EPL228 Annual Environmental Monitoring Report 2022-2023

Report

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Abbreviation and definitions

Abbreviation	Description
µg/L	microgram per litre
µm	micrometre
µs/cm	microsiemens per centimetre
AEMR	annual environmental monitoring report
AGI	acid gas incinerator
AGRU	acid gas removal unit
aMDEA	activated methyl diethanolamine
AOC	accidentally oil contaminated
AQMS	air quality monitoring stations
AS	Australian Standard
ASU	artificial settlement unit
BTEX	benzene, toluene, ethylbenzene, xylenes
BTX	benzene, toluene, xylenes
CCPP	combined cycle power plant
CCR	central control room
CFI	calibrated field instrument
CFU	colony-forming unit
cm	centimetre
COA	certificate of analysis
COC	continuously oily contaminated
COD	chemical oxygen demand
DO	dissolved oxygen
EC	electrical conductivity
E. coli	*Escherichia coli*
EPL228	Environment Protection Licence 228 (as amended)
FRP	filterable reactive phosphorus
GEP	gas export pipeline
GTG	gas turbine generator

Abbreviation	Description
H_2S	hydrogen sulphide
Hg	mercury
HM	hinterland margin
HRSG	heat recovery steam generator
Ichthys LNG	collectively, the onshore gas export pipeline and the gas processing plant
INPEX	Ichthys LNG Pty Ltd
km	kilometre
LIMS	laboratory information management system
LNG	liquified natural gas
LOR	limit of reporting
LPG	liquified propane gas
m	metre
mm	millimetres
MEG	mono ethylene glycol
MDEA	methyl diethanolamine
mg/kg	milligram per kilogram
ml	millilitres
m^3/h	cubic metres per hour
MPN	most probable number
NAGD	National Assessment Guidelines for Dredging (Commonwealth of Australia 2009)
NATA	National Association of Testing Authorities, Australia
NCW	non-contaminated water
NGERS	National Greenhouse and Energy Reporting Scheme
NO	nitrogen monoxide
NO_2	nitrogen dioxide
NOx	nitrogen oxide (NO and/or NO_2)
NPI	National Pollutant Inventory
NSW	New South Wales
NT	Northern Territory

Abbreviation	Description
NT DITT	Northern Territory Department of Industry, Tourism and Trade
NT EPA	Northern Territory Environment Protection Authority
O_2	oxygen
OEMP	Onshore Operations Environmental Management Plan (L060-AH-PLN-60005)
PAH	polycyclic aromatic hydrocarbons
PCS	process control system
pH	measure of acidity or alkalinity
$PM_{2.5}$	particulate matter with aerodynamic diameter less than 2.5 µm
PM_{10}	particulate matter with aerodynamic diameter less than 10 µm
ppm	parts per million
ppmv	parts per million by volume
PSD	particle size distribution
QA/QC	quality assurance/quality control
RBL	rating background level
REMP	Receiving Environment Monitoring Program
SFLA	sample for laboratory analysis
SQGV	sediment quality guideline value
SWL	standing water level
TC	tidal creek
TF	tidal flat
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TPH	total petroleum hydrocarbons
TRH	total recoverable hydrocarbons
TSS	total suspended solid
USEPA	United States Environmental Protection Authority
UV	ultraviolet

EXECUTIVE SUMMARY

Ichthys LNG Pty Ltd (INPEX) was issued Environment Protection Licence 228 (as amended from time to time) on 13 December 2017 (EPL228). Activation of EPL228 occurred on 14 September 2018 triggering several EPL228 monitoring conditions and Onshore Operations Environmental Management Plan (OEMP) monitoring commitments.

Condition 86 of EPL228-04/Condition 76 of EPL228-05[1] requires an Annual Environmental Monitoring Report (AEMR) to be submitted to the Northern Territory Environment Protection Authority (NT EPA) for each year of the licence, unless otherwise agreed, for scheduled activities conducted during the preceding 12 months (i.e., the reporting period) from 1 July to 30 June. For this AEMR, the reporting period is defined as 1 July 2022 to 30 June 2023. This AEMR has been developed to meet the requirements of Condition 87 of EPL228-04/Condition 77 of EPL228-05.

Monitoring undertaken during the reporting period found that liquid effluent discharges were typically within EPL228 discharge limits, and these discharges had no discernible impact on Darwin Harbour.

All other terrestrial and marine monitoring programs (e.g. groundwater, mangroves, weeds, etc.) found that monitoring results were consistent with those reported during the previous years' AEMR and construction phase.

Based on monitoring results for the reporting period, there were no adverse effects to the declared beneficial uses and objectives of Darwin Harbour.

The point source emission monitoring reported that all permanent plant and equipment were typically within EPL228 air emission limits, and the emissions had no discernible impact on the ambient air quality of the Darwin Region.

[1] EPL228-05 came into effect on 13 December 2022.

1 INTRODUCTION

Ichthys LNG Pty Ltd (hereafter referred to as INPEX) was issued Environment Protection Licence 228 (as amended and hereafter referred to as the EPL228) for the purposes of:

Operating premises for processing hydrocarbons so as to produce, store and/or despatch liquefied natural gas or methanol, where:

a. the premises are designed to produce more than 500,000 tonnes annually of liquefied natural gas and/or methanol; and

b. no lease, licence or permit under the Petroleum Act or the Petroleum (Submerged lands) Act relates to the land on which the premises are situated.

All the activities in relation to onshore production design capacity of 12.89 million tonnes per annum of hydrocarbons[2], being up to:

- *9.64 million tonnes of liquefied natural gas per annum from two LNG processing trains;*
- *1.65 million tonnes of liquefied petroleum gas per annum; and*
- *20,000 barrels of condensate per day (1.6 million tonnes of condensate per annum).*

Since the 2019/2020 Annual Environmental Monitoring Report, the Ichthys LNG facility has been in steady state operations. The key milestones are shown in Section 1.4.1.

1.1 Purpose

The purpose of the AEMR is to satisfy Condition 86 of EPL228-04[3] and Condition 76 of EPL228-05 for the Licensed Premises (hereafter Ichthys LNG)[4]. The reporting period for this AEMR is 1 July 2022 to 30 June 2023, with amendment EPL228-05 commencing on 13 December 2022.

1.2 AEMR Condition requirements

Table 1-1 provides details of Condition 87 of EPL228-04 and Condition 77 of EPL228-05 as they relate to the AEMR requirements and the relevant section for where the conditions have been addressed within this report.

Table 1-1: Annual environmental monitoring report condition requirements

EPL288 Condition #	Condition detail	Section
EPL228-04		
87	The Annual Environmental Monitoring Report must:	-
87.1	report on monitoring required under this licence;	This AEMR
87.2	summarise performance of the authorised discharge to water, compared to the discharge limits and trigger values specified in Table 3 in Appendix 2;	2.1

[2] As defined in EPL228-05

[3] EPL 228-04 was in effect for this AEMR from 1 July-12 December 2022. EPL 228-05 was in effect for this AEMR from 13 December 2022 – 30 June 2023.

[4] Condition 86/76 reads: *The licensee must submit an Annual Environmental Monitoring Report to the NT EPA by 30 September for each year of this licence unless otherwise authorised, for the Scheduled Activity conducted during the preceding 12 month period from 1 July to 30 June.*

EPL288 Condition #	Condition detail	Section
87.3	summarise performance of the authorised emissions to air, compared to the emission limits and targets specified in Table 5 in Appendix 3, when the fuel burning or combustion facilities for the Scheduled Activity have operated under normal and maximum operating conditions for the annual period;	3
87.4	summarise operating conditions of each emission source and the resulting air emission quality;	3
87.5	provide total emissions to air in tonnes per year for the air quality parameters listed in Table 6 in Appendix 3;	3
87.6	assess the contribution of the authorised emissions on the Darwin region ambient air quality during periods not affected by bushfire smoke for wet and dry seasons;	3
87.7	report on outcomes of the Receiving Environment Monitoring Program (REMP) monitoring and assessment;	This AEMR
87.8	summarise measures taken to reduce waste;	6
87.9	consider the NT EPA Guideline for Reporting on Environmental Monitoring;	APPENDIX A:
87.10	be reviewed by Qualified Professional(s); and	APPENDIX B:
87.11	be provided to the NT EPA with the Qualified Professional(s) written, certified review(s) of the Annual Environmental Monitoring Report.	APPENDIX B:
EPL228-05		
77	The Annual Environmental Monitoring Report must:	-
77.1	report on monitoring required under this licence;	This AEMR
77.2	include a tabulation in Microsoft ® Excel ® format, of all monitoring data required to be collected in accordance with this licence;	Provided to NT EPA separately
77.3	summarise performance of the authorised discharge to water, compared to the discharge limits specified in Table 3 in Appendix 2;	2.1
77.4	summarise performance of the authorised emissions to air, compared to the emission limits and targets specified in Table 5 in Appendix 3, when the fuel burning or combustion facilities for the Scheduled Activity have operated under normal and maximum operating conditions for the annual period;	3
77.5	summarise operating conditions of each emission source and the resulting air emission quality;	3
77.6	provide total emissions to air in tonnes per year for the air quality parameters listed in Table 6 in Appendix 3;	3
77.7	assess the contribution of the authorised emissions on the Darwin region ambient air quality during periods not affected by bushfire smoke for Wet and Dry seasons;	3
77.8	report on outcomes of the REMP monitoring and assessment;	This AEMR
77.9	summarise measures taken to reduce waste;	6

EPL288 Condition #	Condition detail	Section
77.10	consider the NT EPA Guideline for Reporting on Environmental Monitoring;	APPENDIX A:
77.11	be reviewed by Qualified Professional(s); and	APPENDIX B:
77.12	be provided to the NT EPA with the Qualified Professional(s) written, certified review(s) of the Annual Environmental Monitoring Report.	APPENDIX B:

1.3 Program objective

An overview of the environmental monitoring programs, their objectives, and cross-references to sections within the AEMR which provide more detail, are listed in Table 1-2. Monitoring was undertaken in accordance with the Onshore Operations Environmental Management Plan (OEMP) and EPL228 requirements.

Table 1-2: Monitoring program objectives

Program	Objective	Section
Commingled treated effluent (750-SC-003)	To ensure commingled treated effluent does not exceed discharge criteria specified in EPL228.	2.1
Harbour sediment	To detect changes in surficial sediment quality in the vicinity of the jetty outfall and determine if changes are attributable to Ichthys LNG operations.	2.2
Point source emissions to air	To determine if air emissions from stationary point sources are within acceptable limits	3.2
Dark-smoke events	To determine if air emissions from the flare systems are within acceptable limits.	3.4
Groundwater quality	To detect changes in groundwater quality and determine if these changes are attributable to Ichthys LNG operations.	4.1
Nearshore marine pests	To assess the presence/absence of invasive marine pest at the Ichthys LNG product loading jetties, through a coordinated approach with the Northern Territory (NT) Biosecurity Unit.	5.2
Introduced terrestrial fauna	To determine the presence, location and methods used to control nuisance species.	5.3
Weed survey	To identify the abundance and spatial distribution of known and new emergent weed populations, especially in areas susceptible to weed invasion, to inform weed management control activities.	5.4
Weed management	To manage invasive weeds onsite.	5.5
Vegetation rehabilitation monitoring	To determine if vegetation recovery through natural processes has occurred.	5.6
Cultural heritage	To determine if there has been any interference to cultural heritage sites.	5.7

1.4 Site information

1.4.1 Ichthys LNG operational milestones

Table 1-3 provides an overview of the Ichthys LNG key milestones for the reporting period. A general Ichthys LNG site layout is shown in Figure 1-1.

Table 1-3: Ichthys LNG key milestones during the reporting period

Date	Report
July 2022- August 2022	Shutdown on both trains 26th June – 12 August 2022.
November 2022	Annual environmental audit undertaken by a qualified auditor in accordance with EPL228-04 Condition 34
December 2022	EPL228-04 amended to EPL228-05. Amendments included removal/consolidation of ten conditions from EPL228, a number of which related to completed plant start-up activities.
April 2023	Two heating medium loss of containment incidents resulting in shut down of Train 1 for four weeks and Train 2 for two weeks.

Figure 1-1: Ichthys LNG layout

1.4.2 Environmental context

Ichthys LNG is located on Bladin Point, on the northern side of Middle Arm Peninsula in Darwin Harbour (Figure 1-2). Bladin Point is a low-lying peninsula in Darwin Harbour, which is separated from the mainland by a mudflat. Ichthys LNG is approximately 4 km from Palmerston (the nearest residential zone) and approximately 10 km south-east of the Darwin central business district, across Darwin Harbour.

Figure 1-2: Location of Ichthys LNG

Ichthys LNG lies in the monsoonal tropics of northern Australia, which has two distinct seasons; a hot wet season from November to April and a warm dry season from May to October. April and October are transitional months between the wet and dry seasons. Darwin experiences an overall mean annual rainfall of ~1,730 mm, the majority of which occurs during the wet season. The 2022/23 wet season was the wettest since 2017/2018, with 1,399.4 mm of rainfall recorded (Table 1-4 and Figure 1-3).

Table 1-4: Bladin Point wet season and transitional months rainfall (mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
Darwin average	70.6	141.7	250.8	426.3	374.6	319.0	102.2	1,685.2
2012/2013	36.8	199.8	232.4	282.8	291.2	415.2	141.6	1,599.8
2013/2014	134.8	352	268	780	335	14.4	111	1,995.2
2014/2015	13	226.4	175.4	630	492.2	233.8	54.2	1,825.0
2015/2016	12.6	140.6	709.4	243.2	213.4	231.8	63.8	1,614.8
2016/2017	83.8	265.4	469.8	614.2	736	515.8	220.6	2,905.6
2017/2018	93	249.2	125.4	1,031.6	380.4	423.4	39	2,342.0
2018/2019	2.6	183.8	91.6	311.4	159.6	147.8	125.8	1,022.6
2019/2020	24.0	71.2	51.5	327.2	217.7	179.9	72.9	944.3
2020/2021	69.1	87.8	343.5	333.5	194.7	163.4	55.6	1,247.5
2021/2022	67.9	131.9	282.0	357.0	222.2	121.2	89.6	1,271.7
2022/2023	155.9	177.9	341.3	196.2	228.2	207.8	92.1	1,399.4

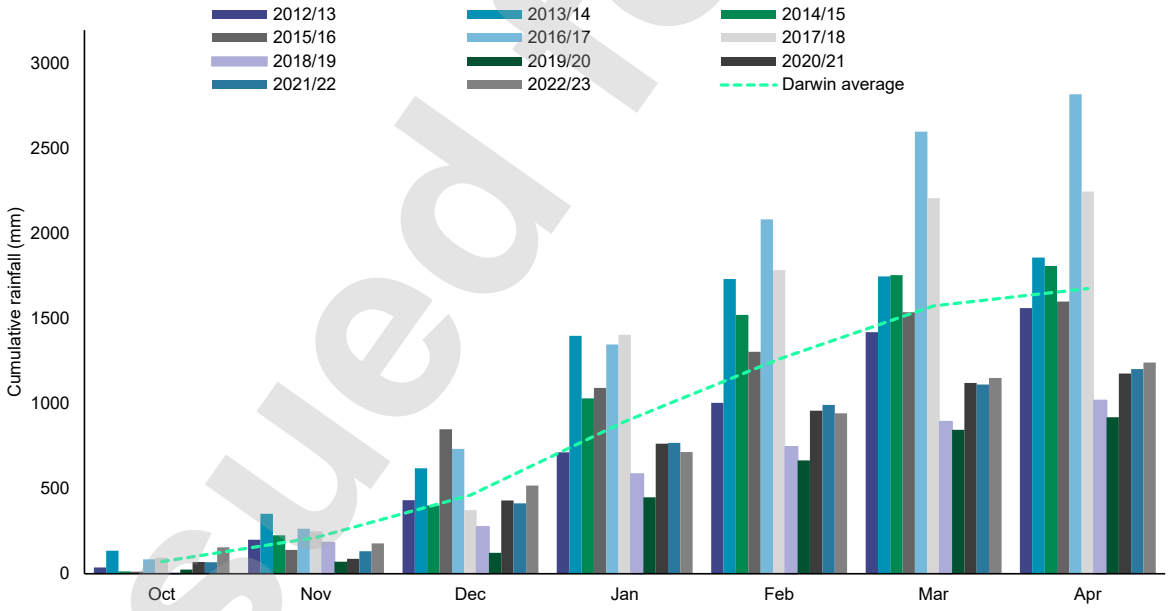

Figure 1-3: Bladin Point cumulative wet seasons

2 DISCHARGES TO WATER

This section describes the outcomes of the comingled treated effluent wastewater monitoring program.

2.1 Commingled treated effluent

The key objective of commingled treated effluent sampling (sampling point 750-SC-003) is to ensure discharge criteria specified in Table 3, Appendix 2 of EPL228 is not exceeded for wastewater discharged from Ichthys LNG.

The monitoring frequency, as specified in Table 3, Appendix 2 of EPL228 was implemented, with sampling occurring monthly (refer to Table 2-1).

Table 2-1: Commingled treated effluent sampling dates

Sample month	Sample collection date(s)
Jul-2022	12
Aug-2022	9
Sep-2022	13
Oct-2022	10, 14*, 16*, 20**, 25*
Nov-2022	8
Dec-2022	14, 16*,18*20*
Jan-2023	10,12*,14*,18*,24*
Feb-2023	8*,14,16**,20*,24*
Mar-2023	14, 15*, 18*, 21*, 23*, 25*, 27*, 28*,30*
Apr-2023	4*, 7*, 11
May-2023	9,18*
Jun-2023	13

* Additional sampling following an exceedance at location 750-SC-003.

** Subsequent sampling from initial monthly sampling event due to lab sampling error

2.1.1 Method overview

The commingled treated effluent sampling point (750-SC-003) is located downstream of treated effluent observation basin and upstream of the jetty outfall. Samples collected from 750-SC-003 represent liquid effluent that is discharged to Darwin Harbour via the jetty outfall. The sampling point consists of two valves, an isolation valve, and a sample needle valve, with the latter used to regulate flow for sample collection. Sampling from the commingled treated effluent sample point was conducted by trained laboratory analysts using National Association of Testing Authorities, Australia (NATA) accredited analysis methods by both the INPEX onshore laboratory and external third-party laboratories.

The parameters, sampling methods, limit of reporting (LOR) and discharge limits for the commingled treated effluent monitoring program are provided in Table 2-2.

All results are reported through the INPEX onshore laboratory database systems (laboratory information management system; (LIMS) that produce sample Certificates of Analysis (COA) inclusive of the laboratory NATA accreditation number. To enable the identification of an exceedance, the discharge limits specified in Table 3, Appendix 2 of EPL228 (refer to Table 2-2) have been entered into the LIMS. Sample results are compared to their respective discharge limits in the COA. If a result exceeds the discharge limit, it is highlighted in the COA and the onshore laboratory generate an out of specification report.

Table 2-2: Commingled treated effluent discharge monitoring, methods, and discharge limits

Parameter	Sampling method*	Unit	LOR	Discharge limit
Volumetric flow rate	CFI	m^3/hr	n/a	180
pH	INPEX Lab	pH Unit	n/a	6.0 - 9.0
Electrical conductivity (EC)	INPEX Lab	µS/cm	10	n/a
Temperature	CFI	°C	-	35°C
Turbidity	INPEX Lab	NTU	0.5	n/a
Dissolved oxygen	CFI	%	-	n/a
TPH as oil and grease	INPEX Lab	mg/L	1.0	6
Total recoverable hydrocarbons (TRH; C10-C40)	External lab	µg/L	100	n/a
Total suspended solids (TSS)	INPEX Lab	mg/L	5	10
Biochemical oxygen demand (BOD)	External lab	mg/L	2	20
Chemical oxygen demand (COD)	INPEX Lab	mg O_2/L	10	125
Free Chlorine	INPEX Lab	mg/L	0.02	2
Ammonia	INPEX Lab	mg N/L	2	n/a
Total nitrogen (TN)†	Calculation	mg N/L	2	10
Total phosphorus (TP)	INPEX Lab	mg P/L	0.5	2
Filterable reactive phosphorus (FRP)	INPEX Lab	mg P/L	0.2 and 0.5	n/a
Cadmium (total)	External lab	µg/L	0.1	n/a
Chromium (total)	External lab	µg/L	1	n/a
Copper (total)	External lab	µg/L	1	n/a
Lead (total)	External lab	µg/L	1	n/a
Mercury (total)	External lab	µg/L	0.1	n/a
Nickel (total)	External lab	µg/L	1	n/a
Silver (total)	External lab	µg/L	1	n/a
Zinc (total)	External lab	µg/L	5	n/a

Parameter	Sampling method*	Unit	LOR	Discharge limit
Enterococci	External lab	cfu/100mL	1	n/a
Escherichia coli	External lab	cfu/100mL	1	100
Faecal coliforms	External lab	cfu/100mL	1	400
Anionic surfactants	External lab	mg/L	0.1	n/a
Activated methyl diethanolamine (aMDEA)	External lab/INPEX lab	mg/L	0.001 and 5	n/a
Glycol	External lab/INPEX lab	mg/L	2 and 5	n/a

* CFI = calibrated field instrument

† Total nitrogen is a sum of Nitrite, Nitrate and total Kjeldahl nitrogen (TKN). TKN analysis was completed by both INPEX onshore laboratory and external laboratory interchangeable, depending on INPEX onshore laboratory equipment availability. Nitrate and nitrite were measured by INPEX onshore laboratory.

2.1.2 Results and discussion

Routine monitoring results

The results for 750-SC-003 sampling for the reporting period are presented in APPENDIX C:.

During the reporting period, there were ten occurrences where wastewater quality was above discharge limits, these are further discussed in Section 2.1.3. Note, following an initial exceedance, further sampling at 750-SC-003 was undertaken to confirm the results as part of an investigation. Any elevated results during the investigation sampling process are considered part of an ongoing original event and the results are included in APPENDIX C:.

Overall, there was little variability of the wastewater quality, with most results below EPL228 discharge limits. This demonstrates the wastewater treatment systems were operating effectively. The main sampling considerations for the reporting period were total nitrogen exceedances (four events) and faecal coliform exceedances (five events). These will be discussed further in Table 2-3.

Volumetric flow rate data for the reporting period is shown in Figure 2-1. The data confirms that the volumetric flow rate throughout the period remained well below the 180 m^3/h discharge limit.

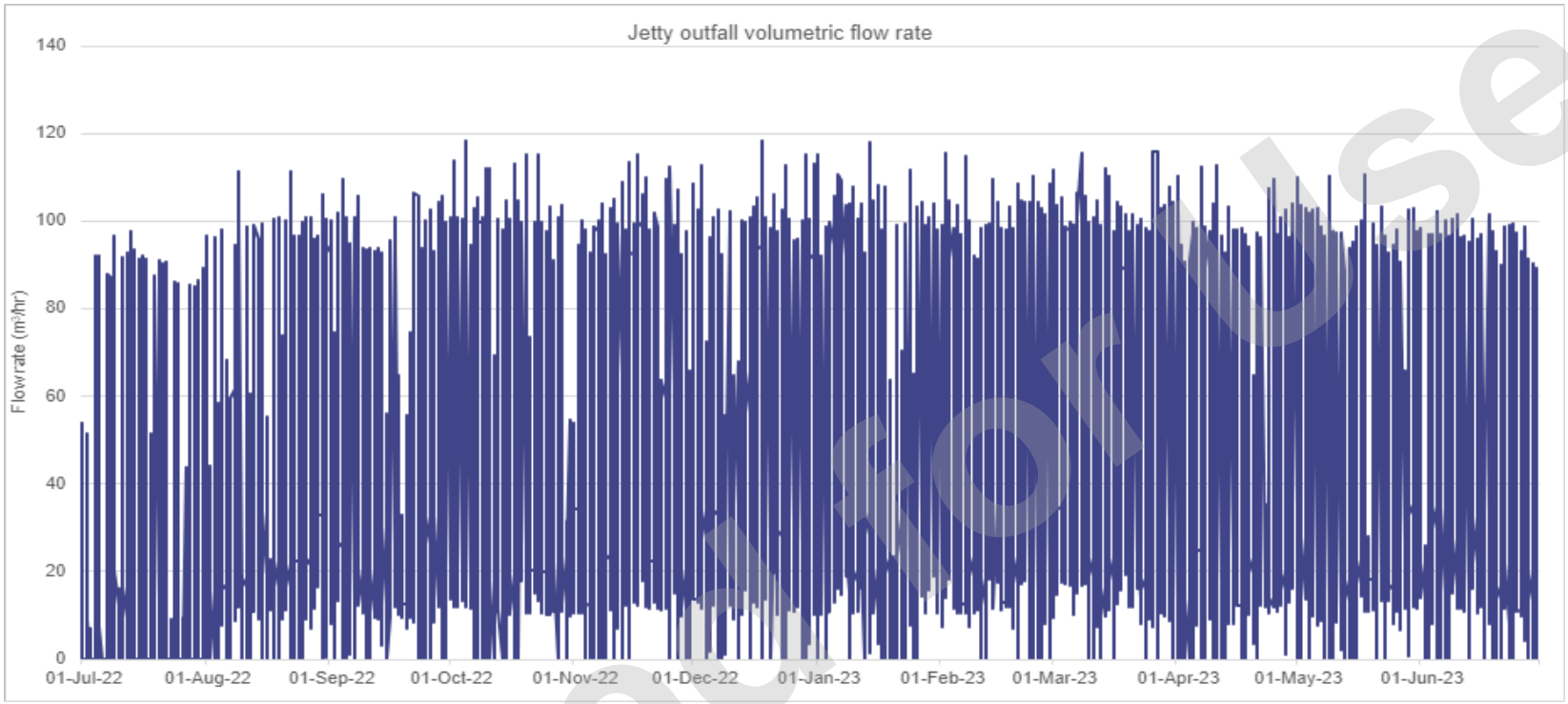

Figure 2-1: Flow rate measured at L-750-FI-0002 flow meter

Quality assurance/quality control

The quality assurance/quality control (QA/QC) procedures specific to the collection and analysis of samples from sample location 750-SC-003 included:

- NATA accredited analytical laboratories were used for all analysis, or a test method managed under a NATA accredited quality management system
- laboratory designated sample holding times met
- chain of custody forms was completed and accompanied the samples
- INPEX laboratory QA/QC procedures were completed as follows:
  - laboratory blanks
  - replicates/duplicate
  - spikes
  - calibration against standard reference materials
  - INPEX laboratory review of external laboratory QA/QC analysis reports
  - annual sampling verification, which involves the collection of two samples and trip blanks
- calibration of all field-testing equipment using the INPEX standard method(s) was undertaken.

2.1.3 Limit exceedances assessment outcomes

Throughout the reporting period, and displayed on the COAs, there were ten discharge limit exceedances (refer to APPENDIX C:). A summary table of all discharge limit exceedances, including corrective actions is provided in Table 2-3.

