ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
16/08/18	A	Issued	JL	JO	HJ

Response to Development Application Information Request

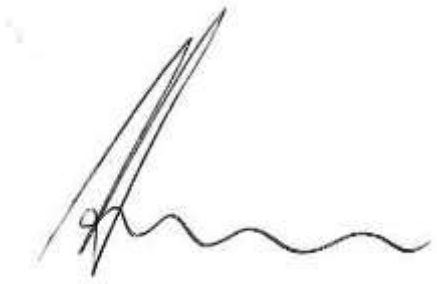
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



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RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	Clarify the total annual production of methane in tonnes (as 100% methane).
	DeLorean / Biogass	The total expected annual production of biogas is 25,500,000 m3. Converting to nominal tonnes of methane (typically constitutes 60% of biogas), total estimated annual production is 10,933,630 TPA CH4. Please refer to *Appendix 1 – Methane Calculations* for calculation workings.
2	EPA	Provide an overall balance showing the quantity of methane produced by anaerobic digestion (AD) as well as: a. Quantity of methane consumed by electrical power generation b. Quantity of methane expected to be exported offsite c. Quantity of methane expected to be lost in any gas treatment or purification process
	DeLorean / Biogass	The plant will generate 69,900m^3 of biogas per day. The gaseous output from the process will be cooled and purified through an activated carbon filtration system, before being burned through a Combined Heat and Power (CHP) unit rated to produce approximately 4.7MW of electricity and 4.9MW of thermal heat or upgraded to 21.7GJ/hr of biomethane. The expected quantities of methane consumed is as follows: a. Methane consumed by the sites electrical energy generation parasitic draw is expected to be 1,903,363 TPA b. Methane exported offsite is expected to be 9,840,267 TPA (injected into general gas system) c. There is no expected methane consumed in any gas treatment, purification process or any wash water technology used onsite. Please refer to *Appendix 1 – Methane Calculations* for calculation workings.
3	EPA	A description of the proposed Biofilter, including but not limited to: a. How the humidity and temperature of the odorous gases presented to the Biofilter would be controlled. b. How peaks in odour arising from reception hall operation would be managed.

		c. A prediction of the odour levels in the air leaving the biofilter. Odour levels should be expressed in Odour Units, as defined by Australian Standard: AS/NZS 4323.3:2001 – *Stationary source emissions.: Determination of odour concentration by dynamic olfactometry.*
	DeLorean / Biogass	Responses in relation to biofilter are provided as follows: a. The biofilter is a single stack unit containing a spongelight rock medium that degrades bacteria and pollutants. The humidity and temperature of the odourous gases are managed with the humidifier system. Temperature and humidity sensors are incorporated to ensure accurate moisture dosing and system control. b. The odour fluctuations in the reception hall will be controlled with the biofilter and humidifer unit. The air is humidified using misting nozzles with fans located inside the air extraction pipe ensuring 4-5 complete air changes per hour. Ducting will be concentrated over the reception hall zones with high concentrations in odour; the feedstock receival area and digestate offtake area. c. The biofilter unit is confirmed and guranteed to deliver <500 OU/m3.
4	EPA	Provide approprate engineering design of the biofilter (to ensure it is designed to work effectively).
	DeLorean / Biogass	Exact engineering design of the biofilter shall be provided following procurement and as soon as an acceptable unit and supplier has been selected through the competitive tendering process.
5	EPA	Provide a management plan for the proposed biofilter that includes contingency planning around the controls that would be in place to ensure the biofilter would be effective 100% of the time.
	DeLorean / Biogass	The biofilter management plan shall include the following to ensure that the biofilter is effective 100% of the time: • Biofilter Standard Operating Procedure (SOP). The SOP shall be duly enforced by the responsible site manager. • Biofilter mainanance and operation shall be conducted by trained responsible persons on a regular basis in accordance with the SOP. • The design of the receival hall incorporates independant fast closing doors operating on approximately 6 seconds. Opening and overlap of the doors is minimised by using on an ad-hoc basis only to contain odours and maintain the slight negative pressure in the building. An exact biofilter management plan shall be provided following procurement and as soon as an acceptable unit and supplier has been selected through the competitive tendering process.
6	EPA	A description of how the ferric sulphide resulting from the reaction betewen ferric chloride and hydrogen sulphide within the AD process would be managed to avoid liberation of hydrogen sulphide.
	DeLorean / Biogass	DeLorean / Biogass removes the previous requirement for ferric chloride dosing as per the *DeLorean Environmental Report*. Sulphide clean up is managed via a biological removal system. The method is an industry standard practice and involves micro dosing air into the head space of the digester to give H2S + O2 = SO4 + H2O. This enables the SO4 – sulphate to precipitate into the digestate for

		safe removal and offtake. The reference facility is currently operating at 20-50ppm, from up to 2000ppm's. Included is a further reduction from 50ppm's to less than 5ppm's ready for input in to the on-site boiler.
7	EPA	A description of how the proposed gas chiller would be operated and how any resultant condensate would be managed.
	DeLorean / Biogass	The gas chiller is operated through the parasitic power generated by the site and controlled by the Master Control Centre (MCC). The condensate is fully captured and recirculated back into the anerobic digestion process.
8	EPA	A description of how the proposed catalytic converter on the CHP exhaust would operate, including (but not limited to): a. Reagents to be used and how they would be stored b. Time required to raise the catalyst bed to operating temperature c. Prediction of the oxides of nitorgen mass flow in the exhaust leaving the bed
	DeLorean / Biogass	DeLorean / Biogass removes the previous requirement for catalytic converters as per the *DeLorean Environmental Report*. Reason is that procurement has now been amended to source only lean-burn CHP engines which are not required to be fitted with catalytic converters. Predicted NOx output is 500mg/Nm3 at STP and 5% O2. Please refer to Appendix 2 – Indicative CHP Emissions for details.
9	EPA	A prediction of the carbon monoxide mass flow in the exhaust ffrom the CHP catalyst bed.
	DeLorean / Biogass	Predicted CO output is 1400mg/Nm3 at STP and 5% O2. Please refer to *Appendix 2 – Indicative CHP Emissions* for details.
10	EPA	A description of the plant proposed the increase the concentration of methane in the gas produced by AD to a level that permits its export off site. This description should include (but not limited to): a. Reagents to be used and how they would be stored b. How the carbon dioxide removed by this step would be managed c. What emissions to air would arise as a result of this operation
	DeLorean / Biogass	The plant will use a biogas upgrade system to convert biogas to biomethane for export through pipeline injection. Answers to the EPA's specific questions are as follows: a. With Greenlane's water-wash system there are no chemicals, that is a major advantage of the Greenlane Biogas design - it is easy to operate, rugged in terms of no pre-treatment requirement of the biogas being fed into the upgrading system. With PSA system whilst the (adsorptive) media is regenerated it would need replenishing over time (depending upon biogas composition). b. On the water-wash systems, the (dissolved) CO2 is stripped out of the water, and the air/gas mixture exits the top of the stripping vessel. The air/gas mixture is usually discharged to a biological filter, carbon filter or Thermal Oxidiser (RTO) - depending upon the level of H2S in the biogas. c. Expected gas output composition as follows 95.7% CH4, 2% CO2, 1.82% N2, 0.47% O2, <3 H2S (ppm).

11	EPA	A description of any other processes for pH control and biogas cleaning/scrubbing that are proposed for this site. This descripton should include (but not be limited to): a. Reagents to be used and how they would be stored b. How any waste products arising from such operations would be managed
	DeLorean / Biogass	Other processes that will be employed by the site are as follows: • Processes outputs are circulated through the onsite digestate treatment plant. The digestate treament is composed of the following steps: 1. Digestate primary treatement – digestate dewatering 2. Bioreactor treament unit 3. Ultrafiltration (UF) units 4. Reverse Osmosis (RO) units Please refer to *Appendix 3 – Digestate Treatement Plant Chemcial Consumption* for detail on expected regents used. • PH (decrease) is a result of the normal biological breakdown of the biomass. Organic loading can be used to control pH and will be monitored regularly through periodic measurement and testing. • Onsite chemical laboratory for regular feedstock and process testing. • Oxygen micro-dosing to remove H2S (refer to point 6 for detailed description).
Water Quality		
12	EPA	A discharge from site of 128m3/day is required for supply to Salisbury Water, describe what contingency would be in place if that supply requirement is disrupted, either though water quality issues or issues on Salibury Water's ability to accept the water. Clarify if there is another dispoal option requried, and if so describe what that option would be.
	DeLorean / Biogass	In the event that the Salisbury Water's supply requirement is disrupted, the site will have a water storage capcity of approximately 5 days until Salisbury Water can rectify the disruption or find an intermediate solution.
13	EPA	For the collection and distribution of stormwater to the City of Salisbury, clarify how would it be confirmed that the water quality is satisfactory to send direct to Salisbury Water if an incident comproising water quity was to occur in the budned area, or clarify if it is the intent that all water collected within the bund would always sent through the treament process.
	DeLorean / Biogass	Confirming that the latter is correct, all water collected within the bund will be sent through a water treatment process. The output will be cleaned to meet the standards required by Salisbury Water for proper disposal. The water treatment process will consist of mechanical separators, reverse osmosis, ultrafiltration and an on-site waste water treament plant.
Waste Management		
14	EPA	Provide details to adequately characterise the digestate and reverse osmosis condensate including the physical and chemical composition. In adressing this aspect please ensure the fate of any chemical additives or regents of the process are included.

	DeLorean / Biogass	The digestate is mechanically separated into solid and liquid fractions. The solid fraction is approximinately 30% dry material content and spade-able product which is used as organic compost. The liquid fraction is expected to be 0.5% dry material content and is recirculated back into the process. Please refer to *Appendix 3 – Digestate Treatement Plant Chemcial Consumption* for detail on expected regents used Please refer to *Appendix 4 – Reference Facility Indicative Digestate Composition* for detail on the outfeed digestate composition.
15	EPA	At any given time, how much waste (in tonnes or m3) would be: a. Stored on site in the reception shed b. Stored in the agricultural waste silos c. Undergoing processing in the hydrolysis, pasteurisation, and digester tanks.
	DeLorean / Biogass	The feedstock storage is as follows: a. The reception building will have capacity to store 48 hours of material or approximately 770 Tonnes. The processes of the receoption buidling will ensure that received waste materials will have an onfloor time of not more then 48 hours prior to processing adn encapsulation within tank systems. During this period the waste material will be within the reception hall only. b. The agricultural grain silos will have capacity to store 48 hours of material or approximately 190 Tonnes. This material is securely stored within a silo as is standard. c. The hydrolysis tank will have capacity to store 3,500KL of biomass and is not open to atmosphere, all gasses produced are captured and treated. The six digester tanks will have capacity to store 3,500KL of biomass each (total 21,000KL) and is not open to atmosphere, all gasses produced are captured and treated The pasturiser has a capacity of approximately 22T/hr and is not open to atmosphere, this is a modified pipework system enroute to tge hydrolosis tank
16	EPA	Clarify the maximum residence time (stockpile turnover timeframe) of any waste (solid and liquid) received at the facility.
	DeLorean / Biogass	The maximum residence time of all incoming feedstock will be; 2 days storage in the reception building awaiting feeding; 5 days in the hyrolysis tank; 30 days in the biodigesters; 2 days in the reception building awaiting offtake (total 39 days). However, the opration of the facility strives for same-day continuous processing.
17	EPA	Clarify whether any digestate or sludge would be stored at the subject site, and the manner of any such storage, for any period of time while awaiting off-site transport.
	DeLorean / Biogass	The maximum residence time of any outgoing digestate will be 48 hours. The solid fraction of the digestate will be fully contained in the reception building and loaded into semitrailers for offtake. The liquid digestate will be cycled through the closed-loop plant process. However, the opration of the facility strives towards same-day

		continuous processing.
18	EPA	Confirmation what testing would take place for all incoming wastes (as stated on page 28 of the *DeLorean Energy Enviornmental Report*).
	DeLorean / Biogass	Feedstock entering the facility will be subject to the following testing: - Inspection by qualified and competent responsible persons in charge for acceptance - Incomming trucks will be required to have their loads recorded on a weighbridge - New complex biomass is sampled and tested for physical and chemcial properties at the on-site chemical laboratory on an as needs basis. For example, a new supplier comes online, their product will be tested. Adhoc deliveries will be tested depending on the source and delivery type. All delivery types will be tested on a rotating basis to ensure that DeLorean can maintain a stong record of the exact type of incoiming material. - All unnaceptable feedstock will be rejected
19	EPA	There is potential for some of the by-products from the proposed processes to generate Listed Wastes (as outlined in Schedule 1 Part B of the Environment Proctection Act), please provide confimation of any such wastes with estimated quanitites and management proposals.
	DeLorean / Biogass	As per Schedule 1 Part B of the Environment Proctection Act, no chemicals from the *Listed Wastes* will be produced as a product from the operation. However, small trace elements of *Sulphides and Sulphide Solutions* may be produced as a by-product only. Please note that Sulphide is not produced on large scale or as a sellable product. The management method will be though biological oxygen micro-dosing to remove H2S (refer to point 6 for detailed description). In additon, screening and testing of incoming waste streams and testing of digestates will be undertaken on a regular basis to ensure that Listed Wastes are not tipped at the site, removed from the system and / or appropriately disposed of.
20	EPA	It is stated that the digestate would consitute a compost produtct ready for sale as organic fertiliser. Clarification is required as to the standard or specification the digestate and RO condensate would meet. Please refer to the *EPA Compost Guideline*, January 2013 for assistance with your response.
	DeLorean / Biogass	As per the *EPA Compost Guideline*, the only the incoming feedstock is classed as Category A as it encompasses food waste according to the guideline. Please note that this is not a waste product but a clean feedstock product. All product entering the facility will be pasturised to ensure pathogens are eliminated to meet PAS110 standards.
21	EPA	Clarify whether pasteurisation of the digestate is required prior to any reuse of this material (as suggested on page 15 of the *DeLorean Energy Environmental Report*).
	DeLorean / Biogass	All material is pasturised during the process to ensure pathogens are eliminated to meet PAS110 standards. The output digestate is a spadable material with the volatile component removed during the anaerobic digestion process. As a result, no further processing is required as the product is be ready for use as organic compost.

22	EPA	Confirmation of the quanitites of digestate / compost that would be: a. Sent off-site for further treatment, e.g. by a licenced composting facility b. Reused or processed in some manner, or directly reused as a fertiliser / compost or Waste Derived Soil Enhancer. Note: the EPA Standard for the production and use of waste derived soil enhancer applies to the direct reuse of waste as a soil enhancer.
	DeLorean / Biogass	The digestate is not a waste product but instead is a salable material ready for use as organic compost. All solid output digestate will be sent to licenced composting facilities. Further treatment is not required as the digestate is a ready to use organic fertiliser however composting facilities may decide to improve compost properties by adding material at their discretion. All liquid digestate will be circulated though the on-site water treatment facility. Total liquid output from the site will be expected to be 456m3/day. Of this volume, 329m3/day is reused and recirculated to assist with the AD process. The remaining volume of 128m3/day is treated though a water treatment system and sent to the aquifer operated by Salisbury Water.
23	EPA	Provide an estimate of the quntities of waste that would be sent to landfill for disposal on an annual basis.
	DeLorean / Biogass	The amount of waste generated to be sent to landfill is highly dependent on the type of incoming material which can vary significantly on a day to day basis. However, taking the reference facility as a baseline, an estimated 0.5% will be of input material will be sent to landfil. This equates to approximately 500TPA from the 100,000TPA expected Commerical & Industrial (C&I) waste. The dry feedstock (i.e. grain material) is clean and is not expected to contain any waste requiring landfill.
Air Quality		
24	EPA	As identified in the *DeLorean Energy Environmental Report*, porovide an air quality assessment report taht comlies with the requirements fo the EPAs Ambient air quality asssessment 2016 publication. The report should contain, as a miniumim, include: a. A map that identities (including distances) all sensitive receptors within 100m of the proposed plant. b. Identification of all potential pollutant emissions, including fugitive emissions, and their emissions rates under a worst case scenario (ie. maximum emission rates) as well as typical operating conditions c. An air dispersion modelling report for all the pollutants of concern (eg. Odour, H2s, NO2, SO2, CO, PM2.5 and PM10), for worst-case scenario and typical operation, based on robust and defenible emission rate data and undertaken by suitably qualified and experienced air quality modeller
	DeLorean / Biogass	A comprehanisve *Air Quality Assessment* has been undertaken by a suitabily qualified consultant and is provided in Appendix 5
Noise		
25	EPA	As identified in teh *DeLorean Energy Environmental Report*, provide a report prepared by a suitably experienced, professional acousitic engineering consultant* demonstrating that tworst case predicted noise from the proposal can meet the following Noise Criteria** (refer to *EPA Develpoment Appolicaiton Information Request*).

	DeLorean / Biogass	A comprehanisve *Noise Assessment* is currently being undertaken by a suitabily qualified consultant and will be provided to the EPA as soon as possible.

APPENDIX 1 – METHANE CALCUALTIONS

Biogas to methane calculation

Biogas	25,500,000	m3
Methane (CH4) in biogas	60%	%

PV=nRT

P	101325	Pa
V	15,300,000	m3
R	8.31	J k-1 mol-1
T	273	T
n (solve)	683,351,847	mols

n=m/M

n	683,351,847	mols
M	16	CH4
m (solve)	10,933,629,547	kg

Methane consumption

Site parasitic	10%	%
	1,093,362,955	kg

Exported	90%	%
	9,840,266,593	kg

Lost in gas treatment	0%	%
	-	kg

APPENDIX 2 – INDICATIVE CHP EMISSIONS

TCG	2020V16	Exhaust analysis								
							Assumptions			
MWM Data exhaust mass flow wet =				8282	kg/h		Biogas contains	55% CH4		
							Combustion air is dry and at STP			
Exhaust Bulk Composition (Wet)						Exhaust Bulk Composition (dry)				
	kg/h (wet)	mass % (wet)	m3/h (wet)	vol % (wet)			kg/h (dry)	mass % (dry)	m3/h (dry)	vol % (dry)
CO2	1319	15.9%	673	10.4%		CO2	1319	17.1%	673	11.8%
N2	5695	68.8%	4570	70.8%		N2	5695	74.1%	4570	79.9%
O2	675	8.2%	474	7.3%		O2	675	8.8%	474	8.3%
H20	593	7.2%	741	11.5%						
TOTAL	8282	1	6459	1		TOTAL	7689	1	5718	1
Density at STP =			1.29	g/l (wet)		Density at STP =			1.35	g/l (dry)
Volume at STP =			6459	Nm3/h (wet)		Volume at STP =			5718	Nm3/h (dry)

NOx will be ≤	500	mg/Nm3 dry gas and STP at 5% O2.				
This is equivalent to		396	mg/Nm3 dry gas and STP at	8.3%	O2	
At full load this will be		2.27	kg/h dry gas and STP in the exhaust maximum			
CO will be ≤	1400	mg/Nm3 dry gas and STP at 5% O2.				
This is equivalent to		1110	mg/Nm3 dry gas and STP at	8.3%	O2	
At full load this will be		6.35	kg/h dry gas and STP in the exhaust maximum			

Exhaust Flow rate will depend on the temperature		
Temperature	Flow rate (wet)	Flow rate (dry)
C	m3/h	m3/h
0	6459	5718
150	10007	8860
180	10717	9488
210	11427	10117
450	17105	15143

APPENDIX 3 – DIGESTATE TREATEMNT PLANT CHEMICAL CONSUMPTION

PARAMETER	VALUE	U.M.
Polyelectrolyte (*)	--	gr/m^3 of treated digestate
Acetic Acid (**); nutrients	--	gr/m^3 of treated digestate
Sulfuric acid (30%) (#)	2000,0 approx.	gr/m^3 of treated digestate
Sodium hydroxide (30%) (#)	200,0 approx.	gr/m^3 of treated digestate
RO Antiscalant (100%)	6,0	gr/m^3 of treated digestate
Sodium hypochlorite (14%)	50,0	gr/m^3 of treated digestate
Acid membrane cleaner (100%)	20,0	gr/m^3 of treated digestate
Caustic membrane cleaner (100%)	50,0	gr/m^3 of treated digestate
Antifoam (100% biodegradable non silicon)	--	gr/m^3 of treated digestate

(#) The dosage of sulphuric acid is necessary for the pH correction (acidification) at the RO entrance in order to control the scaling of the membranes. The consumption of the sulphuric acid strongly depends on many factors; the main ones are: alkalinity concentration in the raw digestate, ammonia concentration in the raw digestate, reduction of nitrogen in the solid separation section, reduction of the nitrogen content carried on in the biological process, hardness and sulphate concentration in the digestate, desired recovery in the RO system. All these parameters have a reciprocal influence and the consumption of sulphuric acid becomes from a specific process optimization. The dosage of sodium hydroxide is necessary for the neutralization of the carbon dioxide in the reverse osmosis permeate. The carbon dioxide presence in the reverse osmosis permeate is due to the sulphuric acid dosage and proportional to this one. So, the sulphuric acid consumption and the sodium hydroxide consumption can be guaranteed only after a detailed analysis of the digestate is received. The reported values come from experience done in similar application.

(*) The consumption of polyelectrolyte strongly depends by the type of polyelectrolyte utilized (there are many type with many different characteristics in the market) and by the optimization tests carried on with the real digestate produced by the plant. The field test is the common practice in order to choice the optimal type and the dosage of polyelectrolyte for the dewatering process.

(**) Normally it is not necessary to dose any biodegradable carbon in the digestate liquid fraction at the biological inlet but sometimes, especially at the plant start-up, a dosage of prompt biodegradable carbon is useful for the biomass growth and consolidation. Anyway, an eventual acetic acid dosage is evaluable after a jar test to be done on the raw digestate in order to evaluate the quality and quantity of COD of the liquid fraction after the solids separation.

APPENDIX 4 – REFERENCE FACILITY INDICATIVE DIGESTATE COMPOSITION

The following information is taken from chemical testing of outfeed samples taken from the reference facility located in Jandakot, Western Australia. Results display the averages of periodic testing and data collection over 3 years.

Chemical	ppm
N	5,003.4
pH	549.2
Cl	1,119.5
N.NH4	3,207.1
N.NO3	1.0
N.NOx	1.4
Ca	649.4
Cu	1.7
Fe	443.5
Mg	91.5
Mn	4.0
K	859.2
Na	703.3
S	165.3
Zn	21.0
Co	0.1
Ni	0.1
Al	170.0
Ar	0.0
Cd	0.0
Cr	0.4
Pb	0.3
Mo	0.0
Se	0.0
Moisture %	96.7
pH	7.9

APPENDIX 5 –AIR QUALITY ASSESSMENT

Intended for
Emissions Assessments Pty Ltd

Date
September 2018

BIOGASS RENEWABLES SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

RAMBOLL

BIOGASS RENEWABLES
SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

Revision	**Final**
Date	**25/09/2018**
Made by	**Martin Parsons**
Checked by	**Ruth Peiffer**
Approved by	**Nick Houldsworth**

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1. INTRODUCTION

1.1 Background

Biogass Renewables Pty Ltd (Biogass) are proposing to develop an Anaerobic Digestion Plant (the Plant) at the parks precinct in Edinburgh, South Australia. The premises are located at Lot 104 - 116 Purling Ave, Edinburgh, South Australia. The location of the proposed facility is shown in Figure 1, with nearest sensitive receptors being located approximately 450 m south-west and 300 m south of the site.

Emissions Assessments Pty Ltd (Emissions Assessments) requested Ramboll Australia Pty Ltd (Ramboll) undertake an air dispersion modelling assessment to determine the likely air quality impacts associated with routine operations and a flaring scenario for the Plant. This report presents the approach, methodology and results of air dispersion modelling for the Plant operating under each of the modelled scenarios. The maximum predicted ground level concentrations (GLCs) of the modelled compounds have been compared against the relevant ambient air quality criteria.

1.2 Overview of Process

The Plant will use organic waste to produce biogas (methane) through an anaerobic digestion process. The anaerobic digestion process is a fully enclosed system.

The organic waste (100,000 tonnes per annum [tpa] of food waste, 25,000 tpa of grain dust) is received, stored and pre-processed in a purpose built, sealed and fully enclosed negative pressure structure, before being pumped in a continuous process to a digester feed tank then onto one of six digester tanks, where it is stirred and agitated at intervals to encourage the release of biogas. An automated system regulates the necessary parameters such as pH and temperature. The digester breaks down the material to produce biogas, comprising approximately methane, carbon dioxide, water and hydrogen sulphide.

The biogas is collected under a fire resistant, double membrane dome on top of each digester. A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, also known as biomethane.
The biomethane will then be fed to a power plant, which drives a generator to produce electricity for onsite use by Biogass. The digestion tanks harvest the steam and hot water from the power plant, which is used to stabilise the temperature of the biomass in the digestion and storage tanks.

Figure 1: General Location of the proposed Biogass Facility

1.3 Details of Process

An overview of the layout of the plant is shown in Figure 2 with detailed description of the operation provided in the following sections.

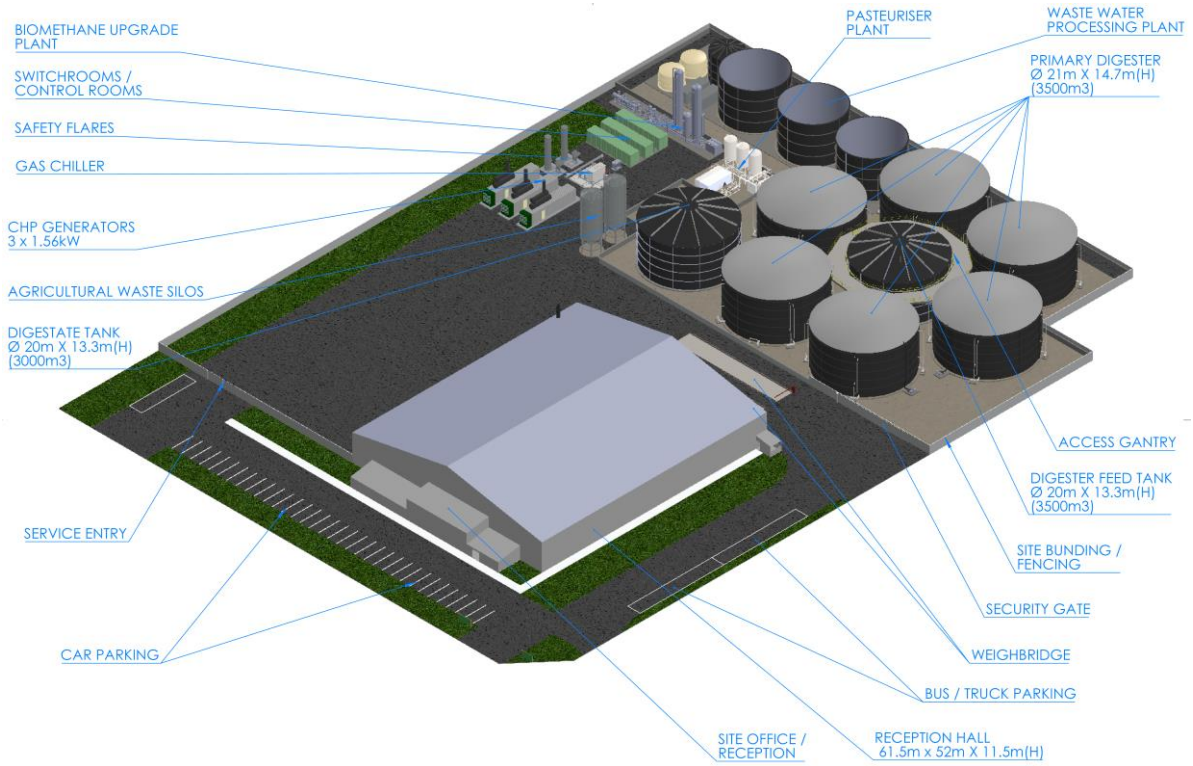

Figure 2: Layout of Plant

Source: Emissions Assessments

1.3.1 Receivals Hall

The waste is received in the receivals hall which is a 60 m x 52 m x 11.5 m high hooped roof building. The receivals hall is fitted with concrete bunkers, graded floor and drainage sump. The receivals hall will be under negative pressure and connected to fully enclosed, single stack biofilter.

All vehicle entry points to process buildings will be via fast acting roller shutter doors which open and close on a pressure switch. All doors associated with process buildings will be connected to an alarm system which alerts operators in the event of doors being left open. Doors will only be opened for entry and exit of trucks with doors sealed before unloading occurs.

The solid and semi-solid waste will be deposited into graded bunkers with liquid waste pumped directly into a sump, for subsequent pumping to a liquid storage tank. Trucks are washed before departure with all wastewater draining to the sump for processing in the digestion system.

1.3.2 Staging Process (no emissions)

Blended and balanced feedstock is pumped in sealed pipes to a fully enclosed digester feed tank where it is mixed and warmed using heat from the plant's biogas generators.

1.3.3 Anaerobic Digestion (no emissions)

Feedstock is pumped daily in sealed pipes from the digester feed tank to the primary digester tanks. These tanks are interoperable or can be isolated. The digesters are warmed using heat from the plant's biogas generators. Biogas accumulates in the gas domes, and can be positively displaced by pumping air between the gas dome's membranes.

1.3.4 Digestate Storage and Reuse (no emissions)

On a daily basis, digestate is pumped in sealed pipes to a digestate storage tank. The digestate will be pumped directly into a tanker truck for transport offsite.

1.3.5 Biogas Processing and Safety Flare

Biogas in the domes is positively displaced and drawn off in sealed gas pipes. The gas will then pass through a biomethane upgrade plant which will be used to upgrade the biogas to a methane-rich product gas, also known as biomethane.

The entire gas management system is connected to an enclosed gas flare system comprising two flares. Gas can be directed to a flare at all gas storage and processing stages so as to bypass any equipment processing failure that may occur. The flare will only be operated on an emergency basis, or when one of the generators is not operating for routine maintenance (estimated 12 days per year), or in the unlikely event that all generators fail (worst case estimated 7 days).

A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, also known as biomethane.

1.3.6 Power and Heat Generation and Application

Clean methane gas, scrubbed and separated (carbon dioxide fraction removed) is compressed as fuel for three generators. Energy generated will be used to power the anaerobic digestion plant. The balance will supply 100% of Biogass' onsite energy requirements. Heat from the generator will be captured via a heat exchanger to heat the digester feed tank and the primary digesters.

2. ATMOSPHERIC EMISSIONS

2.1 Emission Sources

The atmospheric emissions sources included in the air dispersion modelling assessment for the Plant operating under routine conditions include:

- One biofilter stack, with emissions of concern being odour;
- Three gas fired reciprocating engines, with the emissions of concern being biomethane combustion products; and
- Emissions from the biomethane upgrade plant, consisting of hydrogen sulphide and odour.

The receivals hall was also considered as a potential emission source. However, as the Hall will be fitted with fast acting roller shutter doors and will be under negative pressure and connected to the fully enclosed, single stack biofilter, potential emissions are considered to be negligible. The main doors will only open for vehicle entry for waste delivery and digestate transport. With fast door opening and closing times of 6 seconds, it is likely that the doors will be open for around 30 seconds per truck entry. Emissions monitoring at similar sites has indicated emissions from door openings and leakage from buildings with rapid roller shutter doors and comparable management practices are negligible. The receivals hall has not been included in the modelling assessment on this basis.

The full flaring scenario included in this assessment has considered the following atmospheric emission sources:

- Two enclosed flares, used when one or all of the generators are unavailable with the emissions of concern being biomethane combustion products.

2.1.1 Biofilter Emissions

The biofilter will use spongelite as the filter media. Air from the receivals hall will be humidified using misting nozzles running on timer, with a fan running inside the air extraction pipe. All biofilter fans will run on standard electric motor, with a spare which can be connected immediately in event of a failure.

2.1.2 Power Generation

The plant will use three 526 kW capacity Jenbacher 3-type biogas generators (GE JGS312 GS-N.L D225) manufactured by General Electric. The GE Jenbacher engine uses a LEANOX control system with oxides of nitrogen emissions guaranteed < 500 mg/Nm³ (101.3 kPa, dry and 5% O_2).

Emissions associated with the generators include:

- Oxides of nitrogen (NO_x) consisting mostly of nitrogen oxide (NO) and a lesser concentration of nitrogen dioxide (NO_2). NO_x is formed primarily from the oxidation of fuel-bound nitrogen and nitrogen in the air;
- Sulphur oxides (SO_x) which are predominantly in the form of sulphur dioxide (SO_2), formed from the oxidation of sulphur in the fuel; and
- Carbon monoxide (CO) formed from the incomplete combustion of the fuel.

Particulate matter (PM) and non-methane volatile organic emissions from the generators are considered to be negligible as the fuel source is a gaseous fuel with minor higher chain paraffins and as such, have not been included in the modelling assessment.

2.1.3 Enclosed Flares

Each enclosed flare will reach a height of 8 m and diameter of 1.7 m. The biogas is fed in at the bottom and combusted with the combustion temperature and efficiency controlled by a thermocouple near the top of stack, which adjusts the air inflow at the base of the stack via dampers. If the exhaust temperature is too high, the dampers are opened further and more air is drawn in and if too low, the dampers are restricted to restrict the air flow to maintain optimum combustion. Destruction removal efficiencies of 99% and 99.95% for methane and hydrogen sulphide (H_2S) respectively are guaranteed by the manufacturer.

2.1.4 Biomethane Upgrade Plant

A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, also known as biomethane. Emissions of concern from the biomethane upgrade plant will include H_2S and odour.

2.2 Emissions Estimations

Emission estimates for the biofilter, power generation and flares were derived from stack monitoring data from another biogas production facility with a similar configuration located in Jandakot, Western Australia (as provided by Emissions Assessments). The emissions estimates applied in this assessment have been derived from worst case concentrations, as measured when the reference plant was operating at 100% load and are considered conservative.

