients were consistently below Licence trigger values for all sediment ponds in 2020:
  - Sediment Pond 1: The were three occasions where the Licence trigger values for nitrate and dissolved reactive phosphorus were exceeded in January and October. None of these events triggered a reportable non-conformance to the NT EPA.
  - Sediment Pond 2: There was one sampling event in October where the Licence trigger values for ammonium nitrogen and nitrate were exceeded. This event, particularly the nitrate concentrations, did not trigger a reportable non-conformance to the NT EPA as the result was from voluntary sampling (annual sample had been collected in March).
  - Sediment Pond 3: There was one sampling event in October where the Licence trigger values for ammonium nitrogen and dissolved reactive phosphorus were exceeded. This event did not trigger a reportable non-conformance to the NT EPA.

The 2020 average nutrient concentrations were generally consistent with or lower than the 2015-2020 average. An increasing trend in all nutrients was observed in Sediment Pond 1 and select nutrients (total nitrogen, ammonium nitrogen and nitrate) in Sediment Pond 3. Sediment Pond 2 conversely demonstrated a decreasing trend in nutrients.

- BOD for the discharge of all sediment ponds was within the Licence trigger value in 2020 and consistent with the 2015-2020 average.
- Metal concentrations in the discharge from the sediment ponds during 2020 were within the Licence trigger values, apart from copper which exceeded the Licence trigger value on a single occasion in Sediment Pond 2 in October 2020 (**Figure 2-21**). This was the first sampling event after the first wet season rains. This result did not trigger a reportable non-conformance against the Licence.

  The 2020 average metal concentrations were generally consistent with or lower than the 2015-2020 average in all sediment ponds with the exception of increasing trends noted for cadmium, copper and zinc in Sediment Pond 2 and iron in Sediment Pond 3.
- Hydrocarbons (TRH and BTEX) for the discharge of all sediment ponds were below Licence trigger values in 2020 and below the LOR. This is consistent with historical data which demonstrates long term trends where hydrocarbon concentrations are at or below detection limits.
- *E. coli* and *Enterococci* concentrations were elevated in all sediment ponds discharges after the first flush rain event in October 2020 (**Figure 2-22**). Only the Sediment Pond 1 discharge triggered a reportable non-conformance for *E. coli* under the Licence though 2020 (933 MPN/100mL compared to a trigger value of 305 MPN/100mL). The exceedance was reported to the NT EPA on 12 October 2020 in accordance with the Licence.

  The 2020 average microbiological concentrations overall were higher in all sediment ponds compared to the 2015-2020 average.

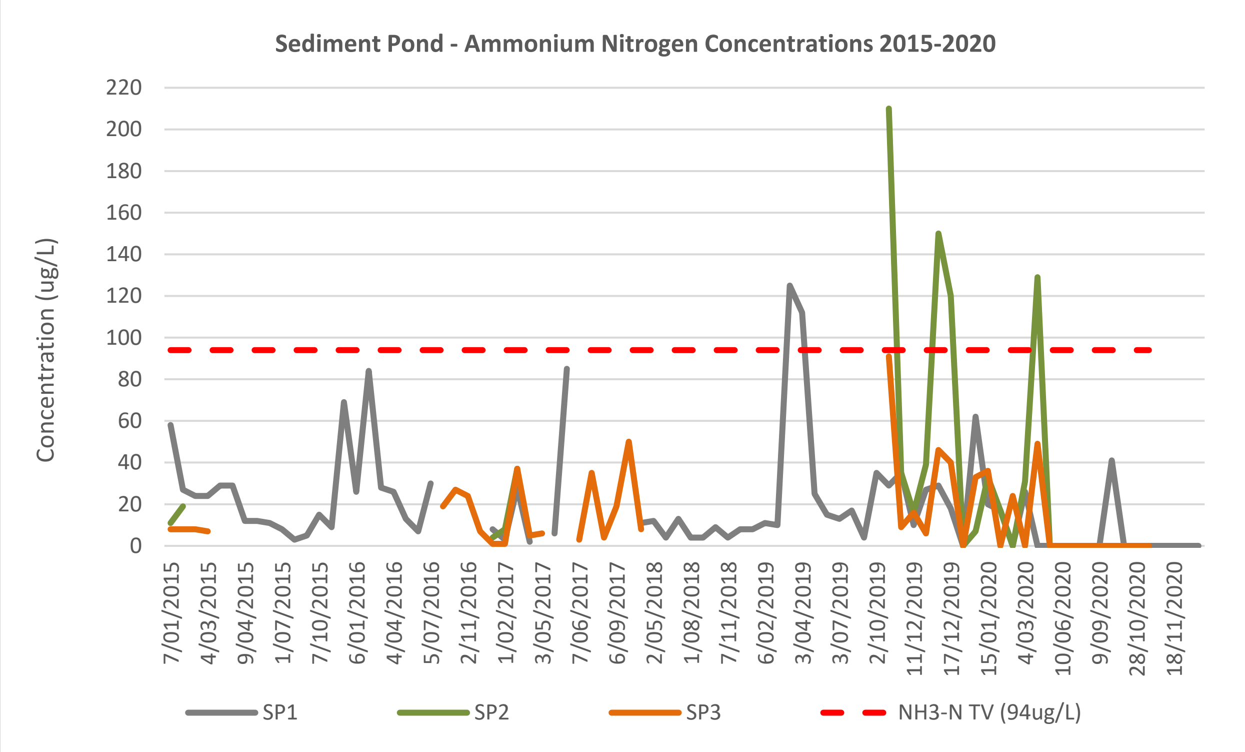


Figure 2-17 Sediment pond ammonium nitrogen concentrations

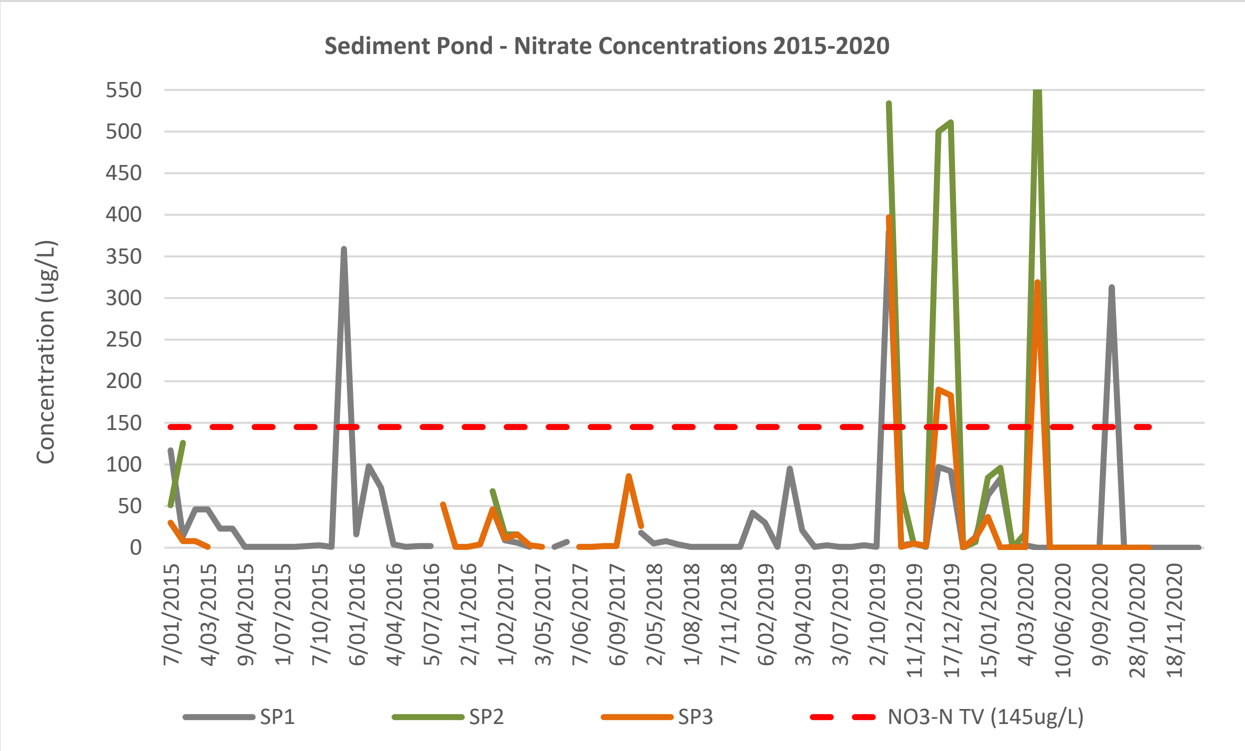


Figure 2-18 Sediment pond nitrate concentrations

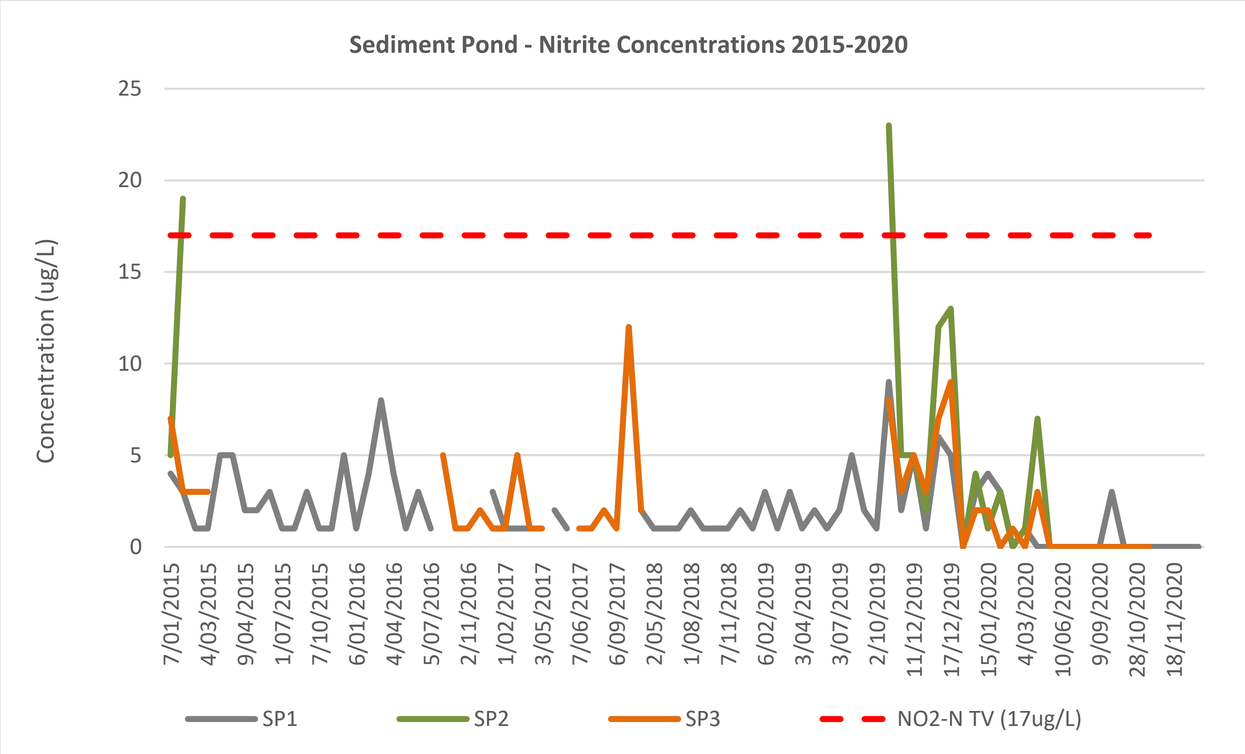


Figure 2-19 Sediment pond nitrite concentrations

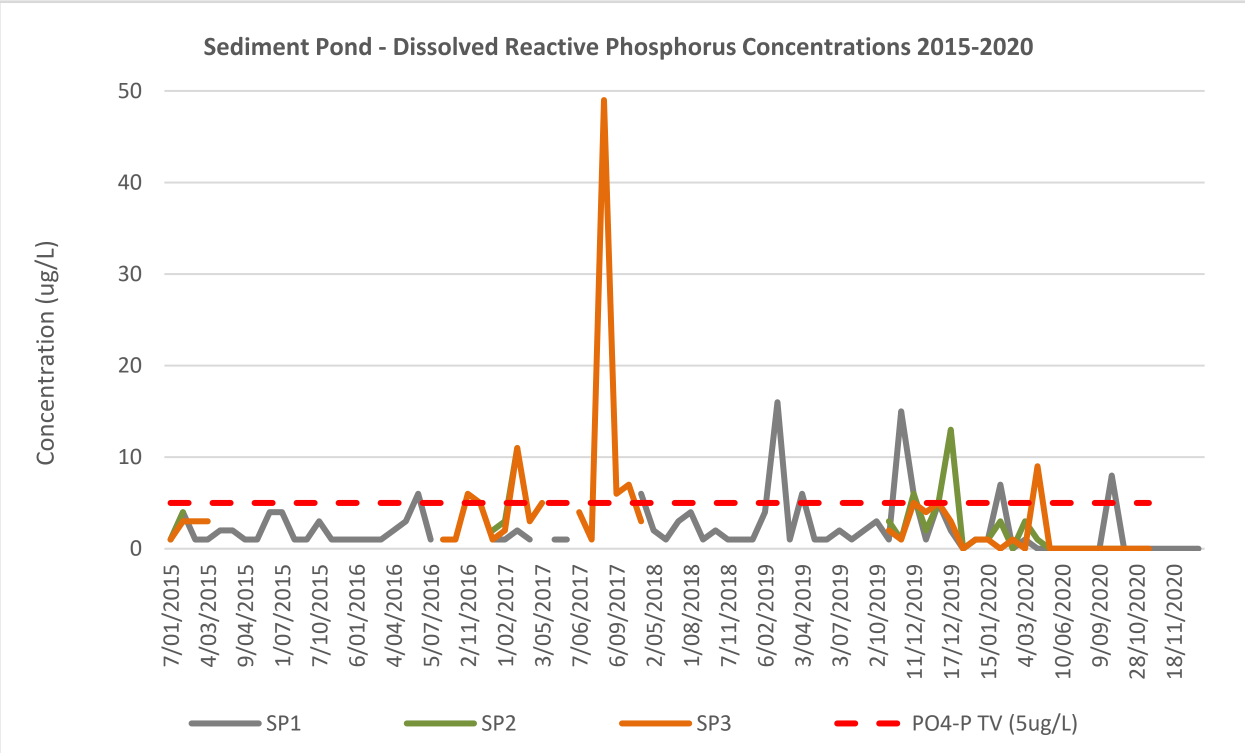


Figure 2-20 Sediment pond dissolved reactive phosphorus concentrations

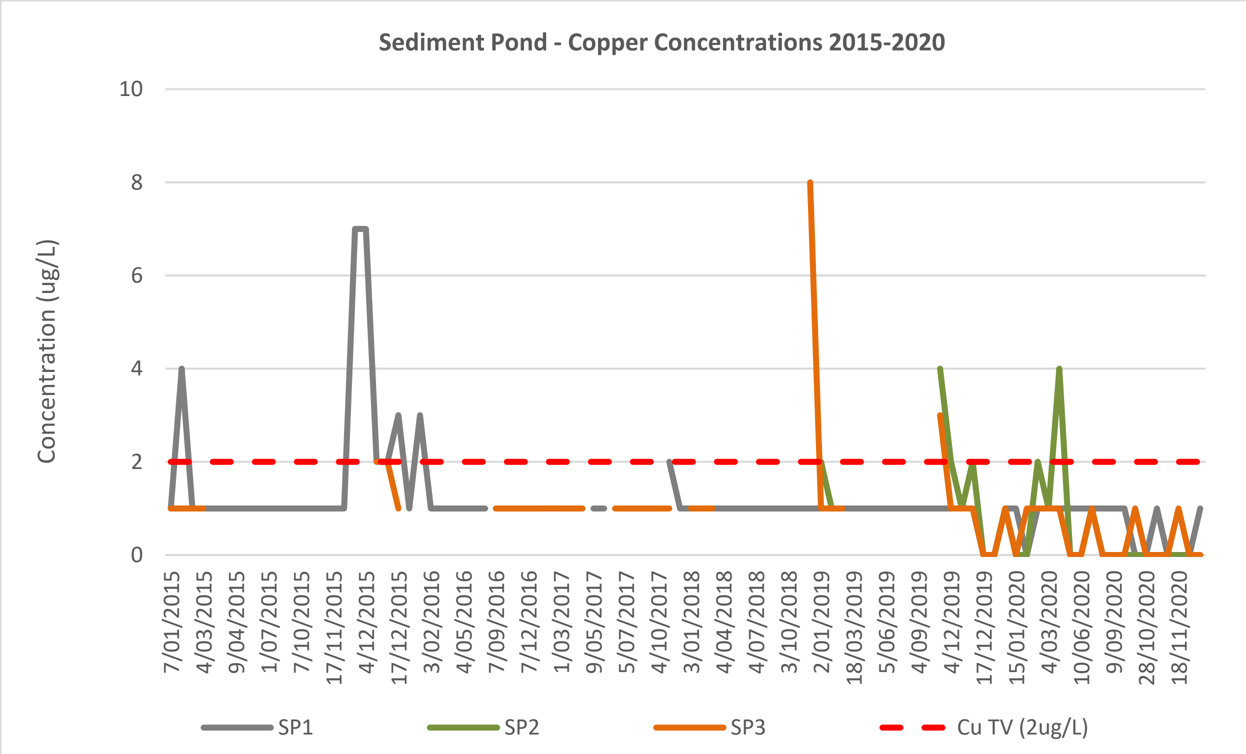


Figure 2-21 Sediment pond copper concentrations

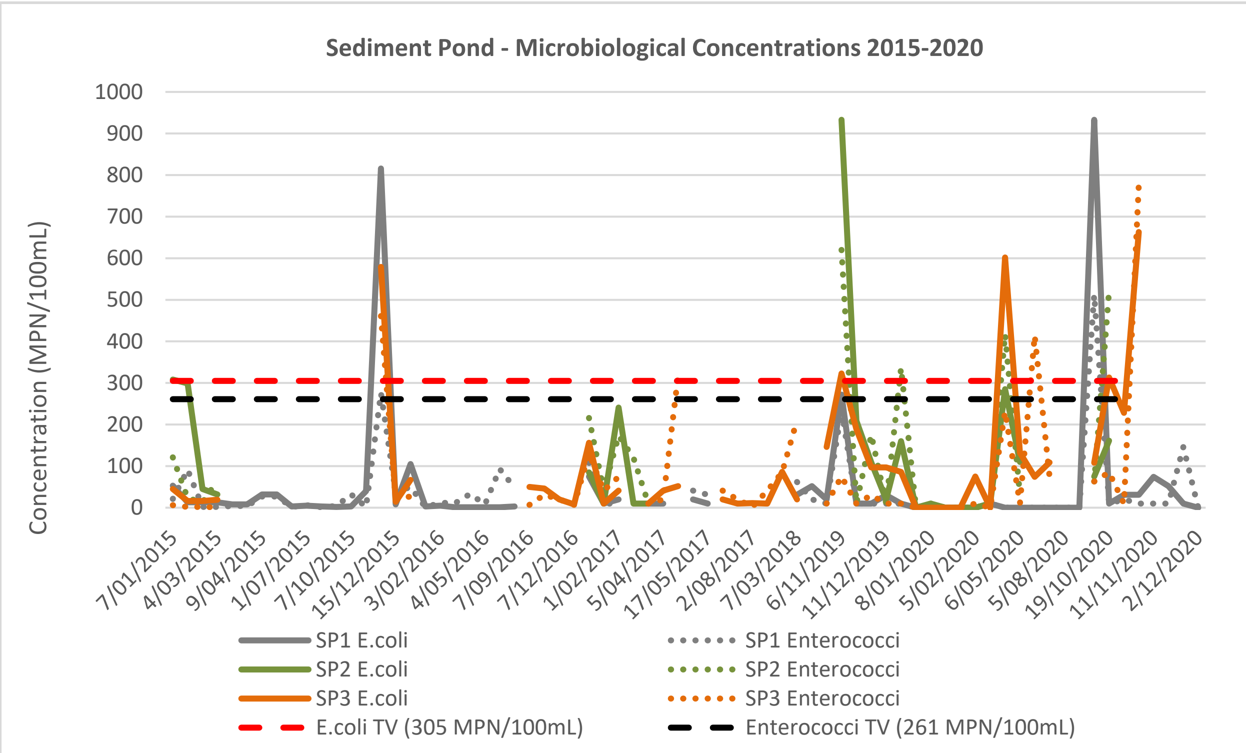


Figure 2-22 Sediment pond microbiological concentrations

Table 2-5 Summary of 2020 Sediment Pond 1 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Field Parameters							
pH	Monthly	6-8.5	7.30	6.48	6.87	6.66	No
Electrical conductivity(µs/cm)	Monthly	No trigger	198	87	141	135	N/A
TSS (mg/L)	Monthly	≤ 75	4	0	1.1	0.6	No
Turbidity (NTU)	Monthly	28	7.28	0.81	2.69	1.81	No
DO (mg/L)	Monthly	No trigger	6.33	3.25	5.12	5.60	N/A
Temperature (°C)	Monthly	No trigger	30.8	23.9	28.5	29.3	N/A
Environmental Indicators							
Ammonium nitrogen (NH_3-N) (µg/L)	Annual	94	62	17	33	24	No
Nitrate (NO_3-N) (µg/L)	Annual	145	313	3	95	37	No
Nitrite (NO_2-N) (µg/L)	Annual	17	4	<1	3	2	No
DRP (PO_4-P) (µg/L)	Annual	5	8	<1	4	3	No
Total Nitrogen (mg/L)	Annual	≤ 40	0.63	0.18	0.34	0.28	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.03	0.01	0.02	0.01	No
BOD (mg/L)	Monthly	≤ 25	3.2	<1	1.5	1.6	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
E. coli (MPN/100 mL)	Biannual	≤ 305	933	<10	144	62	**Yes**
Enterococci (MPN/100 mL)	Biannual	261	512	<10	91	45	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<1	<1	<1	N/A
Cadmium (µg/L)	Monthly	5.5	0.6	<0.1	0.1	0.2	No
Chromium (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Copper (µg/L)	Monthly	2.0	<1	<1	<1	1.3	No
Iron (µg/L)	Annual	No trigger	77	6	42	137	N/A

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Lead (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Manganese (µg/L)	Annual	No trigger	140	3	72	301	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.05	<0.1	<0.1	No
Nickel (µg/L)	Annual	70	<1	<1	<1	1	No
Silver (µg/L)	Annual	1.4	<1	<1	<1	<1	No
Zinc (µg/L)	Monthly	1,000	360	<5	78	103	No
BTEX (µg/L)	Monthly	700	<4	<3	<3	<3	No

* Note: Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.

Table 2-6 Summary of 2020 Sediment Pond 2 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Field Parameters							
pH	Monthly	6-8.5	6.85	6.31	6.56	6.64	No
Electrical conductivity(µs/cm)	Monthly	No trigger	359	106	244	187	N/A
TSS (mg/L)	Monthly	≤ 75	107	0	22	9	No
Turbidity (NTU)	Monthly	28	92.7	3.8	23.0	21.7	**Yes**
DO (mg/L)	Monthly	No trigger	6.60	3.60	5.30	5.38	N/A
Temperature (°C)	Monthly	No trigger	31.7	28.7	30.4	30.2	N/A
Environmental Indicators							
Ammonium nitrogen (NH_3-N) (µg/L)	Annual	94	129	7	43	77	No
Nitrate (NO_3-N) (µg/L)	Annual	145	625	7	166	173	No
Nitrite (NO_2-N) (µg/L)	Annual	17	7	<1	3	7	No
DRP (PO_4-P) (µg/L)	Annual	5	3	<1	2	3	No
Total Nitrogen (mg/L)	Annual	≤ 40	1.15	0.18	0.41	1.02	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.05	0.01	0.03	0.02	No
BOD (mg/L)	Monthly	≤ 25	1.2	<1	1.0	3.8	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
E. coli (MPN/100 mL)	Biannual	≤ 305	285	<10	84	143	No
Enterococci (MPN/100 mL)	Biannual	261	521	<10	221	180	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<1	<1	<1	N/A
Cadmium (µg/L)	Monthly	5.5	0.3	<0.1	0.1	0.1	No
Chromium (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Copper (µg/L)	Monthly	2.0	4	<1	2	2	No
Iron (µg/L)	Annual	No trigger	76	14	45	130	N/A

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Lead (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Manganese (µg/L)	Annual	No trigger	270	78	174	579	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.05	<0.1	<0.1	No
Nickel (µg/L)	Annual	70	2	<1	2	2	No
Silver (µg/L)	Annual	1.4	<1	<1	<1	<1	No
Zinc (µg/L)	Monthly	1,000	270	27	96	79	No
BTEX (µg/L)	Monthly	700	<4	<3	<3	<3	No

* Note: Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.

Table 2-7 Summary of 2020 Sediment Pond 3 water quality monitoring results

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Field Parameters							
pH	Monthly	6-8.5	7.64	6.46	6.88	7.01	No
Electrical conductivity(µs/cm)	Monthly	No trigger	240	69	160	146	N/A
TSS (mg/L)	Monthly	≤ 75	31	0	4	1	No
Turbidity (NTU)	Monthly	28	33.00	1.55	7.51	6.43	No
DO (mg/L)	Monthly	No trigger	8.96	3.63	6.53	6.61	N/A
Temperature (°C)	Monthly	No trigger	32.2	27.2	30.0	30.6	N/A
Environmental Indicators							
Ammonium nitrogen (NH_3-N) (µg/L)	Annual	94	49	24	36	22	No
Nitrate (NO_3-N) (µg/L)	Annual	145	319	<1	92	53	No
Nitrite (NO_2-N) (µg/L)	Annual	17	3	<1	2	3	No
DRP (PO_4-P) (µg/L)	Annual	5	9	<1	3	5	No
Total Nitrogen (mg/L)	Annual	≤ 40	0.87	0.13	0.37	0.30	No
Total Phosphorous (mg/L)	Annual	≤ 10	0.03	0.01	0.02	0.02	No
BOD (mg/L)	Monthly	≤ 25	1.6	<1.0	1.1	1.5	No
TPH (mg/L)	Annual	< 6	<0.65	<0.65	<0.65	<0.65	No
E. coli (MPN/100 mL)	Biannual	≤ 305	663	74	256	115	No
Enterococci (MPN/100 mL)	Biannual	261	776	<10	186	85	No
Metals & BTEX							
Arsenic (µg/L)	Annual	No trigger	<1	<1	<1	1	N/A
Cadmium (µg/L)	Monthly	5.5	<0.1	<0.1	<0.1	0.1	No
Chromium (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Copper (µg/L)	Monthly	2.0	1	<1	1	1	No
Iron (µg/L)	Annual	No trigger	380	170	275	179	N/A

Parameter	Monitoring Frequency	Licence Trigger Value	2020 Maximum	2020 Minimum	2020 Average	Long-term Average (2015-2020)	2020 Reportable Non-Conformance*
Lead (µg/L)	Annual	4.4	<1	<1	<1	<1	No
Manganese (µg/L)	Annual	No trigger	15	2	9	51	N/A
Mercury (µg/L)	Monthly	0.4	<0.1	<0.05	<0.1	<0.1	No
Nickel (µg/L)	Annual	70	<1	<1	<1	1	No
Silver (µg/L)	Annual	1.4	<1	<1	<1	<1	No
Zinc (µg/L)	Monthly	1,000	84	<5	84	72	No
BTEX (µg/L)	Monthly	700	<4	<3	<3	<3	No

* Note: Results from mandatory sampling are only considered when determining reportable non-conformances under the Licence.

2.1.4 Data Management and Quality Control

As outlined in **Section 2.1.2**, 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 enterprise information management system. Any results that are considered to be unreliable are investigated further and additional sampling undertaken if required.

2.1.5 Discussion and Interpretation of Results

2.1.5.1 Irrigation Area

The irrigation discharge volume was lower in 2020 compared to previous years for various reasons; a trial relating to the boiler resulting in less contribution of boiler blowdown, maintenance on the irrigation holding tank T2903 and reduced personnel onsite in 2020 resulting in less contribution from the STP.

In summary, there were four reportable non-conformances relating to the irrigation water during 2020, all of which were deemed to be of low risk and impact to the environment:

- Speciated nutrients exceeded the Licence trigger values in 2020. 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.

  The total nitrogen and total phosphorus results, which are better indicators of total nutrient load, did not exceed the Licence trigger values in 2020 and have a history of compliance during the 2015-2020 monitoring period. A Licence amendment is proposed for 2021 to update the trigger values to better reflect the environmental risks.

  Regardless, opportunities to improve the discharge quality from the STP, and consequently irrigation discharge, have been actioned during the reporting period. This includes the following:

  - Engagement of a wastewater specialist consultant to assist with daily management of the STP and training of the operators for the duration of 2020; and
  - The design and tender for a new STP, utilising better treatment technology and improved reliability, was progressed. Construction of the new STP is planned to commence in 2021 with commissioning in Q2 2022.

- BOD and TSS exceeded the Licence trigger levels in late Q3 – Q4 2020 due to a build up of biological material in the irrigation holding tank, CPI DAF and STP. 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.

- A minor leak from a subsurface irrigation discharge pipe was identified and reported to the

NT EPA on the 24 December 2020. The leak was weeping into a nearby stormwater drain. The discharge water quality from Sediment Pond 1 was not adversely affected or non-compliant with the Licence trigger values after the event. The leaking pipe was promptly rectified in early January 2021.

Potential impacts of the irrigation discharge on groundwater quality is discussed in detail in **Section 4** and, in summary, appear to be localised and limited.

2.1.5.2 Jetty Outfall Discharge and Mixing Zone

The jetty outfall discharge volume was the lowest annual discharge volume in the 2015-2020 period, primarily due to a reduction in losses from the steam system resulting in reduced demand for demineralisation water and the associated reject water production.

Ammonium nitrogen and zinc are the key parameter of concern with concentrations in the jetty outfall discharge exceeding the Licence trigger value during the 2015-2020 period on numerous occasions. With regards to the ammonium nitrogen, this is linked, in part, to the amine-based biocide used in the reverse osmosis plant. A biocide reduction trial was undertaken in 2019 which resulted in improvements to operational dosing practices which continued throughout 2020. This saw a temporary improvement in the effluent quality, however, ad hoc spikes in ammonium nitrogen continued.

This is possibly due to improved performance of EDI cells in the demineralisation plant which were replaced at the end of 2019. A zero biocide dosing campaign is also being considered for Q1 2021. Likewise, the ad hoc spikes in zinc are likely due to concentration of low levels in the source water from the NT POWA through the demineralisation plant.

The ammonium nitrogen and zinc exceedances did not trigger any reportable non-conformances to the NT EPA or translate to any Licence trigger value exceedances in the jetty outfall mixing zone in 2020. As such, the ammonium nitrogen and zinc are considered a low environmental risk.

Likewise, there were no occasions where the median concentration in the mixing zone exceeded both the reference site value and Licence trigger value for any other parameter, and as such there were no reportable non-conformances in 2020.

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.

2.1.5.3 Sediment Pond 1, 2, 3

Overall, in 2020 there was an increasing trend in nutrients, microbiology and select heavy metal concentrations in the sediment pond discharge water quality. While higher than in 2019, the increasing trend is marginal with the 2020 averages for all parameters still meeting the Licence trigger values. The only exception to this is the average nitrate concentration in Sediment Pond 2 (166 ug/L compared to a Licence trigger value of 145 ug/L).

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 frequent 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, 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.

The results from the mangrove monitoring program supports this conclusion; the impact of sediment pond discharges to the receiving mangrove environment is discussed in detail in **Section 12.2**. Although zinc is a parameter of interest in sediments and biota downstream from Sediment Pond 1 only, overall the results of 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.

To minimise any contribution of material to the sediment ponds from the DLNG facility, A Licence amendment is also proposed for 2021 to update the trigger values for sediment ponds to better reflect the environmental risks.

To minimise the contribution of material to the sediment ponds from the DLNG facility, the following improvement actions were implemented in 2020 and will continue annually:

- An annual maintenance plan has been created to ensure routine inspection and clean out as required of the stormwater network and plant bunds in the lead up to wet season rains;
- A more rigorous process for inspecting the quality of stormwater in bunds prior to being discharged has been implemented;
- Monthly testing of process sump Q-2908 during wet season has been established to monitor the input from this key stormwater sump to Sediment Pond 1; and
- An annual maintenance plan has been created to ensure clean out of process sump Q-2908 in the lead up to wet season rains.

In addition, as discussed in **Section 12.2**, Santos are progressing treatment options for the greensands filter backwash discharge to remove the sediment load which contributes to Sediment Pond 1. This is planned for completion in 2021 and is anticipated to significantly reduce the risk of elevated zinc concentrations in the mangrove environment in the long term.

2.2 MANGROVE MONITORING PROGRAM

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 (**Figure 2-23**). 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, was 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, 2020a) and are summarised in this section.

2.2.1 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.

2.2.2 Monitoring Methods

The annual mangrove monitoring was undertaken at the DLNG facility during August 2020. The methods used to undertake the monitoring are summarised in **Table 2-8** 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 2-23** and **Figure 2-24**.

Table 2-8 Summary of 2019 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 Total dissolved solids (TDS) pH	Water quality monitoring probes in monitoring bores	Data on groundwater quality (water table depth, TDS and pH) for comparison of water quality to 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 2-23**).

- 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).

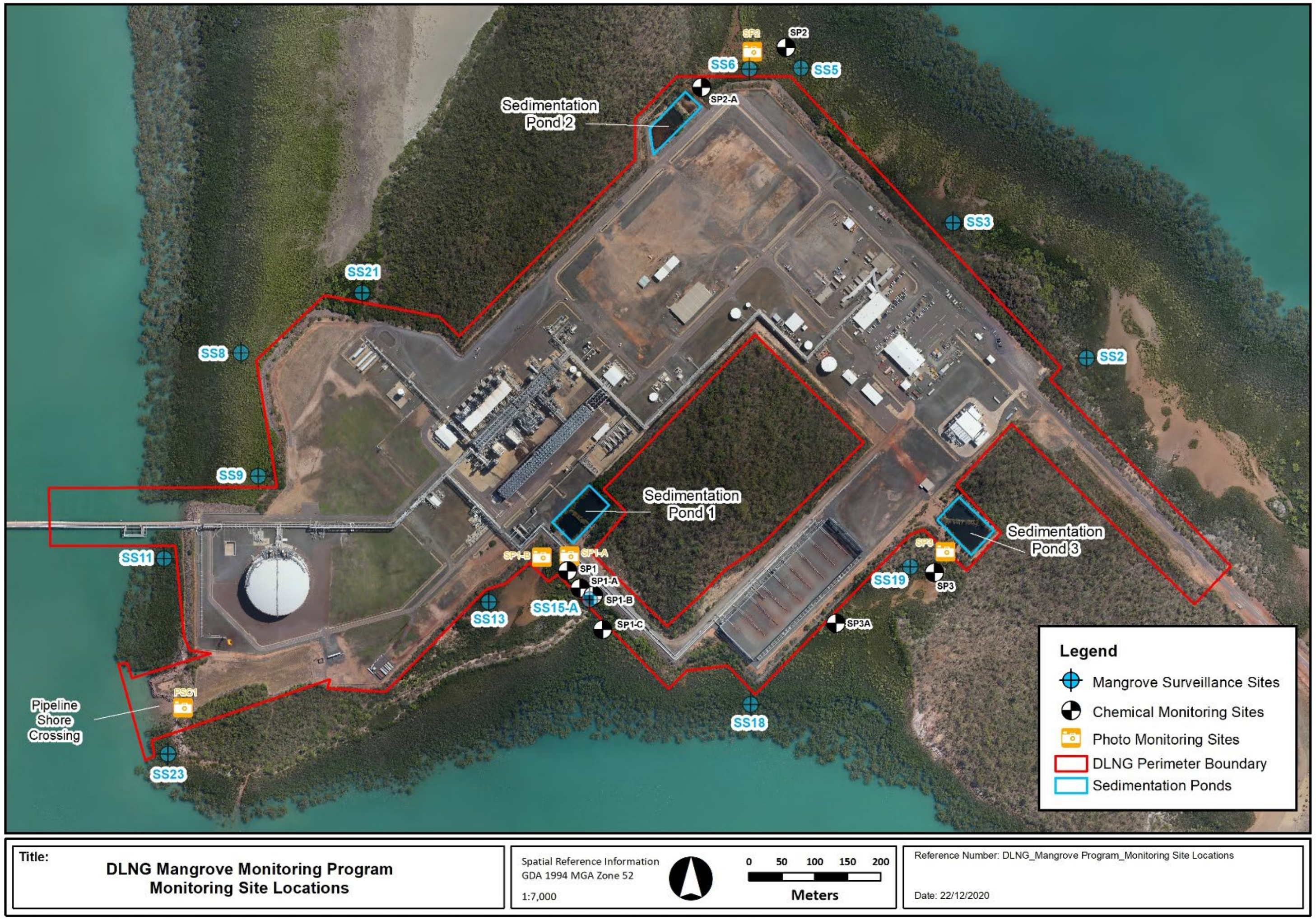


Figure 2-23 Location of sampling sites for the mangrove monitoring program

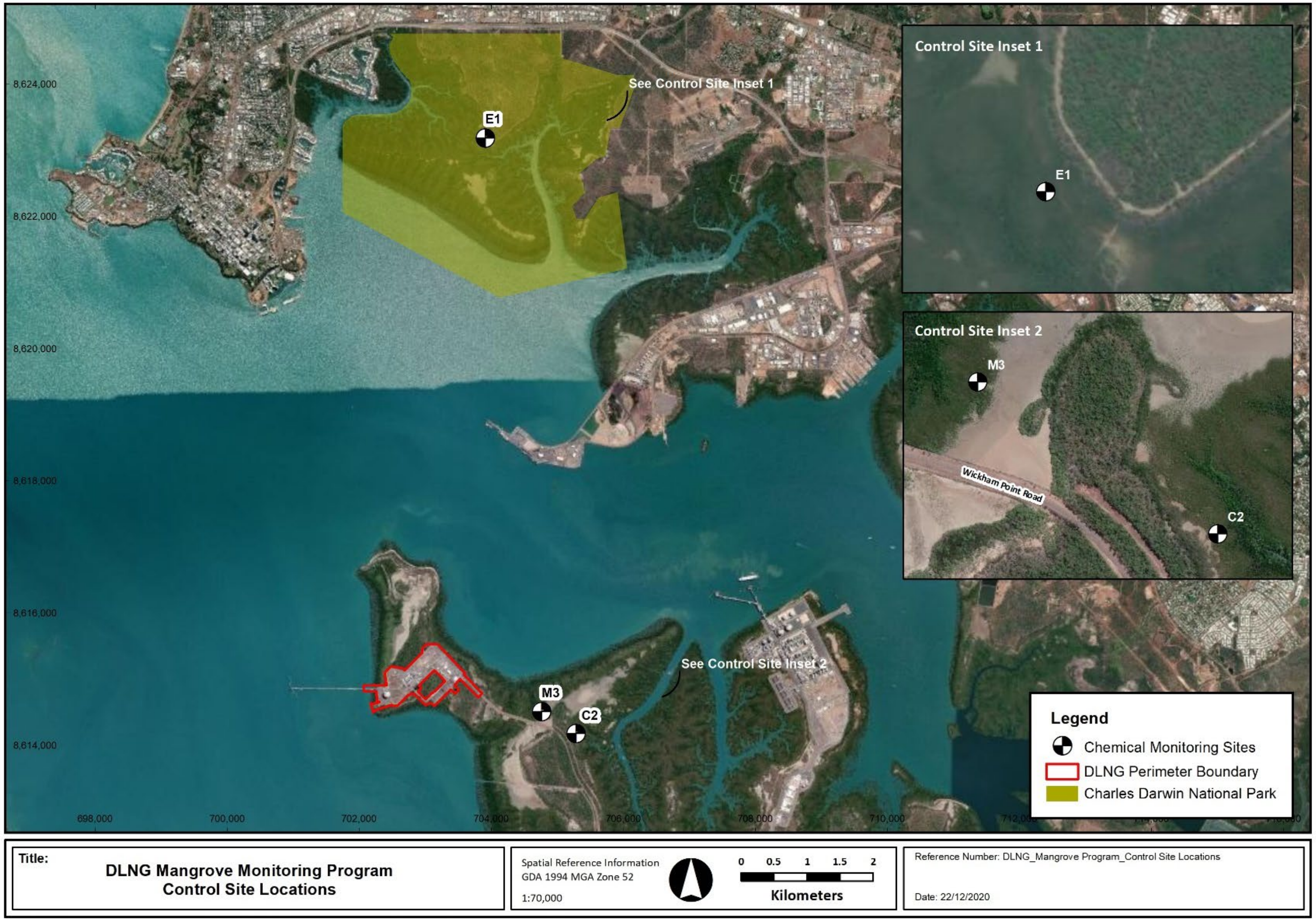


Figure 2-24 Location of control sites for the mangrove monitoring program

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 (Metcalfe, 2007) (**Figure 2-25**). DLNG monitoring sites are in the hinterland margin, tidal flat and tidal creek assemblages. The majority of 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* (**Figure 2-25**). 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 2-25**).