Table 2-3: Summary of commingled treated effluent sample point exceedance events

<table>
<tr><th>Date sampled</th><th>Exceedance reported</th><th>Parameter</th><th>Result</th><th>Limit</th><th>Cause and/or contributing factors</th><th>Corrective actions</th></tr>
<tr><td>10-October -2022</td><td>11-October-2022</td><td>TN</td><td>TN 12 mg/L</td><td>TN 10 mg/L</td><td>The investigation considered whether the elevated TN was originating from the steam plant within the combined cycle power plant (CCPP), due to the TN comprising mostly of ammonia. Sampling up-stream in the steam plant of the CCPP confirmed the off-specification wastewater was originating from this location. The investigation team subsequently noted, that in late September 2022 (prior to exceedance event) the location of ammonia dosing in the steam system changed from the dosing pumps located at the steam condensate manifolds, to the boiler feedwater manifold. This occurred due to faults on chemical injection pumps located in the condensate manifolds, which required them to be taken offline for maintenance.
Following the change in the dosing location, the investigation identified that there was a moderate increase in the amount of ammonia being consumed in the steam system, compared to chemical injection into the condensate manifold. An inspection of the boiler feedwater chemical injection pump subsequently identified that the pump was faulty and overdosing ammonia into the steam system, during a draw down test the dosing rate did not reduce with a reduction of stroke. The change in the ammonia dosing location combined with the impact of the faulty injection pump, resulted in increased TN levels in the wastewater stream being discharged from the CCPP steam system</td><td>Inpex was able to undertake a maintenance campaign on all ammonia injection pumps at the site to improve the reliability of the pumps.</td></tr>
<tr><td>20-October-2022</td><td>24-October -2022</td><td>Faecal Coliforms</td><td>2800 CFU/100ml</td><td>400 CFU/100ml</td><td>A discharge limit exceedance for treated wastewater was detected above the limit specified in column 5 of Table 3 in Appendix 2 of the EPL228. A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Thursday 20 October 2022. The NATA accredited interim testing results issued on Monday 24 October 2022 reported a Faecal Coliform value of 2800 CFU/100mL, which exceeds the discharge limit of 400 CFU/100mL.
Inspections and a further review of the performance of the sewage treatment plant (including additional sampling) confirmed that the plant is operational and producing on-specification treated effluent. INPEX considers that the Faecal Coliform contamination was likely due to a species of Faecal Coliform (not present in domestic sewage) entering into the combined jetty outfall, most likely via the open drain accidently oily contaminated (AOC) wastewater system, as both the E. coli and Enterococci levels were very low in the original sample collected on 20 October 2022 (1 and 10 CFU/100mL), both faecal coliform and Enterococci are used as indicators of human faecal contamination which is not the case in this scenario as confirmed by subsequent testing for e.coli.</td><td>INPEX conducted further sampling on 25 October 2022, at both the sewage treatment plant (sample location 750-SC-009) and the combined jetty outfall stream (sample location 750-SC-003). All results from the sampling conducted on 25 October were below the EPL 228 limits for Faecal Coliforms and E. coli.
<table>
<tr><td>Parameter</td><td>E.coli</td><td>Faecal Coliform</td><td>Enterococci</td></tr>
<tr><td>Units</td><td>cfu/100ml</td><td>cfu/100ml</td><td>cfu/100ml</td></tr>
<tr><td>Discharge Limit</td><td>100</td><td>400</td><td>N/A</td></tr>
<tr><td>750-SC-009</td><td>1</td><td>17</td><td>3</td></tr>
<tr><td>750-SC-003</td><td>1</td><td>1</td><td>1</td></tr>
</table>
INPEX considers that there was no risk of environmental harm associated with Faecal Coliform exceedance, as the source of contamination was not originating from the sewage treatment plant, nor were there direct indicators of human domestic sewage contamination (E. coli and Enterococci). Further sampling was unable to verify the Faecal Coliform result from 20 October 2022 or locate a source.
No further additional actions are proposed to be undertaken as the treated wastewater is now back in specification, at the jetty outfall and the sewage treatment plant.</td></tr>
</table>

<table>
<tr><th>Date sampled</th><th>Exceedance reported</th><th>Parameter</th><th>Result</th><th>Limit</th><th>Cause and/or contributing factors</th><th>Corrective actions</th></tr>
<tr><td>14-December-2022</td><td>20-December-2022</td><td>Faecal Coliforms</td><td>37000 CFU/100ml</td><td>400 CFU/100ml</td><td>A discharge limit exceedance for treated wastewater was detected above the limit specified in column 5 of Table 3 in Appendix 2 of the EPL228-05. A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Wednesday 14 December 2022. The NATA accredited interim testing results issued on Tuesday 20 December 2022 reported a Faecal Coliform value of 37,000 CFU/100mL, which exceeds the discharge limit of 400 CFU/100mL. Verification sampling was conducted by an external laboratory verified an E.coli result of 11 CFU/100ml and Enterococci result of 9 CFU/100ml. INPEX considers that the Faecal Coliform and E. coli values should be similar, as E. coli is the predominant species found in Faecal Coliform. The company who operates the sewage treatment plant for INPEX, Permeate Partners, has also been contacted, and the plant is processing effluent with no identified issues, they commented that if the plant was not processing effluent properly then the E. coli values would also be elevated.</td><td>INPEX determined that the Faecal Coliform exceedance, 14 December 2022, is considered an inaccurate result, which was unable to be replicated. Inspections and a further review of the performance of the sewage treatment plant (including additional sampling) confirmed that the plant was operational and producing on-specification treated effluent.
INPEX considers that the result is inaccurate as the Faecal Coliform is extremely high (37,000 CFU/100mL), compared to both the E. coli and Enterococci levels, which were very low in the original sample collected on 14 December 2022 (11 and 9 CFU/100mL), both E. coli and Enterococci are used as indicators of human faecal contamination. In addition, both the turbidity and total suspended solid (TSS) values were low (1.0 NTU and < 5 mg/L respectively) indicating that there was very little material in the wastewater, for such a high Faecal Coliform result it would be expected that the sample would also return high turbidity and TSS results, which the sample did not.
INPEX conducted further sampling on 20 December 2022, at both the sewage treatment plant (sample location 750-SC-009) and the combined jetty outfall stream (sample location 750-SC-003). With results coming within specification.
<table>
<tr><td>Parameter</td><td>Faecal Coliform</td></tr>
<tr><td>Units</td><td>cfu/100ml</td></tr>
<tr><td>Discharge Limit</td><td>400</td></tr>
<tr><td>750-SC-009</td><td><1</td></tr>
<tr><td>750-SC-003</td><td>8</td></tr>
</table>
INPEX considers that there was no risk of environmental harm associated with Faecal Coliform exceedance, as the source of contamination was not originating from the sewage treatment plant, nor were there direct indicators of human domestic sewage contamination (E. coli and Enterococci). Further sampling was unable to verify the Faecal Coliform result from 14 December 2022 or locate a source. The investigation also confirmed that the sample was collected and transported following standard practise, and no cross contamination occurred.</td></tr>
<tr><td>14-December-2022</td><td>20-December-2022</td><td>TN</td><td>TN 12 mg/L</td><td>TN 10 mg/L</td><td>A discharge limit exceedance for treated wastewater was detected above the limit specified in column 5 of Table 3 in Appendix 2 of the EPL228-05. A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Wednesday 14 December 2022. The NATA accredited interim testing results issued on Wednesday 14 December 2022 reported a total nitrogen (TN) concentration of 12 mg/L, which exceeds the discharge limit of 10 mg/L

The investigation identified that several of the chemical injection dosing pumps were faulty, resulting in overdosing of ammonia into the system. To reduce the ammonia levels the following occurred:
additional service water was added into the system, where possible, upstream of the neutralisation plant;’ and
the main faulty injection pump (L630-P-904-A) was taken offline, and dosing transferred to the standby injection pump (L630-P-904-B).</td><td>Dosing pump L630-P902-B was repaired and returned back to service. Following the addition of the flush, TN levels returned below the EPL228 limit. Maintenance works associated with the reliability improvement program are continuing and the program was completed Q1 2023.
Through the incident investigation, INPEX identified that continued implementation of the reliability improvement program on all ammonia injection pumps at the site to improve the performance of the pumps, through maintenance works and replacement of pumps as an action. .</td></tr>
</table>

Date sampled	Exceedance reported	Parameter	Result	Limit	Cause and/or contributing factors	Corrective actions
10-Jan-2023	11-Jan-2023	Total Suspended Solids	22mg/L	10mg/L	A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday 10 January 2023. The NATA accredited interim testing results issued on Wednesday 11 January 2023 reported a TSS concentration of 22 mg/L, which exceeds the discharge limit of 10 mg/L. As standard practice, the INPEX laboratory collect a duplicate sample when undertaking the required monthly sampling from location 750-SC-003. The duplicate was collected approximately 15 minutes after the primary TSS sample (following the sample collection protocol) and reported a TSS value of <5 mg/L, which is below the discharge limit of 10 mg/L.	INPEX considers that there was no risk of environmental harm associated with the TSS exceedance, as: • Further sampling reported TSS values below the EPL limit. • Any elevated concentration of TSS would have rapidly been dispersed following discharge within the mixing zone (The maximum expected concentration at the boundary of the 50 m mixing zone is ~0.26 mg/L, which is below the Darwin Harbour water quality objective trigger value of 10 mg/L). • Measured concentration is within the range of background concentrations that can occur naturally within Darwin Harbour
24-Jan-2023	3-Feb-2023	Faecal Coliforms	1500 CFU/100ml	400 CFU/100ml	A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday 24 January 2023. The NATA accredited testing results issued on Friday 3 February 2023 reported a Faecal Coliform value of 1500 CFU/100mL, which exceeds the discharge limit of 400 CFU/100mL. The sample reported an *E. coli* result of 40 CFU/100mL, which is below the EPL228-05 limit of 100 CFU/100mL. INPEX considers that the Faecal Coliform and *E. coli* values should be similar, as *E. coli* is the predominant species found in Faecal Coliform, in sewage treatment plants. Following the Faecal Coliform exceedance in December 2022, the sampling frequency was increased to fortnightly, sampling conducted on 10 January 2023 reported a Faecal Coliform value of 31 CFU/100mL, which is below the licence limit.	Through the incident investigation, INPEX identified the following actions: • Initiate a six-month program of monthly sampling from locations upstream of the combined discharge, 750-SC-009 and 750-SU-403 Inlet, with testing for Faecal Coliforms (ongoing at time of writing of report)
14-Feb-2023	14-Feb-2023	TN	TN 11 mg/L	TN 10 mg/L	A discharge limit exceedance for treated wastewater was detected above the limit specified in column 5 of Table 3 in Appendix 2 of the EPL228-05. A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday 14 February 2023. The NATA accredited interim testing results issued on Tuesday 14 February 2023 reported a total nitrogen (TN) concentration of 11 mg/L, which exceeds the discharge limit of 10 mg/L.	Through the incident investigation the following actions were identified to prevent reoccurrence: • The cause was identified as the unplanned trip of the Gas Turbine Generator (GTG). A repair has been implemented to prevent the re-occurrence of the event.
14-March-2023	22-March-2023	Faecal Coliforms	760 CFU/100ml	400 CFU/100ml	A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday March 14 January 2023. The NATA accredited testing results issued on Wednesday 22 March 2023 reported a Faecal Coliform value of 760 CFU/100mL, which exceeds the discharge limit of 400 CFU/100mL. The sample reported an *E. coli* result of 44 CFU/100mL, which is below the EPL228-05 limit of 100 CFU/100mL. INPEX considers that the Faecal Coliform and *E. coli* values should be similar, as *E. coli* is the predominant species found in Faecal Coliform, in sewage treatment plants.	Based on the results of the additional sampling no further actions have been undertaken. The source of contamination is through the AOC drainage system, and not related to domestic sewage. Through the incident investigation, INPEX identified the following actions: • Investigated if a simple pool chlorine float can be installed in the inlet of the AOC holding basins to treat the water. This suggestion was not implemented due to the additional issues that can be introduced • Following the recent Faecal Coliform exceedances in late 2022 and early 2023, sampling is now occurring of both the treated sewage stream and at the inlet of accidentally oily contaminated holding basin, at the same time as the monthly sample for 750-SC-003.
14-March-2023	16-March-2023	TN	TN 16 mg/L	TN 10 mg/L	A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday 14 March 2023. The NATA accredited interim testing results issued on Thursday 16 March 2023 reported a total nitrogen (TN) concentration of 16 mg/L, which exceeds the discharge EPL228-05 limit of 10 mg/L.	Through the incident investigation the following actions were identified to prevent reoccurrence: • INPEX to investigate options to reduce the ammonia levels from the CCPP being treated at the neutralisation plant. • Implement a long-term ammonia monitoring program at the CCPP which is yet to be implemented at time of writing of report

Date sampled	Exceedance reported	Parameter	Result	Limit	Cause and/or contributing factors	Corrective actions
9-May-2023	13-May-2023	Faecal Coliforms	570 CFU/100ml	400 CFU/100ml	A sample was taken from the combined jetty outfall discharge line, sampling location 750-SC-003 on Tuesday 9 May 2023. The NATA accredited interim testing results issued on Saturday 13 May 2023 reported a Faecal Coliform value of 570 CFU/100mL, which exceeds the discharge limit of 400 CFU/100mL. The sample reported an *E. coli* result of 1 CFU/100mL, which is below the EPL228-05 limit of 100 CFU/100mL. INPEX considers that the Faecal Coliform and *E. coli* values should be similar, as *E. coli* is the predominant species found in Faecal Coliform, in sewage treatment plants.	Based on the results of the additional sampling already carried out, no further actions have been undertaken. The source of contamination is through the AOC drainage system, and not related to domestic sewage. Through the incident investigation, INPEX identified the following actions: • Maintain current additional testing regime currently in place

In general, the total nitrogen discharge limit exceedances reported in Table 2-3, have been related to maintenance issues associated with chemical dosing pumps and trips of the GTG equipment. The original manufacturer of the dosing pumps is no longer available which has contributed to the challenges of introducing the proposed replacement pumps.

The main consideration relating to the five faecal coliforms exceedance events has been focusing on the subsequent *E. coli* sample results to ensure ongoing compliance. The faecal coliforms exceedance events have provided a platform to review and improve existing controls measures to ensure *E. coli* mitigation measures are adequate. The primary source of faecal coliforms exceedance(s) has been identified as the AOC holding basin.

Initial corrective actions looked at implementing a chorine float to mitigate and treat the AOC holding basin; however, subsequent testing identified the issue is intermittent and the introduction of a chlorine float would impact on other EPL228 discharge parameters. The implementation of a chorine float will not address the source of the exceedance, which is likely to be matter such as weed growth which, following further investigations, is likely to be related to presence of vegetation within the drain system. This will be managed through drain clearance preventative maintenance work. Aligning the testing schedule for AOC basin (L-750-SU-403) and sewage treatment plant (L-750-SU-009) for a period of six months (January - July 2023) has clarified that the *E. coli* parameter exceedance has not been at risk for the sewage treatment plant, despite the exceedance of indicator parameters such as faecal coliforms.

Further clarification was sought from ALS Testing laboratory which provided the following:

"If the client is looking for the best species in the coliform group for faecal indicators, this would be E. coli. The test of faecal coliforms (thermotolerant) does report some species that may not be of faecal origin"

This identifies the challenges in using faecal coliform parameters as an indicator for *E. coli*, which has been experienced during the recent testing period.

2.1.4 Program rationalisation

Sampling is to remain as per EPL228 requirements, no changes are proposed.

2.2 Harbour sediment

The purpose of the harbour sediment quality monitoring program is to provide an early warning of potential accumulation of contaminants from Ichthys LNG wastewater discharges, in surficial sediments surrounding the jetty outfall. The key objective is to determine if changes are attributable to Ichthys LNG operations.

As per the OEMP (L060-AH-PLN-60005), harbour sediment quality is required to be monitoring biennially. One survey (Survey No. 4) was undertaken within the reporting period. Associated reporting is summarised in Table 2-4.

Table 2-4: Harbour sediment quality survey details

Survey	Date	Report	INPEX Dox #
4	1 July 2022	Harbour Sediment Quality Monitoring – Trigger Assessment Report No. 4	L290-AH-REP-70042
		Harbour Sediment Quality Monitoring – Interpretative Report No. 4	L290-AH-REP-70043

2.2.1 Method overview

The harbour sediment quality survey was performed in accordance with the Harbour Sediment Quality Monitoring Plan (L290-AH-PLN-70003). Surficial sediment samples were collected using a grab sampler from 16 potential impact sites radiating away from the jetty outfall and two control sites in East Arm (Figure 2-2). The sediment grab sampler and QA/QC procedures followed were in accordance with the Harbour Sediment Quality Monitoring Plan, which was developed in consideration of the National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia 2009). The use of NAGD ensures consistency in sediment characterisation programs and is largely adopted for use in the Northern Territory (NT EPA 2013).

Following collection, surficial sediment samples were sent to a NATA accredited laboratory for analysis of parameters listed in Table 2-5. Laboratory results were then compared to benchmark levels to ascertain whether a trigger exceedance had occurred.

Exceedance of a benchmark level is defined as a measured analyte exceeding its relevant sediment quality guideline value (SQGV; also referred to as guideline value) as per ANZG (2018) and the same analyte also exceeding the background level for Darwin Harbour sediment. Background levels were calculated based on results presented in 2012 Darwin Harbour baseline sediment survey (Munksgaard et al. 2013). Note, where measured metal or metalloids exceeded SQGVs, results where possible are normalised for aluminium concentrations based on methods described in Munksgaard (2013) and Munksgaard et al. (2013)[5] and compared to background levels (i.e. baseline or reference levels).

[5] Aluminium normalised metal concentrations can be calculated as the equivalent metal concentration at an aluminium concentration of 10,000 mg/kg (1% by weight).

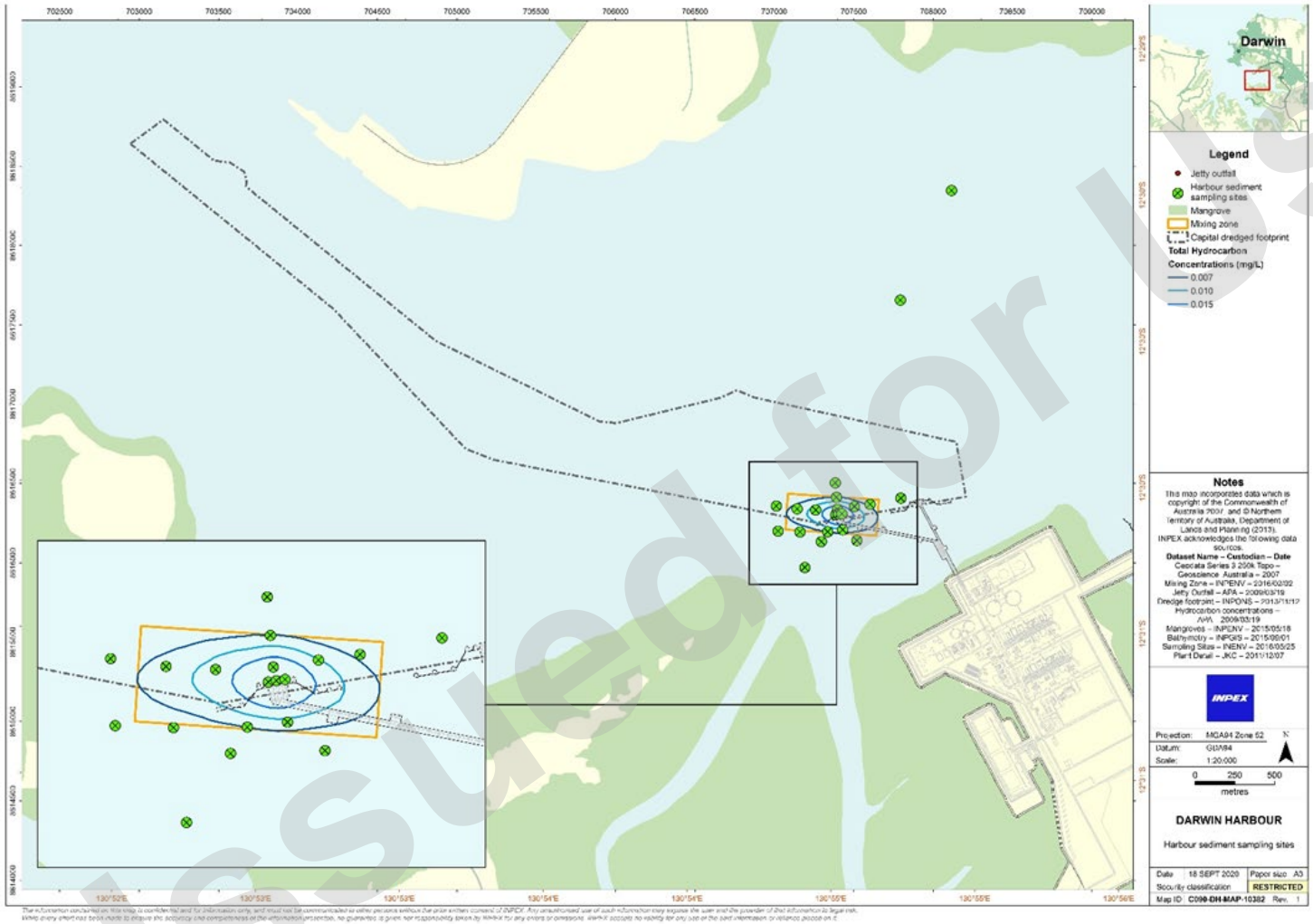

Figure 2-2: Harbour sediment quality sampling locations

Table 2-5: Harbour sediment quality monitoring parameters, trigger, and background values

Parameter	Unit	Trigger value*	Background value†
Total organic carbon (TOC)	%	n/a	n/a
TPH / TRH	mg/kg	280	n/a
Benzene, toluene, ethylbenzene, and xylene (BTEX)	mg/kg	n/a	n/a
Aluminium	mg/kg	n/a	n/a
Antimony	mg/kg	2	n/a
Arsenic	mg/kg	20	16.0
Cadmium	mg/kg	1.5	0.07
Chromium	mg/kg	80	17.5
Copper	mg/kg	65	4.7
Lead	mg/kg	50	8.8
Mercury	mg/kg	0.15	n/a
Nickel	mg/kg	21	8.7
Zinc	mg/kg	200	21.4
Particle size distribution (PSD)	µm	n/a	n/a

* ANZG (2018) sediment quality guideline value.

† Background levels are from Munksgaard et al. (2013), using the average of non-normalised sediment samples collected from intertidal (n=247) areas within the Darwin Harbour.

2.2.2 Results and discussion

Monitoring sites

Metal and metalloid results for harbour sediment quality are presented in Table 2-6. No metal or metalloid exceedances were reported at Impact sites.

All impact and control locations were below the laboratory LOR for Benzene, Toluene, Ethylbenzene and Xylene (BTEX) (Table 2-7). Total recoverable hydrocarbons (TRH) and total petroleum hydrocarbons (TPH) were detected above the LOR at one site (I11; 57 mg/kg); however, the guideline value (280 mg/kg) was not exceeded. The presence of TPH in this sample likely indicates the presence of non-petrogenic hydrocarbons of biological origin (e.g. vegetable/animal oils and greases, humic and fatty acids). Non-petrogenic hydrocarbons of biological origin are known to occur in Darwin Harbour with mangrove sediment samples analysed during the construction and operational phases returning positive results for TPH.

Table 2-6: Harbour sediment quality survey metal and metalloid results (mg/kg)

Site*	Aluminium	Antimony	Arsenic †	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
Trigger values	**n/a**	**2**	**20**	**1.5**	**80**	**65**	**50**	**21**	**200**	**0.15**
Background level	**n/a**	**n/a**	**16.0**	**0.071**	**17.5**	**4.7**	**8.8**	**8.7**	**21.4**	**n/a**
I1	9,000	<0.5	9.8	<0.1	23	5.3	7.8	7.7	17	<0.1
I2	11,000	<0.5	11	<0.1	28	6.9	9.3	10	21	<0.1
I3	13,000	<0.5	11	<0.1	31	6.7	9.5	10	23	<0.1
I4	9,800	<0.5	11	<0.1	26	5.6	8.2	8.9	17	<0.1
I5	14,000	<0.5	11	<0.1	34	6.8	10	11	23	<0.1
I6	13,000	<0.5	11	<0.1	31	6.9	9.6	11	22	<0.1
I7	21,000	<0.5	12	<0.1	44	11	12	14	41	<0.1
I8	17,000	<0.5	12	<0.1	37	9.6	11	13	34	<0.1
I9	17,000	<0.5	14	<0.1	38	9	12	12	34	<0.1
I10	14,000	<0.5	10	<0.1	32	7.1	9.5	9.8	30	<0.1
I11	16,000	<0.5	12	<0.1	34	8.6	10	11	32	<0.1
I12	11,000	<0.5	11	<0.1	28	6.5	8.9	10	21	<0.1
I13	10,000	<0.5	15	<0.1	25	5.4	8.6	8.2	16	<0.1
I14	6,100	<0.5	11	<0.1	21	12	6.8	15	30	<0.1
I15	15,000	<0.5	14	<0.1	35	7.4	12	11	24	<0.1
I16	9,900	<0.5	15	<0.1	27	5.7	9.2	8.6	18	<0.1
C1	2,400	<0.5	20	<0.1	17	2.5	3.8	2.4	7.8	<0.1
C2	19,000	<0.5	16	<0.1	39	9.2	12	12	37	<0.1

* C = Control Site, I = Impact site.

† Bold values indicate trigger exceedance and results in brackets have been normalised for aluminium concentrations as per Munksgaard (2013)

Table 2-7: Harbour sediment quality survey organic results

Site*	TOC (mg/kg)	TPH (mg/kg)	BTEX (mg/kg)
Trigger values	**n/a**	**280**	**n/a**
Background level	**n/a**	**n/a**	**n/a**
I1	31,000	<50	<0.1
I2	28,000	<50	<0.1

Site*	TOC (mg/kg)	TPH (mg/kg)	BTEX (mg/kg)
I3	29,000	<50	<0.1
I4	24,000	<50	<0.1
I5	34,000	<50	<0.1
I6	22,000	<50	<0.1
I7	25,000	<50	<0.1
I8	26,000	<50	<0.1
I9	25,000	<50	<0.1
I10	31,000	<50	<0.1
I11	30,000	57	<0.1
I12	46,000	<50	<0.1
I13	28,000	<50	<0.1
I14	20,000	<50	<0.1
I15	<1,000	<50	<0.1
I16	34,000	<50	<0.1
C1	12,000	<50	<0.1
C2	28,000	<50	<0.1

* C = Control Site, I = Impact site

2.2.3 Trigger assessment outcomes

There were no exceedance of trigger levels for the reporting period.

2.2.4 Program rationalisation

Given there has been no trigger exceedance in harbour sediment monitoring attributable to Ichthys LNG operations, no changes to the monitoring frequency are proposed.

3 EMISSIONS TO AIR

This section includes the outcomes of the following monitoring programs:

- point source emissions (Section 3.2)
- dark smoke events (Section 3.4).

This section also summarises the operating condition of each emission source and the resulting air emission quality (Section 3.3) and provides a summary of total emissions to air in tonnes per year for the main parameters outlined in EPL228 (Section 3.1).

3.1 Total emissions to air

INPEX is required to provide total emissions to air (tonnes/year) for air quality parameters (Condition 87.4 of EPL228-04/Condition 77.5 of EPL228-05 listed in Table 6, Appendix 3 of EPL228). Estimated total emissions to air for the reporting period are provided in Table 3-1, which are based on INPEX's Commonwealth emission reporting requirements for National Pollutant Inventory (NPI) and National Greenhouse and Energy Reporting Scheme (NGERS).

Table 3-1: Estimated total emissions to air for reporting period

Parameter	Emissions (t/yr)
NOx as nitrogen dioxide (NO_2)	1752.32
Nitrous oxide (N_2O)	19.64
Mercury (Hg)	0
Particle matter 2.5 ($PM_{2.5}$)	92.75
Particle matter 10 (PM_{10})	92.75
Carbon monoxide (CO)	2908.86
Benzene	5.51
Toluene	5.33
Ethylbenzene	0.82
Xylenes	3.26
Hydrogen sulphide (H_2S)	190.06

3.2 Point source emissions to air

The key objective of the point source emission monitoring (commonly referred to as stack sampling) is to ensure air emissions do not exceed the concentration limit criteria as specified in Table 5, Appendix 3 of EPL228. The frequency of monitoring is outlined in EPL228, which requires annual monitoring of most emission points, monthly monitoring of hot venting, and hydrocarbons monitoring for all flare events .

Annual monitoring is being undertaken in accordance with the requirements of EPL228.

Table 3-2 provides a summary of the point source emission monitoring conducted for the reporting period.

Table 3-2: Point source emissions survey dates

Survey	Start date	End Date
Survey 8 Q4 2022	October 2022	October 2022

3.2.1 Method overview

Stationary source emissions monitoring is undertaken at 13point sources (with a total of 18 stacks) on the Frame 7 compression turbines, CCPP Frame 6 power generation turbines, CCPP utility boilers, acid gas removal unit (AGRU) incinerators and heating medium furnaces.

For the CCPP Frame 6 turbines, each turbine has two stacks, one which allows for normal operation of the turbine (with exhaust emissions directed to a conventional stack) and a separate stack with an associated heat recovery steam generator (HRSG), allowing for steam to be generated through the duct burning of fuel. The two stacks cannot be operated together so stack monitoring is dependent on which stack is in use at the time of sampling.

Table 3-3 and Table 3-4 show the EPL228 air emission target and limits plus the constituents that are required to be monitored at the point source locations as per Appendix 3, Table 5 and Table 6 respectively, of EPL228-05. Figure 3-1 shows the locations of the stationary source emissions monitoring locations at Ichthys LNG.

The following locations are inline gas sampling points (not ports) and as such are exempt from the standard methods for point source emissions sampling:

- 551-SC-003 (release point number A13-2);
- 552-SC-003 (release point number A14-2);
- 541-SC-001 (release point number A13-3); and
- 542-SC-001 (release point number A14-3).

INPEX conducts inhouse gas sampling and analysis from these locations for BTEX, hydrogen sulphide (H_2S) and mercury (Hg) using conventional industry methods which are not NATA accredited. The analysis of these gases is conducted using test methods that are managed under a NATA accredited Quality Management System.

Stationary source and gas samples are either collected by INPEX laboratory technicians and tested in the on-site NATA-accredited laboratory or are collected by an external NATA-accredited contractor and analysed in the field or by external laboratories.

All stack sampling ports have been installed in accordance with AS4323.1-1995 stationary source emissions – selection of sampling ports.

All stack sampling, where applicable, is undertaken in accordance with:

- New South Wales (NSW) Environment Protection Authority (formerly the Department of Environment and Conservation) Approved Methods for the Sampling and Analysis of Air Pollutants in NSW; or
- USEPA Method 30B for mercury emissions.