Emission estimates for the biomethane upgrade plant were derived from manufacturer's specifications.

The exhaust parameters and emission estimates for each of the modelled sources are provided in Table 1.

Table 1: Emission Parameters for the Plant

Parameter	Units	Routine Operations			Flaring
		Bio Filter	CHP Power Generation x 3	Biomethane Upgrade	Flares x 2
Exhaust Parameters					
Operation		Continuous	Continuous	Continuous	< 12 days per year
Number		1	3	1	2
Coordinates	**UTM**	283634, 6153412	283603, 6153437 283607, 6153435 283611, 6153433	283640, 6153473	283611, 6153455 283615, 6153453
Height	**m**	14.5	8.6	14.5	8.0
Diameter	**m**	0.88	0.32	0.25	1.73
Temp	**Deg C**	22	410	15	1000
	K	295	683	288	1273
Measured Oxygen	**%**	NA	8.3	NA	10.9
Stack Moisture	**%**	1.5	4.4	NA	1.5
Volumetric Flow	**Nm^3/s Dry**	19.1	1.16	0.73	10.2
	Am^3/s	20.3	2.8	0.77	47.0

Parameter	Units	Routine Operations			Flaring
		Bio Filter	CHP Power Generation x 3	Biomethane Upgrade	Flares x 2
Exit Velocity	**m/s**	33.3	34.6	15.7	20.0
Emission Estimates					
OU	**o/u.m^3/s**	1670	NA	105	NA
H_2S	**mg/m$^{3[1]}$**	NA	5.0	55	5.2
	g/s	NA	0.01	0.04	0.05
NO_x	**mg/m$^{3[1]}$**	NA	400	NA	51
	g/s	NA	0.46	NA	0.52
SO_2	**mg/m$^{3[1]}$**	NA	46	NA	8.8
	g/s	NA	0.05	NA	0.09
CO	**mg/m$^{3[1]}$**	NA	590	NA	16
	g/s	NA	0.69	NA	0.16

Notes

1. Referenced to STP (273.15K, 101.3kPa) and expressed as dry values.

2.3 Non-Routine Emissions

Non-routine emissions from biogas plants (apart from the infrequent flaring) may potentially arise as a result of a malfunctioning of the flare, the air extraction system or the biofilter. For the Plant these will be addressed by the management practices outlined in the following sections.

2.3.1 Flaring

Flaring upset conditions may potentially occur if gas is vented via the flare without combustion occurring. The biogas plant flare system will mitigate this risk by configuring the ignition system to be battery powered with backup solar charging. The monitoring system also includes monitoring of the exhaust temperatures and exhaust gases, such that if combustion is not occurring an alarm will be activates to alert to the need for intervention.

2.3.2 Biofilter

Higher than normal emissions can occur through biofilters (or fugitive release from the receivals hall) due to failure of extraction motors, loss of power, loss of humidification of the inlet air and problems in the biofilter media, such as compaction of the bed, degradation in the efficiency and the need to perform maintenance such as replace the filter media. These will be managed as follows:

- The extraction system on all biofilters at the site will utilise standard motors, with one motor always kept onsite as a spare. The biofilter for this plant will use two fans. Loss of a motor will only reduce the extraction flow rate by 50% for a period anticipated for no more than 3 hours;
- The power supply for the pumps will be provided by onsite generators, and when not available, by mains power. Redundancy is therefore built into the power supply and a power failure event could only occur if the onset generators failed, and there happened to be a simultaneous mains power failure. The likelihood of these concurrent events is extremely low. Owing to the redundant design it is therefore expected that odour escape owing to power failure has negligible probability of occurring;
- The humidification system will be designed to ensure humidity for all inlet conditions is maintained at 70%; and

- The biofilter media is anticipated to last for 8 years. This is much longer than organic biofilter media as it does not suffer issues such as compaction and degradation in media performance. The media is anticipated to be replaced on an as-required basis, but not less than every 8 years. Monitoring of the stack emissions will be conducted to assess the performance of the biofilter. If a deterioration in performance below minimum standards is attributed to degradation of the media, all waste receivals will be held over pending a replacement of the media, a process of up to two days.

Given the above design and proposed management of the plant, the probability of non-routine emissions from the Plant occurring is considered to be negligible and as such, have not been included in the modelling assessment.

3. AIR QUALITY CRITERIA

3.1 Human Health

For ambient GLCs, the SA Environment Protection Authority (EPA) outlines state-wide standards in its Environment Protection (Air Quality) Policy 2016. The policy seeks to apply the standards at residential areas or places where people may congregate, such as beaches or picnic areas. The standards relevant to this assessment are listed in Table 2.

Table 2: SA EPA Environment Protection (Air Quality) Policy 2016 - Applicable Air Quality Standards

Pollutant	Averaging Period	Maximum Concentration ($\mu g/m^3$)[1]
CO	1-hour	31,240
	8-hour	11,250
NO_2	1-hour	250
	1-year	60
H_2S	3-minutes	510
SO_2	1-hour	570
	1-day	230
	1-year	60

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.

3.2 Odour

The SA EPA has outlined state-wide standards for odour that are applicable to this study. The standards state that an activity cannot result in the number of odour units being exceeded for the number of persons (as specified in Table 3) over a 3 minute averaging time 99.9% of the time (based on evaluations at ground level using a prescribed testing, assessment, monitoring or modelling methodology for the pollutant and activity).

Table 3: SA EPA Environment Protection (Air Quality) Policy 2016 – Applicable Odour Standards

Number of people	Odour Units (OU) (3-minute average, 99.9% of time)
2000 or more	2
350 - 1999 (inclusive)	4
60 - 349 (inclusive)	6
12 - 59 (inclusive)	8
Single residence (fewer than 12)	10

4. EXISTING AIR QUALITY

In order to determine a background concentration to assess potential cumulative impacts for the purposes of this study, monitoring data from two SA EPA monitoring stations; Elizabeth (NO_2 and CO) and Northfield (SO_2). These locations were chosen as they are the nearest ambient air quality monitoring stations to the proposed site and the monitored values are considered to be generally representative of background concentrations.

Monitoring data collected at each site between 1 January 2015 to 31 May 2018 was utilised for the purpose of this assessment. No specific guidance for selection of an appropriate background concentration is provided by the SA EPA. The Environment Protection Authority Victoria (Vic EPA) State Environment Protection Policy (Ambient Air Quality) (SEPP (AQM)) (Gov. of Vic., 2001) recommends the 75th percentile concentration (concentration which is exceeded by 25% of concentrations for that averaging period) should be adopted as a background level. Correspondence with SA EPA personnel indicated this approach would be suitable to determine ambient background concentrations for use in this assessment.

A summary of the ambient concentrations measured at the Elizabeth and Northfield SA EPA monitoring stations are presented in Table 4.

Table 4 indicates that of the applicable pollutants, background concentrations are relatively low in the region.

Table 4: 75th Percentile and Annual Average Ambient Concentrations for CO, NO_2 and SO_2

Pollutant	Averaging Period	75th Percentile Concentration (µg/m^3)[1]	Annual Average (µg/m^3)[1]
CO[2]	1-hour	25	NA
	8-hour	25	
NO_2[2]	1-hour	10	
	24-hour	NA	8
SO_2[3]	1-hour	0	NA
	24-hour	0.14	
	Annual	NA	0.2

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. As measured at the Elizabeth SA EPA monitoring station.
3. As measured at the Northfield SA EPA monitoring station.

It is noted the annual average SO_2 concentration measured at the Northfield monitoring station is 0.2 µg/m^3, while the 75th percentile 1-hour average is zero; this is reflective of a large proportion of the hourly monitoring data being equal to zero.

5. MODELLING METHODOLOGY

5.1 Model Selection

The SA EPA has stipulated that unless prior agreement has been obtained, all air dispersion modelling should be completed using the CALPUFF air dispersion model using a meteorological dataset from 2009.

5.2 CALPUFF Model Set Up

The following model set up options within CALPUFF were used:

- Building downwash was included using the BPIP-Prime algorithms with site layout and elevation. The tanks, silos and receivals hall were included in the modelling;
- Grid spacing's of 100 m over a 7 km x 7 km model domain were applied, centred approximately on the site;
- The TAPM prognostic meteorological model developed by CSIRO was used to generate a gridded meteorological dataset for the modelling domain. Monitored meteorological data from the Bureau of Meteorology (BoM) Elizabeth monitoring station were used with the TAPM output as inputs into the CALMET meteorological processor to develop a meteorological data file suitable for use in CALPUFF;
- No chemical transformation or deposition, except for the prediction of NO_2 (as discussed in Section 5.3);

A summary of the CALPUFF inputs applied in this assessment is provided in Appendix 1.

An annual wind rose generated by the CALMET meteorological processor for the proposed site location is presented in Figure 3, with the annual frequency of wind speeds presented in Table 5.

Table 5: Distribution of Wind Speeds for 2009 (CALMET-Generated Data)

Wind Speed	Calms	0.5–2.0 m/s	2.0-3.5 m/s	3.5-5.0 m/s	5.0-6.5 m/s	6.5-8.0 m/s	>8m/s
(%)	1.4	36.2	36	19.3	5.4	1.4	0.2

5.3 3 Minute Averaging Periods

A simple averaging-time scaling factor can be used to estimate short-term peak concentrations for applications. This adjustment primarily addresses the effect of meandering (fluctuations in the wind about the mean flow for the hour) on the average lateral distribution of material. The scaling factor used to adjust the lateral dispersion coefficient[1] for averaging time is the 1/5th power law:

$$Cl = Cs(60/tl)^{0.2}$$

where
Cl = Concentration for new averaging period;
Cs = Concentration for the 1 hour average period;
tl is the averaging time (min.) of interest

[1] Turner, D.B., 1970: Workbook of Atmospheric Dispersion Estimates. U.S. EPA Office of Air Programs Publication No. AP-26. Research Triangle Park, NC.

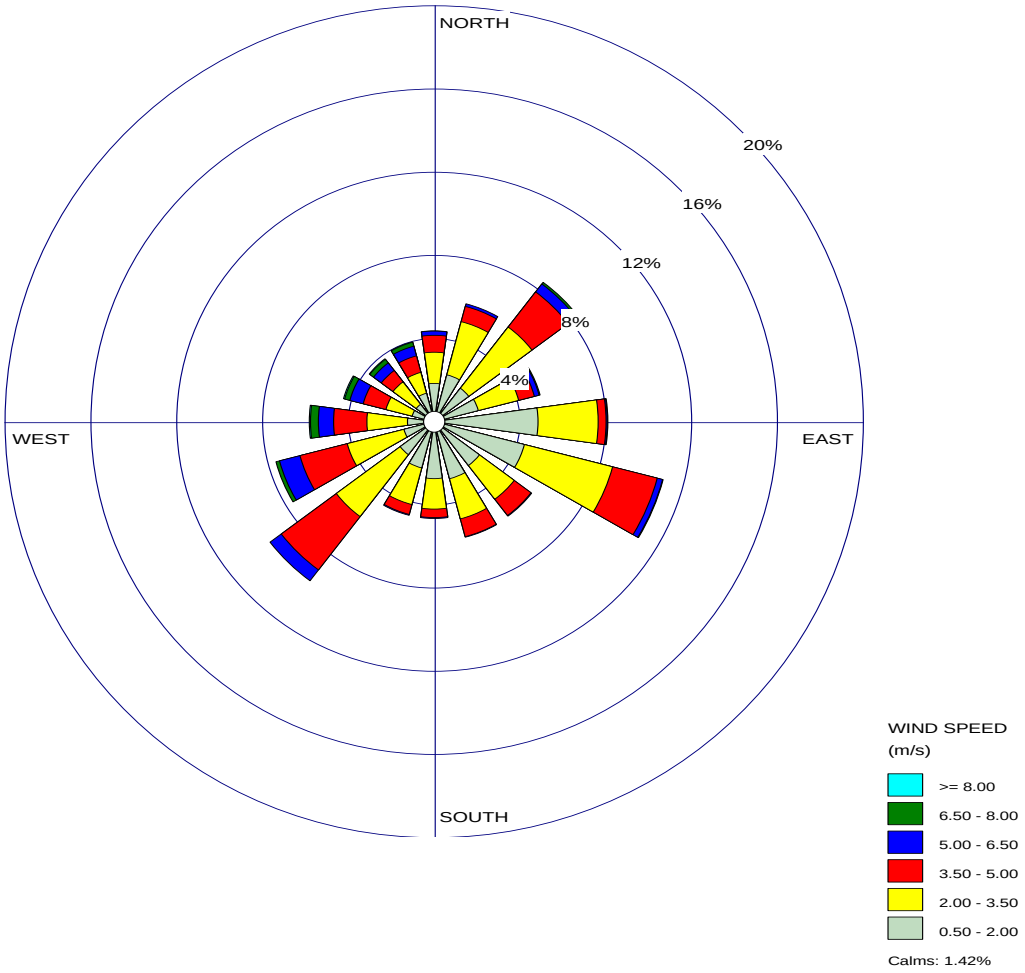

Figure 3: 2009 CALMET-Generated Annual Wind Rose

5.4 Treatment of Oxides of Nitrogen

A key element in assessing the potential environmental impacts from ground level NO_2 concentrations is estimating NO_2 concentrations from modelled NO_x emissions. The final NO_2 concentration is a combination of the NO emitted as NO_2 from the source stacks and the amount of NO that is converted to NO_2 by oxidation in the plume after release.

Generally, after the NO_x is emitted from the stack, additional NO_2 is formed as the plume mixes and reacts with the surrounding air. There are several reactions that both form and destroy NO_2, but the primary reaction is oxidation with ozone according to the following reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

This reaction is essentially instantaneous as the plume entrains the surrounding air. It is limited by the amount of ozone available and by how quickly the plume mixes with the surrounding air. Thus the ratio of NO_2 to NO_x increases as the plume disperses downwind.

In order to predict NO_2 concentrations, Ramboll has applied the US Environmental Protection Agency (USEPA) Ozone Limiting Method (OLM). This method assumes that ozone is the limiting reagent (i.e. the ozone concentration is less than the remaining NO_x concentration) and requires an NO_2 to NO_x in-stack ratio. In the absence of a site-specific in-stack ratio, it has been assumed

that 10% of NO_x emissions are NO_2 (a common assumption for gas combustion sources). Hourly average ozone concentrations for application in the OLM were obtained from the Elizabeth ambient air quality monitoring station.

The OLM approach is considered conservative over short-term averaging periods as it assumes the reaction between NO_x and ozone occurs instantaneously, when in reality this is likely to take place over a number of hours, during which time the plume is subject to dispersion.

6. MODELLING RESULTS

6.1 Ambient Air Quality Assessment

GLCs of the modelled compounds have been predicted for the following scenarios:

- Routine operations, with all three generators operating at maximum load and no flaring. This is considered conservative as the generators are typically sized to run at around 85% maximum load; and
- Full flaring scenario, with both flares are operating at the maximum gas flow rate and no generator operation.

The results of the odour assessment for emissions from the biofilter and the biomethane upgrade stack are presented in Section 6.2.

The predicted GLCs for the Plant operating under routine conditions, both in isolation and cumulatively with background concentrations, are summarised in Table 6. The predicted GLCs concentrations are all expected to remain well below their respective standards across the modelled domain, with the exception of the maximum 1-hour average NO_2 GLC which is predicted to equal 92% of the respective guideline for operations in isolation and 96% of the guideline when considered cumulatively with ambient background concentrations.

The maximum predicted 1-hour average GLCs for NO_2 for routine operations in isolation is presented in Figure 4, indicating that the highest predicted concentrations are expected to occur onsite. The maximum 1-hour average NO_2 GLCs predicted at the nearby residences and other potential sensitive receptor locations (i.e. golf course) are not expected to be any greater than 75 µg/m^3, well below the corresponding SA EPA 1-hour average NO_2 standard of 250 µg/m^3. It is also noted that the predicted NO_2 GLCs are considered conservative given the use of the OLM method (refer to Section 5.4), particularly for short-term concentrations close to the source.

The predicted GLCs for the Plant operating under the full flaring scenario are also summarised in Table 6. The predicted GLCs concentrations are all expected to remain well below their respective standards across the modelled domain when considered both in isolation and cumulatively with background concentrations.

Contours of the predicted GLCs for all modelled compounds and averaging periods for both scenarios are presented in Appendix 2.

Table 6: Predicted Maximum GLCs for Routine Operations and Full Flaring

Pollutant	Averaging Period	Criteria	Background Conc.	Routine Operations (3 Generators)				Full Flaring (2 Flares)			
				Maximum Concentration		Cumulative Maximum Concentration		Maximum Concentration		Cumulative Maximum Concentration	
		µg/m³	µg/m³	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria
CO	1-hour	31,240	25	2,722	9%	2,747	9%	150	0.5%	175	1%
	8-hour	11,250	25	1,535	14%	1,560	14%	68	1%	93	1%
NO_2	1-hour	250	10	229	92%	239	96%	98	39%	108	43%
	Annual	60	8	17	28%	25	41%	6	10%	14	24%
H_2S	3-minute	510	NA	55	11%	55	11%	94	18%	94	18%
SO_2	1-hour	570	0	212	37%	212	37%	82	14%	82	14%
	24-hour	230	0.14	72	31%	72	31%	23	10%	23	10%
	Annual	60	0.2	10	17%	11	18%	2	3%	2	4%

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. Background concentrations are the 75th percentile 1-hour and 24-hour concentrations and annual average concentrations (as per Table 4).

Figure 4: Routine Operations - Maximum Predicted 1-hour Average NO_2 GLCs (µg/m^3) in Isolation

6.2 Odour Assessment

The maximum predicted 99.9th percentile 3-minute average odour concentration for routine operations (considering emissions from the biofilter and the biomethane upgrade stack) is presented in Table 5. Contours of the predicted 99.9th percentile 3-minute average odour levels are presented in Figure 5.

The predicted odour levels remain below the SA EPA criteria of 2 OU throughout the modelled domain. Odour concentrations predicted to occur at the nearest residential and other sensitive receptor locations remain below 0.5 OU (Figure 5).

Table 7: Maximum Predicted Odour Concentrations for the Biogas Plant

Pollutant	Averaging Period	Criteria	Maximum Predicted 99.9th Percentile
		(OU)	(OU)
Odour	3-minute (99.9th Percentile%)	2	1.88

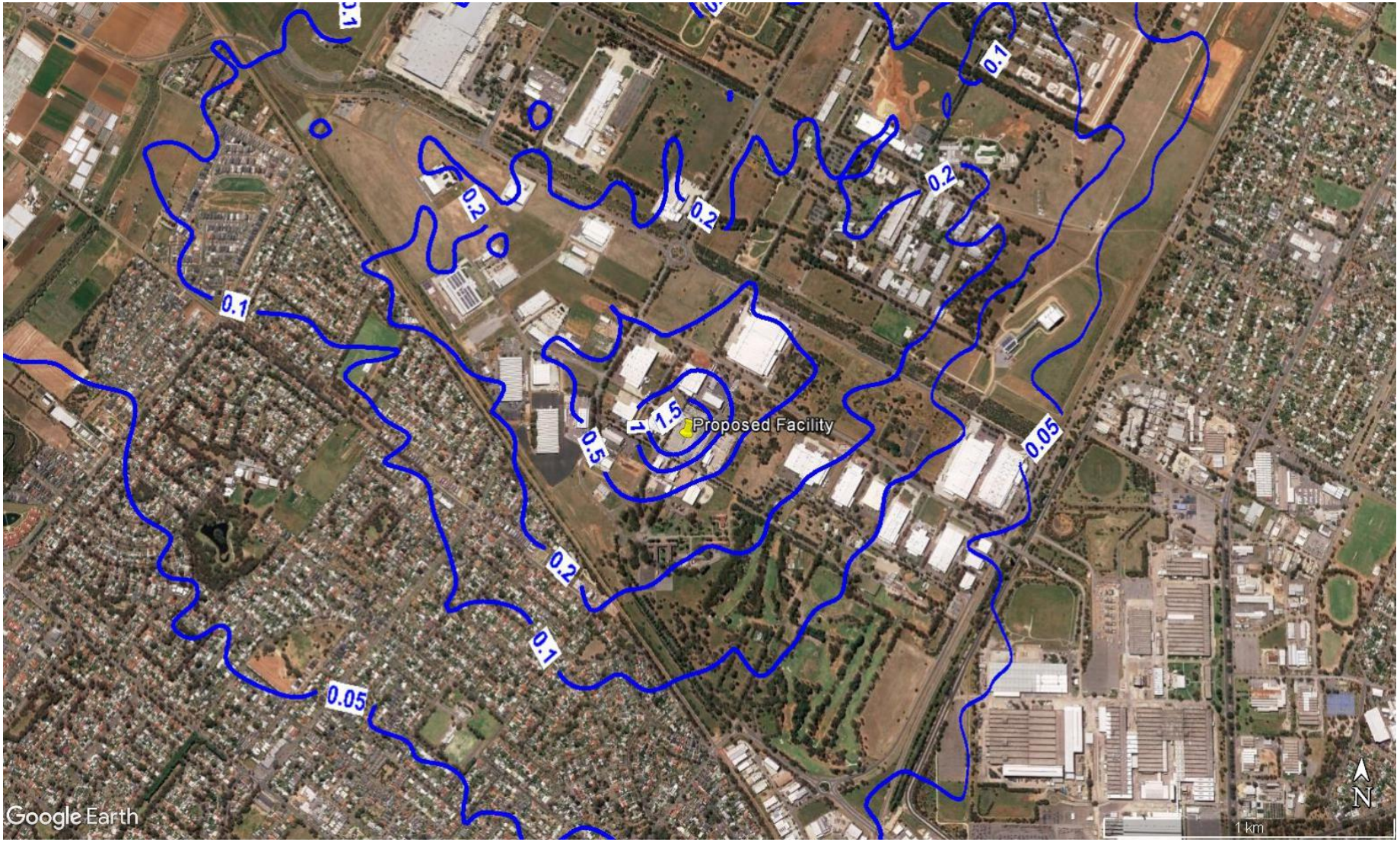

Figure 5: Routine Operations - Predicted 3-minute Average 99.9th Percentile Odour Concentrations (OU)

7. CONCLUSIONS

Air dispersion modelling has been completed to assess the potential air quality impacts associated with emissions from the proposed Plant operating under routine and full flaring operating scenarios.

Predicted GLCs have been estimated using the CALPUFF model and meteorological data generated by TAPM, in combination with meteorological monitoring data recorded at the nearest BoM monitoring station located at Elizabeth.

Where ambient monitoring data was available for compounds of interest, this has been used to determine the cumulative impacts of the proposed Plant.

The key findings of the air dispersion modelling are as follows:

- Predicted GLCs for all modelled compounds remain below the corresponding SA EPA standards across the modelled domain for both routine and full flaring operations, considered in isolation and cumulatively;
- The GLCs predicted at sensitive receptor locations remain well below the relevant SA EPA standards for all pollutants and modelled scenarios;
- The maximum predicted 1-hour NO_2 GLC most closely approaches the relevant guideline, representing 92% of the 1-hour average NO_2 standard of 250 µg/m^3 when considered in isolation. This GLC is considered to be conservative given the assumptions applied to estimate NO_2 GLCs from predicted NO_x GLCs;
- The maximum 1-hour average NO_2 GLCs predicted at the nearby residences and other potential sensitive receptor locations represent no more than 30% of the corresponding standard; and
- Odour concentrations are predicted to remain below the SA EPA criteria for routine operations across the modelled domain and are equal to less than 25% of the applicable criteria at the nearest residential and other sensitive receptor locations.

8. DISCLAIMER AND LIMITATIONS

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APPENDIX 1

CALPUFF INPUTS

CALPUFF Parameters

INPUT GROUP: 0 -- Input and Output File Names

Parameter	Description	Value
PRFDAT	CTDM/AERMET-type meteorological profile data file	PROFILE.DAT
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	8
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-01-01-01-0000-2009-02-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-02-16-00-0000-2009-04-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-04-03-00-0000-2009-05-18-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-05-18-00-0000-2009-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-07-03-00-0000-2009-08-17-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-08-17-00-0000-2009-10-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-10-02-00-0000-2009-11-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-11-16-00-0000-2009-12-31-23-0000.DAT

INPUT GROUP: 1 -- General Run Control Parameters

Parameter	Description	Value

INPUT GROUP: 1 -- General Run Control Parameters

Parameter	Description	Value

METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2009
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	1
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2009
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+0900
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	7
NSE	Number of chemical species to be emitted	7
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1
INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	1
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	3
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	1
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	0
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0
INPUT GROUP: 3 -- Species List		

Parameter	Description	Value
CSPEC	Species included in model run	TR1
CSPEC	Species included in model run	TR2
CSPEC	Species included in model run	TR3
CSPEC	Species included in model run	TR4
CSPEC	Species included in model run	TR5
CSPEC	Species included in model run	TR6
CSPEC	Species included in model run	TR7
INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0.0
FNORTH	False northing at projection origin (km)	0.0
IUTMZN	UTM zone (1 to 60)	54
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	39
NY	Meteorological grid - number of Y grid cells	39
NZ	Meteorological grid - number of vertical layers	11
DGRIDKM	Meteorological grid spacing (km)	1
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 100.0, 200.0, 350.0, 500.0, 750.0, 1000.0, 2000.0, 3000.0, 4000.0, 5000.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	263.8390
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	6133.5530
IBCOMP	Computational grid - X index of lower left corner	17
JBCOMP	Computational grid - Y index of lower left corner	17
IECOMP	Computational grid - X index of upper right corner	23
JECOMP	Computational grid - Y index of upper right corner	23
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	17
JBSAMP	Sampling grid - Y index of lower left corner	17

IESAMP	Sampling grid - X index of upper right corner	23
JESAMP	Sampling grid - Y index of upper right corner	23
MESHDN	Sampling grid - nesting factor	10
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	0
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10
INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		

Parameter	Description	Value
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0
INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1
INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4

BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99

NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1

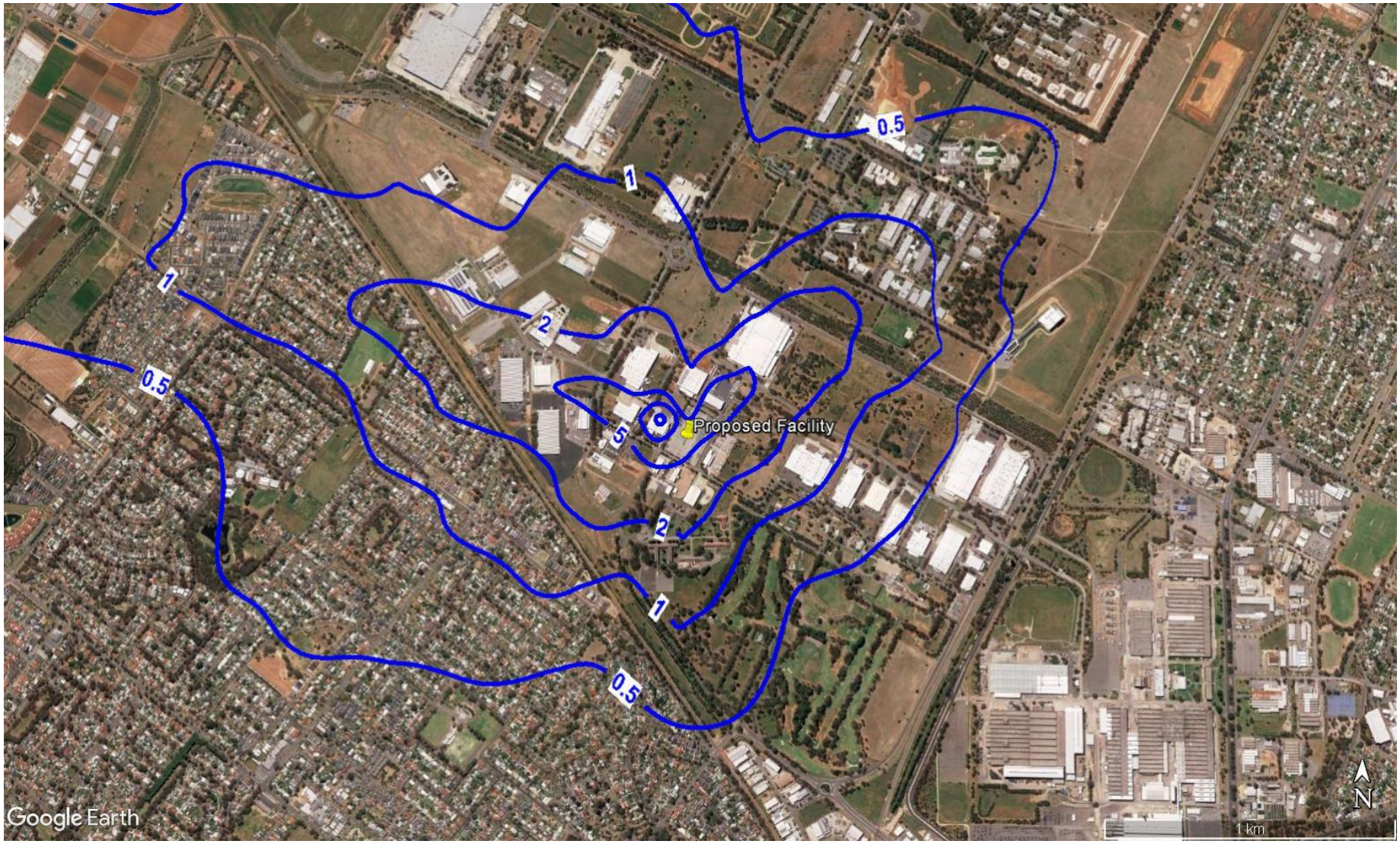
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	1E-007
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1
INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	7
IPTU	Units used for point source emissions (e.g., 1 = g/s)	1
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0
INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6
INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0

NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0
INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0
INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0
INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0
INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	0
NRGRP	Number of receptor group names	0

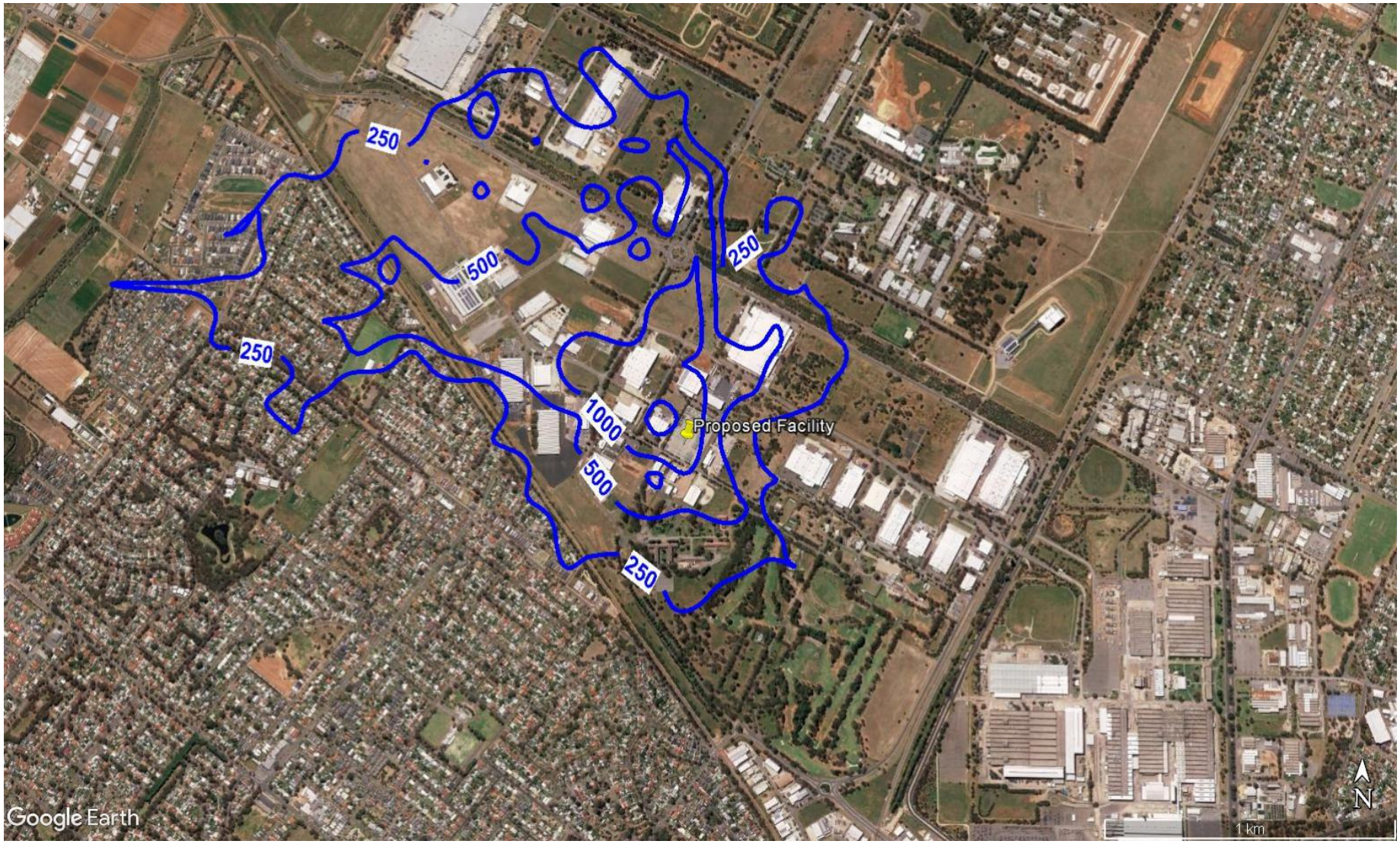
APPENDIX 2

CONTOUR PLOTS

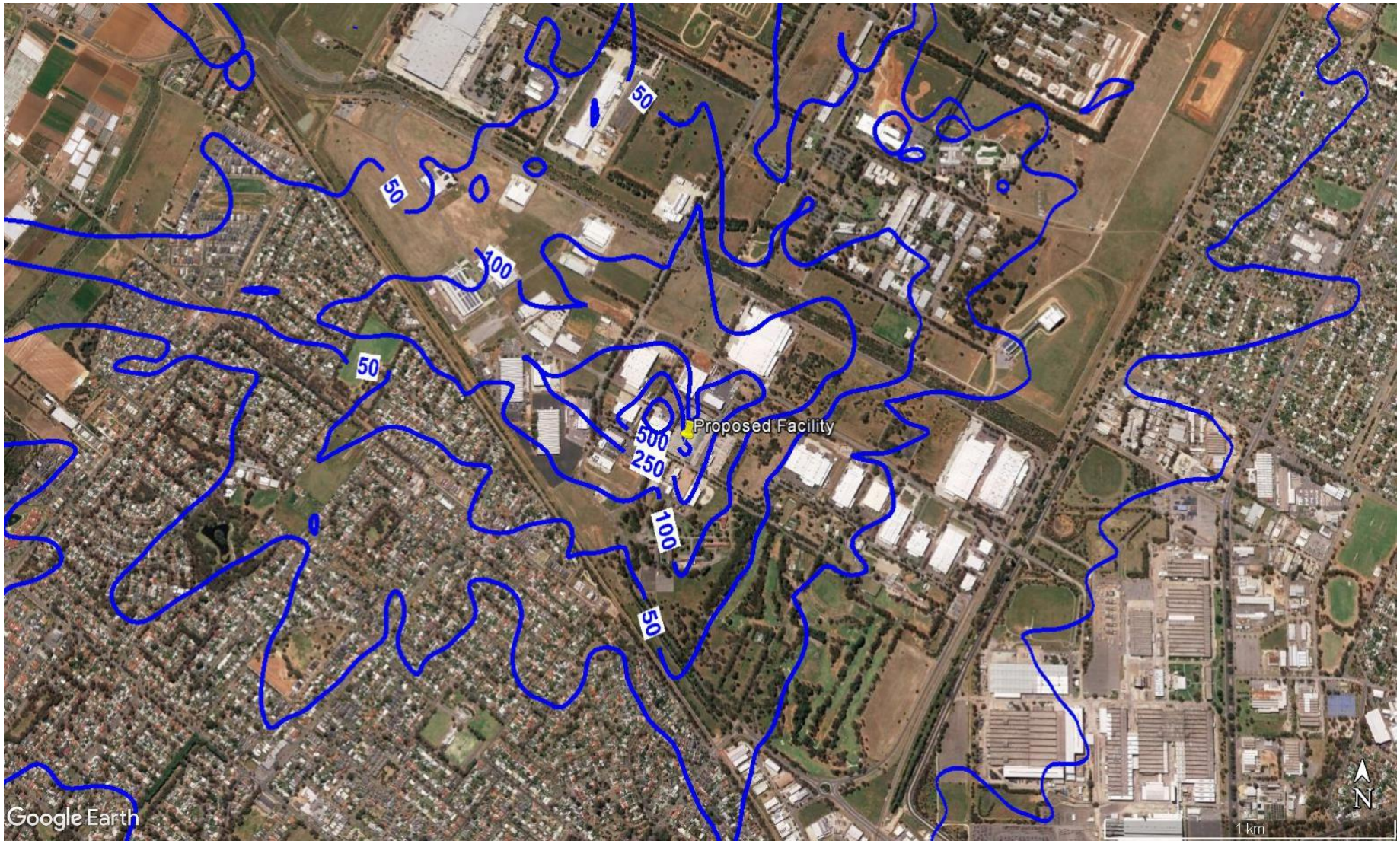
Scenario 1 (Normal Operations) – Annual Average Predicted Concentrations in Isolation of NO_2