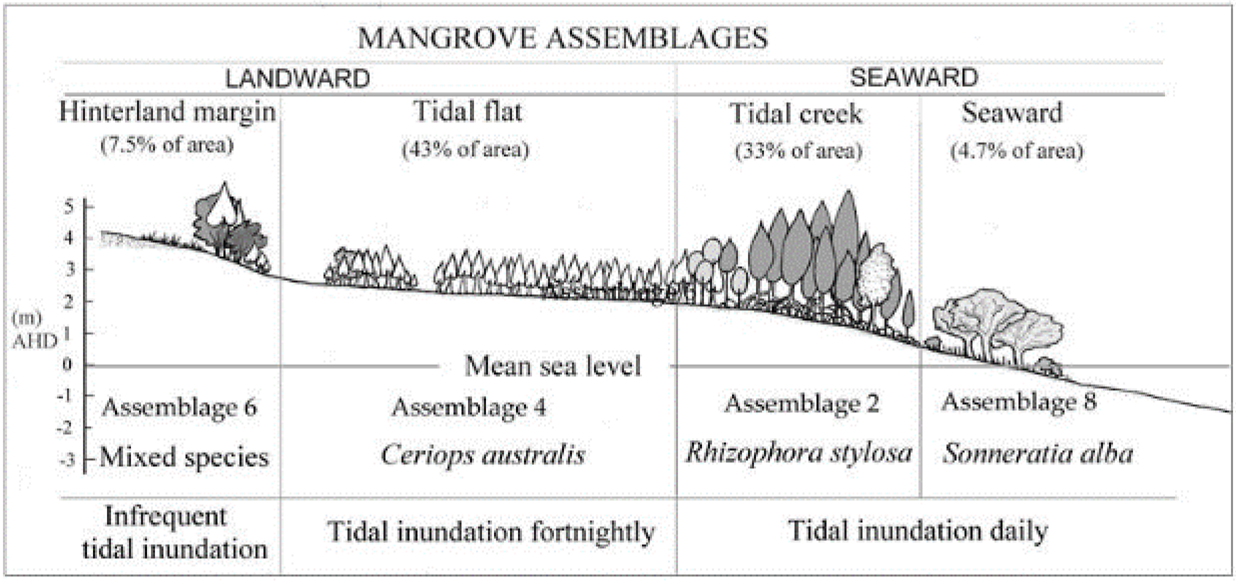


Figure 2-25 Conceptual model of the four main mangrove assemblages found within Darwin Harbour

2.2.3 Monitoring Results

A summary of the mangrove monitoring results is provided in the following sections with a full dataset (2003-2020) provided in **Attachment B**; where applicable, values exceeding guideline limits are bolded and/or shaded.

2.2.3.1 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.

Changes in canopy cover data for each monitoring site is presented in **Table 2-9**. Key findings include:

- Survey results for 2020 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.
- The use of the 17-point densiometer method has demonstrated improved standardisation and efficiency of canopy assessment, noting that some increase in canopy cover was recorded as an effect of the lower height setting for the measurements.
- Declines in canopy cover at two sites (SS03 and SS23) are considered to be natural declines in mangrove health associated with localised forest senescence due to storm or lightning strike (SS03) and severe weather events (SS23).
- Since baseline, canopy cover has declined at only two sites; one in Rhizophora forest (SS23) which was impacted by cyclone damage in 2018 and the other in Hinterland margin forest (SS03) potentially affected by a lightning strike.
- Notable increases in canopy cover since baseline 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 – 4 m 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.
- Recent program improvements include transition to exclusive use of the tripod-mounted 17-point densiometer technique to monitor canopy cover. During the August 2020 survey the 17-point densiometer and a new digital technique (the application % Cover which is run on an iOS device) were utilised to permit detailed comparison of results.

Table 2-9 Differences in mean canopy cover (%) between baseline (2003) and 2015-2020

Assemblage	Site	Standard Densiometer			17 Point Densiometer		
		2015	2016	2017	2018	2019	2020
Hinterland margin	SS01	-1	1	1	6.3	6.5	4
	SS02	-2	4	3	9.1	8.2	7.9
	SS03	-18	-18	-16	-14.0	-16.2	-12.5
	SS04	-2	-1	-1	2.1	2.5	2.9
	SS07	-2	-5	-7	5.9	-1.6	5
	SS09	-1	2	5	11.7	11.1	12.1
	SS13	1	2	3	7.2	6.3	8.2
	SS14	-4	-1	0	10.4	-0.1	0.5
	SS19	0	0	-1	28.3	18.5	17.8
	SS20	2	-7	-16	15.4	3.3	5.9
	SS21	1	0	0	1.2	3.1	2.3
Rhizopora forest	SS10	-3	-5	-5	-8.4	-6.8	-4.2
	SS11	-6	-5	-8	-6.3	-6.5	-4.1
	SS12	-2	-6	-3	1.0	2.1	2.9
	SS15A	N/A	N/A	N/A	N/A	N/A	N/A
	SS16A	N/A	N/A	N/A	N/A	N/A	N/A

Assemblage	Site	Standard Densiometer			17 Point Densiometer		
		2015	2016	2017	2018	2019	2020
	SS17	-3	-2	-4	2.2	0.6	1.1
	SS18	-6	-4	-10	2.2	-3.6	-1.1
	SS22	-3	-3	-6	1.1	0.0	1.8
	SS23	-1	-5	-5	-9.7	-14.2	-13.8
Ceriops forest / tidal flat	SS05	8	8	14	40.6	35.7	37.2
	SS06	N/A	N/A	N/A	N/A	N/A	N/A
	SS08	12	11	5	32.8	28.2	22.1

N/A indicates data unavailable for previous years

2.2.3.2 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:

- Comparison of photo-monitoring images using two techniques demonstrated that during the last year as well as over the previous 17-year period, mangrove forest structure, composition and physiognomy has remained stable at the majority of surveillance sites, indicating the healthy status of mangroves remains unchanged.
- Observed long term changes include increases in forest height and tree density with associated thinning of the understorey layer at some sites, particularly in *Ceriops* forests. In Rhizophora forests some minor changes in structure and species composition were evident (in addition to recent cyclone damage) particularly at dynamic coastal sites.
- Photo-monitoring supplemented results for defoliation index and percentage canopy change, documenting the following:
  - A decline in forest health at SS03 (attributable to localised forest senescence from potential storm damage or lightning strike);
  - An increase in forest cover at SS09 (associated with natural increase in forest cover over time);
  - A decline in density at SS23 (due to cyclone damage); and
  - Localised thinning of the forest at SS10 and SS11 (natural senescence exaggerated by cyclone damage).
- The enduring effects of minor cyclone damage from Cyclone Marcus in March 2018 were still evident in August 2020, particularly at site SS23 on the southern shoreline of Wickham Point which was most exposed to damaging winds.

2.2.3.3 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 2015 and 2020 is presented in **Table 2-10**. Key findings include:

- Defoliation index data indicated that in general, the status of mangrove forests surrounding the LNG plant remains normal with canopy cover characteristic of healthy mangrove assemblages.
- Small decreases in defoliation index were recorded at SS07, SS10, SS13, SS22 and SS23 and small increases were recorded at SS06 and SS18. No change was recorded at most sites. The estimation of defoliation index is problematic due to operator subjectivity, largely associated with the lack of a detailed definition for each of the five categories. Variation between operators is also exacerbated by high variability in the natural condition of mangrove trees. Most mangrove forests are inherently stressed due to extreme habitat conditions, some exhibit seasonal leaf loss and the majority of upper intertidal trees normally have a high proportion of dead branches.

Table 2-10 Annual mean defoliation index data for 2015-2020

Assemblage	Site	2015	2016	2017	2018	2019	2020	Difference between 2019-2020
Hinterland margin	SS01	4.0	4.0	4.0	4.25	4.25	4.25	0.0
	SS02	4.0	4.0	4.0	4.75	4.25	4.25	0.0
	SS03	4.0	3.5	3.5	2.0	2.5	2.5	0.0
	SS04	4.0	4.0	4.0	4.0	5.0	5.0	0.0
	SS07	4.0	4.0	4.0	3.5	4.0	3.5	-0.5
	SS09	4.0	4.0	4.0	4.25	4.25	4.25	0.0
	SS13	4.0	4.0	4.0	4.75	5.0	4.75	-0.3
	SS14	4.0	4.0	4.0	4.25	4.0	4.0	0.0
	SS19	4.0	4.0	4.0	2.75	3.0	3.0	0.0
	SS20	4.0	4.0	4.0	3.0	3.0	3.0	0.0
	SS21	4.0	4.0	4.0	3.25	4.0	4.0	0.0
Rhizopora forest	SS10	4.0	4.0	4.0	4.25	4.5	4.25	-0.3
	SS11	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS12	4.0	4.0	4.0	4.75	4.75	4.75	0.0
	SS15A	4.0	4.0	4.0	3.75	4.0	4.0	0.0
	SS16A	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS17	4.0	4.0	4.0	4.25	4.25	4.25	0.0
	SS18	4.0	4.0	4.0	4.0	4.0	4.25	0.3
	SS22	4.0	4.0	4.0	4.5	4.25	4.0	-0.3
	SS23	4.0	4.0	4.0	3.25	3.5	3.25	-0.3
Ceriops forest / tidal flat	SS05	4.0	4.0	4.0	4.0	4.0	4.0	0.0
	SS06	N/A	N/A	N/A	4.0	4.0	4.25	0.3
	SS08	4.0	4.0	4.0	4.25	4.0	4.0	0.0

N/A indicates data unavailable

2.2.3.4 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.

2.2.3.5 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 (2015 to 2020) net difference since baseline results are presented in **Table 2-11** together with the change recorded between 2019 and 2020. 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 2-26** represents graphically the net difference since baseline to 2020 at all sites.

Key findings include:

- Changes in sediment heights were consistent at most sites with previous data and changes were below the trigger value for accretion.
- Since baseline monitoring in 2003 there has been a small increase in sediment height (1-9.5 cm) at the majority of sites, indicating low sediment accretion rates over the 18-year period. Greater increases in sediment height (11.3-27.5 cm) since baseline have been recorded from sites located in the south west section of Wickham Point, near the LNG jetty.
- Comparison of changes since baseline (2003) indicated that sediment heights have increased in the Rhizophora forests (~15 cm) but ground levels have remained relatively stable in the Hinterland margin (3.5 cm) and *Ceriops* assemblage (~5.5 cm).
- The 2020 data are consistent with previous monitoring and there has been no indication of deterioration in the health of the mangroves subjected to the observed sediment deposition rates.

Table 2-11 Net difference in mean relative sediment height (cm) between baseline (2003) and 2015-2020

Assemblages	Site Number	2015	2016	2017	2018	2019	2020	Difference between 2019-2020
Hinterland margin	SS01	2.0	1.8	2.3	2.9	2.4	2.5	0.1
	SS02	1.7	1.2	2.0	2.3	1.5	1.5	0.0
	SS03	1.7	1.7	1.9	1.1	2.1	2.2	0.1
	SS04	-0.2	0.3	0.3	0.1	1.4	1.6	0.2
	SS07	-2.2	-2.5	-3.0	-2.8	-2.8	-2.8	0.0
	SS09	11.7	12.7	12.9	16.8	15.8	15.9	0.1
	SS13	3.8	3.8	4.8	5.3	5.5	5.6	0.1
	SS14	0.0	2.7	2.7	2.5	1.8	2.2	0.4
	SS19	0.1	-0.2	0.6	0.2	0.1	0.1	0.0
	SS20	2.3	1.8	2.3	1.8	2.5	2.6	0.1
	SS21	7.7	8.4	7.9	6.2	6.5	6.9	0.4
Rhizopora forest	SS10	11.0	11.5	13.6	21.0	24.9	27.5	2.6
	SS11	9.5	10.8	11	8.3	10.5	11.3	0.8
	SS12	9.9	10.6	12.6	13.8	13.9	14.6	0.7
	SS15A**	N/A	N/A	1.3	2.3	-4.1	-4.3	-0.2
	SS16A**	N/A	N/A	0	1.0	0.4	0.3	-0.1
	SS17	2.7	3.2	3.2	4.2	4.2	4.4	0.2
	SS18	6.4	7.1	7.1	9.5	9.1	8.9	-0.2
	SS22*	0.5	0.3	-0.3	0.5	0.5	0.5	0.0
	SS23*	0.8	1.0	-0.5	1.3	-2.1	-1.0	1.1
Ceriops forest / tidal flat	SS05	2.1	2.8	2.6	2.1	3.1	4.1	1.0
	SS06	1.9	1.4	1.2	0.8	1.3	0.9	-0.4
	SS08	7.6	8.9	10.1	11.1	11.4	11.6	0.2

* 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.
** Sites 15A and 16A were established in 2015
N/A indicates data unavailable

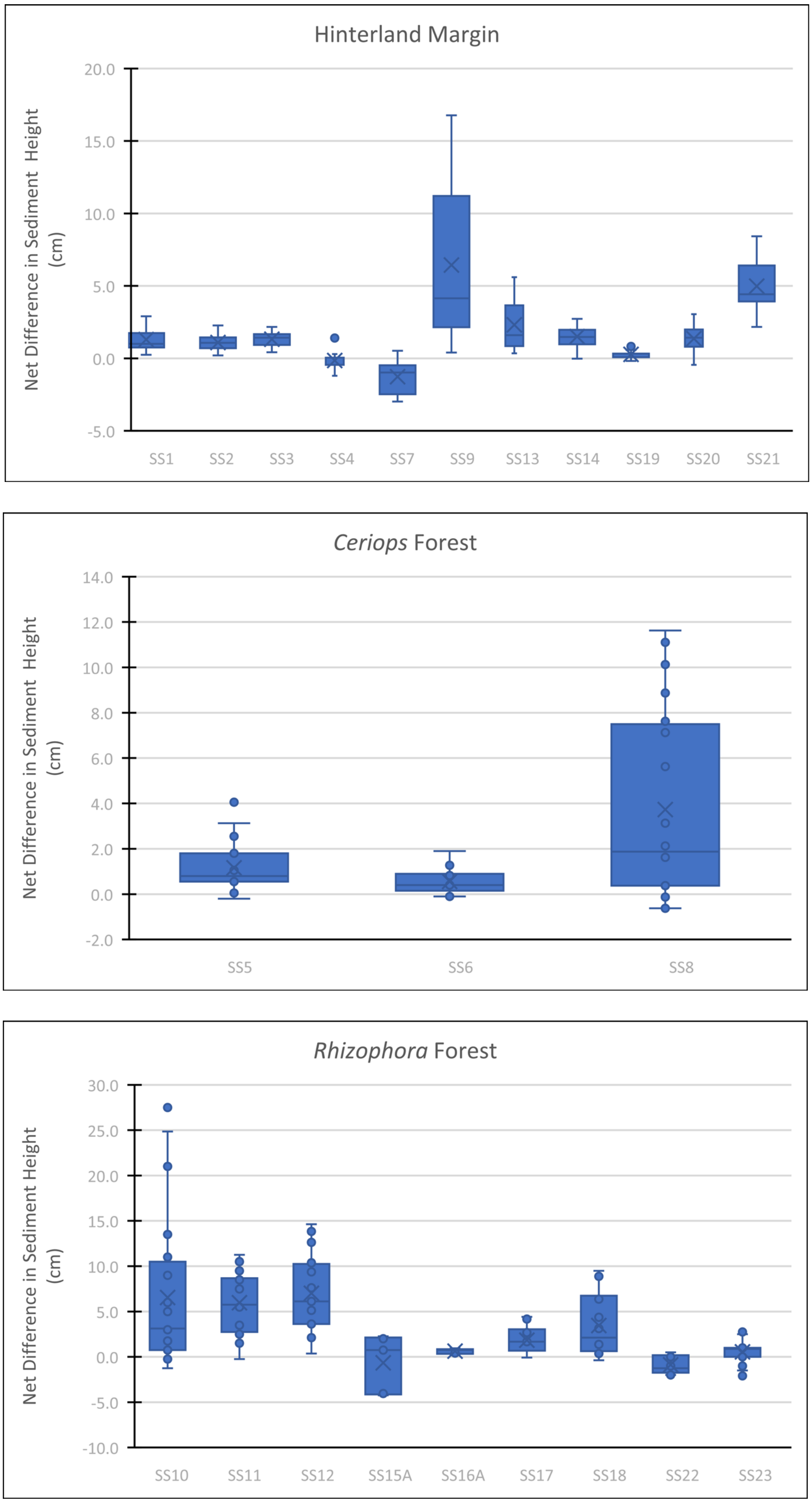


Figure 2-26 Change in sediment height distribution since baseline (2003 to 2020)

2.2.3.6 Groundwater Characteristics

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 (refer to **Figure 2-23**). 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 2015 to 2020 are presented in **Table 2-12**. Boxplots of all monitoring results from baseline to 2020 are presented in (**Figure 2-27**). 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 2020 mangrove monitoring was undertaken during elevated coefficient tides. Spring tides occurring on in the days (20-23 August) immediately prior to the survey would have inundated the entire mangrove zone, including the hinterland fringe sites, therefore, only site (SS1) was dry and could not be sampled.
- Comparison of salinity over the last five years indicates there has been minimal change over time with no evidence of increasing salinities that may impact mangrove health.

Table 2-12 Groundwater salinity (TDS ‰) from hinterland mangrove monitoring sites from 2015 to 2020

Site No.	2015	2016	2017	2018	2019	2020	Salinity Range and Mean (‰)
SS1	NC	N/A	NC	NC	NC	NC	49 (6-78)
SS2	70	NC	70	73	NC	65	66 (56-73)
SS3	66	NC	69	67	68	66	66 (58-72)
SS4	67	NC	66	NC	NC	63	67 (61-73)
SS5	62	60	59	58	55	60	60 (48-66)
SS6	68	70	61	NC	NC	62	64 (54-76)
SS7	48	NC	48	NC	NC	45	49 (32-70)
SS9	68	67	70	72	70	60	68 (60-73)
SS13	50	NC	NC	24	NC	52	50 (24-61)
SS14	68	68	67	69	66	37	64 (37-71)
SS19	64	65	22	NC	NC	54	59 (22-68)
SS20	NC	NC	NC	NC	NC	26	58 (26-70)
SS21	50	NC	40	41	NC	41	40 (19-67)

Note: "NC" indicates that sample/data was not collected due to lack of water in the bore

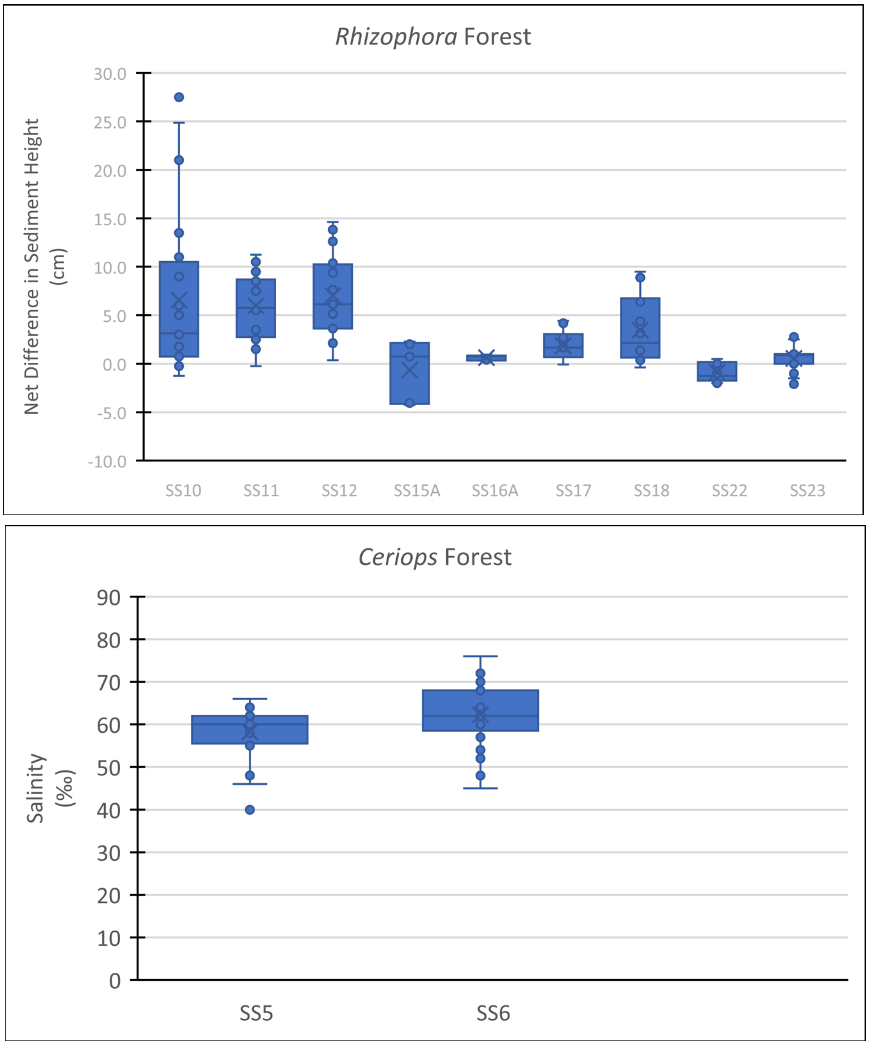


Figure 2-27 **Boxplots of groundwater salinity (TDS ‰) for all monitoring periods (baseline to 2020)**

2.2.3.7 Sediment Characteristics

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).

A total of fourteen sites were visited for sediment sampling (refer to **Figure 2-23**). Sediment samples were analysed for particle size and melas (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 annual 2020 chemical monitoring results were compared with historical data and relevant criteria. Key findings include:

- 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 downstream of Sediment Pond 1only.
- Concentrations of zinc derived from the acid soluble metals analysis exceeded the ANZG (2018) DGV value (200mg/kg) at site SP1-A (340 mg/kg) and the GV-high concentration (410 mg/kg) at site SP1 (520 mg/kg) (**Table 2-13** and **Figure 2-28**). 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 has occurred 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. Although low concentrations of zinc have typically been recorded within Sediment Pond 1 this data has been limited to the dissolved fraction and an assessment of load contribution is not possible at this point in time.
- 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 are 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 are likely to 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 and 2020, 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. This scope is planned for completion in 2021 and is anticipated to significantly reduce the risk of elevated zinc concentrations in the mangrove environment in the long term.
- Concentrations of hydrocarbons (as TRH) in sediments were below the laboratory limits of detection at all sites again in 2020. Hence, no results are presented here. This is consistent with previous monitoring results, which have typically been close to or below the laboratory limits of detection.

Table 2-13 Weak acid concentrations in mangrove sediments (mg/kg dry weight) (2018-2020

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

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

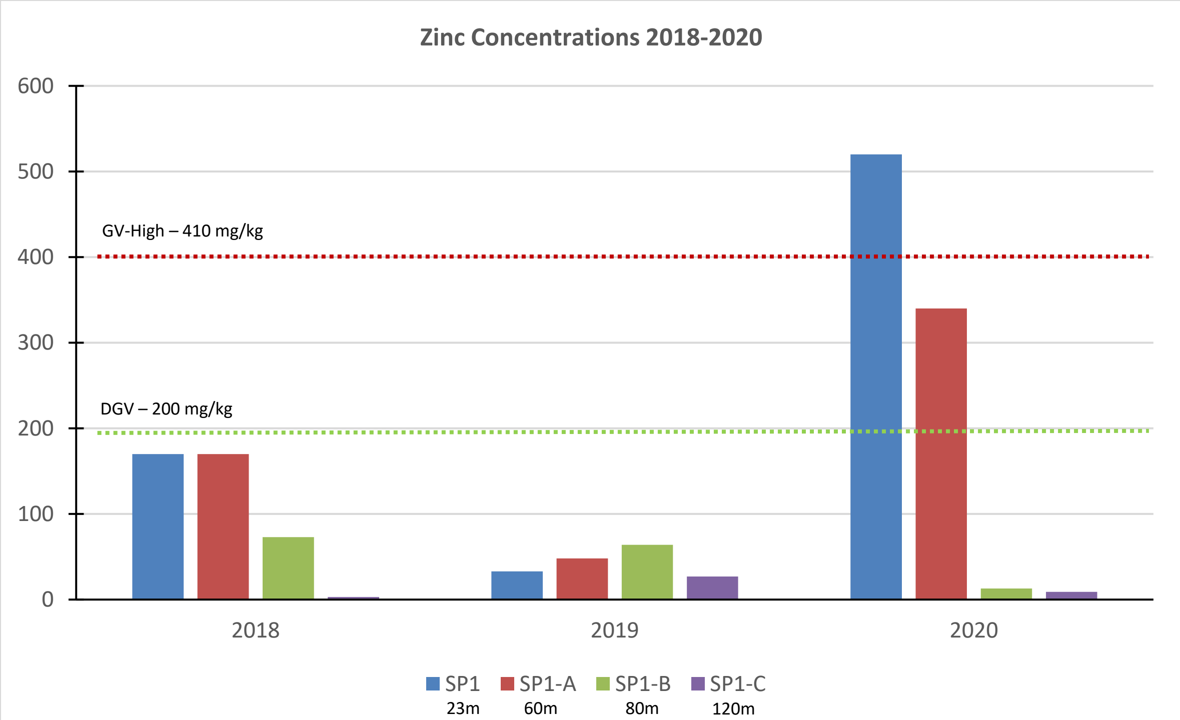


Figure 2-28 Weak acid soluble zinc concentrations at sites located downstream to Sediment Pond 1 SP1 (23 m), SP1-A (60 m), SP1-B (80 m) and SP1-C (120 m) (2018 to 2020)

2.2.3.8 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 2-23**) 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:

- Copper concentrations in mudwhelks exceeded the trigger value (GEL 90th percentile) at various sites (LG1, LG2, LG3, SP1-C, SP2, SP3-A) at Wickham Point as well as at two control sites M3 and C2 (**Table 2-14**). 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.

- Although below the assessment criteria, elevated zinc concentrations in mudwhelks were observed at site SP1-A relative to most other sites were observed in 2019 and 2020 (**Table 2-14** and **Figure 2-29**). The location of this site downstream of Sediment Pond 1, a potential source of zinc, and historical occurrences of elevated total and bioavailable zinc in sediments in this area (i.e. SP1-A, SP1-B and SP1-C) suggest there could be a relationship, however it is not supported statistically at this point in time.
- Metal concentrations in *Telescopium telescopium* recorded at most sites in 2020 are within the range of those recorded by a Darwin Harbour wide study in 1990 (Table 7-12, Appendix B.4) and, more recently, from sampling undertaken in mangroves at Bladin Point (and control sites) for the Ichthys LNG project. This observation, in addition to the lack of FSANZ criteria exceedances for most sites, indicates that the mudwhelk colonies occurring in mangroves next to the Darwin LNG site have not been subject to any significant contamination, including for zinc which has been elevated at sites downstream from Sediment Pond 1.
- 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 2-14 Metal concentrations in mudwhelks in 2020

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 90th Percentile		**N/G**	**N/G**	**30**	**N/G**	**N/G**	**N/G**	**N/G**	**290**
Wickham Pt	LG1	0.03	<1	**53**	53	65	<1	<1	48
	LG2	0.03	<1	**44**	44	12	<1	<1	18
	LG3	0.16	<1	**32**	62	46	<1	0.40	24
	SP1	0.03	<1	24	81	44	<1	<1	37
	SP1-A	0.11	<1	17	53	254	<1	0.42	165
	SP1-B	0.05	<1	19	61	45	<1	<1	42
	SP1-C	<0.1	<1	**41**	31	7	<1	<1	17
	SP2	0.05	<1	**35**	95	54	<1	0.27	35
	SP3-A	0.10	<1	**43**	105	25	<1	0.50	23
Control Site	M3	0.08	<1	**33**	103	141	<1	0.25	71
	E1	<0.1	<1	27	85	18	<1	<1	28
	C2	0.02	<1	**41**	67	38	<1	<1	22

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.

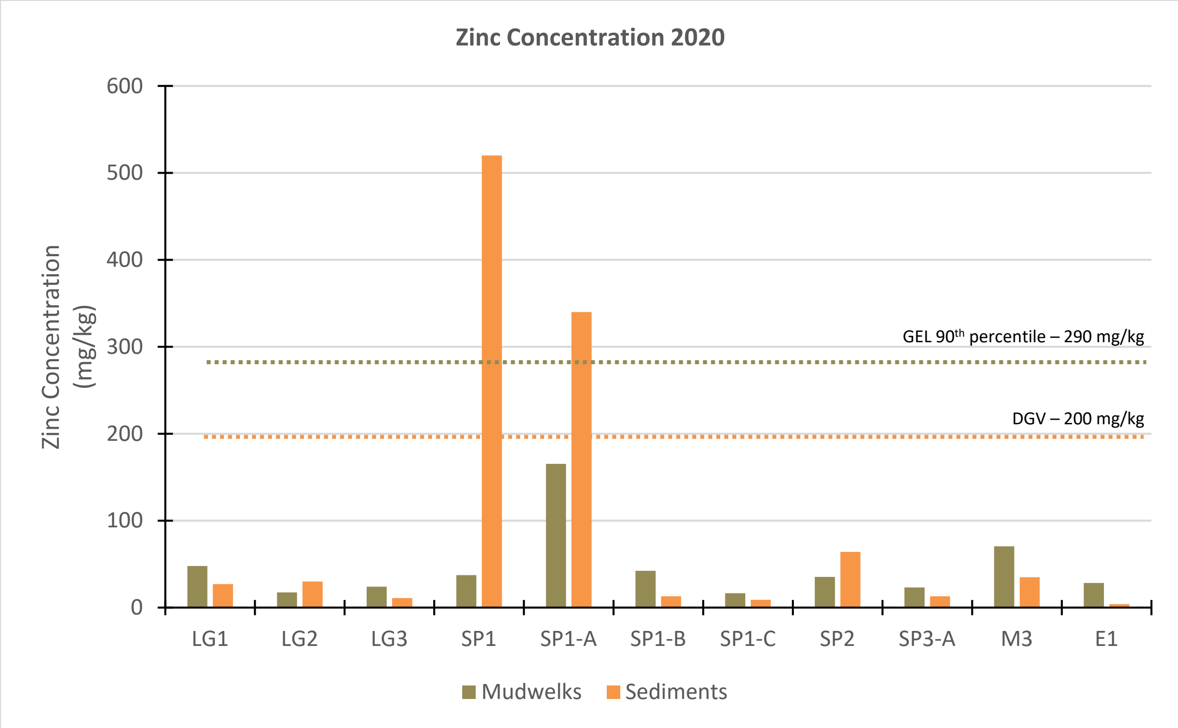


Figure 2-29 Zinc concentrations for biota and sediment in 2020

2.2.4 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.

2.2.5 Discussion and Interpretation of Results

The following key conclusions have been derived from a review of the historical and annual surveillance and chemical monitoring results:

- The results of the 2020 mangrove monitoring program indicate that mangrove forests around the DLNG facility remain in a stable, healthy condition. There is little evidence of anthropogenic impacts to mangroves, with most of the measured changes in mangrove health the result of natural causes (i.e. damage from tropical cyclone Marcus). The 2020 data recorded for canopy density, tree condition, sedimentation/erosion (sediment heights) and groundwater conditions were compared to the substantial data set that exists from previous monitoring. This comparison showed that values for the key mangrove health parameters remained largely unchanged in 2020 and were similar to those recorded over the last six years.
- Results of mangrove sediment and biota monitoring indicated that surface water discharged from the DLNG facility did not have any significant impact on mangrove sediment and biota surrounding the facility, this has been consistent since post-commissioning monitoring began in 2006.
- Weak acid soluble concentrations of all metals analysed in sediments were below the ANZG (2018) DGV and GV-High trigger values at all sites with the exception of the elevated zinc concentrations at site SP1 and SP1-A downstream of Sediment Pond 1. The scale of this influence appears to have been localised and confined to areas within the

DLNG Approved Disturbance Boundary. In consideration of the broader mangrove metrics that demonstrate system health, the occurrence of these concentrations are considered low risk.

- Concentrations of metals in mudwhelks were below the FSANZ ML and GEL guidelines for human consumption with the exception of copper which exceeded the GEL 90th percentile trigger value. Since monitoring commenced in 2006, copper concentrations exceeding the GEL have been regularly recorded at various sites. This is assessed as not being linked to DLNG operations for the following reasons:
  - Biologically copper is essential for marine invertebrates and plays an important role in respiration and detectable concentrations can be present in molluscs from unpolluted waters (Peerzada, Eastbrook and Guinea, 1990).
  - Similar copper concentrations were recorded in a Darwin Harbour wide study and, more recently, from sampling undertaken in mangroves at Bladin Point control sites for the Ichthys LNG operations (CDM Smith, 2019).
  - Historic sediment pond discharge water quality data indicates a history of generally being near, and often below, the detection limits for copper.
- A licence amendment is proposed to reduce the scale of the mangrove monitoring program, given eighteen years of data is supporting the conclusion that the DLNG facility has had negligible impact on the surrounding mangrove environment. The sites for continued monitoring are proposed to be those downstream from any discharge points such as the sediment ponds.

To better understand and manage the sources of zinc in the mangrove environment downstream from Sediment Pond 1, the following actions have been initiated:

- Monthly testing of process sump Q-2908 during wet season was initiated to monitor the input from this key stormwater sump to Sediment Pond 1. This commenced in 2019, was ongoing throughout 2020 and will continue in 2021. The results to date have confirmed that dissolved zinc is present in the water collected in this process sump. It is not considered a significant contributor by volume as the concentrations at the discharge of Sediment Pond 1 are significantly lower than those recorded in the sump.
- The installation of a treatment system on the greensands filter backwash discharge to remove the sediment load in planned for completion in 2021 and is anticipated to significantly reduce the risk of elevated zinc concentrations in the mangrove environment in the long term.

3. MONITORING DISCHARGES TO AIR

Conditions 44 to 52 of the Licence permits Santos to discharge emissions to air from the following sources (**Figure 3-1**):

- Stack emissions from the power generation turbines, compressor turbines, acid gas incinerator and process boiler (**Section 3.1**); and
- Hydrocarbon flaring and venting (**Section 3.2**).

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 sections are also included in relation to monitoring discharges to air:

- Ambient air quality monitoring program (**Section 3.3**); and
- Greenhouse gas emissions (**Section 3.4**).

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

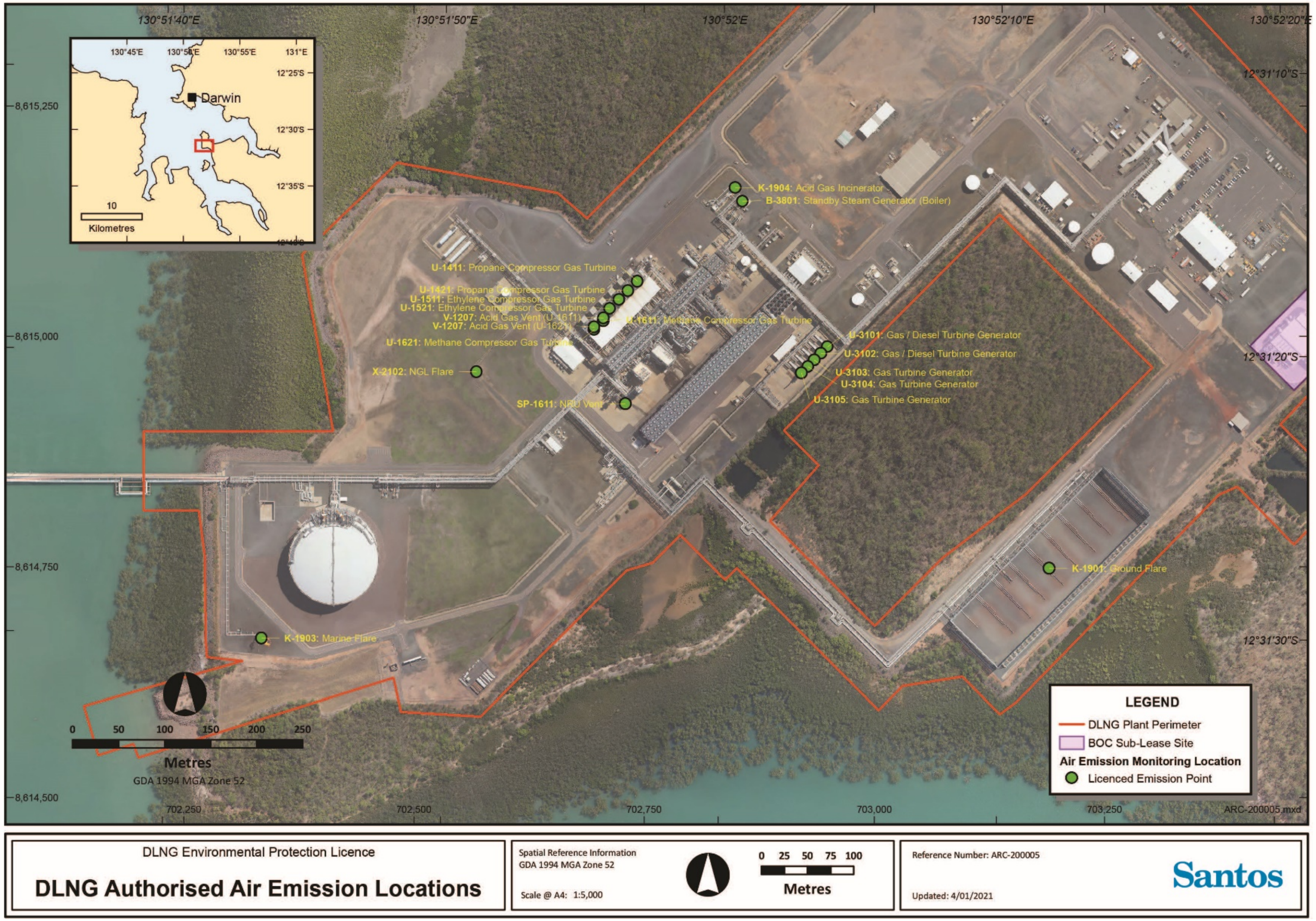


Figure 3-1 Map of emissions to air locations permitted by the Licence

3.1 STACK EMISSIONS MONITORING PROGRAM

The majority 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.