However, currently there are no approved NSW test methods for the sampling and analysis of nitrous oxide, nor any approved Australian Standard or USEPA methods.

For the sampling and analysis of nitrous oxide, INPEX and the stack emission monitoring Contractor, Ektimo, have followed the procedures as listed in NSW Test Method 11, which cross references to USEPA Method 7E *Determination of Nitrogen Oxide Emission from Stationary Sources (Instrumental Analyser Procedure)*. This lists comprehensive quality control and calibration procedures that must be followed to ensure accurate and reliable results. The analysis of nitrous oxide is also managed under a NATA accredited Quality Management System.

Table 3-3: Contaminant release limits to air at authorised stationary emission release points

Release point number	Source	Pollutant	Concentration target		Concentration limit	
			mg/Nm^3	ppmv	mg/Nm^3	ppmv
A1, A2, A3, A4	LNG Refrigerant Compressor Driver Gas Turbines (GE Frame 7s)	NO_x as NO_2	50 @ 15% O_2 dry	25 @ 15% O_2 dry	70@ 15% O_2 dry	35 @ 15% O_2 dry
A5-1, A6-1, A7-1, A8 1, A9-1	CCPP Gas Turbine Generators (GE Frame 6s, 38 MW)	NOx as NO_2	50 @ 15% O_2 dry	25 @ 15% O_2 dry	70@ 15% O_2 dry	35 @ 15% O_2 dry
A5-2, A6-2, A7-2, A8 2, A9-2	CCPP Gas Turbine Generators (GE Frame 6s, 38 MW) also burning vaporised iso-pentane in duct burners	NO_x as NO_2	150 @ 15% O_2 dry	75 @ 15% O_2 dry	350@ 15% O_2 dry	175 @ 15% O_2 dry
A13-1, A14-1	AGRU Incinerators	NO_x	320 @ 3% O_2 dry	160 @ 3% O_2 dry	350@ 3% O_2 dry	175 @ 15% O_2 dry
A15, A16	Heating Medium Furnaces	NO_x	160 @ 3% O_2 dry	80 @ 3% O_2 dry	350@ 3% O_2 dry	175 @ 3% O_2 dry

Table 3-4: Air emission monitoring program

Release Point Number	Sampling Location Number	Source	Monitoring Frequency	Parameter
A1	L-641-A-001	LNG Train 1 Refrigerant Compressor Driver Gas Turbine (GE Frame 7)	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A2	L-642-A-001	LNG Train 2 Refrigerant Compressor Driver Gas Turbine (GE Frame 7)		
A3	L-641-A-002	LNG Train 1 Refrigerant Compressor Driver Gas Turbine (GE Frame 7)		
A4	L-642-A-002	LNG Train 2 Refrigerant Compressor Driver Gas Turbine (GE Frame 7)		
A5-1	L-780-GT-001	CCPP Gas Turbine Generator #1 (GE Frame 6) – conventional stack	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A6-1	L-780-GT-002	CCPP Gas Turbine Generator #2 (GE Frame 6) – conventional stack		
A7-1	L-780-GT-003	CCPP Gas Turbine Generator #3 (GE Frame 6) – conventional stack		
A8-1	L-780-GT-004	CCPP Gas Turbine Generator #4 (GE Frame 6) – conventional stack		
A9-1	L-780-GT-005	CCPP Gas Turbine Generator #5 (GE Frame 6) – conventional stack		
A5-2	L-630-F-001	CCPP Gas Turbine Generator #1 (GE Frame 6) – HRSG stack		
A6-2	L-630-F-002	CCPP Gas Turbine Generator #2 (GE Frame 6) – HRSG stack		
A7-2	L-630-F-003	CCPP Gas Turbine Generator #3 (GE Frame 6) – HRSG stack		
A8-2	L-630-F-004	CCPP Gas Turbine Generator #4 (GE Frame 6) – HRSG stack		
A9-2	L-630-F-005	CCPP Gas Turbine Generator #5 (GE Frame 6) – HRSG stack	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A13-1	L-551-FT-031	AGRU Incinerator – LNG Train 1	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A13-2	551-SC-003	AGRU Hot Vent – LNG Train 1, prior to release at A3	monthly	BTEX, H_2S, volumetric flow rate
A13-3	541-SC-001	Feed gas to AGRU – LNG Train 1 – prior to release at A3	monthly	Hg
A14-1	L-552-FT-031	AGRU Incinerator – LNG Train 2	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A14-2	552-SC-003	AGRU Hot Vent – LNG Train 2, prior to release at A4	monthly	BTEX, H_2S, volumetric flow rate
A14-3	542-SC-001	Feed gas to AGRU – LNG Train 2 – prior to release at A4	monthly	Hg
A15	L-640-A-001-A	Heating Medium Furnaces	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, , CO, temperature, efflux velocity, volumetric flow rate
A16	L-640-A-001-B	Heating Medium Furnaces	annually	NO_x as NO_2, N_2O, Hg, $PM_{2.5}$, PM_{10}, CO, temperature, efflux velocity, volumetric flow rate
A17	L-700-F-002	Ground flare #5 warm	all flare events	mass of hydrocarbons flared
A18	L-700-F-001-A/B	Ground flare #2 cold		
A19	L-700-F-003	Ground flare #1 spare		
A20	L-700-F-005-A/B	Tank flare #1 LNG		
A21	L-700-F-006-A/B	Tank flare #2 LPG		
A22	L-700-F-007	Tank flare #3 LNG/LPG		
A23	L-700-F-004	Liquid flare		

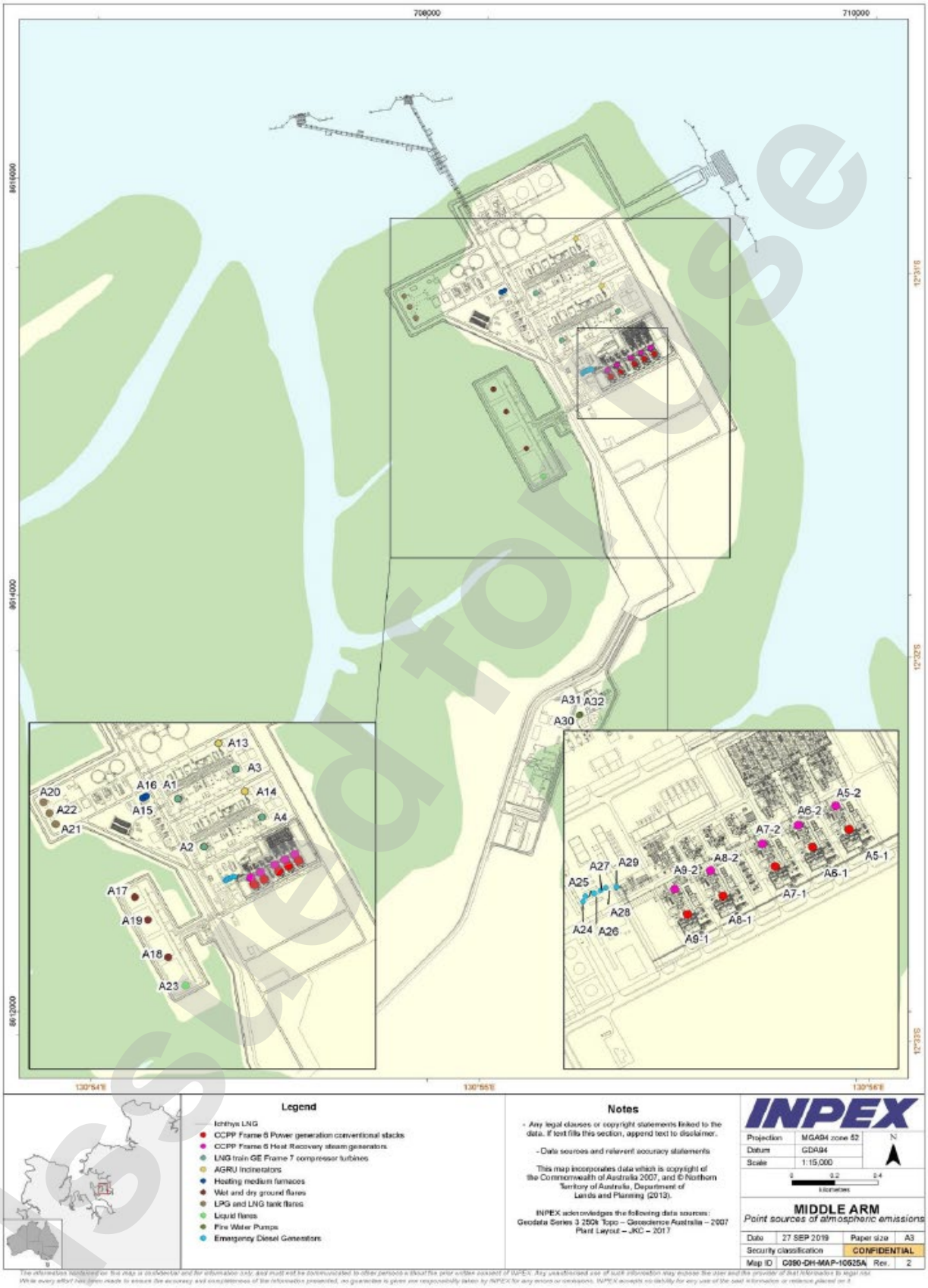

Figure 3-1: Location of authorised stationary emission release points

3.2.2 Results and discussion

All results for the permanent plant were below limit criteria provided in Appendix 3, Table 5 of EPL228 (Table 3-3). The stationary source emission monitoring results are provided in APPENDIX D:

Due to equipment being offline for planned maintenance and extended unplanned equipment fault outages, release point number A6-2 (L-630-F-002 & L-780-GT-002 was unable to be tested during the Q4 2022 survey. Noting that in normal operations for the CCPP only 4 of the 5 turbines will be online, with one generally on standby or offline for planned maintenance. As previously mentioned in section 3.2.1, CCPP frame 6 turbines have two stacks with only one of the two stacks running at a time. As such, release port numbers A5 1 to A9 1 (conventional stack series) were not tested in this reporting period as they not online. The "HRSG stack series" frame 6 sampling locations were utilised in this survey.

The mass of hydrocarbons flared for the reporting period for each flare source is presented in Table 3-5.

Table 3-5: Mass of hydrocarbons flared

Release Point number	Location Number	Source	Mass of hydrocarbons flared (tonnes)
A17 / A19	L-700-F-002 / L-700-F-003	Ground flare #5 warm/ Ground flare #1 spare	30,686
A18 / A19	L-700-F-001-A/B / L-700-F-003	Ground flare #2 cold / Ground flare #1 spare	35,161
A20	L-700-F-005-A/B	Tank flare #1 LNG	3.8
A21	L-700-F-006-A/B	Tank flare #2 LPG	9,485
A22	L-700-F-007	Tank flare #3 LNG/LPG	11,702
A23	L-700-F-004	Liquid flare	0

Figure 3-2 and Figure 3-3 show the vented acid gas flow rates in m^3/h for Train 1 and Train 2. During the time the acid gas incinerators were offline, the acid gas was hot vented when the LNG trains were online. Figure 3-4 and Figure 3-5 provide the flow rate of acid gas to the Train 1 and Train 2 acid gas incinerators, while the incinerator was in service.

While the acid gas incinerators were offline and venting was occurring, gas sampling was undertaken in accordance with EPL228-5 condition 58.1 In December 2022, Inpex experienced an issue with train 1 & 2 AGI's relating to a valve by-passing hydrocarbons which resulted in a subsequent trip of both AGI's. Both train 1 & train 2 AGI's were taken offline for a full review and Management of Change process before being re-implemented.

At time of writing of this report, Management of Change corrective actions are yet to be finalised prior to coming back online.

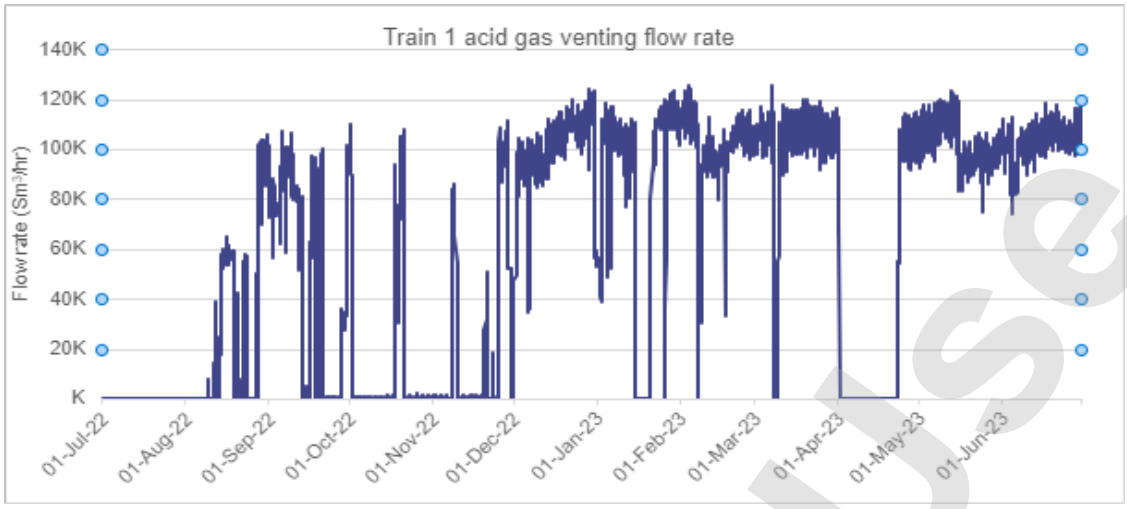

Figure 3-2 Train 1 acid gas venting flow rates

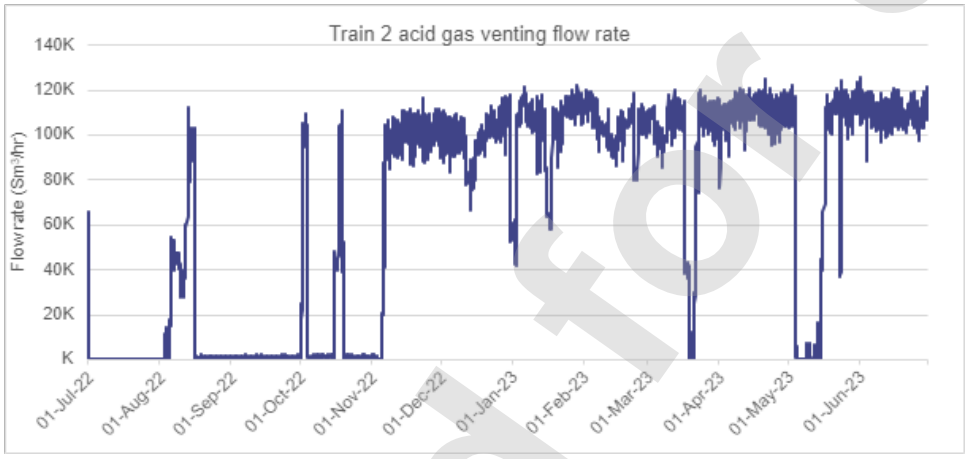

Figure 3-3 Train 2 acid gas venting flow rate

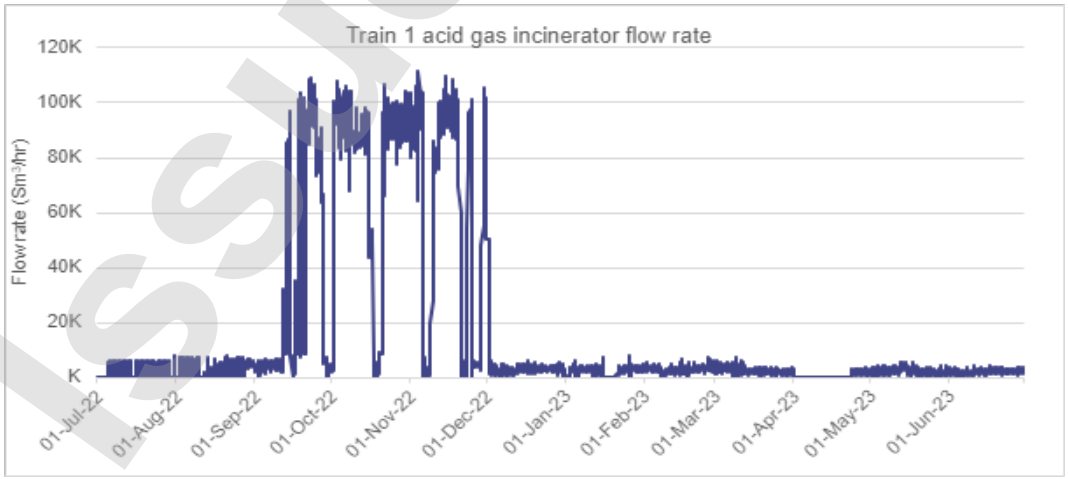

Figure 3-4 Train 1 acid gas incinerator flow rates

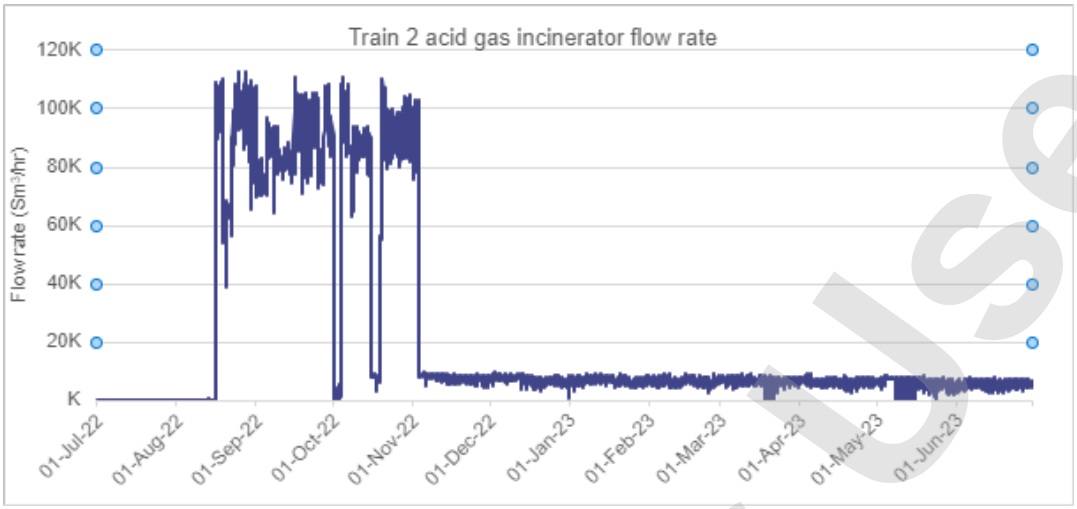

Figure 3-5 Train 2 acid gas incinerator flow rates

3.2.3 Program rationalisation

No rationalisation is currently proposed, and monitoring will be conducted as per the EPL228 requirements.

3.3 Overall summary of performance of stationary emission sources

The status of the stationary point source emissions at Ichthys LNG is provided in Table 3-6 based on information presented in Sections 3.1 and 3.2. As stated above the acid gas incinerators for both LNG Train 1 and LNG Train 2 was offline from December 2022. During the period that the acid gas incinerators were offline, sampling of the vented gas occurred as per EPL228-05 condition 58.1.

Table 3-6: Stack emission status and air quality

Release point number	Emission source	Status	Air emissions
A1	Compressor turbine WHRU West 1 (Frame 7)	Operational	Acceptable
A2	Compressor turbine WHRU West 2 (Frame 7)	Operational	Acceptable
A3	Compressor turbine WHRU East 1 (Frame 7)	Operational	Acceptable
A4	Compressor turbine WHRU East 2 (Frame 7)	Operational	Acceptable
A5-1	Power generation turbine 1 (Frame 6)	Intermittent use, when HRSG offline	Not tested in this survey
A6-1	Power generation turbine 2 (Frame 6)	Intermittent use, when HRSG offline	Not tested in this survey

Release point number	Emission source	Status	Air emissions
A7-1	Power generation turbine 3 (Frame 6)	Intermittent use, when HRSG offline	Not tested in this survey
A8-1	Power generation turbine 4 (Frame 6)	Intermittent use, when HRSG offline	Not tested in this survey
A9-1	Power generation turbine 5 (Frame 6)	Intermittent use, when HRSG offline	Not tested in this survey
A5-2	Power generation turbine 1 HRSG (Frame 6)	Operational	Acceptable
A6-2	Power generation turbine 2 HRSG (Frame 6)	Off-line during survey	Not tested in this survey
A7-2	Power generation turbine 3 HRSG (Frame 6)	Operational	Acceptable
A8-2	Power generation turbine 4 HRSG (Frame 6)	Operational	Acceptable
A9-2	Power generation turbine 5 HRSG (Frame 6)	Operational	Acceptable
A13-1	AGRU Incinerator – LNG Train 1	Offline since December 2022	Acceptable while online
A13-2	AGRU Hot Vent – LNG Train 1, prior to release at A3	Operational	Acceptable
A14-1	AGRU Incinerator – LNG Train 2	Offline since December 2022	Acceptable while online
A14-2	AGRU Hot Vent – LNG Train 2, prior to release at A4	Operational	Acceptable
A15	Heating medium furnace 1	Operational	Acceptable
A16	Heating medium furnace 2	Operational	Acceptable

3.4 Darksmoke events

Ichthys LNG has been designed to minimise dark-smoke events; however, dark smoke can result during flaring due to incomplete combustion of hydrocarbons. The environmental impacts from smoke emitted from Ichthys LNG are considered negligible, though smoke could become a cause of visual amenity impact and community concern.

3.4.1 Method overview

Visual monitoring and closed-circuit television monitoring of flares is undertaken to detect possible dark smoke events. If dark smoke is produced during operations, the shade (or darkness) of the smoke is estimated using the Australian Miniature Smoke Chart (AS 3543:2014), which uses Ringelmann shades. The shade and duration of the dark-smoke event is recorded. Dark smoke monitoring targets and limits for all the flare systems are provided in Table 3-7.

Table 3-7: Dark smoke monitoring targets and limits

Emission source	Pollutant	Target	Limit
Flares	Smoke	<Ringelmann 1	Visible smoke emissions darker than Ringelmann shade 1

Flaring and other data is stored in the sites Process Control System (PCS). The PCS serves as the primary means to control and monitor Ichthys LNG and automatically maintains operating pressures, temperatures, liquid levels, and flow rates within the normal operating envelope with minimal intervention from operator consoles in the central control room (CCR). The system has built-in redundancy in communication, control, and human interface. Information from the PCS is displayed on visual display units in the CCR. During process upset conditions, the system has detailed alarm handling and interrogation functions to minimise operator overload. The PCS is also equipped with a database function that permits operations personnel to investigate a historical sequence of events. In addition, volatile organic compound emissions are estimated by use of the NPI and NGERS reporting tools.

3.4.2 Results and discussion

On 25 November 2022 during the restart of Train 1, black smoke was reported to be observed coming from the Train 1 acid gas incinerator (AGI). The observed smoke was not a result of flaring.

This smoke event was not charted on the Ringelmann smoke chart as the causation of the event did not allow this information to be captured in time. This event led to both AGI's taken offline from December 2022 to prevent further reoccurrence.

3.4.3 Program rationalisation

No program rationalisation is proposed.

4 UNPLANNED DISCHARGES TO LAND

4.1 Groundwater quality

The key objective of the groundwater monitoring program is to detect changes in groundwater quality and determine if these changes are attributable to Ichthys LNG operations. Note there are no planned discharges directly to groundwater, other than rainfall and non-contaminated water (NCW); however, there is potential for groundwater to become contaminated as a result of an accidental spill, leak, or rupture during Ichthys LNG operations.

As per the OEMP, groundwater quality is required to be monitored biannually (e.g. twice yearly at 15 sites). Table 4-1 provides a summary of the groundwater quality surveys completed during the reporting period.

Table 4-1: Groundwater quality monitoring survey details

Survey	Sampling period	Report	INPEX Doc #
10	24-26 October 2022	Groundwater Quality Monitoring – Trigger Assessment: Report No 10	L290-AH-REP-70031
		Groundwater Quality Interpretive Report No 10	L290-AH-REP-70032
11	18-20 April 2023	Groundwater Quality Monitoring – Trigger Assessment: Report No 11	L290-AH-REP-70052
		Groundwater Quality Interpretive Report No 11	L290-AH-REP-70051

4.1.1 Method overview

The groundwater quality monitoring surveys were undertaken in accordance with the Groundwater Quality Monitoring Plan (L290-AH-PLN-70000). The Groundwater Quality Monitoring Plan was developed in consideration of Australian, State and Territory groundwater sampling standards and guidelines. A high-level summary of methods is provided below.

Prior to sampling, groundwater wells were gauged with an interface probe to determine the standing water level (SWL). Following gauging, groundwater wells were purged using a low flow micro purge pump with SWL and in situ parameters being measured every three to five minutes. Once the well had been purged and in-situ parameters were stable, groundwater samples were then collected for analysis.

Following collection, groundwater samples were sent to NATA accredited laboratories for analysis of parameters listed in Table 4-2. Results were then compared to benchmark levels to ascertain whether a trigger exceedance had occurred.

Exceedance of a benchmark level is defined as a measured analyte exceeding its relevant trigger value (see Table 4-2) and the same analyte also exceeding the background level for each groundwater well. While specific background level trigger values were calculated using the approach described in ANZG (2018). The 80th and/or 20th percentile value for each parameter was determined using the monthly groundwater data collected during the construction phase of Ichthys LNG between 2013 and 2018.

Table 4-2: Groundwater quality monitoring parameters, methods, and trigger values

Parameter	Unit	Sampling method*	Trigger value	Trigger value reference
pH	pH units	CFI	Outside 6.0 and 8.5	NRETAS 2010
EC	µS/cm	CFI	n/a	n/a
Dissolved oxygen	%	CFI	n/a	
Oxygen reduction potential	mV	CFI	n/a	
Temperature	°C	CFI	n/a	
Total dissolved solids	mg/L	SFLA	n/a	
Oxides of nitrogen	µg N/L	SFLA	20	NRETAS 2010
Ammonia	µg N/L	SFLA	20	
TN	µg N/L	SFLA	300	
TP	µg P/L	SFLA	30	
FRP	µg/L	SFLA	10	
Phenols	µg/L	SFLA	n/a	n/a
TRH‡	µg/L	SFLA	600	Ministry of Infrastructure and the Environment (2009)
Benzene	µg/L	SFLA	500	ANZG 2018
Toluene	µg/L	SFLA	180	
Ethylbenzene	µg/L	SFLA	5	
Xylenes	µg/L	SFLA	75	
Aluminium	µg/L	SFLA	24	Golding et al. 2015
Arsenic	µg/L	SFLA	2.3	ANZG 2018
Cadmium	µg/L	SFLA	0.7	
Chromium III	µg/L	SFLA	10	
Chromium VI	µg/L	SFLA	4.4	
Cobalt	µg/L	SFLA	1	
Copper	µg/L	SFLA	1.3	
Lead	µg/L	SFLA	4.4	
Manganese	µg/L	SFLA	390	J. Stauber and R. Van Dam Pers.Com. 23 March 2015 cited in Greencap (2016)
Mercury	µg/L	SFLA	0.1	ANZG 2018
Nickel	µg/L	SFLA	7	

Parameter	Unit	Sampling method*	Trigger value	Trigger value reference
Silver	µg/L	SFLA	1.4	
Vanadium	µg/L	SFLA	100	
Zinc	µg/L	SFLA	15	
Biological oxygen demand (BOD)†	mg/L	SFLA	n/a	n/a
Faecal coliform†	cfu-100mL	SFLA	n/a	
Escherichia coli†	cfu-100mL	SFLA	n/a	

* SFLA = sample for laboratory analysis, CFI = calibrated field instrument

† Only at BPGW19A and BPGW27A

‡ Where TRH is detected over the prescribed limits a silica gel clean-up will be undertaken and reanalysed to remove false positive natural oil results

Figure 4-1: Groundwater quality sampling locations

4.1.2 Results and discussion

A high-level summary of groundwater results and trends is provided in the following sections, with data collected during the reporting period provided in APPENDIX E:. Note, presentation of groundwater data trends include data collected during the construction phase. Groundwater surveys undertaken during the reporting period are specified in Table 4-1. To date, groundwater monitoring during the operations phase of Ichthys LNG shows that there has been no change in groundwater quality.

Survey 10: October 2022

Thirty-one exceedances against both the trigger and background concentrations were recorded in the tenth groundwater monitoring event in October 2022. Exceedances include one for pH, 17 for nutrients and 13 for dissolved metals. No exceedances were recorded for hydrocarbons. This is less than the 47 exceedances recorded during the eighth groundwater monitoring event undertaken during October 2021.

All exceedances have been compared to data recorded during the dry season months of May to October between May 2016 and October 2021 using Mann-Kendall trend analysis.

A single exceedance of pH was recorded during the October 2022 monitoring event (VWP341). Whilst historic data indicates that pH fluctuates at VWP341, a decreasing trend in pH is apparent at this bore.