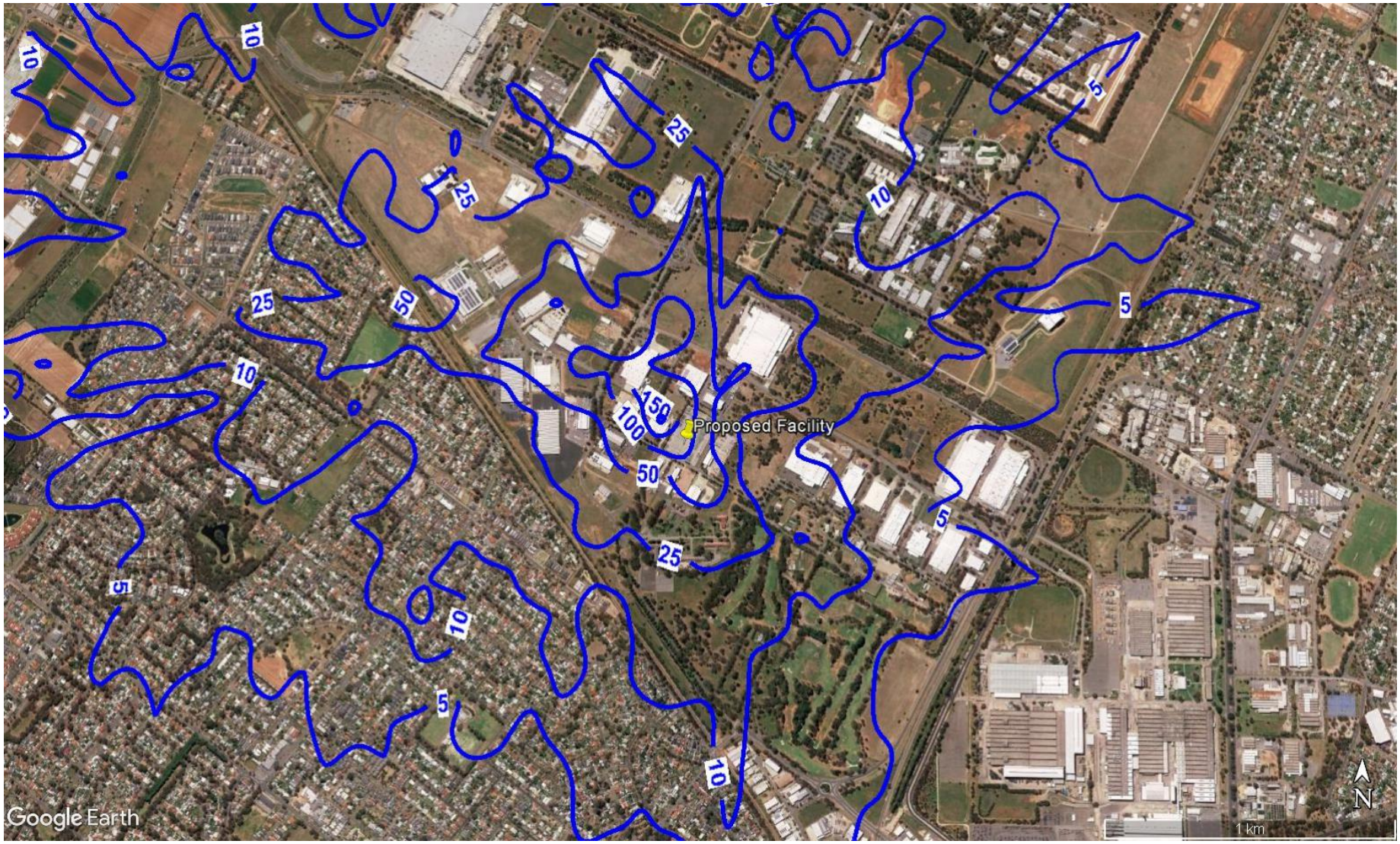
Scenario 1 (Normal Operations) – 1 Hour Average Maximum Predicted Concentrations in Isolation of CO



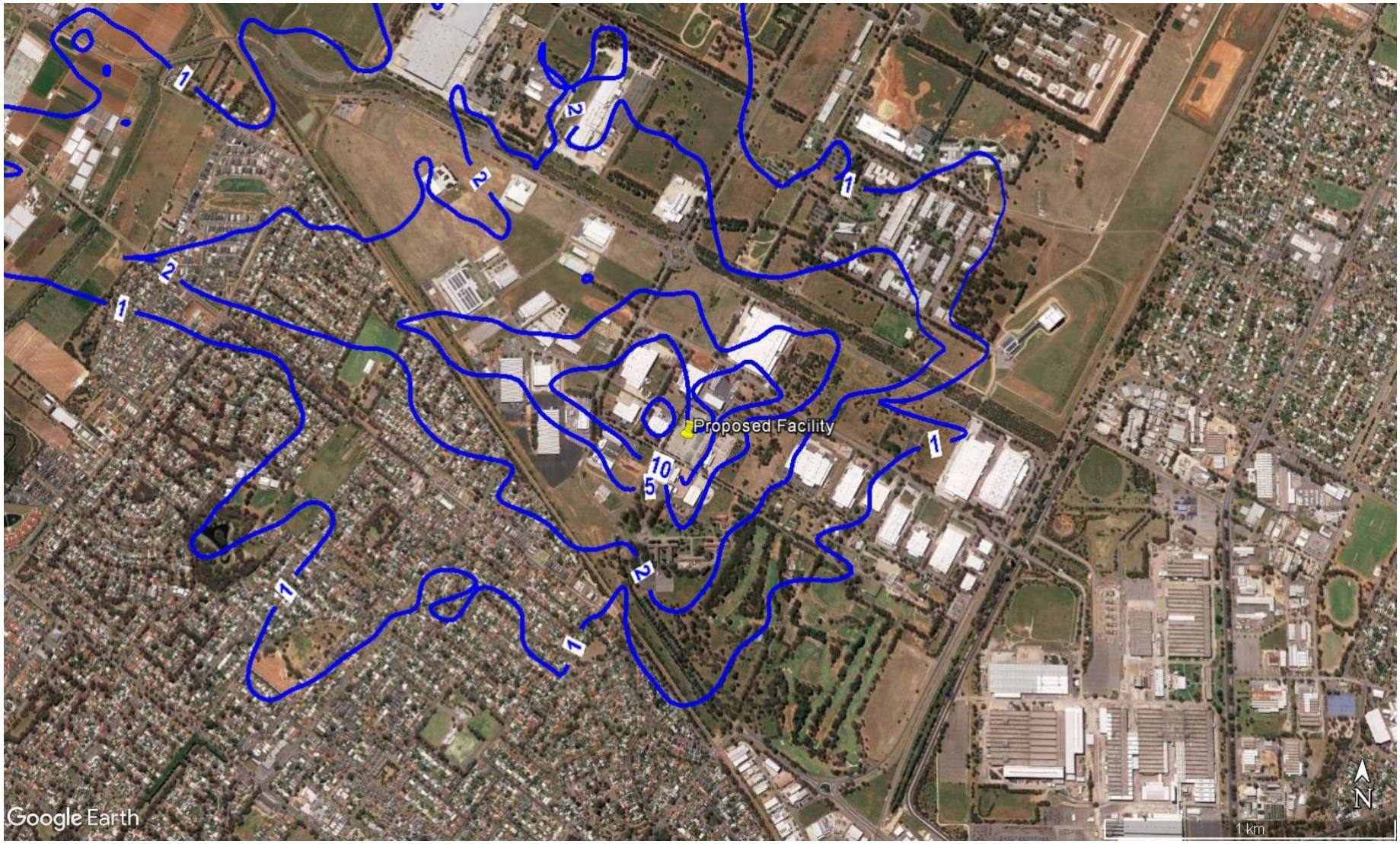
Scenario 1 (Normal Operations) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO



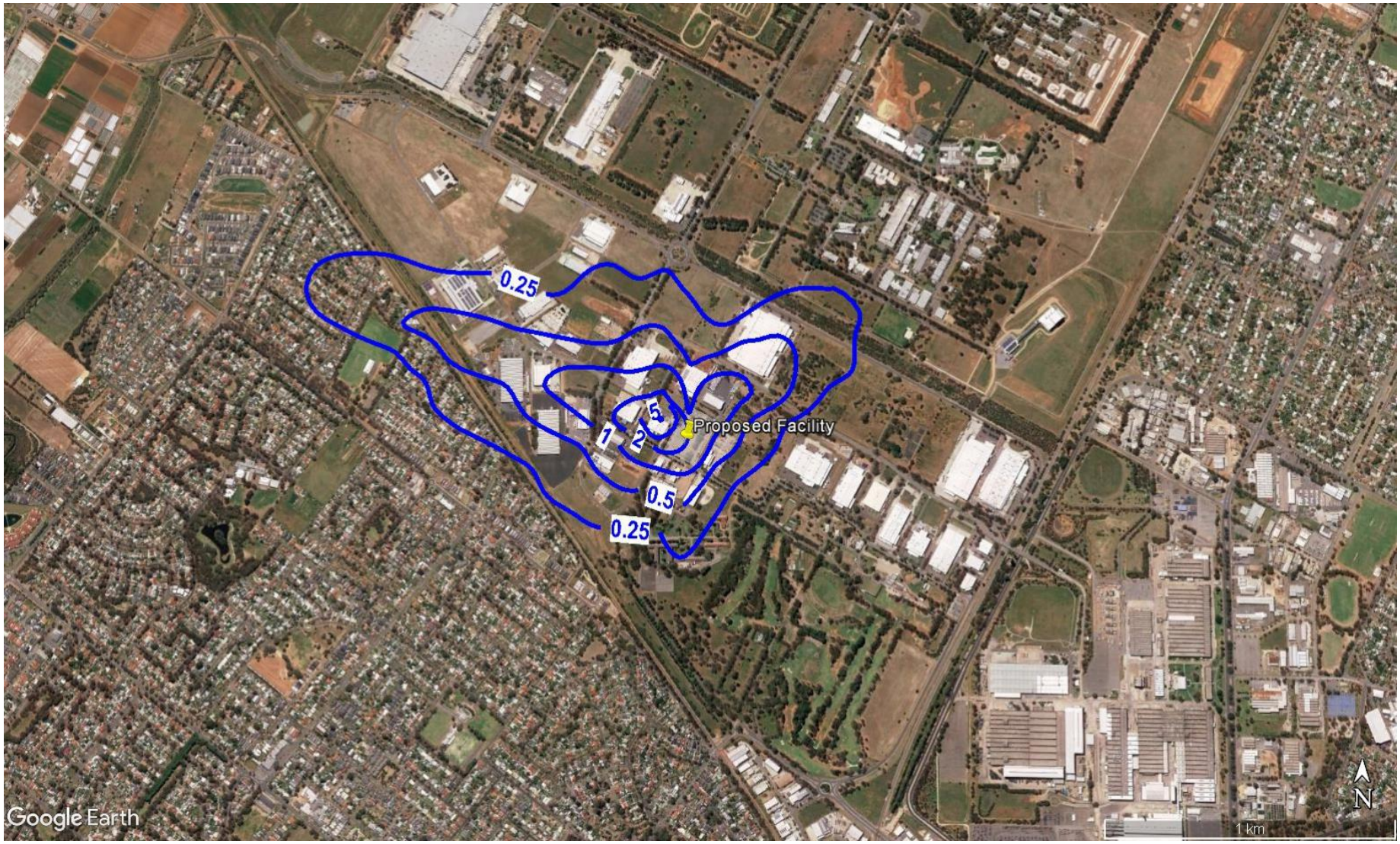
Scenario 1 (Normal Operations) – 1 Hour Average Maximum Predicted Concentrations in Isolation of SO_2



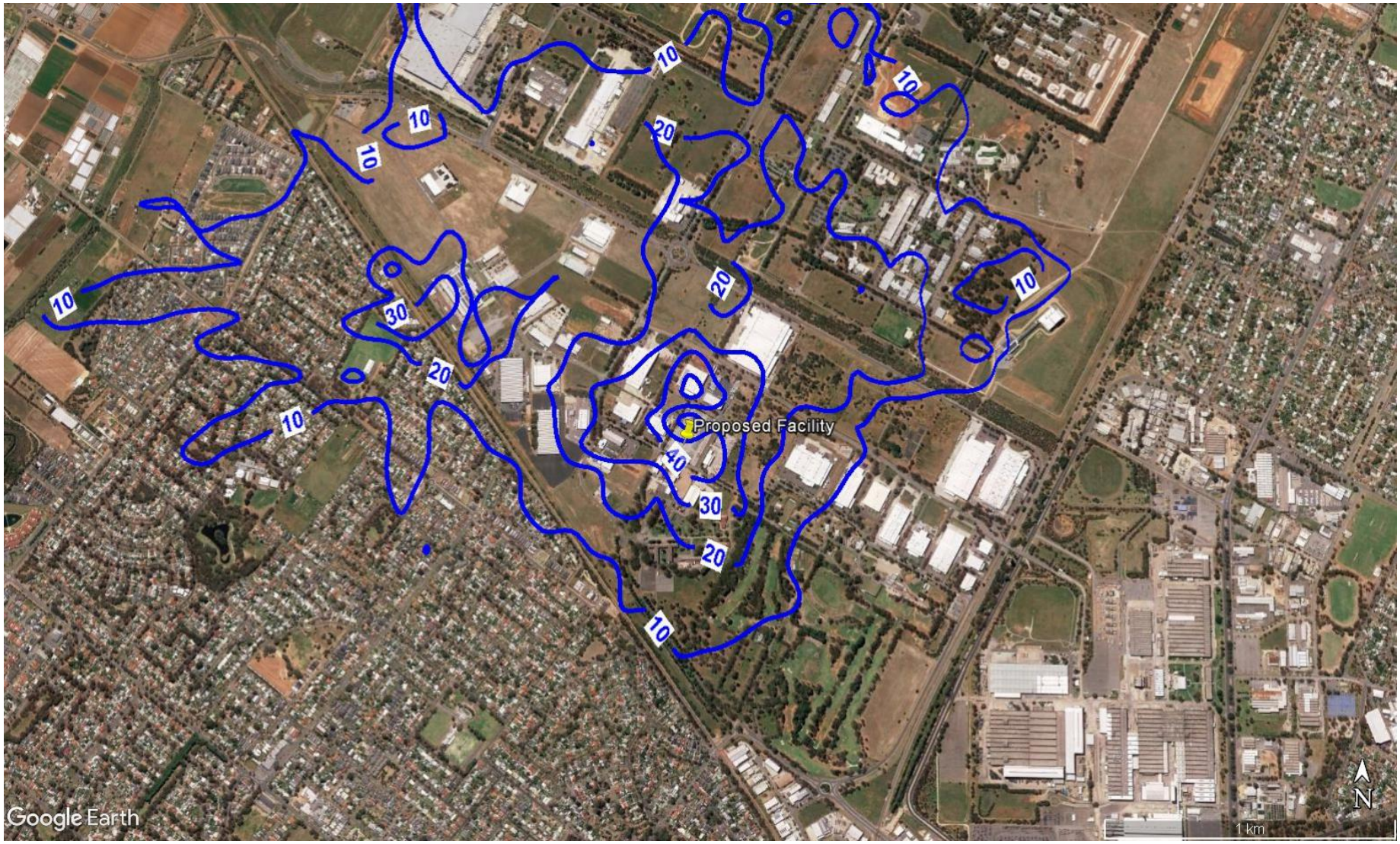
Scenario 1 (Normal Operations) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2



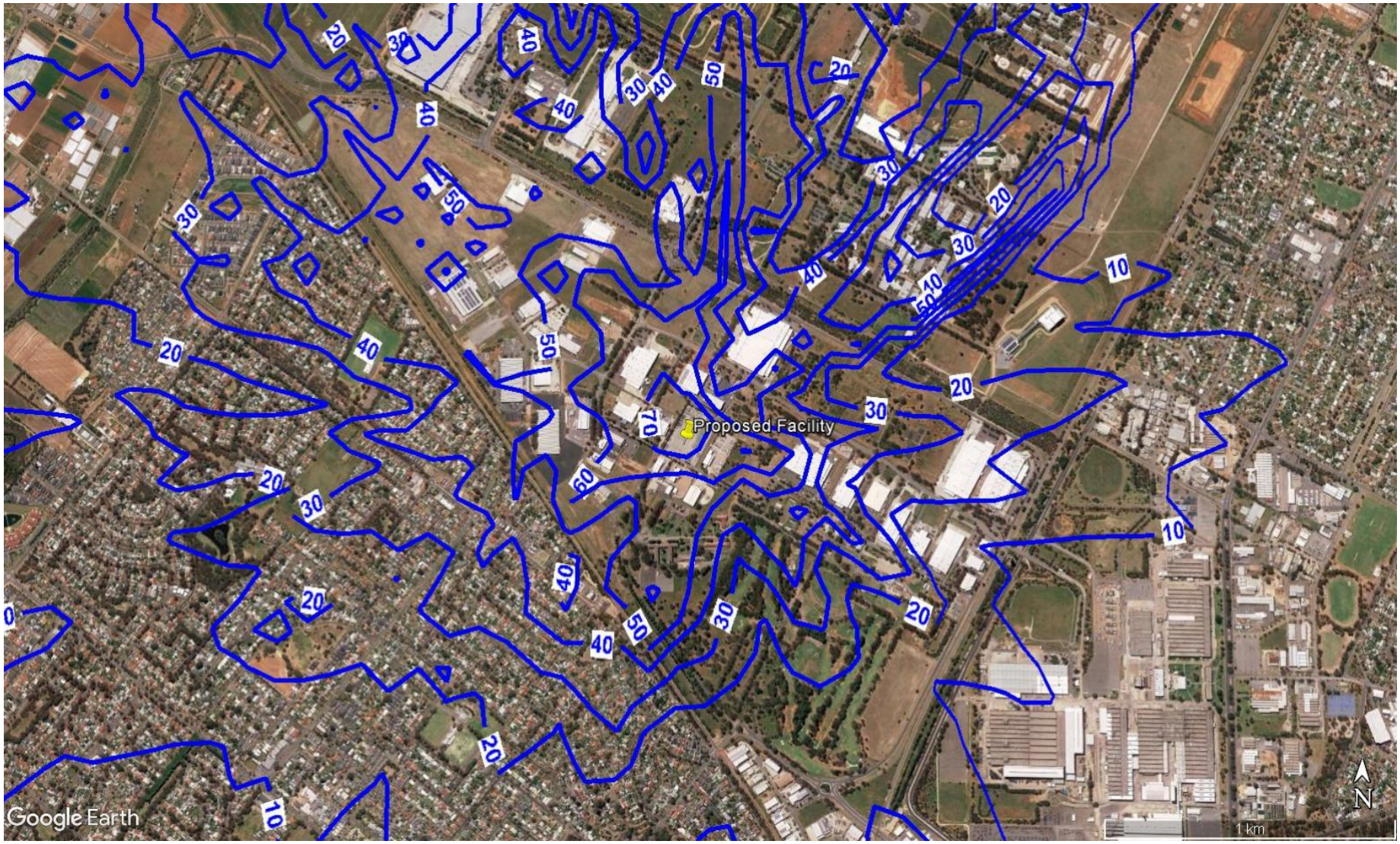
Scenario 1 (Normal Operations) – Annual Average Predicted Concentrations in Isolation of SO_2



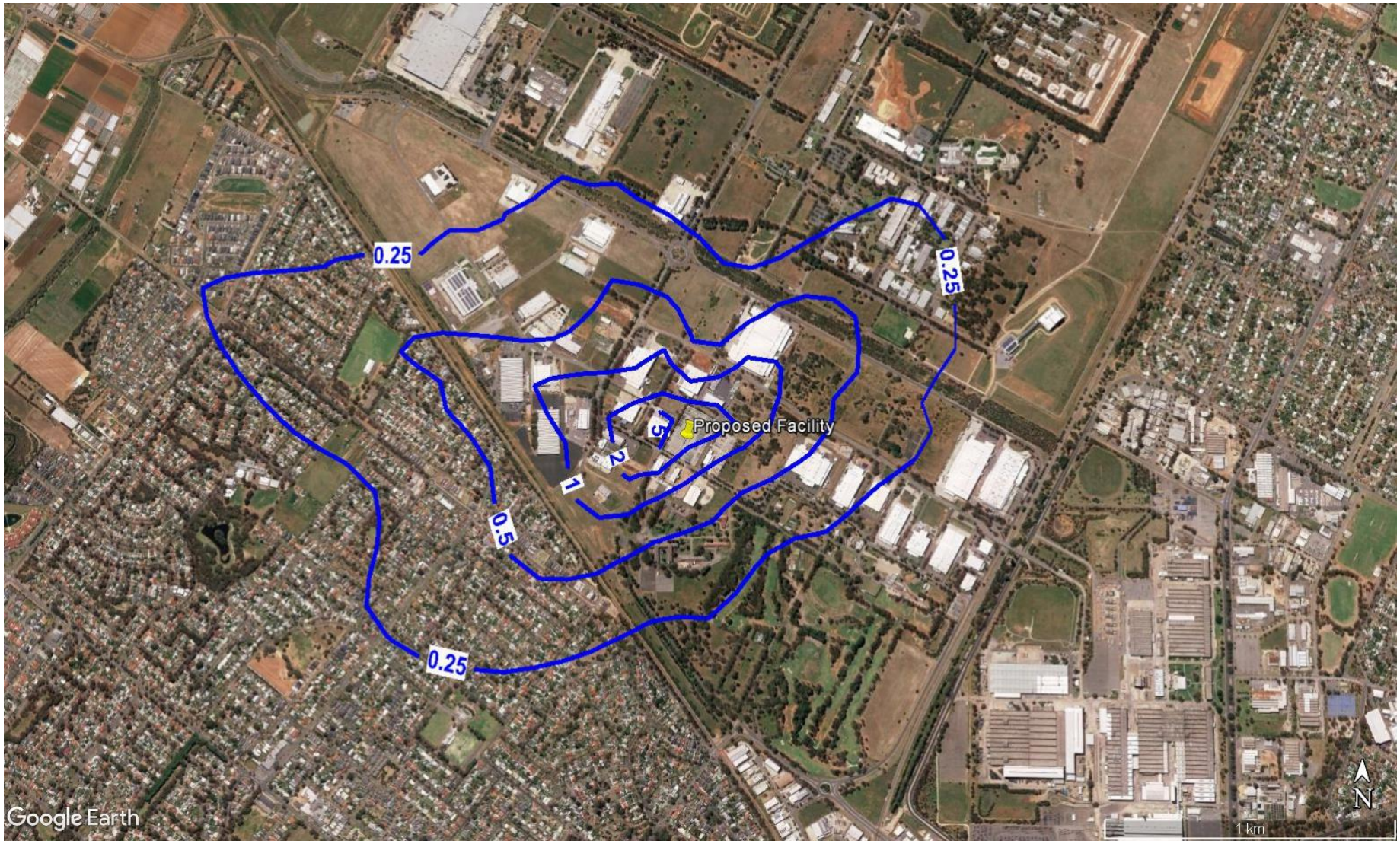
Scenario 1 (Normal Operations) – 3-minute Average Maximum Predicted Concentrations in Isolation of H2S



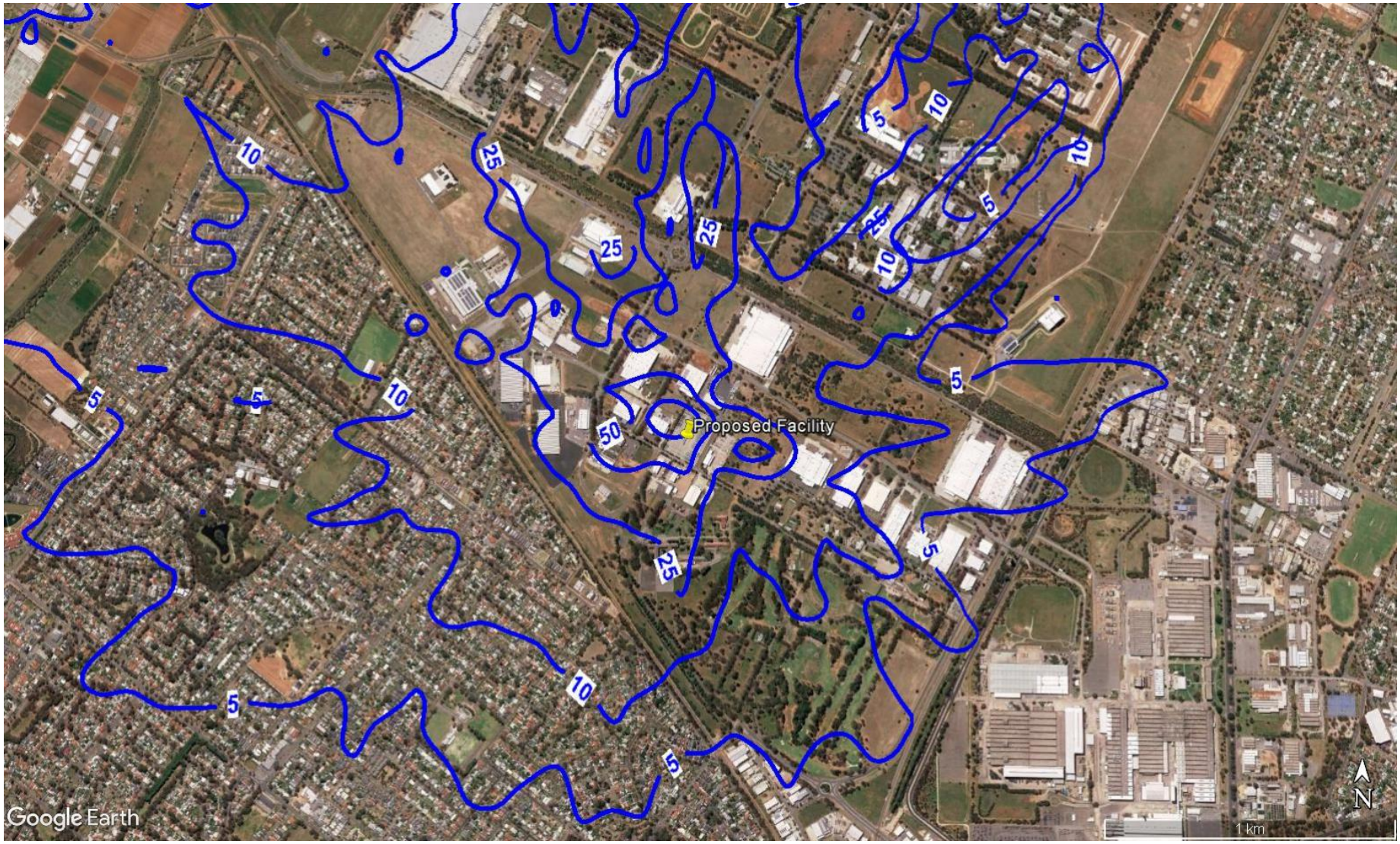
Scenario 2 (Upset Conditions) – 1 Hour Average Maximum Predicted Concentrations in Isolation of NO_2



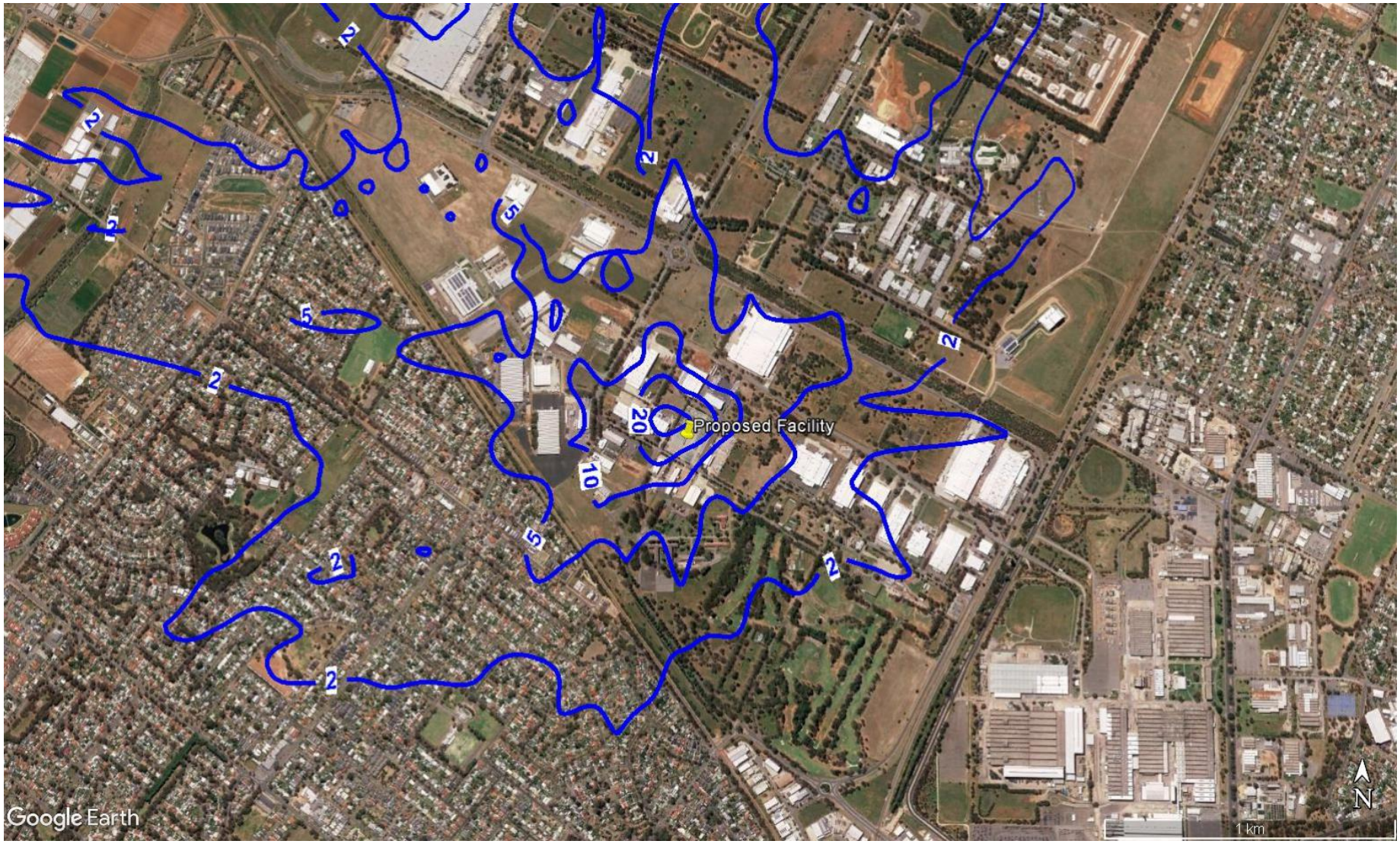
Scenario 2 (Upset Conditions) – Annual Average Predicted Concentrations in Isolation of NO_2