3.1.1 Monitoring Objectives

The objectives 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.

3.1.2 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 3-1**.

Biannual testing of the power generation turbines, compressor turbines and boiler stack emissions was undertaken in August and November 2020. Quarterly testing of AGI and solvent regenerator reflux drum was undertaken in February, August and November 2020. No testing was conducted in Q2 2020 due to the absence of locally available stack testing specialists and COVID-19 travel restrictions.

3.1.3 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**; values exceeding current Licence trigger values are bolded.

3.1.3.1 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 2020 and overall for the 2015-2020 period (**Figure 3-2**);
- Compliant carbon monoxide (CO) mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-3**); and
- Compliant sulphur dioxide (SO_2) mass emissions rates and concentration for 2020 and overall for the 2015-2020 period. All results were below the LOR in 2020 (**Figure 3-4**).

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 SO_2 concentrations can be attributed to low H_2S concentrations in the feed gas.

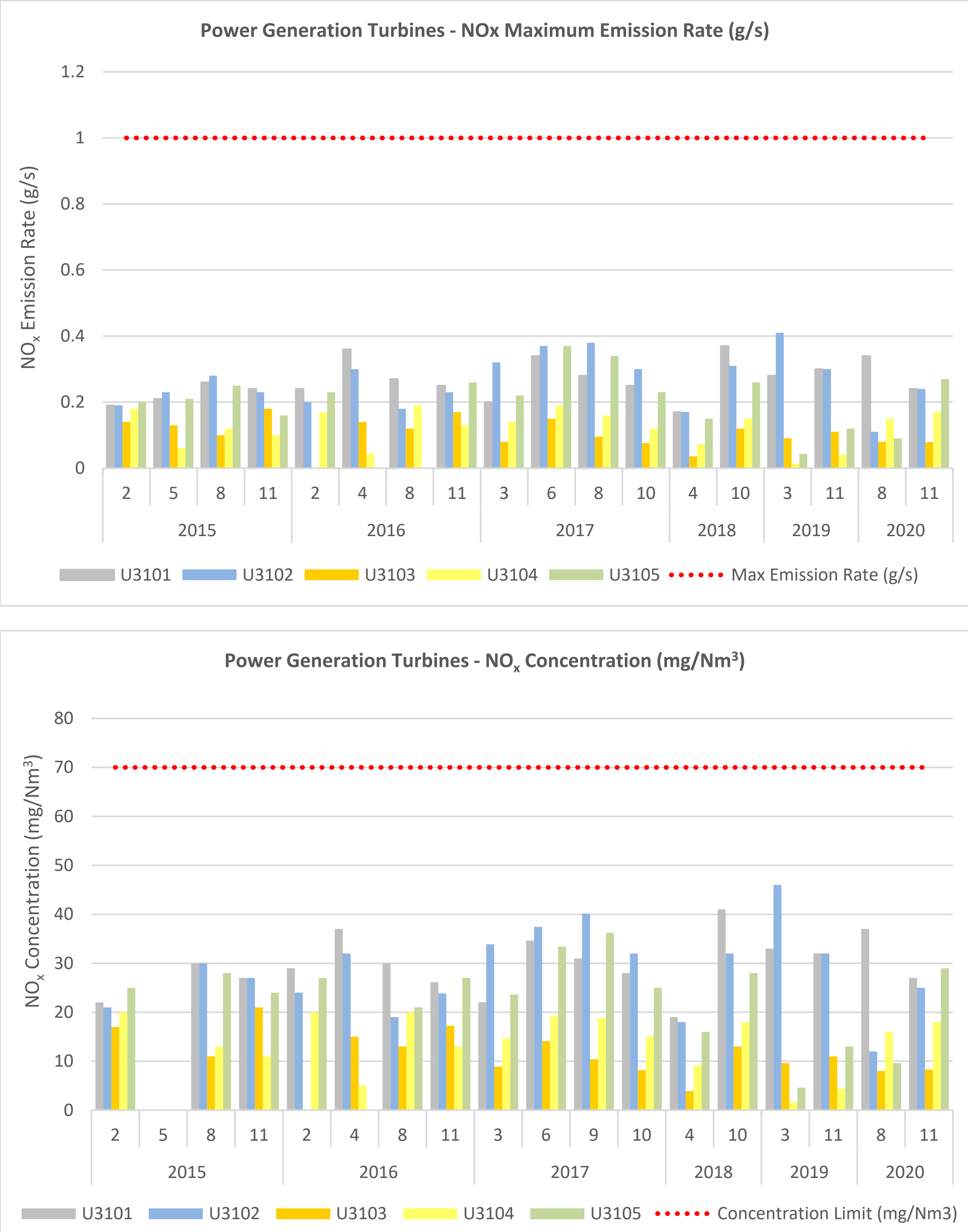
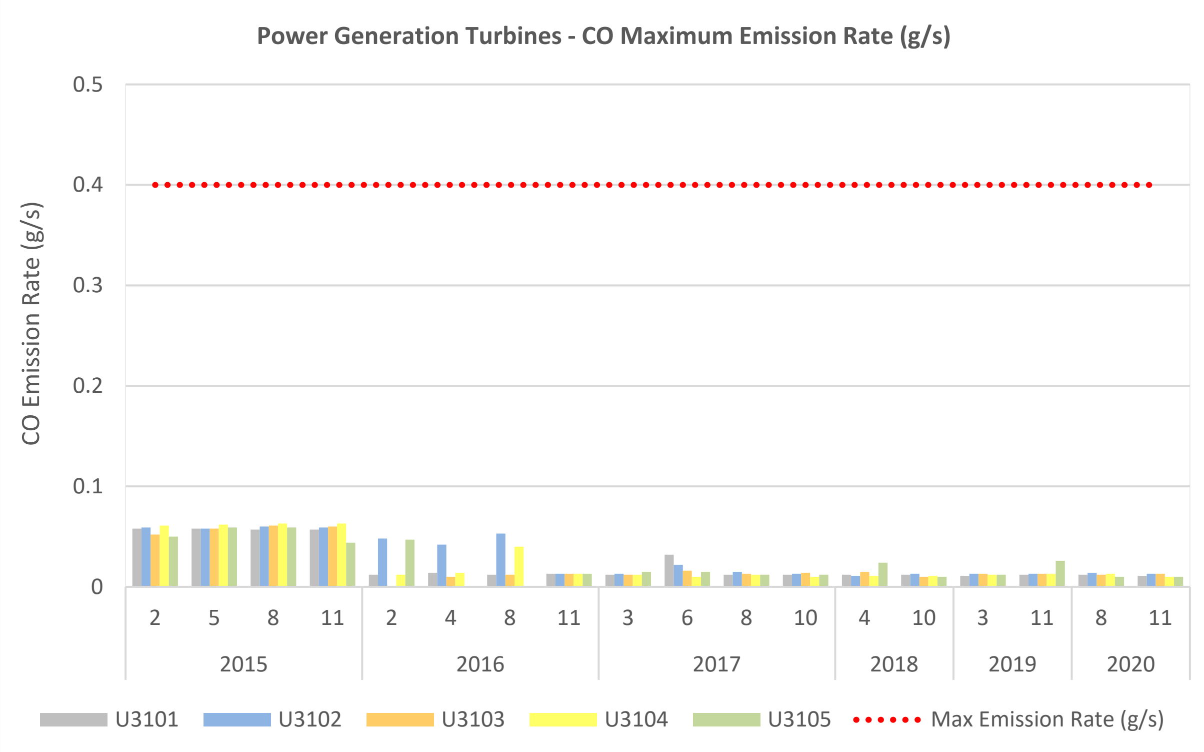


Figure 3-2 Power generation turbines NO_x emissions from 2015-2020



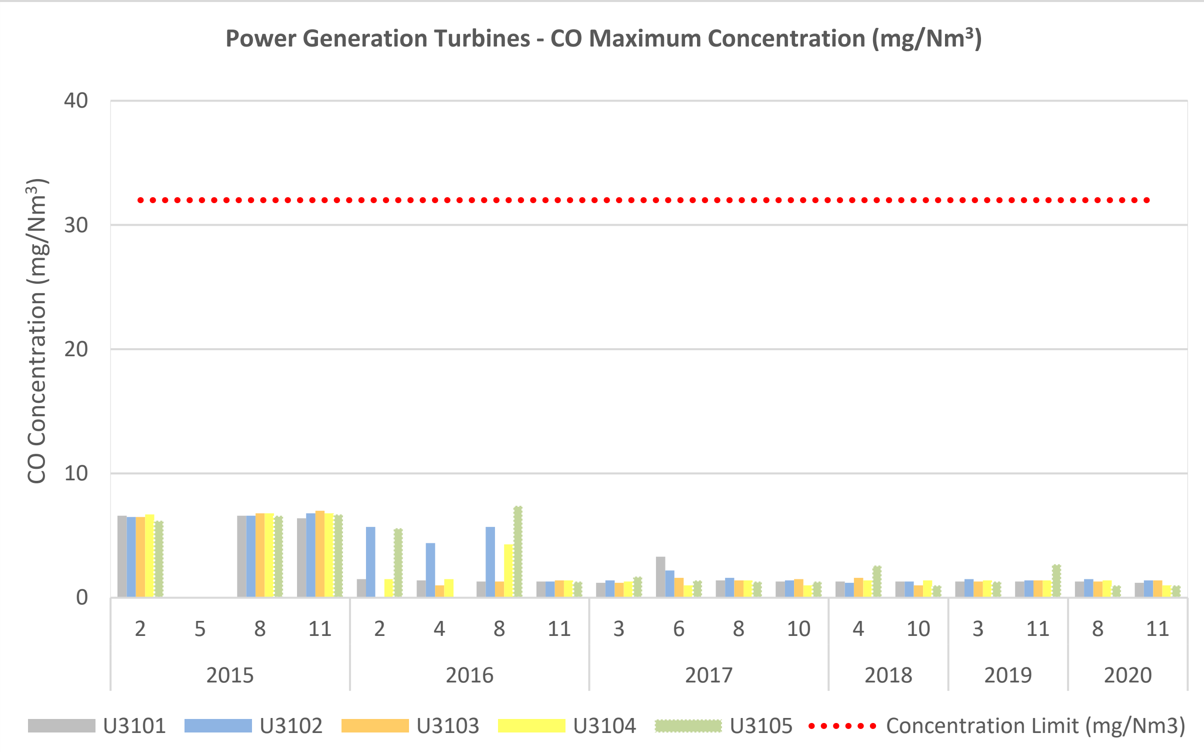
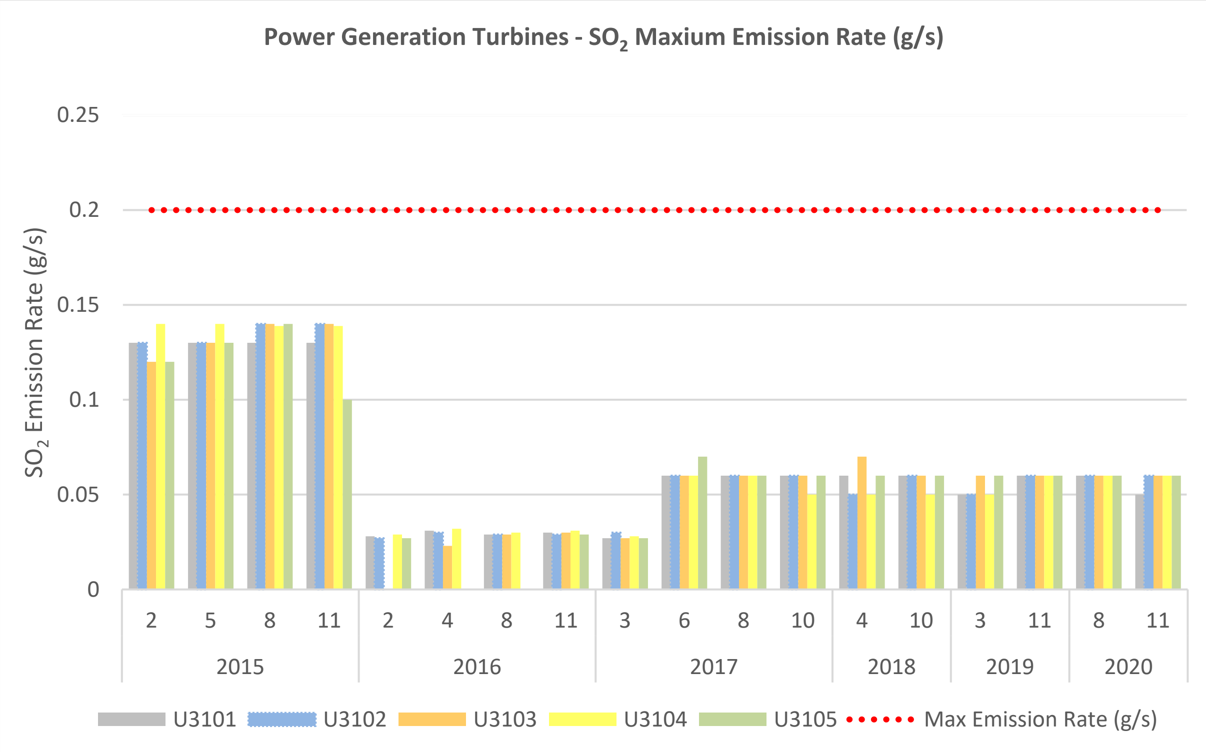


Figure 3-3 Power generation turbines CO emissions from 2015-2020



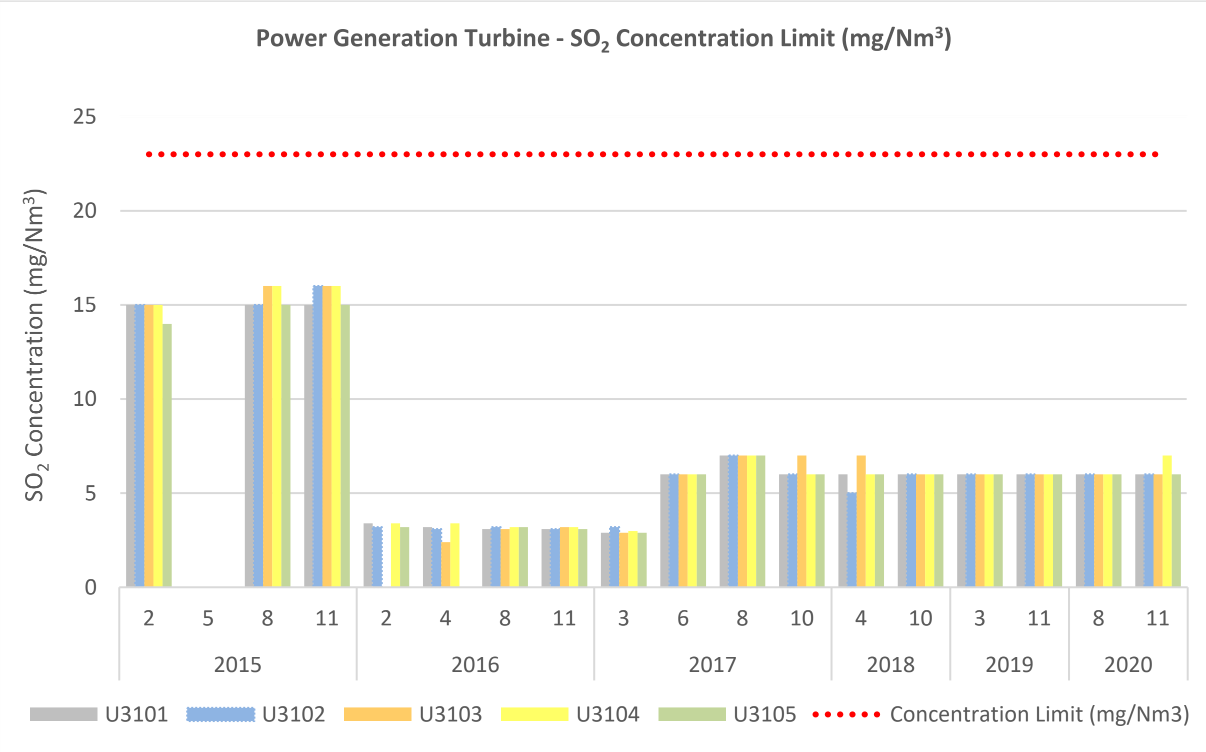


Figure 3-4 Power generation turbines SO_2 emissions from 2015-2020

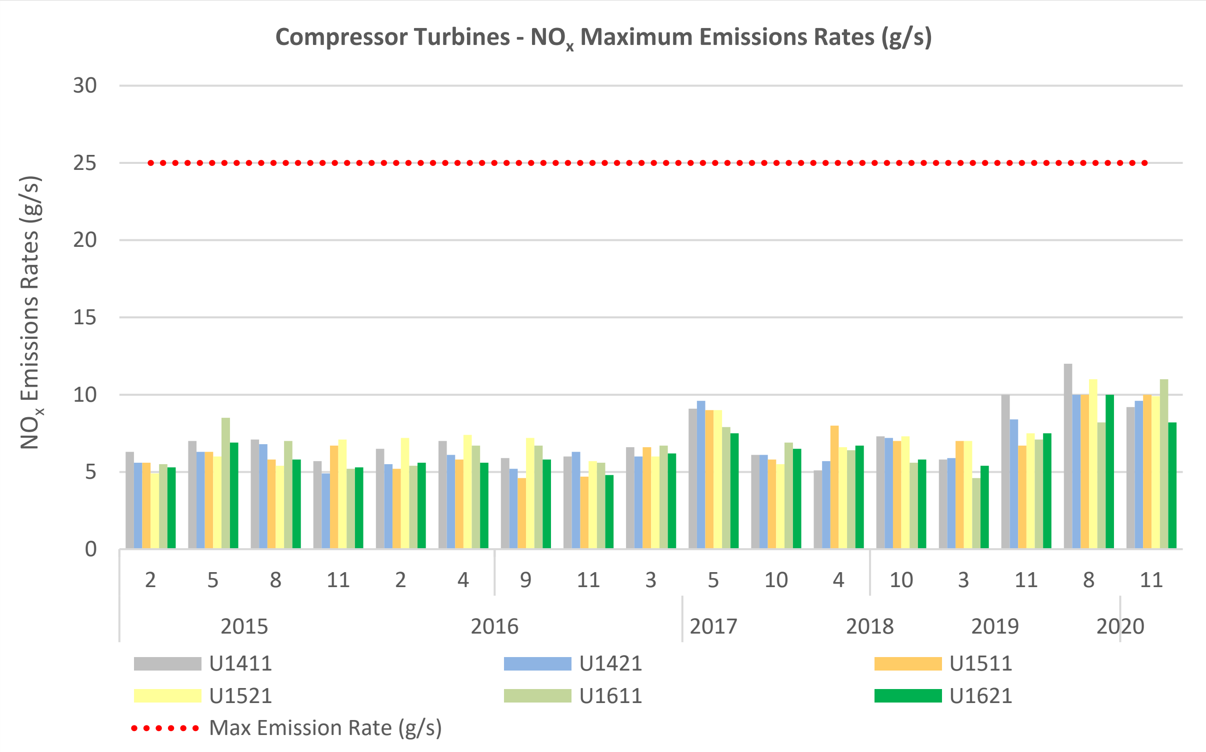
3.1.3.2 Compressor Turbines

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

- Compliant NO_x mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-5**);
- Compliant CO mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-6**); and
- Compliant SO_2 mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-7**).

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 NOx in the gas stream.

The variable SO_2 concentrations in 2020 can be attributed to variable fuel gas composition and power turbine demand due to changes in ambient conditions affecting LNG production.



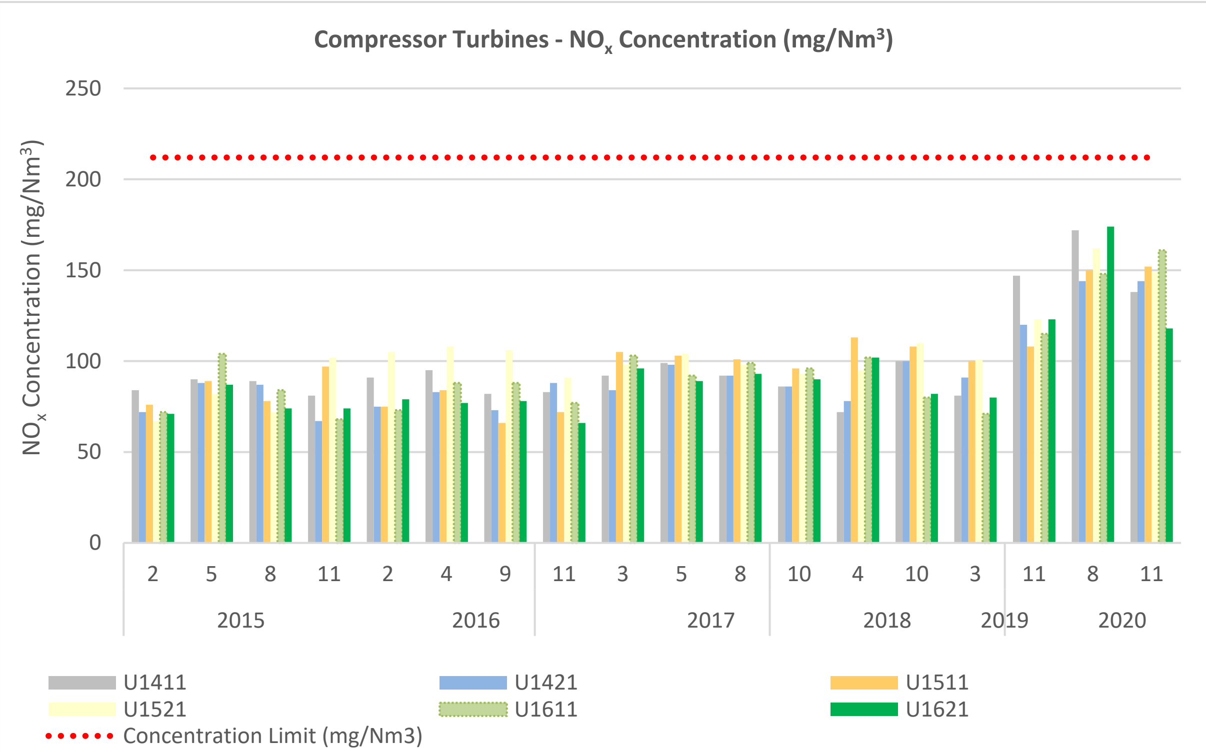
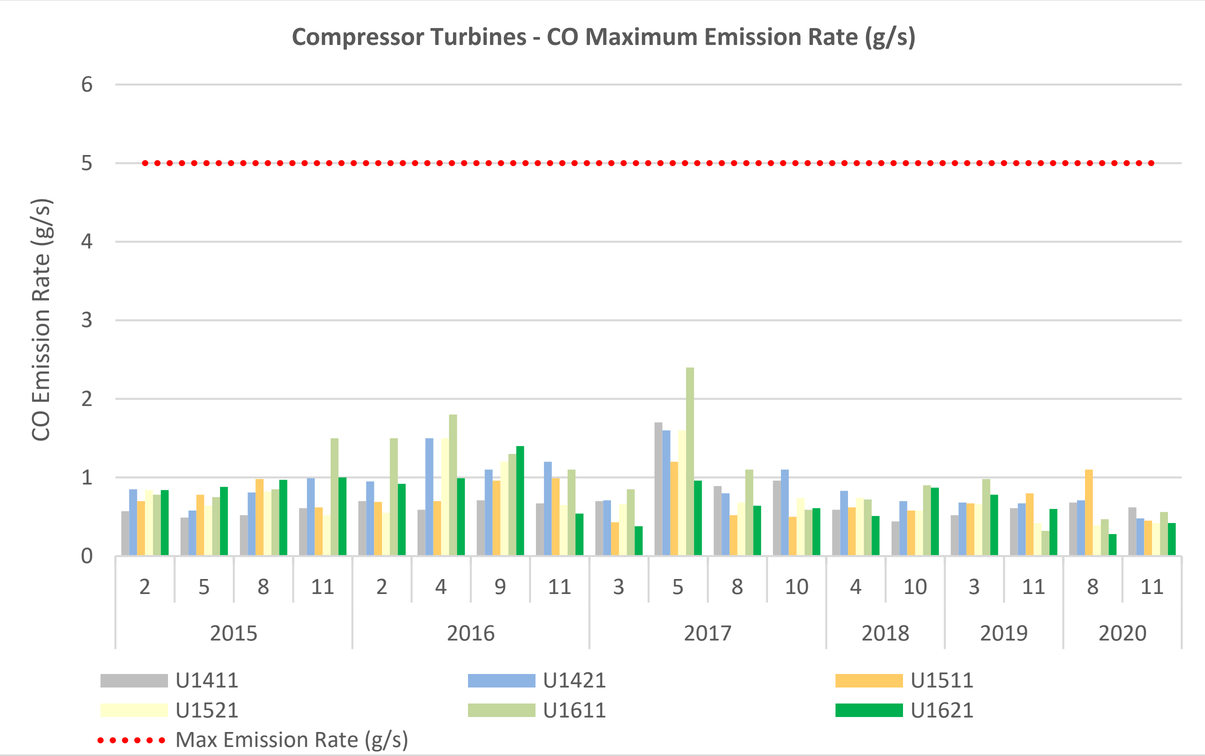


Figure 3-5 **Compressor gas turbine NO_x emissions 2015-2020**



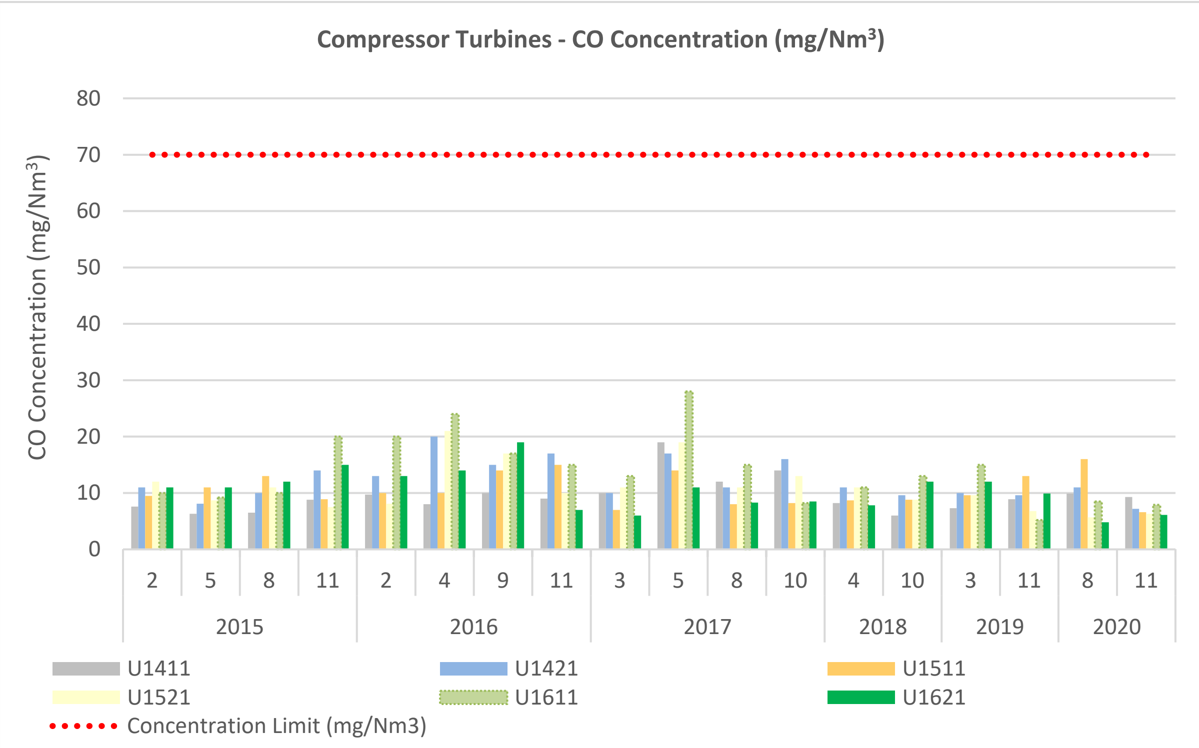
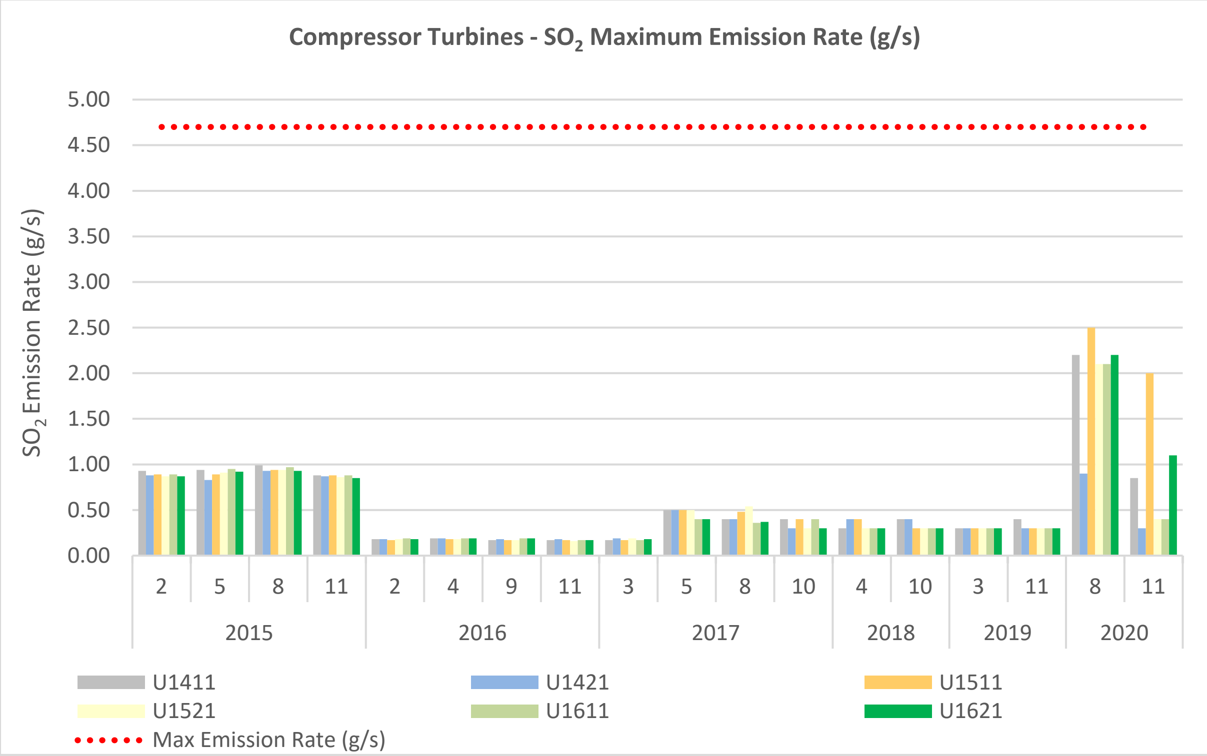


Figure 3-6 Compressor gas turbine CO emissions 2015-2020



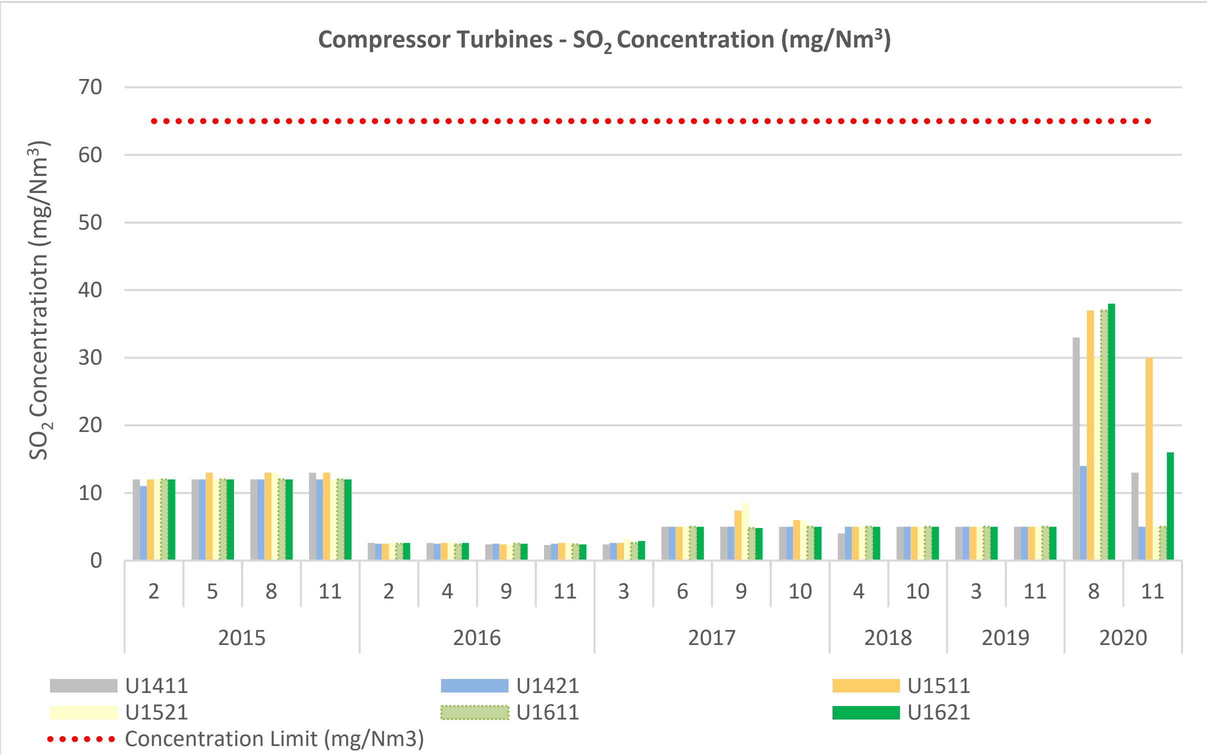


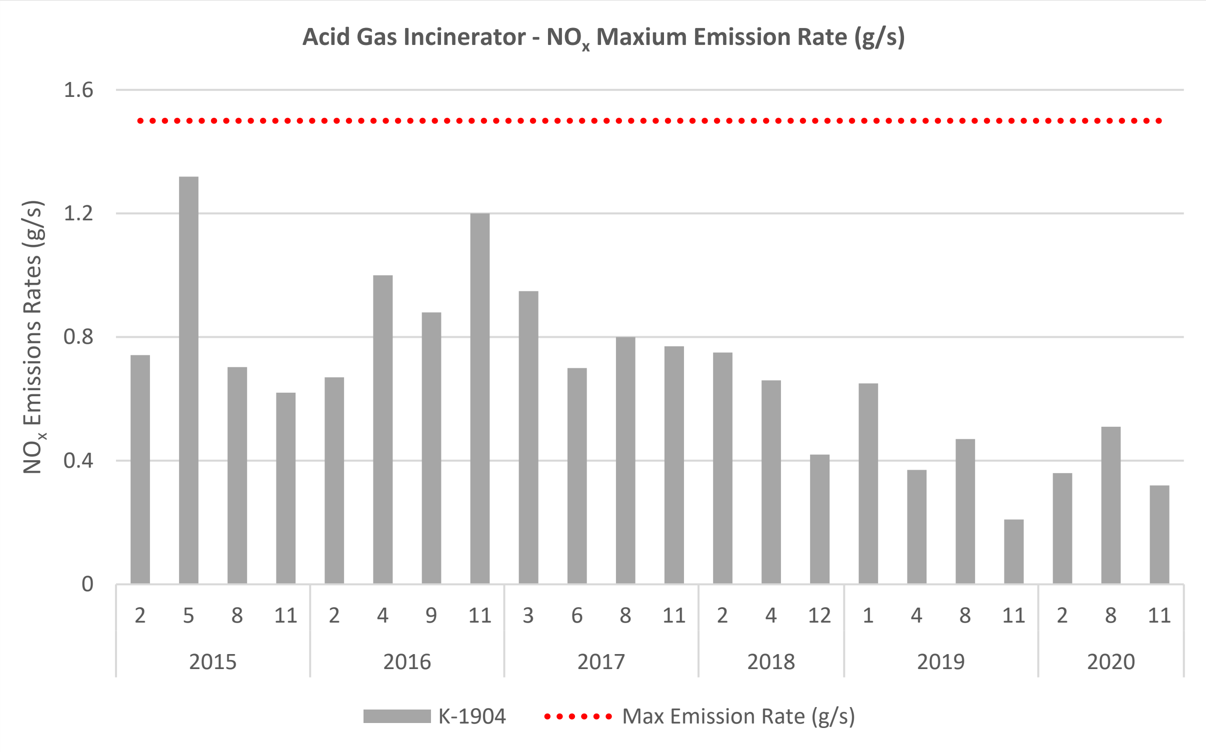
Figure 3-7 Compressor gas turbine SO_2 emissions 2015-2020

3.1.3.3 Acid Gas Incinerator

The AGI was the primary disposal method for acid gas in 2020 since the hot vent trial was suspended in Q3 2019 (refer to **Section 13.23.2.3.4**).

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

- Compliant NO_x mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-8**);
- Compliant CO mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period with the exception of a historic spike recorded in February 2015 (**Figure 3-9**);
- Compliant SO_2 mass emissions rates and concentrations for overall for the 2015-2020 period (**Figure 3-10**); and
- Compliant hydrogen sulphide (H_2S) mass emissions rates and concentrations for overall for the 2015-2020 period with the exception of a historic spikes recorded in June 2017 and February, May and November 2015 (**Figure 3-11**).