Visual assessment of time plotted data indicate that several of the nutrient analyte exceedances represent short-term spikes, potentially related to seasonal environmental variables, rather than increasing trends. Visual assessment of time plotted data has confirmed the following trends identified by the Mann-Kendall analysis for nutrient exceedances:

- Ammonia: Increasing trends at BPGW40, BPGW41 and VWP341.

Visual assessment of time plotted data for metal exceedances has confirmed the following trends that were also identified by the Mann-Kendall analysis:

- Arsenic: increasing trend at BPGW08
- Cobalt: Increasing trend at BPGW40 and VWP341
- Zinc: Increasing trend at VWP341.

The following historical maximum values were recorded during the October 2022 monitoring event:

- Phosphorus at BPGW18 (850 µg/L)
- Cadmium at BPGW08A (1.1 µg/L)
- Cobalt at BPGW07 (38 µg/L), BPGW08A (77 µg/L) and VWP341 (112 µg/L)
- Nickel at BPGW09 (17 µg/L)
- Zinc at VWP341 (145 µg/L).

Results of the investigation into each of the exceedances are described in Section 4.1.3.

Survey 11: April 2023

Thirty-two exceedances against both the trigger and background concentrations were recorded in the eleventh groundwater monitoring event in April 2023. Exceedances include five for pH, 13 for nutrients and 14 for dissolved metals. No exceedances were recorded for hydrocarbons and mercury.

Exceedances have been plotted on time series graph to compare to pre-construction and construction data and discern trends in the data.

The five pH exceedance recorded during the eleventh groundwater monitoring event represent an increase from the one trigger exceedance recorded during the April 2022 monitoring event. Overall, April 2023 monitoring event results showed a slight increase in pH (i.e. less acidic) across all sites when compared to April 2022.

A review of the 13 nutrient exceedances from April 2023 monitoring event found that six of the exceedances were consecutive for at least three surveys. Trend analysis completed by the monitoring contractor indicates:

- Ammonia:
  - Increasing trends for ammonia at VWP341, BPGW40 and BPGW41
  - Fluctuating trends for ammonia at BPGW20, BPGW27A and BPGW28
- Nitrogen: Fluctuating long-term trend for total nitrogen at BPGW40 and BPGW41
- Oxides of nitrogen: Consistent fluctuating trend of oxides of nitrogen, with concentrations increasing in the wet season and decreasing in the dry season at BPGW38A.
- Phosphorus: Stable and short-term spike in phosphorus concentrations at BPGW40, BPGW41 and VWP328.

Trend analysis of the 14 metals exceedances completed by the monitoring contractor indicates that:

- Arsenic: Increasing long-term trend at BPGW09 and VWP328.
- Cobalt: Stable but fluctuating at BPGW26; and increasing trend at WVP328, BPGW40 and VWP341.
- Zinc: Increasing trend at VWP341.
- Copper: Increasing trend at BPGW07.
- Manganese: Short-term spike at VWP341 and fluctuation at BPGW09.
- Nickel: Stable overall but fluctuate at VWP341.
- Zinc: Fluctuations at BPGW07 and VWP341 and short-term spike in concentrations at BPGW28.

The following historical maximum values were recorded during the April 2023 monitoring event:

- Cobalt (6.6 µg/L) and manganese (673 µg/L) at BPGW09
- Cobalt (1.6 µg/L) and FRP (11 µg/L) at BPGW40
- Cobalt (146 µg/L) at VWP341
- Nitrogen (500 µg/L) at BPGW26.

Results of the investigation into each of the exceedances are described in Section 4.1.3.

4.1.3 Trigger assessment outcomes

In accordance with the receiving environment adaptive management process outlined in Section 7.5 of the OEMP, groundwater trigger exceedances were investigated (i.e. results that exceeded benchmark levels, see Section 4.1.1). A summary of the number of trigger exceedances by survey is provided in Table 4-3 with corresponding investigation reports listed below:

- Groundwater Survey 10 – Trigger Investigation Report (L290-AH-REP-70049)
- Groundwater Survey 11 – Trigger Investigation Report (L290-AH-REP-70067).

Investigation for all trigger exceedances using multiple lines of evidence concluded that the reported trigger exceedances were likely natural (e.g. represent seasonal trends and natural variability) and no further evaluation or management response was required.

Table 4-3: Summary of groundwater trigger exceedances

Date	Month	Physio-chemical	Nutrients	Metals
Survey 10†	Oct	1	17	13
Survey 11†	April	5	13	14

† Includes multiple technical trigger exceedances, which occurred as a result of samples being analysed to LORs higher than those required for the monitoring program, as well trigger exceedances resulting from the relative percentage difference (RPD) of QA/QC samples above the performance criteria of <30%.

4.1.4 Program rationalisation

No changes to groundwater monitoring at Ichthys LNG are proposed, as the current biannual monitoring is appropriate to capture seasonal impacts from unplanned discharges to ground.

5 FLORA, FAUNA, AND HERITAGE

5.1 Mangrove health and intertidal sediment

As per the OEMP (L060-AH-PLN-60005), mangrove health and intertidal sediments are monitored biennially. Mangrove health and intertidal sediments were monitored last in June 2022 and, therefore, were not monitored in this reporting period.

5.2 Nearshore marine pests

5.2.1 Method overview

Nearshore monitoring is undertaken to assess the presence/absence of invasive marine species at the Ichthys LNG LPG/condensate product loading jetties (Figure 5-1). The two sites located on the product loading jetties have been incorporated in the wider Darwin Harbour program, managed by NT Aquatic Biosecurity Unit, within the Fisheries Division of the Northern Territory Department of Industry, Tourism and Trade (NT DITT). NT DITT provide the artificial settlement units (ASUs; Figure 5-2) for INPEX to deploy at the jetties. Each ASU consists of four settlement plates (back-to-back) and two rope mops.

Photo-monitoring of ASUs is undertaken monthly with ASUs collected and replaced every fourth month (an example of monitoring photographs is shown in Figure 5-3). Collected ASUs and monthly photos of the traps are sent to NT DITT for species identification.

The ASUs were installed in September 2018 with monthly monitoring commencing in October 2018. During the reporting period monthly photo inspections occurred and the traps were collected and provided to NT DITT every four months for identification of species.

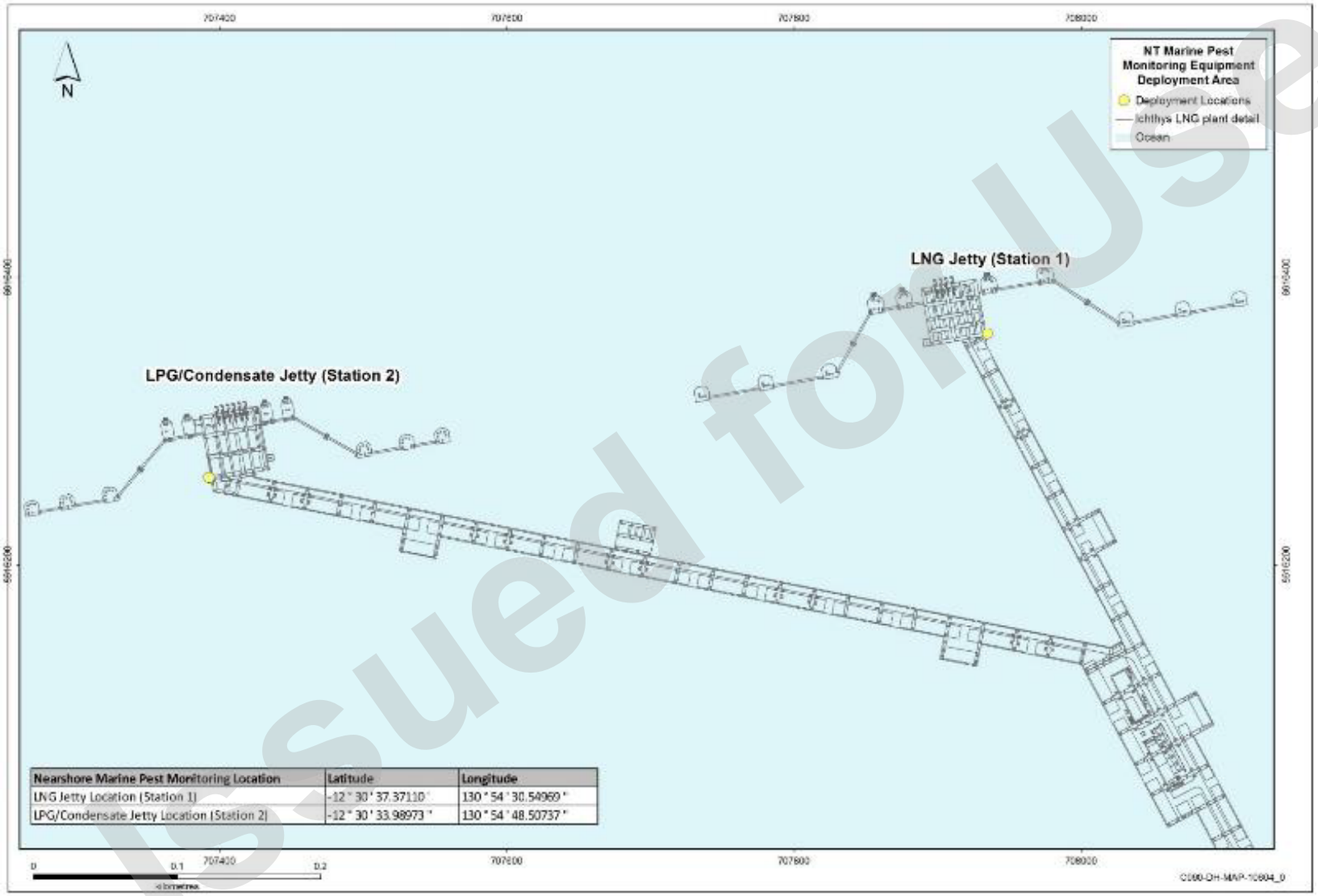

Figure 5-1: Nearshore marine pest monitoring locations

Figure 5-2: Nearshore marine pest ASU

Figure 5-3: Example of monitoring photographs taken during monthly inspection a) rope mop, b) inside the plates and c) plates surface biofouling conditions

5.2.2 Results and discussion

NT DITT did not identify any invasive marine species on settlement devices deployed as part of the Darwin Harbour marine pest monitoring program. NT DITT examined plates and rope mops on submission every four months, and photos submitted after monthly inspections.

5.2.3 Program rationalisation

No change proposed to the marine pest monitoring.

5.3 Introduced terrestrial fauna

Introduced terrestrial fauna may be monitored to determine the presence, location and methods used to control nuisance species.

5.3.1 Method overview

In the event introduced terrestrial fauna are deemed to be a nuisance at Ichthys LNG, INPEX will undertake an annual survey using a third-party licenced pest management contractor.

5.3.2 Results and discussion

During the reporting period there were no reports of introduced terrestrial fauna being deemed a nuisance, as such, no annual survey was undertaken. The routine and ad-hoc pest management programs including baiting and trapping adequately managed introduced terrestrial fauna at Ichthys LNG.

5.3.3 Program rationalisation

No change to the current program is proposed.

5.4 Weed mapping

The key objectives of the weed mapping program are to:

- identify the abundance and spatial distribution of known and new emergent weed populations; and
- inform weed management and control activities.

Weed surveys are undertaken annually at the end of the wet season (nominally in April). Table 5-1 provides a summary of surveys completed during the reporting period.

Table 5-1: Weed survey details

Survey	Date	Report	INPEX Doc #
Survey 8	May 2023	Weed Management Report No. 8	L290-AH-REP-70057

5.4.1 Method overview

Weed surveys were performed in accordance with the INPEX LNG Weed Mapping and Vegetation Surveillance Monitoring Plan (L290-AH-PLN-70001). The area surveyed is shown in Figure 5-4. Parameters monitored during the weed surveys are listed in

Table 5-2. Where identification of a species was not possible in the field, a voucher sample, together with photographs were taken to facilitate post survey identification.

Figure 5-4: Weed survey area

Table 5-2: Weed survey parameters

Key Parameter	Descriptor
Weed names	Scientific and common names
Physical locations	Coordinates of localised outbreaks, polygons for larger occurrences
Abundance	Individual numbers and/or percentage cover, enabling comparison with previous and historic monitoring events
Date	Date of data collection for future and historic comparison

5.4.2 Results and discussion

Survey 8: May 2023

Two new declared weed species were recorded during the May 2023 survey. A single *Lantana camara* (lantana) plant was detected just outside of the perimeter fence along the south-east boundary of the production area and a single *Senna obtusifolia* (sicklepod) plant was recorded along the beach valve within the GEP Corridor.

No other new declared or non-declared weed species were recorded at Ichthys LNG during the reporting period. Declared weed species previously identified during weed surveys include:

- perennial mission grass (not detected in 2023)
- neem tree
- flannel weed (not detected in 2023)
- gamba grass
- hyptis/horehound.

Non-declared weed species recorded during the 2023 survey were annual mission grass, stylo, stinking passionfruit, chloris grass and physalis. It is noted that annual mission grass is abundant within the GEP corridor and Section 1888.

The results of the May 2023 weed survey show a slight decrease in the density and distribution of gamba grass across the site since the April 2022 survey. However, whilst the total infestation of gamba grass within Section 1888 had reduced from 7,087 m^2 in 2022 to 5,263 m^2 in 2023, the density of the infestation within some areas of Section 1888 has increased to dense monocultures.

Gamba grass distribution has reduced within the Bladin Point road corridor and GEP corridor. Whilst hyptis had decreased considerably within the GEP corridor, infestations within the Bladin Point road corridor had increased since the 2022 survey, from 280 m^2 to 410 m^2 in 2023. Weed maps covering surveyed areas can be found in the weed survey report (Table 5-1).

These findings are generally consistent with operations phase weed monitoring surveys in 2020/21, which recorded gamba grass, annual mission grass, and horehound/hyptis as the weeds with the highest abundance. These weeds were also recorded in the highest abundance during the construction phase weeds monitoring, indicating no significant change in weed species present on the site.

Weeds identified during the weed mapping surveys were communicated to the weed management contractor and managed accordingly (see Section 5.5).

Declared weed infestation trend analysis

A trend analysis for weed results from all surveys was completed (Figure 5-5). Gamba grass infestations decreased slightly during the 2022-2023 wet season. There has been a decrease in both individual gamba grass plants and multi-plant infestations (Survey 8 compared to Survey 7).

Favourable growth conditions over the 2021-22 wet season had resulted in significant patches of hyptis establishing with the GEP corridor and Bladin Point road corridor (reflected in Survey 6 results; Figure 5-5). However, Survey 7 and Survey 8 have recorded a steady decrease in multi-plant infestation. However, individual hyptis plants have increased significantly in Survey 8.

Notably, no perennial mission grass was recorded in Survey 8. Patches of this species are a very high priority for control.

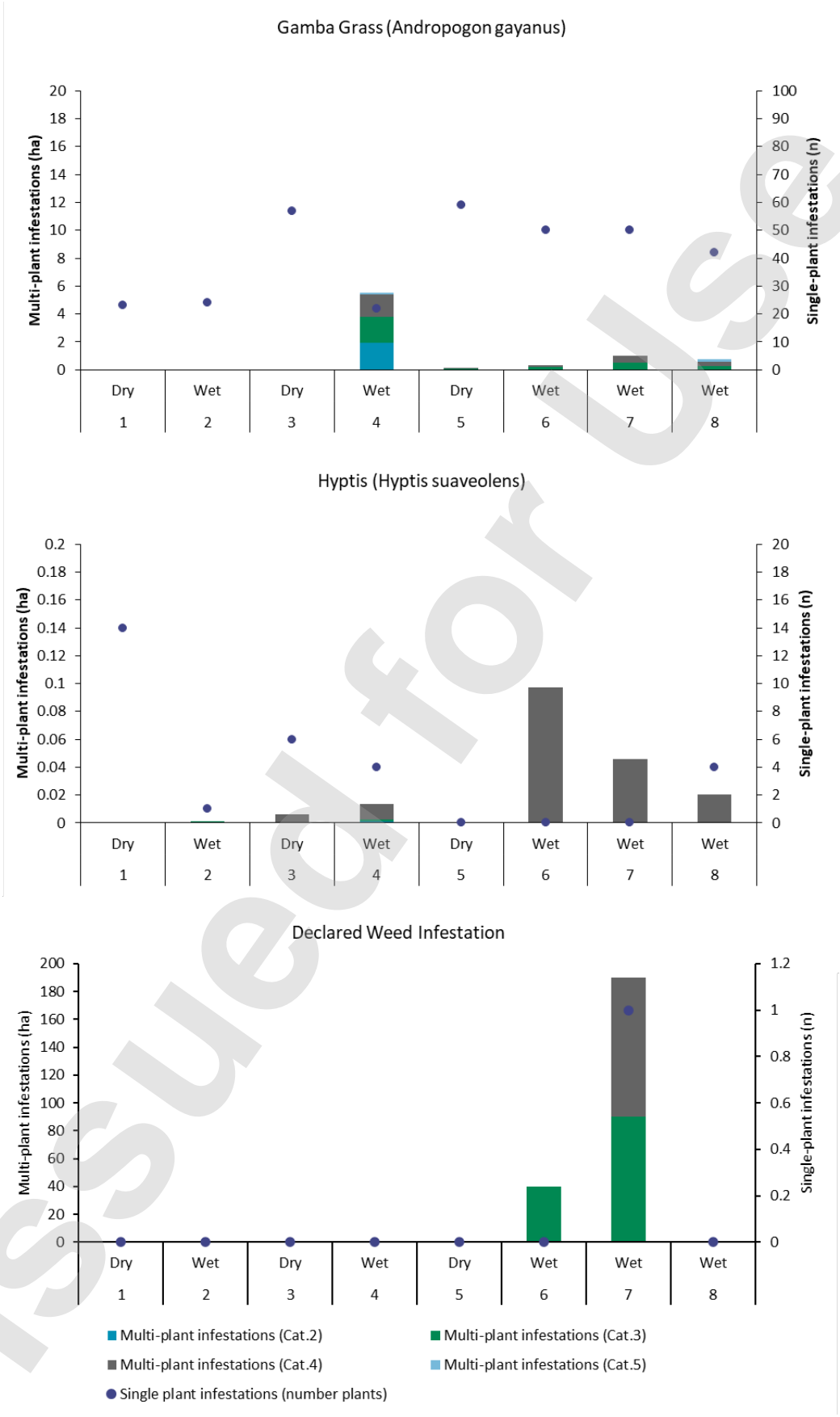

Figure 5-5: Comparison of declared weed infestations between AEMR reporting periods

5.4.3 Program rationalisation

No changes to weed surveys is proposed. The current annual weed surveys will still allow INPEX to fulfil its commitments under the OEMP and *Weeds Management Act* (NT).

5.5 Weed management

5.5.1 Method overview

Weed control at the site was undertaken and managed by a weed management contractor during the reporting period. Vegetation control at the site occurred along the fence lines, drains, inside the facility and along the GEP corridor, including the Section 1888 laydown yard. Weed control was conducted in the wet season through spray application of herbicides, boom spray, quick-spray handguns, and backpacks.

Total vegetation and woody weed control was undertaken through hand pulling and slashing along the GEP corridor.

5.5.2 Results and discussion

Overall weed management measures undertaken during the reporting period were adequate. It is recommended that a gamba grass treatment program is implemented in Section 1888, the operations area and the production area immediately following each wet season until it has been sufficiently controlled.

5.5.3 Program rationalisation

No changes are proposed to weed management at Ichthys LNG.

5.6 Vegetation rehabilitation monitoring

The key objectives of the vegetation rehabilitation monitoring were to:

- monitor native vegetation recovery; and
- provide management advice to ensure the establishment of stable, self-sustaining vegetation communities.

A summary of the vegetation rehabilitation monitoring (also known as vegetation surveillance) for the reporting period is detailed in Section 5.6.2. Table 5-1 provides a summary of surveys completed during the reporting period.

Table 5-3: Vegetation rehabilitation survey details

Survey	Date	Report	INPEX Doc #
Survey 4	14-15 June 2023	Vegetation Surveillance Report No. 4	L290-AH-REP-70058

5.6.1 Method overview

A vegetation surveillance survey (Survey 4) was performed in accordance with the Northern Territory guidelines and field methodology for vegetation survey and mapping (Brocklehurst et al. 2007). Key parameters assessed during the surveillance survey are shown in Table 5-4. Rehabilitation categories (discussed in Section 5.6.2) are provided in Table 5-5. The area surveyed are shown in Figure 5-6.

Table 5-4: Vegetation surveillance parameters

Key Parameter	Descriptor
Vegetation community description	Describing remnant vegetation communities immediately adjacent to the GEP corridor
Physical locations	Mapping the distribution of vegetation communities within the GEP corridor
Rehabilitation progress	Assessing and classifying rehabilitation progress of areas within the GEP corridor
Soil erosion	Recording any areas of active soil erosion in rehabilitation areas
Vegetation on rehabilitated areas (VS01 – VS05 and VS10)	Observations recorded at each site included: • Plant species composition, cover, and abundance (including weeds) • Vegetation structure • Recruitment of perennial species • Soil and land surface characteristics • Disturbances such as grazing, erosion and fire.

Table 5-5: Rehabilitation categories – assessment criteria

Vegetation Community	Category 1	Category 2	Category 3
Low Eucalypt woodland	• Annual grassland / herb land • Total vegetation cover less than 30% (post wet season, with large bare areas) • Tree or shrub seedlings or juveniles absent • Large continuous areas of bare ground • Low litter levels • Surface structures very sparse or absent • Evidence of accelerated surface run-off	• *Acacia* spp. low sparse shrubland • Scattered individuals or small patches of juveniles and seedings of Acacia and other native shrub species • Evidence of more than one shrub recruitment event i.e., mixed age stands • Moderate litter levels • Stable soil surface	• Mixed Acacia shrubland • Several life forms presenting including shrubs, woody forbs, annual and perennial grasses • Evidence of several recruitment events of perennial species i.e., a range of cohorts • Continuous litter cover • No evidence of accelerated surface water run-off
Low mangrove closed forest	• Seedlings or juvenile mangroves absent or present as very scattered individuals of single age cohort	• Seedlings and juvenile mangroves widespread with canopy cover > 5%	• Moderately dense stands of mangrove juvenile and seedlings with canopy cover >20%

Vegetation Community	Category 1	Category 2	Category 3
		• Usually, evidence of more than one recruitment event, as shown by multiple age-classes	• Evidence of several mangrove recruitment events i.e., a range of age cohorts are present
Low *Melaleuca* sp. open woodland / sedgeland	• Sparse patchy cover of sedges • Melaleuca sp. seedlings or juveniles absent or present as very scattered individuals of single age cohort • Evidence of accelerated surface water run-off	• Open sedgeland with < 50% cover with small discontinuous bare patches. • Scattered individuals or sparse patches of Melaleuca sp. and other native perennials on slightly elevated ground (*Note establishment of native perennial tree and shrub species were not observed during Survey No. 2) • Moderate litter levels	• Elevated areas with Melaleuca shrubland • Evidence of several recruitment events of perennial species i.e., a range of age cohorts • Extensive litter cover • Stable soil surface with no accelerated surface run-off
Low Monsoon vine forest	• Annual grassland/herbland • Total vegetation cover less than 30% (post wet season, with large bare areas) • Tree or shrub seedlings or juveniles absent • Large continuous areas of bare ground • Low litter levels • Surface structures very sparse or absent • Evidence of accelerated surface run-off	• *Acacia* spp. and *Melaleuca* spp. Low sparse shrubland • Scattered individuals or small patches of juveniles and seedings of native shrub species • Evidence of more than one shrub recruitment event i.e., mixed age stands • Moderate litter levels • Stable soil surface	• Mixed *Acacia* spp./*Melaleuca spp*. • shrubland • Several life forms presenting including shrubs, woody forbs, annual grasses, and herbs • Evidence of several recruitment events of perennial species i.e., a range of cohorts • Continuous litter cover • No evidence of accelerated surface water run-off

Figure 5-6: Vegetation surveillance survey area

5.6.2 Results and discussion

The results of Survey 4 indicate that regeneration rates of vegetation within the GEP corridor differs for each of the vegetation communities, as follows:

- *Low eucalyptus woodland (LEW):* When previous survey results (Survey 3) were compared with Survey 4, an increase in the area allocated for category 3 was recorded. Total LEW at categories 1 and 2 have decreased from 0.27 ha (3.5%) to 0.04 ha (0.5%) and 3.27 ha (42.4%) to 2.3 ha (29.5%), respectively; whereas, the total LEW area allocated at category 3 has increased from 4.17 ha (54.1%) to 5.40 ha (69.9%). Since the first survey, category 1 has decreased from 2.76 ha (38.6%) to 0.04 ha (0.5%) and category 3 has increased from 1.55 ha (21.7%) to 5.40 ha (69.9%). This trend of change reveals that there is a successional development occurring within LEW areas. However, Acacia sp. made up most of the new species present, as observed during Survey 2. A small number of Eucalyptus sp. seedlings were observed within the GEP corridor during surveys 3 and 4 and it is anticipated that Eucalyptus sp. will continue to establish from adjacent remnant vegetation. Overall improvement in LEW establishment was recorded along the GEP corridor.
- *Low mangrove closed forest (LMCF):* LMCF rehabilitated communities demonstrated improvement since the previous survey (Survey 3) with categories 2 and 3 increasing from 2.68ha (44.8%) to 3.14 ha (51.4%) and 1.08ha (18.1%) to 1.86ha (30.6%), respectively. Category 1 decreased from 2.22 ha (37.1%) to 1.10 ha (18%), indicating development of the LMCF rehabilitated communities are progressing towards late seral stages (intermediate stage of ecological succession advancing towards the climax community). It is expected that areas originally cleared of the dominant mangrove species, *Ceriops australis*, will remain suitable for the species to re-establish. This is because the environmental conditions associated with the previously cleared land such as salinity, tidal effects, drainage, nutrient and oxygen levels may be suitable for this species to re-establish. This applies also to tidal flat areas that were originally mangroves before clearing of the GEP corridor.
- *Low Melaleuca sp. open woodland/sedgeland*: Results show that the area allocated within rehabilitation category 3 has slightly increased from 0 ha (0%) to 0.12 ha (10.1 %) since Survey 3. In contrast, a decrease in areas of category 2 was recorded in Survey 4 from 0.81 ha (67.5 %) to 0.69 ha (57.4%). This indicates that the area allocated within rehabilitation category 1 did not show a change in structural development to reach the next seral stage (i.e. category 2). Very low seedling recruitment of *Melaleuca* sp. was recorded within areas that most of the rehabilitation areas described as Low Melaleuca sp. Open woodland / sedgeland, and these areas were therefore characterised as category 1. This indicates that rehabilitation areas described as Low Melaleuca sp. open woodland / sedgeland are likely to establish as sedgelands, providing a stable ground cover and opportunity for *Melaleuca* sp. to establish in the future.

- *Low monsoon vine forest:* Results indicate a decrease in category 2 and an increase in category 3 from 0.61 ha (21.7%) to 0.22ha (8.1%) and 1.32 ha (47%) to 1.5 ha (58.6%), respectively. Category 1 has increased slightly from 0.88 ha (31.3%) to 0.89 ha (33.3%). Approximately 68.70 % of the area was allocated within category 2 and 3 in the 2021 survey and the current survey results show that 66.7% of the area were recorded within categories 2 and 3. Therefore, rehabilitation of low monsoon vine forest areas within the GEP corridor has resulted in no change in the area allocated to rehabilitation categories 2 and 3 since the previous survey. New plants of Acacia spp. were the dominant revegetation species recorded within the low monsoon vine forest. Acacia spp. regenerate from long lived dormant soil seed banks and require natural triggers, such high temperature, to break seed dormancy for germination and seedlings recruitment. Therefore, regeneration of Acacia spp. is very slow and there is limited evidence of a successional shift to occur from category 2 to category 3.

The results of Survey No. 4 indicate that natural regeneration is occurring within GEP corridor and that the majority of the GEP corridor is progressing toward a self-sustaining native vegetation community. Since last survey in 2021, there has been an increase from 78.7 % to 86.4% in the total GEP corridor area categorised within either rehabilitation category 2 or category 3. This indicates a progression towards a self-sustaining native vegetation community, dominated by perennial native vegetation species on a stable soil surface. The majority of natural regeneration is within the low eucalypt woodland community, where approximately 99% of area was assessed as either rehabilitation category 2 or category 3.

5.6.3 Program rationalisation

No program rationalisation is proposed for vegetation rehabilitation surveillance. The next proposed survey will occur in 2025.

5.7 Cultural heritage

The objective of cultural heritage surveys is to determine if there has been any interference to cultural heritage sites as a result of Ichthys LNG operations.

5.7.1 Method overview

Visually inspections of cultural heritage sites will be undertaken when required at a frequency determined by the Larrakia Advisory Committee.