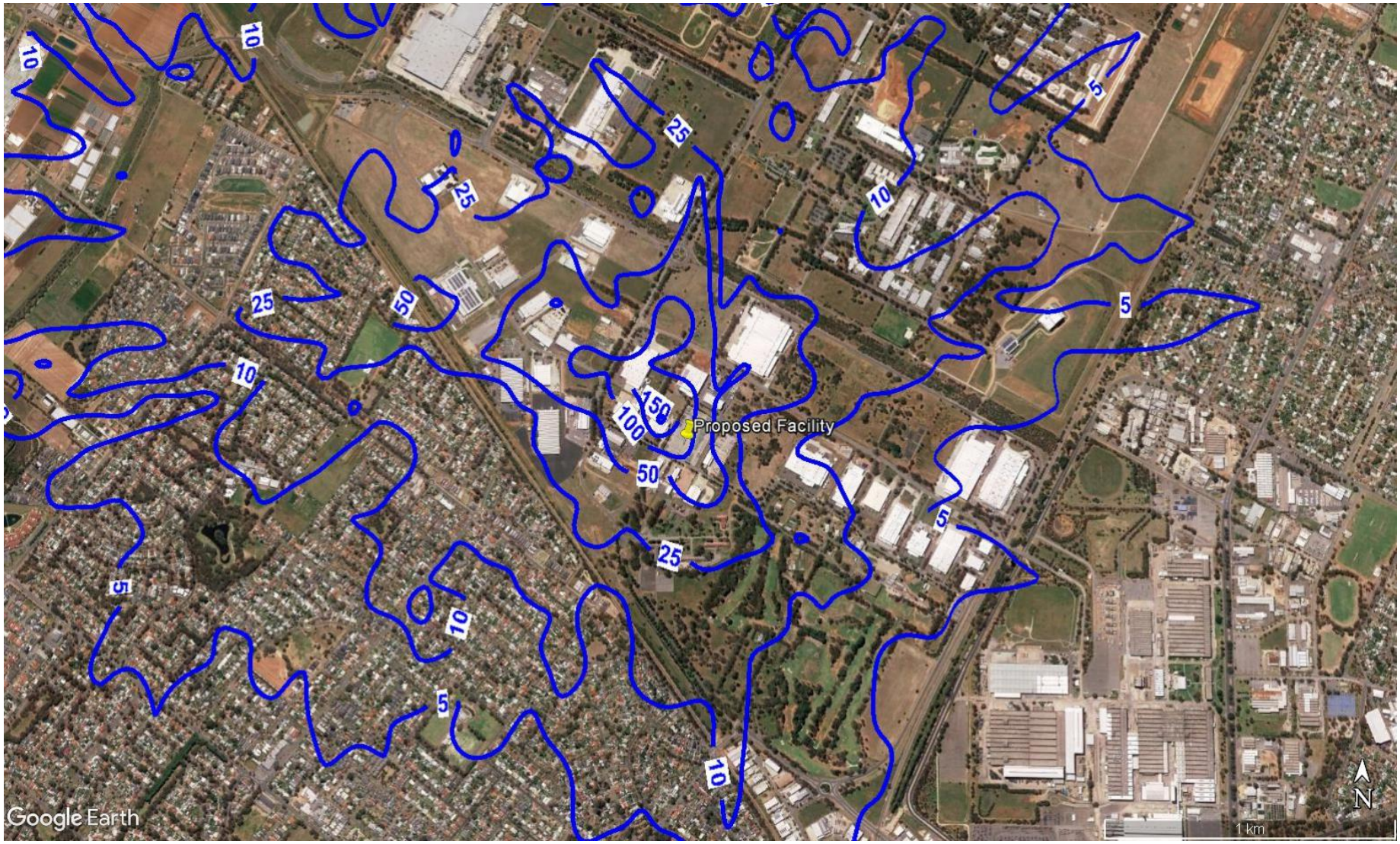
Scenario 2 (Upset Conditions) – 1 Hour Average Maximum Predicted Concentrations in Isolation of CO



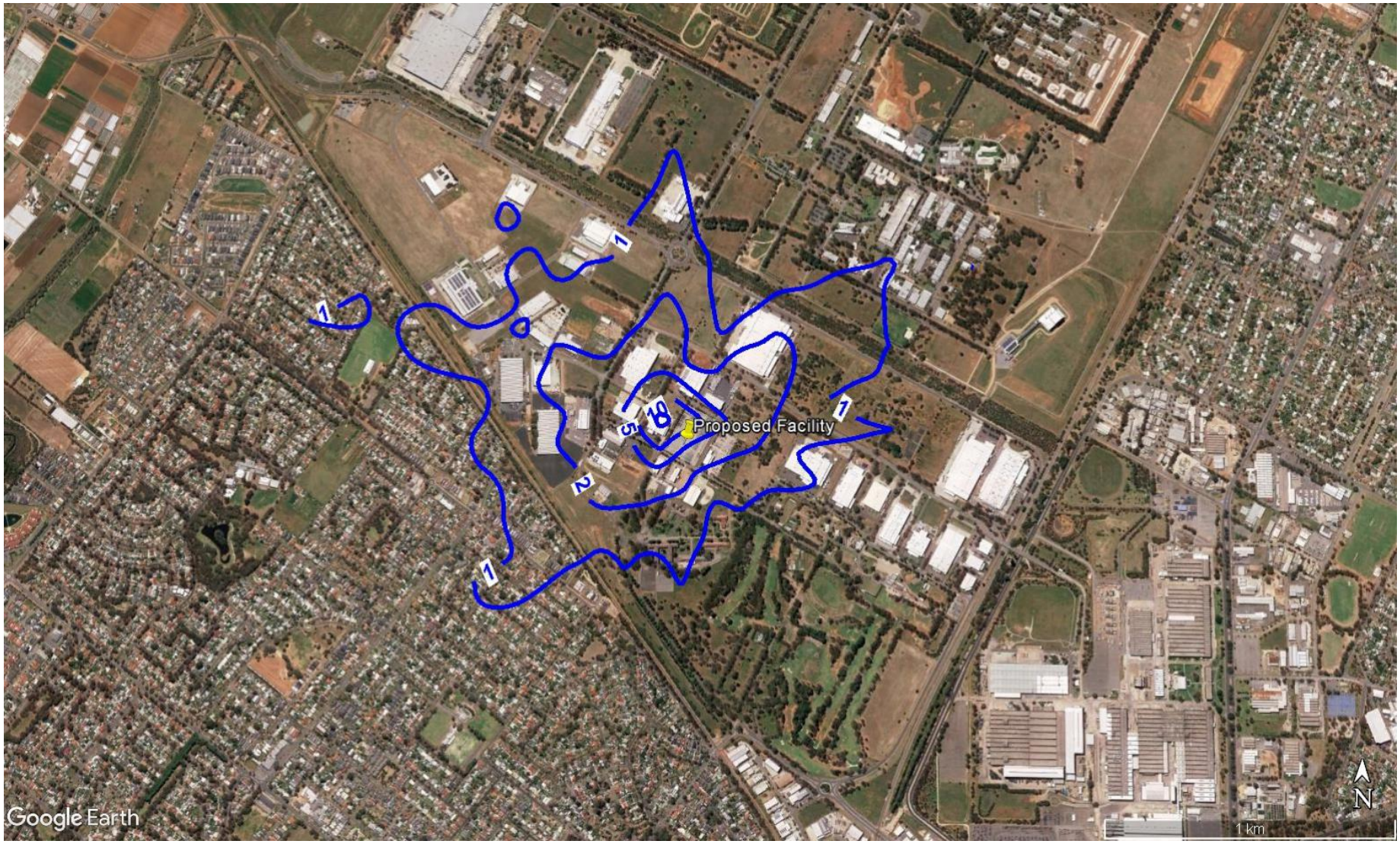
Scenario 2 (Upset Conditions) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO



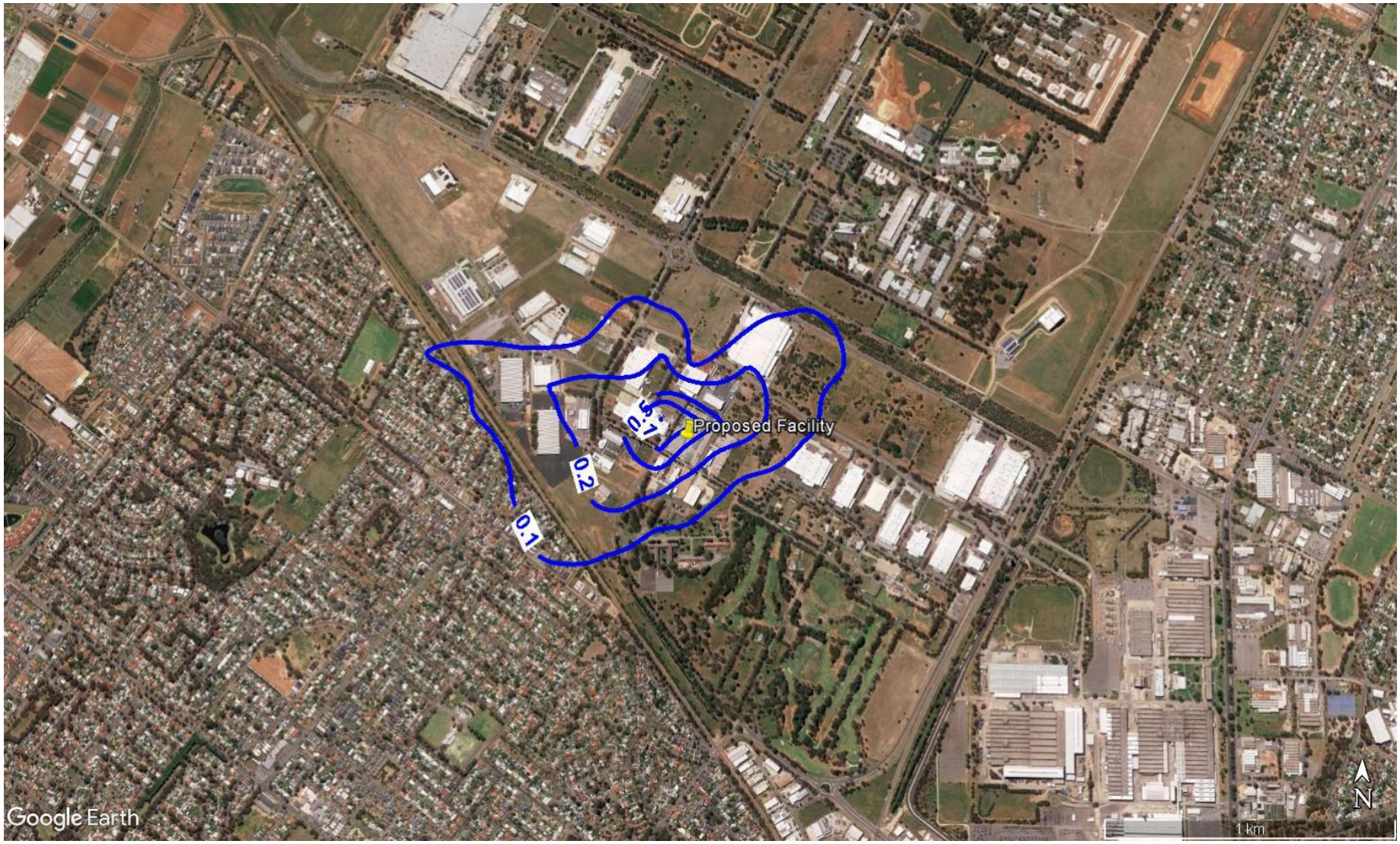
Scenario 2 (Upset Conditions) – 1 Hour Average Maximum Predicted Concentrations in Isolation of SO_2



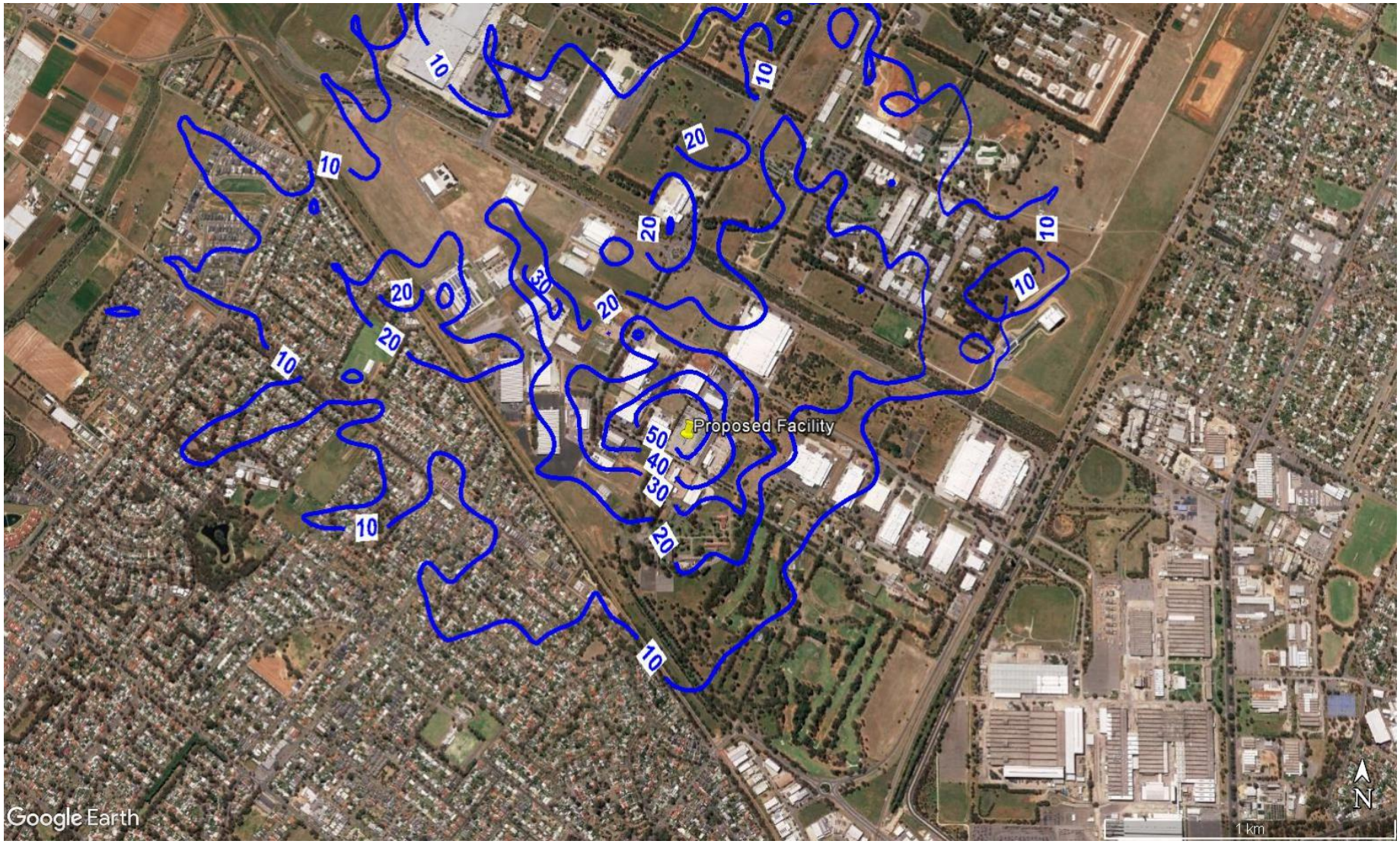
Scenario 2 (Upset Conditions) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2



Scenario 2 (Upset Conditions) – Annual Average Predicted Concentrations in Isolation of SO_2



Scenario 2 (Upset Conditions) – 3-minute Average Maximum Predicted Concentrations in Isolation of H2S



ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

ROUND 2 CLARIFICATIONS

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
18/10/18	A	Issued	JL	JO	HJ

Response to Development Application Information Request

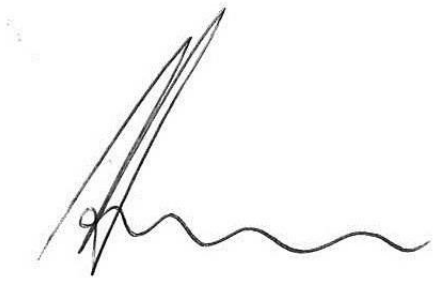
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



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RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	Provide reference information relating to the destruction efficiencies for H2S of the generator and flare.
	DeLorean / Biogass	Results from previous testing on comparable equipment (generator and flare) at the reference facility are attached in *Appendix 1 – Reference Facility Emissions Testing Results*. Duplicate runs were conducted during testing to ensure consistency of results. H2S emissions were not detected during these tests implying approximately 100% destruction.
2	EPA	Provide supporting information for the consistency of the destruction efficiencies for H2S of the generator and the flare (i.e. are the exhaust emission estimates worse-case?)
	DeLorean / Biogass	As mentioned above, duplicate tests conducted at the reference facility have not identified H2S present in the generator and flare. The testing results are considered typical of the equipment used.
3	EPA	Provide supporting information for the consistency of the exhaust emission estimates for the combustion pollutants from the generator and the flare.
	DeLorean / Biogass	Results from previous testing on comparable equipment (generator and flare) at the reference facility are attached in *Appendix 1 – Reference Facility Emissions Testing Results*. Duplicate runs were conducted during testing to ensure consistency of results.
4	EPA	Identify all the nearest sensitive receivers for the purposes of assessment against the 1-hour NO2 ground level concentration and modelling predictions of worse-case maxima ground level concentrations at all these receivers.
	DeLorean / Biogass	Please see below the predictions from the emissions modelling: **Routine Operations**

<table>
<tr><td></td><td></td><td>
<table>
<tr><th colspan="2">UTM 54S</th><th rowspan="2">Receptor</th><th rowspan="2">1 Hour NO_2 $\mu g/m^3$</th></tr>
<tr><th>x</th><th>y</th></tr>
<tr><td>283139</td><td>6153053</td><td>Nearest Residential Receptor</td><td>57</td></tr>
<tr><td>282639</td><td>6153753</td><td>Residential Receptor with Maximum Impact</td><td>91</td></tr>
<tr><td>283839</td><td>6153153</td><td>Closest Part of Golf Course</td><td>77</td></tr>
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Flaring Operations
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<tr><th colspan="2">UTM 54S</th><th rowspan="2">Receptor</th><th rowspan="2">1 Hour NO_2 $\mu g/m^3$</th></tr>
<tr><th>x</th><th>y</th></tr>
<tr><td>283139</td><td>6153053</td><td>Nearest Residential Receptor</td><td>43</td></tr>
<tr><td>282639</td><td>6153753</td><td>Residential Receptor with Maximum Impact</td><td>48</td></tr>
<tr><td>283839</td><td>6153153</td><td>Closest Part of Golf Course</td><td>47</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>EPA</td><td>Identify all the nearest sensitive receivers for the purposes of assessment against the 3-minute H2S odour ground level concentration and modelling predictions of worse-case maxima ground level concentrations at all these receivers.</td></tr>
<tr><td></td><td>DeLorean / Biogass</td><td>Please see below the predictions from the emissions modelling:
Routine Operations
<table>
<tr><th colspan="2">UTM 54S</th><th rowspan="2">Receptor</th><th rowspan="2">3-Min H_2S $\mu g/m^3$</th></tr>
<tr><th>x</th><th>y</th></tr>
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<tr><td>282639</td><td>6153753</td><td>Residential Receptor with Maximum Impact</td><td>37</td></tr>
<tr><td>283839</td><td>6153153</td><td>Closest Part of Golf Course</td><td>32</td></tr>
</table>
Routine Operations
<table>
<tr><th colspan="2">UTM 54S</th><th rowspan="2">Receptor</th><th rowspan="2">3-Min H_2S $\mu g/m^3$</th></tr>
<tr><th>x</th><th>y</th></tr>
<tr><td>283139</td><td>6153053</td><td>Nearest Residential Receptor</td><td>13</td></tr>
<tr><td>282639</td><td>6153753</td><td>Residential Receptor with Maximum Impact</td><td>27</td></tr>
<tr><td>283839</td><td>6153153</td><td>Closest Part of Golf Course</td><td>32</td></tr>
</table>
</td></tr>
<tr><td>6</td><td>EPA</td><td>Provide evidence to demonstrate that handling of digesate does not cause an odour nuisance.</td></tr>
<tr><td></td><td>DeLorean / Biogass</td><td>Confirming that all digestion of organic material happens within a closed-loop process inside of comletely sealed tanks and pipes. The only point where digestate is released from the system is during offtake. The solid digestate exits the process via mechanical separators which occurs within the enclosed reception building under negative pressure due to the biofilter which ensures 4-5 air changes per hour. The only physical handling of solid digestate may occur using loading</td></tr>
</table>

		and trucking equipment inorder to offtake and transport from site. No material is handled directly by personnel.
7	EPA	Provide clarification regarding the signficant discprepancies between the predicted ground level concentrations of H2S and the predicted ground level odour in odour units.
	DeLorean / Biogass	To clarify, predicted emissions are as stated in the emissions modelling report. The modelled predicted concentrations of H2S at sensitive receptors were predominantly associated with emissions from the biomethane upgrade plant. The H2S emission rates and the OU for the biomethane stack were derived from equipment information.
8	EPA	Provide confirmation of the expected heat release from the proposed plant.
	DeLorean / Biogass	To confirm, there will be 3 x 1.56MW CHP co-generators producing up to 4.68MW of electrical energy. All surplus biogas is upgraded to biomenthane. This design was intentionally selected to limit both electrial and thermal production below 5MW to alleviate the requirment of additional permits. Heat release from the CHP co-genertors is expected to be 4.9MW.
9	EPA	Provide confirmation of the quantities of digestate / compost that would be: a. Sent off-site for further treatment, e.g. to a licenced composting facilitiy b. Provide confirmation of the anticipated quanities of digestate (solids) to be sent off site in tonnes or m3 p.a.
	DeLorean / Biogass	Responses to question 9 as follows: a. All output digestate solids are sent to licenced composting facilities is anticipated to be 41,650TPA. No output solid digestate will be further processed or permanently stored on site. b. As above in part (a).
10	EPA	As identitied in the DeLorean energy Environmental Report and Response to Development Application Information Request prepared by Biogass Renewables, provide a report prepared by a suitably experienced, professional acoustic engineering consultatn demonstrating that worst case predicted noise from the proposal can meet the following Noise Cirteria (refer to Information Request).
	DeLorean / Biogass	Emissions assessment has been conducted by a qualified acoustic consultant and full report is attached. Please see Appendix 2 - *Environmental Noise Assessment – AD Plant – Lot505 Woomera, Avenue Salisbury.*

APPENDIX 1 - REFERENCE FACILITY EMISSIONS TESTING RESULTS

Table 1: Summary Table – Generator Stack and Flare Stack

Analyte	Units	Generator Stack		Flare Stack	
		Run 1 (50%)	Run 2 (100%)	Run 1 (50%)	Run 2 (100%)
Oxygen (O_2)	%	7.6	8.3	9.7	10.9
Carbon Dioxide (CO_2)	%	13.4	12.6	11	10.3
Carbon Monoxide (CO)	mg/dscm	580	590	45	16
	g/s	0.46	0.81	0.035	0.026
Sulphur Dioxide (SO_2)	mg/dscm	48	46	11	8.8
	g/s	0.038	0.062	0.0087	0.015
Total oxides of nitrogen*1 (NO_x as NO_2)	mg/dscm	520	400	79	51
	g/s	0.42	0.54	0.062	0.084
Total VOCs (as n-hexane)	mg/dscm	<0.36	<0.37	<0.38	<0.35
	g/s	<0.00029	<0.00051	<0.018	<0.035
Hydrogen Sulphide	mg/dscm	<5.6	<5	<5.5	<5.2
	g/s	<0.0045	<0.0068	<0.0043	<0.0086
Odour Concentration	ou/dscm	1450	1720	215	279
	$ou.m^3/s$	1180*	2460*	174*	472*
Moisture (H_2O)	% vol.	2.1	4.4	3.1	1.5
Stack Flow	dscm/min	73	131	47	100
Stack Temperature	°C	130.1	145.1	1000	1000

* Mass emission rate of odour concentration are expressed a wet value.

All concentration and mass emission data is referenced to STP (273.15K, 101.3kPa) and expressed as dry values.

APPENDIX 2 - ENVIRONMENTAL NOISE ASSESSMENT

(Please see attachment - *Environmental Noise Assessment – AD Plant – Lot505 Woomera, Avenue Salisbury*)

ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

ROUND 3 CLARIFICATIONS

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
13/11/2018	0	Issued	JL	JO	HJ

Response to Development Application Information Request

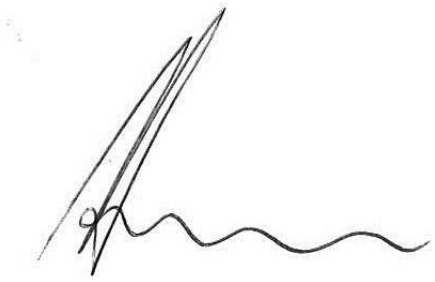
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



Hamish Jolly, Director
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hamish.jolly@biogass.com.au
www.biogass.com.au

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	Please confirm the make and model of the CHP co-generation unit (previous documentation indicated that three x 526kW capacity Jenbacher 3-type biogas (GEJGS312 GS-N.L D225)), and provide the supplier technical specification sheet/s which support the nominated electrical total output of 4.68MW and thermal output of 4.9MW.
	DeLorean / Biogass	To confirm the model of the CHP co-generation unit is expected to be three (3) x 1560kW capacity MWM TCG2020V16 engines packaged by Edina. Please disregard the previously stated Jenbachers in the emissions report as this was inadvertently included. Please refer to *Appendix 1 – CHP Co-generator Data Sheet* for the supplier technical specifications of the energy outputs stated. Calculations as follows: Total electrical output = 3,629kW (fuel consumption at worst case 100% load) x 43% (electrical efficiency) x 3 (no. of units) = ~4.68MW(e) Total thermal output = 3,629kW (fuel consumption at worst case 100% load) x 44.6% (electrical efficiency) x 3 (no. of units) = ~4.855MW(th)
2	EPA	Identify all the nearest sensitive receivers for the purposes of and undertake assessment against the 3-minute H2S odour ground level concentration and modelling predictions of worst-case maxima ground level concentrations at all these receivers.
	DeLorean / Biogass	The existing model displays sensitive receptors as the Residential properties. EPA wish to expand this to anyone who is exposed for >3 minutes. This is no longer a relevant point with the biomethane upgrade plant which will now emit zero H2S utilising mitigation techniques outlined in response No. 4. This will be proven during commissioning. The Generators and Flare have had previous emissions testing performed on them with no H2S detected. This can again will be proven during commissioning.
3	EPA	Provide clarification regarding the significant discrepancies between the predicted ground level concentrations of H2S and the predicted ground level odour in odour units.
	DeLorean / Biogass	Please refer to response No. 4.

4	EPA	Provide methodology for mitigation of H2S that would result in a reduction of the emission rate that can also be demonstracted to meet the Schedule 2 GLC for H2S odour criterion (3-minute average) at the nearest sensitive recepotrs (including adjacent businesses).
	DeLorean / Biogass	To confirm, the design shall incorportate all necessary mitigation methods to reduce H2S to meet the Schedule 2 GLC for H2S odour criterion (3-minute average) at the nearest sensitive recepotrs and achieve an output of As Low As Reasonably Possible (ALARP). The design shall incorporate the following 2 stage H2S removal process inorder to guarantee zero H2S output: *Stage 1: Micro-dosing Gas Treament System* Sulphide clean-up managed via a biological removal system. The method is an industry standard practice and involves micro dosing air into the head space of the digester to give H2S + O2 = SO4 + H2O. This enables the SO4 – sulphate to precipitate into the digestate for safe removal and offtake. *Stage 2: Carbon Activated Filter* Biogas is piped through a H2S carbon activated filter for the removal of H2S prior to it entering the biomethane upgrade equipment. The activated carbon filter consists of a stainless steel tank with loading and unloading hatches, entry/exit valves, by-passes and connection pipes. The flow to be treated passes through an activated carbon layer, absorbing contaminants. In the filter two components are removed; the corrosive portion of sulphur compounds present in the gas flow and organic silicon compounds, in particular siloxanes.
5	EPA	Amend the title of the acousitc report to include the same address given for the development application, which is Lot A505, 1-2 Gidgie Court, Edinburgh, South Australia.
	DeLorean / Biogass	Updated in new report. Please refer to *Environmental Noise Assessment AD Plant Lot A505, 1-2 Gidgie Court Edinburgh South Australia - Doc No.: 23621-2-18204*.
6	EPA	If an acousitc attenuation package is required to be fitted to the generators to achieve noise criteria stated in the EPA letter dated 20 July 2018, provide specific details of the attenuation package in the acousitc report. Please also confirm that any attenuation package is proposed to be installed/constructed as part of the development application
	DeLorean / Biogass	Updated in new report. Upon receival of EPA Letter showing lower assigned noise levels, the attenuation of the facility has undergone a complete review. Specific details of how the site intends to comply is stated therin. Please refer to *Environmental Noise Assessment AD Plant Lot A505, 1-2 Gidgie Court Edinburgh South Australia - Doc No.: 23621-2-18204*.
7	EPA	Provide tabulated numerical results of noise predictions (in addition to the modelling plots provided in the Herring Storer Acousitcs report), that demonstrate, after the inclusion of noise mitication measures, the predicted noise levels meet the noise affected criteria provided in the EPA letter dated 20 July 2018 at all noise-affected premises in both the City of Slisbury Residential Zone and the City of Salisbury Urban Employment Zone.
	DeLorean / Biogass	Updated in new report. Please refer to *Environmental Noise Assessment AD Plant Lot A505, 1-2 Gidgie Court Edinburgh South Australia - Doc No.: 23621-2-18204*.

		Table 4.1 shows tabulated nosie predictions at sensitive recievers.
8	EPA	Provide drawings that clearly demonstrate the location of acousitc attenuation barriers required to achieve the noise criteria stated 9in the EPA letter dated 20 July 2018. Please also confirm that any attenuation barriers are prosed to be installed/constructed as part of the devleopment application. NB. The digaragm showing the location of the barrier shown in plot 17W, Appendix B of the Herring Storer Acoustics report is too ambiguous. The drawing must be easiy interpreted (incluidng the fences mentioned inthe last sentace on page 1 of the Herring Storer Acoustics report). Drawing of a quality at least as good as drawings J116-001, sheets 5 of 8 and 6 of 8 or J116-002 sheet 1 of 1 must be used.
	DeLorean / Biogass	Updated in new report. Please refer to *Environmental Noise Assessment AD Plant Lot A505, 1-2 Gidgie Court Edinburgh South Australia - Doc No.: 23621-2-18204*. Complementary detailed drawings to the *Environmental Noise Assessment Report* are also attached seperately in J116-003.

APPENDIX 1 – CHP CO-GENERATOR DATA SHEET

Edina Containerised CHP Range
TCG 2020V16 Natural Gas Australia

MWM
Energy. Efficiency. Environment.

Technical data
1560 kWel; 400 V, 50 Hz; Natural gas, MN = 80

Design conditions			*Fuel gas data:* [2]		
Comb. air temperature / rel. Humidity:	[°C] / [%]	35 / 60	Methane number:	[-]	80
Altitude:	[m]	100	Lower calorific value:	[kWh/Nm³]	10,17
Exhaust temp. after heat exchanger:	[°C]	120	Gas density:	[kg/Nm³]	0,79
NO_x Emission (tolerance - 8%):	[mg/Nm³ @5%O_2]	500	Standard gas:	Natural gas, MN = 80	

Genset:		
Engine:	**TCG2020V16**	
Speed:	[1/min]	1500
Configuration / number of cylinders:	[-]	V / 16
Bore / Stroke / Displacement:	[mm]/[mm]/[dm³]	170 / 195 / 71
Compression ratio:	[-]	13,0
Mean piston speed:	[m/s]	9,8
Mean lube oil consumption at full load:	[g/kWh]	0,2
Engine-management-system:	[-]	TEM EVO
Generator:	**Marelli MJB 500 LA4**	
Voltage / voltage range / cos Phi:	[V] / [%] / [-]	400 / ±10 / 1
Speed / frequency:	[1/min] / [Hz]	1500 / 50

Energy balance				
Load:	[%]	100	75	50
Electrical power COP acc. ISO 8528-1:	[kW]	**1560**	**1170**	**780**
Engine jacket water heat:	[kW ±8%]	820	626	452
Intercooler LT heat:	[kW ±8%]	138	97	57
Lube oil heat:	[kW ±8%]			
Exhaust heat with temp. after heat exchanger:	[kW ±8%]	799	654	493
Exhaust temperature:	[°C]	426	449	479
Exhaust mass flow, wet:	[kg/h]	8665	6558	4507
Combustion mass air flow:	[kg/h]	8381	6340	4354
Radiation heat engine / generator:	[kW ±8%]	54 / 46	52 / 37	41 / 30
Fuel consumption:	[kW+5%]	3629	2795	1963
Electrical / thermal efficiency:	[%]	43,0 / 44,6	41,9 / 45,8	39,7 / 48,2
Total efficiency:	[%]	87,6	87,7	87,9

System parameters [1]		
Ventilation air flow (comb. air incl.) with ΔT = 15K	[kg/h]	40700
Combustion air temperature minimum [3] / design:	[°C]	27 / 35
Exhaust back pressure from / to:	[mbar]	30 / 50
Maximum pressure loss in front of air cleaner:	[mbar]	5
Zero-pressure gas control unit selectable from / to: [2]	[mbar]	20 / 200
Pre-pressure gas control unit selectable from / to: [2]	[bar]	0,5 / 10
Starter battery 24V, capacity required:	[Ah]	430
Starter motor:	[kWel.] / [VDC]	15 / 24,0
Lube oil content engine / base frame:	[dm³]	265 / -
Dry weight engine / genset:	[kg]	6090 / 13290

Cooling system		
Glycol content engine jacket water / intercooler:	[% Vol.]	35 / 35
Water volume engine jacket / intercooler:	[dm³]	151 / 20
KVS / Cv value engine jacket water / intercooler:	[m³/h]	46 / 30
Jacket water coolant temperature in / out:	[°C]	80 / 93
Intercooler coolant temperature in / out:	[°C]	40 / 44
Engine jacket water flow rate from / to:	[m³/h]	50 / 65
Water flow rate engine jacket water / intercooler:	[m³/h]	58 / 35
Water pressure loss engine jacket water / intercooler:	[bar]	1,5 / 1,4

1) See also "Layout of power plants" 2) See also Techn. Circular 2199-99-2017 3) In individual cases, the value may differ due to the final turbocharger design.