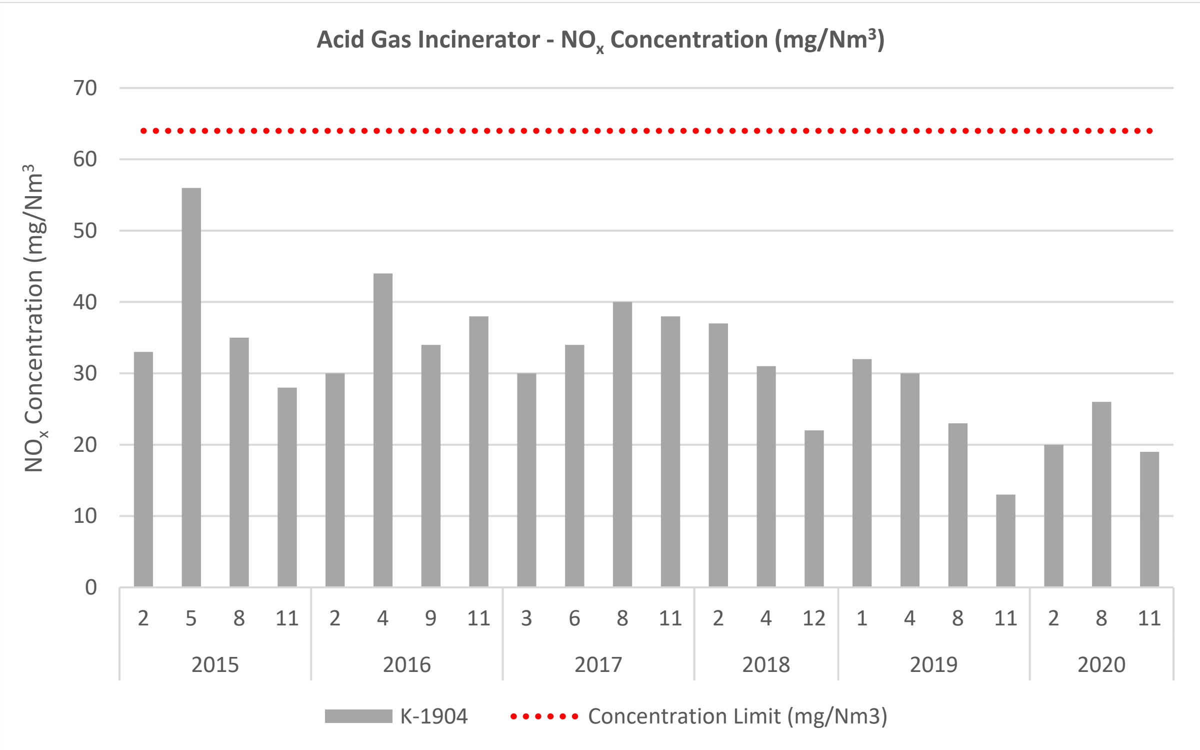
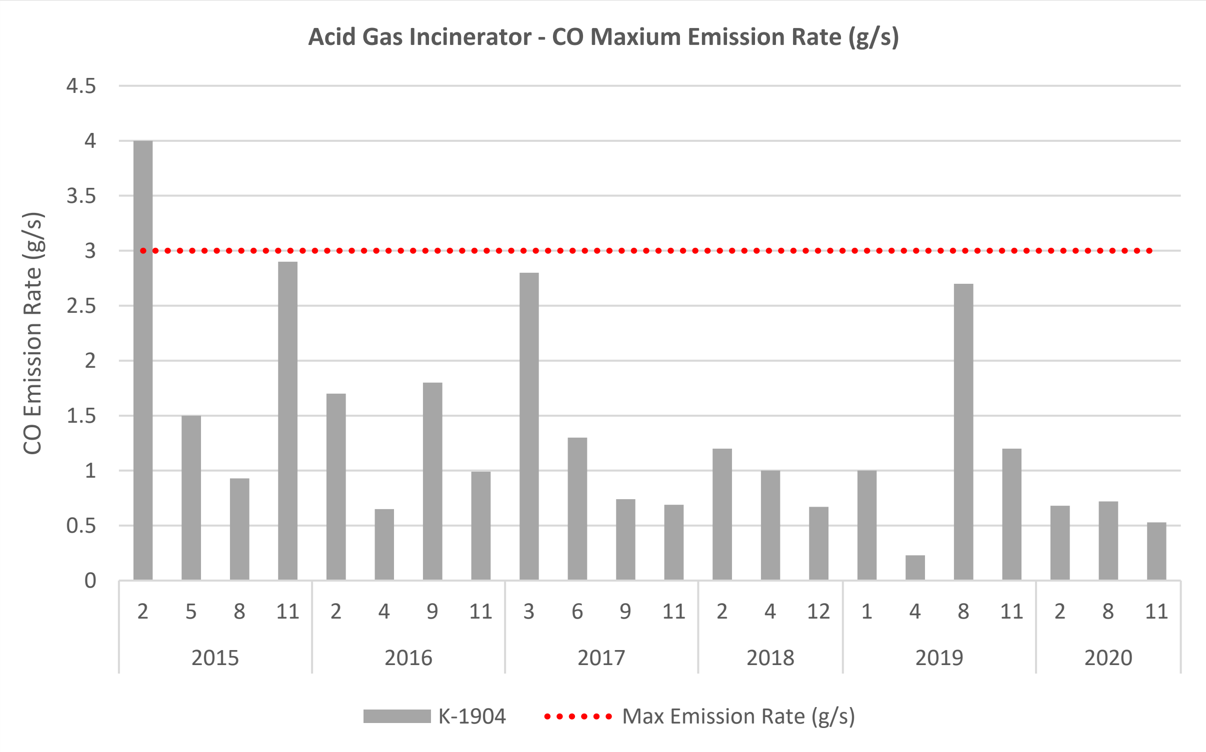


Figure 3-8 **AGI NO_x emissions 2015-2020**



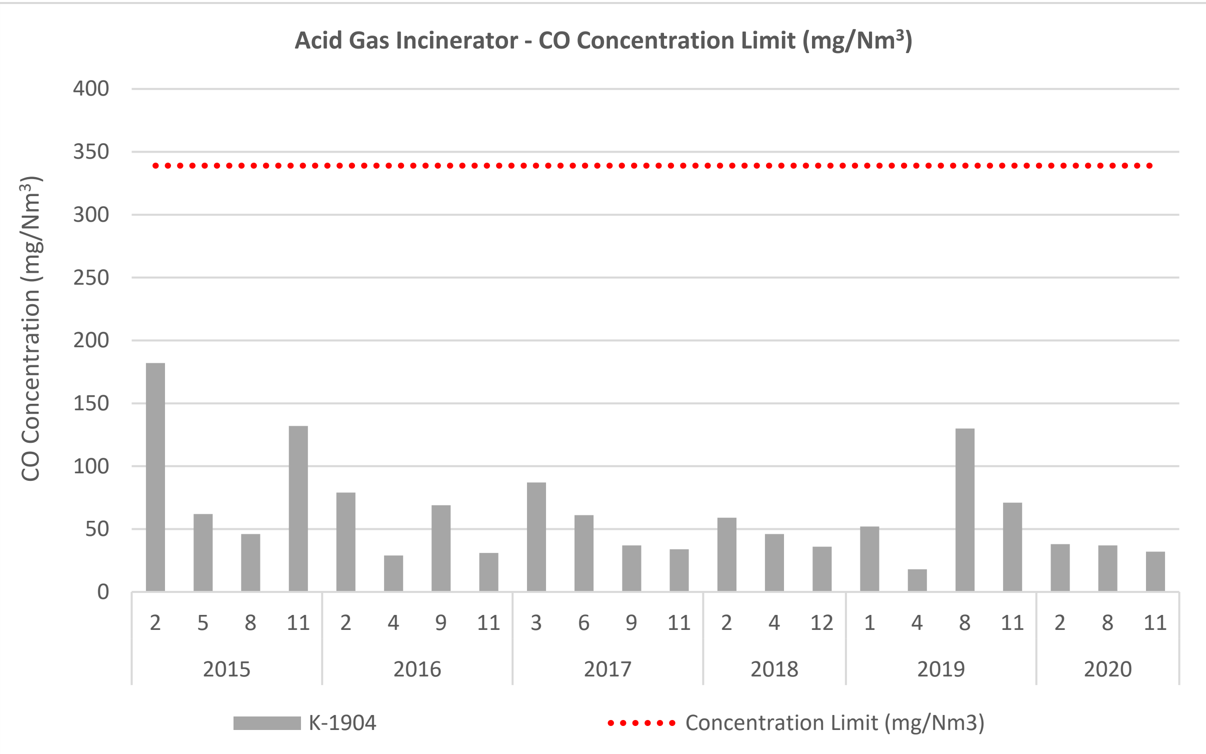
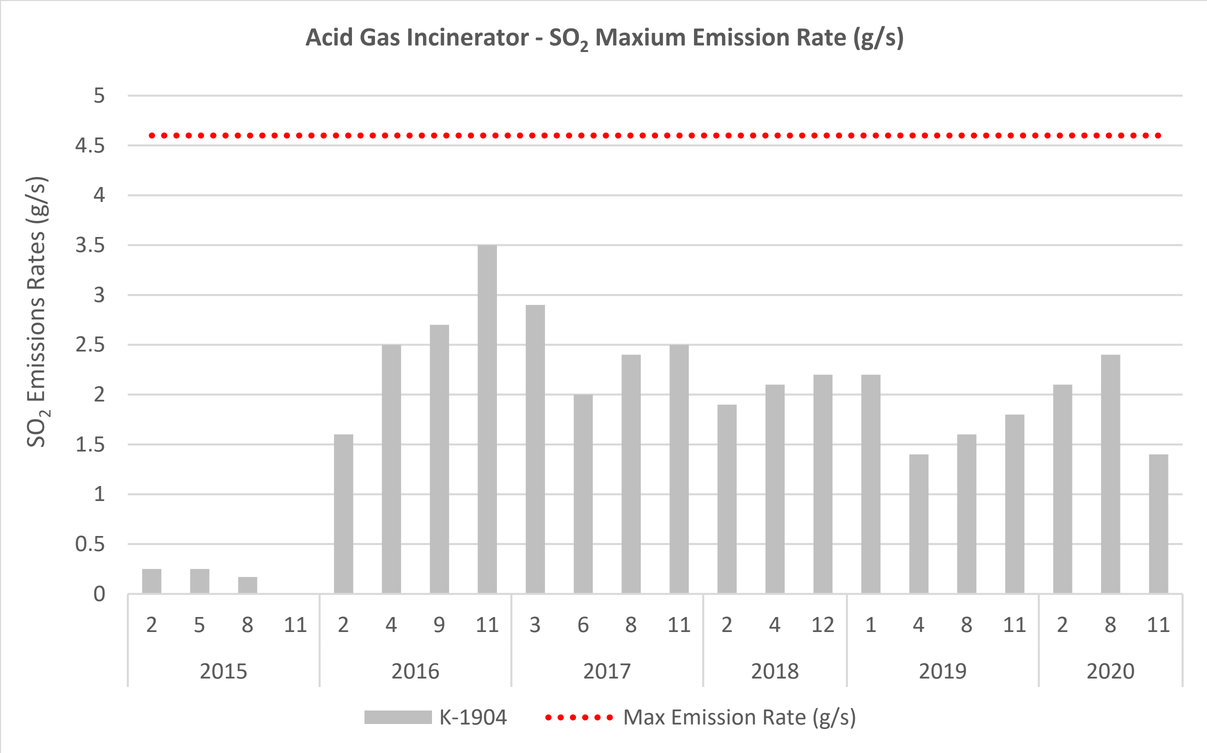


Figure 3-9 AGI CO emissions 2015-2020



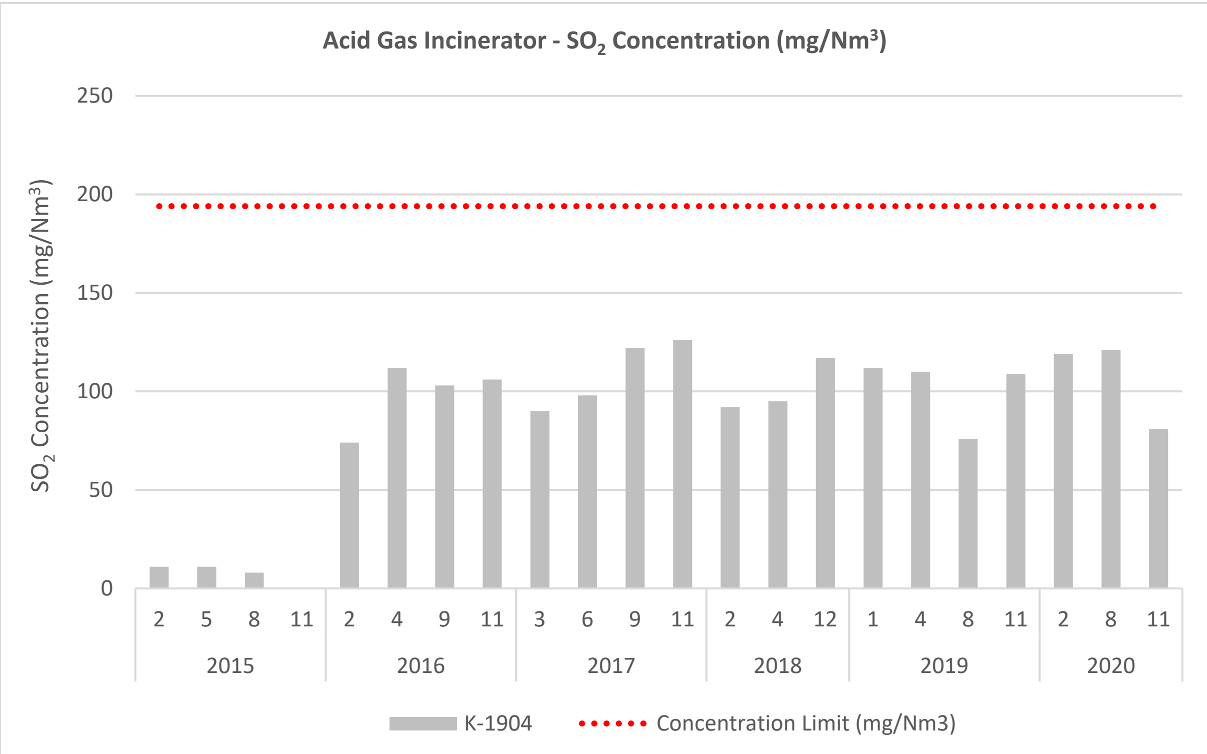
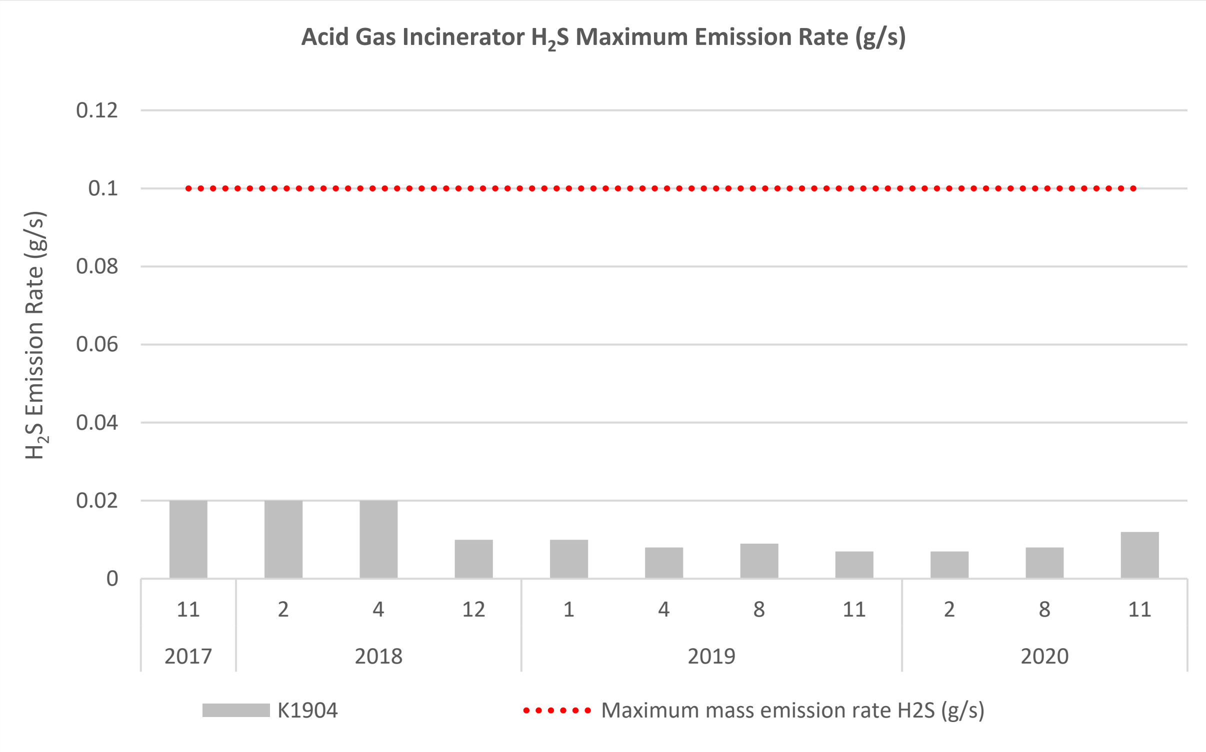


Figure 3-10 AGI SO_2 emissions 2015-2020



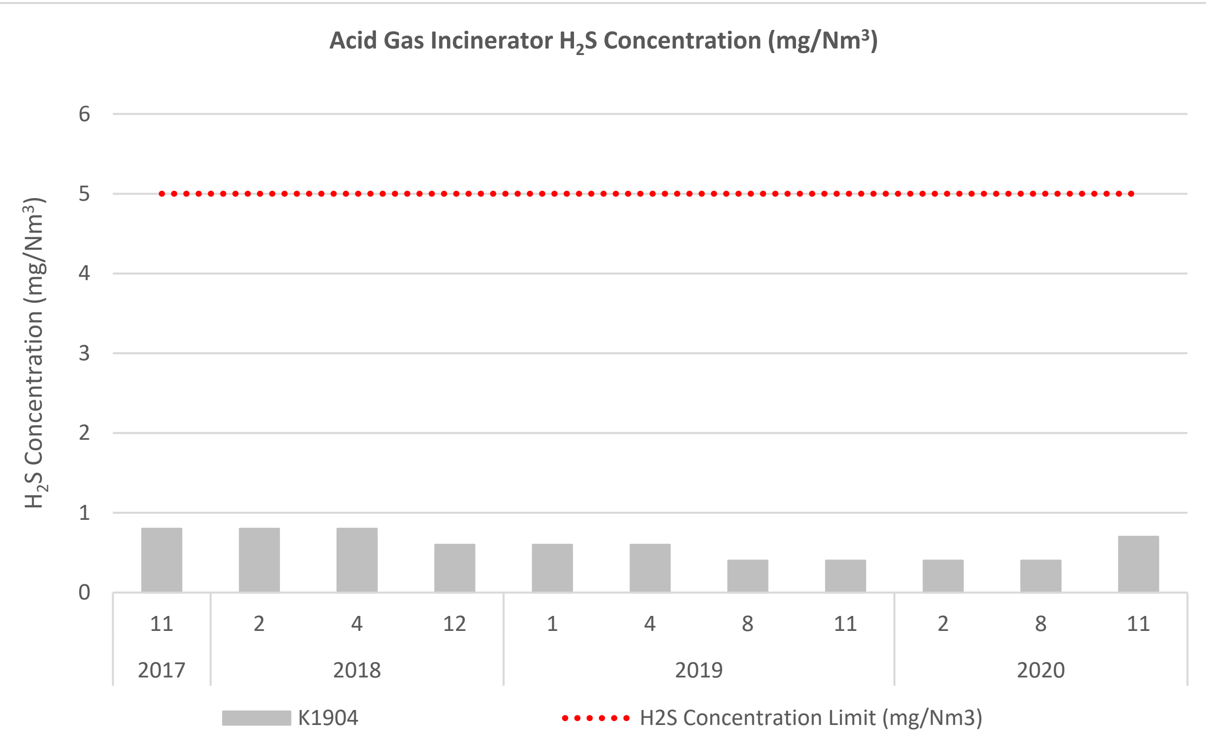
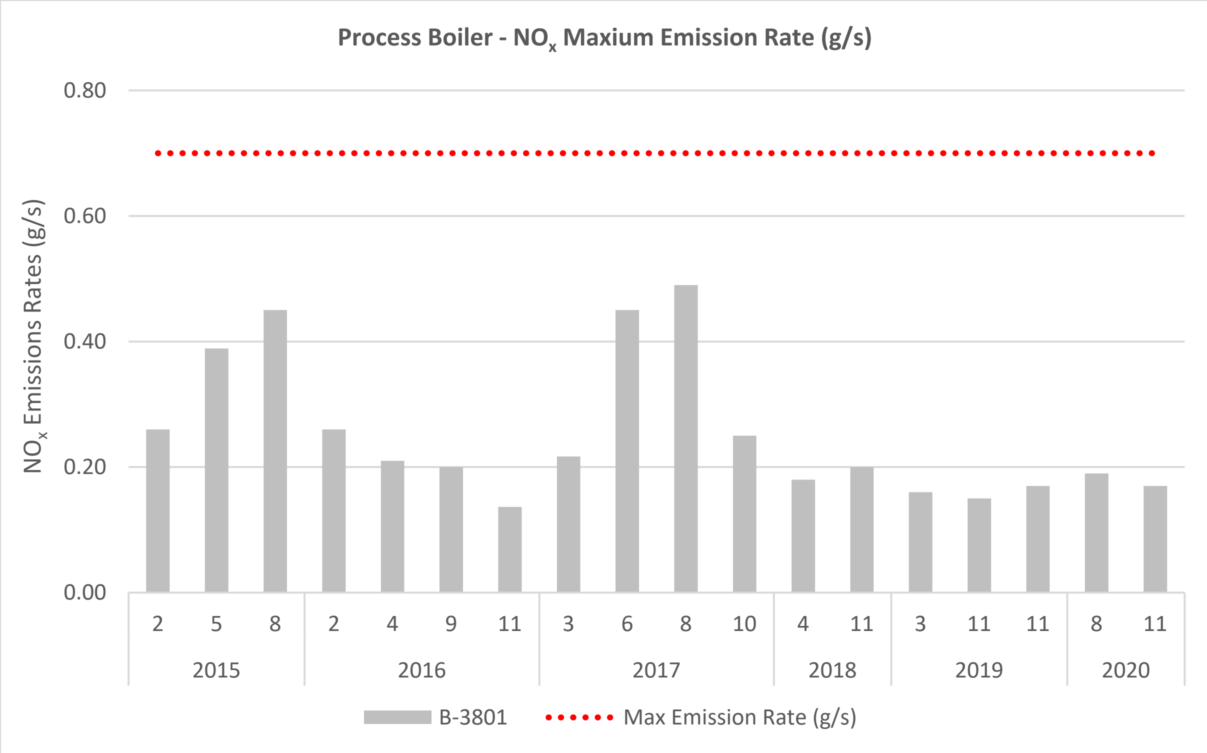


Figure 3-11 AGI H_2S emissions Q4 2017-2020

3.1.3.4 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 2020 and overall for the 2015-2020 period (**Figure 3-12**).
- Compliant CO mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period with the exception of an isolated spike recorded in October 2019 (**Figure 3-13**).
- Compliant SO_2 mass emissions rates and concentrations for 2020 and overall for the 2015-2020 period (**Figure 3-14**).



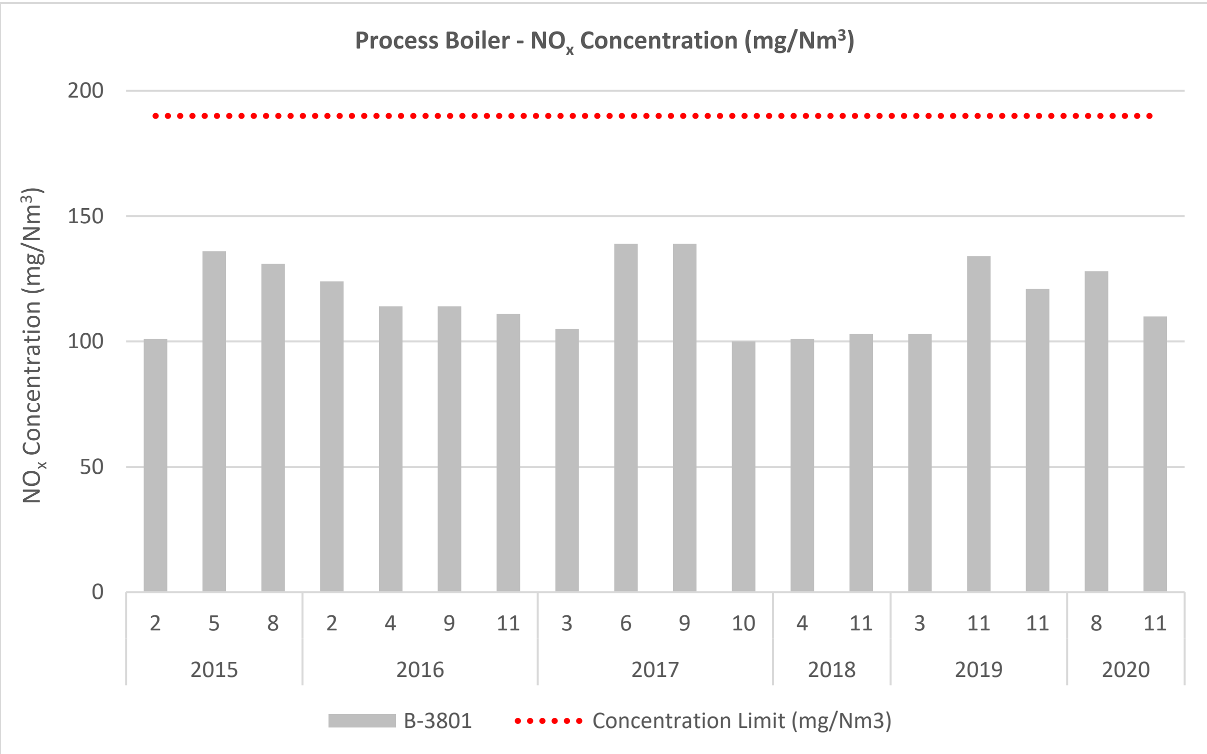
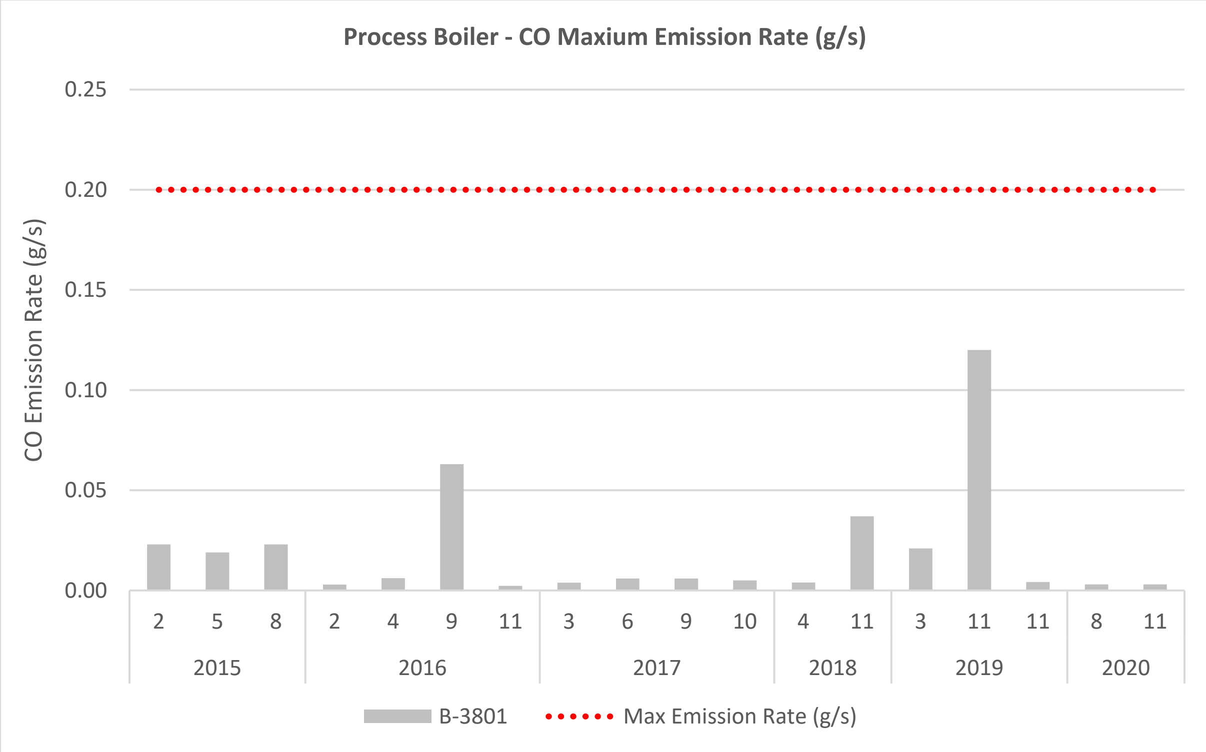


Figure 3-12 Process boiler NO_x emissions 2015-2020



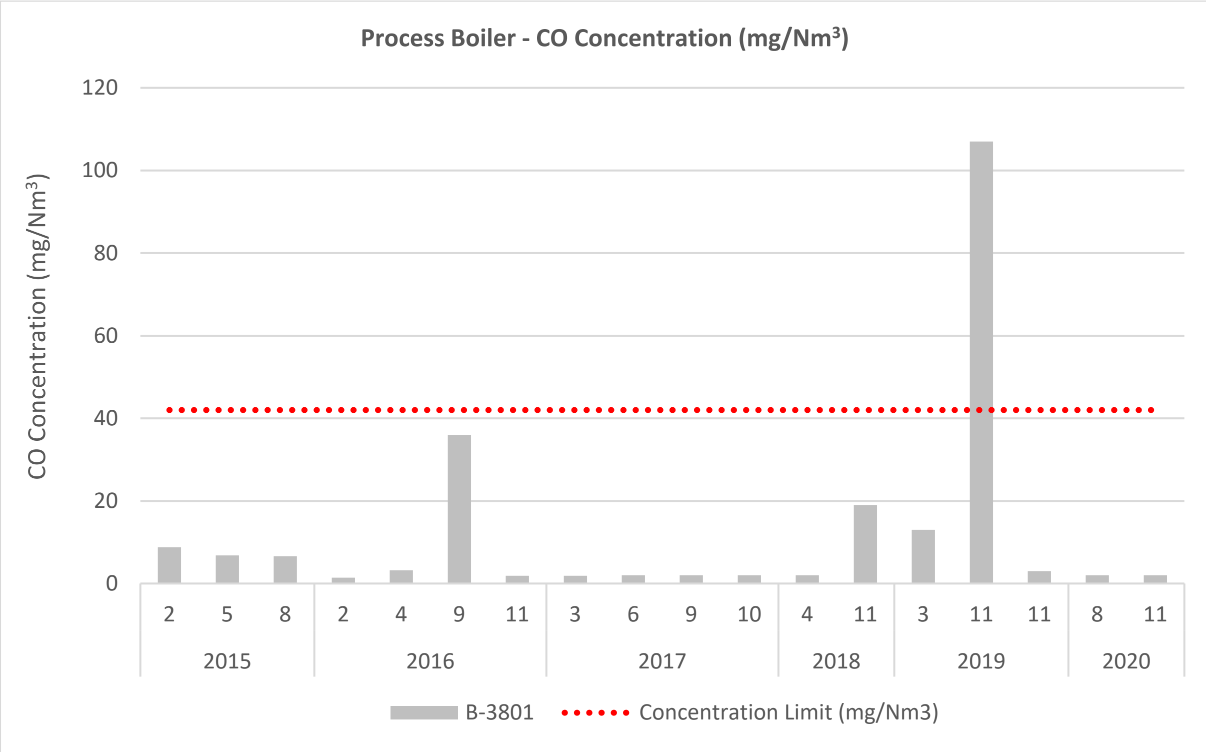
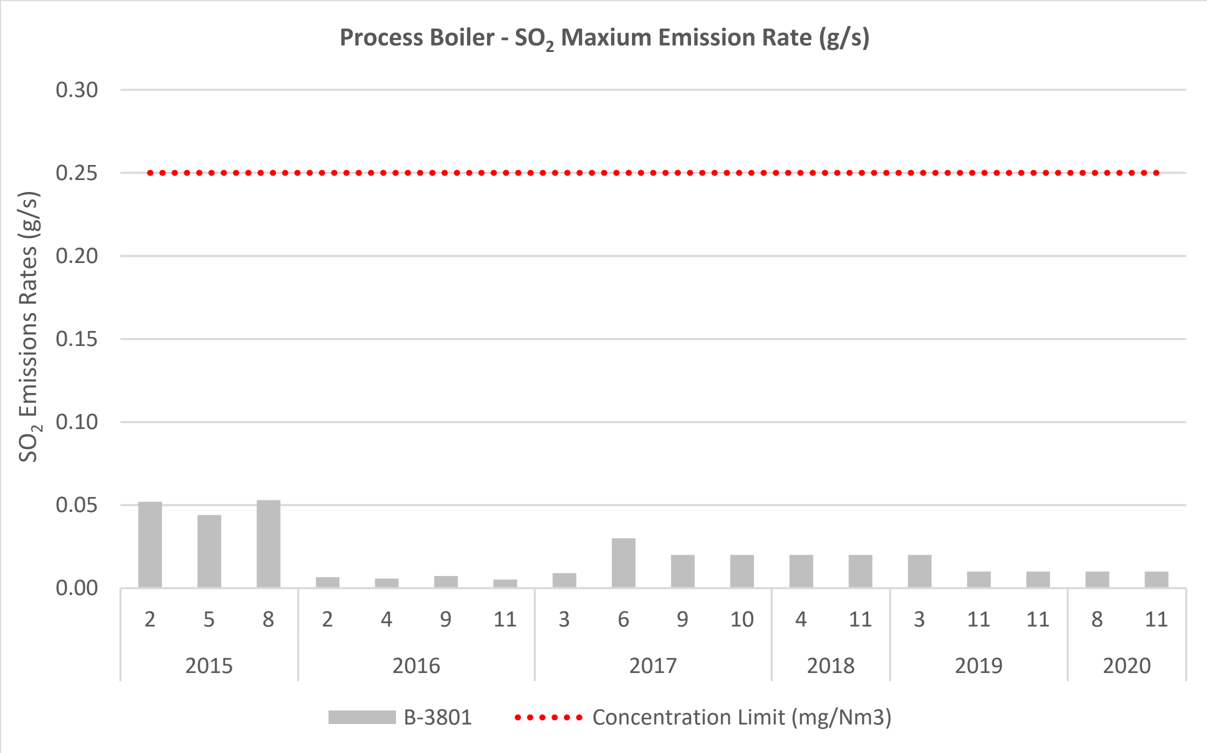


Figure 3-13 Process boiler CO emissions 2015-2020



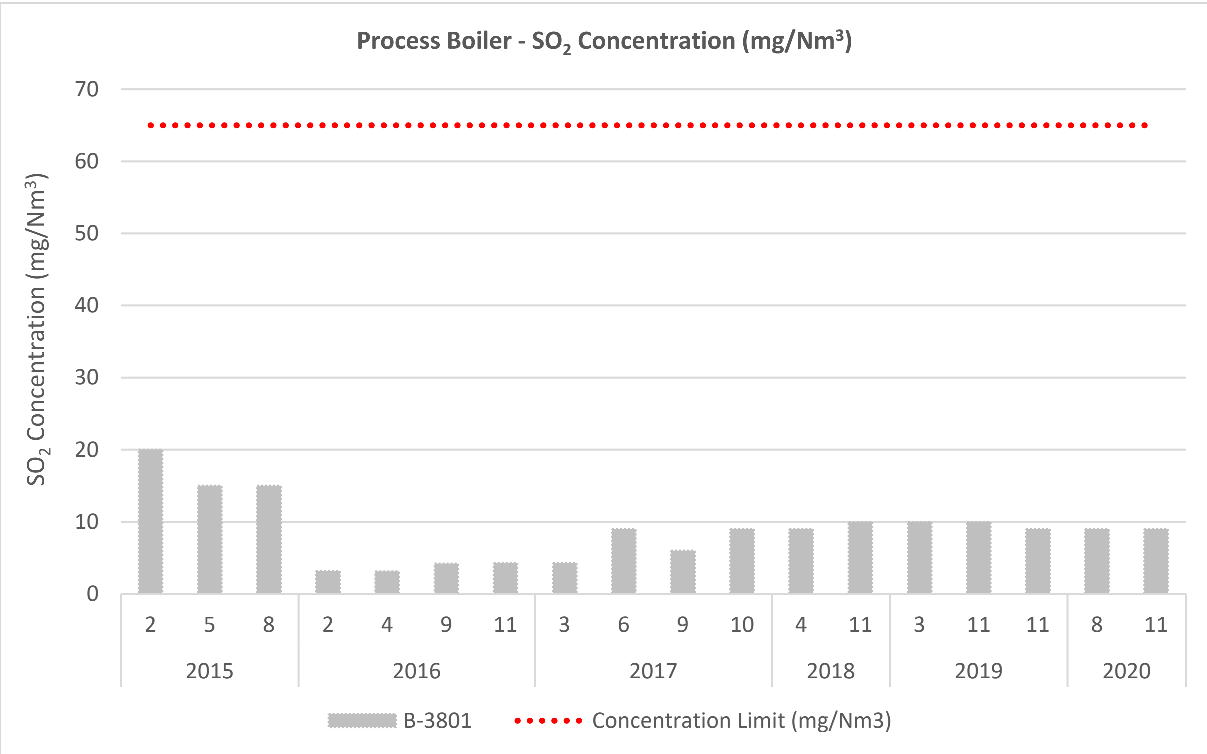


Figure 3-14 Process boiler SO_2 emissions 2015-2020

3.3.4 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.

3.3.5 Discussion and Interpretation of Results

Monitoring of stack emissions sources at the DLNG facility indicated that 2020 results were compliant with the Licence and generally within range of recent historical data (2015-2020). The preventative actions implemented to reduce the risk of elevated boiler CO emissions in November 2019 have been effective with 2020 concentrations well below the Licence limits.

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 3.3**), 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.

3.2 HYDROCARBON FLARING AND VENTING

Hydrocarbon flaring and venting is an unavoidable activity and is required to operate the DNLG 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 (CO_2,) although methane has a shorter average residence time in the atmosphere. Hence, flaring of hydrocarbons to convert methane to CO_2 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 now hot vented on occasions when the AGI is unavailable (e.g. AGI or plant trip).

3.2.1 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 and the National Greenhouse and Energy Reporting (NGER) scheme. 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.

3.2.2 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.

3.2.3 Monitoring Results

3.2.3.1 Flaring

During the reporting period, the total flaring volume from routine and non-routine sources was 10,261 kNm^3 (**Figure 3-15**). The flaring volume was marginally higher than in 2019 but lower compared to 2018 and previous years. There was a major planned shutdown in 2018 resulting in higher flaring volumes. Over the six-year period, excluding 2018, the 2020 flaring volume was reduced due to the following reasons:

- Overall reduction in production rates;
- 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.

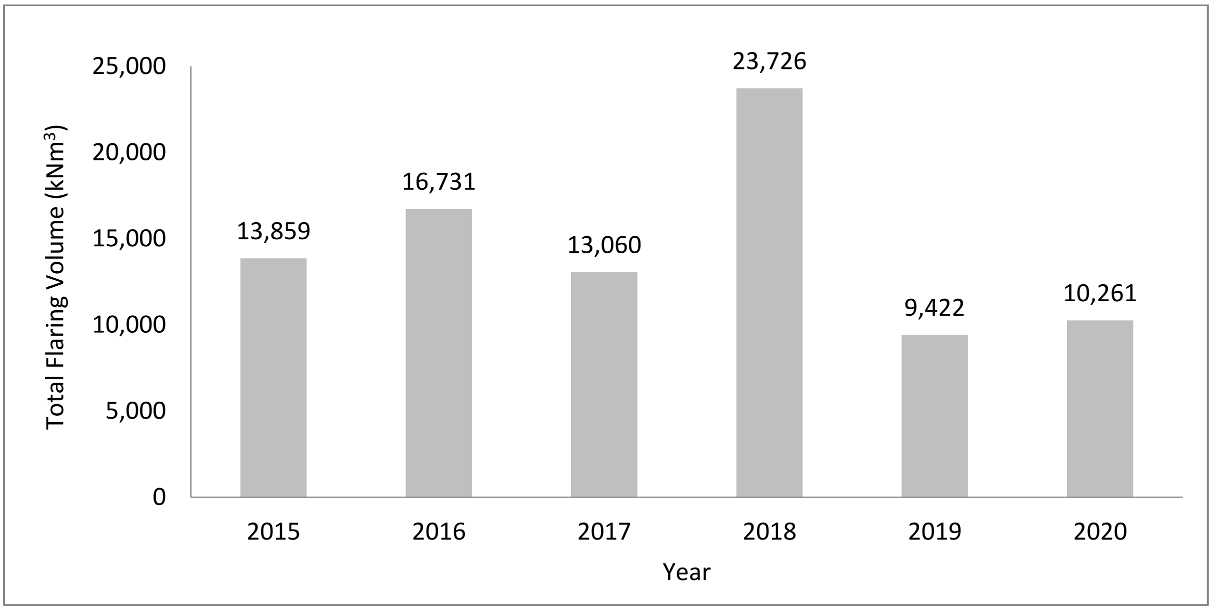


Figure 3-15 Annual flaring volumes (2015-2020)

3.2.3.2 Nitrogen Rejection Vent

During the reporting period, the total venting from the NRU was 21.21kNm^3 (**Figure 3-16**). NRU venting was within the historical range recorded following commissioning of the Helium Plant in 2011 but was higher than in 2019 due to the following reasons:

- Maintenance campaign conducted in May 2020 which required venting during shutdown and start-up of the facility;
- The pressure controller on the outlet of the NRU developed operability issues in mid-2020 which resulted in unplanned trips to the BOC Helium Plant and the associated venting to flare; and
- BOC Helium Plant outages resulting in venting to flare.