5.7.2 Results and discussion

No inspections of heritage site were required during the reporting period. No heritage breaches occurred within the reporting period.

6 WASTE REDUCTION MEASURES

Following the activation of EPL228 in September 2018, the OEMP and supporting waste management documentation were implemented. This involved management of waste in accordance with the INPEX waste management processes and the waste control hierarchy (Figure 6-1).

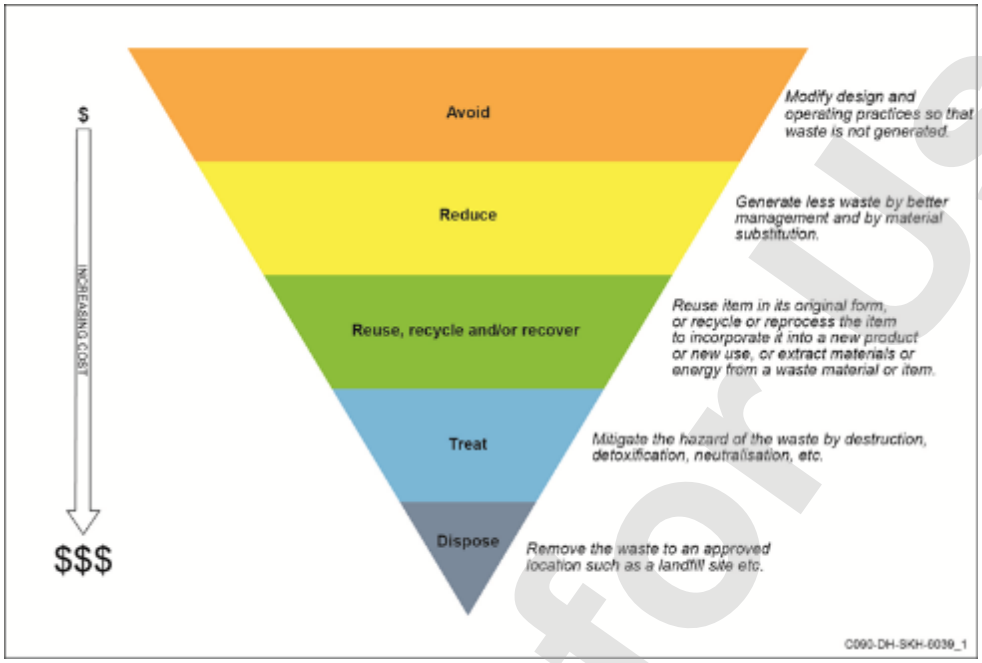

Figure 6-1: INPEX waste control hierarchy

Waste streams at the site are categorised into four broad classes (which include both liquid and solid waste, as outlined in section 3.8.7 of the OEMP):

- recyclable (non-hazardous) waste
- non-recyclable (non-hazardous) waste
- recyclable (hazardous) waste
- non-recyclable (hazardous) waste.

Note, the onsite treatment of wastewater and disposal via the onsite evaporation basin are excluded from reportable waste data (refer to Table 6-1), and only records from licenced waste contractors are used for this waste section.

Solid waste segregation measures involved the placement of various recyclable and non-recyclable waste receptacles around Ichthys LNG, while liquid wastes were segregated into recyclable and non-recyclable streams and then disposed of offsite to suitable treatment and disposal facilities following classification by waste contractors. The expected waste generated by onsite activities and subsequent control measures are detailed further and in Inpex's Onshore Environmental Management Plan L060-AH-PLN-60005 section 3.8.7

Table 6-1 presents a comparison of the waste streams from the 2020-2021 and 2021-2022 reporting periods against the current reporting period (2022-2023). Note, firefighting foam wastewater is included in Table 6-1 as a non-recyclable hazardous waste stream.

Table 6-1: Waste stream data comparison

Waste Stream	2020-2021 (tonnes)	2021-2022 (tonnes)	2022-2023 (tonnes)
Recyclable / non-hazardous	304.4	1126.4	459.7
Recyclable / hazardous	6.4	10.4	15.7
Non-recyclable / non-hazardous	2413.2	2090.5	4328.3
Non-recyclable / hazardous	1122.2	626.0	1196.1

The reporting period 2021-2022 provided an anomality in waste classified as recyclables/non-hazardous as it captured the processing of recyclable steel associated with remedial works onsite during that period. This has is reflected when comparing the 2021-2022 & 2022-2023 reporting period data in the table above. The reporting period 2022-2023 saw a decrease in comparison to 2021-2022 due to the steel recycling event(s) mentioned previously. The 2022-2023 reporting period experienced an increase in non-recyclable waste (both hazardous & non-hazardous) The significant increase of non-recyclable/hazardous waste is related to the shut down at the start of the reporting period and addition of an ablution block requiring removal of waste offsite. The main waste reduction measure implemented during the reporting period (i.e. reduce waste being disposed or treated offsite) was through the use of the onsite evaporation basin. The evaporation basin is designed to handle low level chemical and hydrocarbon contaminated water generated at Ichthys LNG, while inter-site transfers to the wastewater treatment plants took place. Approximately 5,168 tonnes of liquid waste were transferred to the evaporation basin and 652 tonnes of wastewater transferred to the various water treatment plants during the reporting period, which resulted in this liquid waste not being taken offsite for treatment and disposal.

Site wide waste reduction initiatives are implemented via the Waste Management Standard (0000-AH-STD-600047) which applies to all waste streams onsite. For the 2022-2023 reporting period, measures were put in place to minimise the amount of liquid waste being generated at Ichthys LNG. This included the capture and storage of chemical waste streams to avoid the mixture of waste streams and rainwater runoff from Ichthys LNG. This prevents the generation of large volumes of wastewater predominately in the AGRU of each LNG train, where amine is used as a solvent to extract acid gases (including carbon dioxide).

Although not directly related to solid and liquid waste, there was a significant amount energy recovery that occurred at the site through the use of the waste heat recovery systems. Heat recovery units are located on the GE Frame 7 gas turbine stacks, which capture the heat of the turbine exhaust and then transfer the energy to the site heating medium system. A similar heat transfer method is also used in the CCPP, where the exhaust heat form the GE Frame 6 turbine stacks used to generate steam, which is then transferred into energy in the steam turbines. Use of the waste heat recovery systems reduce the overall fuel consumption and air emissions.

7 PROGRAM RATIONALISATION AND FUTURE SURVEYS SUMMARY

There were no proposed recommendations for changes to monitoring programs and future monitoring will be undertaken in accordance with the current OEMP and EPL228. The proposed next survey dates are outlined below in Table 7-1.

Table 7-1 Survey forecast for future monitoring periods

Survey/Data Collection Scope	Frequency	Previous Survey	Next Survey
Commingled treated effluent	Monthly	June 2023	July 2023 – June 2024
Harbour sediment	Biennial	July 2022	July 2024
Total emissions to air	Annual	June 2023	June 2024
Point source emissions to air	Annual	October 2022	October 2023
Dark smoke events	Ad-hoc	n/a	n/a
Groundwater quality	Bi-annual	April 2023	October 2023 April 2024
Mangrove health and intertidal sediments	Biennial	June 2022	April 2024
Nearshore marine pests	Monthly	June 2023	July 2023 – June 2024
Introduced terrestrial fauna	Annual	June 2023	April 2024
Weed mapping	Annual	April 2023	April 2024
Weed management	Annual – as required	June 2023	~April 2024
Vegetation rehabilitation monitoring	Biennial	June 2023	June 2025
Cultural heritage	Ad-hoc	n/a	n/a

8 REFERENCES

ANZECC/ARMCANZ—*see* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

ANZG—*see* Australian and New Zealand Governments and Australian State and Territory Governments

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. 2000. *Australian and New Zealand guidelines for fresh and marine water quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

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Department of Natural Resources, Environment, the Arts and Sport. 2010. *Water Quality Objectives for the Darwin Harbour Region*. Background Document. February 2010. Darwin.

FSANZ – *see* Food Standards Australia and New Zealand

Golding, L.A., Angel, B.M., Batley, G.E., Apte, S.C., Krassoi, R. and Doyle, C.J. 2015. Derivation of a Water Quality Guideline for Aluminium in Marine Waters. *Environmental Toxicology and Chemistry*. 34(1): 141-151.

Greencap. 2016. *Environmental Impact Monitoring Program*. Report prepared for JKC Australia LNG Pty Ltd by Greencap Ltd, Winnellie, NT.

Ministry of Infrastructure and the Environment. 2009. *Soil Remediation Circular 2009*. Amsterdam, The Netherlands: Author

Munksgaard, N.C. 2013. *Recommendations for sampling and analysis of Darwin Harbour sediment*. Environmental Chemistry and Microbiology Unit (ECMU) Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin, NT.

Munksgaard, N.C., Kaestli, M., Gibb, K., Dostine, P. and Townsend, S. 2013. *Darwin Harbour sediment survey 2012*. Environmental Chemistry and Microbiology Unit (ECMU) Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin, NT.

Northern Territory Environment Protection Authority. 2013. Guidelines for the environmental assessment of marine dredging in the Northern Territory. Northern Territory Environment Protection Authority, Darwin, NT.

NRETAS—see Department of Natural Resources, Environment, the Arts and Sport

NT EPA—see Northern Territory Environment Protection Authority

Padovan, A.V. 2003. *Darwin Harbour water and sediment quality. Marine and Estuarine Environments of Darwin Harbour*. Proceeding of the Darwin Harbour Public Presentations, February 2003.

APPENDIX A: NT GUIDELINE FOR ENVIRONMENTAL REPORTING

NT Guideline for Environmental Reporting	NT Guideline Information	AEMR Reference
Title page	The title page should include: • report name • reporting period (e.g., October 2014–October 2015) • date of submission • version number • where relevant, licence/approval number, or reference to other document the report is being submitted in relation to (e.g., environmental impact statement, pollution abatement notice) • details of report author, including company details.	Title page and Section 1.
Executive summary	The executive summary should succinctly summarise each section of the report, and in particular, the findings of the report.	Executive summary.
Monitoring objective	The monitoring objective(s) should be clearly stated in order to enable the results of monitoring to be assessed in the context of the objectives. Note, where monitoring is linked to a licence or approval, the objectives of monitoring: • may already be specified in an approved monitoring plan, or • may simply be the specific conditions on monitoring included in the • licence/approval that state monitoring point locations, analytes, analysis type, frequency, and limits/trigger values.	Each section includes a subsection with monitoring objectives for each monitoring program.
Monitoring method	*Where there is an approved monitoring plan* Provide details of the approved plan (title, version number, date of submission). *Where there is not an approved monitoring plan* Provide details including: • current map showing sampling locations (including control/reference sites), discharge/emission points, major infrastructure, sensitive environmental receptors, key, scale bar and north arrow • a description of the receiving environment, including environmentally sensitive receptors and significant features • a description of sampling and analysis methods, including detail on reasons for selection of sampling locations (e.g., random stratified), assumptions and deviations from standard sampling/analysis methods1	Each section includes a subsection with monitoring methods for each monitoring program.

NT Guideline for Environmental Reporting	NT Guideline Information	AEMR Reference
	• factors that may affect variability in monitoring results (e.g., tidal movement, climate, fauna migration, peak production months).	

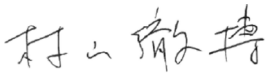
Monitoring results–presentation	The clear and concise presentation of monitoring results is a critical component of a monitoring report.
	When presenting results, it is important to ensure that:
	• current results are presented in a table and graph
	• results are presented along with:
	  • units
	  • assessment criteria (e.g., limits/trigger values specified in licences/approvals, or in relevant standards or guidelines2)
	  • analysis type (e.g., for filtered/unfiltered with filter pore size, five-day or
	  • three-day biological oxygen demand, wet or dry weights)
	  • analytical methods
	  • limit of reporting (LOR), or level of precision for results obtained from
	  • field instruments
	  • measures of uncertainty
	• necessary calculations have been made, to compare data with assessment
	• criteria (e.g., calculation of medians, means, running averages and loads)
	• modification calculations (such as for hardness) have been made using the modifying parameter recorded at the time of sampling
	• all results that exceed the assessment criteria are clearly highlighted
	• summary of previous results (sufficient to highlight trends – usually a minimum of 2–5 years data) is included.
		Each section includes a subsection with monitoring results and discussion for each monitoring program.

Monitoring results–quality assurance/ quality control (QA/QC) evaluation	Results presented in the monitoring report should be reviewed for data completeness, accuracy, and precision. Some typical QA/QC questions include: • for completeness – were all samples taken at the correct location and frequency? • for quality control – _ were all samples collected, preserved in accordance with the specified sampling method or standard sampling methods? • were calibration checks made and were results within an acceptable range? • was analysis undertaken in accordance with relevant national standards (such as accredited under the National Association of Testing Authorities)?	Monitoring plans (referenced in the method overview section) include QA/QC processes.

NT Guideline for Environmental Reporting	NT Guideline Information	AEMR Reference
Discussion and interpretation of results	This section should include: • discussion of results in context with the monitoring objective(s) • discussion of results where assessment criteria were exceeded, including likely cause of exceedances and likelihood of further exceedances • discussion of trends (consideration of spatial and temporal trends in comparison to previous monitoring data) • discussion of anomalous results, including likely cause • statistical analysis where appropriate • a table of non-conformances with monitoring method.	Each section includes a subsection with monitoring results and discussion for each monitoring program
Conclusion and proposed actions	In this section the submitter of an environmental monitoring report must confirm that the report is true and accurate. Where the report relates to a licence/approval, confirmation must be provided by a person(s) authorised to legally represent the holder of the licence/approval. The wording for this section should be: *I [NAME AND POSITION], 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.* Note: significant penalties may apply where it is demonstrated that false or misleading information has been supplied to the NT EPA.	APPENDIX B:
Abbreviations	Use of abbreviation should be minimised. However, if they are used to improve readability, this section should specify all abbreviations used in the report.	Throughout AEMR
References	If information (facts, findings etc.) from external documents is to be included in the report, the information must be referenced. If references are from documents that are not freely available (e.g., internal reports, mine management plans) then such documents will need to be provided to the NT EPA on request.	Throughout AEMR
Appendices	Appendices should be used for information that is too detailed or distracting to be included in the main body of the report (such as raw data tables, laboratory reports, QA/QC data).	Appendices

APPENDIX B: EPL228 AEMR 2022-2023 CERTIFICATION

B.1 INPEX

INPEX	I, Tetsuhiro Murayama (President Director, Ichthys LNG Pty Ltd, Australia) confirm that to the best of my knowledge and ability all the information provided in the *EPL228 Annual Environmental Monitoring Report 2022-2023* (L060-AH-REP-70055) is true and accurate.
Name	Tetsuhiro Murayama
Position	President Director, Ichthys LNG Pty Ltd
Signature	
Date	07 September 2023

B.2 Qualified Professional

ERM

Level 3, 1 Havelock St
West Perth WA 6005

Telephone: +61 8 6467 1600

www.erm.com

INPEX Corporation
Ben Davis
Senior Environmental Advisor
Onshore Operations
144 Wickham Road
Wickham NT 0822

11 September 2023

Reference: ERM 0565508

Dear Ben

Subject: 2022-2023 AEMR Review and certification report

Environmental Resources Management Australia Pty. Ltd (ERM) was engaged by INPEX Corporation (INPEX) to undertake an independent review of the Ichthys LNG Plant's Annual Environmental Monitoring Report (AEMR) by Qualified Professionals[1]. This report documents the review process, identifies the issues raised and their resolution, resulting in a statement of verification and Statutory Declaration as required by the Northern Territory EPA (NT EPA).

The scope of the review is pursuant to Condition 87 of the Environmental Protection Licence (EPL) 228-04/Condition 76 of EPL 228-05 (EPL228-05 came into effect on 13.12.2022), stated as follows:

87 The Annual Environmental Monitoring Report must:

87.1 report on monitoring required under this licence;

87.2 summarise performance of the authorised discharge to water, compared to the discharge limits and trigger values specified in Table 3 in Appendix 2;

87.3 summarise performance of the authorised emissions to air, compared to the emission limits and targets specified in Table 5 in Appendix 3, when the fuel burning or combustion facilities for the Scheduled Activity have operated under normal and maximum operating conditions for the annual period;

87.4 summarise operating conditions of each emission source and the resulting air emission quality;

87.5 provide total emissions to air in tonnes per year for the air quality parameters listed in Table 6 in Appendix 3;

87.6 assess the contribution of the authorised emissions on the Darwin region ambient air quality during periods not affected by bushfire smoke for Wet and Dry seasons;

87.7 report on outcomes of the REMP monitoring and assessment;

87.8 summarise measures taken to reduce waste;

87.9 consider the NT EPA Guideline for Reporting on Environmental Monitoring

87.10 be reviewed by Qualified Professional(s); and

87.11 be provided to the NT EPA with the Qualified Professional(s) written, certified review(s) of the Annual Environmental Monitoring Report.

[1] A '*qualified professional*' as described by the EPL228-01 is a person who has professional qualifications, training or skills or experience relevant to the nominated subject matters and can give authoritative assessment, advice and analysis about performance relevant to the subject matters using relevant protocols, standards, methods or literature.

The purpose of the qualified professional review of the AEMR is to provide an independent assessment verifying that the AEMR is compliant with the conditions of EPL228-04/05. The review was undertaken by three qualified professionals as deemed appropriate for the content of the AEMR. The qualified professionals are listed in Table 1.

Table 1. Qualified professionals

Area of expertise	Qualified professional
Discharges to Water	Ken Kiefer
Air Quality	Christopher Thomson
Waste	Ronald Ho

Each of the qualified professionals individually reviewed the Draft AEMR (Revision B) dated 11 August 2023 with respect to the EPL228-04 condition 87/Condition 76 EPL228-05 (as stated above) and the relevant corresponding area of expertise. The comments raised were recorded in a comments register which is appended to this report in **Annex A**. The register was provided to INPEX seeking comment on how the identified issues will be closed out. INPEX resubmitted the revised AEMR (Revision 0) dated 4 September 2023 to ERM for review, which incorporated the agreed changes and the comments register cross-referenced with the revised sections of the AEMR.

ERM was satisfied that each of the responses had been appropriately incorporated into the updated revision and the comments were closed out. Therefore the following statement of verification was made and signed by each of the qualified professionals who undertook the review.

Statement of verification: Based on the review as outlined in this report, ERM confirms that INPEX responded to all comments raised. ERM has reviewed INPEX responses to the comments provided and is satisfied that the content of the AEMR comply with Condition 87 of the EPL228-04/Condition 76 of the EPL228-05 for the 2022-2023 period.		
Area of expertise	**Qualified professional**	**Qualified profession Signatures**
Discharges to Water	Ken Kiefer	
Air Quality	Christopher Thomson	
Waste	Ronald Ho	

Yours sincerely,

For Environmental Resources Management Australia Pty. Ltd.

Christopher Thomson
Consulting Director

Paul Fridell
Partner

Annex A: Comments Register
Annex B: Statutory Declarations
Annex C: Qualified Professionals – profile and CVs

ANNEX A: - COMMENTS REGISTER

COMMENTS REGISTER - QUALIFIED PROFESSIONALS REVIEW: AEMR 2022/2023

Contract Number	INPEX PO 4500135825 (ERM proposal P0550625)
Reviewer	ERM
Document Name	EPL228 Annual Environmental Monitoring Report 2022-2023
Company Document No#	L060-AH-REP-70055
Document Revision No# / Date	Revision 0 / 04 Sep 2023

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
Discharges to Water (Qualified Professional – Ken Kiefer)				
1	Table 2-1 Table C.1	Monthly sampling results are missing for several of the bacterial parameters for the 10/10/2022 and 1402/2023 samples. Clarify if there are results but just not added to the table or was there an issue with sampling or laboratory analysis. From the sampling and analysis for those parameters shortly after the monthly sample and before the next monthly sample does indicates there was some issue with these monthly samples for those parameters. Clarifying in Table 2-1 or elsewhere if the samples on 20/10/2022 and 16/02/2023 were analysed for the bacterial parameters were based on exceedances or some other issue in sampling/analysis.	Footnote added to provide clarity about missed samples.	Checked final report, comment closed.
2	Table 2-3 10/10/2022 TN Exceedance	The note comments on investigation activities in September, pre-dating the exceedance reported on 11/10/2022. Is this typo or was there ongoing maintenance and investigations given previous TN exceedances	Re-worded to provide clarity	Checked final report, comment closed.

COMMENTS REGISTER - QUALIFIED PROFESSIONALS REVIEW: AEMR 2022/2023

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
3	Table 2-3 20/10/2022 Faecal Coliforms Exceedance	This statement seems to be contradictory. *"both E. coli and Enterococci are used as indicators of human faecal contamination which is not the case in this scenario as confirmed by subsequent testing for e.coli".* should it read- "both faecal coliform and Enterococci are used…."?	Replaced e.coli with faecal coliform	Checked final report, comment closed.
4	Table 2-3 Faecal Coliforms Exceedance	The discussion and validation of the source of the faecal coliforms exceedances would be helped with providing results from the testing from AOC basin (L-750-SU-403) and sewage treatment plant (L-750-SU-009) along with the results from 750-SC-003.	• Results added to 20/10/22 event • Results added to 14/12/22 event Note if table numbering required for additional results	Checked final report, comment closed.
5	Section 2.1.3 Faecal coliform exceedances	ERM agrees with INPEX's determination that the Faecal coliform exceedances are not related to the sewage treatment plant, given: • *e. coli* and Enterococci were consistently within the discharge limits; • wide variation between Faecal coliform results *e. coli* and Enterococci and the laboratory notes that- "The test of faecal coliforms (thermotolerant) does report some species that may not be of faecal origin" indicate non-sewage sources; • INPEX having identified likely source material within the AOC drainage system;	Noted.	Checked final report, comment closed.

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
		• On going monitoring will be done to further understand the source and actions to address. Given the issues of the Faecal coliform creating false positives for e. coli and Enterococci additional review of the method should be considered. Similarly, once the source is identified and further characterised a review of the need for the Faecal coliform monitoring is warranted given e. coli and Enterococci are also monitored. This comment does not require an edit to this AEMR but provides comment on next steps.		
Air Quality (Qualified Professional – Nathalie Tomson/Chris Thomson)				
1	Page x	Footnote – should this read '13 December 2022' rather than '13 December 2023'?	Footnote amended	Checked final report, comment closed.
2	Page 32, Section 3.2, Paragraph 1	Text states '…, which requires annual monitoring'. However, for Release Point Numbers A13-2, A13-3, A14-2, and A14-3, monitoring frequency appears to be monthly (Appendix 3, Table 5 of EPL228-05). Suggest rewording to 'which requires annual monitoring of most emission points, monthly monitoring of hot venting, and hydrocarbons monitoring for all flare events.'	Replaced text with suggested phrase	Checked final report, comment closed.
3	Page 33, Section 3.2.1, Paragraph 1	Change '13-point' to '13 point'	Removed "-"	Checked final report,

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
				comment closed.
4	Page 33, Section 3.2.1, Paragraph 3	Amend to "show": 'Table 3-3 and Table 3-4 shows…'. Also, add a reference to the table numbers in the EPL228-05 (i.e., Appendix 3, Table 5 and Table 6 respectively, of EPL228-05) either on this paragraph, in the respective table headings or as table notes.	Amended to suit	Checked final report, comment closed.
5	Page 33, Section 3.2.1, First bullet point	Remove the comma.	Comma removed	Checked final report, comment closed.
6	Page 34, Table 3-3	Add reference conditions to second column from the right.	Reference conditions added	Checked final report, comment closed.
7	Page 35, Table 3-4	Parameters 'N_2O, Hg, $PM_{2.5}$, PM_{10}' are not listed in the EPL228-05. Is there a reason why they are monitored?	Required to test these under previous EPL 288 – 04 revision of license, therefore we have left in	Checked final report, comment closed.
		In the 'Parameter' column of the Release Point Number A15, CO is subscripted.	Amended	Checked final report, comment closed.
		The table note is no longer applicable:	Footnote removed	Checked final report,

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
		'* If AGRU off gas quality can be demonstrated to be predictable and does not vary greatly when the by-pass of the incinerator occurs, the NT EPA may approve quarterly sampling for first 18 months after commencement of Steady-State, then annual'.		comment closed.
8	Page 37, Section 3.2.2, first paragraph	Extra ':' after 'APPENDIX'	This is a formatting issue without templates and cannot be amended.	Checked final report, comment closed.
9	Page 37, Section 3.2.2	While this is noted in Method section 3.2.1, an explanation here as to why Release Point Numbers A5-1 to A9-1 were not monitored would be helpful.	Added text into S 3.2.2 with an explanation of why port numbers A51-A91 were not tested	Checked final report, comment closed.
10	Page 37, Section 3.2.2, Paragraph 3	The statement 'No monitoring results exceeded concentration limit criteria' seems to repeat the first statement of the section: 'All results for the permanent plant were below limit criteria provided in Appendix 3, Table 5 of EPL228 (Table 3-3)'.	repeated comment deleted	Checked final report, comment closed.
11	Page 37, Section 3.2.2, Paragraph 4	Amend to "provide": 'Figure 3-4 and Figure 3-5 provided…'	Amended	Checked final report, comment closed.
12	Page 37, Section 3.2.2, Paragraphs 6 and 7	Write 'Train 1 and Train 2', and 'Management of Change' with consistent capitalising.	Amended	Checked final report, comment closed.

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No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
13	Page 39, Section 3.3, Paragraph 1	Pluralise incinerators/were: 'As stated above the acid gas incinerator for both LNG Train 1 and LNG Train 2 was offline from December 2022'.	Pluralised	Checked final report, comment closed.
14	Pages 39 and 40, Table 3-6	There are no monitoring results for Release Point Numbers A5-1 to A9-1, so a status other than 'Acceptable' would be more appropriate (n/a?).	Status changed	Checked final report, comment closed.
15	Page 40, Table 3-6	Delete rows for Release Point Numbers A10, A11 and A12.	Deleted	Checked final report, comment closed.
16	Page 40, Section 3-4, Heading and Paragraph	Use "Dark smoke" with no hyphen for consistency.	Hyphen removed	Checked final report, comment closed.
17	Page 69, Appendix B Header	Fix '2022-2023'.	Amended	Checked final report, comment closed.
18	Page 76, Appendix D, Table D.1	Use subscript on $\%O_2$ throughout the table.	Amended	Checked final report, comment closed.

COMMENTS REGISTER - QUALIFIED PROFESSIONALS REVIEW: AEMR 2022/2023

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
Waste (Qualified Professional – Ronald Ho)				
1	Licence Condition 21 – Waste Management Plan (WMP)	Clause 21.1 and 21.2 of the EPA licence (EPL228-05) stated that the WMP must "include description of activities that may generate waste" and "include the types and amounts of wastes generated by Scheduled Activity". It would be beneficial to reference section 5.7 of the OEMP in the AEMR so the readers know where to find the activities and types of waste that are typically generated on site.	Reference to OEMP waste control section added to AEMR.	Checked final report, comment closed.
2	Table 6-1, Section 6	The title of the table still reads 'Table 6 1: Waste stream data comparison 2019-2020 and 2021-2022'. It should read 'Table 6 1: Waste stream data comparison between 2020-2021 and 2022-2023".	Removed nominated years from heading to assist in clarity. years are nominated within table	Checked final report, comment closed.
3	Table 6-1, Section 6	The tonnage of "Non-recyclable / non-hazardous" waste in 2022-2023 has more than doubled from 2021-2022 while the "Recyclable / non-hazardous" has more than halved comparing the two period. Could INPEX please elaborate on the change on the increase of non-recyclable waste and reduction in recyclable waste? Was that due to the type of waste being handled? Please also provide more elaboration/context on the increase tonnage of non-recyclable/hazardous waste. If looking at the numbers only, there was an apparent trend of decrease in recyclables captured at the site in 2022-2023.	Explanation of table data added	Checked final report, comment closed.
4	Table 6-1, Section 6	Could INEPX please clarify/confirm that "recyclable" refers to the tonnage of materials that were actually recycled, rather	Yes – the amount of waste classified as recyclable was recycled and can be traced via	Noted, accepted, there is no

No.	Context	Reviewer Comment/Recommendation	INPEX Response	ERM response
		than the tonnage of waste identified as recyclables but not actually all recycled?	data from onsite waste contractor	change to report.
5	"Solid waste segregation measures involved the placement of various recyclable and non-recyclable waste receptacles around Ichthys LNG" , *Section 6*	Non-recyclable hazardous solid wastes could have been reduced, treated or disposed. Any further details that could be provided here? Any good waste reduction or avoidance practices should be discussed here if available. Currently the waste reduction measures are predominantly focused on liquid waste in the 2022-2023 AEMR.	Have amended text to reflect initiatives completed under the Waste Management Standard doc.	Checked final report, comment closed.
6	*General Comment, Section 6*	According to the OEMP, it is understood that the non-recyclable waste was either transported to landfill or incineration facilities. Some of the landfill sites in NT/WA have landfill gas-to-energy facilities. INPEX is recommended to check whether the landfill(s) receiving INPEX's non-recyclable waste has energy-from-landfill gas or energy-from-waste capability. If they do have such capability, it is recommended to document that in the AEMR. Following the waste hierarchy, where possible, INPEX is recommended to choose a disposal facility that have the capability to recover energy from waste.	Noted	Noted, accepted, there is no change to report.