Frequency band f [Hz]	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k	12.5k	16k	L_{WA} [dB(A)]	S [m²]
Air-borne noise [4] L_{WATen} [dB(in)]	91	92	95	97	100	107	110	112	110	114	116	114	112	113	112	113	113	112	113	113	113	110	108	105	114	106	104	113	101	124	115
Exhaust noise [4] $L_{WAExhaust}$ [dB(A)]					129			139			130			128			125			124			122			115					132	15,5

3) DIN EN ISO 3746 4) DIN 45635-11 Appendix A (±3 dB) L_{WA}: Sound power level S: Area of measurement surface (S_o=1m²)

BIOGASS RENEWABLES PTY LTD

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

OCTOBER 2018

OUR REFERENCE: 23621-2-18204

Rochdale Holdings Pty Ltd A.B.N. 85 009 049 067 trading as:
HERRING STORER ACOUSTICS
P.O. Box 219, Como, W.A. 6952
(08) 9367 6200
hsa@hsacoustics.com.au

DOCUMENT CONTROL PAGE

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

Job No: 18204

Document Reference : 23621-2-18204

FOR

BIOGASS RENEWABLES PTY LTD

DOCUMENT INFORMATION			
Author:	**Paul Drew**	**Checked By:**	
Date of Issue :	**9th November 2018**		

REVISION HISTORY				
Revision	**Description**	**Date**	**Author**	**Checked**
1	**Report**	**17/10/2018**	**PD**	**GH**

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APPENDICIES

A Sound Power Levels

B Noise Contour Plots

1. INTRODUCTION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed Anaerobic Digestion (AD) facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The acoustic modelling and assessment is based on design data and plan layouts provided in October 2018 and previous measurement of the major noise sources at a similar facility in Jandakot, Western Australia.

An aerial image of the area surrounding Lot A505, 1-2 Gidgie Courtis shown in Figure 1.

Figure 1 - Site Location and Key receptors – Lot A505, 1-2 Gidgie Court, Edinburgh

The nearest residential area is 470m to the south-west, with another residential area located 1,400m to the east. The proposed site is within an Urban Employment zone, with General Industry surrounding the site. To the south-east are established sporting facilities including a golf course and shooting range.

Trucks of size ranging up to 25 tonne B-doubles will bring material to site, reversing into the facility Reception Hall via fast acting roller doors, which will be closed when not providing access to trucks (for odour control reasons). Trucks will be unloaded within the Reception Hall. Acoustically solid fences surround the digestion area and the truck access areas.

The major external noise sources are three generators, which are fitted with acoustic attenuation packages, two gas flares (generally on standby) and a number of gas and liquid pumps at the base of digestion tanks. Both flares would normally only operate if a number of generators were shut down. Trucks will generate noise within the site when entering and reversing, however truck movements will be at low speed and tipping will occur within the Receivals Hall, thereby limiting truck noise emission duration and level from the site.

A 3D diagram of the proposed facility layout is shown in Figure 2.

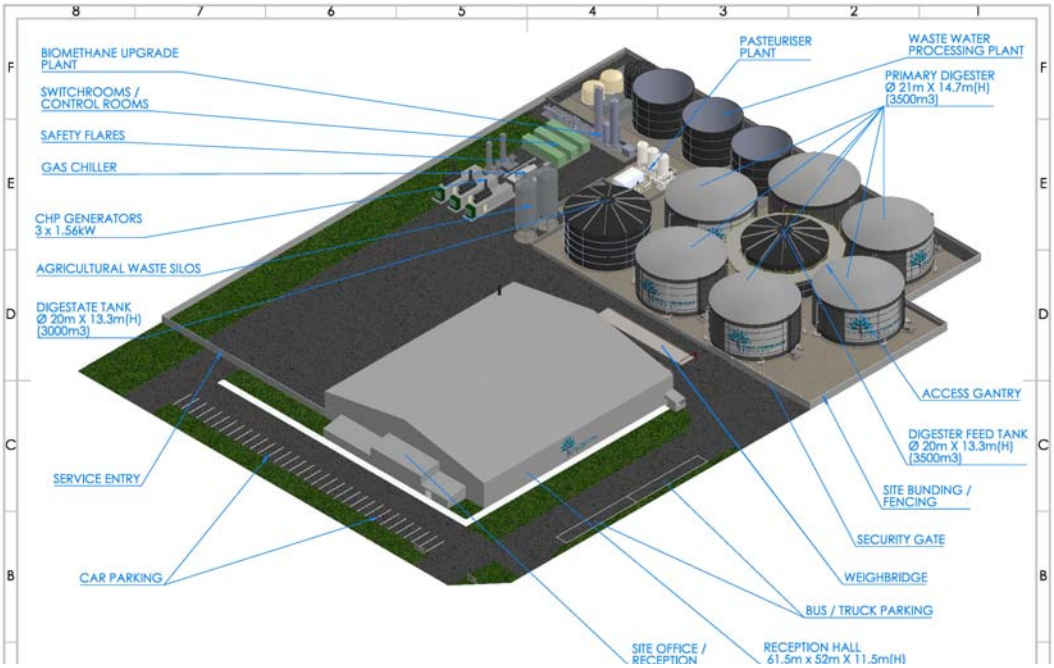


Figure 2 – AD Facility Layout

This assessment has been based on the following:

- The proposed site layout and equipment as shown in document "Lot 505 Assembly V5.pdf" issued 22nd May 2018.

- Previous noise measurements for the Richgro Jandakot AD Facility

2. ASSESSMENT CRITERIA

The proposed site is located within an Urban Employment Zone of the Salisbury Council Development Plan. The premises surrounding the proposed site at Lot A505, 1-2 Gidgie Court are used for automotive manufacturing (General Industry) or equipment hire (premises to the east of Gidgie Court). The premises on the western boundary (71 – 75 Woomera Avenue) is occupied by the North Adelaide Waste Management Authority, consisting of offices at the front (day hours) and recycling building currently operating 6am – midnight.

Residential areas are located to the south-west, 470m from the proposed site.

The Development Plan's interface between land uses principle of development control 7 states:

> *Development that emits noise (other than music noise) should include noise attenuation measures that achieve the relevant Environment Protection (Noise) Policy criteria when assessed at the nearest existing noise sensitive premises.*

Development Plan makes specific reference to the *Environment Protection (Noise) Policy 2007*.

The policy provides noise levels (L_{Aeq}) not to be exceeded at noise sensitive receivers, based on the principally promoted land use where the noise source and the noise receivers are located. The relevant criteria are:

Residential Zone

- 52 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 45 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#
- 60 dB(A) L_{Amax} between the hours of 10pm and 7am when measured;

At the nearest noise-affected premises in the City of Salisbury Residential zone in accordance with the *Environmental Protection (Noise) Policy 2007*.

Urban Employment Zone

- 59 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 50 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#

When measured and adjusted# at noise-affected premises in the City of Salisbury Urban Employment zone in accordance with the Environmental Protection (Noise) Policy.

The measured noise levels should be adjusted in accordance with the *Environmental Protection (Noise) Policy 2007* by the inclusion of a penalty for each characteristic where tonal/modulating/impulsive/low frequency characteristics are present.

The dominant noise sources at distance are the generators, which have significant acoustic attenuation packages and based on measurement at Richgro Jandakot will not have dominant noise characteristics at the residential area. Therefore no adjustment for noise characteristic applies for the proposed noise emissions to the residential area.

However some noise characteristics may be audible at the adjacent premises and appropriate adjustment are required.

3. METHODOLOGY

Noise levels were predicted using the acoustic software SoundPlan using the Concawe algorithm for Pasquill Class 6 climatic conditions. The sound power levels used in the acoustic modelling are tabulated in the Appendix A. Sound power levels were determined from measurement of a similar AD Plant at Jandakot, Western Australia.

The proposed AD facility is to operate continuously.

The AD facility operations consist of continuous operation of bio-filtration, digesters and associated pumps and fans, pasteuriser, biomethane upgrade plant, generators and safety flares (normally on standby). Intermittent noise will be generated on site by entry / exit of trucks and operation of high-speed roller doors.

Information relating to vehicle movements:

- A maximum (worst case scenario, otherwise could be as low as 35) of 50 trucks are likely to be entering site, comprised of:
    - Rigid trucks – 34 per day
    - Semitrailer trucks – 12 per day
    - B-double trucks – 4 per day
- All vehicles except for the B-double trailers will be loading/unloading within the receival shed.
    - B-doubles will take approximately 1 – 2 hours to fully unload

4. PREDICTED NOISE EMISSIONS

Predicted noise contour plots for 'worst case' winds for the proposed operations are shown in Appendix B.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are provided. The required heights are 3m adjacent the generators and adjacent the truck access area, as shown in plot 20W, Appendix B.

The generators and flares are capable of emitting noise exceeding the noise criteria at the adjacent premises. Noise mitigation by selection of attenuated generator package units rated at 65 dB(A) at 1m and provision of acoustic barrier walls around the generators and flare units is shown to attenuate noise emissions within acceptable levels.

TABLE 4.1 PREDICTED NOISE LEVELS

Receptor	Night 3 Generators		Night Two Flare Units		Day 3 Generators Trucks		Compliance
	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	
Residences							
Criteria	**45**	**45**	**45**	**45**	**52**	**52**	
R1: 20 Diruwa Drive, Salisbury North	26	26	21	21	36	36	Yes
R2: 60 Hogarth Rd, Elizabeth South	10	10	9	9	11	11	Yes
Adjacent Premises							
Criteria	**50**	**50**	**50**	**50**	**59**	**59**	
I1: 59-61 Woomera Ave (Coates Hire)	39	44^{t}	38	43^{t}	41	49^{ti}	Yes
I2: 4 Gidgie Crt	38	43^{t}	36	41^{t}	38	46^{ti}	Yes
I3: 3 Gidgie Crt	44	49^{t}	43	48^{t}	44	52^{ti}	Yes
I4: 71-75 Woomera Ave (NAWMA)	45	50^{t}	41	46^{t}	51	59^{ti}	Yes
I5: 76 Woomera Ave	41	46^{t}	38	43^{t}	51	59^{ti}	Yes
I6: 78 Woomera Ave	39	44^{t}	34	39^{t}	51	59^{ti}	Yes

The noise emissions for Night scenario two flares is dominated by pump noise, flare noise levels are relatively low compared to the overall predicted level. Characteristic adjustment for tonal noise only of 5 dB(A).

The noise emission for day scenario is conservative as trucks have been modelled at the passby emission level to consider busy periods where noise may be present for much of the 15 minute assessment period. Generally the L_{Aeq} noise level will be lower as trucks are only in the yard for short periods while entering or leaving the receival facility. Adjustments for tonal characteristic and impulsive characteristic have been applied, an adjustment of +8 dB(A) to the predicted noise level at the receptor premises.

5. NOISE MITIGATION MEASURES

The following noise mitigation measures are required to comply with the requirements of the Regulations:

- Fan selection or attenuation of the Bio-filter blower outlet to achieve a sound power of no more than 85 dB(A) at the external outlet.
- Section of 3m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the generators as shown in plot 20W, Appendix B.
- Section of 3.0m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the truck access area as shown in plot 20W, Appendix B.
- Generators to be fitted with acoustic attenuation package equivalent to those provided to generators at Richgro Jandakot site, rated at 65 dB(A) at 1m.
- Acoustic barrier walls to be installed around the generators and flare units as shown in plot 20W, Appendix B. The walls may be constructed metal framing with roof sheeting or coolroom panel with a mass density of at least 10 Kg/m^2 for the combination. The wall on the western side of the generators and flare units should have a minimum mass density of 17 Kg/m^2 for the lower 5 meters, and if a lightweight construction, be a cavity wall type construction with minimum of 100mm between each side with 100mm acoustic insulation infil to assist in the control of lower frequency noise emissions. (90mm sandwich panel one side, 100mm channel with roof sheeting on the other side with 100mm fiberglass insulation infil for example). Concrete tilt-up panel would also be suitable.

6. CONCLUSION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed AD facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are installed adjacent the generators and truck access area to ensure compliance at the adjacent premises to the west. The required heights of acoustic barriers are shown in plot 20W, Appendix B.

APPENDIX A

Sound Power Levels

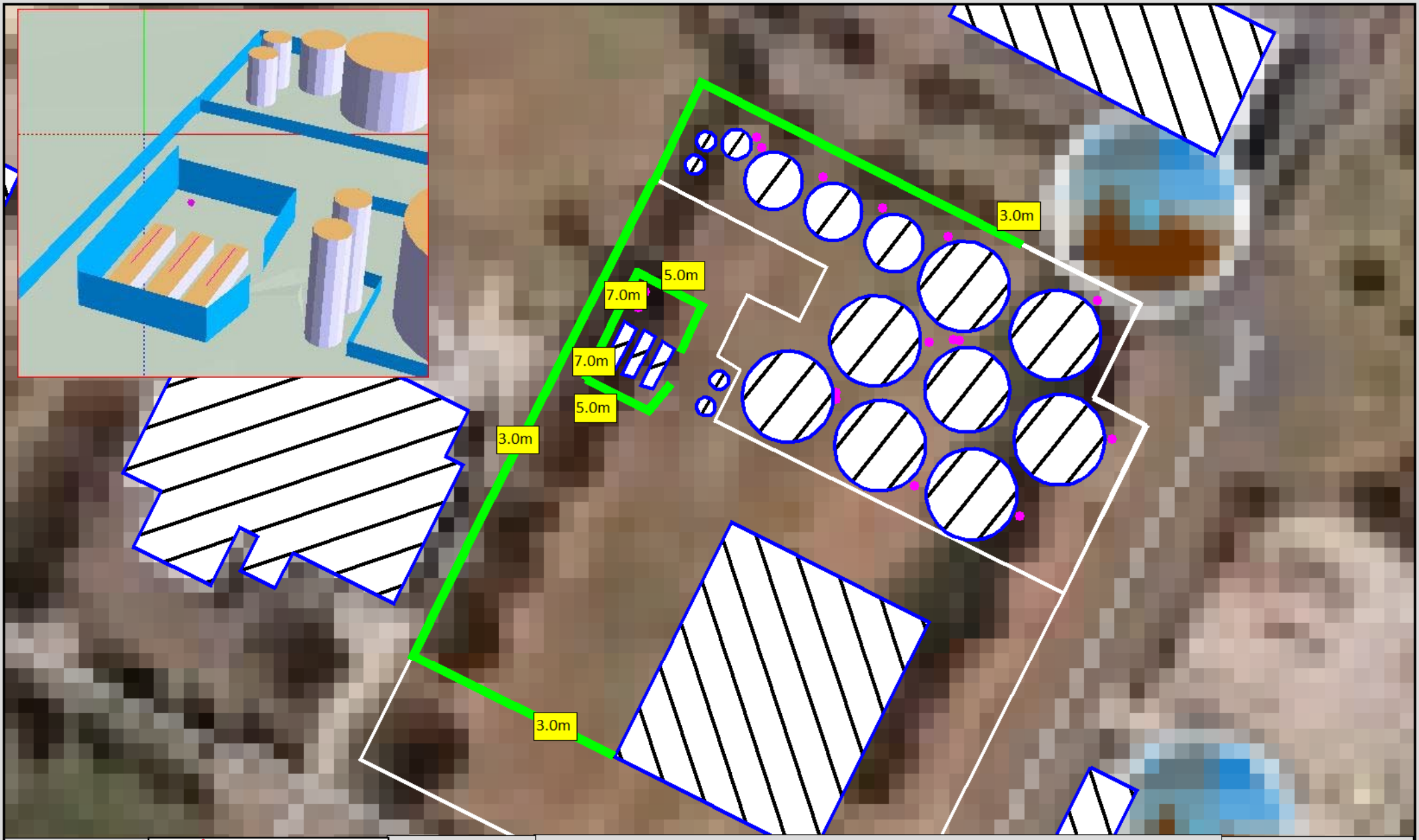
Acoustic Model Sound Power Levels

Sound Power in dB

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Generator 1	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 2	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 3	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Biofilter Blower	89.1	81	86	84	89	85	83	86	87	88	86	80	78	82	77	74	77	72	71	70	68	75	84	71	69	68	65
AD Flare 1 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
AD Flare 2 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
Digester Feed Tank - Pump 1	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digester Feed Tank - Pump 2	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digestate Feed Tank - Pump 1	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digestate Feed Tank - Pump 2	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digester - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 5	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 6	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
25 Ton Truck	100.1	92	95	109	100	94	110	98	98	98	95	91	91	91	92	90	89	88	88	87	87	84	79	77	74	72	73
12 Ton Truck Moving	94.3	94	105	101	102	96	108	90	92	88	84	83	85	87	85	82	83	85	78	77	78	74	74	71	69	67	68

APPENDIX B

Noise Contour Plots



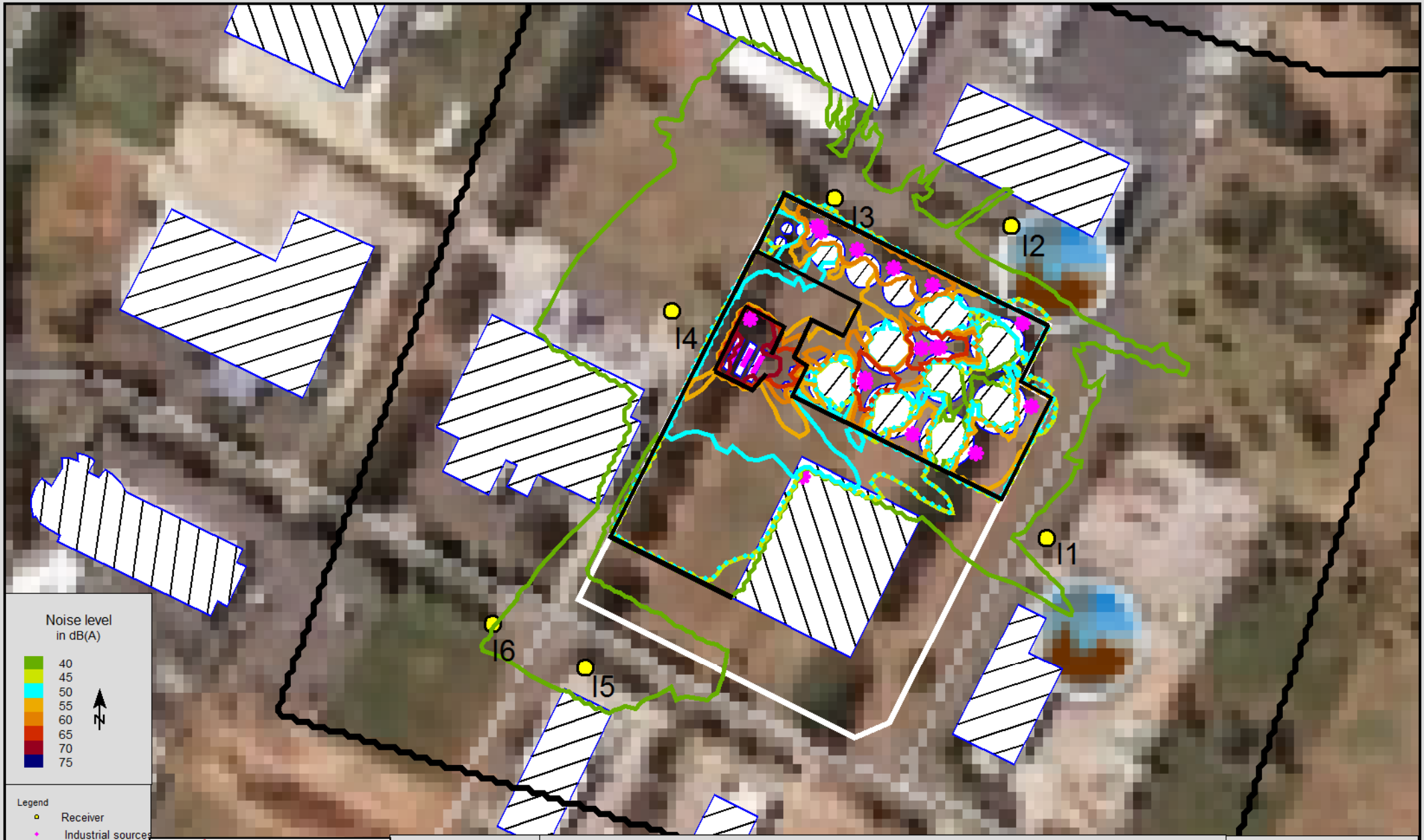
Legend
- Main building
- Wall
- Industrial sources
- Line source

HERRING STORER ACOUSTICS

Ref: 18204 Run: 20W
Date: 9/11/2018

BIOGAS RENEWABLES - SAILSBURY
3m BARRIER WALL ON BOUNDARY AND
7.0m WALL ON WEST SIDE OF GENERATORS AND FLARE
UNITS, 5.0m TO OTHER GENERATOR AND FLARE UNIT ENCLOSURE WALLS

Scale 1:1200
0 5 10 20 30



HERRING STORER ACOUSTICS

Ref: 18204 Run: 20L
Date: 8/11/2018

BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE - 45 dB(A)

Scale 1:2000
0 10 20 40 60

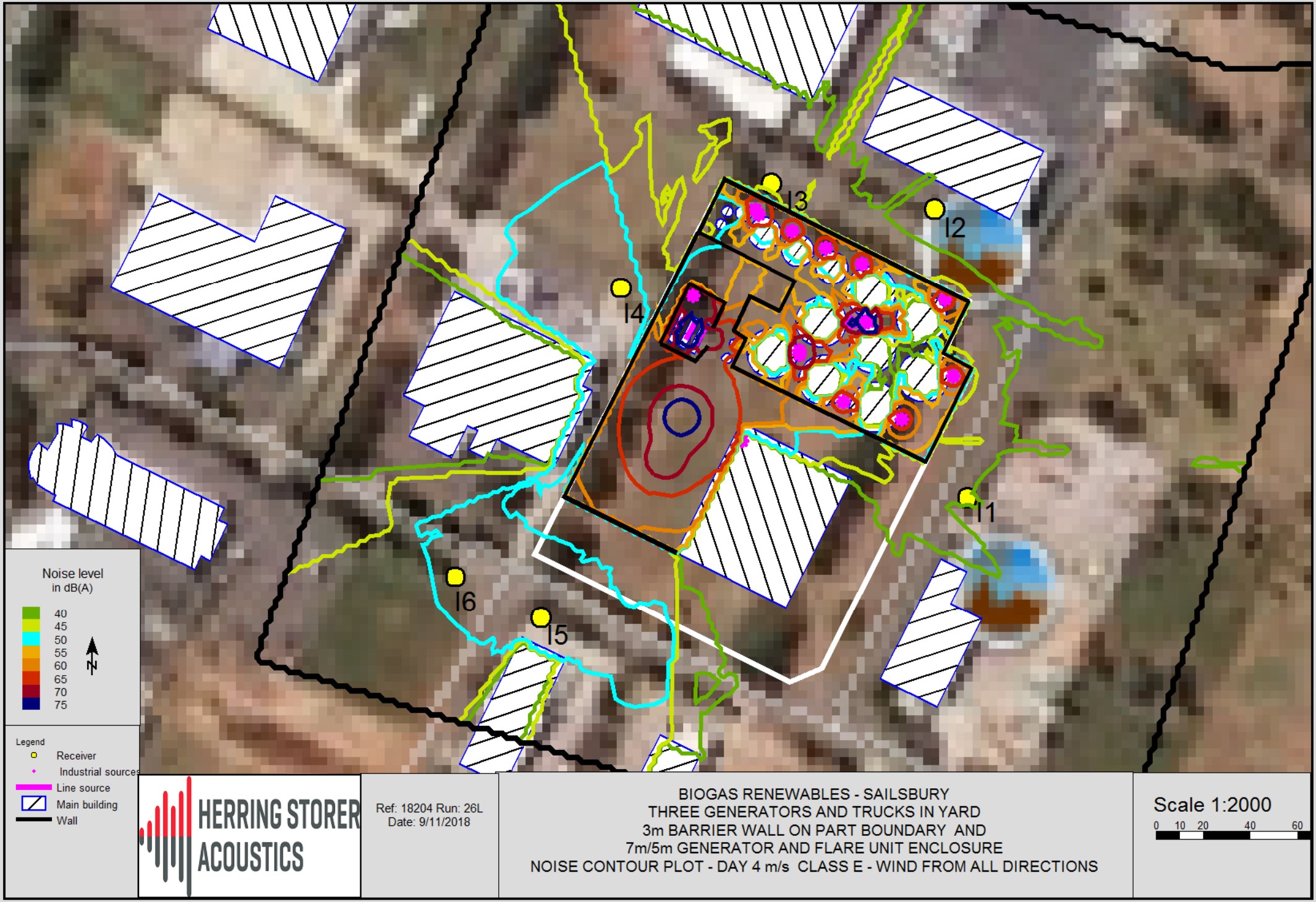

Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 20
Date: 8/11/2018
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400
R1
R2
I1
I2
I3
I4
I5
I6
Edinburgh
Sturton Rd
Wyatt Rd
Tappa Rd
Kadina Ave
Camira Way
Leila Ave
Maronga St
Kulma Dr
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
Diment Rd
Harold Rd
Horwood Rd
McCormack Crescent
Perry St
Arura Rd
Pibugi St
Illara St
Barrin St
Bolivar Rd
Oronga St
Paratta St
Tugger Way
Woomera Ave
Kettering Rd
Bayer Rd
Grainger Rd
Goodman Rd
Willison Rd
Philip Hwy

HERRING STORER ACOUSTICS

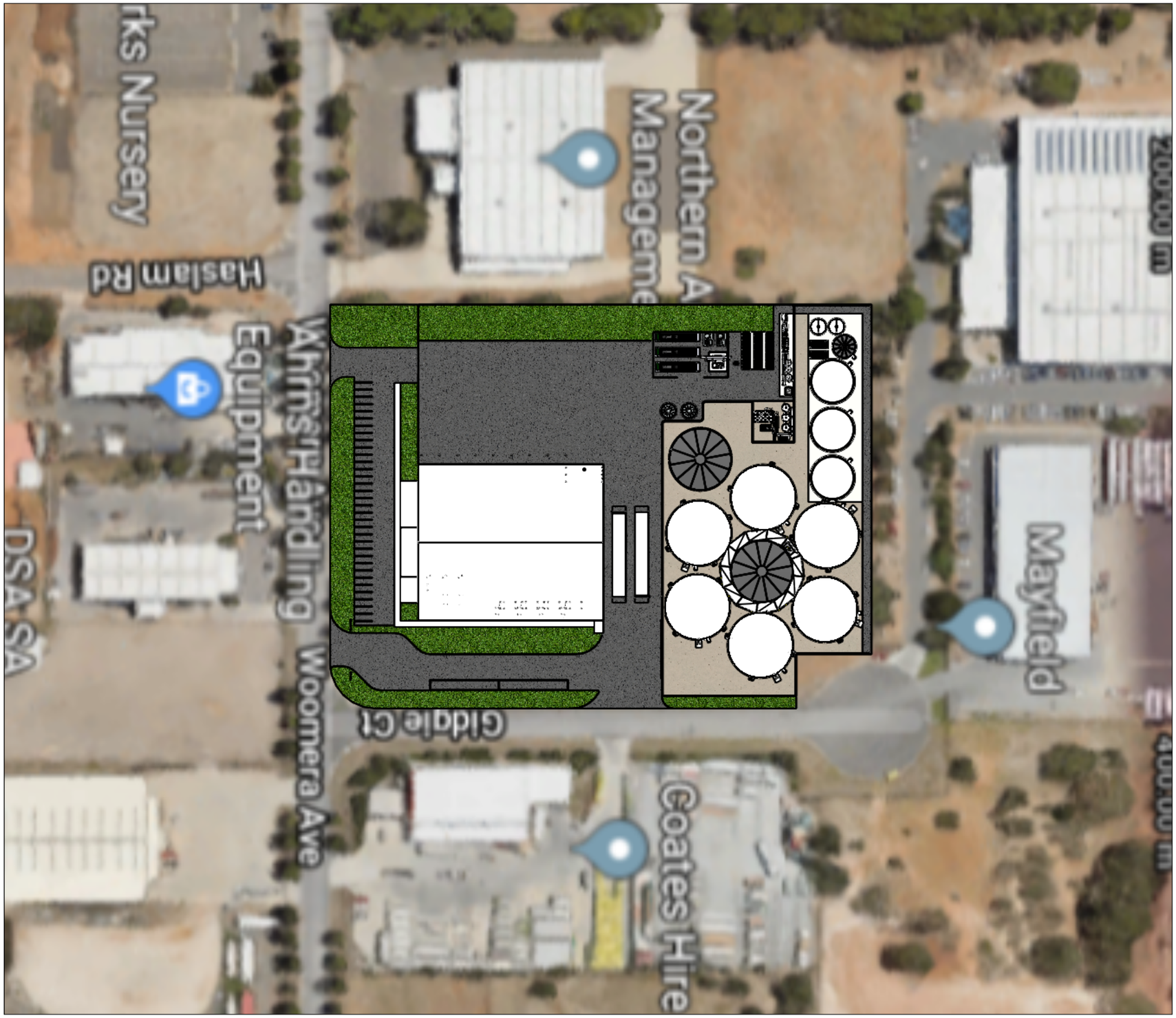
Ref: 18204 Run: 23L
Date: 8/11/2018

BIOGAS RENEWABLES - SAILSBURY - NO GENERATORS, FLARING
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m ENCLOSURE TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE 45 dB(A)

Scale 1:2000
0 10 20 40 60


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 26L
Date: 9/11/2018
BIOGAS RENEWABLES - SAILSBURY
THREE GENERATORS AND TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:2000
0 10 20 40 60


Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
N
Legend
Receiver
Industrial source
Line source
Main building
Wall
R1
R2
I1
I2
I3
I4
I5
I6
Edinburgh
Sturton Rd
Wyatt Rd
Tappa Rd
Paratta St
Bolivar Rd
Oronga St
Sarrin St
Camira Way
Leila Ave
Illara St
Perry St
Arura Rd
Horwood Rd
McCormack Crescent
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
Diment Rd
Harold Rd
Woomera Ave
Tugye Way
Kettering Rd
Bayer Rd
Grainger Rd
Goodman Rd
Willison Rd
Philip Hwy
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 28L
Date: 9/11/2018
BIOGAS RENEWABLES - SAILSBURY
3 GENERATORS OPERATING WITH TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400



0	ISSUED	12/11/2018	J. LUU	J. OLIVER	J. OLIVER
REVISION	REVISION DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED

BIOGASS RENEWABLES PTY LTD
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WESTERN AUSTRALIA 6005
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Email: info@biogass.com.au