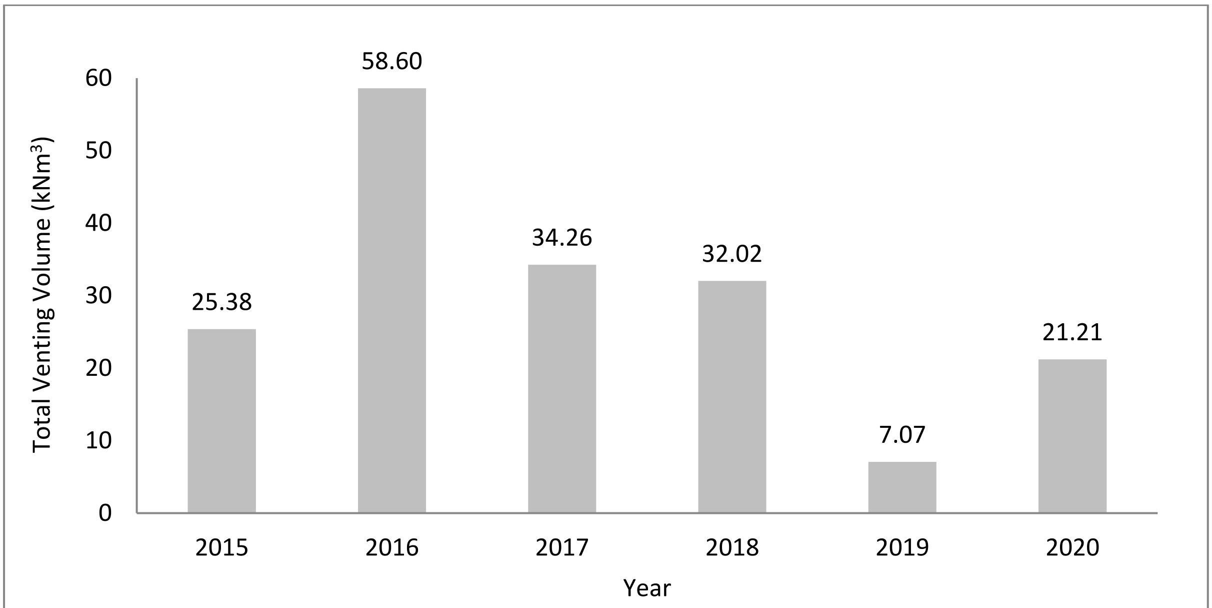


Figure 3-16 DLNG annual NRU venting volumes (2015-2020)

3.2.3.3 Acid Gas Vent

During the reporting period, the total acid gas venting volume for planned and unplanned downtime was 10,416 kNm^3 (**Figure 3-17**), the lowest result in the 2015-2020 reporting period. Acid gas was vented due to planned repair and maintenance for a total duration of 9.07 days in 2020. The duration of trips or unplanned maintenance in 2020 was 7.14 days, bringing the annual total venting duration to 16.21 days.

Santos were 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.

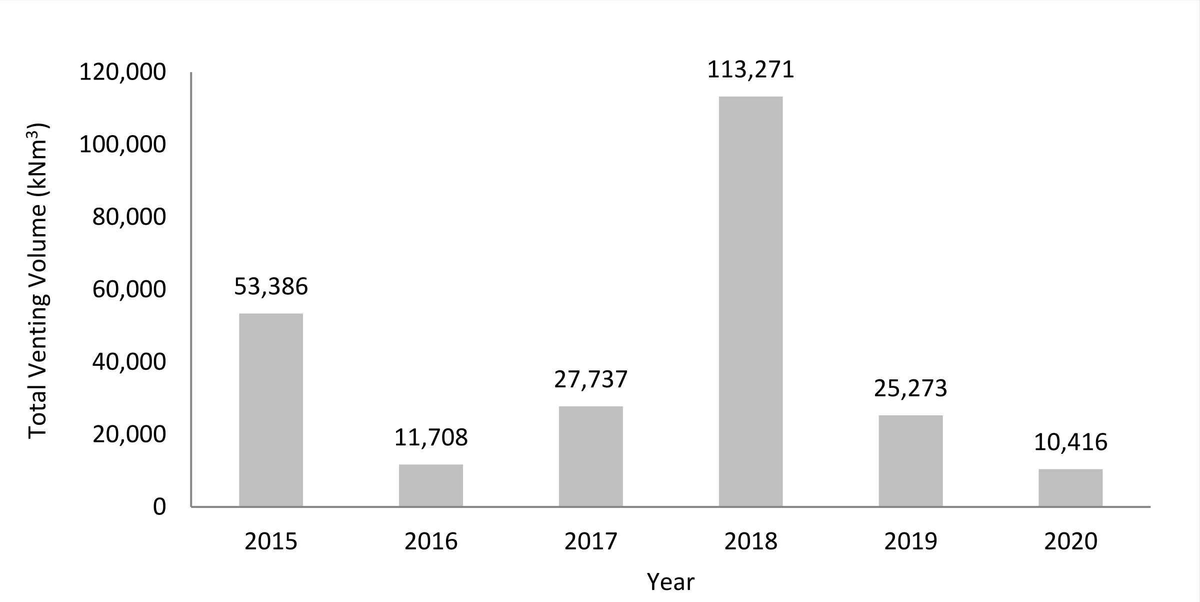
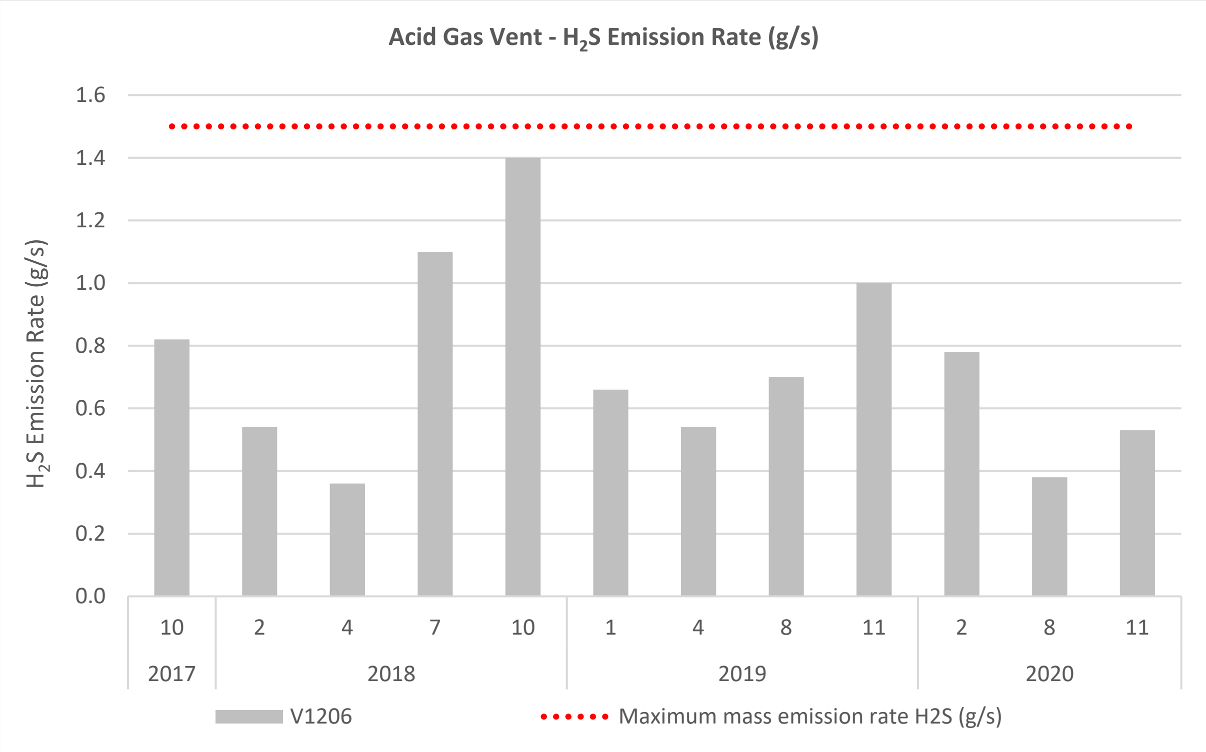


Figure 3-17 DLNG annual acid gas venting volumes (2015-2020)

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 H_2S mass emissions rates and concentrations for 2020 and overall for the Q4 2017-2020 period with the exception of a minor concentration exceedance in October 2018 (**Figure 3-18**); and
- Compliant benzene mass emissions rates and concentrations for 2020 and overall for the Q4 2017-2020 period with the exception of an exceedance in April 2019 and elevated levels at the Licence limit in November 2019 (**Figure 3-19**). 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.



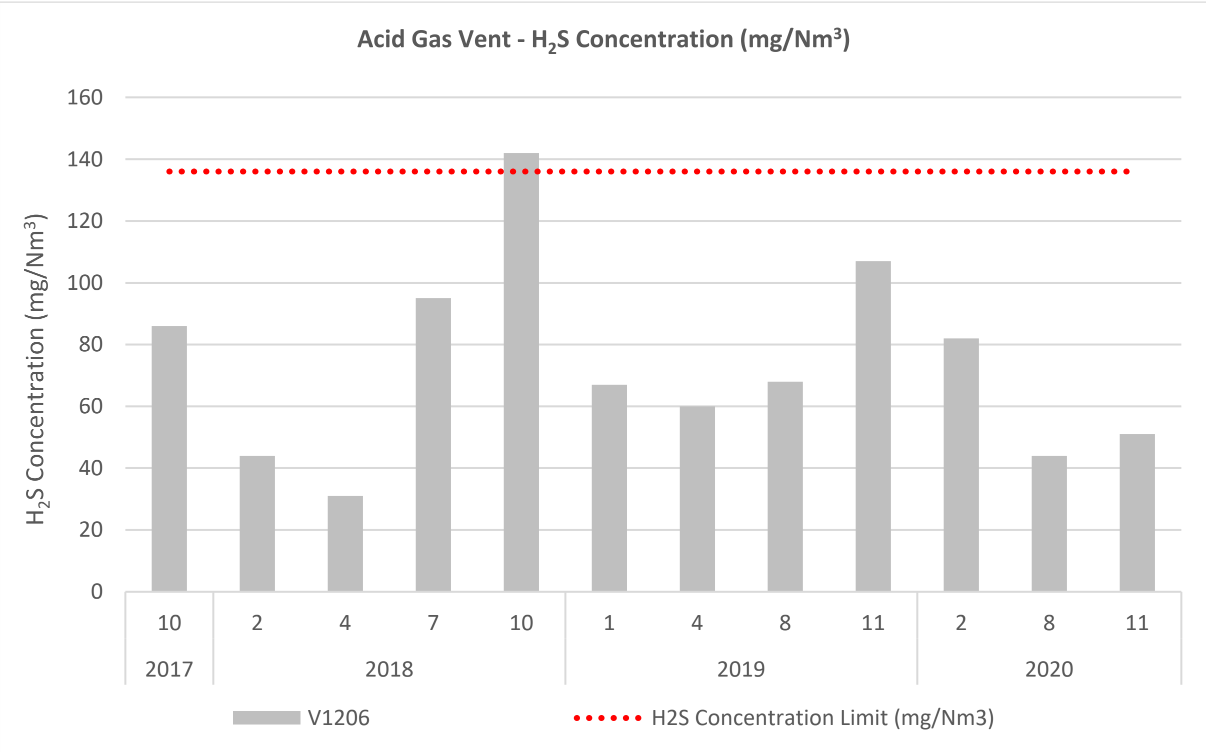
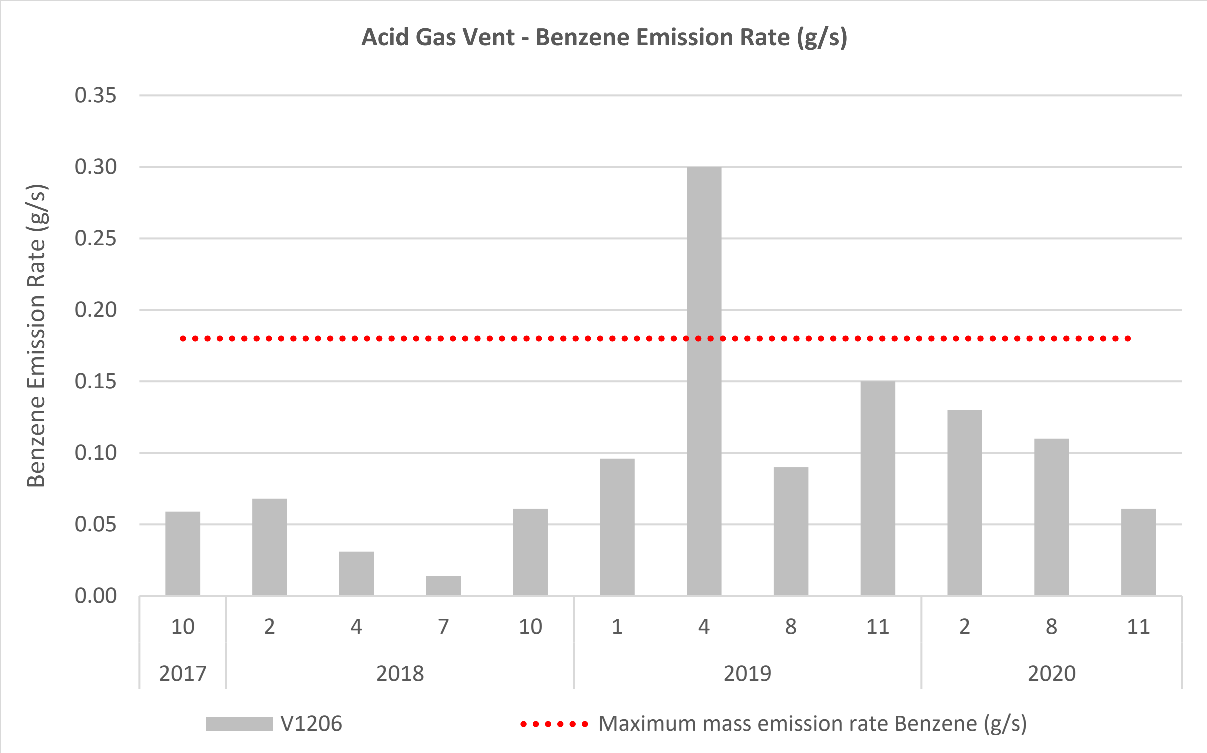


Figure 3-18 AGV H_2S emissions Q4 2017-2020



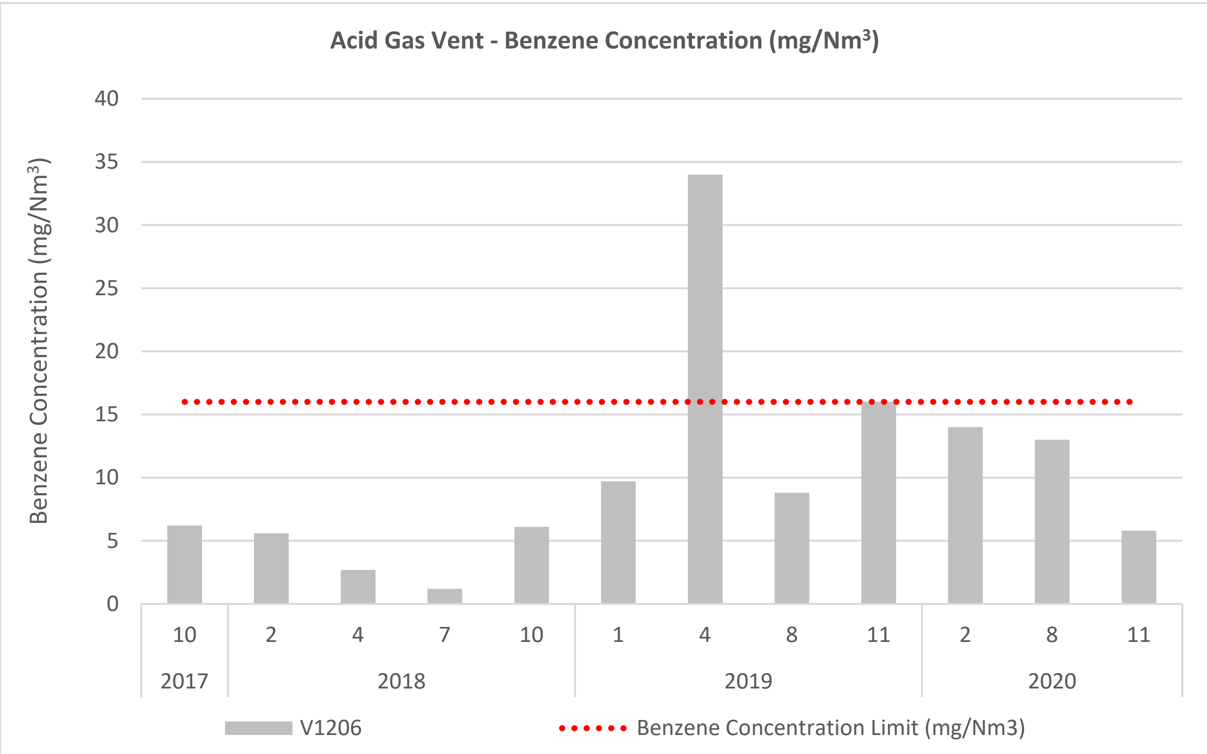


Figure 3-19 AGV benzene emissions Q4 2017-2020

3.2.3.4 Acid Gas Hot Vent Trial

The disposal of acid gas via hot venting was identified by Santos as potentially having lower environmental impact than acid gas disposal via the AGI due to reduced carbon dioxide emissions. In collaboration with the NT EPA, Santos (at the time ConocoPhillips) commenced a hot vent trial in 2018 in accordance with conditions contained in Appendix C of the Licence.

The hot vent trial was suspended on the 3rd October 2018 due to emission exceedances at which point the AGI returned to being the primary disposal method for acid gas. An investigation report was provided to the NT EPA in December 2018.

During 2019 additional sampling and investigation was undertaken to assess the viability of the trial and the results were provided to the NT EPA via a follow up investigation report on 24th May 2019. After review and assessment of the results, and in consultation with the NT EPA, Santos decided in November 2019 to cancel the trial indefinitely. A future licence amendment is planned to remove the related conditions from the Licence.

3.2.4 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.

3.2.5 Discussion and Interpretation of Results

The flaring emissions in 2020 were comparable with the 2019 emissions and overall there is a decreasing trend evident over the six-year period from 2015-2020 indicating a reduced risk to the environment.

Venting from the NRU in 2020 was higher than in 2019 but within the recorded ranges for the 2015-2020 period.

Stack testing of the AGV indicated that the mass emissions rates and concentrations of acid gas were compliant with the Licence limits.

Hot venting of acid gas occurred during 2020 due to planned shutdowns in June and August 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. The duration of these events was made as short as practicable.

Overall, the flaring and venting volumes in 2020 presents a negligible environmental risk or impact as supported by ambient air monitoring data of the Darwin airshed. Refer to **Section 3.3** for more information on ambient air quality monitoring results.

3.3 AMBIENT AIR QUALITY MONITORING PROGRAM

As outlined in the summary of the 2019 stack emissions monitoring program results (**Section 3**), the DLNG facility has several 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 H_2S 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 both the Santos and NT EPA managed stations into two succinct annual ambient air monitoring reports (Katestone, 2020 and Katestone, 2021). The results of these reports are summarised in this section.

3.3.1 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 indefinitely in 2019 (refer to **Section 3.2.3.4**) and the Santos ambient air stations are proposed for decommissioning in March 2020.

3.3.2 Monitoring Methods

3.3.2.1 Santos Network

The program includes the management and maintenance of air monitoring equipment at the following three monitoring station locations for January and February 2020 only:

- Onsite at DLNG (‘LNG’) – 218 m from the compressor turbines and is generally representative of on-site air quality.
- Offsite along the access road to DLNG (‘GLDS’), located 1.65 km away and is reflective of an industrial site to the east of DLNG.
- Within the Darwin central business district (‘TWN’), located 8.6 km away and is representative of residential area located to the north of DLNG.

The monitoring stations were continuously monitored for metrological and pollutant parameters for January and February 2020. A map of the monitoring locations is provided in **Figure 3-1** and detailed in **Table 3-1**. Sensors at the ambient air quality monitoring sites are operated and maintained at each of the sites to record the parameters listed in **Table 3-1**.

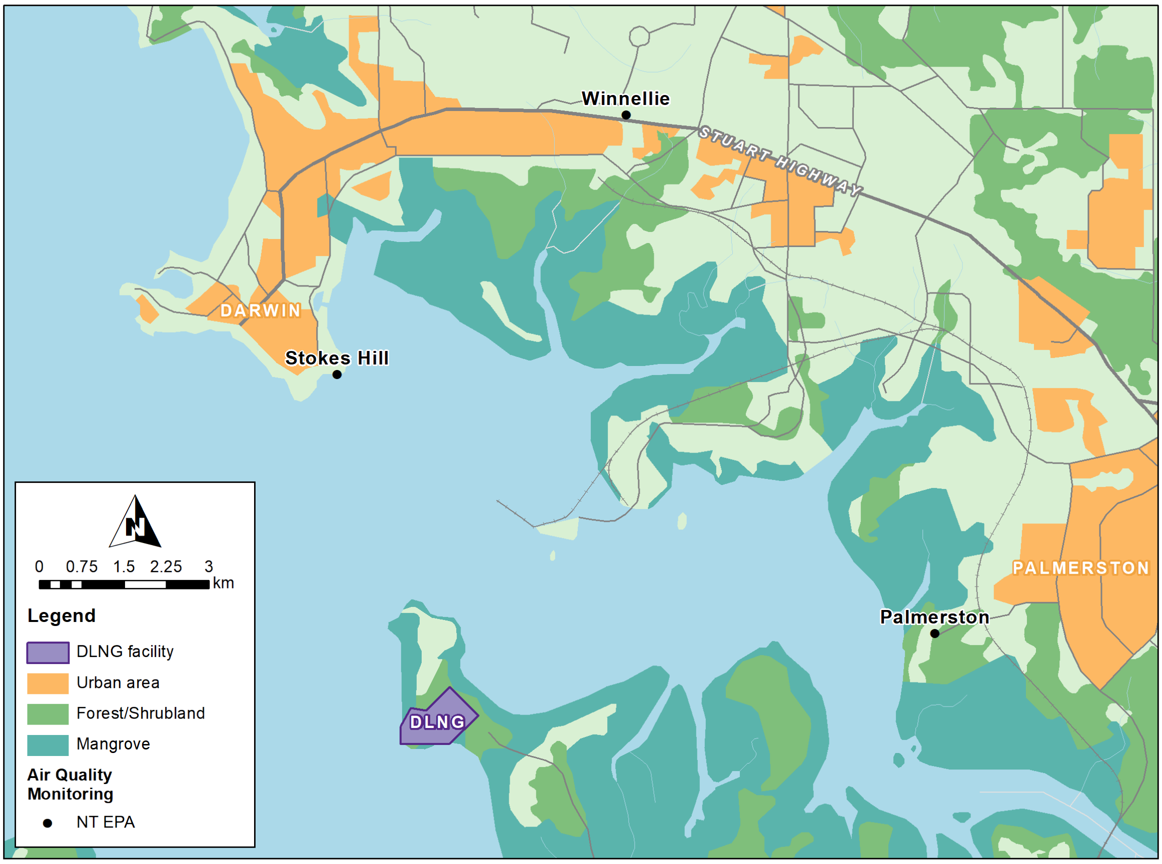


Figure 3-20 Ambient air quality monitoring stations locations for Santos

Table 3-1 DLNG ambient air monitoring network

Site description		Gas Let-Down Station	Darwin LNG Facility	Darwin Town
Site name		GLDS	LNG	TWN
Geographical coordinates	Latitude	12°31'37.76"S	12°31'18.99"S	12°26'48.45"S
	Longitude	130°52'45.21"E	130°51'48.82"E	130°51'0.1"E
Classification		Industrial	Industrial	Residential
Meteorology				
Wind speed		✓	✓	✓
Wind direction		✓	✓	✓
Sigma		✓	✓	✓
Pollutants				
NO, NO_2, NOx		✓	✓	✓
SO_2		✓	✓	✓
H_2S		✓	✓	✓
Benzene		✓	✓	✓
CO_2			✓	

3.3.2.2 NT EPA Network

In addition to the Santos ambient air monitoring network, the NT EPA maintain their own network of three stations. The NT EPA program has evolved over the years, commencing with particulate monitoring in Darwin in 2004. In late 2010, the monitoring network was expanded to include a full ambient air quality station located near Palmerston. In mid-2012, the monitoring network was further expanded with the commissioning of a monitoring site at Winnellie and in May 2017 a third monitoring site was commissioned at Stokes Hill Wharf. The NT EPA monitoring sites are shown in **Figure 3-20** and detailed in **Table 3-2**. These sites will form the basis of ambient air quality monitoring from March 2020 moving forward.

All three sites currently monitor particulate matter (PM_{10} and $PM_{2.5}$), CO, oxides of nitrogen (NO_X, NO and NO_2), SO_2 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, NO_2 and SO_2 all occur at very low levels compared to large cities in other parts of Australia, while O_3 occurs at moderate levels, typically due to natural processes.

Table 3-2 NT EPA ambient air monitoring network

Site description		Palmerston	Stokes Hill	Winnellie
Site name		GLDS	LNG	TWN
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, NOx	✓	✓	✓
	SO_2	✓	✓	✓
	O_3	✓	✓	✓
	CO	✓	✓	✓
	PM_{10}, $PM_{2.5}$	✓	✓	✓

3.3.2.3 Data Processing

The ambient air quality monitoring network data was provided to Katestone for processing and assessment in accordance with the National Environment Protection (Ambient Air Quality) Measure Technical Paper No. 5 Data Collection and Technical Paper No.8 Annual Reports. The data were then quality assured, and a 24-hour average dataset created from the 1-hour average dataset.

Data at each monitoring site was compared with relevant air quality standards, guidelines and monitoring investigation limits (MIL), including:

- National Environmental Protection (Ambient Air Quality) Measure (Air NEPM);
- National Environment Protection (Air Toxics) Measure;
- Approved methods for the modelling and assessment of air pollutants in NSW (NSW EPA, 2017); and
- Environmental Protection (Air) Policy 2008 (Air EPP).

Data capture for each parameter at each monitoring station was also compared with the standard criterion of at least 75% capture per calendar quarter, as per the Air NEPM.

3.3.2.4 Summary of Exceedances

The majority of the ambient air monitoring results for from the Santos network and NT EPA network were below the relevant guidelines for the atmospheric pollutants and air toxics emissions guideline values in the reporting period. Exceedances events are summarised in **Table 3-3** and discussed in the following sections.

Table 3-3 Summary of elevated results above air monitoring investigation limits (MIL) during monitoring in 2020

Atmospheric Pollutant and Air Standard	Monitoring Location	Date and time
H_2S Average period: 30-minute Standard Source: QLD Air EPP Standard: 0.0049 ppm	TWN	• 13 February 2020 at 14:30 to 16:30
	GLDS	• 10 January 2020 at 3:00 to 5:00 • 10 January 2020 at 17:30 to 19:00
PM_{10} Average period: 24-Hour Standard Source: NEPM Standard: 50 µg/m^3 Note: Exceedances are from midnight to midnight	Winnellie	• 2 May 2020 • 5 June 2020 • 8 July 2020
	Palmerston	• 2 May 2020
$PM_{2.5}$ Average period: 24-Hour Standard Source: NEPM Standard: 25 µg/m^3 Note: Exceedances are from midnight to midnight	Stokes Hill	• 2 May 2020 • 4 June 2020 • 5 June 2020 • 6 June 2020
	Winnellie	• 2 May 2020 • 3 May 2020 • 4 June 2020 • 5 June 2020 • 6 June 2020 • 25 June 2020 • 8 July 2020
	Palmerston	• 2 May 2020 • 3 May 2020 • 29 May 2020 • 3 June 2020 • 4 June 2020 • 5 June 2020 • 8 July 2020

3.3.3 Monitoring Results – Santos Network

3.3.3.1 Data Capture

The DLNG monitoring network achieved a minimum of 75% valid data capture for the January to February 2020 period at all stations except at LNG in January 2020; SO_2 (58%), H_2S (52%) and benzene (77%). This was due to multiple power supply issues to the LNG station.

3.3.3.2 Meteorological Conditions

Meteorological conditions play an important role in the dispersion of air pollutants from their point of emission. The DLNG ambient air monitoring network measures wind speed and wind direction at the three monitoring sites. The wind roses at GLDS, LNG, and TWN indicate the following (**Figure 3-21**, **Figure 3-22** and **Figure 3-23**):

- The predominant wind directions are west to north-westerly and south-easterly;
- Winds are rarely observed from directions in the southwest quadrant; and
- Winds are generally light to moderate (less than 5 m/s).

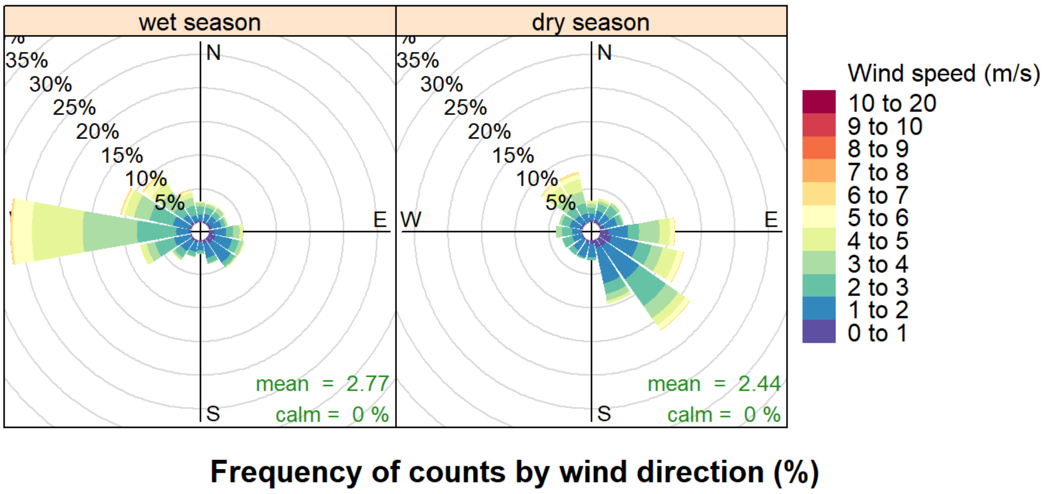


Figure 3-21 January 2019 to February 2020 wind rose for GLDS monitoring site

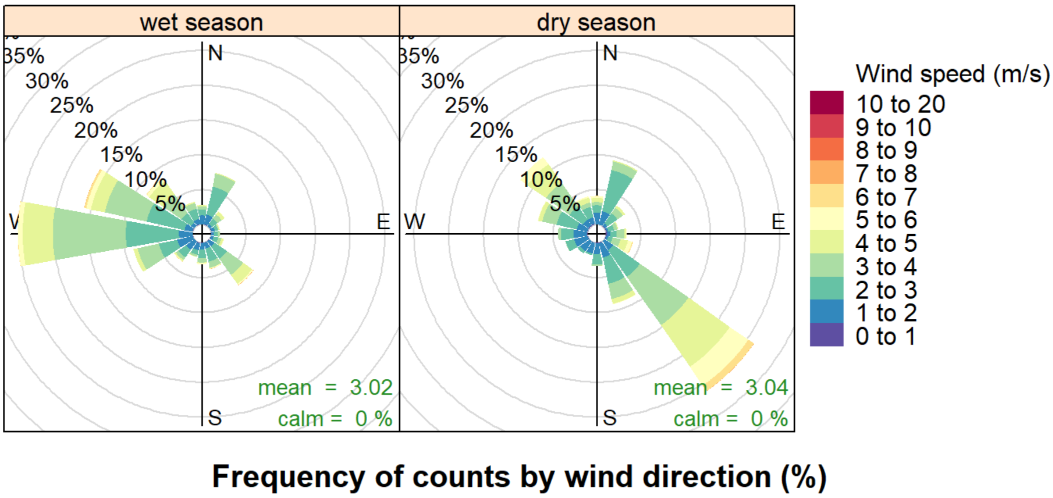


Figure 3-22 January 2019 to February 2020 wind rose for LNG monitoring site

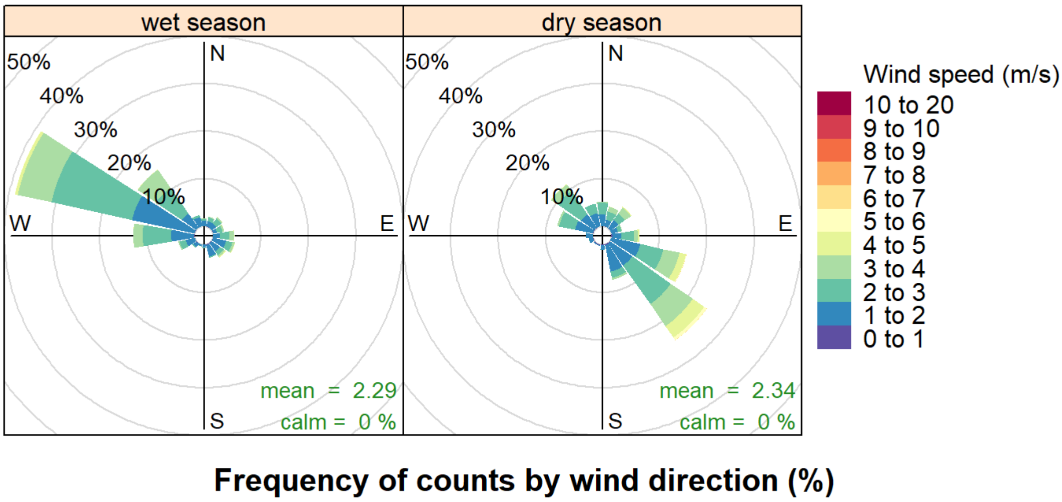


Figure 3-23 January 2019 to February 2020 wind rose for TWN monitoring site

3.3.3.3 Santos Network Site Results

3.3.3.4 Nitrogen Dioxide (NO_2)

NO_2 monitoring results from the Santos network sites are provided in **Figure 3-24**. Performance against relevant air quality standards is summarised below:

- 1-hour average concentrations of NO_2 are well below the Air NEPM standard of 0.12 ppm.
- Annual average concentrations of NO_2 are well below the Air NEPM standard of 0.03 ppm.
- Measured concentrations of NO_2 were at most 33% of the Air NEPM standards.

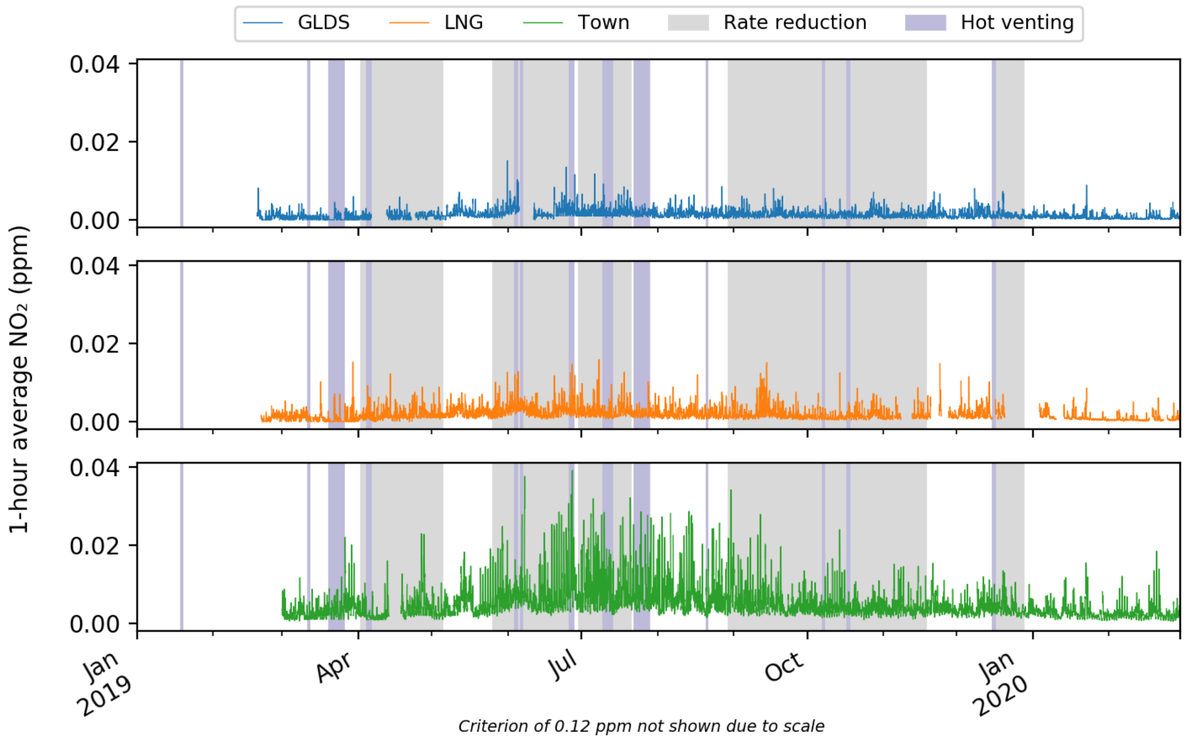


Figure 3-24 1-hour average concentrations of NO_2 measured by the DLNG monitoring network from January 2019 – February 2020

3.3.3.5 Sulphur Dioxide (SO_2)

SO_2 monitoring results from the Santos network sites are provided in **Figure 3-25** and **Figure 3-26**. Performance against relevant air quality standards is summarised below:

- 1-hour average concentrations of SO_2 are well below the Air NEPM standard of 0.20 ppm.
- 24-hour average concentrations of SO_2 are well below the Air NEPM standard of 0.08 ppm.
- Annual average concentrations of SO_2 are well below the Air NEPM standard of 0.02 ppm.
- Measured concentrations of SO_2 were at most 22% of the Air NEPM standards.