ANNEX B: - STATUTORY DECLARATIONS

THE NORTHERN TERRITORY OF AUSTRALIA

STATUTORY DECLARATION

(1) Insert full name and address of person making declaration

I, Kenneth Kiefer of Environmental Resources Management Australia Pty Ltd located at Level 14, 207 Ken St., Sydney, New South Wales 2000.

(2) Here insert the matter declared to, either directly following the word "declare" or, if the matter is lengthy, insert the words "äs follows" and thereafter set out the matter in numbered paragraphs

solemnly and sincerely declare that the results are accurate to the best of my knowledge or belief and that I have not included in the results information that I know or suspect to be false or misleading or failed to include in the report information that I know to be relevant.

This declaration is true and I know it is an offence to make a statutory declaration knowing it is false in a material particular.

Declared at Sydney on the 8th day of September 2023.

(3) Signature of the person making the declaration

.....

(4) Signature of the person before whom the declaration is made

Witnessed by:

(5) Here insert full name of person before whom the declaration is made, legibly written, typed or stamped

JOE FERRINO

.....

(6) Here insert contact address or telephone number of person before whom the declaration is made

.....

Tel. 0424 970 468

NOTE: This declaration may be witnessed by any person who is at least 18 (eighteen) years of age.

NOTE: This written statutory declaration must comply with Part 4 of the *Oaths Affidavits and Declarations Act.*

NOTE: Making a declaration knowing it is false in a material particular is an offence for which you may be fined or imprisoned.

THE NORTHERN TERRITORY OF AUSTRALIA

STATUTORY DECLARATION

(1) Insert full name and address of person making declaration

I, Christopher James Thomson of Environmental Resources Management Australia Pty Ltd located at Level 3, 1 Havelock St, West Perth, Western Australia 6005.

(2) Here insert the matter declared to, either directly following the word "declare" or, if the matter is lengthy, insert the words "äs follows" and thereafter set out the matter in numbered paragraphs

solemnly and sincerely declare that the results are accurate to the best of my knowledge or belief and that I have not included in the results information that I know or suspect to be false or misleading or failed to include in the report information that I know to be relevant.

This declaration is true and I know it is an offence to make a statutory declaration knowing it is false in a material particular.

Declared at Perth on the 8th day of September 2023.

(3) Signature of the person making the declaration

.....

(4) Signature of the person before whom the declaration is made

Witnessed by:

.....

(5) Here insert full name of person before whom the declaration is made, legibly written, typed or stamped

Julie Ophel

(6) Here insert contact address or telephone number of person before whom the declaration is made

Tel. 0415 265 087

NOTE: This declaration may be witnessed by any person who is at least 18 (eighteen) years of age.

NOTE: This written statutory declaration must comply with Part 4 of the *Oaths Affidavits and Declarations Act.*

NOTE: Making a declaration knowing it is false in a material particular is an offence for which you may be fined or imprisoned.

THE NORTHERN TERRITORY OF AUSTRALIA

STATUTORY DECLARATION

(1) Insert full name and address of person making declaration

I, Long-Hin Ronald Ho of Environmental Resources Management Australia Pty Ltd located at Level 8, 501 Swanston Street, Melbourne, VIC 3000.

(2) Here insert the matter declared to, either directly following the word "declare" or, if the matter is lengthy, insert the words "as follows" and thereafter set out the matter in numbered paragraphs

solemnly and sincerely declare that the results are accurate to the best of my knowledge or belief and that I have not included in the results information that I know or suspect to be false or misleading or failed to include in the report information that I know to be relevant.

This declaration is true and I know it is an offence to make a statutory declaration knowing it is false in a material particular.

Declared at Melbourne on the 8th day of September 2023.

(3) Signature of the person making the declaration

.....

(4) Signature of the person before whom the declaration is made

Witnessed by:

.....

(5) Here insert full name of person before whom the declaration is made, legibly written, typed or stamped

Nicholas Zajicek

.....

(6) Here insert contact address or telephone number of person before whom the declaration is made

Tel. +61 9696 8011

NOTE: This declaration may be witnessed by any person who is at least 18 (eighteen) years of age.

NOTE: This written statutory declaration must comply with Part 4 of the *Oaths Affidavits and Declarations Act.*

NOTE: Making a declaration knowing it is false in a material particular is an offence for which you may be fined or imprisoned.

ANNEX C: - QUALIFIED PROFESSIONAL PROFILE AND CV

Air Quality

Christopher Thomson (Air Quality Qualified Professional)

Chris is a Principal Environmental Scientist and has gained his 20+ years' experience in Australia and internationally. His oil and gas experience is highlighted by being seconded as the environment advisor to the Chevron's Central Environment team for Wheatstone, with a focus on streamlining the air quality monitoring scope for the project, whilst maintaining compliance. He was also the air quality lead for the baseline component of the INPEX Masela Project in rural Indonesia. A role that included the planning, development and execution of the air quality monitoring programme, including reporting in accordance with IFC requirements and coordinating the efforts of an international team.

Chris led the preparation of the Ichthys LNG Plant's air quality monitoring plan, and participated in the annual statutory audit for the Ichthys LNG facility in October 2019, providing a focus on the air quality components of the site's operating licence. He also undertook the review of the Ichthys AEMR and OEMP for the 2018/2019 and the AEMR review and endorsement for the 2019/2020-2022/2023 periods of operations. These opportunities have provided Chris with a deeper understanding of the operations of the plant and an appreciation of the project's performance.

Water

Ken Kiefer (Water Quality - Qualified Professional)

Ken has over 20 years of experience in the risk assessment and environmental toxicology. He is currently the ERM global risk assessment technical community leader. Ken has experience quantitative health risk assessments for the management of water discharges to the environment to meet a range of client and regulatory objectives in line with environmental policy frameworks within all Australian states, U.S., New Zealand, India, and other international jurisdictions.

Ken has provided human health and ecological risk assessment support for Oil and Gas clients of operational use chemicals in drilling or enhanced production of gas and oil. Ken has also recently provided the aquatic toxicology advice to INPEX supporting the INPEX submission to NT EPA seeking regulatory approval of modified licensed discharge limits of key chemicals likely to be found in discharge water from Ichthys project into Darwin Harbour.

Waste

Ronald Ho (Waste – Qualified Professional)

Ronald Ho is an experienced and versatile waste management and contaminated site management consultant at ERM with over 10 years of consulting experience in a variety of environmental projects with a focus on waste management, landfill audits, contaminated site management and infrastructure development. Ronald has experience developing waste management plan and waste management strategies for large-scale facilities such as airports, theme park, oil & gas facilities, hotel groups and government authorities in Australia and across Asia.

Ken Kiefer

Technical Director –
Global Human Health and Ecological Risk Assessment Technical Community Director

Mr. Kiefer has over 20 years of experience in the risk assessment and environmental toxicology. He is currently the ERM global risk assessment technical community leader. Mr. Kiefer has experience quantitative health risk assessments for the management of contaminated sites to meet a range of client objectives in line with environmental policy frameworks within all Australian states, U.S., New Zealand, India, and other international jurisdictions.

Mr. Kiefer has provided human health and ecological risk assessment support for Oil and Gas clients of operational use chemicals in drilling or enhanced production of gas and oil. Mr. Kiefer has also provided aquatic toxicology support for regulatory approval of discharge of chemicals.

Experience: 20 years' experience in environmental consultancy, project management and research

LinkedIn: https://www.linkedin.com/in/ken-kiefer-79b07940/

Email: ken.kiefer@erm.com

Education

- M.S., Agricultural and Environmental Chemistry, University of California, Davis (1998)
- B.S., Environmental Toxicology, University of California, Davis (1993)

Professional Affiliations & Registrations

- Australasian College of Toxicology and Risk Assessment
- Australian Contaminated Land Consultants Association
- Australian Land and Groundwater Association (ALGA)

Key Industry Sectors

- Government
- Mining
- Oil and Gas
- Chemical
- Manufacturing
- Power

Languages

- English, native speaker

Fields of Competence

- PFAS
  - Design of investigations of PFAS impact in soil, groundwater, surface water, sediment and biota
  - Environmental fate and transport
  - Quantitative health and ecological risk assessment
  - Toxicological evaluations
- Quantitative health and ecological risk assessment
- Vapour intrusion evaluations
- Environmental fate and transport
- Probabilistic risk assessment
- Toxicological evaluations

Key Recent PFAS Conference Presentations

- Vida Maulina, Lisa Thomson, and **Ken Kiefer**. *(Abstract Accepted)* September 2019. *Derivation Of Water Quality Guideline Value For Marine Discharge Of Monoethylene Glycol*. CleanUp Conference, Adelaide, SA.
- Ron Arcuri, **Ken Kiefer**, Belinda Goldsworthy. October 2013. *Developing Surface Water Screening Levels For Compounds Associated With Aqueous Film Forming Foams*. CleanUp Conference, Melbourne, VIC.

Key Projects

- Aquatic toxicity assessment and derivation EPL discharge limits. The assessment provided a review of specific products that maybe discharged. The derivation of EPL limits also provided a review of the on-site laboratory analytical methodologies to meet the derived EPL criteria.
- Ecological risk assessment for Water Treatment Plant effluent as part of remediation of former gas works. Risk assessment successfully led to increases in discharge limits.
- Human health and ecological risk assessment for residual coal tar impacts to remain post-remediation due to the practical limits of the remediation. Successfully demonstrated isolated residual coal tar impacts do not pose a risk.
- Provided senior technical review and oversight over the delivery of over 30 quantitative human health and ecological risk assessments as part of the management of a large portfolio (>100 sites) of petroleum hydrocarbon sites. The completion of risk assessments include wide ranging complex sites including: site with impact groundwater seeping into car parks of multi-story residential buildings; shallow groundwater plumes affecting multiple residential properties; and emerging contaminants (e.g. PFAS and MTBE).
- PFAS human health and ecological risk assessment for Refinery Senior Technical Lead. Development of surface water Site-Specific Screening Levels (SSSL) for PFOS and PFOA for human health and ecological receptors. The methodology used to derive the ecological screening criteria was based on the NEPM (1999) and the ANZECC (2000) methods used to derive trigger values. The result was a set of surface water SSSLs for PFOS and PFOA protective of aquatic species present in the site area. Human health SSSLs were also developed to be protective of humans consuming fish caught within the site area. The outcomes of the risk assessment process were used to eliminate the need for remediation to mitigate potential risks and highlight areas of the site where management of LNAPL was warranted to meet regulatory requirements. The risk assessment was accepted by the EPA-appointed site Auditor
- PFAS human health and ecological risk assessment. Airport JUHI Facility. Senior Technical Lead. An off-site sediment and surface water sampling program was also undertaken to determine the extent of PFOS and PFOA impacts. Human health and ecological screening criteria were selected for PFOA and PFOS. PFOS and PFOA were not measured above Tier 1 criteria in media relevant to potential fish or ecologically sensitive benthic assemblages. No risks posed by PFOS and PFOA were identified on-site and off-site human or ecological receptors. ERM employed a proactive communication and consultation strategy throughout the life of the project, to assist in the acceptance of the risk assessment outcomes by the Federal Assessor.

PFAS Projects

- **Legacy AFFF and Non-AFFF Product Sampling for PFAS – Multiple Sites, Australia (Department of Defence).** ERM was commissioned to conduct product sampling of both Aqueous Film Forming Foam (AFFF) and non-AFFF (such as aviation hydraulic oils) in order to build an understanding of the type and variability of PFAS compounds in products used across the Defence estate. One of the key objectives was to provide inputs to ongoing investigations, and support management and remediation actions. Ken is providing technical expert support for this work developing sampling strategies and data interpretation.
- **Auditor Technical Expert Support – RAAF Edinburgh and RAAF Wagga, Australia (Department of Defence)** Ken is providing technical expert support to State accredited auditors of the site investigations and risk assessment of legacy PFAS impacts.
- **AFFF Loss of Containment– Brisbane International Airport, Australia (Qantas).** PFAS human health and ecological risk assessment Senior Technical Lead for an AFFF loss of containment to adjacent river and estuary. A multi-media sampling program of sediment, soil, groundwater, surface water, and biota was developed to support the site-specific

risk assessment. The risk assessment used multiple lines of evidence to separate the risks related to the loss of containment with residual baseline pre-existing PFAS impacts; included mass balance assessment; and detailed laboratory analysis as a method to differentiate the PFAS fingerprint of the loss of containment from other PFAS sources. The Federal Assessor accepted the risk assessment. Successfully working with Commonwealth and state (QLD) regulators to demonstrate residual impact post initial water containment treatment efforts did not pose further risk to human health and the environment including indirect exposures associated with bioaccumulation of PFAS in biota. The outcomes of the risk assessment process were used to eliminate the need for further remediation to mitigate potential risks.

- **PFAS human health and ecological risk assessment for a Refinery (Confidential Client).** PFAS human health and ecological risk assessment for a Refinery. Senior Technical Lead. Development of surface water Site-Specific Screening Levels (SSSL) for PFOS and PFOA for human health and ecological receptors. The methodology used to derive the ecological screening criteria was based on the NEPM (1999) and the ANZECC (2000) methods used to derive trigger values. The result was a set of surface water SSSLs for PFOS and PFOA protective of aquatic species present in the site area. Human health SSSLs were also developed to be protective of humans consuming fish caught within the site area. The outcomes of the risk assessment process were used to eliminate the need for remediation to mitigate potential risks and highlight areas of the site where management of LNAPL was warranted to meet regulatory requirements. The risk assessment was accepted by the EPA-appointed site Auditor
- **PFAS human health and ecological risk assessment for a Refinery (Confidential Client).** PFAS human health and ecological risk assessment. Airport JUHI Facility. Senior Technical Lead. An off-site sediment and surface water sampling program was also undertaken to determine the extent of PFOS and PFOA impacts. Human health and ecological screening criteria were selected for PFOA and PFOS. PFOS and PFOA were not measured above Tier 1 criteria in media relevant to potential fish or ecologically sensitive benthic assemblages. No risks posed by PFOS and PFOA were identified on-site and off-site human or ecological receptors. ERM employed a proactive communication and consultation strategy throughout the life of the project, to assist in the acceptance of the risk assessment outcomes by the Federal Assessor.
- **PFAS human health assessment. RAAF Amberley (Department of Defence).** PFAS human health assessment. RAAF Amberley. Senior Technical Lead. Reviewed the consolidation of over six years of soil and groundwater data (for both hydrocarbons and Perfluorinated Compounds (PFCs) to refine the site Conceptual Site Model and understand the risks of undertaking the redevelopment works. Developed Site Specific Target Levels (SSTLs) to inform the remedial requirements and ensure construction works and future use of the site do not have an adverse impact upon human health or the environment.

Risk Assessment Projects

- Mr. Kiefer has provided health and ecological risk assessments as well as senior technical and quality programmes management as part of the management of a large portfolio (>100 sites) of petroleum hydrocarbon sites (including complex major hazard facilities such as refineries and terminals) across Australia, New Zealand and southeast Asia.
- Indoor Air Risk Assessment. Carson, California. Completed a human health risk assessment for exposure to VOCs including TCE and PCE to current on-site commercial workers and off-site residents due vapor intrusion from groundwater plume. Developed site-specific soil vapor attenuation factors and soil vapor target levels. Delineated indoor air concentrations of VOCs related to ambient air from the sub-surface sources.

- Prepared a risk assessment for off-site receptors to supplement an existing on-site risk assessment for a Superfund site. Off-site exposures included indoor air impacts to homes above the chlorinated VOC ground water plume. A number of different approaches were used to evaluate indoor air risks including vapour intrusion modelling from ground water, measured indoor and crawlspace air concentrations. Incorporated the use of GIS to present and communicate the complex environmental and risk information to regulators and the public.
- Human Health Risk Assessment of Rocket Testing Facility - Ventura, CA. Development of site-specific vapour migration model and vapour migration model validation field study focused on vapour transport through fractured bedrock.
- Determination of Ambient Chloroform Indoor Air Concentrations. Hill Air Force Base, UT. Established chloroform indoor air screening concentrations due to chlorinated drinking water.
- Vapour Intrusion Modelling, Mather Air Force Base, CA. Conducted vapour intrusion modelling in support of closure at Castle Air Force Base. Human health risk assessments for potential future receptors at multiple sites. COPCs include TCE and PCE.
- Prospective, Deterministic Baseline Human Health Risk Assessment (Vapour Intrusion) at a Sacramento Brownfield Site. Chico, CA. Industrial Site Redeveloped to Multi-family Land-use. Vapour intrusion assessment for BTEX and 1,2-DCA.
- Area–Specific Risk Assessment. Industrial Complex, South Bend, Indiana. Performed an area-specific risk assessment and developed of risk-based cleanup levels (RBCLs) for COPCs including PCE. The assessment included modelling to evaluate the potential of site constituents in soil to migrate to on-site indoor air and off-site groundwater.
- Soil Vapor Characterization and Risk Assessment, Los Angeles, CA. Developed strategy to address concerns regarding potential risks due to exposure in on-site and off-site indoor air to site related VOCs, including TCE and PCE. Performed risk assessment for current and future indoor receptors.
- Human Health Risk Assessment, Superfund, Olathe, KS. Multi-media human health risk assessment at a former industrial chemical storage and recycling centre. Qualitative and quantitative risk assessment conducted on measured and modelled VOCs in indoor air.
- Focused Human Health Risk Assessment at a former chemical facility, West Sacramento, CA. Conducted exposure and human health risk assessment to volatized CVOCs in indoor and outdoor air under the future land use conditions of a professional sports stadium.
- Performed Human health risk assessment evaluated risks to receptors due to dermal contact or ingestion exposures related to the beneficial use of red and brown mud and phosphogypsum as levee construction materials. This evaluation used the results material specific physiochemistry and aquatic toxicology studies. The evaluation included metals and radionuclides. Radionuclides were evaluated using USEPA RESRAD risk assessment model.
- Development of surface water discharge target levels for groundwater remediation system for a former coal fired power plant. Evaluation considered short-term and long term ecological effects.
- Post-release assessments of material harm to harbour water of high ecological and tourist value. Included innovated multiple-lines of evidence including understanding the nature of the release, the short-lived nature of the contaminants and understand of the complex mixing processes between the release and harbour.
- Human Health Risk Assessment for Complex Industrial Site. Human Health Risk Assessment for the redevelopment of waste-water ponds of former industrial complex of over 2,000 acres. Conducted human health risk assessments for multiple sites. Evaluation includes radionuclide, asbestos, dioxins/furans, PCBs, TPH, metals, SVOCs, and VOCs.
- Conducted human health risk assessment on two proposed >30-acre rural residential development

that was a former orchard. Soils contained arsenic, lead, and organochlorine pesticides. Assessment included probabilistic exposure assessment methodologies; site-specific in-vitro bioaccessability assessment; and background assessment. California regulatory agency approved the risk assessment.

- Provided senior technical review and oversight over the delivery of over 30 quantitative human health and ecological risk assessments as part of the management of a large portfolio (>100 sites) of petroleum hydrocarbon sites.
- Development of surface water Site-Specific Screening Levels (SSSL) for aqueous film forming foam (AFFFs) chemicals perfluorooctane sulphonate (PFOS) and perfluorooctanoic acid (PFOA) for human health and ecological receptors.
- Developed risk-based cleanup levels for arsenic, copper, and hexavalent chromium at wood treating facility. Cleanup levels were developed for protection of current and future workers as well as ground water quality.
- Completed a prospective human health risk assessment for future hypothetical beneficial uses for impacted ground water beneath a former Naval facility slated for commercial redevelopment. Chemicals of concern included chlorinated hydrocarbons, and BTEX. The assessment included a qualitative screening of many future potential ground water uses to focus the quantitative portion of the risk assessment to the two or three scenarios of greatest concern. Measured ground water concentrations were kriged to estimate areal average concentrations of each constituent, and subsequently three scenarios were quantitatively assessed: two worker scenarios and a school scenario. All scenarios were shown to be below acceptable hazard indices and EPA's risk range.
- Developed site-specific site-specific vapour migration modelling to evaluate potential migration from soil, shallow ground water, and deep ground water, which accounted for potential transport through fractured bedrock.
- Developed site-wide risk assessment methodologies risk from soil, shallow ground water, and deep ground water at a complex rocket testing facility.
- Baseline human health and ecological risk assessment for nitroammonia plant in Mexico to aid in divestment for on-going use. Primarily focused on assessment of off-site risks to current water users and ecological receptors potentially impacted by site groundwater. Included fate and transport modelling for migration of nitrate and ammonia in groundwater.
- Human health and ecological risk assessment related to the sub-surface fraccing and development of coal seam gas wells. Included evaluation of chemical and radiological tracer composition of frac fluids and return; pathway assessment of the potential release scenarios of frac fluids to the environment; and modelling of potential exposures frac fluid due potential surface and sub-surface release scenarios.
- Human health risk assessment related to the sub-surface fraccing and development of shale gas wells. Included evaluation of chemical and naturally occurring radioactive material (NORM) composition of frac fluids and return; pathway assessment of the potential release scenarios of frac fluids to the environment; and modelling of frac fluid into ground water aquifers.
- Human Health and Ecological Risk Assessment of Superfund Site - Former Radionuclide Research Facility and University Landfills. Risk assessment for a former radionuclide research facility and university landfills. Evaluation included tiered ecological and human health evaluation. Evaluation includes metals, VOCs, and radionuclides.
- Ecological Screening Risk Assessment. Performed screening ecological risk assessment for abandoned petroleum storage facility. Evaluated risks terrestrial and aquatic receptors. Developed site-specific surface water and sediment benchmarks.
- Performed screening ecological risk assessment for chemical manufacturing facility including

development of surface water and sediment benchmarks for site-specific constituents.

- Performed screening ecological risk assessment for abandoned petroleum storage facility. Evaluated risks terrestrial and aquatic receptors. Developed site-specific surface water and sediment benchmarks.
- Performed supplemental cumulative ecological risk assessment for U.S. Air Force. Evaluated risks of far-ranging species due to cumulative exposure to multiple individual sites that is not accounted for in individual site assessments.
- Performed baseline human health and ecological risk assessment and development of risk-based corrective action levels at a solvent recycling centre as part of RCRA facility investigations. Implemented a fractionation risk assessment approach for TPH. Performed environmental fate assessment of chemical constituents from soil into ground water using the SESOIL and Summers environmental fate and transport models. Performed environmental fate assessment of chemical constituents from soil into indoor air using the Johnson and Ettinger environmental fate and transport models. Provided statistical characterization and distribution analysis of soil and ground water concentrations.
- Performed screening ecological risk assessment for chemical manufacturing facility including development of surface water and sediment benchmarks for site-specific constituents.
- Developed strategy address concerns regarding potential risks due to exposure in on-site and off-site indoor air to site related VOCs. Assisted in developing site characterization work plan to support future risk assessment.
- Performed an area-specific risk assessment and developed of risk-based cleanup levels (RBCLs). The assessment included modelling to evaluate the potential of site constituents in soil to migrate to on-site indoor air and off-site ground water. The evaluation included VOCs and PCBs.
- Prepared risk assessment in support of RCRA facility investigations. Developed site-wide risk assessment methodologies including site-specific vapour migration modelling to evaluate potential migration from soil, shallow ground water, and deep ground water, which accounted for potential transport through fractured bedrock.
- Conducted risk assessment for a former radionuclide research facility and university landfill. A tiered ecological and human health evaluation included metals, VOCs, and radionuclides.
- Conducted health risk assessment on estimated emissions from a proposed waste to energy facility in Hong Kong. Evaluation included metals, VOCs, and dioxins.
- Performed a preliminary endangerment assessment human health risk assessment for a proposed new school on former agricultural property.
- Performed human health risk assessment and geostatistical evaluation using GIS (ArcView) as part of an analysis of historically released DDT at a manufacturing facility.
- Assisted with exposure and human health risk assessment of volatile organic chemicals in ground water. Performed modelling to assess exposure and risk to volatized chemicals under the future land use conditions of a sports stadium.
- Assisted with exposure and human health risk assessment of inorganic and organic chemicals in soil and sediments. Developed sediment target concentrations for chemicals based on recreational fish ingestion. Modelled transfer from sediments to fish for bioconcentrating chemicals including PCBs, Dioxins, Furans, PARs, and chlorinated pesticides.
- Assisted with exposure and toxicity assessment of over 20 chemicals in soil and ground water. Performed environmental fate assessment in soil and ground water using the SESOIL and VHS environmental fate and transport models. Provided statistical characterization and distribution analysis of soil and ground water concentrations.
- Performed environmental fate assessment of chemical constituents from soil and ground water into indoor and outdoor air using the Johnson and Ettinger and Hannah environmental fate and transport models in support of multiple site-specific risk assessments and development of risk based clean-up levels.

- Performed environmental fate assessment of chemical constituents from domestic water use into indoor air using published air stripping methodologies in support of multiple site-specific risk assessments as well as litigation support.
- Performed air dispersion modelling based on the accidental release scenario using EPA's ALOHA model. Used model outputs to estimate probable exposure levels for comparison with toxicity information.
- Provided litigation support for testifying toxicology and risk assessment expert for plaintiff on a case involving alleged illegal disposal of hazardous waste by a furniture stripping company. Evaluated available data for ability to determine amounts material illegally disposed.
- Provided litigation support for testifying toxicology and risk assessment expert for the defense on a case involving environmental damages resulting from an accidental release of Cl-containing gases. Researched information and performed air dispersion modelling for expert report in support of a lawsuit regarding phytotoxic effects from an accidental release of chlorine gas. Reviewed phytoxicity studies of chlorine gas to develop toxicity threshold for pine trees and determine the long term effects from an acute exposure event. Performed air dispersion modelling based on the accidental release scenario using EPA's ALOHA model. Used model outputs to estimate probable exposure levels for comparison with toxicity information.
- Provided litigation support for testifying toxicology and risk assessment expert for the defense on a case involving migration of VOCs and methane from an adjacent landfill into a commercial building.
- Provided litigation support for testifying toxicology and risk assessment expert for the defense on a case involving alleged health effects in inmates in California's Tehachapi Prison associated with hazardous substances in ground water at the prison. Lawsuit regarding potential health effects from exposure to PCE, TCE and nitrate impacted ground water. Reviewed database of ground water analytical results for completeness and reliability. Evaluated exposure levels for toxicological significance, comparing water levels, length of exposure to known toxicology of substances.
- Prepared GIS for a property development at a former orchard site. The GIS was used to geographically integrate risk assessment results with sample locations, and future property planning. Risk-based cleanup decisions were based on the results of GIS geostatistical analyses. Subsequent remediation alternative decisions were also based on the GIS developed for the site.
- Assisted in development of a GIS to support air modelling conducted for several commercial facilities for Proposition 65 warning requirements. The GIS was used to develop a mailing list database for properties within the air emissions plume using GIS geocoding.
- Developed database of surface water and soil concentrations for cadmium, copper, lead, and zinc from available data. Database was designed for use in a GIS for the purpose of evaluating spatial relationships in metal background concentrations. Access and Arc View were used in the development of the GIS.
- Developed GIS database of soils characteristics for use in the exposure and risk assessment model CalTOX. Data from the USDA STATSGO database was used for the development of GIS database of CalTOX soil inputs. ArcINFO was used in the development of the GIS.

Publications

- Kenneth L. Kiefer, Chuck E. Schmidt, Mark K. Jones, Ranajit (Ron) Sahu. 2013. *Assessing Vapour Intrusion - How do assessment technologies compare?* Remediation Australasia. Issue 12. 2013
- Norbeck et al. 1998. *Evaluating Factors That Affect Diesel Exhaust Toxicity*. Center for Environmental Research and Technology, College of Engineering, University of California, Riverside. Final Report Contract No. 94-312.
- Hsieh D.P.H., McKone, T.E., Geng, S., Schwalen, E.T. and Kiefer, K.L., 1995. *The Distribution of Landscape Variables for CalTOX within California*,

Department of Toxic Substances Control, California Environmental Protection Agency, Sacramento, California.

- T.E. McKone, Kiefer, K.L., Currie, R.C., Geng, S. and Hsieh, D.P.H., 1995. *Representing Uncertainty in Risk Assessments; Task I a: Constructing Distributions*, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, California.
- T.E. McKone, Currie, R.C., Chiao, F.F., Kiefer, K.L. and Hsieh, D.P.H., 1995. *Representing Uncertainty in Risk Assessments; Task I b: Representing Uncertainty in Intermedia Transfer Factors: Case Studies*, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, California.

Invited Speaker

Presenter at the ALGA 2-Day Risk Assessment 101 training course. Auckland and Christchurch, NZ (2017) and Hobart (2018).