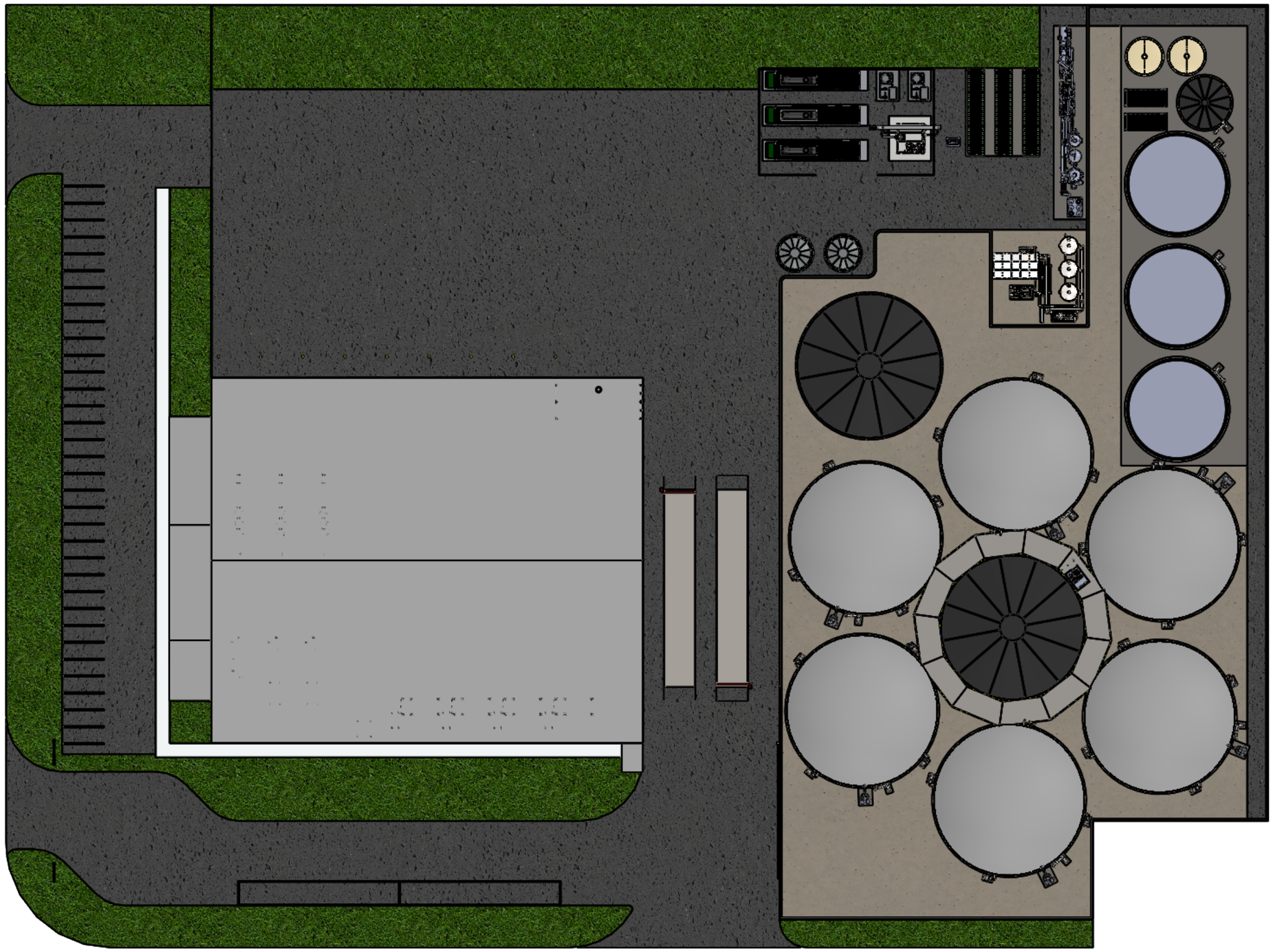
CLIENT: DELOREAN

PROJECT NO: J116

TITLE: BIOGASS RENEWABLES PLANT CONCEPT SITE PROPOSAL

ALL DIMENSIONS IN mm

DWG NO. J116-003 SHEET NO. 1 OF 4 REV 1



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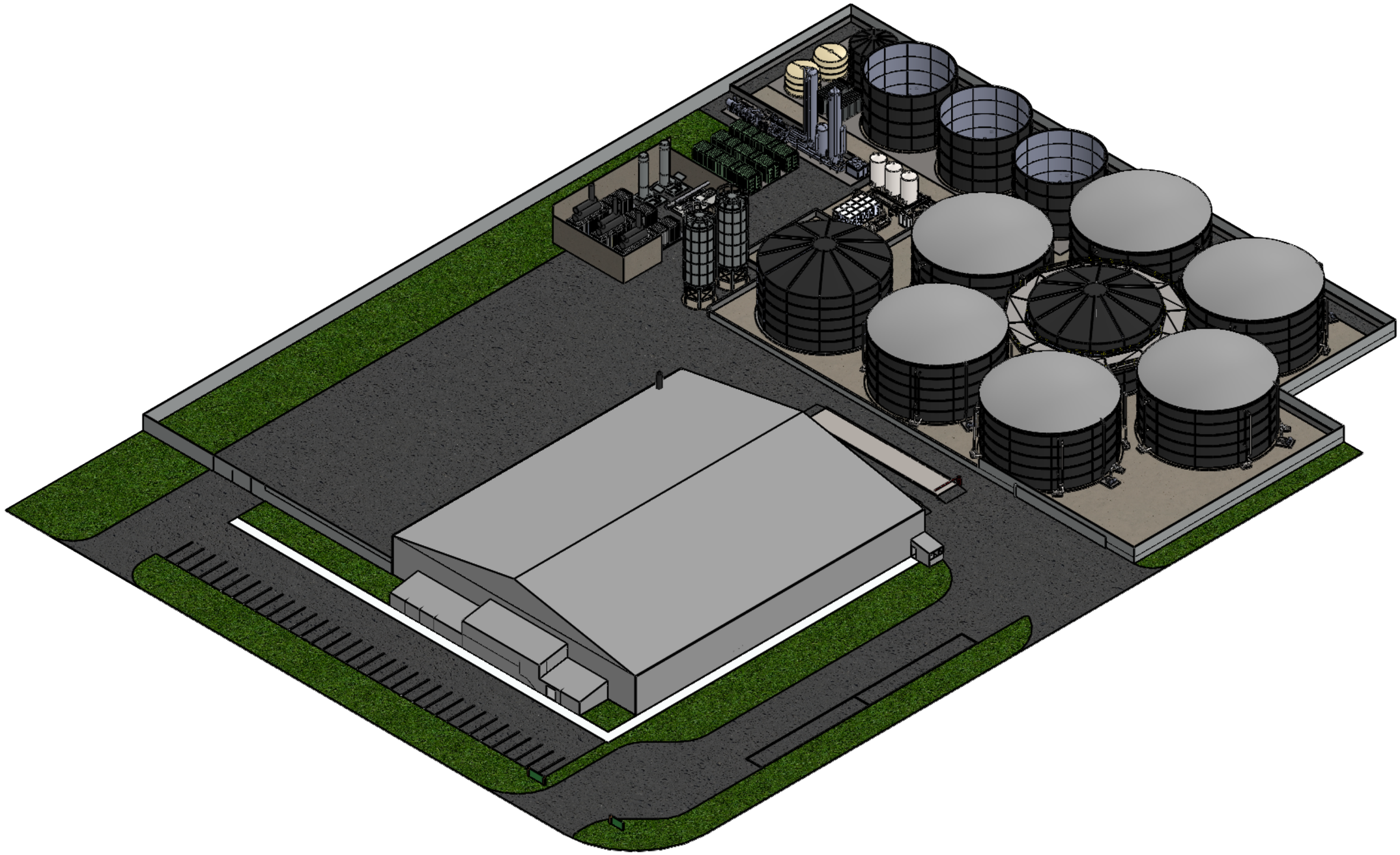
0	ISSUED	12/11/2018	J. LUU	J. OLIVER	J. OLIVER		
REVISION	REVISION DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED		

CLIENT: DELOREAN
PROJECT NO: J116

TITLE: BIOGASS RENEWABLES PLANT CONCEPT SITE PROPOSAL

ALL DIMENSIONS IN mm

DWG NO. J116-003 SHEET NO. 2 OF 4 REV 1



REVISION	REVISION DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
0	ISSUED	12/02/2018	J. LUU	J. OLIVER	J. OLIVER

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CLIENT: DELOREAN

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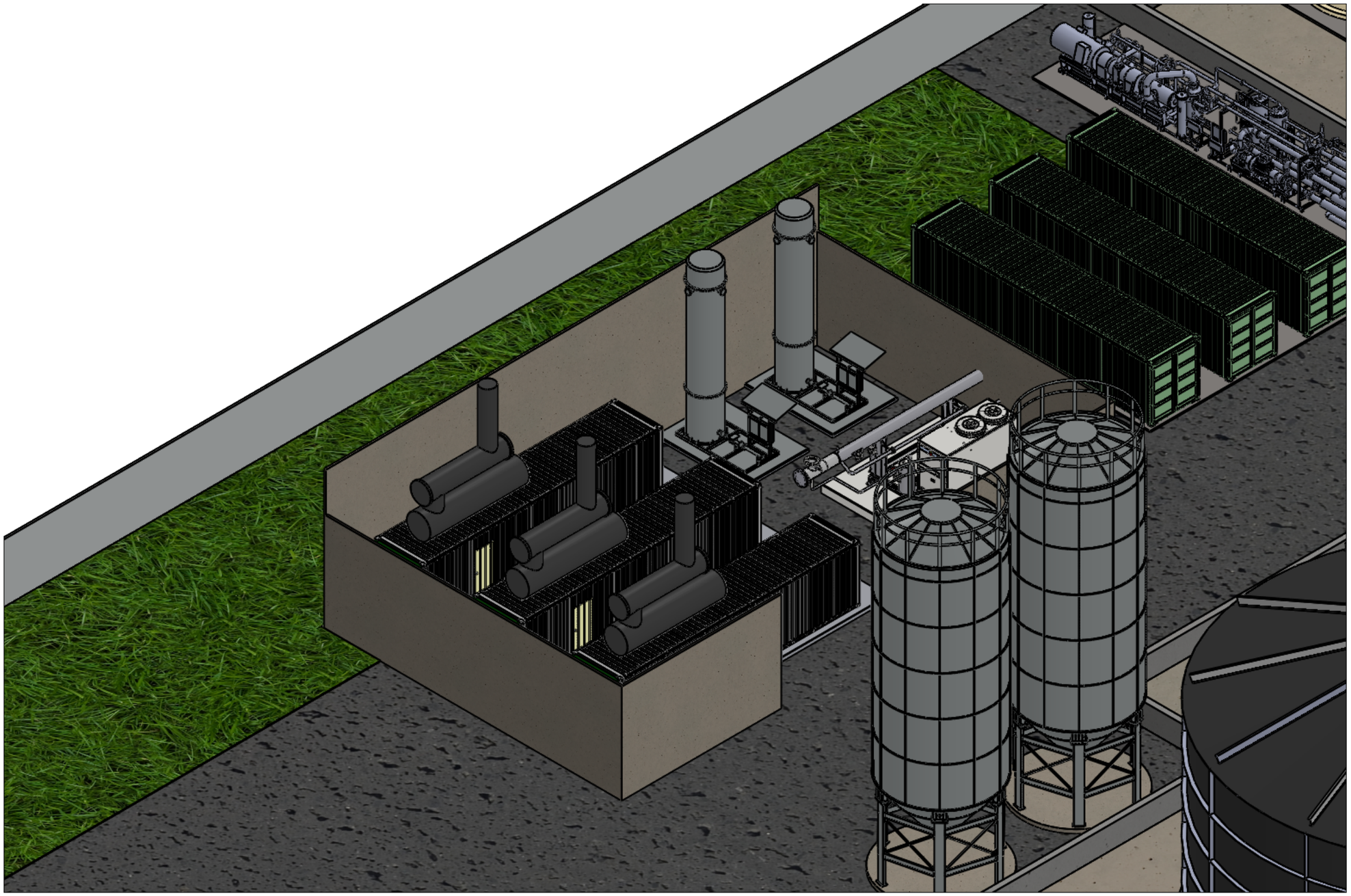
TITLE: BIOGASS RENEWABLES PLANT CONCEPT SITE PROPOSAL

ALL DIMENSIONS IN mm

DWG NO. J116-003 SHEET NO. 3 OF 4 REV 1



REVISION	REVISION DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
0	ISSUED	12/02/2018	J. LUU	J. OLIVER	J. OLIVER

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CLIENT: DELOREAN

PROJECT NO: J116

ALL DIMENSIONS IN mm

TITLE: BIOGASS RENEWABLES PLANT CONCEPT SITE PROPOSAL

DWG NO. J116-003 SHEET NO. 4 OF 4 REV 1

ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

ROUND 4 CLARIFICATIONS

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
20/12/18	0	Issued	JL	JO	HJ

Response to Development Application Information Request

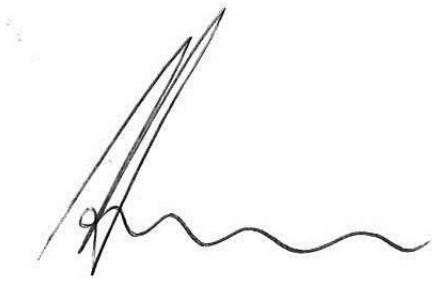
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



Hamish Jolly, Director
Biogass Renewables Pty Ltd
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RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	Provide data from a commissioned plant (proof of concept) that shows zero H2S emission due to the proposed mitigation methodology.
	DeLorean / Biogass	The proposed development has been updated to ensure effective reduction of H2S. The previously stated Stage 2 "Carbon Activated Filter" will be replaced with a more rigorous "Iron Oxide Filter" guaranteed to output <0.1 PPM's H2S. Nonetheless, the design and operation of the plant shall target zero H2S output at all times. Please refer to *Appendix 1* for product specifications of the Iron Oxide Filter (Product ID SULFATREAT 2242 Plus). Please refer to *Appendix 2 for* data for examples of various commissioned plants demonstrating where this technology has been effectively implemented. The relevant data has been provided by preferred supplier *Schlumberger*.
2	EPA	Update the predictive dispersion modelling to demonstrate that the Biofilter emissions (based on current configuration) would meet odour criteria of Schedule 3 of the *Environment Protection (Air Quality) Policy 2016*.
	DeLorean / Biogass	Please refer to *Air Quality Assessment - Section 6.2 - Odour Assessment* attached separately for results dispersion modelling demonstrating biofilter emissions meets criteria of Schedule 3. For convenience, extract is as follows: *"The maximum predicted 99.9th percentile 3-minute average odour concentration for routine operations (considering emissions from the biofilter and the biomethane upgrade stack) is presented in Table 8. Contours of the predicted 99.9th percentile 3-minute average odour levels are presented in Figure 5.* *The predicted odour levels remain below the SA EPA criteria of 2 OU throughout the modelled domain. Odour concentrations predicted to occur at the nearest residential and golf course receptor locations remain below 0.5 OU (Figure 5)."*

		Table 8: Maximum Predicted Odour Concentrations for the Biogas Plant <table><tr><th rowspan="2">Compound</th><th rowspan="2">Averaging Period</th><th>Criteria</th><th>Maximum Predicted 99.9th Percentile</th></tr><tr><th>(OU)</th><th>(OU)</th></tr><tr><td>Odour</td><td>3-minute (99.9th Percentile%)</td><td>2</td><td>1.88</td></tr></table> For avoidance of doubt, please note that *Table 1* of the *Air Quality Assessment - Section 6.2 - Odour Assessment* displays "NA" where modelling parameters are not applicable i.e. H2S, NOx, SO2 and CO will not be present or input / output by the biofilter.
3	EPA	Provide design details of the Biofilter including temperature control during hot days, humidity control and how the "Greenlane" waste gas would be managed. As above, it must be demonstrated where this technology has been successfully used on similar applications.
	DeLorean / Biogass	Addressing the EPA's question in two parts: *a)* <u>*Biofilter Design and Control*</u> The biofilter is a point source capture system treating odorous emissions captured within the receival building. The biofilter will incorporate a full plenum distribution chamber diverting the odorous airflow through the filter medium for biological oxidation of the odorous compounds in the airstream. The porous filter medium allows for intimate contact and absorption with the incoming airstream to enable oxidation by micro-organisms. Humidification of the air is required at 85% relative humidity to ensure sustainable and effective biofilter performance. It is acknowledged that lower levels will invariably result in uneven and dry patches in the biofilter medium potentially resulting in incomplete odour removal. Likewise, the biofilter will have a practical temperature operating limit of approximately 45degC to ensure survival of the aerobic micro-organisms. To mitigate the risk of an ineffective biofilter in treating odour, humidification will be incorporated by spraying the inlet airstream with atomised water. This preconditioning of the airstream creates adiabatic cooling of the airstream. To monitor and control the biofilter, temperature and relative humidity sensors will be placed the inlet and outlet of the biofilter with ongoing monitoring and control to ensure operational effectiveness. Please refer to *Air Quality Assessment - Section 2.3.2 - Biofilter* attached separately for further biofilter design information. Please refer to *Appendix 3* for odour emissions testing results conducted on the reference facility at Jandakot conducted by *Emissions Assessments*. *b)* <u>*Greenlane Waste Gas Management*</u> The Greenlane biogas-biomethane upgrade equipment will incorporate an Iron Oxide Filter (as per previous Response 1) on the "waste gas" outlet to ensure H2S emissions to atmosphere are reduced to <0.1PPM's. Please refer to *Greenlane Totara 2000 Process Flow* attached separately.
4	EPA	Provide a description of the "micro dosing air" to oxidise sulphur dioxide to

		"sulphate" in the head space of the anaerobic digestor, including (but not limited to): a. How much air would be required; b. Whether this air requires a compressor; c. How the good mixing of air and hydrogen sulphide in the headspace of the anaerobic digestor would be achieved; and d. What form the "sulphate" takes.
	DeLorean / Biogass	The following information regarding the H2S biological scrubber has been supplied in conjunction with preferred micro-dosing equipment supplier *Allison Engineering*: Biological desulphurisation uses naturally occurring aerobic bacteria present in air, to breakdown the H2S. The air is injected in small quantities into the biogas in the head space of the digester. Because there are no chemicals involved, there are no operational costs & it is environmentally friendly. If the retention time of the biogas in the digester is greater than 1 – 1.5 hrs, we can expect a reduction of H2S up to 95%. The use of chemotropic bacterial species (Thiobacillus genus) to condition biogas is well established & most thiobacteria are autotrophic, consuming CO2 and generating chemical energy from the oxidation of reduced inorganic H2S. The result is elemental sulphur & water. 2 H2S + O2 -> S2 + 2 H2O Ultimately the aim is to keep the air input to a minimum whilst maintaining control of the H2S. However, most biological treatment consists of a blower with a fixed speed fan & a small but constant air flow into the gas space. Alternatively, plant technicians can manually operate the blower whenever they decide it's necessary. Responses to the EPA's specific questions are as follows: a. The AwiFlex analyser from Awite Gmbh measures O2 & H2S (as well as CH4/CO2/H2) & has its own air blower. It uses a combination of PI & Fuzzy logic control to automatically adjust the air flow from the blower based on the rise & fall of O2 & H2S. It will typically control the H2S with between 0.4 & 1% O2 depending on the H2S concentration, with an upper limit of 2.4% O2. b. Confirming that an air compressor is required as part of the biological scrubbing / micro air dosing process c. Mixing in the headspace of the anaerobic digester is achieved through the following: i. Air will be introduced via multiple points in the headspace of the digester; ii. Venturi / gas mixing systems operating in the headspace of each digester tank to ensure adequate mixing; iii. Gas analyser installed in the gas outlet pipe to frequently sample biogas and provide performance data indicating effectiveness of micro dosing air system d. The sulphate is removed as a solid precipitate in the outfeed digestate
5	EPA	Provide a description of the "Greenlane" process including whether or not a compressor is required to enhance carbon dioxide and hydrogen sulphide solubility into water.
	DeLorean / Biogass	Please refer to *Appendix 4* for process information provided by Greenlane. Confirming that two stage rotary sliding vane compressors are required as part of the process.

6	EPA	Ammend the Environmental Noise Assessment, prepared by Herring Storer Acoustics (Reference: 23621#2#18204) as follows: a. Specify the type of fan (provide make, model, etc.) that would be installed (it is acceptable to include "…or equivalent") for the bio-filter blower which would have a sound power level no greater than 85dB(A) at the external outlet; b. Specify what type of attenuation (if required) to ensure the sound power at the external outlet of bio-filter blower fan would be no greater than 85dB(A).
	DeLorean / Biogass	Please refer to the updated *Environmental Noise Assessment* attached separately. Responses to the EPA's specific questions are as follows: a. Please refer to *Appendix 5* for the biofilter fan data sheets. b. As per the updated *Environmental Noise Assessment - Section 5 - Noise Mitigation Measures*, each fan discharge outlet to be fitted with 2D cylindrical podded silencer minimum 1m gap (duct), 1D unpodded silencer. Furthermore, the fans will be located inside of the receival hall building to ensure adequte noise attenuation. The recevial hall design will incorporate insulated roof and walls consisting of expanded polystyrene core of 100mm thickness manufactured to Austalian Standard AS 1366.3 and outer prestressed panel faces of 0.4mm or 0.6mm thickness.
7	EPA	Provide a list of treatment chemicals / aids to manufacture (including inventories) and how they would be stored within a bunded area or otherwise stored to prevent water pollution.
	DeLorean / Biogass	Please refer to the *Appendix 6* for a complete list and expected inventory of chemicals stored on site.
8	EPA	Provide a current process diagram which shows all the proposed major plant items.
	DeLorean / Biogass	Please refer to the attached *Process Flow Diagram* as requested.

APPENDIX 1 – SUFATREAT 2242 PLUS PRODUCT INFORMATION

Schlumberger

SULFATREAT 2242 Plus

Reduced-pressure-drop iron oxide–based hydrogen sulfide adsorbent

APPLICATIONS

- Hydrogen sulfide (H_2S) removal from water-vapor-saturated gas
- Odor control

BENEFITS

- Simple, reliable, predictable performance
- Cost-effective removal of H_2S
- Minimal operator attention required
- Ability to adapt to variable process conditions

FEATURES

- Straightforward vessel changeout
- Low pressure drop
- Operating flexibility
- Simplified disposal of spent media
- Industry-leading performance warranty

SULFATREAT 2242 Plus* reduced-pressure-drop iron oxide–based H_2S adsorbent is a nonhazardous granular material engineered for the purification of gas streams. During the absorption process, water-vapor-saturated gas or vapor flows down through the SULFATREAT 2242 Plus adsorbent in the vessel's bed. Hydrogen sulfide chemically reacts to form a stable by-product.

Product consumption is dependent only on the amount of H_2S that passes through the bed. This economically matches the need for H_2S removal with variations in system flow conditions and outlet specifications regardless of the total volume or other common components of the gas. Upstream of the SULFATREAT 2242 Plus adsorbent vessel(s), the installation requires water injection to assure 100% water-vapor-saturated gas and an inlet separator with a high-efficiency demister pad to remove free liquids from the gas.

Typical Physical Properties	
Form	Granular
Nominal size	4–10 mesh
Packing density	58.9–65.1 lb/ft^3 [0.94–1.04 kg/L]
Packaging	2,000-lb [907-kg] bulk bags

Handling and disposal

SULFATREAT 2242 Plus adsorbent should be handled in compliance with proper safety procedures, such as permit-to-work systems and risk assessments, such as a job safety analysis, chemical-handling assessments, lifting studies, and applicable disposal regulations. It is recommended that an experienced contractor be engaged for product loading and discharge.

The spent media is nonpyrophic. Our experts can help you determine the best option for recycling or disposing of spent material. Disposal routes are well established and personnel are available for onsite installation and removal support as needed.

Should any foreign contaminating materials be contained in the gas or otherwise be introduced to the reactor, the resultant mixture may require special disposal considerations. Spent media should be analyzed by the operator and any regulatory or local approvals needed obtained.

APPENDIX 2 – IRON OXIDE FILTER DATA FROM COMMISSIONED PLANT CASE STUDIES (PROOF OF CONCEPT)

The following table displays data from commissioned sites employing SULFATREAT iron oxide filters. Data has been provided by preferred supplier *Schlumberger* from their worldwide site portfolio.

Customer	Status	Product	Application Type	Kg H2S / Day	Inlet Stream	Outlet H2S (ppm)
DECATUR UTILITIES	Onstream	SULFATREAT 410CHP	Waste & Sewage Gasification	2.0	500	0.1
T2C ENERGY LLC	Onstream	SULFATREAT CHP	Waste & Sewage Gasification	0.2	100	0.01
REAGENT CHEMICAL & RESEARCH, INC.	Onstream	SULFATREAT 410 HP	Biogas	0.5	360	0.1
HIGGINS AND HEWINS LIMITED	Onstream	SULFATREAT 410CHP	Waste & Sewage Gasification	1.8	500	0.1
M/S INDIA GLYCOLS LTD	Onstream	SULFATREAT CHP	Biogas	17.5	600	0.1
DCL INTERNATIONAL INC	Onstream	SULFATREAT 2242	Biogas	1.9	100	0.1
Confidential Application – Singapore	Onstream	SELECT HP	Food Grade CO_2	29.0	350	0.1
Confidential Application– Rotterdam	Onstream	SELECT HP	Food Grade CO_2	1.8	20	<0.1
HABAS1	Onstream	SULFATREAT CHP	Food Grade CO_2	1.4	10	<0.1
Linde Gas Various sites	Onstream	SULFATREAT 2242 / 410 CHP /	Food Grade CO_2	6-48	650-160	<0.1
HG Energy Ltd UK	Onstream	SELECT HP	Natural Gas	24.4	10	<0.1

APPENDIX 3 – BIOFILTER EMISSIONS TESTING DATA FROM REFRENCE FACILITY

Biofilter emissions testing results conducted on the reference facility at Jandakot conducted by *Emissions Assessments* during commissioning in 2015.

Table 2: Summary Table for Bio-filter – Inlet and Outlet

	Units	Bio-filter Inlet		Bio-filter Outlet	
		Run 1	Run 2	Run 1	Run 2
Sampling Time	hh:mm	14:31	14:57	13:42	14:07
Date	dd/mm/yy	15/04/2015	15/04/2015	15/04/2015	15/04/2015
Stack Concentration	ou/dscm	2050	2440	724	789
Mass Emission Rate (Wet at STP)	o/u.m³/s	8530	10200	1530	1670
Odour Character	-	Fatty acid / rancid	Fatty acid / rancid	Fatty acid / rancid	Fatty acid / rancid
Average Mass Emission Rate (Wet at STP)	o/u.m³/s	9365		1600	
Bio-filter Odour Removal Efficiency	%	82.9%			

APPENDIX 4 – GREENLANE BIOGAS UPGRADING SYSTEM

2 Process Description

The Greenlane upgrading system consists of three main processes – the biogas process, the water process and the stripping air process

2.1 Biogas Process

Raw biogas is provided to the inlet isolation valve at the contract interface point.

The biogas flows through an inlet separator to the stage one compressor. Refer to Section 2.1.1 for details of compressor function. The compression process is two stage, complete with inter & after-cooling via water-cooled shell and tube heat exchangers. Temperature, pressure and level instrumentation monitor operation and provide control and safe operation. Discharge check valves are provided to prevent reverse flow of biogas when the system is stopped.

A condensate collector vessel and coalescing filter are provided following the stage 1 & stage 2 discharge coolers respectively. These devices collect and remove condensate and compressor lube oil from the biogas. The condensate collectors also act as receivers for the gas recovered from the flashing vessel. The coalescing filter discharge and scrubbing vessel weir decant drain lines are also connected to this collector vessel.

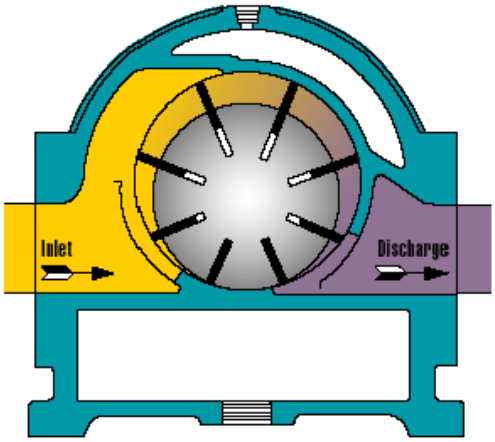
After compression, the biogas enters the bottom of the scrubbing vessel. Inside the vessel the biogas rises to the top, which is counter-flow to the process water flowing downwards. The water preferentially absorbs the more soluble gases such as CO_2 and H_2S. Product gas, which is now almost pure CH_4, exits from the top of the vessel. Packing balls and distributors inside the scrubbing vessel provide increased surface contact area between the gas and water to maximise absorption efficiency.

After the scrubbing vessel the product gas passes through a PSA/TSA adsorber. The molecular sieve media in the drier vessels adsorbs moisture and further purifies the product gas. The dried product gas passes through a filter and a pressure control valve, before being discharged at the skid boundary. The control valve maintains a steady set pressure at the scrubbing vessel, thus ensuring consistent CO_2 and H_2S absorption.

2.1.1 Gas Compression

The RMT series of upgrading plants utilise two stage rotary sliding vane compressors which are considered to be one of the most robust and reliable compressors on the market, ideally suited to dirty and corrosive gases such as wet biogas. The compressor has no valves which significantly reduces maintenance requirements and increases reliability and availability. Spare parts and service are hence low cost, quick and simple compared to other compression technologies such as reciprocating.

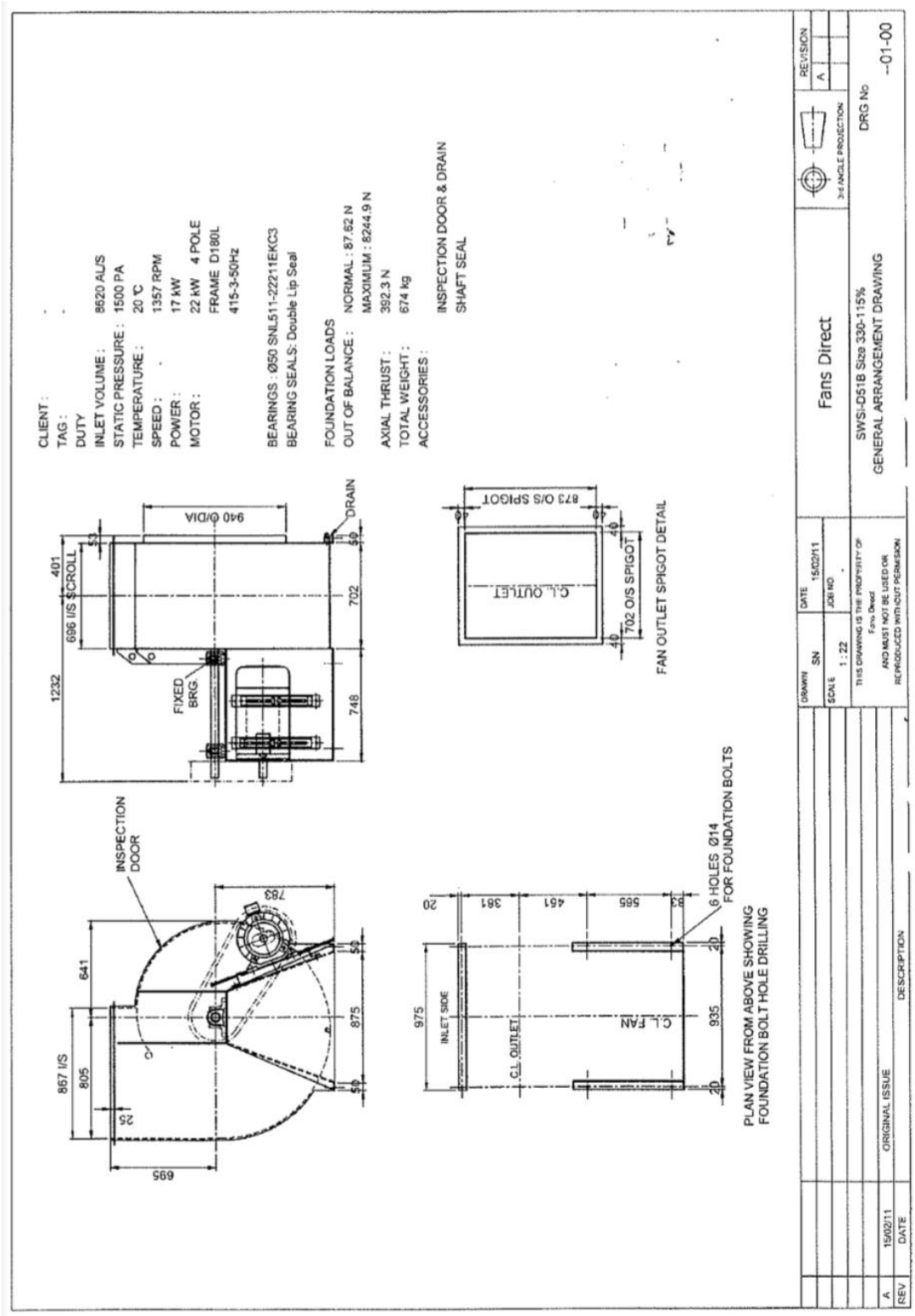
Vane compressors feature a one-piece rotor eccentrically mounted inside a water-jacketed cylinder. The rotor is fitted with blades that are free to move radially, in and out of longitudinal slots. These blades are forced out against the cylinder wall by centrifugal force, creating individual pockets of gas, which are compressed as the rotor turns.



The two compressor stages are directly coupled to a common motor, which has Variable Speed Drive (VSD) to enable efficient capacity control. Drive layout is as follows:

The compressors may be lubricated with biodegradable oil. The lubricating oil may be recovered in an oil separator and can normally be disposed by decomposition; i.e. anaerobic digestion.

APPENDIX 5 – BIOFILTER FAN DATA SHEETS



Fans Direct

Phone : 61-3-9707 8135
Fax : 61-3-9773 3822

FANS

CHICAGO BLOWER

Customer : Internal
Project : Fan Selection by Sudevan Nallathamby
Item 1 - Ref : Temp 1

Quote Ref : Centrix Temp
1/03/2011

Fluid Properties :

Barom Pressure :	101325	pa
Operating Temp :	20	Deg.C.
Humidity :	50	%
Specific Gravity :	1	
Inlet Density :	1.2001	Kg/m3

Duty Required :

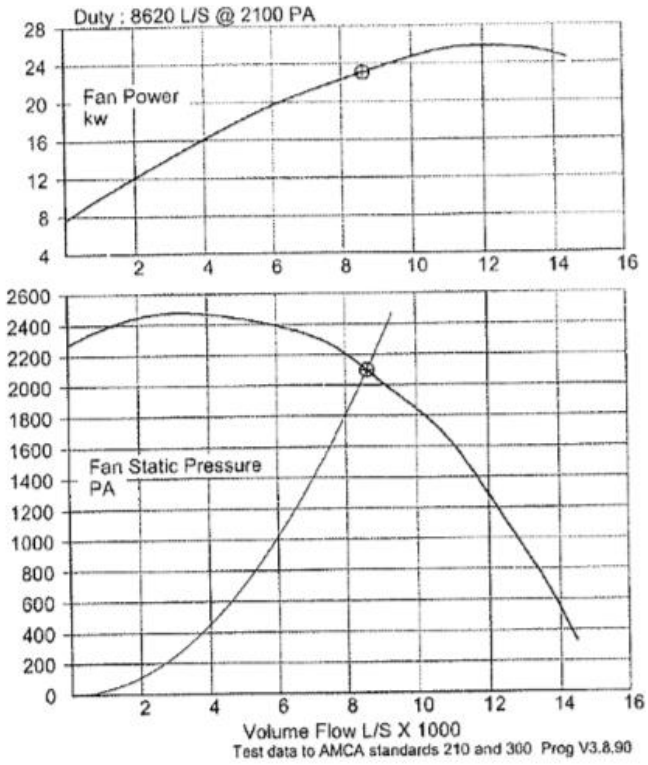
Inlet Volume Flow :	8620	l/s
Inlet Pressure :	-0	pa
Outlet Pressure :	2100	pa

Fan Selected :

SWSI-D51B Size 365-100%

Speed :	1370	Rpm
Wheel Diameter :	903	mm

Fan Shaft Power :		
@ 20 Deg C :	23.1	kW
@ Duty Temp :	23.1	kW
Tip Speed :	64.8	m/s
Inlet Velocity :	10.4	m/s
Outlet Velocity :	12.2	m/s
Temp Rise :	2.2	Deg.C.