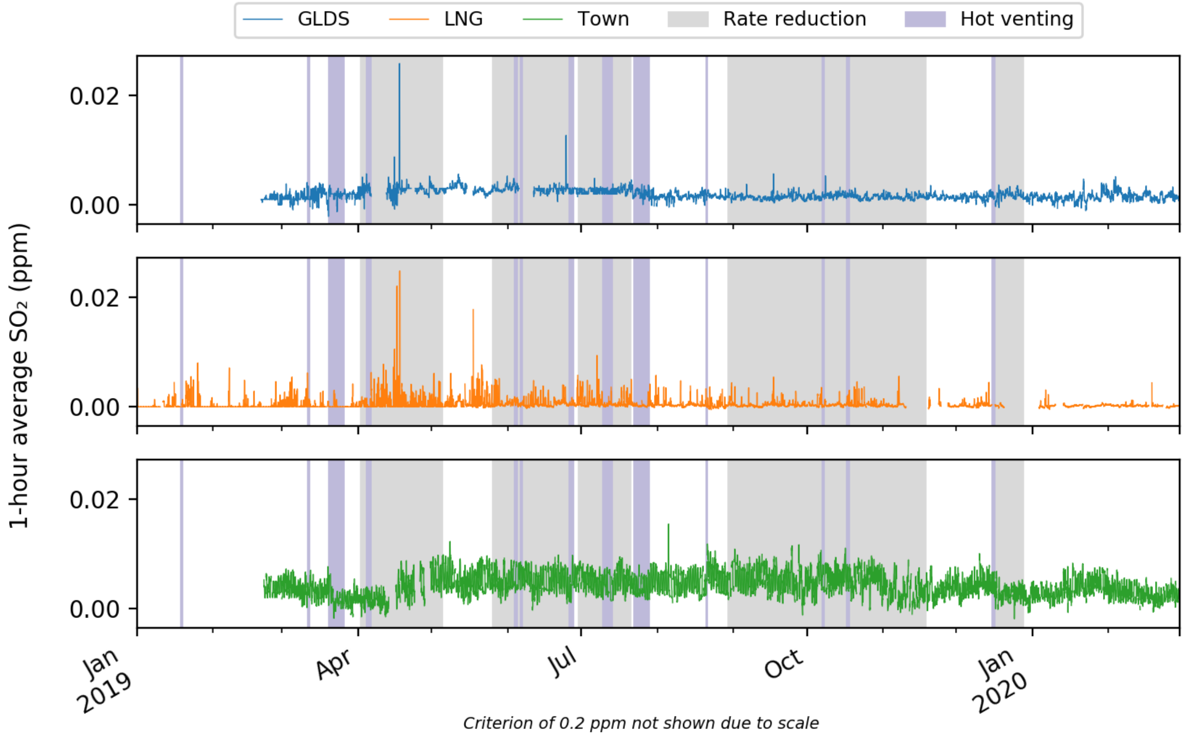


Figure 3-25 1-hour average concentrations of SO_2 measured by the DLNG monitoring network from January 2019 – February 2020

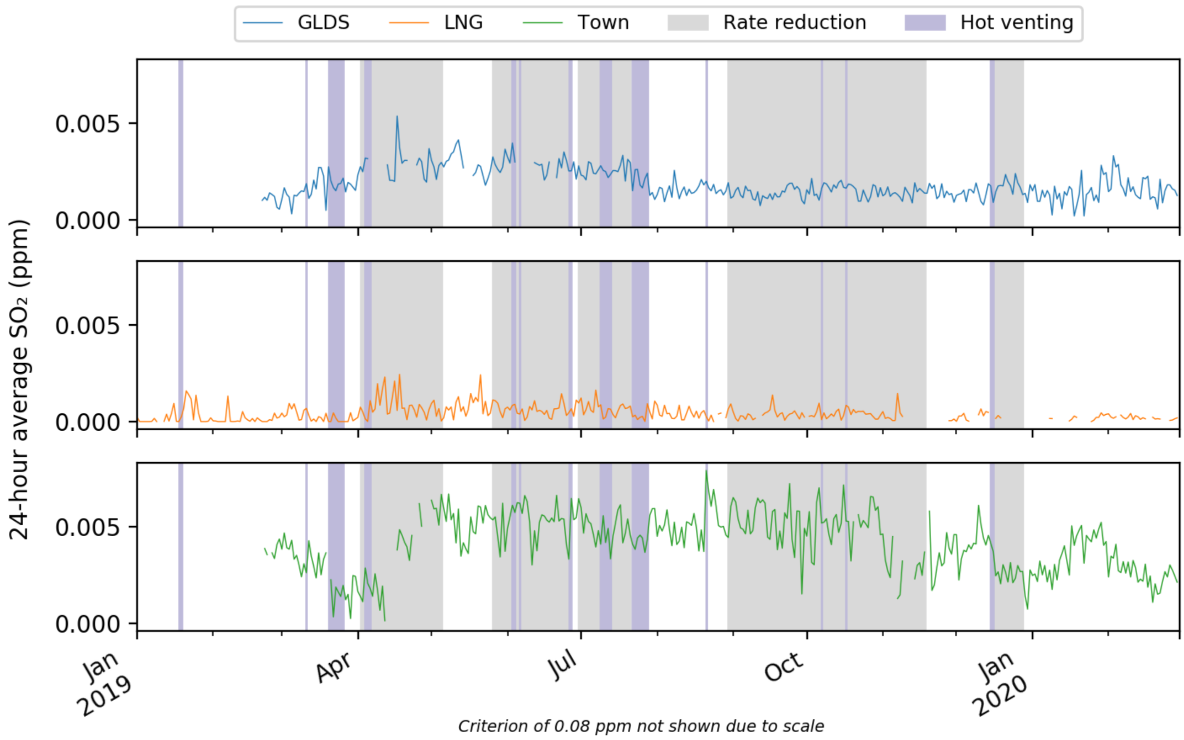


Figure 3-26 24-hour average concentrations of SO_2 measured by the DLNG monitoring network from January 2019 – February 2020

3.3.3.6 Benzene

Benzene monitoring results from the Santos network sites are provided in **Figure 3-27**. Performance against relevant air quality standards is summarised below:

- 1-hour average concentrations of benzene are well below the Approved Methods criterion of 0.009 ppm.
- Annual average concentrations of benzene are well below the Air Toxics NEPM MIL of 0.003 ppm at GLDS and LNG.
- Measured concentrations of benzene were at most 35% of the Approved Methods criterion and Air Toxics NEPM MIL.

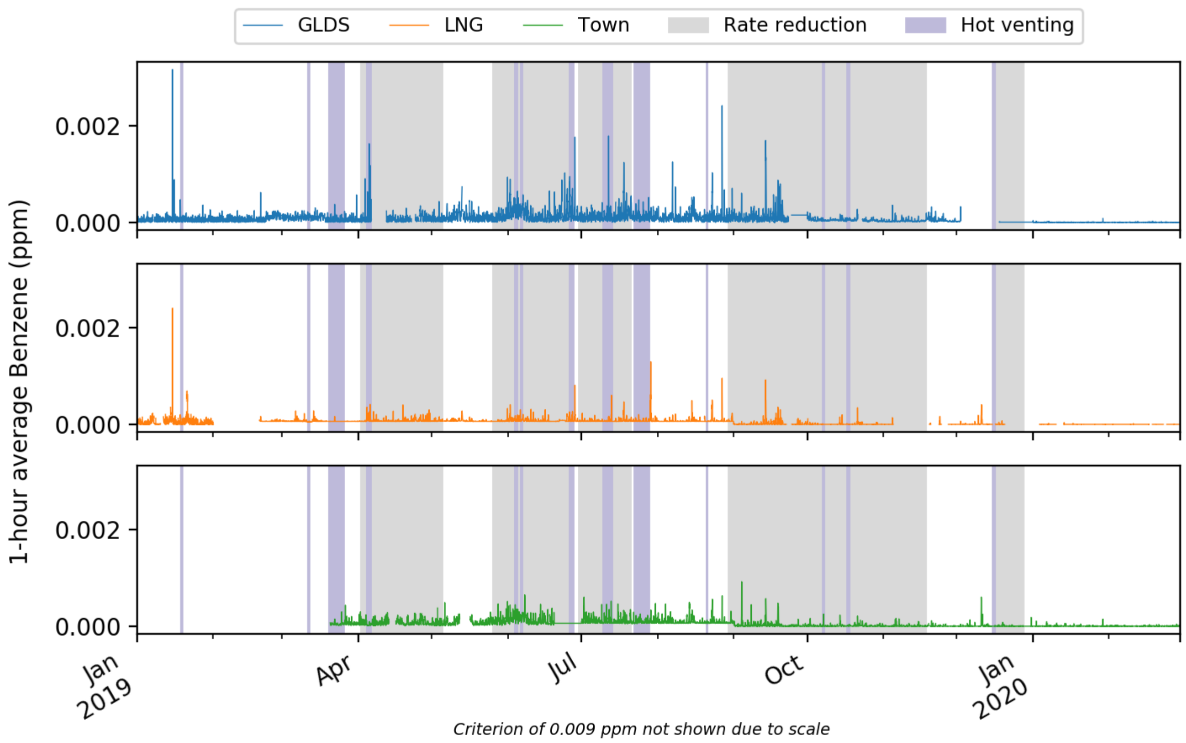


Figure 3-27 1-hour average concentrations of benzene measured by the DLNG monitoring network from January 2019 to February 2020

3.3.3.7 Hydrogen Sulphide (H_2S)

H_2S monitoring results from the Santos network sites are provided in **Figure 3-28** and **Figure 3-29**. Performance against relevant air quality standards is summarised below:

- 24-hour average concentrations of H_2S are well below the Air EPP objective for the protection of human health of 0.11 ppm.
- 30-minute average concentrations of H_2S exceeded the Air EPP objective for the protection of aesthetic environment of 0.0049 ppm on three occasions:
  - From 3:00 to 5:00 and 17:30 to 19:00 on 10 January 2020 at GLDS; and
  - From 14:30 to 16:30 on 13 February 2020 at Town.
- Of these, only one event on the 10 January 2020 may be associated with emissions from DLNG operations for the following reasons:
  - The wind direction was north-westerly prior to the exceedance which makes the DLNG facility upstream to the GLDS station;
  - The close proximity of GLDS to the DLNG facility; and
  - When the winds eased this coincided with a decrease in H_2S concentrations at GLDS.

  There were no known operations, including hot venting, occurring at DLNG at the time of this exceedance that was likely to have resulted in the elevated H_2S emissions. Given that the GLDS monitoring site is not located near any sensitive receptors and that elsewhere concentrations of H_2S were below the Air EPP objective, these elevated levels are of no wider consequence.

  With regards to the two other exceedances, similarly there were no known operations, including hot venting, occurring at DLNG at the time of the exceedance that are likely to have resulted in the H_2S emissions.

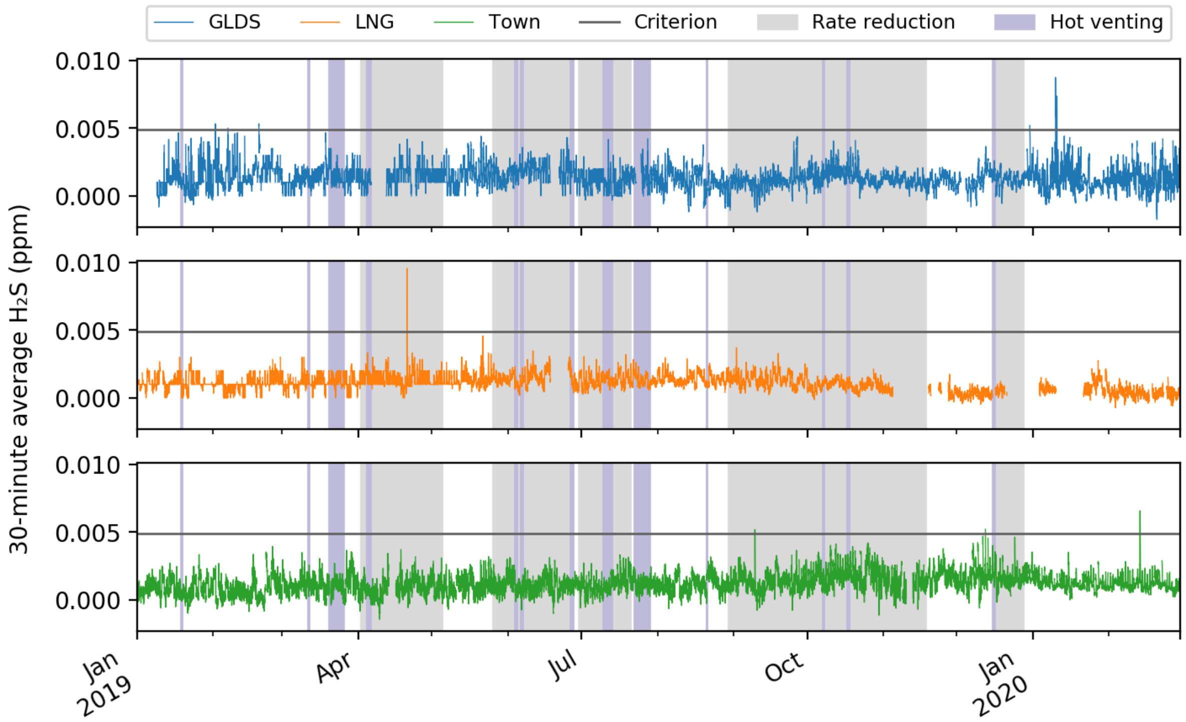


Figure 3-28 30-minute average concentrations of H_2S measured by the DLNG monitoring network from January 2019 to February 2020

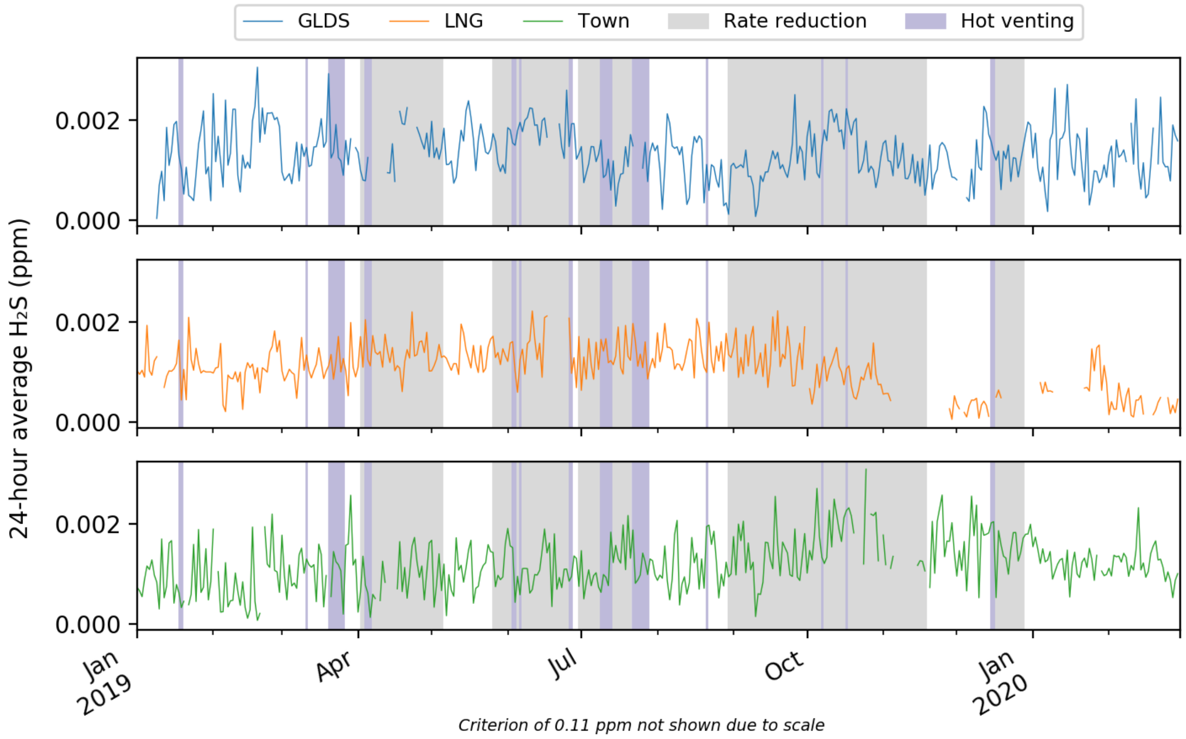


Figure 3-29 24-hour average concentrations of H_2S measured by the DLNG monitoring network from January 2019 to February 2020

3.3.4 Monitoring Results - NT EPA Network

3.3.4.1 Data Capture

The NT EPA monitoring network achieved a minimum of 75% valid data capture annually in 2020 for all relevant pollutants except CO. An outage of the Palmerston and Stokes Hill CO analysers between May and September 2020 resulted in data capture rates of 63.4% and 67.6%, respectively.

3.3.4.2 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 3-30**):

- The predominant winds in the region are east-west; northerly winds are uncommon and southerly winds are rare;
- Wind direction generally shifts from easterly in the dry season (May to October) to westerly in the wet season (November to April); and
- All sites recorded similar wind speeds, on average.

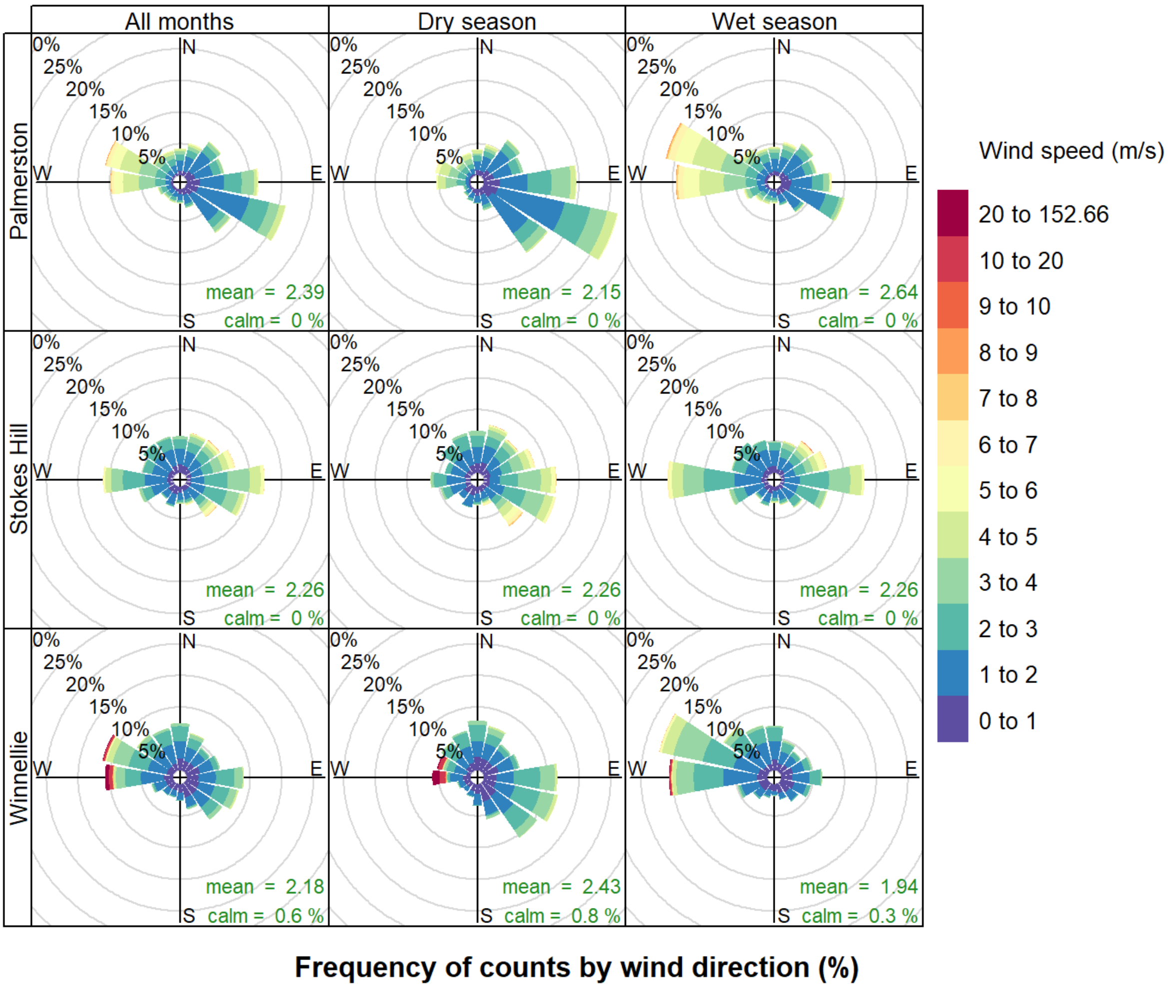


Figure 3-30 2020 wind rose for the NT EPA monitoring sites

3.3.4.3 Nitrogen Dioxide (NO_2)

NO_2 monitoring results from the NT EPA network sites are provided in **Figure 3-31**. Performance against relevant air quality standards is summarised below:

- 1-hour average concentrations of NO_2 are well below the Air NEPM standard of 0.12 ppm.
- Annual average concentrations of NO_2 are well below the Air NEPM standard of 0.03 ppm.
- Measured concentrations of NO_2 were at most 17% of the Air NEPM standards.

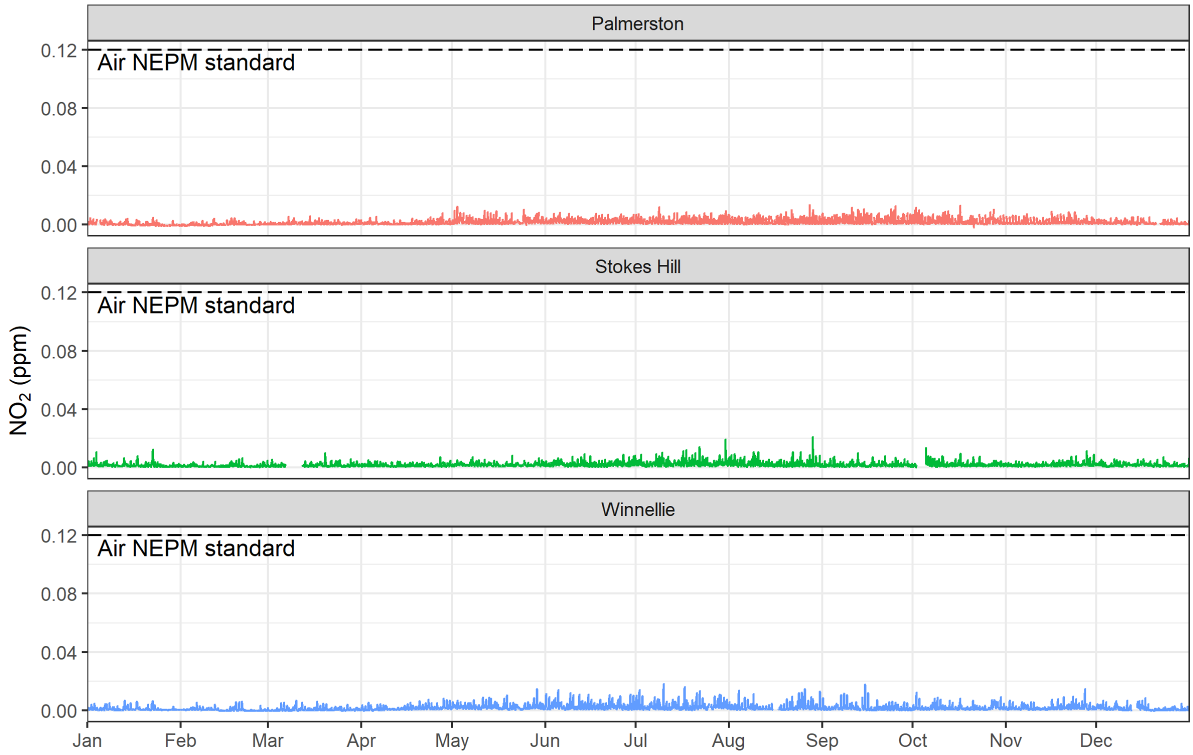


Figure 3-31 1-hour average concentrations of NO_2 measured by the NT EPA monitoring network in 2020

3.3.4.4 Sulphur Dioxide (SO_2)

SO_2 monitoring results from the NT EPA network sites are provided in **Figure 3-32** and **Figure 3-33**. Performance against relevant air quality standards is summarised below:

- 1-hour average concentrations of SO_2 are well below the Air NEPM standard of 0.20 ppm.
- 24-hour average concentrations of SO_2 are well below the Air NEPM standard of 0.08 ppm.
- Annual average concentrations of SO_2 are well below the Air NEPM standard of 0.02 ppm.
- Measured concentrations of SO_2 were at most 4% of the Air NEPM standards.

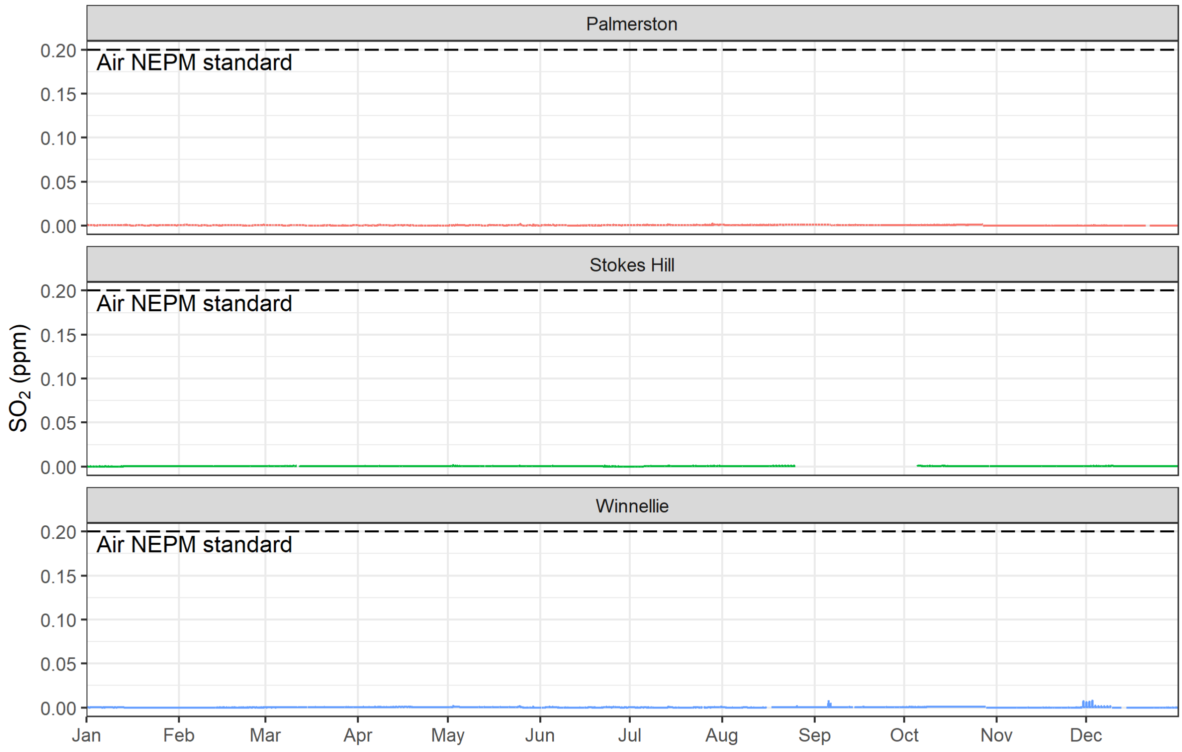


Figure 3-32 1-hour average concentrations of SO_2 measured by the NT EPA monitoring network in 2020

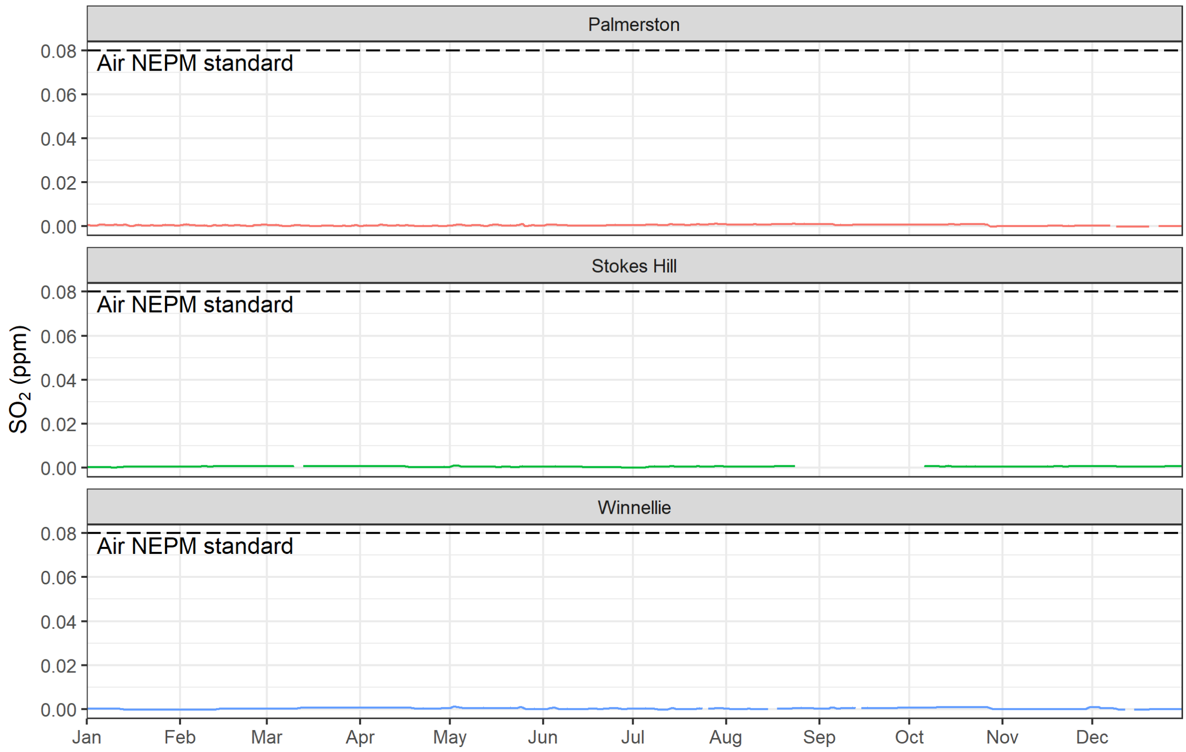


Figure 3-33 24-hour average concentrations of SO_2 measured by the NT EPA monitoring network in 2020

3.3.4.5 Carbon Monoxide (CO)

CO monitoring results from the NT EPA network sites are provided in **Figure 3-34**. Performance against relevant air quality standards is summarised below:

- 8-hour rolling average concentrations of CO are well below the Air NEPM standard of 9.0 ppm.
- Concentrations of CO complied with the relevant Air NEPM standard Winnellie. Data capture at Palmerston and Stokes Hill was insufficient to assess compliance with the Air NEPM standard; however, concentrations were at most 15% of the standard at any site.

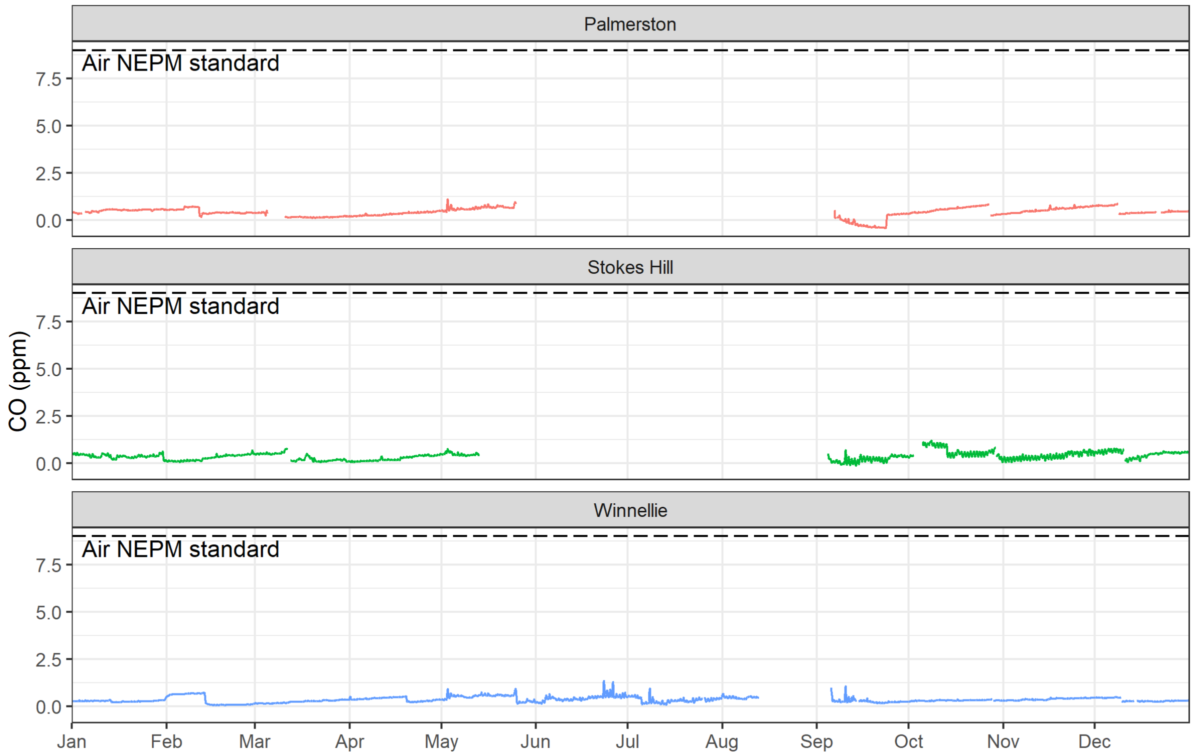


Figure 3-34 8-hour rolling average concentrations of CO measured by the NT EPA monitoring network in 2020

3.3.4.6 Particulate Matter (PM_{10})

PM_{10} monitoring results from the NT EPA network sites are provided in **Figure 3-35**. Performance against relevant air quality standards is summarised below:

- Annual average concentrations of PM_{10} are below the Air NEPM standard of 25 µg/m^3.
- 24-hour average concentrations of PM_{10} exceeded the Air NEPM standard of 50 µg/m^3 on three occasions:
  - 2nd May 2020 at Palmerston and Winnellie
  - 5th June 2020 at Winnellie
  - 8th July 2020 at Winnellie
- Concentrations of PM_{10} complied with the relevant Air NEPM standards at Stokes Hill, reaching at most 93% of either standard value.

The 24-hour average PM_{10} concentrations measured by the NT EPA monitoring network on the abovementioned exceedance days show that all sites recorded elevated concentrations on these days, indicative of a widespread dust event. Consistent with this is the fact that all exceedances occurred during the dry season (May to October), when natural dust events are common.

While hot venting did occur at the DLNG facility during one of the exceedances (5 June 2020), this is not associated with significant emissions of particulate matter. Furthermore, elevated concentrations of PM_{10} were predominantly associated with south-easterly winds at all sites during this time (**Figure 3-36**). It is therefore unlikely that any of the exceedances of the Air NEPM standard for PM_{10} were caused by DLNG operations.

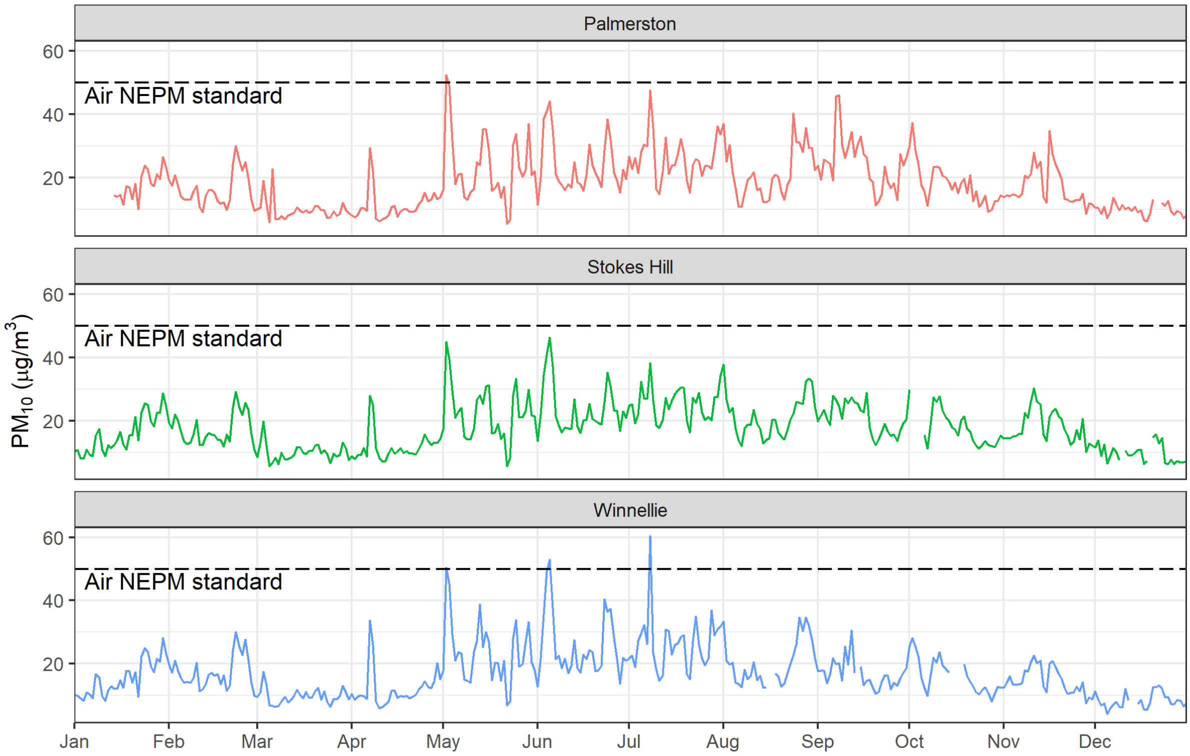


Figure 3-35 24-hour average concentrations of PM_{10} measured by the NT EPA monitoring network in 2020

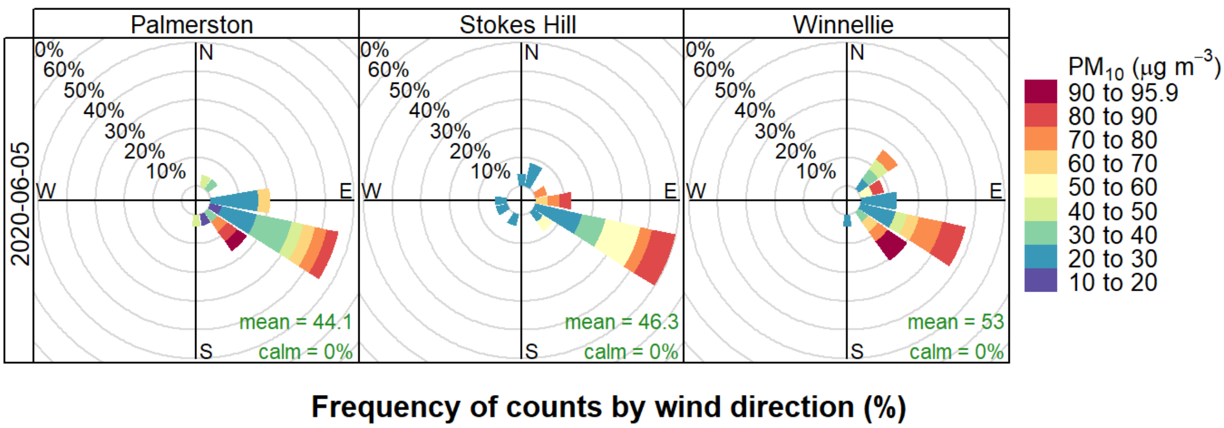


Figure 3-36 Distribution of 1-hour average PM_{10} concentrations measured by the NT EPA monitoring network on 5 June 2020

3.3.4.7 Particulate Matter ($PM_{2.5}$)

$PM_{2.5}$ monitoring results from the NT EPA network sites are provided in **Figure 3-37**. Performance against relevant air quality standards is summarised below:

- 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 nine occasions:
  - 2nd May 2020 at all sites
  - 3rd May 2020 at Palmerston and Winnellie
  - 29th May 2020 at Palmerston
  - 3rd June 2020 at Palmerston
  - 4th June 2020 at all sites
  - 5th June 2020 at all sites
  - 6th June 2020 at Stokes Hill and Winnellie
  - 25th June 2020 at Winnellie
  - 8th July 2020 at Palmerston and Winnellie

The 24-hour average $PM_{2.5}$ concentrations measured by the NT EPA monitoring network on the abovementioned exceedance days show that all sites recorded elevated concentrations on these days, indicative of a widespread dust event. Consistent with this is the fact that all exceedances occurred during the dry season (May to October), when natural dust events are common.