Presentations

- **Ken Kiefer** and Darren Reedy. ***PFAS*** *Health Risk Assessment*. EcoForum 2018 Conference, Sydney, NSW.
- **Ken Kiefer** Kylie Dodd and Darren Reedy. *The Distribution of* ***PFAS*** *Compounds in the Marine Environment and Implications for Ecological Risk*. EcoForum 2018 Conference, Sydney, NSW.
- Lisa Thomson, **Ken Kiefer**, Kylie Dodd and Darren Reedy *Bioaccumulation of* ***PFAS*** *Within Aquatic Trophic Levels in an Australian Estuarine Environment*. EcoForum 2018 Conference, Sydney, NSW.
- Gavin Powell, Rob MacIntosh, **Ken Kiefer**, Wijnand Gemson, and Peter Madden. ***PFAS*** *and Urban Stormwater: Use of Mass Discharge Assessment in the Interpretation of the Conceptual Site Model*. EcoForum 2018 Conference, Sydney, NSW.
- **Ken Kiefer**, Kylie Dodd, and Darren Reedy. *Using* ***TOPA*** *in Risk Assessment.* EcoForum 2018 Conference, Sydney, NSW.
- **Ken Kiefer**, Wijnand Germs, Nathan Seaver, Kylie Dodd, and Ed Dennis. *Differentiating Groundwater Sources Using Mass Flux*. CleanUp 2017 Conference, Melbourne, NSW.
- **Ken Kiefer**. Re-Assessing Remedial Targets Based on Changes in Total Recoverable Hydrocarbons Mixtures During Remediation. CleanUp 2017 Conference, Melbourne, NSW.
- **Ken Kiefer**. Reducing Uncertainty in Vapour Intrusion Risks and Conservatism in Chlorinated Hydrocarbon Site Decision Making. CleanUp 2017 Conference, Melbourne, NSW.
- Kathryn East, **Ken Kiefer**. Extended **PFAS** Suite: Future-Proofing, or Creating More *Uncertainty?* EcoForum 2016 Conference, Freemantle, WA.
- W. Germs, **K. Kiefer**, and A. Kohlrusch. You Can't Manage What You Don't Measure: 1,4–Dioxane as Co-Contaminant at Chlorinated Solvent Sites. EcoForum 2016 Conference, Freemantle, WA.
- Sophie Wood, Phillippa Biswell, **Ken Kiefer** and Warren Pump. *The Trouble with Environmental Management Plans….* EcoForum 2016 Conference, Freemantle, WA.
- **Ken Kiefer** and Thavone List. What Are Total Recoverable Hydrocarbons? Implications for Contaminated Site Management. EcoForum 2016 Conference, Freemantle, WA.
- **Ken Kiefer** and Kathleen Prohasky. Evaluation of Primary Industry Beneficial Water Use and Consideration of Non-Health and –Environmental Risk Endpoints. EcoForum 2016 Conference, Freemantle, WA.
- Joseph Ferring and **Ken Kiefer**. *Using D Data Analysis and Visualisation to Reduce Uncertainty.* EcoForum 2016 Conference, Freemantle, WA.
- **Kenneth Kiefer**, Kathleen Prohasky, Wijnand Germs, Neil Gray and Tamie Weaver. September 2015. A Comparison Of Passive Sampling And Low-Flow Or Bailed Sampling Results Across A Range Of Australian Hydrogeological Settings. Cleanup 2015, Melbourne, Vic.
- **Kenneth Kiefer** and Thavone Shaw. September 2015. *Using Mass Balance In Risk Assessment.* Cleanup 2015, Melbourne, Vic.
- Kathleen Prohasky and Kenneth Kiefer. September 2015. *Complications Of Ambient*

Sources In Assessing Vapour Intrusion Risks. Cleanup 2015, Melbourne, Vic.

- Kathleen Prohasky and Kenneth Kiefer. September 2015. Developing Groundwater Tier 1 Screening Criteria For Chronic And Acute Vapour Risks For Chlorinated Hydrocarbons. Cleanup 2015, Melbourne, Vic.
- **Ken Kiefer,** Joseph Ferring, & Will Ellis. October 2014. *Differentiating Between Soil and Groundwater Solvent Sources in Soil Vapour Risk Assessment.* EcoForum 2014 Conference, Gold Coast, QLD.
- Christine Lussier, Kathryn East & Ken Kiefer. October 2014. *Screening Levels for Polychlorinated Biphenyls in Water.* EcoForum 2014 Conference, Gold Coast, QLD.
- Jeremy Hogben, Steven Morrison & Kenneth Kiefer. October 2014. *Assessing Polar Compounds as Degradation Metabolites of Hydrocarbon Sources – The Need for Change.* EcoForum 2014 Conference, Gold Coast, QLD.
- Kathleen V. Prohasky and Kenneth L. Kiefer. October 2014. *Tier 1 Screening of Vapour Risks from Groundwater Data for Chlorinated Hydrocarbons*. ACTRA Conference. Coogee, NSW.
- **Kenneth L. Kiefer,** Alyson N. Macdonald, Kathleen Prohasky & Sophie Wood. October 2013. *Tier 1.5 Soil Vapour Screening For Non-Petroleum Volatile Organic Compounds.* CleanUp Conference, Melbourne, VIC.
- Kathleen V. Prohasky and Kenneth L. Kiefer. October 2013. Assessing Degradation Processes of Subsurface Vapours from a Petroleum Source in Fractured Basalt Using a Carbon Filter. CleanUp Conference, Melbourne, VIC.
- Ron Arcuri, Ken Kiefer, Belinda Goldsworthy. October 2013. Developing Surface Water Screening Levels For Compounds Associated With **Aqueous Film Forming Foams**. CleanUp Conference, Melbourne, VIC.
- **Kenneth Kiefer,** Alyson Macdonald, and Sophie Wood. October 2012. *Why do we need two different methods for screening vapour intrusion risks?* ACTRA. Adelaide SA.
- Dr. Sophie Wood, Ken Kiefer and Olivia Patterson. October 2012. *Health and Ecological Risk Assessment of Hydraulic Fracturing Fluids.* ACTRA. Adelaide SA.
- **Kenneth L. Kiefer**, Jonathan Lekawski, Valerie Phipps, Harrison Swift, and Sophie Wood. March 2012. *Case Studies of Implementing HSLs in Petroleum Hydrocarbon Sites*. EcoForum. Sydney. NSW.
- **Kenneth L. Kiefer**, Chuck E. Schmidt, Mark K. Jones, Ranajit (Ron) Sahu. September 2011. Comparison of Technologies for Assessing Vapour Intrusion In Future Structures from Subsurface Sources - Case Study with Side-by-Side Measured Flux and J&E Modelling. CleanUp Conference, Adelaide, SA.
- Kiefer, K.L., Jones, M., Shibata, M., Olsen, H., Steinmacher, S., and Case, J. April, 2005. *Dealing with Confounding Background Indoor Air Concentrations*. Air & Waste Management Association. Symposium on Air Quality Measurement Methods and Technology, San Francisco, CA
- Shull, L. and Kiefer, K. March 2005. *Those Pesky Emerging Contaminants: Will We Ever Be Done With Them?* Association for Environmental Health and Sciences: The 15th Annual AEHS Meeting & West Coast Conference on Soils, Sediments and Water, San Diego, CA.
- Kiefer, K.L., Shull, L., Bowland, M., and Jones, M. October 2003. Risk Based Decision Making Tools: Property Redevelopment and Arsenic Case Study, Brownfields 2003, Portland, Oregon.

Christopher Thomson

Principal Environmental Scientist

Chris has 19 years' international experience coordinating Environmental Impact Statements, drafting impact assessments and executing air quality monitoring programs for a range of mining, infrastructure and oil and gas projects.

During his 11 years working in WA, Chris' oil and gas experience is highlighted by be a number of key projects which exemplify his broad capabilities. These include being seconded as the environment advisor to the Chevron's Central Environment team for Wheatstone; successfully managing the execution of 3D Oil's Sauropod EP; undertaking compliance audits for INPEX's Ichthys project in Darwin as well as coordinating a fugitive emissions assessment for Buru Energy in Australia's Kimberly region for its onshore gas operations. This experience allows him to enjoy the advisory aspect to his project management and client-facing role and delivering projects, which meet stakeholder expectation.

Experience: 19 years in air quality and EIA

LinkedIn: https://www.linkedin.com/in/christopher-thomson-6977988a/
Email: Christopher.thomson@erm.com

Fields of Competence

- Air quality impact assessment
- Air quality monitoring and environmental management
- Certified Project Manager
- Environmental impact assessment and approvals preparation / coordination

Education

- Master of Science (Environmental Impact Assessment, Environmental Management Systems and Environmental Auditing), University of East Anglia (UK), 2003
- Bachelor of Science (Chemistry and Environmental Science – double major), Murdoch University W.A, 1997

Languages

- English, native speaker
- Spanish, fluent

Environmental Impact Assessment

HazerGroup: Environmental Approvals strategy and Scoping Study 2019

This study provided an approvals strategy, schedule and risk assessment for a proposed industrial facility within the Perth Metropolitan area. This piece of work identified all relevant approvals for the proponent and allowed the proponent to visualise the development progress allowing decisions to be made at board level.

Teck Australia: Teena Resource, Environmental Approvals strategy and Scoping Study 2019

This study outlined the NT and federal environmental approvals strategy for the development of the Teena Resource. This comprehensive approach included identification of risks and environmental sensitivities related to the development and provision of costings and schedules for execution of the preferred development option. Chris co-authored and reviewed the project for submission.

3D Oil: Sauropod Seismic Environment Plan 2019

Chris was the PM for executing the scopes to produce the offshore seismic environment plan. This involved, coordinating sub-consultant and internal ERM technical expertise to deliver a timely and robust document for public and regulatory review.

Strandline Resources: Coburn Zircon Project 2018

Project manager, and lead approvals advisor for this current project, which is based on his and his team's previous experience at the site. The scope of this project involves the execution of EMP's regulator liaison, site team coordinator, preparation of approvals / obligations register to facilitate execution of the project.

Telstra Singapore Perth fibre optic cable approvals 2018

Engaged to deliver approvals for the beach-landing directional drilling component of this project. This involved preparation of a Development Application to the City of Cambridge, liaison with the DoEE related to potential EPBC referrals and coordination of the delivery of approvals and consultation with the public, though the planning process.

Holcim Australia: Baldivis Quarry Stage 2 expansion 2018

Project manager and approvals lead. Project included preparation of Mining proposal, Mine closure plan, clearing permit, licence amendment for two project options. Project was delivered adhering to budget and time constraints.

Cassini Resources: West Musgraves Environmental Approvals Scoping Study 2017

Project manager and author providing an update to the 2015 study encompassing not only changes to the project but the 2016 changes to the impact assessment process, EPA guidance and preparation of mining proposals under the *Mining Act 1978.* This scoping document outlined an approvals strategy roadmap for successful delivery of the project, covering environmental risks, budget and schedule.

BC Iron: Iron Valley Above / Below Water Table 2011-2012/2015-2017

Project manager, EIA coordinator and lead environmental approvals author for the BCI Iron Valley Below Water Table mining project, this included Part IV and Part V environmental approvals (API level of assessment) and requirements under the Mining Act. The PM role also involved providing ongoing approvals advice to the client throughout the project.

Water Corporation: Neerabup Sewer District Upgrade Project 2016

Preparation of construction environmental management plan, preliminary environmental impact assessment for the placement of sewer pipelines and infrastructure through urban areas north of Perth WA. Involved provision of advice and assessment against clearing principals constrained by environmental sensitive areas and black cockatoo habitat.

Australian Department of Defence: J0091 Replacement Aviation Fire Truck Facilities Project, 2015

This project applied to bases nation-wide, it required effective and coordinated approach. This work involved the technical review of environmental assessments and the preparation of a comprehensive Construction Environmental Management Plan.

Cassini Resources: West Musgraves Environmental Approvals Scoping Study 2015

This study outlined the WA and federal environmental approvals strategy for the development of the Nebo Babel deposit. This provided a comprehensive approach, costings and schedules for execution of the preferred development option. Chris co-authored and reviewed the project for submission.

Chevron Wheatstone LNG Project 2009-2012

Project team lead for the pollution studies which included, air quality, greenhouse gases and noise impact assessments. Authored impact assessments chapters for inclusion to the ERMP approval document. The role also included coordinating sub-consultants for execution of the various technical monitoring studies. Time and schedules were kept on delivering this aspect of the broader project.

BHP Billiton/ Nickel West NDS1 Project 2010-2011

EIA co-ordinator, project manager and lead environmental approvals author for a Nickel expansion mining project (NDS1) in the Northern Goldfields, WA. This involved preparation of all approvals documentation, but also development of the EIA strategy with the client team that was most suitable for its particular circumstances.

BHP Billiton Yeelirrie Project 2010-2011

Project manager for the development of the project's formal environmental approvals. This role involved providing approvals advice to the client as well as being a contributing author to the approvals documentation. (ERMP).

Aviva – Coolimba Power Station project 2008-2009

EIA co-ordinator and project manager and lead approvals author for the Public Environmental Review. This involved power plant and linear infrastructure approvals for the project near Eneabba in Mid-West Region of WA.

Air Quality Monitoring and Environmental Management

Amazon: Environmental Site Assessment, Obligations Register and Environmental Management Plan, 2019- ongoing

Chris was the lead assessor on this project covering a scope that included a site visit / due diligence audit, preparation of the site's operational EMP including comprehensive risk assessment, preparation of a site audit schedule, monitoring plan.

INPEX Australia: Ichthys LNG Plant compliance audit EPL 228 2019

Chris was part of the ERM site team to execute the annual Compliance Audit of INPEX operating licence 228. Chris' focus included the air quality, greenhouse gas and facility emissions from the plant.

GEMCO: Groote Eylandt Air quality management plan, best practice gap analysis 2019

Chris provided technical input to GEMCO's air quality management plan in identifying international best practice management measures ahead of the proposed mine expansion.

Hastings Technology Metals: Yangibana Rare Earths project, AQMP and plume dispersion review assessment 2019

Chris provided project management and technical review of the outgoing deliverables. Purpose of the reporting was to meet approval conditions and present options for process stack heights to feed back into the design and ultimately the works approval for the project.

Woodside LCA comparative assessment – 2019/20

Project manager for the development of a gas reserve specific LCA and energy intensity study. Chris

sustained momentum on the project and coordinated the information flow between the client and ERM project team, to ensure timely delivery of the project within budget.

INPEX air toxics and ambient air quality monitoring plan – 2019

Project manager and air quality lead for the development of the Ichthys LNG Plant air quality monitoring plan.

Roy Hill dust deposition study on mangroves, Port Hedland 2015-2018

Project manager and air quality lead for the execution and management of the study. Data management and report preparation, trouble shooting and programme refinement. Study executed to determine extent of dust deposition and the subsequent effects on mangrove communities near RHI operations.

Buru Energy Fugitive Emissions Assessment 2015-2016

Project manager and local air quality lead. This project involved monitoring fugitive emissions during well completion for onshore gas wells in the Kimberly region of WA. Chris' role included, designing the monitoring program, coordinating field work and drafting final report. The project was supported by technical skills in Brisbane and Texas (USA). The design was an innovative approach which matched technical requirements and project economic constraints.

INPEX Masela LNG Project 2013-2015

Air quality lead for an LNG project in Indonesia. This role included the planning and execution of the air quality component of the impact assessment and monitoring programme, including development of the programme and reporting in accordance with IFC and World Bank best practice requirements.
This also involved management of logistical challenges with monitoring in such environments.

Chevron Wheatstone LNG Project 2014

Environmental Advisor on air quality to the Central Environment Team. This involved deploying air quality monitoring station to Onslow, reviewing technical sub-consultant reports and troubleshooting air quality queries raised by the Central Environment Team. My return to the Wheatstone project was because of my previous experience allowing for historical knowledge gained during the original ERMP 2009 assessment, allowing for delivery of a more streamlined monitoring program entailing cost efficiencies to be incorporated.

JKC – Ichthys LNG Project 2012-2013

Team lead of the air quality (dust) monitoring programme for the construction phase of the project in Darwin. This role included coordinating technical personnel and troubleshooting challenges that result in a smooth delivery of the client's data and reporting requirements. Innovative inclusion of real time data was linked to sms alerts for the site team to implement site dust management activities. This approach proved useful to limit extent of dust emissions from the construction site.

Rio Tinto Nammuldi Below Water Table Project 2012

Project manager for the execution of the project's construction phase dust and noise monitoring programme. This programme focussed on dust and noise emissions from construction on the accommodation village. This involved directional analysis of dust and management of noise sub consultant.

UK Experience

Environmental Impact Assessment

EIA coordinator for the West Wight Wind Farm for Your Energy ltd. 2007
EIA coordinator and author for Bournemouth airport redevelopment, Manchester Airport Group 2007 EIA coordinator and author for the Crowthorne mixed use / business park scheme, Legal & General, 2007
EIA coordinator and author for the West Wight Wind Farm for Your Energy ltd. 2007
EIA coordinator and author for Crewkerne mixed use development, Wimpey homes, 2003
EIA coordinator and author for Newbury Racecourse redevelopment, Newbury Racecourse 2006. Chris

also undertook the air quality impact assessment and baseline monitoring for this project.

Air quality monitoring and Environmental management

Carbon balance and dust impact assessment for inclusion into environmental statement for Six Penny Wood Wind Farm, Your Energy Ltd, 2006.
Carbon balance and dust impact assessment for inclusion into environmental statement for North Rhins Wind farm, Wind Energy Ltd. 2006.
Carbon balance and dust impact assessment for inclusion into environmental statement for A'Chruach Wind Farm, Novera Energy. 2007.
Carbon balance and dust impact assessment for inclusion into environmental statement for Lissett Wind Farm, Wind Energy. 2006.
Drafting of environmental statement air quality chapter of environmental statement from technical report. Newhaven Energy Recovery Facility, Onyx 2004.
Drafting of environmental statement air quality chapter of environmental statement from technical report Hollingdean Materials Recovery Facility, Onyx, 2004.
Traffic emissions monitoring and dust impact assessment for Warren Way Materials Recovery Facility, Onyx, 2004.
Traffic emissions monitoring and dust impact assessment for Leavesden Studio development, MEPC group, 2007.
Traffic emissions monitoring and dust impact assessment South Kilburn Redevelopment, London, 2007.
Traffic emissions monitoring and dust impact assessment, Hollands Wood, campsite extension, New Forest, Forest Enterprises, 2004.

Environmental Management

Drafted environmental management plans for Lissett Wind Farm, Wind Energy, 2006. Drafted dust management plans for Kingston housing project Isle of Wight, 2005.
Drafted dust management plans for Hollands Wood, campsite extension, New Forest, Forest Enterprises, 2004.

Key member of EMS team responsible for implementing and co-ordinating the company EMS (to the ISO14001 standard), which was accredited June 2006. This role included internal audits, communicating initiatives and environmental awareness and monitoring of all key indicators for the firm to achieve carbon neutrality.

BAA Terminal 5, Heathrow Airport, Environmental Management

Using the Terminal 5 project as a case study, Chris carried out a series of internal environmental audits across several of the sub-projects within the wider project. This was done in accordance with the ISO14001 EMS standard, and the information gathered fed into his Masters dissertation, titled *The influence of EIA in developing EMS's and potential for their further integration*.

Casella – Stanger Group West Midlands, UK 1998 to 2002

Chris led small teams to carry out isokinetic industrial emissions air quality compliance monitoring surveys at a variety of processes around the UK. Specific projects included atmospheric emission surveys from automotive and aviation paint spray booths incinerator emission optimisations for commissioning new plant equipment as well as noise and ambient and indoor air quality surveys (environmental and occupational exposure) and COSHH assessments were also included in this work. The client base comprised predominantly multinational automotive manufacturing companies and their suppliers, some clients include Toyota UK - Bernaston Plant, Honda Motors - Swindon, Jaguar Cars - Castle Bromwich, Ford - Southampton, Peugeot - Coventry, Vauxhall Motors – Luton, British Airways – Heathrow Airport.

Other environment professional experience

Universidad de Chile, Santiago, Chile (short term placement) Jan – March 1998

Employed to commission a BAS100B Voltametry and Polarography apparatus for the University's metallurgy faculty. This included research on the suitability of the apparatus for trace analysis of industrial wastewaters

and development of operating procedures designed for the laboratory's routine analysis.

Mining and Environmental Department of SERGEOMIN Oruro, Bolivia, Environmental Chemist (short term) Nov 1997/Jan 1998
Conducted the environmental department's water quality monitoring and treatment programme for the Santa Rita Tin, Lead, Copper and Zinc mine, operated by COMIBOL. Specific duties included onsite monitoring, sampling and lab analysis of surface and subsurface acidic waters.

Yorke Environmental Consultants – Perth, WA. Environmental Assistant, May 1997/Sept 1997
Carried out air emissions monitoring and inline sampling for particulates, sulphurous and nitrous oxides from mining operations and industrial sites around WA. The work required the use of an Andersen GS 80 Stack sampler, ambient sampling and laboratory preparation.

Tiwest Joint Venture Chandala Site, Muchea, Western Australia, Under Graduate Environmental Officer Student Placement, Dec 1995 to Feb 1996
Required to design and implement an ambient dust monitoring programme for the mineral sands separation plant at Muchea in order to determine the quantity, composition and radioactivity of dust in the immediate environment of Chandala. Further duties included groundwater monitoring from onsite bores. Vegetation Health Assessment of dieback contaminated areas and its management.

Ronald Ho

Principal Consultant

Ronald Ho is an experienced and versatile waste management and contaminated site management consultant at ERM with 10 years of consulting experience in a variety of environmental projects including waste management, contaminated site management, waste audit, government policy studies, business and economic analysis and stakeholder engagement.

He has strong business development, consulting and leadership skills and has proven record of managing large and complex waste management consultancy projects with favourable client feedback.

Experience: 10 years of experience in the waste management and environmental sector.

Email: Ronald.Ho@erm.com

Education

- Master of Science (MSc.) in Environmental Engineering and Management, University of Science and Technology, Hong Kong, 2015
- Bachelor of Science (BSc.) (Distinction) in Agricultural & Environmental Economics, McGill University, Canada, 2013

Languages

- English, Native
- Cantonese, Native
- Mandarin, Fluent

Fields of Competence

- Waste Management
- Circular Economy
- Environmental Policy
- Economic and Business Impact Assessment
- Stakeholder Engagement
- Business Case Development
- Contaminated Site Management

Key Industry Sectors

- Government
- Power
- Hospitality
- Food & Beverage

Professional Institutions

- Member, Chartered Institution of Water and Environmental Management
- Former Vice-Convener of Young Members Chapter, Hong Kong Waste Management Association

Key Projects

Dow Chemical Former Chlor-Alkali Plant Mercury Contaminated Waste Excavation and Management (2021-2022)
ERM was engaged Dow Chemical as lead environmental consultant in managing the remediation and waste disposal of mercury contaminated waste at the former chlor-alkali plant in Altona, Victoria. Ronald was the Project Manager responsible for day-to-day communication and delivery of the project.

ENGIE Hazelwood Landfill Annual Interpretive Report (Annually, 2019-2022)
ERM was engaged by ENGIE Australia to prepare an Annual Monitoring and Interpretive Report for the 2018 monitoring period of the various EPA Victoria licensed landfills within the Eastern Overburden Dump (EOD) and Hazelwood Ash Retention Area (HARA) at the Hazelwood Power Complex in Morwell, Victoria.
The main purpose of this annual report is to evaluate the extent to which ENGIE has implemented the landfill environmental monitoring program (LEMP) and to assess the results of the monitoring with respect to environmental discharges and potential environmental impact. Ronald was the Project Manager in charge of analysing the 2018 monitoring data on leachate, groundwater, surface water, landfill gas and dust.

ENGIE Hazelwood Asbestos Landfill Alternative Daily Cover Monitoring & Performance Report (2019 – 2020)
EPA Victoria has granted approval for a 6 month trial period starting on 1 May 2019 for ENGIE to use an alternative daily cover (ADC) known as 'Acryrubber' at the asbestos landfill site located within the Hazelwood Power Complex Landfill in Hazelwood. Ronald was the Project Manager in charge of reviewing the adequacy of the monitoring procedures and assessing the performance of the ADC in order to submit the performance report to EPA Victoria by end of September 2019.

Surf Coast Council Anglesea Landfill Audit (June 2019 – 2020)
ERM was engaged by the Surf Coast Council in Victoria to undertake a section 53V audit of the Anglesea Landfill due on June 2020. Ronald was the Project Manager supporting the Auditor on this landfill audit. He is responsible for assessing the risk of possible harm or detriment to the environment caused by the operation of the landfill including but not limited to groundwater, surface water, landfill gas and make recommendations to address the identified risks.

Hume City Council Riddell Road Landfill Audit (April 2019 – 2020)
ERM was engaged by Hume City Council in Victoria to undertake a section 53V audit of the Riddell Road Landfill due by end of September 2019. Ronald was part of the core team supporting the Auditor on this landfill audit. He is responsible for assessing the risk of possible harm or detriment to the environment caused by the operation of the landfill including but not limited to groundwater, surface water, landfill gas and make recommendations to address the identified risks.

Food Waste Management Plan & Operation Waste Management Plan for Third Runway System Development, for Airport Authority Hong Kong (2016 –2017)
Ronald was responsible for preparing the food waste management plan and operation waste management plan of the 3RS development recommending AAHK the arrangement of waste logistics, associated waste facilities and waste measures to optimise organic waste and recyclable collection.

Waste Management Audit and Strategy Study, for Airport Authority Hong Kong (2015 – 2016)
The study involved a waste stream identification task, a waste composition survey and design of waste management strategy for the airport authority. Ronald was the Project Coordinator managing 50 interns for a three-week-long waste stream identification and composition survey tasks and involved in analysing and producing reports of the analysed waste data.

Waste Characterisation Study, for Hong Kong International Theme Park (2015)
The study involved a waste characterisation study to analyse the composition of waste generated at a major theme park in Hong Kong. The project involved a waste sampling exercise conducted over 4 days with 12 interns in total during the Chinese New Year period and a final report of the analysed waste composition. Ronald was the site supervisor for this study.

Waste Audit & Strategy Study, for a Leading Luxury Hotel Group in Asia (2014)
Ronald was in charge of the Waste Characterisation Study part of the study. He carried out site study and data analysis of the waste composition of hotels in China and South-East Asia and advised the client on how waste could be minimised from an economic and environmental perspective.

TWS Audit Waste Facilities and Waste Management Plan for an International Offshore Oil & Gas Drilling Company (2013)
This study involved desktop research, site audits of up to three hazardous waste treatment facilities and update of the Waste Management Plan (WMP) for an offshore activity for South East Asia. Ronald was part of the project team support team leader in reviewing.

Project Drink Without Waste, for The Single-Use Beverage Packaging Working Group (2018)
The Consultant was commissioned by the Working Group, a consortium of beverage companies, retailers, NGOs, think-tanks etc. to carry out a research report and develop a Positioning Statement on how best Hong Kong can comprehensively and effectively manage single-use beverage packaging. Ronald is the local waste specialist responsible for baseline anaylsis, stakeholder engagement and strategy recommendation.

ENGIE Hazelwood Water Management Strategy Program Management (2019 – 2021)
Ronald is overall program manager responsible for consolidating and reviewing the program of the Water Management Strategy (WMS) of the Eastern Overburden Dump (EOD) and the Hazelwood Ash Retention Area (HARA) of the Hazelwood Power Complex Rehabilitation Project. The WMS is anticipated to be completed by end of 2021.

Study on Enhancing the Cost Effectiveness of Glass Bottle Collection and Recycling Services in Hong Kong, for Environmental Protection Department (EPD) of HKSAR (2014 – 2015)
The objective of this study is to advise EPD on optimising the cost effectiveness of glass collection service in Hong Kong with reference to local and overseas experience. Stakeholders from local glass collection and recycling sectors were engaged and interviewed to assess the best practice in glass collection. Field work on glass collection technology was also conducted. Ronald was the Project Coordinator.

Business Impact Assessment on Producer Responsibility Scheme for Glass Beverage Containers, for EPD (2013 – 2015). The objective of the study is to understand and mitigate the business impact of the glass beverage bottle PRS on relevant stakeholders. Ronald is the Project Coordinator responsible for doing market research on the business structure and environment of HK Beverage Industry, quantitative analysis of trade statistics, conducting stakeholder view-seeking interviews, business impact analysis and recommending mitigation measures.

Low-Level Radioactive Waste Storage Facility Follow-On Contract, for EPD (2014 – 2015)
Ronald engaged users of the LLRWSF to review how the performance of the facility can be improved. He is also responsible for forecasting the waste arising of low level radioactive waste in Hong Kong in the next 20 to 30 years using the Monte Carlo Simulation Model and reviewing the Environmental Monitoring & Audit practice of the Initial Contract.