Noise Details :	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Total
Internal SWL dB	109	109	102	98	93	90	84	82	**113**
Free Inlet SPL dBA	75	88	90	92	90	88	82	78	**97**
Free Outlet SPL dBA	73	86	89	91	89	87	81	77	**96**
Outside Casing dBA	59	68	65	67	65	63	57	51	**73**

Motor noise is NOT included in the figures above. Average dBA for Motor at 1 metre is 74

Sound Pressure levels (SPL) assume Free Field Hemispherical Radiation at 1 metre(s)
Breakout at 1 metre from 3 mm thick casing(inside Near Field range).
Casing levels assume the inlet / outlet are ducted and noise does not breakout through duct.
All values are averages. Free Inlet assumes that outlet is ducted and vice versa.

FANS

CHICAGO BLOWER

TECHNICAL AND PRICE SCHEDULE. SUBJECT TO OUR STANDARD CONDITIONS OF SALE.

SALES ENGINEER : Sudevan Nallathamby 1/03/2011
PHONE : 61-3-9707 8135
FAX : 61-3-9773 3822

QUOTATION : Centrix Temp

CUSTOMER : Internal
PROJECT : Fan Selection by Sudevan Nallathamby
ITEM REF : Temp 1

ITEM 1
QTY 1

FAN SELECTED	SWSI-D51B Size 365-100%
CONFIGURATION	Single Width CW90
DRIVE TYPE	Belt Drive Arrangement 9
CLASS	2
ROTOR TYPE	Backward Inclined
IMPELLER DIAMETER	903
PERFORMANCE DETAILS	DESIGN DUTY
INLET FLOW (ACTUAL) L/S	8620
DISCHARGE PRESSURE PA	2100
INLET PRESSURE PA	-0 (Fan Static Pressure)
SELECTION TEMPERATURE ℃	20
MAX INLET TEMPERATURE ℃	40
ELEVATION metres	0
INLET DENSITY Kg/m3	1.2001
FAN SPEED rpm	1370
OUTLET VELOCITY m/sec	12.2
TIP SPEED m/sec	64.8
SHAFT POWER at 20℃.	23.10
FAN EFFICIENCY %	77.7 (82.5% excluding accessories).
TEMPERATURE RISE ℃	2.2
SHAFT POWER at 20℃. kW	23.1

MOTOR DETAIL Teco MONARCH : 30 kW; 4 pole; Frame : D200L.
(SIZED FOR D.O.L. OR AUTO TRANSFORMER START) ELECTRICAL SUPPLY : 415-3-50Hz

CONSTRUCTION MATERIALS	316(L) St St Casing. 316(L) St St Impeller.
EXTERNAL FINISH	Passivate Weld Areas
INTERNAL FINISH	Passivate Weld Areas

DELIVERY : EX WORKS

EQUIPMENT INCLUDED :

Electric Motor	Guards
Inspection Door (316(L) St St)	Drain socket and plug (316(L) St St)
Slide Rails (Pair): Teco Monarch M2022	Inlet Box
Vee Drive: Motor Kw = 30 Ratio = 1.08	Shaft seal.

Bearings : Ø60 SNL513 + 22213EKC3 + H313 + Double Lip Seal

APPENDIX 6 – CHEMICALS MANAGEMENT

Chemicals inventory stored onsite are is anticipated as follows:

No.	Item	Inventory	Storage
1	Polyelectrolyte	1,000L	Standard 1000L IBC Container
2	Acetic acid	1,000L	Standard 1000L IBC Container
3	Sulfuric acid (30%)	1,000L	Standard 1000L IBC Container
4	Sodium hydroxide (30%)	1,000L	Standard 1000L IBC Container
5	RO anti-scalant (100%)	1,000L	Standard 1000L IBC Container
6	Sodium hypochlorite (14%)	1,000L	Standard 1000L IBC Container
7	Acid membrane cleaner (100%)	1,000L	Standard 1000L IBC Container
8	Caustic membrane cleaner (100%)	1,000L	Standard 1000L IBC Container
9	Antifoam (100% biodegradable non-silicone)	1,000L	Standard 1000L IBC Container

Chemicals will be stored onsite in a lockable chemical storage container. Liquids are typically stored in standard IBC containers or steel drums. The chemical storage unit (left) and IBC containers (right) will be similar to the examples displayed below.

BIOGASS RENEWABLES PTY LTD

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

DECEMBER 2018

OUR REFERENCE: 23621-3-18204

Rochdale Holdings Pty Ltd A.B.N. 85 009 049 067 trading as:
HERRING STORER ACOUSTICS
P.O. Box 219, Como, W.A. 6952
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DOCUMENT CONTROL PAGE

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

Job No: 18204

Document Reference : 23621-3-18204

FOR

BIOGASS RENEWABLES PTY LTD

DOCUMENT INFORMATION			
Author:	**Paul Drew**	**Checked By:**	
Date of Issue :	**9th November 2018**		

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Revision	**Description**	**Date**	**Author**	**Checked**
1	**Report**	**17/10/2018**	**PD**	**GH**
2	**Addition of BioFilter Fan details**	**19/12/2018**	**PD**	

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APPENDICIES

A Sound Power Levels

B Noise Contour Plots

1. INTRODUCTION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed Anaerobic Digestion (AD) facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The acoustic modelling and assessment is based on design data and plan layouts provided in October 2018 and previous measurement of the major noise sources at a similar facility in Jandakot, Western Australia.

An aerial image of the area surrounding Lot A505, 1-2 Gidgie Courtis shown in Figure 1.

Figure 1 - Site Location and Key receptors – Lot A505, 1-2 Gidgie Court, Edinburgh

The nearest residential area is 470m to the south-west, with another residential area located 1,400m to the east. The proposed site is within an Urban Employment zone, with General Industry surrounding the site. To the south-east are established sporting facilities including a golf course and shooting range.

Trucks of size ranging up to 25 tonne B-doubles will bring material to site, reversing into the facility Reception Hall via fast acting roller doors, which will be closed when not providing access to trucks (for odour control reasons). Trucks will be unloaded within the Reception Hall. Acoustically solid fences surround the digestion area and the truck access areas.

The major external noise sources are three generators, which are fitted with acoustic attenuation packages, two gas flares (generally on standby) and a number of gas and liquid pumps at the base of digestion tanks. Both flares would normally only operate if a number of generators were shut down. Trucks will generate noise within the site when entering and reversing, however truck movements will be at low speed and tipping will occur within the Receivals Hall, thereby limiting truck noise emission duration and level from the site.

A 3D diagram of the proposed facility layout is shown in Figure 2.

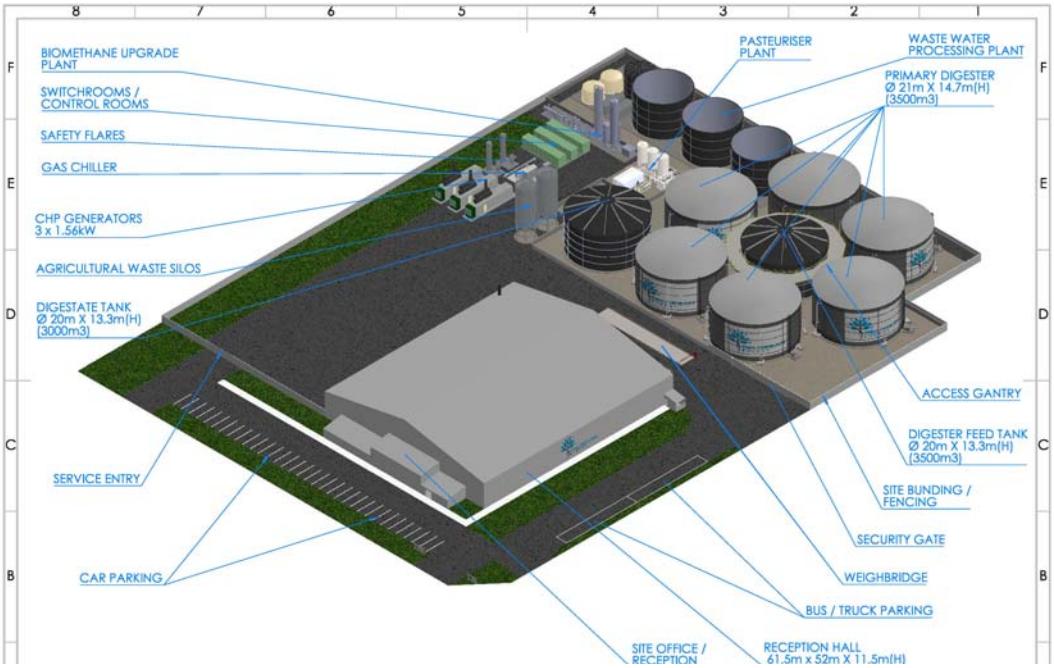


Figure 2 – AD Facility Layout

This assessment has been based on the following:

- The proposed site layout and equipment as shown in document "Lot 505 Assembly V5.pdf" issued 22nd May 2018.

- Previous noise measurements for the Richgro Jandakot AD Facility

2. ASSESSMENT CRITERIA

The proposed site is located within an Urban Employment Zone of the Salisbury Council Development Plan. The premises surrounding the proposed site at Lot A505, 1-2 Gidgie Court are used for automotive manufacturing (General Industry) or equipment hire (premises to the east of Gidgie Court). The premises on the western boundary (71 – 75 Woomera Avenue) is occupied by the North Adelaide Waste Management Authority, consisting of offices at the front (day hours) and recycling building currently operating 6am – midnight.

Residential areas are located to the south-west, 470m from the proposed site.

The Development Plan's interface between land uses principle of development control 7 states:

> *Development that emits noise (other than music noise) should include noise attenuation measures that achieve the relevant Environment Protection (Noise) Policy criteria when assessed at the nearest existing noise sensitive premises.*

Development Plan makes specific reference to the *Environment Protection (Noise) Policy 2007*.

The policy provides noise levels (L_{Aeq}) not to be exceeded at noise sensitive receivers, based on the principally promoted land use where the noise source and the noise receivers are located. The relevant criteria are:

Residential Zone

- 52 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 45 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#
- 60 dB(A) L_{Amax} between the hours of 10pm and 7am when measured;

At the nearest noise-affected premises in the City of Salisbury Residential zone in accordance with the *Environmental Protection (Noise) Policy 2007*.

Urban Employment Zone

- 59 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 50 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#

When measured and adjusted# at noise-affected premises in the City of Salisbury Urban Employment zone in accordance with the Environmental Protection (Noise) Policy.

The measured noise levels should be adjusted in accordance with the *Environmental Protection (Noise) Policy 2007* by the inclusion of a penalty for each characteristic where tonal/modulating/impulsive/low frequency characteristics are present.

The dominant noise sources at distance are the generators, which have significant acoustic attenuation packages and based on measurement at Richgro Jandakot will not have dominant noise characteristics at the residential area. Therefore no adjustment for noise characteristic applies for the proposed noise emissions to the residential area.

However some noise characteristics may be audible at the adjacent premises and appropriate adjustment are required.

3. METHODOLOGY

Noise levels were predicted using the acoustic software SoundPlan using the Concawe algorithm for Pasquill Class 6 climatic conditions. The sound power levels used in the acoustic modelling are tabulated in the Appendix A. Sound power levels were determined from measurement of a similar AD Plant at Jandakot, Western Australia.

The proposed AD facility is to operate continuously.

The AD facility operations consist of continuous operation of bio-filtration, digesters and associated pumps and fans, pasteuriser, biomethane upgrade plant, generators and safety flares (normally on standby). Intermittent noise will be generated on site by entry / exit of trucks and operation of high-speed roller doors.

Information relating to vehicle movements:

- A maximum (worst case scenario, otherwise could be as low as 35) of 50 trucks are likely to be entering site, comprised of:
    - Rigid trucks – 34 per day
    - Semitrailer trucks – 12 per day
    - B-double trucks – 4 per day
- All vehicles except for the B-double trailers will be loading/unloading within the receival shed.
    - B-doubles will take approximately 1 – 2 hours to fully unload

4. PREDICTED NOISE EMISSIONS

Predicted noise contour plots for 'worst case' winds for the proposed operations are shown in Appendix B.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are provided. The required heights are 3m adjacent the generators and adjacent the truck access area, as shown in plot 20W, Appendix B.

The generators and flares are capable of emitting noise exceeding the noise criteria at the adjacent premises. Noise mitigation by selection of attenuated generator package units rated at 65 dB(A) at 1m and provision of acoustic barrier walls around the generators and flare units is shown to attenuate noise emissions within acceptable levels.

TABLE 4.1 PREDICTED NOISE LEVELS

Receptor	Night 3 Generators		Night Two Flare Units		Day 3 Generators Trucks		Compliance
	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	
Residences							
Criteria	**45**	**45**	**45**	**45**	**52**	**52**	
R1: 20 Diruwa Drive, Salisbury North	26	26	21	21	36	36	Yes
R2: 60 Hogarth Rd, Elizabeth South	10	10	9	9	11	11	Yes
Adjacent Premises							
Criteria	**50**	**50**	**50**	**50**	**59**	**59**	
I1: 59-61 Woomera Ave (Coates Hire)	39	44^{t}	38	43^{t}	41	49^{ti}	Yes
I2: 4 Gidgie Crt	38	43^{t}	36	41^{t}	38	46^{ti}	Yes
I3: 3 Gidgie Crt	44	49^{t}	43	48^{t}	44	52^{ti}	Yes
I4: 71-75 Woomera Ave (NAWMA)	45	50^{t}	41	46^{t}	51	59^{ti}	Yes
I5: 76 Woomera Ave	41	46^{t}	38	43^{t}	51	59^{ti}	Yes
I6: 78 Woomera Ave	39	44^{t}	34	39^{t}	51	59^{ti}	Yes

The noise emissions for Night scenario two flares is dominated by pump noise, flare noise levels are relatively low compared to the overall predicted level. Characteristic adjustment for tonal noise only of 5 dB(A).

The noise emission for day scenario is conservative as trucks have been modelled at the passby emission level to consider busy periods where noise may be present for much of the 15 minute assessment period. Generally the L_{Aeq} noise level will be lower as trucks are only in the yard for short periods while entering or leaving the receival facility. Adjustments for tonal characteristic and impulsive characteristic have been applied, an adjustment of +8 dB(A) to the predicted noise level at the receptor premises.

5. NOISE MITIGATION MEASURES

The following noise mitigation measures are required to comply with the requirements of the Regulations:

- Fan selection and attenuation of the Bio-filter blower outlets to achieve a combined sound power of no more than 85 dB(A) external. This assessment is based on three fans, being "Fans Direct: SWS1-D51B Size 365-100% CS90 Fans, 23 kW with fan speed of 1370 rpm". Each fan discharge outlet to be fitted with 2D cylindrical podded silencer, minimum 1m gap (duct), 1D unpodded silencer.

- Section of 3m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the generators as shown in plot 20W, Appendix B.

- Section of 3.0m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the truck access area as shown in plot 20W, Appendix B.

- Generators to be fitted with acoustic attenuation package equivalent to those provided to generators at Richgro Jandakot site, rated at 65 dB(A) at 1m.

- Acoustic barrier walls to be installed around the generators and flare units as shown in plot 20W, Appendix B. The walls may be constructed metal framing with roof sheeting or coolroom panel with a mass density of at least 10 Kg/m^2 for the combination. The wall on the western side of the generators and flare units should have a minimum mass density of 17 Kg/m^2 for the lower 5 meters, and if a lightweight construction, be a cavity wall type construction with minimum of 100mm between each side with 100mm acoustic insulation infil to assist in the control of lower frequency noise emissions. (90mm sandwich panel one side, 100mm channel with roof sheeting on the other side with 100mm fiberglass insulation infil for example). Concrete tilt-up panel would also be suitable.

6. CONCLUSION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed AD facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are installed adjacent the generators and truck access area to ensure compliance at the adjacent premises to the west. The required heights of acoustic barriers are shown in plot 20W, Appendix B.

APPENDIX A

Sound Power Levels

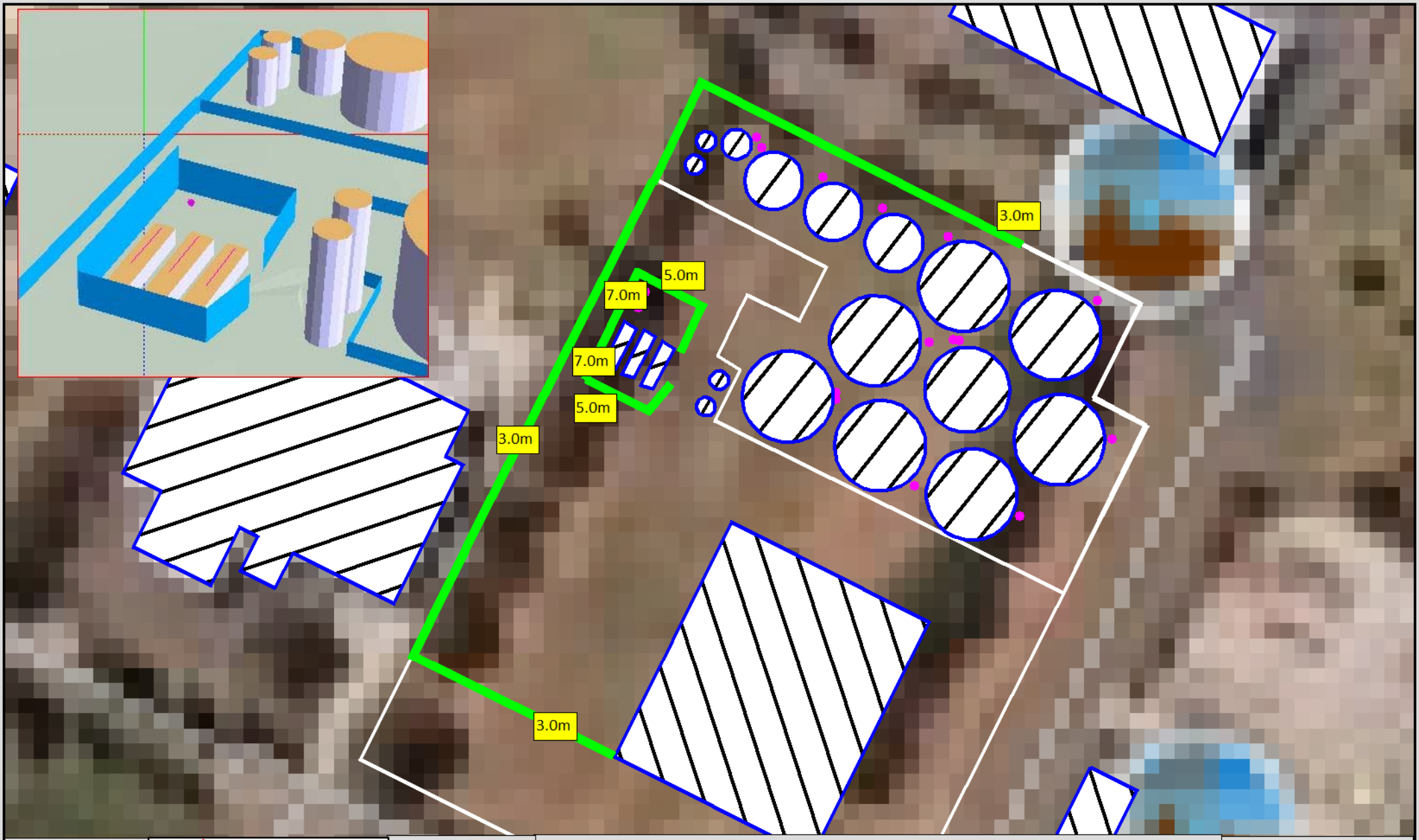
Acoustic Model Sound Power Levels

Sound Power in dB

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Generator 1	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 2	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 3	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Biofilter Blower	89.1	81	86	84	89	85	83	86	87	88	86	80	78	82	77	74	77	72	71	70	68	75	84	71	69	68	65
AD Flare 1 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
AD Flare 2 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
Digester Feed Tank - Pump 1	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digester Feed Tank - Pump 2	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digestate Feed Tank - Pump 1	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digestate Feed Tank - Pump 2	90.6	76	75	71	81	87	74	71	75	74	74	76	83	89	77	83	81	80	78	77	75	74	70	67	66	64	60
Digester - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 5	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Pump 6	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
25 Ton Truck	100.1	92	95	109	100	94	110	98	98	98	95	91	91	91	92	90	89	88	88	87	87	84	79	77	74	72	73
12 Ton Truck Moving	94.3	94	105	101	102	96	108	90	92	88	84	83	85	87	85	82	83	85	78	77	78	74	74	71	69	67	68

APPENDIX B

Noise Contour Plots



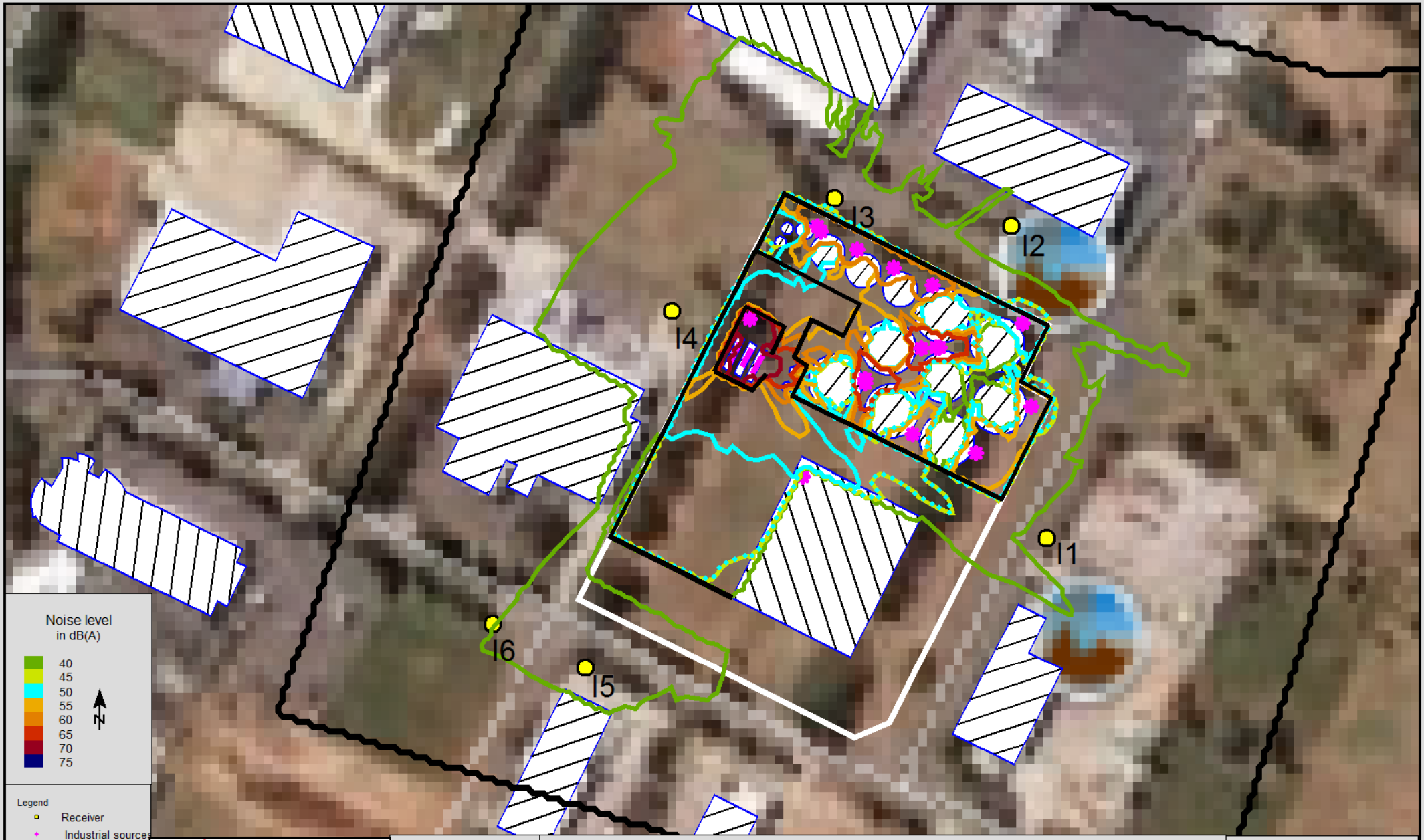
Legend
- Main building
- Wall
- Industrial sources
- Line source

HERRING STORER ACOUSTICS

Ref: 18204 Run: 20W
Date: 9/11/2018

BIOGAS RENEWABLES - SAILSBURY
3m BARRIER WALL ON BOUNDARY AND
7.0m WALL ON WEST SIDE OF GENERATORS AND FLARE
UNITS, 5.0m TO OTHER GENERATOR AND FLARE UNIT ENCLOSURE WALLS

Scale 1:1200
0 5 10 20 30



HERRING STORER ACOUSTICS

Ref: 18204 Run: 20L
Date: 8/11/2018

BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE - 45 dB(A)

Scale 1:2000
0 10 20 40 60

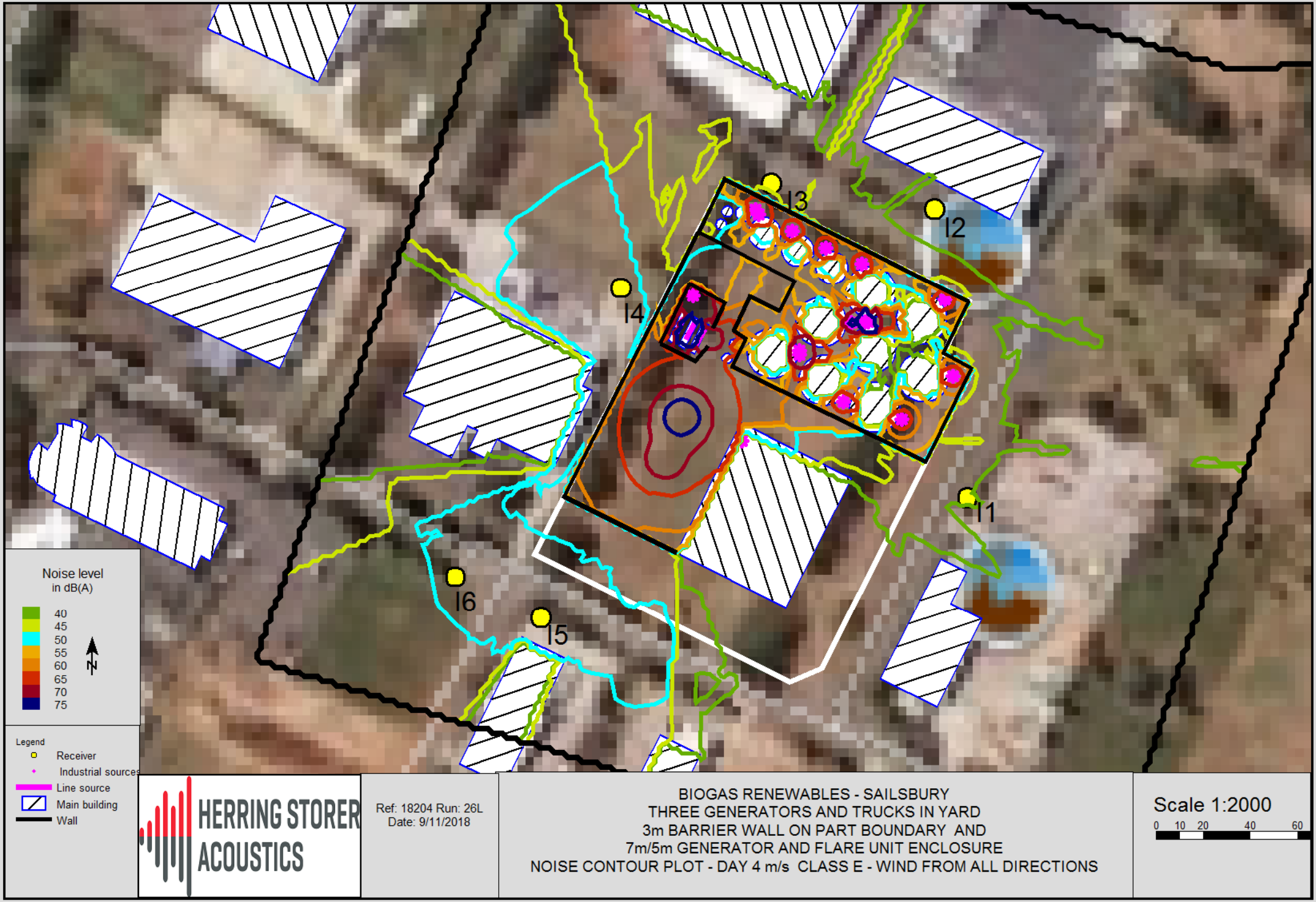

Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 20
Date: 8/11/2018
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400
R1
R2
I1
I2
I3
I4
I5
I6
Edinburgh
Sturton Rd
Wyatt Rd
Tappa Rd
Kadina Ave
Camira Way
Leila Ave
Maronga St
Kulma Dr
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
Diment Rd
Harold Rd
Horwood Rd
McCormack Crescent
Perry St
Arura Rd
Pibugi St
Illara St
Barrin St
Bolivar Rd
Oronga St
Paratta St
Tugger Way
Woomera Ave
Kettering Rd
Bayer Rd
Grainger Rd
Goodman Rd
Willison Rd
Philip Hwy

HERRING STORER ACOUSTICS

Ref: 18204 Run: 23L
Date: 8/11/2018

BIOGAS RENEWABLES - SAILSBURY - NO GENERATORS, FLARING
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m ENCLOSURE TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE 45 dB(A)

Scale 1:2000
0 10 20 40 60


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 26L
Date: 9/11/2018
BIOGAS RENEWABLES - SAILSBURY
THREE GENERATORS AND TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:2000
0 10 20 40 60


Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
N
Legend
Receiver
Industrial source
Line source
Main building
Wall
R1
R2
I1
I2
I3
I4
I5
I6
Edinburgh
Sturton Rd
Wyatt Rd
Tappa Rd
Paratta St
Bolivar Rd
Oronga St
Sarrin St
Camira Way
Leila Ave
Illara St
Perry St
Arura Rd
Horwood Rd
McCormack Crescent
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
Diment Rd
Harold Rd
Woomera Ave
Tugye Way
Kettering Rd
Bayer Rd
Grainger Rd
Goodman Rd
Willison Rd
Philip Hwy
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 28L
Date: 9/11/2018
BIOGAS RENEWABLES - SAILSBURY
3 GENERATORS OPERATING WITH TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400

Intended for
Emissions Assessments Pty Ltd

Date
December 2018

BIOGASS RENEWABLES
SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

RAMBOLL

BIOGASS RENEWABLES
SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

Revision	**Final**
Date	**19/12/2018**
Made by	**Martin Parsons**
Checked by	**Ruth Peiffer**
Approved by	**Nick Houldsworth**

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1. INTRODUCTION

1.1 Background

Biogass Renewables Pty Ltd (Biogass) are proposing to develop an Anaerobic Digestion Plant (the Plant) at the parks precinct in Edinburgh, South Australia. The premises are located at Lot 104 - 116 Purling Ave, Edinburgh, South Australia. The location of the proposed facility is shown in Figure 1, with nearest sensitive receptors being located approximately 450 m south-west and 300 m south of the site.

Emissions Assessments Pty Ltd (Emissions Assessments) requested Ramboll Australia Pty Ltd (Ramboll) undertake an air dispersion modelling assessment to determine the likely air quality impacts associated with routine operations and a flaring scenario for the Plant. This report presents the approach, methodology and results of air dispersion modelling for the Plant operating under each of the modelled scenarios. The maximum predicted ground level concentrations (GLCs) of the modelled compounds have been compared against the relevant ambient air quality criteria.

1.2 Overview of Process

The Plant will use organic waste to produce biogas (methane) through an anaerobic digestion process. The anaerobic digestion process is a fully enclosed system.

The organic waste (100,000 tonnes per annum [tpa] of food waste, 25,000 tpa of grain dust) is received, stored and pre-processed in a purpose built, sealed and fully enclosed negative pressure structure, before being pumped in a continuous process to a digester feed tank then onto one of six digester tanks, where it is stirred and agitated at intervals to encourage the release of biogas. An automated system regulates the necessary parameters such as pH and temperature. The digester breaks down the material to produce biogas, comprising approximately methane, carbon dioxide, water and hydrogen sulphide.

The biogas is collected under a fire resistant, double membrane dome on top of each digester. A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, known as biomethane.

The biomethane will then be fed to a power plant, which drives a generator to produce electricity for onsite use by Biogass. The digestion tanks harvest the steam and hot water from the power plant, which is used to stabilise the temperature of the biomass in the digestion and storage tanks.

Figure 1: General Location of the proposed Biogass Facility

1.3 Details of Process

An overview of the layout of the Plant is shown in Figure 2 with detailed description of the operation provided in the following sections.