While hot venting did occur at the DLNG facility during four of the exceedances (3 May 2020 and 3 to 5 June 2020), this is not associated with significant emissions of particulate matter. Furthermore, elevated concentrations of $PM_{2.5}$ were predominantly associated with south-easterly winds at all sites during this time (**Figure 3-38**). It is therefore unlikely that any of the exceedances of the Air NEPM standard for $PM_{2.5}$ were caused by DLNG operations.

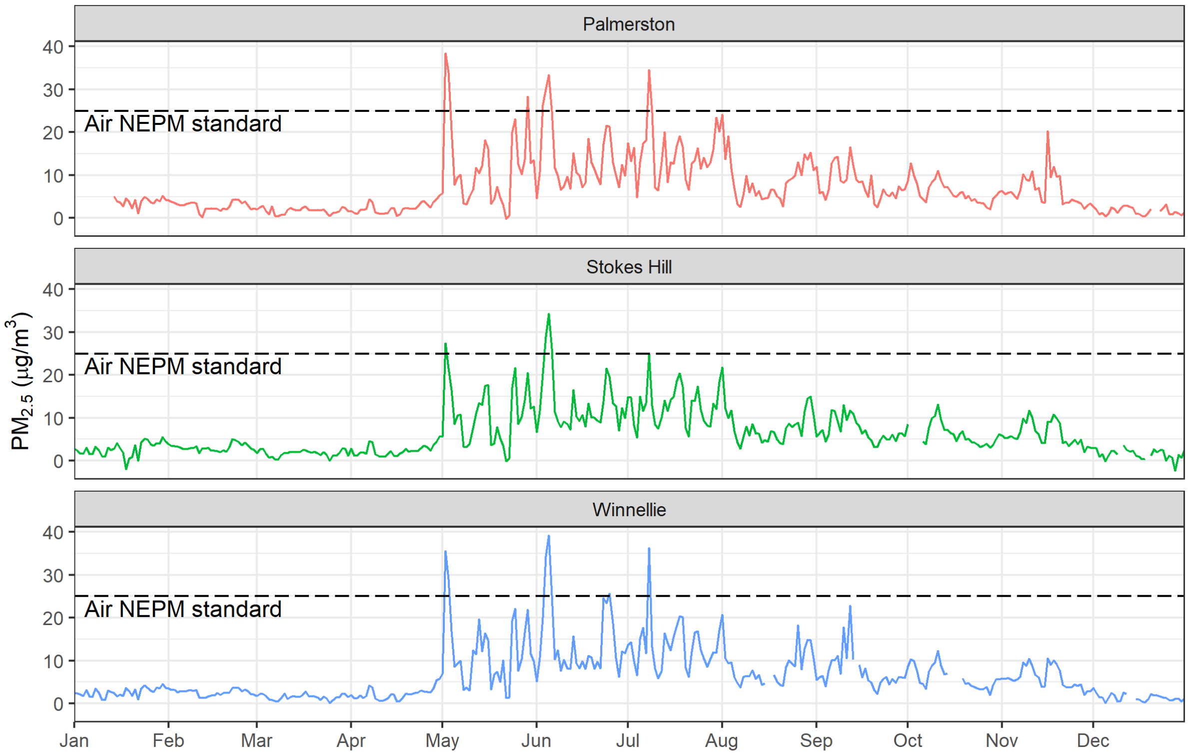


Figure 3-37 24-hour average concentrations of $PM_{2.5}$ measured by the NT EPA monitoring network in 2020

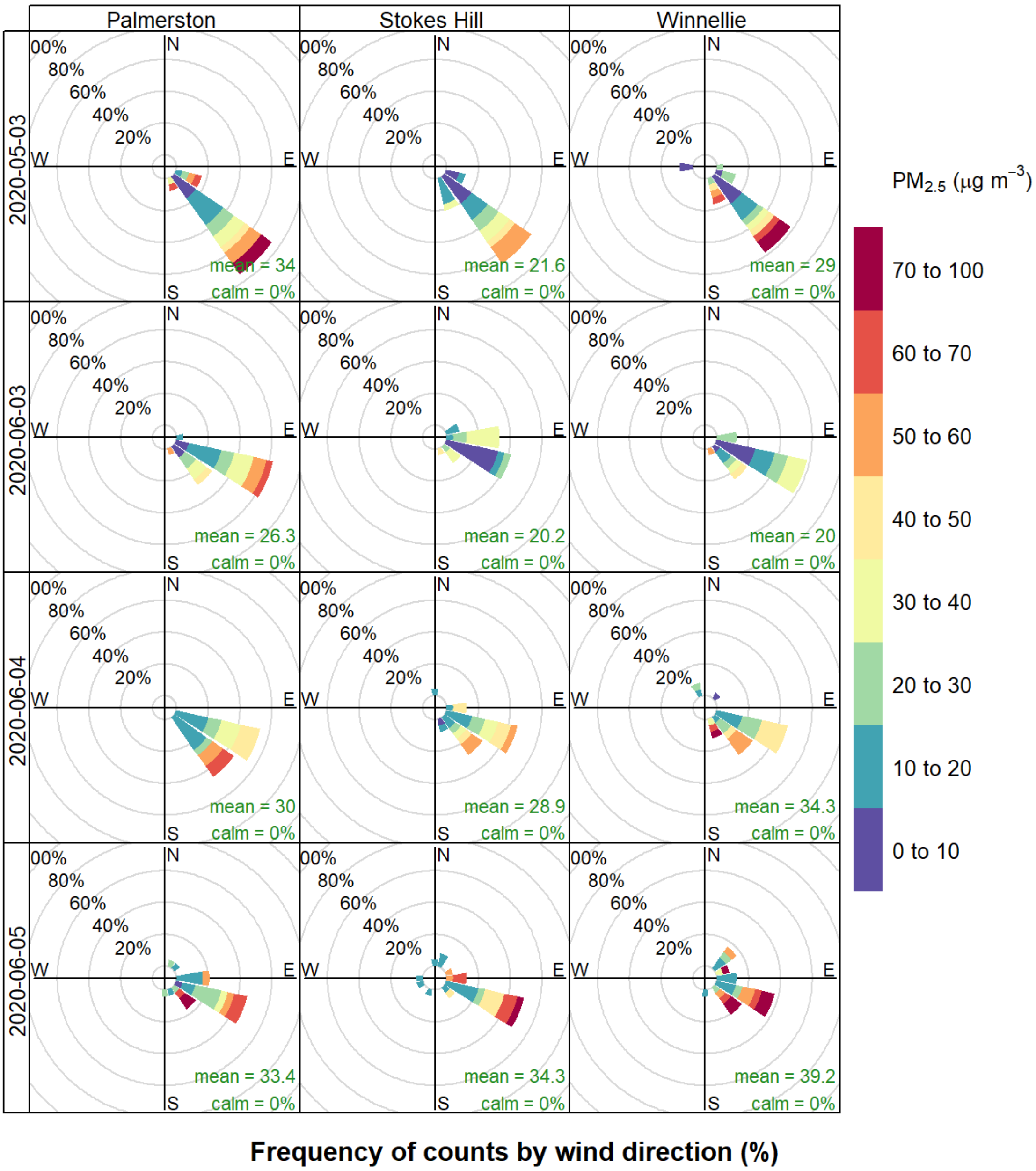


Figure 3-38 Distribution of 1-hour average $PM_{2.5}$ concentrations measured by the NT EPA monitoring network on 5 May 2020 and 3-5 June 2020

3.3.5 Data Management and Quality Control

The ambient air stations are maintained by Ecotech on behalf of Santos. Monthly maintenance is completed at the stations to meet requirements of Australian standards and Ecotech QA/QC procedures. Station data and maintenance logs are held within an electronic database management system. Data from the stations is check daily by qualified professionals, maintenance is also completed onsite by qualified professionals.

3.3.6 Discussion and Interpretation of Results

Overall, results of the ambient air quality monitoring demonstrated that air quality was generally within the relevant NEPM, Air EPP and NSW EPA air quality standards and monitoring investigation limits (MIL) during the reporting period. This indicates that ambient air emissions fell within appropriate standards for human health in Darwin City and DLNG air emissions did not pose a risk of material or serious environmental harm to the flora, mangrove communities and terrestrial fauna in the Darwin air sheds.

With regards to the elevated H_2S exceedances recorded at the Santos network sites, only one event may be plausibly related to DLNG operations, however, there were no known operations, including hot venting, occurring at DLNG at the time of this exceedance that is likely to have resulted in the elevated H_2S emissions. Elsewhere the concentrations of H_2S were below the Air EPP objective, therefore this event is of no wider consequence or environmental impact.

With regards to the elevated PM_{10} and $PM_{2.5}$ exceedances recorded at the NT EPA network sites, these were derived from widespread dust events common in dry season conditions and are not considered to be attributable to DLNG emission sources.

3.4 GREENHOUSE GAS EMISSIONS

Atmospheric emission from the DLNG facility have the potential to contribute to global greenhouse gas emissions. As a responsible operator, Santos completed estimation of GHG emissions in accordance with industry standards and the National Greenhouse and Energy Reporting Scheme, which is administered by the Commonwealth Clean Energy Regulator.

3.4.1 Monitoring Objectives

The objective of the GHG emissions monitoring program is to estimate the GHG emissions from the DLNG facility in accordance with the requirements of the NGER Scheme. While there are no Licence conditions that require Santos to monitor and report in GHG emissions, they have been included in this report to provide context for the air emissions aspects of the DLNG facility.

3.4.2 Monitoring Methods

The DLNG GHG emissions inventory has been calculated in accordance with the technical guidance, provided under the NGER (Measurement) Determination (the determination).

The methodology used to compile the GHG emissions figures complies with NGER Method 1. This Method primarily requires the application of a default emissions factor to a sum of raw data, such as tonnes of gas flared, or cubic meters of fuel gas consumed.

Criterion BBB is the only measurement criteria used to calculate the DLNG inventory. This measurement method is consistent with industry practice and can only be used when a financial transaction hasn't occurred (i.e. there is no invoice supporting the quantity of fuel gas consumed). The source of criterion BBB is the determination.

No hydrofluorocarbons or perfluorocarbons are used at DLNG. Therefore, the greenhouse gases reported for DLNG are CO_2, Methane (CH_4) and Nitrous oxide (N_2O).

3.4.3 Monitoring Results

GHG emissions from the DLNG facility are shown in **Figure 3-39**. There was a slight increase in GHG emissions in 2020 compared to 2019 due to increased production. Over the six-year reporting period there is an overall decreasing trend in GHG emissions.

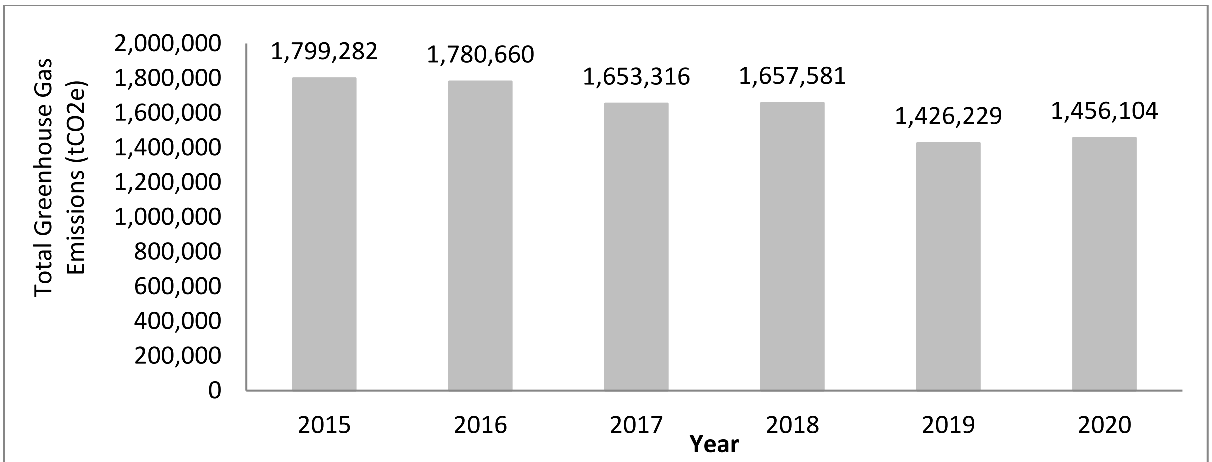


Figure 3-39 DLNG facility GHG emissions for 2015-2020

Note: GHG emissions estimates provided are interim values and subject to technical review. Any material changes to updated following completion of the technical review.

3.4.4 Data Management and Quality Control

The inputs for the emissions calculations were derived using fuel purchasing records and the Santos plant operating process data system. This system is routinely monitoring as part of the operation of the DLNG facility and is considered reliable. The methods used to estimate emissions conform to NGER methods and are considered to be standard practice under the NGER Scheme.

3.4.5 Discussion and Interpretation of Results

There is an overall decreasing trend in GHG emissions over the 2015-2020 reporting period due to overall reduced DLNG production rates resulting in less energy consumption. Santos implements a range of initiatives aimed at reducing the company's GHG emissions. The DLNG facility complies with GHG reporting requirements in Australia, including annual reporting to the Clean Energy Regulator under the NGER scheme.

4. MONITORING DISCHARGES TO LAND AND SURROUNDING ENVIRONMENT

4.1 GROUNDWATER MONITORING PROGRAM

Treated wastewater (defined in **Section 2.1**) 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, 2020b), the results of which are summarised in this section.

4.1.1 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).

4.1.2 Monitoring Methods

Groundwater samples were taken by qualified personnel from a network of seven monitoring bores (**Figure 4-1**). 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 4-1**; the bores are shown in **Figure 4-1**.

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 surveys (April 2020 and August 2020) were undertaken during the reporting period to capture wet and dry seasonality. 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 4-1 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

4.1.2.1 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 2019 and 2020 and 2020 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 2020 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 4-2** and the investigation trigger values for compliance and the assessment of impacts to groundwater are represented in **Table 4-2** and **Table 4-3.**

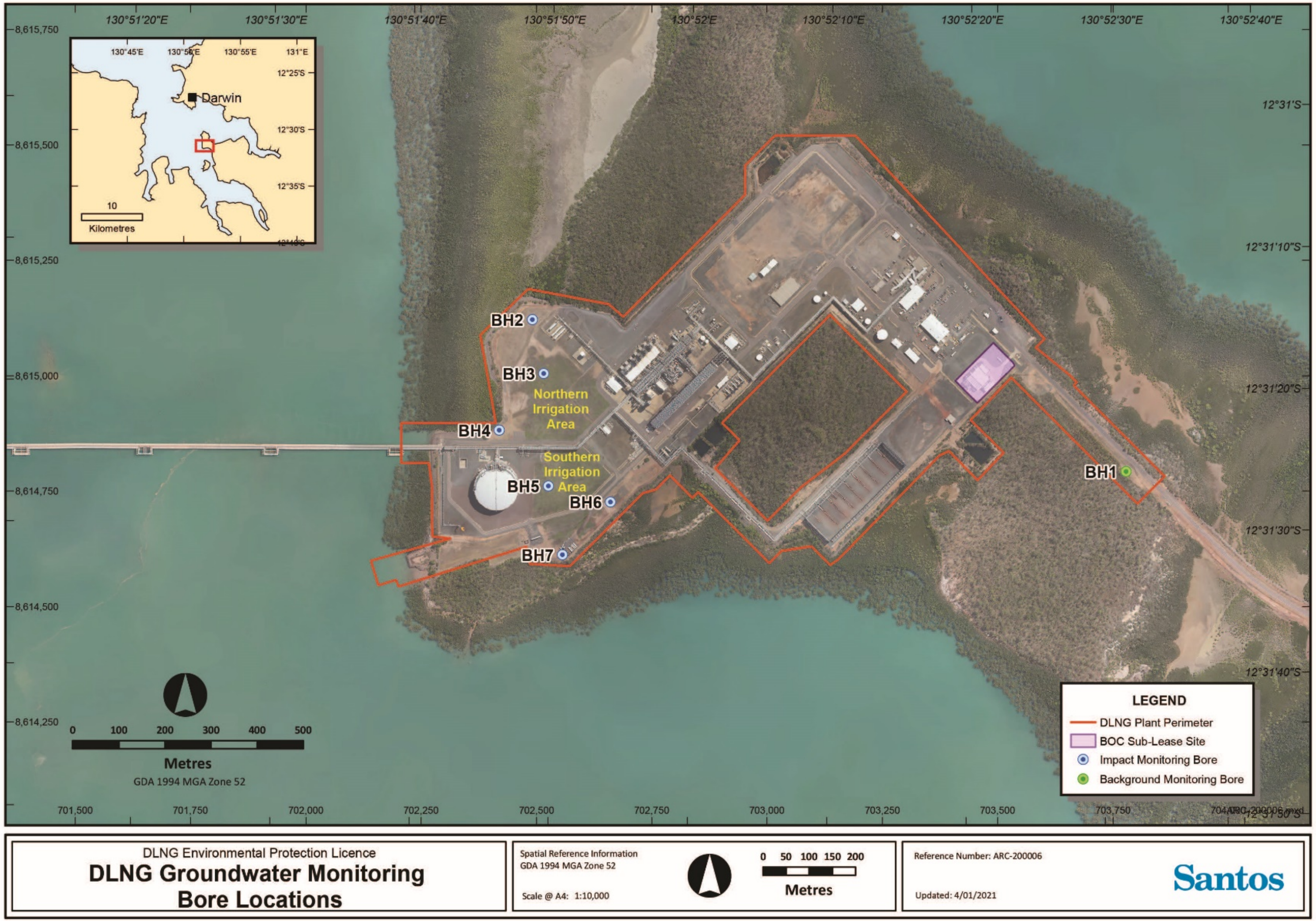


Figure 4-1 Groundwater monitoring program bore locations

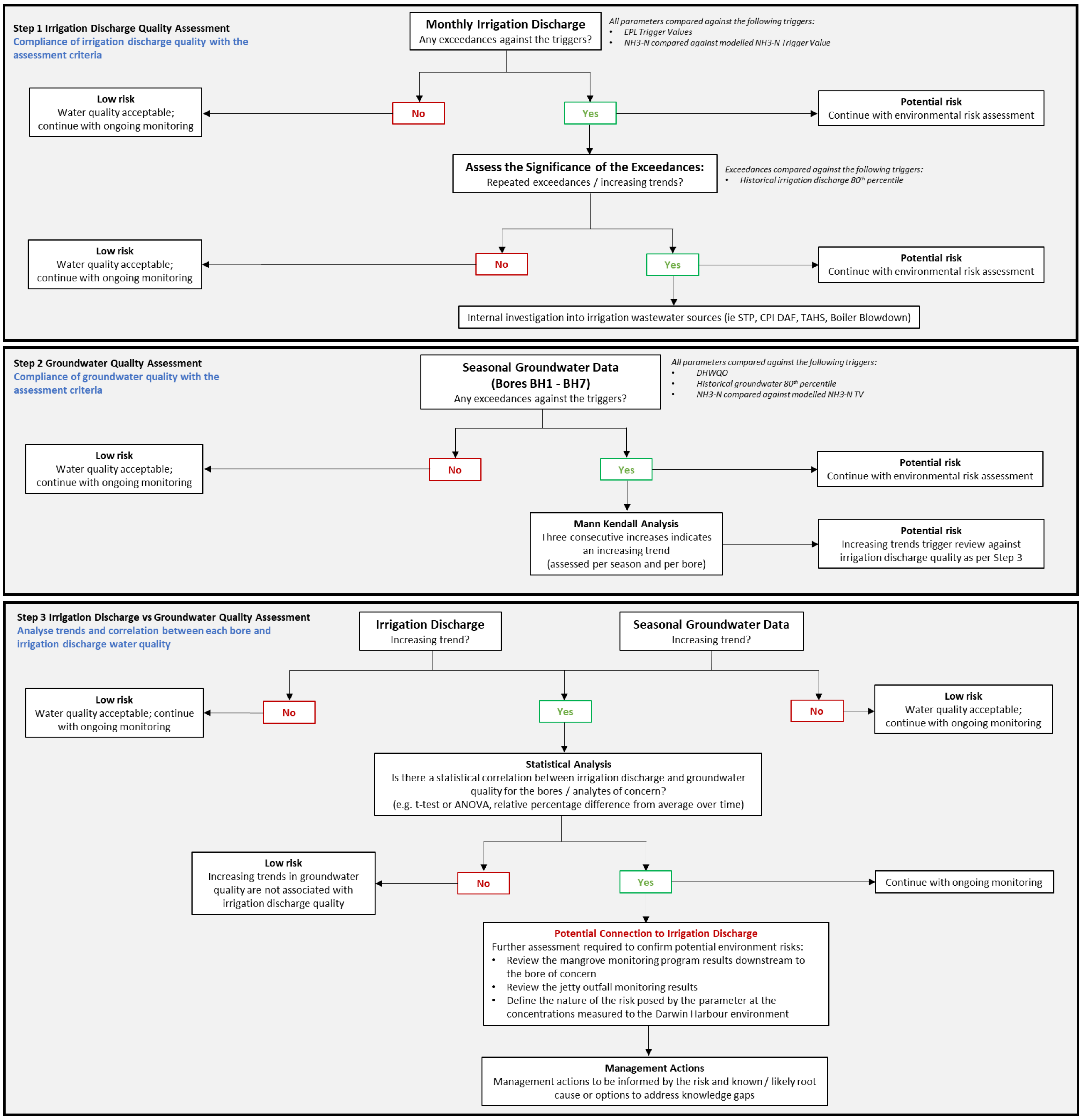


Figure 4-2 Assessment framework of impact to groundwater from irrigation discharge

Table 4-2 Step 1: Assessment for irrigation discharge

Parameter	Units	EPL 217-02 Irrigation Discharge TV	Modelled TV	Historical 80th 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
E. coli	MNP/100ml	≤75	N/A	<16.80
Enterococci	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 4-3 Step 2: 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 2015-2019 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	26.800	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	27.300	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
E. coli	MNP/100ml	≤200	N/A	2	2	2	2	2	22	2	2	2	2	2	2	2	2
Enterococci	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 (NO_3-N), however NOx (nitrite + nitrate) in the groundwater is mainly composed of nitrate. The trigger value for NOx was used for NO_3-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.

4.1.3 Monitoring Results and Discussion

The results of the 2020 groundwater monitoring program are discussed in the following sections with the 2015-2020 groundwater quality dataset provided in **Attachment D**.

4.1.3.1 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 m AHD using survey data.

Groundwater levels were also monitored using three data loggers:

- May 2019 to April 2020 – monitoring wells BH2, BH3 and BH7.
- April 2020 to August 2020 – monitoring wells BH4, BH5 and BH6.

Key findings from groundwater level data includes:

- Monitoring results from groundwater levels during 2020 is consistent 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 4-3**). 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 conclusion is supported by the groundwater data loggers; the limited variation and delay in water level response suggests limited mixing and tidal affects 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.

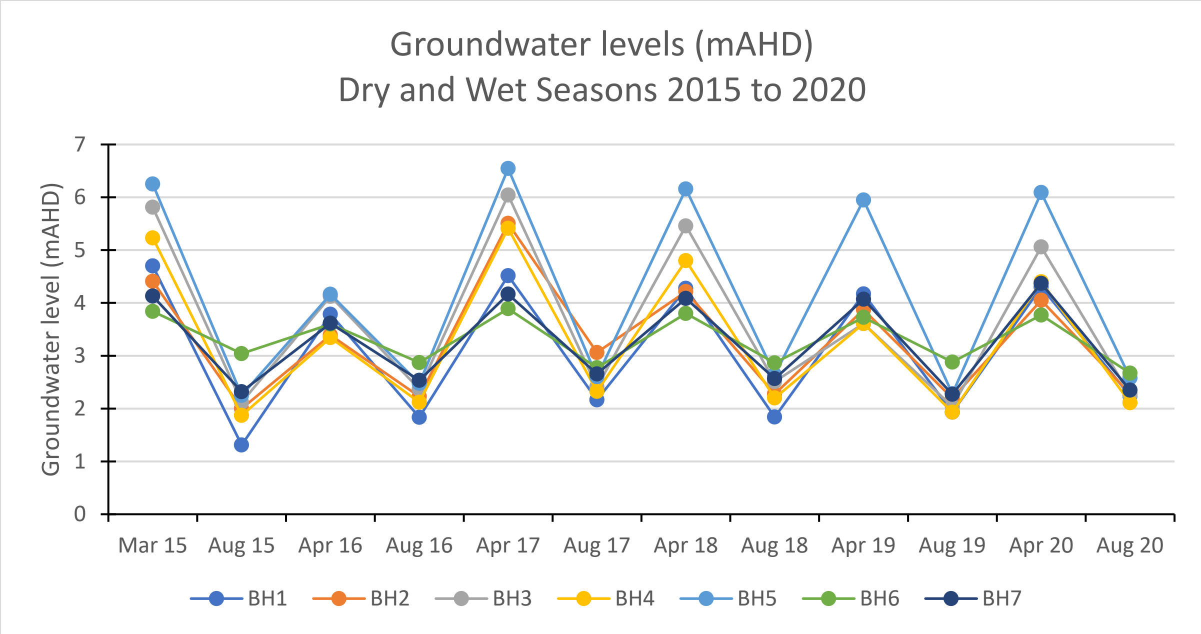


Figure 4-3 Groundwater levels for all bores at DLNG facility 2015-2020

4.1.3.2 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 2020 monitoring event are generally consistent with the previous records with the following main observations:
  - pH: Bores BH1 and BH4 continue to display a reducing trend in pH. 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): An increasing trend in EC is observed in monitoring well BH6 during the wet seasons and BH5 during the dry seasons since March 2015. All other monitoring wells (BH2, BH3, BH4, BH6 & BH7) show a decreasing trend in EC over both wet seasons and dry seasons since March 2015. The variations in EC observed in the 2015-2020 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 -125.7 mV (BH7) to 265.6 mV (BH4) during the 2020 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 since 2015. BH1 and BH4 demonstrate a similar trend over the 2015 to 2020 groundwater monitoring events (both wet and dry seasons), with an increasing ORP since 2016, although decreasing since 2019. A downward trend is observed in BH3 during the dry seasons groundwater monitoring events. Compared to the wet seasons groundwater monitoring events records, the ORP is

only marginally lower than the first measurement in March 2015 demonstrating a U-shaped recovery in readings over time.

- Dissolved Oxygen (DO): DO in groundwater ranges from 15.4 % (BH7) to 46.0 % (BH5) during the 2020 groundwater monitoring events, indicating varying aerobic conditions across the site. A slight increasing trend in DO is observed in the monitoring wells over the wet seasons since March 2015 with only BH4 defying this trend. DO concentrations in all monitoring wells measured during the 2020 dry seasons show an upward trend from the dry season in 2019 and a downward trend overall when compared against the readings taken in August 2015. Variation of data for the dry season groundwater monitoring events has decreased markedly since 2018.

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

Visual and olfactory observations were recorded during the purging and groundwater sampling program. Apart from BH2 and BH7, no odours or sheens were recorded for the majority of groundwater bores. 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 2019 monitoring program were compared against the DHWQO TV (**Table 4-4**) and the groundwater historical 80th percentile (**Table 4-5**). 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 4-4 Field groundwater parameter trends

Table 4-4 In-situ water quality measurements wet and dry season 2019 compared against DHWQO trigger values

Monitoring Bore	Date	EC (µS/cm)	pH	Redox Potential (mV)	Temperature	DO (% Saturation)	Field Observations
DHWQO		NA	7-8.5	NA	NA	80-100 %	
BH1	08/04/2020	20,220	4.44	151.9	31.3	39.7	Red colour. Mica.
	05/08/2020	63,183	4.12	251.30	30.90	30.90	
BH2	07/04/2020	65,755	6.39	-120.6	31.5	23.2	Sulfuric smell. Turbid. Mica.
	06/08/2020	61,466	6.33	-45.10	31.20	15.40	Sulfuric smell
BH3	07/04/2020	164.9	5.39	87.1	29.7	29.7	Sediment. Slightly turbid. White and milky colour.
	06/08/2020	215	6.03	81.50	29.60	25.60	Turbid, sulfuric smell. Highly sedimented filtration very difficult.
BH4	07/04/2020	425	3.92	140.2	32.9	29.5	No odour. Turbid. Brown color. Mica. Logger #V8472 installed ~13 m
	06/08/2020	412	4.16	265.60	32.60	23.20	Broken hook for logger #v8472 replaced by carabiner.
BH5	08/04/2020	1,369	5.18	107	29.3	46	Mica. Milky white. A lot of sediment. No odour. Logger #V8473 installed ~14.5m
	05/08/2020	2,391	5.54	203.90	29.70	27.30	Broken hook for logger #v8473 replaced by carabiner.
BH6	07/04/2020	1,167	5.4	26.7	34.2	24.4	Turbid. Slightly white. No odour. Mica. Logger # V8463 installed ~9.5 m
	05/08/2020	7,817	5.12	184.00	33.50	22.60	Creamy/turbid in colour, mica. Filtration really difficult, hook for logger #v8463 replaced by carabiner.
BH7	08/04/2020	1,432	6.18	-125.7	32.9	20.5	Sediments. Sulfuric odour. Slightly turbid.
	06/08/2020	3,735	6.15	25.70	31.20	30.00	Sulfuric smell, silty, mica.

Grey shades cells indicate where a value is outside the Darwin Harbour Water Quality Objectives trigger values

Table 4-5 In-situ water quality measurements wet and dry seasons 2015-2020 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**
	2015-2019	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**
Unit	**(µS/cm)**			**pH Unit**			**pH Unit**			**mV**			**% Saturation**	
BH1	32,581	20,220		4.22	**4.44**		5.14	4.44		268.36	151.90		60.85	39.70
BH2	73,925	65,755		6.30	**6.39**		6.53	6.39		-30.76	-120.60		33.32	23.20
BH3	272	165		4.62	**5.39**		5.95	5.39		109.58	87.10		31.50	29.70
BH4	506	425		4.09	3.92		5.50	3.92		296.04	140.20		38.38	29.50
BH5	2,308	1,369		5.71	5.18		6.46	5.18		120.24	107.00		60.42	46.00
BH6	9,433	1,167		5.35	**5.40**		5.55	5.40		82.72	26.70		24.10	**24.40**
BH7	3,270	1,432		6.09	**6.18**		6.27	6.18		-54.56	-125.70		27.37	20.50
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**
	2015-2019	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**		**2015-2019**	**2020**
Unit	**(µS/cm)**			**pH Unit**			**pH Unit**			**mV**			**% Saturation**	
BH1	80,357	63,183		4.13	4.12		4.51	4.12		330.52	251.30		63.81	30.90
BH2	74,556	61,466		6.40	6.33		6.54	6.33		-10.40	-45.10		50.68	15.40
BH3	387	215		4.40	**6.03**		5.76	**6.03**		175.52	81.50		55.96	25.60
BH4	1,095	412		4.31	4.16		5.19	4.16		337.78	265.60		50.15	23.20
BH5	2,263	**2,391**		6.13	5.54		6.63	5.54		167.76	**203.90**		79.02	27.30
BH6	14,207	7,817		5.07	**5.12**		5.31	5.12		166.48	**184.00**		45.10	22.60
BH7	8,954	3,735		6.01	**6.15**		6.14	**6.15**		13.40	25.70		52.57	30.00

Note: Bold text indicates where value exceeds the historical 80th percentile of Groundwater based on data since 2015 to 2019.

4.1.3.3 Groundwater Quality Laboratory Results

The analytical results for the 2020 biannual groundwater monitoring are presented below in line with the assessment framework outlined in **Section 4.1.2.1**.

4.1.3.4 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 (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 4-6** and **Figure 4-5**:
    - pH was recorded above the historical 80th percentile trigger values for three events in 2019, with no exceedances recorded in 2020.
    - Enterococci exceeded the EPL 217-02 and the historical 80th percentile at one event only in 2019 and E. coli exceeded trigger values of the assessment criteria at various events during 2019 only.
    - BOD exceeded the EPL 217-02 and the historical 80th percentile at one event in 2019. It should be noted that further BOD exceedances were detected in September to December 2020 after the completion of the dry season groundwater report which considers results from January 2019 to August 2020 only.
    - Most nutrients (ammonium nitrogen, nitrite, nitrate and dissolved reactive phosphorus) were recorded above the irrigation discharge trigger values of the EPL 217-02. Exceedances against the modelled trigger value for ammonium nitrogen were recorded for three events in 2019 only. Exceedances of historical 80th percentiles were recorded various occasions during 2019 and 2020.
    - Low levels of BTEX were detected at four events in 2019 above the historical 80th percentiles but were well below the EPL 217-02 trigger value.
    - Various metals (cadmium, copper, iron, manganese and zinc) were recorded above the historical 80th percentiles in 2019 and 2020. Copper was the only metal that exceeded the EPL 217-02 trigger value.
- Total Recoverable Hydrocarbons (TRH) were not detected in the irrigation discharge during 2019 and 2020.

Irrigation discharge water quality is discussed in further detail in **Section 2.1.3.1**.

Table 4-6 Step 1: Summary of irrigation discharge exceedances against the assessment criteria from January 2019-August 2020

Date Sampled / Analyte	DO	Temp	Turbidity	pH	EC	TSS	E Coli	Enterococci	BOD	TN	TP	NH3-N	NO3-N	NO2-N	PO4-P	TKN	Cd	Cu	Fe	Mn	Zn	Toluene	Xylene	BTEX
	mg/L	˚C	NTU		µS/cm	mg/L	MPN/100mL	MPN/100mL	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EPL 217 Trigger Value	**N/A**	**N/A**	**N/A**	**7-8.5**	**N/A**	**30**	**75**	**50**	**25**	**40**	**10**	**20**	**17**	**17**	**5**	**N/A**	**3.2**	**69**	**1,300**	**15,500**	**1780**	**N/A**	**N/A**	**700**
80th percentile (2009-2019)	**0.50**	**39.8**	**16.08**	**7.80**	**272**	**14**	**16.8**	**41**	**26**	**13.40**	**2.17**	**6882**	**2126**	**163.2**	**1326**	**10.07**	**0.10**	**41.4**	**268**	**42**	**25.8**	**0.5**	**1.6**	**3**
Modelled TV												**9000**												
Wet Season																								
2/01/2019	0.15	39.4	15.90	7.57	193	6	<10	<10	18.0								<0.1	14			6	<0.5	3.1	4.00
6/02/2019	0.23	37.2	9.91	7.52	185	2	108	<10	21.0								<0.1	17			17	<0.5	1.9	<3
20/02/2019							6,488	331																
27/02/2019							197	41																
4/03/2019							<10	<10																
6/03/2019	0.50	40.4	6.41	7.87	189	0	<10	<10	1.6	6.15	1.33	5,890	22	2	1,150	6.11	<0.1	17	88	18	9	<0.5	<1.5	<3
3/04/2019	0.10	40.0	15.30	7.15	176	14	275	<10	18.0								<0.1	9			<5	0.50	<1.5	<3
8/04/2019							<10	<10																
Dry Season																								
1/05/2019	0.10	39.8	4.99	7.30	220	12	31	<10	2.1								<0.1	14			7	<0.5	<1.5	<3
5/06/2019	0.13	27.7	5.41	7.88	249	6	<10	<10	1.2								<0.1	18			16	<1	<3	<6
3/07/2019	0.09	37.2	12.40	7.96	298	6	313	20	32.0	14.80	3.08	**12,600**	<1	3	2,460	14.80	<0.1	24			28	0.60	<1.5	<3
17/07/2019							<100	<100	7.9															
7/08/2019	0.15	34.8	14.60	7.63	292	10	10	<10	6.3	13.20	3.63	8,000	1,520	60	3,230	11.70	<0.1	16			10	<0.5	1.8	<3
4/09/2019	0.06	37.8	5.76	7.28	298	8	<10	<10	2.9	9.63	2.79	4,220	3,820	190	2,340	5.65	<0.1	21			18	<0.5	<1.5	<3
2/10/2019	0.17	38.5	6.09	7.50	343	11	<10	<10	10.0	14.50	2.41	**12,900**	3.0	3	1,960	14.00	<0.1	11			<5	<0.5	<1.5	<3
Wet Season																								
6/11/2019	2.42	36.8	2.93	7.28	329	5	<10	<10	<1	20.80	2.81	**9,800**	980	77	2,390	10.10	0.2	400	150	31	210	<0.5	<1.5	<3
18/11/2019																	<0.1	82	100	21	50			
4/12/2019	0.67	38.6	7.54	7.01	238	11	<10	<10	<1	13.40	1.31	2,810	676	186	1,130	4.79	<0.1	190	150	37	120	<0.5	<1.5	<3
11/12/2019			25.40		170	28				7.50	1.10	910	<5	<5	31	7.50	<0.1	40	480	58	42			
11/12/2019										6.41	1.01	981[1]	<1	2	6	5.92								
17/12/2019	0.14	38.2	8.75	7.09	164	12				4.10	2.10	480[1]	<5	<5	1,400	4.10	<0.1	10	270	33	10			
17/12/2019										3.87	2.21	51	<1	<1	1,340	3.61								
8/01/2020	0.06	36.1	1.98	7.40	216	2	<10	<10	1.4	5.47	1.34	453	3,120	151	994	3.09	<0.1	5	120	20	19	<1	<1	<4
15/01/2020										3.46	0.52	65	2	<1	4		<0.1	2	320	29	<5			
22/01/2020										3.64	0.71	205	<1	1	9		<0.1	2	230	32	10			
29/01/2020																	<0.1	2	190	24	10			
5/02/2020	0.15	35.4	15.10	7.23	210	22			23.0	0.50	2.25	99	<1	1	610		<0.1	6			6	<0.5	<1.5	<3
4/03/2020	0.09	37.9	16.40	7.35	206	17	10	<10	15.0	5.58	1.80	235	2.0	1	931		<0.1	11	200	40	16	<0.5	<1.5	<3
1/04/2020	0.15	35.0	2.73	7.62	258	0			2.5	5.95	2.77	3,330	<1	<1	2,500		<0.1	5			<5	<0.5	<1.5	<3
Dry Season																								
6/05/2020	0.11	36.0	2.12	7.29	255	1			1.5	8.76	0.74	2,410	4,580	123	731		<0.1	13			30	<0.5	<1.5	<3
10/06/2020	0.10	32.0	1.92	7.37	338	0			3.1	13.10	1.44	2,730	6,890	1,670	1,330		<0.1	18			34	<0.5	<1.5	<3
8/07/2020	0.12	32.5	5.06	7.45	311	3			6.9	8.77	1.25	2,200	2,870	191	100		<0.1	12			10	<0.5	<1.5	<3
5/08/2020	0.14	35.3	6.92	7.40	213	5			3.9	4.51	1.48	309	1,280	38	992		<0.1	16			10	<0.5	<1.5	<3

Orange cells denotes concentration exceeds the EPL 217-02 TV
Red text denotes value exceeds the historical 80th percentile of groundwater based on data since 2015 to 2019.
Bolded text indicates where value exceeds the modelled TV.
Note 1: These results were generated by SGS. Re-test samples were analysed by Intertek. Intertek results: 11/12/2019 - Ammonia 0.981 mg/L, reactive phosphorus 0.006 mg/L, 17/12/2019 – Ammonia 0.051 mg/L, reactive phosphorus: 1.34 mg/L