Environmental Impact Assessment for Development of a New Seawater Cooling System – Intake Offshore & Discharge Culvert in Macau, for Companhia de Electricidade de Macau (2016 – 2017)
CEM is the utility company that supplies electricity to the Macau. ERM was commissioned to undertake an EIA to assess the impact of developing a new seawater cooling system to supplement the new at the Coloane Power Station. Ronald is responsible for assessing the waste management impact of the development.

South East New Territories (SENT) Landfill Annual Audit (2014-2017)
SENT landfill was one of the three strategic operating landfills in Hong Kong with a space of 100ha. Ronald was the Project Manager and Audit Leader in conducting a focused site audit annually, ensuring the Operator fulfil all the regulatory requirements and adopt good environmental, health and safety practice. The findings from the annual audit were submitted as part of the audit report.

Consultancy Service to Review the Administrative and Regulatory Frameworks for Implementation of the Minamata Convention on Mercury in the HKSAR, for EPD (2015 – 2017)
The objective of the study is to review and identify the gaps between regulations of Hong Kong and the clauses of the Convention and devise an implementation roadmap for the Government. Ronald is the Project Coordinator responsible for regulatory review, business environment research, stakeholder engagement, impact analysis and recommendation of implementation strategies. The study included strategies of disposal of mercury containing waste.

APPENDIX C: COMMINGLED TREATED EFFLUENT (750-SC-003) LABORATORY RESULTS

C.1 Monthly sampling results for 750-SC-003

Shaded cells with bold text indicate a trigger exceedance associated with subsequent discharge via jetty outfall. These are further described in Table 2-3. Note: monitoring exceedances are not captured in table-23 as they were not discharged

Date	TIME	LIMS Sample ID	pH	Electrical conductivity	Temperature	Turbidity	Dissolved oxygen	TPH as oil & grease	TRH (C6-C10)	TRH (C10-C40)	TSS	BOD	COD	Free Chlorine	Ammonia	Total nitrogen	Total phosphor	Filterable Reactive	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc	Enterococci	E coli	Faecal coliforms	Anionic surfactant	aMDEA	Glycol (MEG)	Glycol (TEG)
Unit			pH units	µS/cm	°C	NTU	%	mg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg N/L	mg N/L	mg P/L	mg P/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	cfu/ 100mL	cfu/ 100mL	cfu/ 100mL	mg/L	mg/L	mg/L	mg/L
Discharge limit			6- 9	n/a	35	n/a	n/a	6	n/a	n/a	10	20	125	2	n/a	10	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	100	400	n/a	n/a	n/a	n/a
12/07/2022	08:00	L2203006001	8.1	337	23.2	0.5	90	< 1	<20	<100	< 5	6	13	< 0.02	< 2	3	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	<1	<1	48	20	4	4	0.4	< 5	< 5	< 5
09/08/2022	08:01	L2203420001	8.0	156	28.3	1.0	79	3	<20	<100	< 5	<2	14	0.02	< 2	2	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	<1	<1	136	5	<1	60	<0.1	< 5	< 5	< 5
13/09/2022	08:10	L2203978001	8.4	241	30.3	<0.5	87	< 1	<20	<100	< 5	6	11	< 0.02	8	7	0.6	< 0.5	<0.1	<1	2	<1	<0.1	1	<1	281	6	20	92	<0.1	< 5	< 5	< 5
10/10/2022	09:00	L2204500001	8.9	369	31.3	2.0	91	< 1	<20	<100	< 5	<2	7	< 0.02	12	**12**	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	1	<1	409				<0.1	< 5	< 5	< 5
14/10/2022	08:50	L2204570001														4																	
16/10/2022	09:20	L2204571001														4																	
20/10/2022	09:05	L2204698001																									10	1	**2800**				
25/10/2022	07:56	L2204760001																									<1	<1	<1				
08/11/2022	07:40	L2204965001	8.3	330	31.7	2.0	98	< 1	<20	<100	< 5	<2	13	0.04	8	8	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	2	<1	286	5	13	50	<0.1	< 5	< 5	< 5
14/12/2022	08:05	L2205542001	8.8	394	31.1	1.0	92	< 1	<20	<100	< 5	3	11	< 0.02	11	**12**	< 0.5	< 0.5	<0.1	<1	3	<1	<0.1	3	<1	300	9	11	**37000**	<0.1	< 5	< 5	< 5
16/12/2022	09:05	L2205605001													<2	3																	
18/12/2022	08:35	L2205606001													<2	<2																	
20/12/2022	08:10	L2205677001																											8				
10/01/2023	08:05	L2300171001	8.8	128	29.8	6.0	105	3	<20	<100	**22**	4	18	0.03	3	5	< 0.5	< 0.5	<0.1	<1	<1	<1	<0.1	<1	<1	261	3	1	31	<0.1	< 5	< 5	< 5
12/01/2023	10:40	L2300229001				2.0					<5																						
14/01/2023	07:28	L2300234001				1.5					< 5																						
18/01/2023	08:45	L2300236001				1.0					< 5																						
24/01/2023	08:15	L2300126001																										40	**1500**				
08/02/2023	07:50	L2300556001																											23				

Date	TIME	LIMS Sample ID	pH	Electrical conductivity	Temperature	Turbidity	Dissolved oxygen	TPH as oil & grease	TRH (C6-C10)	TRH (C10-C40)	TSS	BOD	COD	Free Chlorine	Ammonia	Total nitrogen	Total phosphor	Filterable Reactive	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc	Enterococci	E coli	Faecal coliforms	Anionic surfactant	aMDEA	Glycol (MEG)	Glycol (TEG)
14/02/2023	07:35	L2300676001	8.8	317	30.2	1.0	86	< 1	<20	<100	< 5	<2	15	0.02	13	**11**	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	<1	<1	162		4		<0.1	< 5	< 5	< 5
16/02/2023	08:45	L2300709001													14	13											<1	4	18				
20/02/2023	15:55	L2300808001													17	17																	
24/02/2023	09:45	L2300865001													6	6																	
14/03/2023	08:35	L2301251001	7.9	426	30.2	2.0	90	< 1	<20	<100	< 5	<2	9	0.04	18	**16**	< 0.5	< 0.5	<0.1	<1	3	<1	<0.1	2	<1	260	200	44	**760**	<0.1	< 5	< 5	< 5
15/03/2023	13:25	L2301326001														10																	
18/03/2023	12:35	L2301339001													16	16																	
21/03/2023	10:30	L2301412001													20	21																	
23/03/2023	08:30	L2301413001													< 2	< 2												2	10				
25/03/2023	08:16	L2301414001													12	12																	
27/03/2023	08:17	L2301579001																										40	980				
28/03/2023	11:10	L2301579001													17	18																	
30/03/2023	09:45	L2301585001														10																	
04/04/2023	08:05	L2301651001														< 2																	
07/04/2023	08:30	L2301702001														17																	
11/04/2023	07:05	L2301799001	8.3	312	28.2	0.5	88	< 1	<20	<100	< 5	3	14	0.04	6	8	< 0.5	< 0.5	<0.1	<1	3	<1	<0.1	1	<1	481	30	<2	70	<0.1	< 5	< 5	< 5
09/05/2023	07:50	L2302242001	7.9	354	28.0	1.0	79	< 1	<20	<100	< 5	11	15	0.04	3	4	< 0.5	< 0.5	0.1	<1	6	<1	<0.1	1	<1	297	5	1	**570**	<0.1	< 5	< 5	< 5
18/05/2023	08:55	L2302358001																										5	890				
13/06/2023	07:45	L2302816001	8.5	200	27.0	0.5	82	2	<20	<100	< 5	<2	11	0.03	7	8	< 0.5	< 0.5	<0.1	<1	2	<1	<0.1	<1	<1	98	9	2	84	<0.1	< 5	< 5	< 5

APPENDIX D: AUTHORISED STATIONARY SOURCE EMISSION RELEASE RESULTS

D.1 Stationary source emission test results by Ektimo

Sampling Point Number	Sampling Location Number	Date/Time	LIMS Number	NO_x as NO_2 - Concentration Target		NO_x as NO_2 - Concentration Limit		N_2O		Hg - un spiked method USEPA 30B	$PM_{2.5}$	PM_{10}	CO		temperature	efflux velocity	volumetric flow rate
				mg/Nm³	ppm	mg/Nm³	ppm	mg/Nm³	ppm	mg/Nm³	mg/m³	mg/m³	mg/m³	ppm	ºC	m/s	m³/min
LNG Refrigerant Compressor Driver Gas Turbines (GE Frame 7s)				50 @ 15%O_2	25 @ 15%O_2	70 @ 15% O_2	35 @ 15% O_2	-	-	-	-	-	-	-	-	23	-
A1	L-641-A-001	09/10/2022 08:22	L2202521001	27	13	27	13	1.5	0.79	<0.0057	<0.4	<0.4	36	29.0	178	23	14000
A2	L-642-A-001	08/10/2022 08:00	L2202523001	37	18	37	18	1.1	0.58	<0.000035	<0.4	<0.4	12	9.2	177	24	15000
A3	L-641-A-002	05/10/2022 08:21	L2202522001	8.3	4.0	8.3	4.0	1.1	0.54	<0.00002	<0.4	<0.4	6.9	5.5	170	25	15000
A4	L-642-A-002	07/10/2022 09:15	L2202524001	15	7.1	15	7.1	1.4	0.7	<0.00002	<0.4	<0.4	15	12	170	27	17000
CCPP Gas Turbine Generators (GE Frame 6s, 38MW) - HRSG stack				150 @ 15% O_2	75 @ 15% O_2	350 @ 15% O_2	175 @ 15% O_2	-	-	-	-	-	-	-	-	19	-
A5-2	L-630-F-001	12/10/2022 10:44	L2202525001	9.9	4.8	9.9	4.8	1.1	0.55	<0.0062	<0.7	<0.7	79	64	198	20	6400
A6-2	L-630-F-002	N/A Unit offline at the time of sampling for planned maintenance, no results available															
A7-2	L-630-F-003	12/10/2022 08:05	L2202527001	5.1	2.5	5.1	2.5	<1	<0.5	<0.000025	<0.7	<0.7	6.2	4.9	220	21	6400
A8-2	L-630-F-004	11/10/2022 11:20	L2202528001	13	6.3	13	6.3	1.5	0.76	0.000024	<0.5	<0.5	54	43	221	19	5700
A9-2	L-630-F-005	11/10/2022 08:20	L2202529001	14	6.8	14	6.8	1.1	0.55	0.000028	<0.4	<0.4	25	20	190	20	6400
AGRU Incinerators				320 @3% O_2	160 @3% O_2	350@3% O_2	175 @15% O_2	-	-	-	-	-	-	-	-	19	-
A13-1	L-551-FT-031	05/10/2022 12:55	L2202517001	76	3.7	76	3.7	55	28	0.0038	<0.7	<0.7	45	36	482	21	2800
A14-1	L-552-FT-031	06/10/2022 11:06	L2202516001	24	11	24	11	78	40	<0.00002	<0.5	<0.5	1300	1000	482	25	3600
Heating medium furnaces				160 @3% O_2	80 @3% O_2	350@3% O_2	175 @3% O_2	-	-	-	-	-	-	-	-	-	-
A15	L-640-A-001-A	10/10/2022 09:35	L2202515001	150	75	150	75	<1	<0.5	<0.000027	<0.9	<0.9	140	120	164	4.6	770
A16	L-640-A-001-B	10/10/2022 12:48	L2202514001	160	77	160	77	<1	<0.5	<0.000027	<1	<1	120	94	164	6.2	1000

D.2 Gas Sampling Test Results Reported by the INPEX Laboratory

Date	LIMS number	Hydrogen Sulfide (H_2S)	Benzene	Toluene	Ethylbenzene	m/p-Xylene	o-Xylene	Mercury
	Unit	ppmV	ppmV	ppmV	ppmV	ppmV	ppmV	µg/Nm³
A13-2 (L-551-SC-003) AGRU Hot Vent - LNG Train1, prior to release at A3								
30/08/2022 11:12	L2203389001	160	200	< 30	< 30	< 30	< 30	-
19/09/2022 09:14	L2203954001	160	40	< 30	< 30	< 30	< 30	-
03/10/2022 10:50	L2204380001	160	290	< 30	< 30	< 30	< 30	-
20/10/2022 10:50	L2204685001	140	40	< 30	< 30	< 30	< 30	-
10/11/2022 12:10	L2204934001	140	30	< 30	< 30	< 30	< 30	-
27/11/2022 10:31	L2205189001	160	40	< 30	< 30	< 30	< 30	-
05/12/2022 09:40	L2205342001	140	< 30	< 30	< 30	< 30	< 30	-
07/01/2023 10:00	L2300119001	160	< 30	< 30	< 30	< 30	< 30	-
11/02/2023 13:39	L2300628001	160	< 30	< 30	< 30	< 30	< 30	-
13/03/2023 08:20	L2301209001	160	40	< 30	< 30	< 30	< 30	-
29/04/2023 14:40	L2301759001	140	< 30	< 30	< 30	< 30	< 30	-
08/05/2023 13:26	L2302204001	140	50	< 30	< 30	< 30	< 30	-
09/06/2023 14:57	L2302731001	150	< 30	< 30	< 30	< 30	< 30	-
A13-3 (L-541-SC-001) Feed gas to AGRU – LNG Train 1 – prior to release at A3								
29/08/2022 09:55	L2203497001	-	-	-	-	-	-	< 0.005
17/09/2022 09:20	L2202523001	-	-	-	-	-	-	< 0.005
09/10/2022 11:15	L2204455001	-	-	-	-	-	-	< 0.005
10/11/2022 09:30	L2204935001	-	-	-	-	-	-	< 0.005

Date	LIMS number	Hydrogen Sulfide (H_2S)	Benzene	Toluene	Ethylbenzene	m/p-Xylene	o-Xylene	Mercury
	Unit	ppmV	ppmV	ppmV	ppmV	ppmV	ppmV	µg/Nm³
27/11/2022 11:45	L2205188001	-	-	-	-	-	-	< 0.005
03/12/2022 10:25	L2205341001	-	-	-	-	-	-	< 0.005
27/01/2023 14:30	L2300262001	-	-	-	-	-	-	< 0.005
19/02/2023 09:35	L2300778001	-	-	-	-	-	-	< 0.005
21/03/2023 10:00	L2301395001	-	-	-	-	-	-	< 0.005
25/04/2023 10:00	L2301896001	-	-	-	-	-	-	< 0.005
24/05/2023 11:00	L2302316001	-	-	-	-	-	-	< 0.005
20/06/2023 07:40	L2302913001	-	-	-	-	-	-	< 0.005
A14-2 (L-552-SC-003) AGRU hot Vent Train2, prior to release at A4								
16/08/2022 13:55	L2203390001	140	140	< 30	< 30	< 30	< 30	-
19/09/2022 10:24	L2203955001	140	80	40	< 30	< 30	< 30	-
04/10/2022 14:02	L2204381001	140	240	40	< 30	< 30	< 30	-
17/10/2022 10:26	L2204669001	160	130	40	< 30	< 30	< 30	-
08/11/2022 10:22	L2204912001	160	< 30	< 30	< 30	< 30	< 30	-
05/12/2022 13:50	L2205377001	140	50	< 30	< 30	< 30	< 30	-
07/01/2023 15:12	L2300129001	160	< 30	< 30	< 30	< 30	< 30	-
11/02/2023 15:38	L2300635001	140	40	< 30	< 30	< 30	< 30	-
14/03/2023 09:09	L2301210001	160	40	< 30	< 30	< 30	< 30	-
10/04/2023 10:10	L2301760001	160	< 30	< 30	< 30	< 30	< 30	-

Date	LIMS number	Hydrogen Sulfide (H_2S)	Benzene	Toluene	Ethylbenzene	m/p-Xylene	o-Xylene	Mercury
	Unit	ppmV	ppmV	ppmV	ppmV	ppmV	ppmV	µg/Nm³
22/05/2023 09:10	L2302205001	140	120	70	< 30	< 30	< 30	-
10/06/2023 12:16	L2302732001	150	< 30	< 30	< 30	< 30	< 30	-
A14-3 (L-542-SC-001) Feed gas to AGRU – LNG Train 2 – prior to release at A4								
17/08/2022 11:00	L2203187001	-	-	-	-	-	-	< 0.005
27/09/2022 14:25	L2204221001	-	-	-	-	-	-	< 0.005
11/10/2022 11:30	L2204456001	-	-	-	-	-	-	< 0.005
17/10/2022 10:15	L2204668001	-	-	-	-	-	-	< 0.005
08/11/2022 14:55	L2204913001	-	-	-	-	-	-	< 0.005
03/01/2023 12:00	L2205753001	-	-	-	-	-	-	< 0.005
24/01/2023 14:10	L2300354001	-	-	-	-	-	-	< 0.005
19/02/2023 08:50	L2300862001	-	-	-	-	-	-	< 0.005
24/03/2023 11:00	L2301394001	-	-	-	-	-	-	< 0.005
21/04/2023 07:38	L2301895001	-	-	-	-	-	-	< 0.005
25/05/2023 09:12	L2302315001	-	-	-	-	-	-	< 0.005
20/06/2023 07:20	L2302912001	-	-	-	-	-	-	< 0.005

APPENDIX E: GROUNDWATER QUALITY DATA

Monitoring Round	LocCode	Sampled Date-Time	Ammonia as N	Nitrogen (Total)	Oxides of Nitrogen	Phosphate total (P)	Reactive Phosphorus as P	TSS	TDS	Aluminium (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (hexavalent) (Filtered)	Chromium (Trivalent) (Filtered)	Cobalt (Filtered)	Copper (Filtered)	Lead (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Silver (Filtered)	Vanadium (Filtered)	Zinc (Filtered)	Benzene	Ethylbenzene	Toluene	Xylene Total	TRH C6-C40	Biological oxygen demand (BOD)	E. coli	Dissolved Oxygen (%)	EC (field)	pH (Field)	Redox	Temp
Units	n/a	n/a		mg/l																										MPN/ 100mL	% sat	uS/cm	pH_Units	mV	°C
Operations Survey 10	BPGW01	24/10/2022	0.02	1.4	1.25	17	<0.01	-	103	0.02	<0.001	0.0004	<0.01	<0.01	<0.001	<0.001	<0.001	0.051	<0.0001	0.002	<0.001	<0.01	0.018	<1	<2	<2	<2	<100	-	-	-	360	4.82	5.7	31.1
	BPGW07	24/10/2022	0.35	<1	0.06	22	0.01	-	64,800	<0.1	0.016	<0.001	<0.01	<0.01	0.038	<0.01	<0.01	1.29	<0.0001	0.024	<0.01	<0.1	0.073	<1	<2	<2	<2	<100	-	-	-	143,777	4.47	5.4	31.0
	BPGW08A	24/10/2022	0.35	<0.5	0.01	15	0.03	-	17,800	0.22	<0.01	0.0011	<0.01	<0.01	0.077	<0.01	<0.01	6.28	<0.0001	0.043	<0.01	<0.1	0.092	<1	<2	<2	<2	<100	-	-	-	43,462	3.65	0.7	31.5
	BPGW09	24/10/2022	0.31	3.8	<0.1	24	<0.01	-	89,400	<0.1	0.051	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	0.37	<0.0001	0.017	<0.01	<0.1	<0.05	<1	<2	<2	<2	<100	-	-	-	182,567	4.95	9.9	31.2
	BPGW18	26/10/2022	0.8	<1	<0.1	50	<0.01	-	55,700	<0.1	0.015	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	0.081	<0.0001	<0.01	<0.01	<0.1	<0.05	<1	<2	<2	<2	<100	-	-	0.82	87,460	6.24	-242.0	30.3
	BPGW19A	25/10/2022	1.62	2.5	<0.01	44	<0.05	-	47,300	<0.1	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	0.024	<0.0001	<0.01	<0.01	<0.1	<0.05	<1	<2	<2	<2	<100	1.3	<1	1.44	78,804	6.00	-90.8	32.0
	BPGW20	26/10/2022	0.12	0.1	<0.01	5	<0.01	-	597	<0.01	0.002	<0.0001	<0.01	<0.01	0.001	<0.001	<0.001	0.026	<0.0001	0.001	<0.001	<0.01	0.006	<1	<2	<2	<2	<100	-	-	1.48	1,415	5.59	-218.0	33.0
	BPGW26	25/10/2022	0.32	0.3	<0.01	6	<0.01	-	6620	0.02	0.004	<0.0001	<0.01	<0.01	0.007	<0.001	<0.001	2.34	<0.0001	0.001	<0.001	<0.01	0.006	<1	<2	<2	<2	<100	-	-	1.21	14,010	5.40	-65.2	31.9
	BPGW27A	25/10/2022	0.26	0.3	<0.01	12	<0.01	-	1360	<0.01	<0.001	<0.0001	<0.01	<0.01	0.002	<0.001	<0.001	0.023	<0.0001	<0.001	<0.001	<0.01	0.008	<1	<2	<2	<2	<100	1.3	<1	1.62	2,960	5.17	-81.1	33.8
	BPGW28	26/10/2022	0.96	<1	<0.01	38	<0.01	-	82,200	<0.1	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	<0.0001	<0.01	<0.01	<0.1	<0.05	<1	<2	<2	<2	<100	-	-	1.25	123,785	6.57	-180.5	30.8
	BPGW38A	26/10/2022	0.11	0.2	0.01	5	0.01	-	1310	<0.01	<0.001	0.0038	<0.01	<0.01	<0.001	<0.001	<0.001	0.028	<0.0001	0.002	<0.001	<0.01	0.006	<1	<2	<2	<2	<100	-	-	2.83	2,775	6.01	-169.8	31.8
	BPGW40	25/10/2022	0.27	0.7	<0.01	6	<0.05	-	3070	<0.01	0.006	<0.0001	<0.01	<0.01	0.001	<0.001	<0.001	0.154	<0.0001	<0.001	<0.001	<0.01	0.005	<1	<2	<2	<2	<100	-	-	1.91	6,269	5.94	-90.9	30.6
	BPGW41	25/10/2022	0.56	<1	<0.01	13	<0.05	-	13,500	<0.01	0.004	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.001	0.017	<0.0001	<0.001	<0.001	<0.01	<0.005	<1	<2	<2	<2	<100	-	-	1.31	24,944	6.40	-88.9	30.1
	VWP328	26/10/2022	0.04	<1	<0.1	47	<0.01	-	74,900	<0.1	0.47	<0.001	<0.01	<0.01	0.022	<0.01	<0.01	0.489	<0.0001	<0.01	<0.01	<0.1	<0.05	<1	<2	<2	<2	<100	-	-	3.22	111,778	6.06	-197.8	31.4
	VWP341	25/10/2022	0.4	0.6	<0.01	<5.0	<0.01	-	1910	0.02	0.005	<0.0001	<0.01	<0.01	0.112	<0.001	<0.001	1.56	<0.0001	0.014	<0.001	<0.01	0.145	<1	<2	<2	<2	<100	-	-	1.84	4,046	5.16	-105.2	32.7
Operations Survey 11	BPGW01	18/04/2023	0.023	0.163	<0.002	14	-	-	–	0.015	0.0042	<0.00005	<0.01^	0.25	0.0033	<0.0005	0.0012	0.232	<0.00004	0.0009	<0.0001	<0.0002	0.013	<1	<2	<2	<2	<100	-	-	2.4	134.5	5.00	132.2	29.2
	BPGW07	18/04/2023	0.035	0.723	0.046	26	-	-	-	0.007	0.0174	0.0004	0.002	0.5	0.0236	0.003	0.0021	0.987	<0.00004	0.0263	<0.0001	<0.0005	0.059	<1	<2	<2	<2	<100	-	-	10.7	85,805	5.69	81.4	30.6
	BPGW08A	18/04/2023	0.083	0.132	<0.002	18	<0.01	-	2,640	<0.005	0.0296	<0.00005	<0.001	0.25	0.0453	<0.0005	0.0001	2.93	<0.00004	0.0187	<0.0001	<0.0002	0.011	<1	<2	<2	<2	<100	-	-	2.0	4,592	5.62	-12.1	31.3
	BPGW09	18/04/2023	<0.005	0.344	<0.002	26	-	-	-	0.005	0.0837	<0.0002	<0.001	0.5	0.0066	<0.001	0.001	0.673	<0.00004	0.0025	<0.0001	<0.0005	0.013	<1	<2	<2	<2	<100	-	-		270.2	6.15	-20.0	30.5

Monitoring Round	LocCode	Sampled Date-Time	Ammonia as N	Nitrogen (Total)	Oxides of Nitrogen	Phosphate total (P)	Reactive Phosphorus as P	TSS	TDS	Aluminium (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (hexavalent) (Filtered)	Chromium (Trivalent) (Filtered)	Cobalt (Filtered)	Copper (Filtered)	Lead (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Silver (Filtered)	Vanadium (Filtered)	Zinc (Filtered)	Benzene	Ethylbenzene	Toluene	Xylene Total	TRH C6-C40	Biological oxygen [illegible]	E. coli	Dissolved Oxygen (%)	EC (field)	pH (field)	Redox	Temp
	BPGW18	20/04/2023	0.501	0.672	<0.02	80	0.006	42	-	<0.005	0.0109	<0.0002	0.004	0.25	<0.0002	<0.001	<0.0002	0.0787	<0.0001	<0.0005	<0.0001	0.0007	0.011	<1	<2	<2	<2	<100	-	-	3.4	71,689	6.27	-30.3	29.5
	BPGW19A	20/04/2023	1.14	1.11	<0.02	<5.0	0.01	55	-	0.006	0.006	<0.0002	0.003	0.6	<0.0002	<0.001	<0.0002	0.0545	<0.0001	<0.0005	<0.0001	0.0031	0.007	<1	<2	<2	<2	<100	<1	<1	2.8	72,758	6.26	-38.3	30.6
	BPGW20	20/04/2023	0.111	<0.25	<0.02	<5.0	0.002	<5	-	<0.005	0.0017	<0.0002	<0.001	0.25	0.0015	<0.001	<0.0002	0.0252	<0.0001	0.0008	<0.0001	<0.0005	0.007	<1	<2	<2	<2	<100	-	-	2.3	1,041	5.47	43.2	32.7
	BPGW26	19/04/2023	0.24	0.5	<0.02	5	<0.01	-	5,110	0.006	0.0037	<0.0002	<0.01	0.25	0.0087	<0.001	<0.0002	3.01	<0.0001	0.001	<0.0001	<0.0005	0.005	<1	<2	<2	<2	<100	-	-	2.3	9,266	5.74	73.0	31.3
	BPGW27A	19/04/2023	0.292	0.329	<0.02	<5.0	0.003	-	1,430	<0.005	0.001	<0.0002	<0.001	0.25	0.0019	<0.001	<0.0002	0.0274	<0.0001	<0.0005	<0.0001	<0.0005	<0.005	<1	<2	<2	<2	<100	<1	<1	3.6	2,588	5.46	77.4	33.4
	BPGW28	20/04/2023	0.861	0.924	0.02	20	<0.001	57	-	<0.005	0.0033	<0.0002	0.002	0.25	<0.0002	<0.001	<0.0002	0.18	<0.0001	<0.0005	<0.0001	0.0006	0.019	<1	<2	<2	<2	<100	-	-	22.8	104,847	6.58	-51.6	30.5
	BPGW38A	19/04/2023	0.005	0.346	0.367	<5.0	0.005	-	200	<0.005	<0.0005	<0.0002	<0.001	24	<0.0002	<0.001	<0.0002	<0.0005	<0.0001	<0.0005	<0.0001	<0.0005	<0.005	<1	<2	<2	<2	<100	-	-	45.2	326.5	6.31	91.1	31.6
	BPGW40	19/04/2023	0.441	0.471	<0.02	8	0.011	-	2,370	<0.005	0.0018	<0.0002	<0.001	0.25	0.0016	<0.001	<0.0002	0.148	<0.0001	<0.0005	<0.0001	<0.0005	<0.005	<1	<2	<2	<2	<100	-	-	2.4	3,949	6.29	-25.1	30.4
	BPGW41	19/04/2023	0.67	0.735	<0.002	14	0.014	-	13,400	<0.005	0.0013	<0.0002	<0.001	0.6	<0.0002	<0.001	<0.0002	0.0187	<0.0001	<0.0005	<0.0001	<0.0005	<0.005	<1	<2	<2	<2	<100	-	-	2.3	20,610	6.86	-68.0	29.8
	VWP328	20/04/2023	0.359	<0.5^	<0.02	14	0.011	684	-	<0.005	0.61	<0.0002	<0.001	0.25	0.0248	<0.001	<0.0002	0.413	<0.0001	0.0043	<0.0001	<0.0005	0.011	<1	<2	<2	<2	<100	-	-	3.0	93,072	5.99	-2.1	30.4
	VWP341	18/04/2023	0.65	<1.25^	<0.002	5	-	-	-	0.016	0.0053	<0.00005	<0.001	0.25	0.146	<0.0005	0.0003	2.13	<0.00004	0.0152	<0.0001	0.0004	0.171	<1	<2	<2	<2	<100	-	-	3.1	3,074	5.21	54.9	32.3