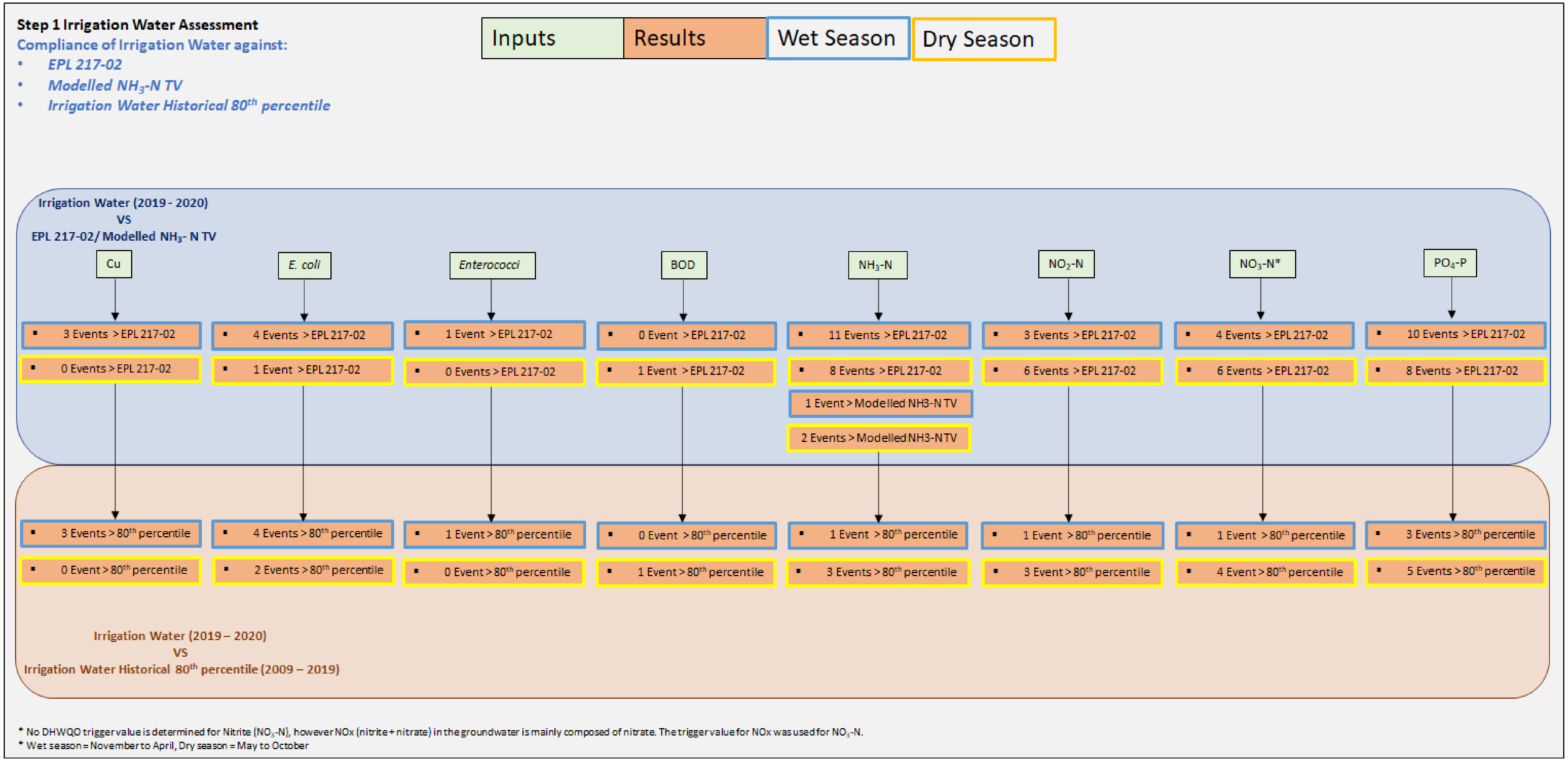


Figure 4-5 Summary of Step 1 results: Irrigation discharge water quality compared against the assessment criteria

4.1.3.5 Step 2: Groundwater Quality Trend Assessment

Key findings from a review of the groundwater quality trends for each bore against the assessment framework include:

- Groundwater quality exceeded the assessment criteria (DHWQO, modelled trigger value and groundwater historical 80th percentiles) for the following analytes and the results are summarised in **Table 4-7, Figure 4-6, Figure 4-7** and **Figure 4-8**:
  - Microbiology: *Escherichia Coli (E. Coli)* and *Enterococci* were sampled within the groundwater for the first time in 2019 and this continued in 2020. Laboratory results indicated that *Enterococci* was detected in BH3 during the April 2020 groundwater monitoring event at a concentration of 20 CFU/100 mL and again in BH3 and BH4 at a concentration of ~10 CFU/100 mL in the August 2020 groundwater monitoring event. *E. coli* was only detected during the April groundwater monitoring event at BH3 and BH5 at concentrations of 1 CFU/100 mL and ~13 CFU/100 mL respectively. These concentrations are below the DHWQO Interim Recreation Guidelines and Objectives for Primary Contact of ≤200 *E. coli* / 100 mL and ≤50 Enterococci / 100 mL but is likely to be related to the irrigation discharge.
  - Nutrients: Exceedances of the DHWQO and / or groundwater historical 80th percentiles were recorded in the majority of bores for total and speciated nutrients during the biannual groundwater monitoring in 2020. Ammonium nitrogen exceeded the modelled trigger value of 9 mg/L during the 2020 wet and dry seasons in BH2 only with concentrations of 13.5 mg/L and 23.8 mg/L reported respectively. It should be noted that no exceedances of the modelled trigger value have been recorded within BH3 or BH5 which are in the central areas to the irrigation fields.
  - Metals: During the 2020 groundwater monitoring events, copper (BH1, BH2, BH3, BH4 and BH6), lead (BH2 and BH4), nickel (BH1 and BH5), silver (BH1) and zinc (BH1, BH3, BH4, BH5 and BH6) and chromium VI (BH1) registered above the DHWQO for either wet or dry season or both. BH7 is the only monitoring well that did not record any metal concentrations above the DHWQO in 2020. Exceedances of the historical 80th percentiles are observed for aluminium, arsenic, cadmium, copper, iron, manganese, lead and nickel during both wet and dry seasons in various monitoring wells, although exceedances for zinc are only observed in the dry season (BH4, BH5 and BH6).
  - Hydrocarbons: Total Recoverable Hydrocarbons (TRH), Total Petroleum Hydrocarbons (TPH), Benzene, Toluene, Ethylene, Xylene and Naphthalene (BTEXN) concentrations were below the limit of reporting during the dry season (August 2020) which is consistent with historical data. Low level concentrations of TPH (C10-C28 and C10-C36) and TRH (C16-C34 and C10-C40) were detected within BH2 during the 2020 dry season, although this monitoring bore has in the past (2016) recorded similar values for hydrocarbons. No TPH was recorded in the irrigation discharge in 2020 and is generally always below the detection limit for TPH. As such, the concentrations detected in BH2 are not considered to be related with the DLNG operations including the irrigation discharge and are likely attributable to natural sources.
- The Mann Kendall results for the parameters showing an increasing trend are presented in **Table 4-8**. In total, 14 groundwater parameters show an increasing trend from the data collected between April 2015 to August 2020 with key results summarised below:
  - The analysis identified an increasing trend for copper concentrations within BH1 groundwater for both wet and dry seasons in 2020. A decreasing trend is observed for pH (lab) and TSS, with pH showing four consecutive decreases in a row at BH3 and

BH5 during the past four wet seasons. Note, both parameters (pH and TSS) have been ignored in past Mann Kendall analyses due to their naturally high concentrations within the local groundwater.

- No trend as derived from the Mann Kendal analysis is evident for alkalinity (as bicarbonate and total), aluminium, calcium, chloride, iron, magnesium, nickel, nitrate, potassium, sodium, TKN and total nitrogen at any of the bores despite these parameters having increased four consecutive times over the recent monitoring events. This is likely a result of the Mann Kendall analysis being unable to detect a trend from the available data for these parameters. As sampling events are split into seasons, the available data set for each well is generally between 5 and 6 samples per period, i.e. wet or dry season 2015 to 2020. A Mann Kendall trend analysis can theoretically be calculated with as few as five samples, but in practice, an environmental monitoring program requires that each well has sufficient sample to account for natural variability. In limited data sets, a Mann Kendall trend can still be detected in situations where the data set is clearly increasing or decreasing, however, this suppresses the ability to detect potential trends in more variable wells until a larger data set is available.

- To assist with the interim assessment of potential trends in wells with limited seasonal data, the consecutive increasing concentrations over time have also been considered in the analysis. This has been assessed as consecutive increasing concentrations within the last four sampling events, e.g. fictional arsenic concentrations of 10, 15, 20, and 25 mg/L sampled from May, June, July and August respectively would classify as four-consecutive increases. This is evident for majority of parameters shown in **Table 4-8** (excluding copper at BH1 during the wet season) which therefore qualify for further analysis under Step 3 of the risk assessment framework.

Table 4-7 Step 2: Summary of groundwater exceedances against the assessment criteria

Sample ID	Sampling Date	Dissolved Metals by ICP-MS											Physico-Chemical	Major Cations and Anions								Hardness and Alkalinity		Nutrients							Microbiology	
		Aluminium-	Arsenic-	Cadmium-	Copper-	Iron-	Lead-	Manganese-	Nickel-	Zinc-	Silver-	Chromium VI	Total Suspended Solids	Calcium - Dissolved	Magnesium - Dissolved	Sodium - Dissolved	Potassium - Dissolved	Fluoride	Chloride	Sulfate	Ionic Balance	Bicarbonate HCO3 as CaCO3	Total Alkalinity as CaCO3	Total Nitrogen	Ammonia as N	Nitrite + Nitrate as N	Nitrate as N	Kjeldahl Nitrogen Total	Dissolved Reactive Phosphorus as P	Total Phosphorus	*Enterococci*	*Escherichia coli*
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	mg/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	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
DHWQO		NC	NC	0.0055	0.0013	NC	0.0044	NC	0.0700	0.0150	0.0014	0.0044	10	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.27	0.02	0.02	NC	NC	0.005	0.02	50	200
Modelled TV																									**9.00**							
BH1 (Wet)	8/04/2020	0.840	0.0040	0.0008	0.0140	0.160	0.0010	4.710	0.0740	0.3860	0.0010	<0.1	3,430.00	220.00	555.00	3,790.00	75.00	<0.1	5,620.00	733.00	12.50	<1	<1	0.800	0.050	0.150	0.150	0.600	<0.01	0.410	<2	<2
80th percentile		0.166	0.0012	0.0006	0.0056	1.140	0.0010	5.576	0.0536	0.5728	0.0010	0.0100	571.80	105.20	232.00	1744.00	37.60	0.66	3376.00	361.20	7.46	12.00	12.00	1.020	0.180	0.532	0.478	0.680	0.026	0.300	2.00	2.00
BH1 (Dry)	5/08/2020	2.070	0.0045	0.0031	0.0890	2.320	0.0028	16.300	0.3460	1.5300	0.0026	<0.001	1,030.00	612.00	1,550.00	11,200.00	233.00	0.40	18,100.00	3,050.00	6.29	6.00	6.00	0.720	0.135	0.344	0.344	0.380	0.026	0.058	-	-
80th percentile		1.544	0.0100	0.0033	0.0772	1.116	0.0108	15.840	0.2892	1.6840	0.0100	0.0280	7976.00	948.00	2428.00	19360.00	432.40	1.40	30400.00	4180.00	8.57	22.40	22.40	2.040	0.640	0.498	0.638	2.000	0.070	1.348	2.00	2.00
BH2 (Wet)	7/04/2020	3.780	0.1260	<0.001	0.1110	45.700	0.0320	35.000	0.0180	<0.05	<0.01	0.00300	3,760.00	844.00	1,890.00	15,200.00	477.00	0.60	24,200.00	3,280.00	6.48	701.00	701.00	19.800	**13.500**	0.050	0.050	19.800	<0.01	0.140	<2	<2
80th percentile		1.340	0.0496	0.0010	0.0130	57.328	0.0100	95.460	0.0268	0.4264	0.0100	0.0100	6300.00	886.00	1758.00	15640.00	483.40	1.40	26500.00	2766.00	3.31	593.00	593.00	30.240	23.640	0.046	0.022	21.300	0.026	1.674	2.00	2.00
BH2 (Dry)	6/08/2020	0.006	0.0116	<0.0002	<0.001	0.197	0.0008	29.500	0.0073	<0.005	0.0003	<0.001	892.00	494.00	1,250.00	11,600.00	347.00	0.90	18,400.00	1,140.00	7.47	455.00	455.00	27.900	**23.800**	<0.002	<0.002	27.900	0.003	<0.005	<2	<2
80th percentile		0.100	0.0228	0.0012	0.0100	6.792	0.0100	40.000	0.0170	0.0500	0.0100	0.0280	7264.00	908.00	1864.00	15320.00	520.00	1.40	25200.00	2520.00	10.51	663.20	663.20	26.800	27.300	0.034	0.020	22.240	0.070	0.962	2.00	2.00
BH3 (Wet)	7/04/2020	0.080	0.0060	<0.0001	0.0060	0.150	0.0001	0.068	<0.001	0.0070	<0.001	<0.001	4,630.00	7.00	4.00	16.00	5.00	0.10	27.00	12.00	-	28.00	28.00	1.900	0.060	0.360	0.360	1.500	0.020	1.110	20.00	1.00
80th percentile		0.364	0.0044	0.0002	0.0082	1.028	0.0018	0.214	0.0086	0.1292	0.0010	0.0100	7342.00	22.00	17.40	108.00	4.66	0.26	57.80	12.40	70.72	26.20	26.20	4.320	0.382	0.050	0.934	4.320	0.026	2.396	2.00	22.00
BH3 (Dry)	6/08/2020	<0.005	0.0517	<0.00005	0.0008	0.923	<0.0001	0.115	0.0019	0.0090	<0.0001	<0.001	4,590.00	7.00	4.00	17.00	4.00	<0.1	29.00	10.00	-	35.00	35.00	0.840	0.108	0.009	0.006	0.830	<0.001	0.021	10.00	<2
80th percentile		0.506	0.0192	0.0001	0.0044	9.340	0.0010	0.158	0.0100	0.0428	0.0010	0.0100	16540.00	13.60	4.36	41.20	4.88	0.26	85.60	14.20	2.15	25.20	25.20	1.140	0.430	0.046	0.024	1.140	0.070	4.108	2.00	2.00
BH4 (Wet)	7/04/2020	1.570	0.0040	<0.0001	0.0070	0.760	0.0020	0.206	0.0030	0.0180	<0.001	<0.001	1,850.00	6.00	8.00	47.00	3.00	<0.1	80.00	31.00	2.27	2.00	<1	<0.1	<0.01	0.030	0.030	<0.1	<0.01	0.010	<2	<2
80th percentile		0.530	0.0098	0.0001	0.0100	0.800	0.0010	0.270	0.0020	0.0560	0.0010	0.0100	2632.00	22.00	10.00	56.80	4.00	0.18	130.40	39.80	4.90	24.60	24.60	0.620	0.039	0.050	0.034	0.460	0.026	0.464	2.00	2.00
BH4 (Dry)	6/08/2020	0.486	0.0027	0.0001	0.0054	0.718	0.0067	0.248	0.0077	0.1340	<0.0001	<0.001	1,390.00	5.00	10.00	47.00	4.00	<0.1	78.00	42.00	0.38	6.00	6.00	0.030	0.014	0.016	0.016	0.010	0.006	0.023	10.00	<2
80th percentile		0.260	0.0110	0.0001	0.0048	1.072	0.0010	0.286	0.0032	0.0690	0.0010	0.0100	17184.00	14.80	11.40	66.40	4.86	0.18	112.00	43.80	7.17	26.40	26.40	2.020	0.034	0.042	0.030	1.440	0.070	2.038	2.00	2.00
BH5 (Wet)	8/04/2020	0.120	<0.001	0.0003	<0.001	<0.05	<0.001	7.430	0.0600	0.0830	<0.001	<0.001	2,260.00	24.00	23.00	245.00	3.00	<0.1	532.00	74.00	8.66	11.00	11.00	4.100	0.040	2.960	2.960	1.100	<0.01	0.270	<2	13.00
80th percentile		0.124	0.0026	0.0002	0.0014	0.272	0.0018	7.188	0.0346	0.1312	0.0460	0.0100	13740.00	117.60	45.20	392.00	6.80	0.42	590.00	95.00	15.47	122.20	122.20	2.860	0.100	1.434	1.672	0.540	0.026	0.972	2.00	2.00
BH5 (Dry)	6/08/2020	0.198	0.0007	0.0003	0.0071	0.004	0.0004	7.630	0.0926	0.1840	<0.0001	<0.001	74.00	13.00	20.00	203.00	2.00	0.20	414.00	59.00	7.42	3.00	3.00	1.370	0.019	1.360	1.360	<0.10	0.012	0.048	<1	<1
80th percentile		0.052	0.0030	0.0002	0.0010	0.050	0.0010	5.168	0.0176	0.0208	0.0010	0.0100	14048.00	57.60	27.20	291.00	4.72	0.18	538.80	78.20	4.94	66.40	66.40	2.860	0.100	0.910	1.088	1.420	0.070	0.480	2.00	2.00
BH6 (Wet)	7/04/2020	0.060	0.0010	<0.0001	0.0020	10.600	<0.001	7.140	0.0030	0.0070	<0.001	<0.001	196.00	10.00	22.00	159.00	6.00	<0.1	253.00	146.00	2.24	26.00	26.00	0.500	0.310	<0.01	<0.01	0.500	<0.01	<0.01	<2	<2
80th percentile		0.058	0.0022	0.0004	0.0022	14.920	0.0016	8.040	0.0066	0.4352	0.0060	0.0180	4492.00	221.40	552.00	3374.00	52.60	1.10	6320.00	830.00	3.95	40.60	40.60	1.100	0.682	0.050	0.048	0.920	0.034	0.252	2.00	2.00
BH6 (Dry)	5/08/2020	0.016	0.0013	0.0002	0.0049	7.710	0.0007	3.720	0.0080	0.0380	<0.0001	<0.010	444.00	28.00	78.00	622.00	16.00	<0.1	885.00	222.00	8.38	12.00	12.00	0.390	0.260	0.015	0.015	0.380	0.002	<0.005		
80th percentile		0.060	0.0032	0.0011	0.0034	13.680	0.0022	6.568	0.0138	0.0302	0.0010	0.0100	2644.80	158.00	406.00	2602.00	47.60	0.60	3844.00	630.20	17.38	24.80	24.80	0.780	0.396	0.050	0.038	0.620	0.070	0.092	2.00	2.00
BH7 (Wet)	8/04/2020	<0.01	<0.001	<0.0001	<0.001	12.200	<0.001	29.800	0.0020	<0.005	<0.001	<0.001	194.00	12.00	29.00	170.00	12.00	0.20	327.00	176.00	5.99	87.00	87.00	3.000	1.440	0.020	0.020	3.000	<0.01	0.080	<2	<2
80th percentile		0.026	0.0018	0.0001	0.0014	66.520	0.0010	60.140	0.0044	0.1644	0.0050	0.0100	2120.00	25.60	70.00	458.40	22.40	0.38	836.40	256.80	5.52	80.00	80.00	7.880	3.328	0.050	0.040	3.580	0.034	0.198	2.00	2.00
BH7 (Dry)	6/08/2020	<0.005	0.0057	<0.00005	<0.0005	19.300	<0.0001	36.100	0.0048	0.0050	<0.0001	<0.010	3,520.00	36.00	99.00	805.00	36.00	0.30	1,470.00	114.00	0.73	69.00	69.00	2.760	1.890	0.012	0.004	2.750	0.007	0.007	<2	<2
80th percentile		0.016	0.0074	0.0002	0.0012	38.440	0.0010	67.260	0.0102	0.0160	0.0010	0.0100	34280.00	73.60	199.60	1710.00	70.40	0.50	3062.00	616.60	6.06	63.20	63.20	5.960	3.420	0.046	0.050	5.380	0.070	0.810	2.00	2.00

Grey text denotes value less than LOR.
Orange cells denotes concentration exceeds the DHWQO
Red text denotes value exceeds the historical 80th percentile of groundwater based on data since 2015 to 2019.
Blue text denotes 80th percentile value
Bolded text indicates where value exceeds the modelled TV.

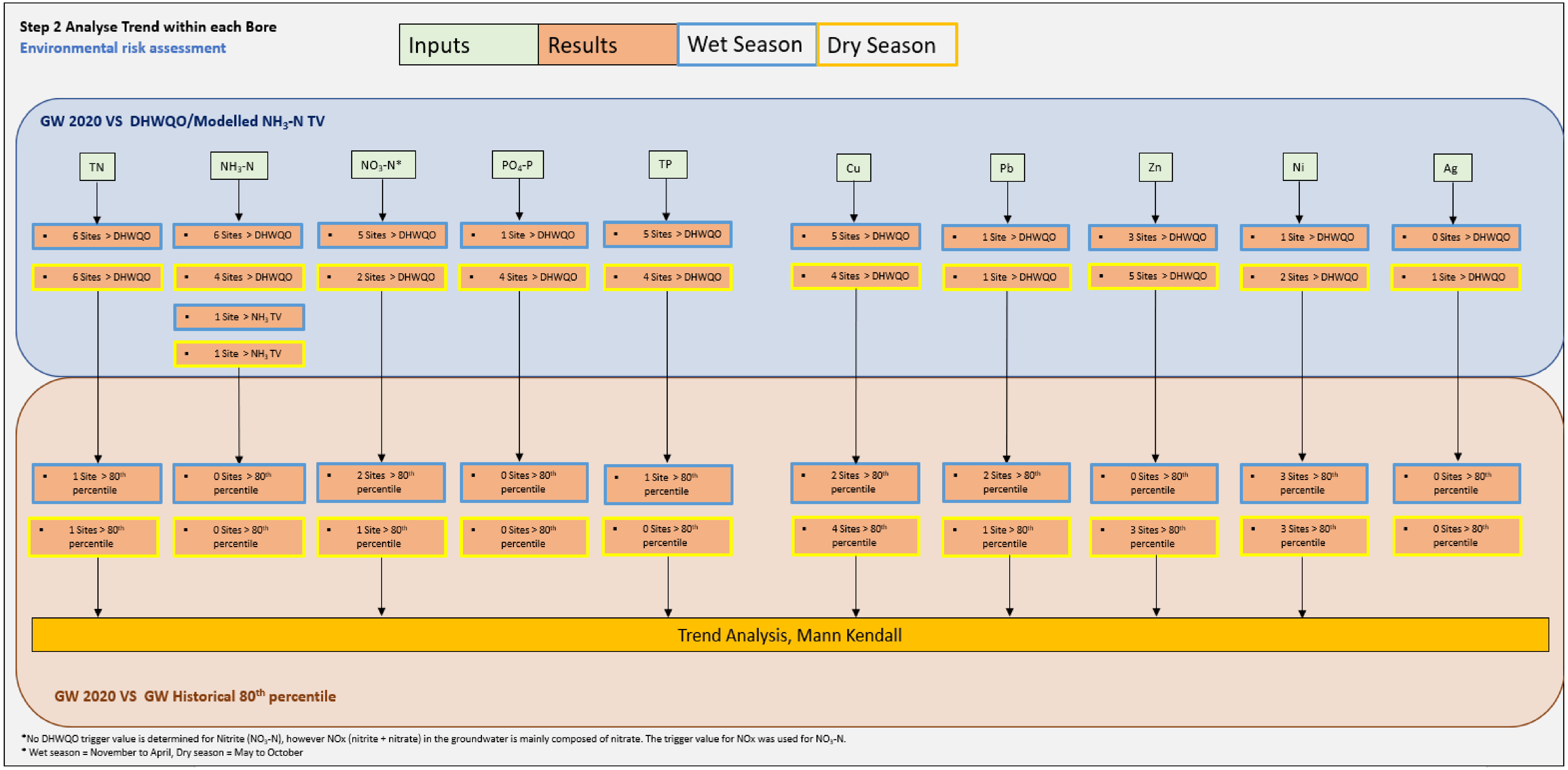


Figure 4-6 Summary of Step 2 results: Groundwater quality compared against the assessment criteria

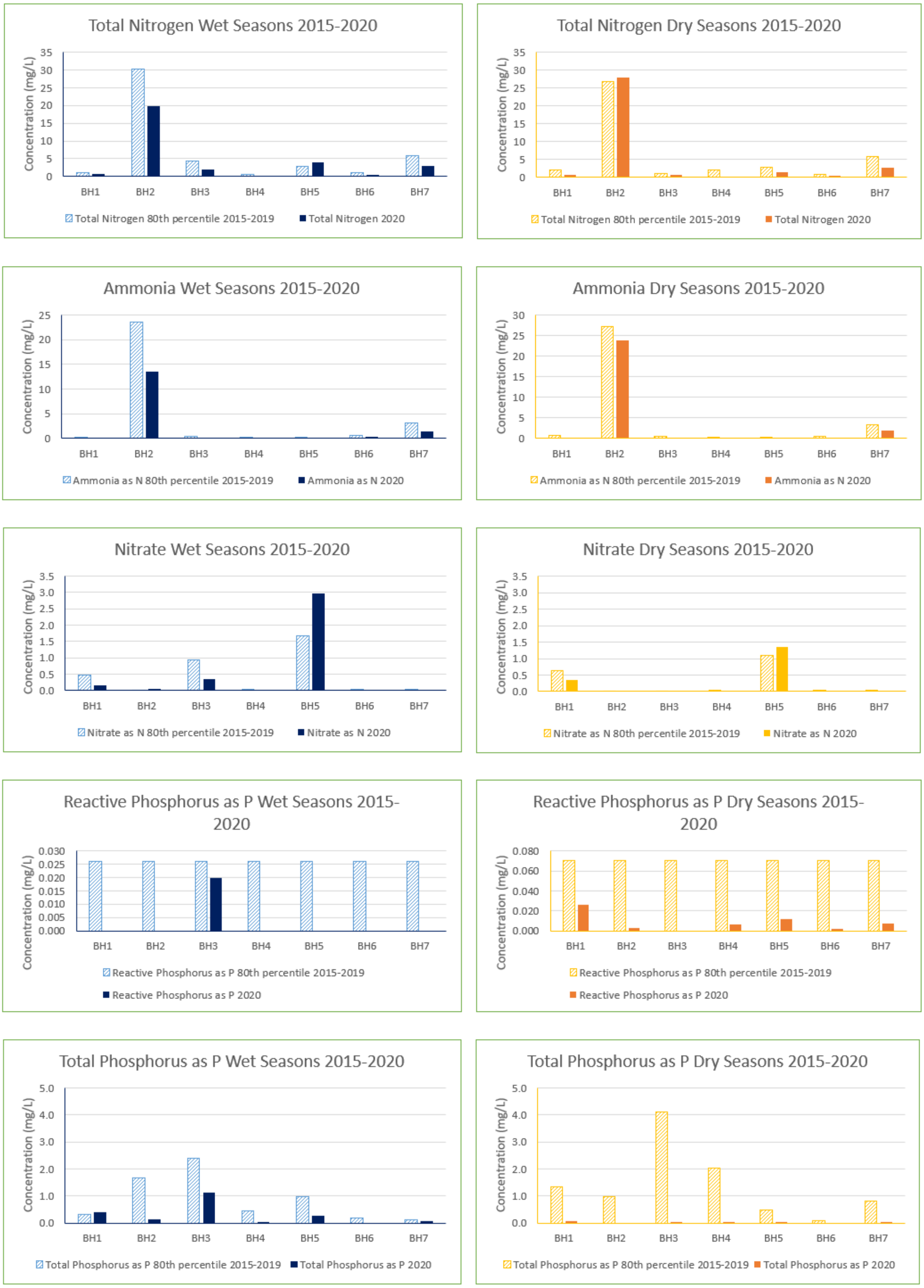


Figure 4-7 Key groundwater nutrient trends

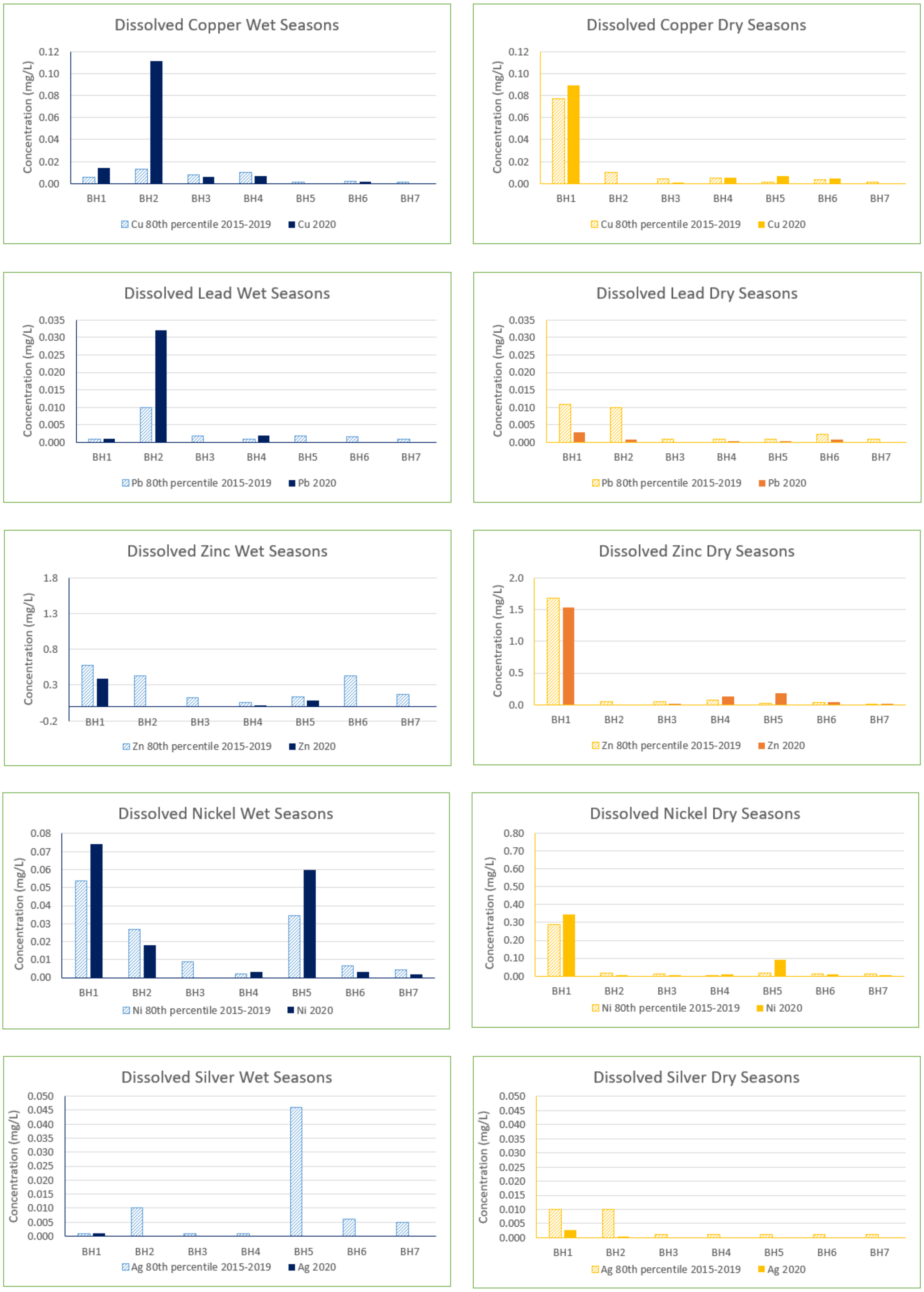


Figure 4-8 Key groundwater metal trends

Table 4-8 Mann Kendall analysis results for the 2020 groundwater parameters which show an increasing trend

Parameter	Location	Min Concentration Recorded since 2015	Max Concentration Recorded since 2015	Season	Mann Kendall Trend	General Trend Consistency	DHWQO	Modelled TV	80th Percentile
Alkalinity (Bicarbonate as CaCO3)	BH2	376	701	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Alkalinity (total) as CaCO3	BH2	376	701	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Aluminium	BH2	0.02	3.78	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
	BH4	0.03	1.57	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
	BH4	0.06	0.486	Dry Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Calcium	BH1	27	220	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Chloride	BH1	615	5620	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Copper	BH1	0.001	0.014	Wet Season	Increasing Trend	Variable	Below Criteria	No Criteria	Above Criteria
	BH1	0.013	0.089	Dry Season	Increasing Trend	4 Increasing	Below Criteria	No Criteria	Above Criteria
Iron	BH1	0.1	2.32	Dry Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Kjeldahl Nitrogen Total	BH2	13.1	27.9	Dry Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Magnesium	BH1	40	555	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
	BH2	1280	2350	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
Nickel	BH1	0.211	0.346	Dry Season	No Trend	4 Increasing	Below Criteria	No Criteria	Above Criteria
	BH5	0.001	0.0926	Dry Season	No Trend	4 Increasing	Below Criteria	No Criteria	Above Criteria
Nitrate (as N)	BH2	0.005	0.05	Wet Season	No Trend	4 Increasing	Above Criteria	No Criteria	Above Criteria
Total Nitrogen	BH2	13100	28400	Dry Season	No Trend	4 Increasing	Above Criteria	No Criteria	Above Criteria
Potassium	BH1	8	75	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria
	BH2	250	653	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Below Criteria
Sodium	BH3	7	380	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Below Criteria
	BH1	286	3790	Wet Season	No Trend	4 Increasing	No Criteria	No Criteria	Above Criteria

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

Key findings from analysing the trends and correlations between each bore and the irrigation discharge include:

- A total of eighteen parameters from the irrigation water and groundwater show an increasing trend identified by either a Mann Kendal trend or as four consecutive monitoring event increases (**Table 4-9**):
  - Alkalinity (as bicarbonate and total) (BH1);
  - Calcium (BH1);
  - Chloride (BH1 and irrigation water);
  - Potassium (BH1, BH2 and irrigation water);
  - Sodium (BH1, BH3 and irrigation water);
  - Magnesium (BH1 and BH2);
  - Copper (BH1);
  - Nickel (BH1, BH5);
  - Iron (BH1 and irrigation water);
  - Aluminium (BH2 and BH4);
  - BOD (Irrigation water);
  - *E. Coli* (irrigation water);
  - *Enterococci* (irrigation water);
  - Total nitrogen (BH2);
  - Nitrate (BH2);
  - TKN (BH2 and irrigation water); and
  - TSS (irrigation water).
- These results are thought to be related with potential ASS impact (ERM, 2019) affecting metal concentrations with an increasing trend in copper in BH1, displayed in the Man-Kendall analysis during both April and August 2020 groundwater monitoring events. The source of these changes remains unknown, but are likely not related with the DLNG operations, specifically the irrigation water in which copper concentrations have shown a decreasing trend from the Mann Kendall analysis, contrary to the groundwater.
- Four parameters (chloride, iron, potassium and sodium) demonstrate four consecutive increases within groundwater while the same parameters for irrigation water show a Mann Kendal trend. No further statistical assessment has been undertaken for these parameters as there is no trend for the groundwater identified by the Mann Kendall analysis.
- A decreasing trend is observed for pH (lab) and TSS, with pH showing four consecutive decreases in a row at BH3 and BH5 during the past four wet seasons.
- No discernible trend is evident for alkalinity (as bicarbonate and total), aluminium, calcium, chloride, iron, magnesium, nickel, nitrate, potassium, sodium, TKN and total nitrogen despite these parameters having increased four consecutive times in recent

groundwater monitoring events.

- Detection of *Enterococci* and *E. coli* below the DHQWO has been made during the 2020 groundwater monitoring events, although there is currently insufficient data for the Mann Kendall analysis to detect a trend within the groundwater. Further monitoring of the groundwater and irrigation water quality will allow for a more definitive understanding of a potential correlation.

Table 4-9 Mann Kendall analysis results for irrigation discharge and groundwater parameters which show an increasing trend

Parameter	Location	Min Concentration Recorded since 2015	Max Concentration Recorded since 2015	Season	Mann Kendall Trend	General Trend Consistency	EPL 217-02	DHWQO	Modelled TV	80th Percentile
Alkalinity (Bicarbonate as CaCO3)	BH2	376	701	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
Alkalinity (total) as CaCO3	BH2	376	701	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
Aluminium	BH2	0.02	3.78	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	BH4	0.03	1.57	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	BH4	0.06	0.486	Dry Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
BOD	Irrigation Water	1	250	-	Increasing Trend	Variable	Above Criteria	N/A	No Criteria	Above Criteria
Calcium	BH1	27	220	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
Chloride	BH1	615	5620	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	Irrigation Water	12.898	64.386	-	Increasing Trend	Variable	No Criteria	N/A	No Criteria	Above Criteria
Copper	BH1	0.001	0.014	Wet Season	Increasing Trend	Variable	N/A	Below Criteria	No Criteria	Above Criteria
	BH1	0.013	0.089	Dry Season	Increasing Trend	4 Increasing	N/A	Below Criteria	No Criteria	Above Criteria
E. Coli	Irrigation Water	0	24196	-	Increasing Trend	Variable	Above Criteria	N/A	No Criteria	Above Criteria
Enterococci	Irrigation Water	1	2420	-	Increasing Trend	Variable	Above Criteria	N/A	No Criteria	Above Criteria
Iron	BH1	0.1	2.32	Dry Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	Irrigation Water	0.025	3.6	-	Increasing Trend	Variable	Below Criteria	N/A	No Criteria	Above Criteria
Kieldahl Nitrogen Total	BH2	13.1	27.9	Dry Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	Irrigation Water	0.67	79.3	-	Increasing Trend	4 Decreasing	No Criteria	N/A	No Criteria	Above Criteria
Magnesium	BH1	40	555	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	BH2	1280	2350	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
Nickel	BH1	0.211	0.346	Dry Season	No Trend	4 Increasing	N/A	Below Criteria	No Criteria	Above Criteria
	BH5	0.001	0.0926	Dry Season	No Trend	4 Increasing	N/A	Below Criteria	No Criteria	Above Criteria
Nitrate (as N)	BH2	0.005	0.05	Wet Season	No Trend	4 Increasing	N/A	Above Criteria	No Criteria	Above Criteria
Total Nitrogen	BH2	13100	28400	Dry Season	No Trend	4 Increasing	N/A	Above Criteria	No Criteria	Above Criteria
Potassium	BH1	8	75	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	BH2	250	653	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Below Criteria
	Irrigation Water	1.971	17.7	-	Increasing Trend	Variable	No Criteria	N/A	No Criteria	Above Criteria
Sodium	BH1	286	3790	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Above Criteria
	BH3	7	380	Wet Season	No Trend	4 Increasing	N/A	No Criteria	No Criteria	Below Criteria
	Irrigation Water	3.379	27.225	-	Increasing Trend	4 Increasing	No Criteria	N/A	No Criteria	Above Criteria
Total Suspended Solids	Irrigation Water	0	120	-	Increasing Trend	Variable	Below Criteria	No Criteria	No Criteria	Above Criteria

4.1.4 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.

4.1.5 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 2020 groundwater monitoring events demonstrate that current irrigation practices present a low environmental risk. The condition of the groundwater is considered in good health as determined by the long-term groundwater monitoring results.

Ongoing monitoring is required to determine if there are any linkages for parameters with a limited dataset and investigations into groundwater levels and well integrity are ongoing.

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