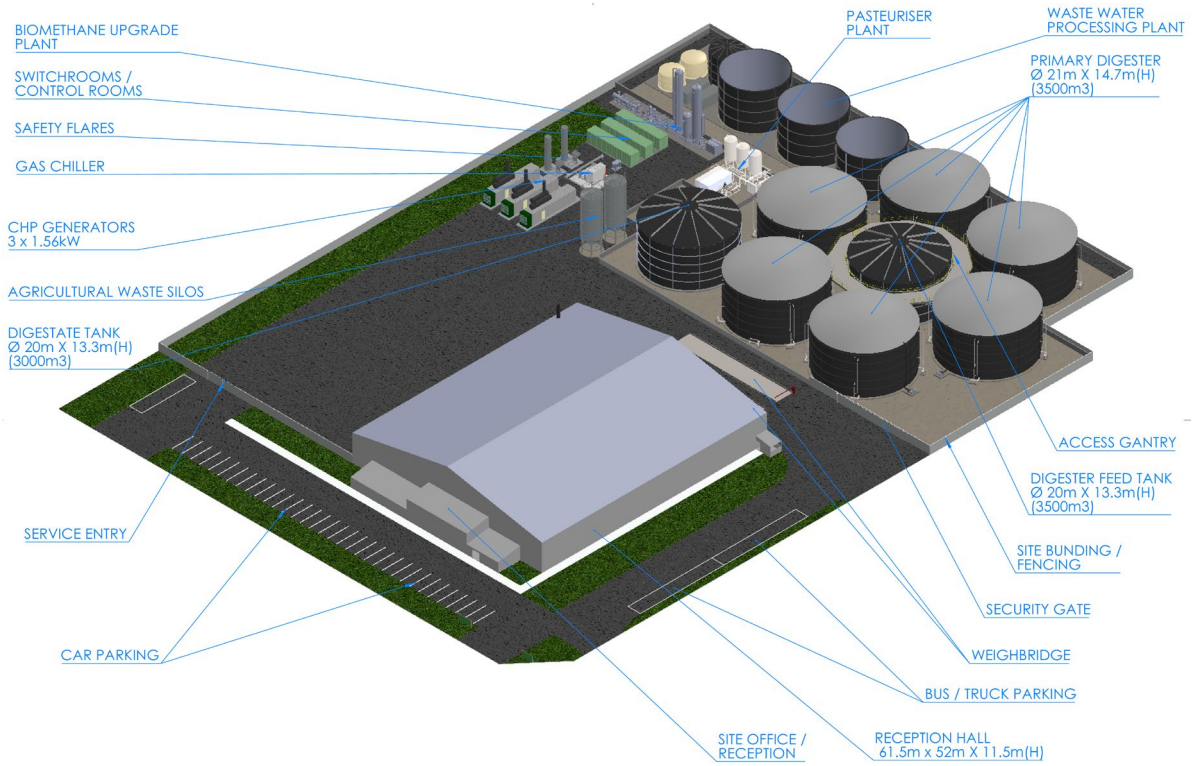

Figure 2: Layout of Plant

Source: Emissions Assessments

1.3.1 Receivals Hall

The waste is received in the receivals hall which is a 60 m x 52 m x 11.5 m high hooped roof building. The receivals hall is fitted with concrete bunkers, graded floor and drainage sump. The receivals hall will be under negative pressure and connected to the fully enclosed, single stack biofilter.

All vehicle entry points to process buildings will be via fast acting roller shutter doors which open and close on a pressure switch. All doors associated with process buildings will be connected to an alarm system which alerts operators in the event of doors being left open. Doors will only be opened for entry and exit of trucks with doors sealed before unloading occurs.

The solid and semi-solid waste will be deposited into graded bunkers with liquid waste pumped directly into a sump, for subsequent pumping to a liquid storage tank. Trucks are washed before departure with all wastewater draining to the sump for processing in the digestion system.

1.3.2 Staging Process (no emissions)

Blended and balanced feedstock is pumped in sealed pipes to a fully enclosed digester feed tank where it is mixed and warmed using heat from the Plant's biogas generators.

1.3.3 Anaerobic Digestion (no emissions)

Feedstock is pumped daily in sealed pipes from the digester feed tank to the primary digester tanks. These tanks are interoperable or can be isolated. The digesters are warmed using heat from the Plant's biogas generators. Biogas accumulates in the gas domes and can be positively displaced by pumping air between the gas dome's membranes.

1.3.4 Digestate Storage and Reuse (no emissions)

On a daily basis, digestate is pumped in sealed pipes to a digestate storage tank. The digestate will be pumped directly into a tanker truck for transport offsite.

1.3.5 Biogas Processing and Safety Flare

Biogas in the domes is positively displaced and drawn off in sealed gas pipes. The gas will then pass through a biomethane upgrade plant which will be used to upgrade the biogas to a methane-rich product gas, known as biomethane.

The entire gas management system is connected to an enclosed gas flare system comprising two flares. Gas can be directed to a flare at all gas storage and processing stages so as to bypass any equipment processing failure that may occur. The flare will only be operated on an emergency basis, or when one of the generators is not operating for routine maintenance (estimated 12 days per year), or in the unlikely event that all generators fail (worst case estimated 7 days).

1.3.6 Power and Heat Generation and Application

Clean methane gas, scrubbed and separated (carbon dioxide fraction removed) is compressed as fuel for three generators. Energy generated will be used to power the anaerobic digestion plant. The balance will supply 100% of Biogass' onsite energy requirements. Heat from the generator will be captured via a heat exchanger to heat the digester feed tank and the primary digesters.

2. ATMOSPHERIC EMISSIONS

2.1 Emission Sources

The atmospheric emissions sources included in the air dispersion modelling assessment for the Plant operating under routine conditions include:

- One biofilter stack, with emissions of concern being odour;
- Three gas fired reciprocating engines, with the emissions of concern being biomethane combustion products; and
- Emissions from the biomethane upgrade plant, consisting of hydrogen sulphide and odour.

The receivals hall was also considered as a potential emission source. However, as the hall will be fitted with fast acting roller shutter doors and will be under negative pressure and connected to the fully enclosed, single stack biofilter, potential emissions are considered to be negligible. The main doors will only open for vehicle entry for waste delivery and digestate transport. With fast door opening and closing times of 6 seconds, it is likely that the doors will be open for around 30 seconds per truck entry. Emissions monitoring at similar sites has indicated emissions from door openings and leakage from buildings with rapid roller shutter doors and comparable management practices are negligible. The receivals hall has not been included in the modelling assessment on this basis.

The full flaring scenario included in this assessment has considered the following atmospheric emission sources:

- Two enclosed flares, used when one or all of the generators are unavailable with the emissions of concern being biomethane combustion products.

2.1.1 Biofilter Emissions

The biofilter will use spongelite as the filter media. Air from the receivals hall will be humidified using misting nozzles running on timer, with a fan running inside the air extraction pipe. All biofilter fans will run on standard electric motor, with a spare which can be connected immediately in event of a failure.

2.1.2 Power Generation

The plant will use three 526 kW capacity Jenbacher 3-type biogas generators (GE JGS312 GS-N.L D225) manufactured by General Electric. The GE Jenbacher engine uses a LEANOX control system with oxides of nitrogen emissions guaranteed < 500 mg/Nm³ (101.3 kPa, dry and 5% O_2).

Emissions associated with the generators include:

- Oxides of nitrogen (NO_x) consisting mostly of nitrogen oxide (NO) and a lesser concentration of nitrogen dioxide (NO_2). NO_x is formed primarily from the oxidation of fuel-bound nitrogen and nitrogen in the air;
- Sulphur oxides (SO_x) which are predominantly in the form of sulphur dioxide (SO_2), formed from the oxidation of sulphur in the fuel; and
- Carbon monoxide (CO) formed from the incomplete combustion of the fuel.

Particulate matter (PM) and non-methane volatile organic emissions from the generators are considered to be negligible as the fuel source is a gaseous fuel with minor higher chain paraffins and as such, have not been included in the modelling assessment.

2.1.3 Enclosed Flares

Each enclosed flare will reach a height of 8 m and diameter of 1.7 m. The biogas is fed in at the bottom and combusted with the combustion temperature and efficiency controlled by a thermocouple near the top of stack, which adjusts the air inflow at the base of the stack via dampers. If the exhaust temperature is too high, the dampers are opened further and more air is drawn in and if too low, the dampers are restricted to restrict the air flow to maintain optimum combustion. Destruction removal efficiencies of 99% and 99.95% for methane and hydrogen sulphide (H_2S) respectively are guaranteed by the manufacturer.

2.1.4 Biomethane Upgrade Plant

A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, known as biomethane. Emissions of concern from the biomethane upgrade plant will include H_2S and odour.

2.2 Emissions Estimations

Emission estimates for the biofilter, power generation and flares were derived from stack monitoring data from another biogas production facility with a similar configuration located in Jandakot, Western Australia (as provided by Emissions Assessments). The emissions estimates applied in this assessment have been derived from measured concentrations when the reference plant was operating at 100% load and are considered conservative. The H_2S emissions from the CHP power generators and the flare were below detection limit during monitoring and have been assumed to be negligible.

Emission estimates for the biomethane upgrade plant were derived from manufacturer's specifications. The manufacturer guarantees an emission limit below 0.1 ppm for H_2S.

The exhaust parameters and emission estimates for each of the modelled sources are provided in Table 1.

Table 1: Emission Parameters for the Plant

Parameter	Units	Routine Operations			Flaring
		Bio Filter	CHP Power Generation x 3	Biomethane Upgrade	Flares x 2
Exhaust Parameters					
Operation		Continuous	Continuous	Continuous	< 12 days per year
Number		1	3	1	2
Coordinates	**UTM**	283634, 6153412	283603, 6153437 283607, 6153435 283611, 6153433	283640, 6153473	283611, 6153455 283615, 6153453
Height	**m**	14.5	8.6	14.5	8.0
Diameter	**m**	0.88	0.32	0.25	1.73
Temp	**Deg C**	22	410	15	1000
	K	295	683	288	1273
Measured Oxygen	**%**	NA	8.3	NA	10.9
Stack Moisture	**%**	1.5	4.4	NA	1.5

Parameter	Units	Routine Operations			Flaring
		Bio Filter	CHP Power Generation x 3	Biomethane Upgrade	Flares x 2
Volumetric Flow	**Nm^3/s Dry**	19.1	1.16	0.73	10.2
	Am^3/s	20.3	2.8	0.77	47.0
Exit Velocity	**m/s**	33.3	34.6	15.7	20.0
Emission Estimates					
OU	**$o/u.m^3/s$**	1670	NA	105	NA
H_2S	**$mg/m^{3[1]}$**	NA	BDL	0.15	BDL
	g/s	NA	NA	0.00011	NA
NO_x	**$mg/m^{3[1]}$**	NA	400	NA	51
	g/s	NA	0.46	NA	0.52
SO_2	**$mg/m^{3[1]}$**	NA	46	NA	8.8
	g/s	NA	0.05	NA	0.09
CO	**$mg/m^{3[1]}$**	NA	590	NA	16
	g/s	NA	0.69	NA	0.16

Notes

1. Referenced to STP (273.15K, 101.3kPa) and expressed as dry values.
2. BDL = Below Detection Limit

2.3 Non-Routine Emissions

Non-routine emissions from biogas plants (apart from the infrequent flaring) may potentially arise as a result of a malfunctioning of the flare, the air extraction system or the biofilter. For the Plant these will be addressed by the management practices outlined in the following sections.

2.3.1 Flaring

Flaring upset conditions may potentially occur if gas is vented via the flare without combustion occurring. The biogas plant flare system will mitigate this risk by configuring the ignition system to be battery powered with backup solar charging. The monitoring system also includes monitoring of the exhaust temperatures and exhaust gases, such that if combustion is not occurring an alarm will be activated to alert to the need for intervention.

2.3.2 Biofilter

Higher than normal emissions can occur through biofilters (or fugitive release from the receivals hall) due to failure of extraction motors, loss of power, loss of humidification of the inlet air and problems in the biofilter media, such as compaction of the bed, degradation in the efficiency and the need to perform maintenance such as replace the filter media. These will be managed as follows:

- The extraction system on all biofilters at the site will utilise standard motors, with one motor always kept onsite as a spare. The biofilter for this plant will use two fans. Loss of a motor will only reduce the extraction flow rate by 50% for a period anticipated for no more than 3 hours;
- The power supply for the pumps will be provided by onsite generators, and when not available, by mains power. Redundancy is therefore built into the power supply and a power failure event could only occur if the onset generators failed, and there happened to be a simultaneous mains power failure. The likelihood of these concurrent events is extremely low.

Owing to the redundant design it is therefore expected that odour escape owing to power failure has negligible probability of occurring;

- The humidification system will be designed to ensure humidity for all inlet conditions is maintained at 70%; and
- The biofilter media is anticipated to last for 8 years. This is much longer than organic biofilter media as it does not suffer issues such as compaction and degradation in media performance. The media is anticipated to be replaced on an as-required basis, but not less than every 8 years. Monitoring of the stack emissions will be conducted to assess the performance of the biofilter. If a deterioration in performance below minimum standards is attributed to degradation of the media, all waste receivals will be held over pending a replacement of the media, a process of up to two days.

Given the above design and proposed management of the plant, the probability of non-routine emissions from the Plant occurring is considered to be negligible and as such, have not been included in the modelling assessment.

3. AIR QUALITY CRITERIA

3.1 Human Health

For ambient GLCs, the SA Environment Protection Authority (EPA) outlines state-wide standards in its Environment Protection (Air Quality) Policy 2016. The policy seeks to apply the standards at residential areas or places where people may congregate, such as beaches or picnic areas. The standards relevant to this assessment are listed in Table 2.

Table 2: SA EPA Environment Protection (Air Quality) Policy 2016 - Applicable Air Quality Standards

Pollutant	Averaging Period	Maximum Concentration ($\mu g/m^3$)[1]
CO	1-hour	31,240
	8-hour	11,250
NO_2	1-hour	250
	1-year	60
H_2S	3-minutes	510
SO_2	1-hour	570
	1-day	230
	1-year	60

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.

3.2 Odour

The SA EPA has outlined state-wide standards for odour that are applicable to this study. The standards state that an activity cannot result in the number of odour units being exceeded for the number of persons (as specified in Table 3) over a 3 minute averaging time 99.9% of the time (based on evaluations at ground level using a prescribed testing, assessment, monitoring or modelling methodology for the pollutant and activity).

Table 3: SA EPA Environment Protection (Air Quality) Policy 2016 – Applicable Odour Standards

Number of people	Odour Units (OU) (3-minute average, 99.9% of time)
2000 or more	2
350 - 1999 (inclusive)	4
60 - 349 (inclusive)	6
12 - 59 (inclusive)	8
Single residence (fewer than 12)	10

The SA EPA also stipulates a maximum 3-minute averaged odour based standard concentration for hydrogen sulphide of 0.15 $\mu g/m^3$.

4. EXISTING AIR QUALITY

In order to determine a background concentration to assess potential cumulative impacts for the purposes of this study, monitoring data from two SA EPA monitoring stations; Elizabeth (NO_2 and CO) and Northfield (SO_2). These locations were chosen as they are the nearest ambient air quality monitoring stations to the proposed site and the monitored values are considered to be generally representative of background concentrations.

Monitoring data collected at each site between 1 January 2015 to 31 May 2018 was utilised for the purpose of this assessment. No specific guidance for selection of an appropriate background concentration is provided by the SA EPA. The Environment Protection Authority Victoria (Vic EPA) State Environment Protection Policy (Ambient Air Quality) (SEPP (AQM)) (Gov. of Vic., 2001) recommends the 75th percentile concentration (concentration which is exceeded by 25% of concentrations for that averaging period) should be adopted as a background level. Correspondence with SA EPA personnel indicated this approach would be suitable to determine ambient background concentrations for use in this assessment.

A summary of the ambient concentrations measured at the Elizabeth and Northfield SA EPA monitoring stations is presented in Table 4.

Table 4 indicates that of the applicable pollutants, background concentrations are relatively low in the region.

Table 4: 75th Percentile and Annual Average Ambient Concentrations for CO, NO_2 and SO_2

Pollutant	Averaging Period	75th Percentile Concentration (µg/m^3)[1]	Annual Average (µg/m^3)[1]
CO[2]	1-hour	25	NA
	8-hour	25	
NO_2[2]	1-hour	10	
	24-hour	NA	8
SO_2[3]	1-hour	0	NA
	24-hour	0.14	
	Annual	NA	0.2

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. As measured at the Elizabeth SA EPA monitoring station.
3. As measured at the Northfield SA EPA monitoring station.

It is noted the annual average SO_2 concentration measured at the Northfield monitoring station is 0.2 µg/m^3, while the 75th percentile 1-hour average is zero; this is reflective of a large proportion of the hourly monitoring data being equal to zero.

5. MODELLING METHODOLOGY

5.1 Model Selection

The SA EPA has stipulated that unless prior agreement has been obtained, all air dispersion modelling should be completed using the CALPUFF air dispersion model using a meteorological dataset from 2009.

5.2 CALPUFF Model Set Up

The following model set up options within CALPUFF were used:

- Building downwash was included using the BPIP-Prime algorithms with site layout and elevation. The tanks, silos and receivals hall were included in the modelling;
- Grid spacings of 100 m over a 7 km x 7 km model domain were applied, centred approximately on the site;
- The TAPM prognostic meteorological model developed by CSIRO was used to generate a gridded meteorological dataset for the modelling domain. Monitored meteorological data from the Bureau of Meteorology (BoM) Elizabeth monitoring station were used with the TAPM output as inputs into the CALMET meteorological processor to develop a meteorological data file suitable for use in CALPUFF;
- No chemical transformation or deposition, except for the prediction of NO_2 (as discussed in Section 5.3);

A summary of the CALPUFF inputs applied in this assessment is provided in Appendix 1.

An annual wind rose generated by the CALMET meteorological processor for the proposed site location is presented in Figure 3, with the annual frequency of wind speeds presented in Table 5.

Table 5: Distribution of Wind Speeds for 2009 (CALMET-Generated Data)

Wind Speed	Calms	0.5–2.0 m/s	2.0-3.5 m/s	3.5-5.0 m/s	5.0-6.5 m/s	6.5-8.0 m/s	>8m/s
(%)	1.4	36.2	36	19.3	5.4	1.4	0.2

5.3 3 Minute Averaging Periods

A simple averaging-time scaling factor can be used to estimate short-term peak concentrations for applications. This adjustment primarily addresses the effect of meandering (fluctuations in the wind about the mean flow for the hour) on the average lateral distribution of material. The scaling factor used to adjust the lateral dispersion coefficient[1] for averaging time is the 1/5th power law:

$$Cl = Cs(60/tl)^{0.2}$$

where
Cl = Concentration for new averaging period;
Cs = Concentration for the 1-hour average period;
tl is the averaging time (min.) of interest

[1] Turner, D.B., 1970: Workbook of Atmospheric Dispersion Estimates. U.S. EPA Office of Air Programs Publication No. AP-26. Research Triangle Park, NC.

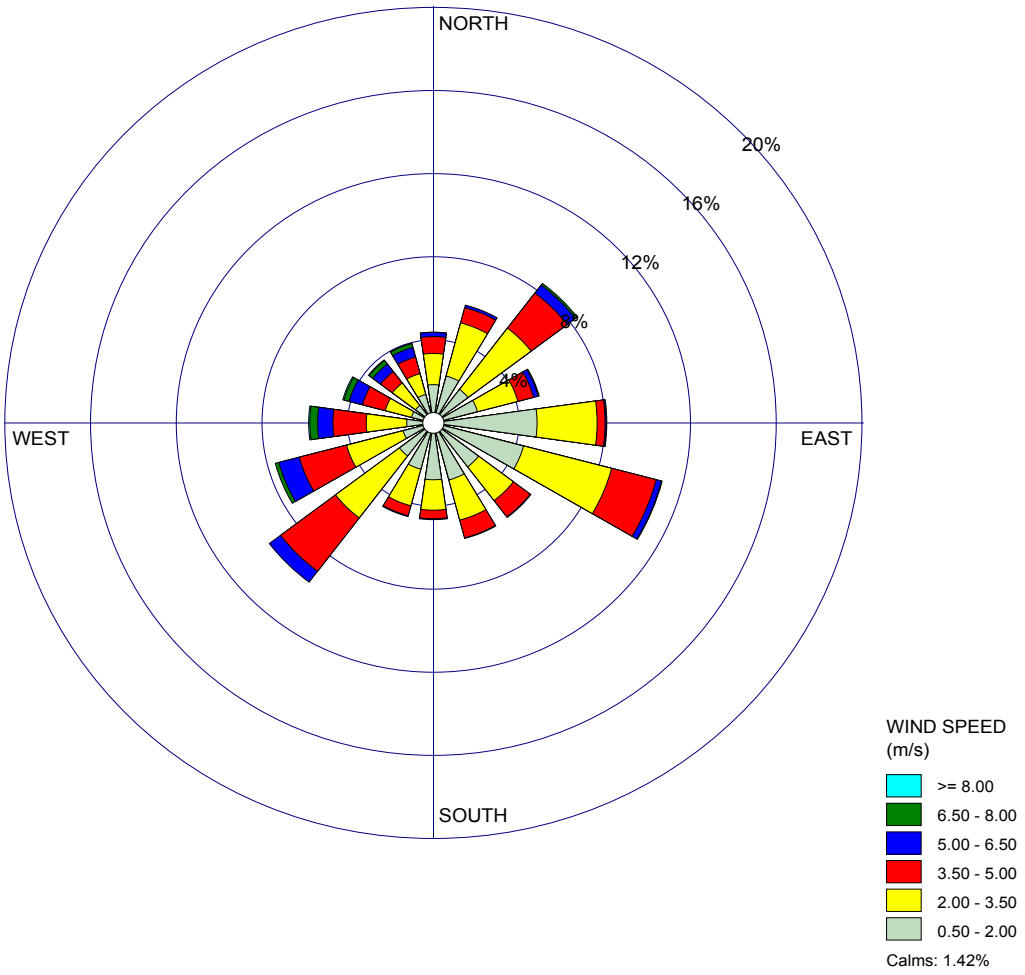

Figure 3: 2009 CALMET-Generated Annual Wind Rose

5.4 Treatment of Oxides of Nitrogen

A key element in assessing the potential environmental impacts from ground level NO_2 concentrations is estimating NO_2 concentrations from modelled NO_x emissions. The final NO_2 concentration is a combination of the NO emitted as NO_2 from the source stacks and the amount of NO that is converted to NO_2 by oxidation in the plume after release.

Generally, after the NO_x is emitted from the stack, additional NO_2 is formed as the plume mixes and reacts with the surrounding air. There are several reactions that both form and destroy NO_2, but the primary reaction is oxidation with ozone according to the following reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

This reaction is essentially instantaneous as the plume entrains the surrounding air. It is limited by the amount of ozone available and by how quickly the plume mixes with the surrounding air. Thus the ratio of NO_2 to NO_x increases as the plume disperses downwind.

In order to predict NO_2 concentrations, Ramboll has applied the US Environmental Protection Agency (USEPA) Ozone Limiting Method (OLM). This method assumes that ozone is the limiting reagent (i.e. the ozone concentration is less than the remaining NO_x concentration) and requires an NO_2 to NO_x in-stack ratio. In the absence of a site-specific in-stack ratio, it has been assumed

that 10% of NO_x emissions are NO_2 (a common assumption for gas combustion sources). Hourly average ozone concentrations for application in the OLM were obtained from the Elizabeth ambient air quality monitoring station.

The OLM approach is considered conservative over short-term averaging periods as it assumes the reaction between NO_x and ozone occurs instantaneously, when in reality this is likely to take place over a number of hours, during which time the plume is subject to dispersion.

6. MODELLING RESULTS

6.1 Ambient Air Quality Assessment

GLCs of the modelled compounds have been predicted for the following scenarios:

- Routine operations, with all three generators operating at maximum load and no flaring. This is considered conservative as the generators are typically sized to run at around 85% maximum load; and
- Full flaring scenario, with both flares operating at the maximum gas flow rate and no generator operation.

The results of the odour assessment for emissions from the biofilter and the biomethane upgrade stack are presented in Section 6.2.

The predicted GLCs for the Plant operating under routine conditions, both in isolation and cumulatively with background concentrations, are summarised in Table 6. The predicted GLCs remain well below their respective standards across the modelled domain, with the exception of the maximum 1-hour average NO_2 GLC which is predicted to equal 92% of the respective guideline for operations in isolation and 96% of the guideline when considered cumulatively, with ambient background concentrations. The maximum predicted 1-hour average GLCs of NO_2 for routine operations in isolation are presented in Figure 4a. This figure indicates that the highest predicted concentrations are expected to occur close to the site.

Further analysis of the maximum 1-hour average NO_2 predicted concentrations was undertaken at nine nominated receptor locations. Six of these represent the nearest commercial receptors surrounding the proposed Plant, as shown in Figure 4b. A seventh receptor was located at the nearest residential receptor and an eighth at the residential receptor that was predicted to have the largest impact. Another was located at the nearby golf course. Table 7 presents the predicted 1-hour average NO_2 concentrations at these receptor locations, the highest being 239 $\mu g/m^3$ (cumulative concentration).

The maximum 1-hour average NO_2 GLCs predicted at the nearby residences and the golf course were not predicted to be any greater than 101 $\mu g/m^3$ (cumulative concentration), well below the corresponding SA EPA 1-hour average NO_2 standard of 250 $\mu g/m^3$. It is noted that the predicted NO_2 GLCs are considered conservative given the use of the OLM method (refer to Section 5.3), particularly for short-term concentrations close to the source.

The predicted GLCs for the Plant operating under the full flaring scenario are also summarised in Table 6. The predicted GLCs are all expected to remain well below their respective standards across the modelled domain when considered both in isolation and cumulatively with background concentrations.

Contours of the predicted GLCs for all modelled compounds and averaging periods for both scenarios are presented in Appendix 2.

Table 6: Predicted Maximum GLCs for Routine Operations and Full Flaring

Compound	Averaging Period	Criteria	Back-ground Conc.	Routine Operations (3 Generators)				Full Flaring (2 Flares)			
				Maximum Concentration		Cumulative Maximum Concentration		Maximum Concentration		Cumulative Maximum Concentration	
		µg/m³	µg/m³	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria
CO	1-hour	31,240	25	2,722	9%	2,747	9%	150	0.5%	175	1%
	8-hour	11,250	25	1,535	14%	1,560	14%	68	1%	93	1%
NO_2	1-hour	250	10	229	92%	239	96%	98	39%	108	43%
	Annual	60	8	17	28%	25	41%	6	10%	14	24%
H_2S	3-minute[3]	510	NA	0.13	<0.1%	0.13	<0.1%	94	<0.1%	94	<0.1%
SO_2	1-hour	570	0	212	37%	212	37%	82	14%	82	14%
	24-hour	230	0.14	72	31%	72	31%	23	10%	23	10%
	Annual	60	0.2	10	17%	11	18%	2	3%	2	4%

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. Background concentrations are the 75th percentile 1-hour and 24-hour concentrations and annual average concentrations (as per Table 4).
3. Toxicity based criteria.

Table 7: Predicted Maximum NO_2 GLCs for Routine Operations at Nominated Receptor Locations

Receptor	Description	Background Concentration	Maximum Concentration in Isolation		Cumulative Maximum Concentration	
		($\mu g/m^3$)	($\mu g/m^3$)	% of Criteria	($\mu g/m^3$)	% of Criteria
R1	Commercial Property on Boundary	10	229	92%	239	96%
R2	Commercial Property on Boundary		100	40%	110	44%
R3	Commercial Property on Boundary		83	33%	93	37%
R4	Commercial Property on Boundary		133	53%	143	57%
R5	Commercial Property on Boundary		150	60%	160	64%
R6	Commercial Property on Boundary		102	41%	112	45%
R7	Nearest Residential Receptor		58	23%	68	27%
R8	Residential Receptor with Maximum Impact		91	36%	101	40%
R9	Closest Part of Golf Course		77	31%	87	35%

Figure 4a: Routine Operations - Maximum Predicted 1-hour Average NO_2 GLCs (µg/m^3) in Isolation

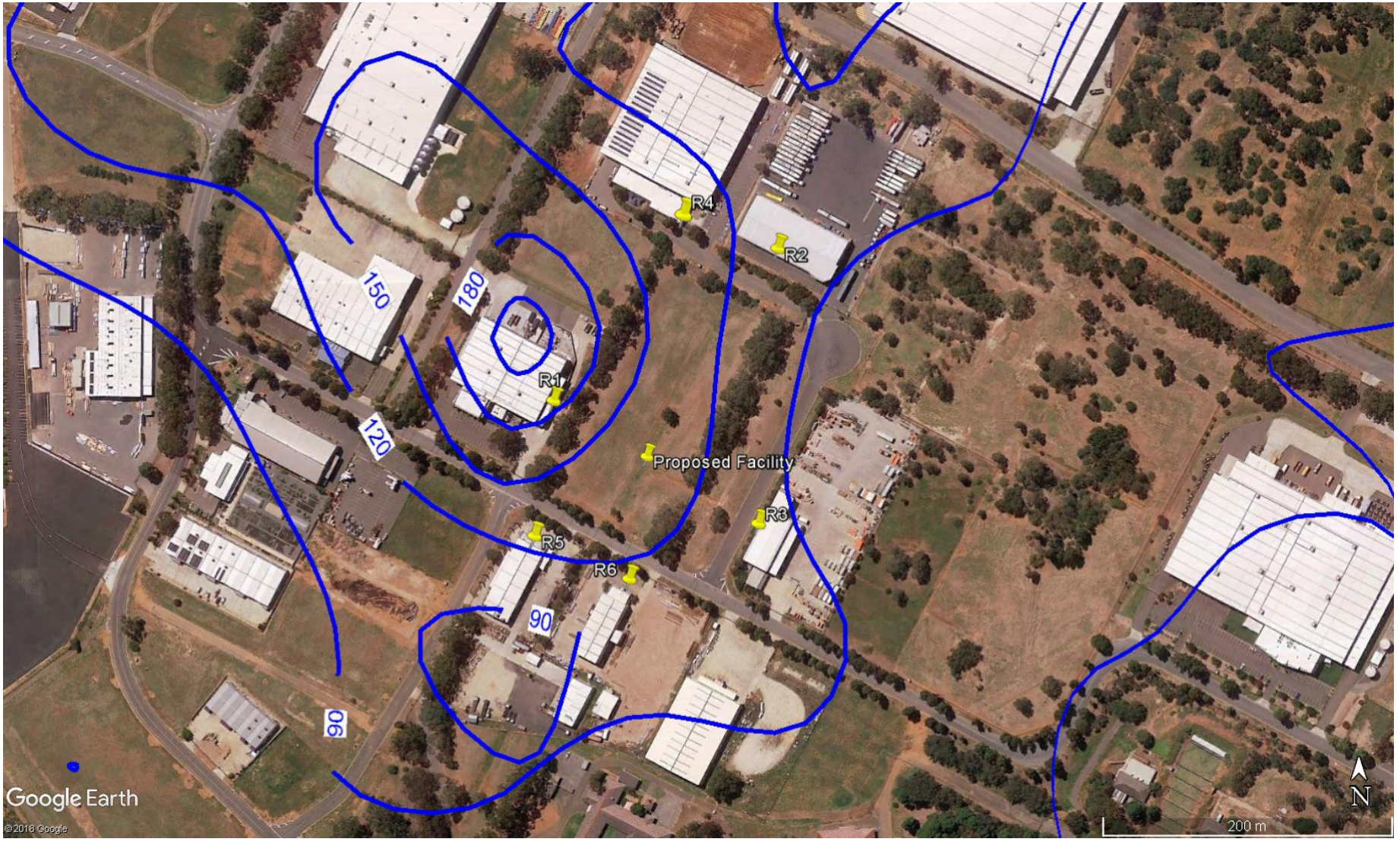

Figure 5b: Routine Operations - Maximum Predicted 1-hour Average NO_2 GLCs (µg/m^3) in Isolation (Zoomed)

6.2 Odour Assessment

The maximum predicted 99.9th percentile 3-minute average odour concentration for routine operations (considering emissions from the biofilter and the biomethane upgrade stack) is presented in Table 8. Contours of the predicted 99.9th percentile 3-minute average odour levels are presented in Figure 5.

The predicted odour levels remain below the SA EPA criteria of 2 OU throughout the modelled domain. Odour concentrations predicted to occur at the nearest residential and golf course receptor locations remain below 0.5 OU (Figure 5).

Table 8: Maximum Predicted Odour Concentrations for the Biogas Plant

Compound	Averaging Period	Criteria	Maximum Predicted 99.9th Percentile
		(OU)	(OU)
Odour	3-minute (99.9th Percentile%)	2	1.88

The maximum 3-minute average H_2S concentration for both routine and upset operations is presented in Table 9. The maximum predicted 3-minute average H_2S concentration of 0.13 µg/m^3 complies with the SA EPA odour based standard for H_2S of 0.15 µg/m^3
. A contour plot of H_2S concentrations predicted near the facility boundary is presented in Figure 6.

Table 9: Predicted Maximum 3-Minute GLCs of Hydrogen Sulphide for Routine and Upset Operations at Receptor Locations

Receptor	Description	Maximum Concentration in Isolation	
		(µg/m^3)	% of Criteria
R1	Commercial Property on Plant Boundary	0.08	53%
R2	Commercial Property on Plant Boundary	0.11	73%
R3	Commercial Property on Plant Boundary	0.12	80%
R4	Commercial Property on Plant Boundary	0.13	87%
R5	Commercial Property on Plant Boundary	0.09	60%
R6	Commercial Property on Plant Boundary	0.1	67%
R7	Nearest Residential Receptor	0.03	20%
R8	Residential Receptor with Maximum Impact	0.07	47%
R9	Closest Part of Golf Course	0.08	53%

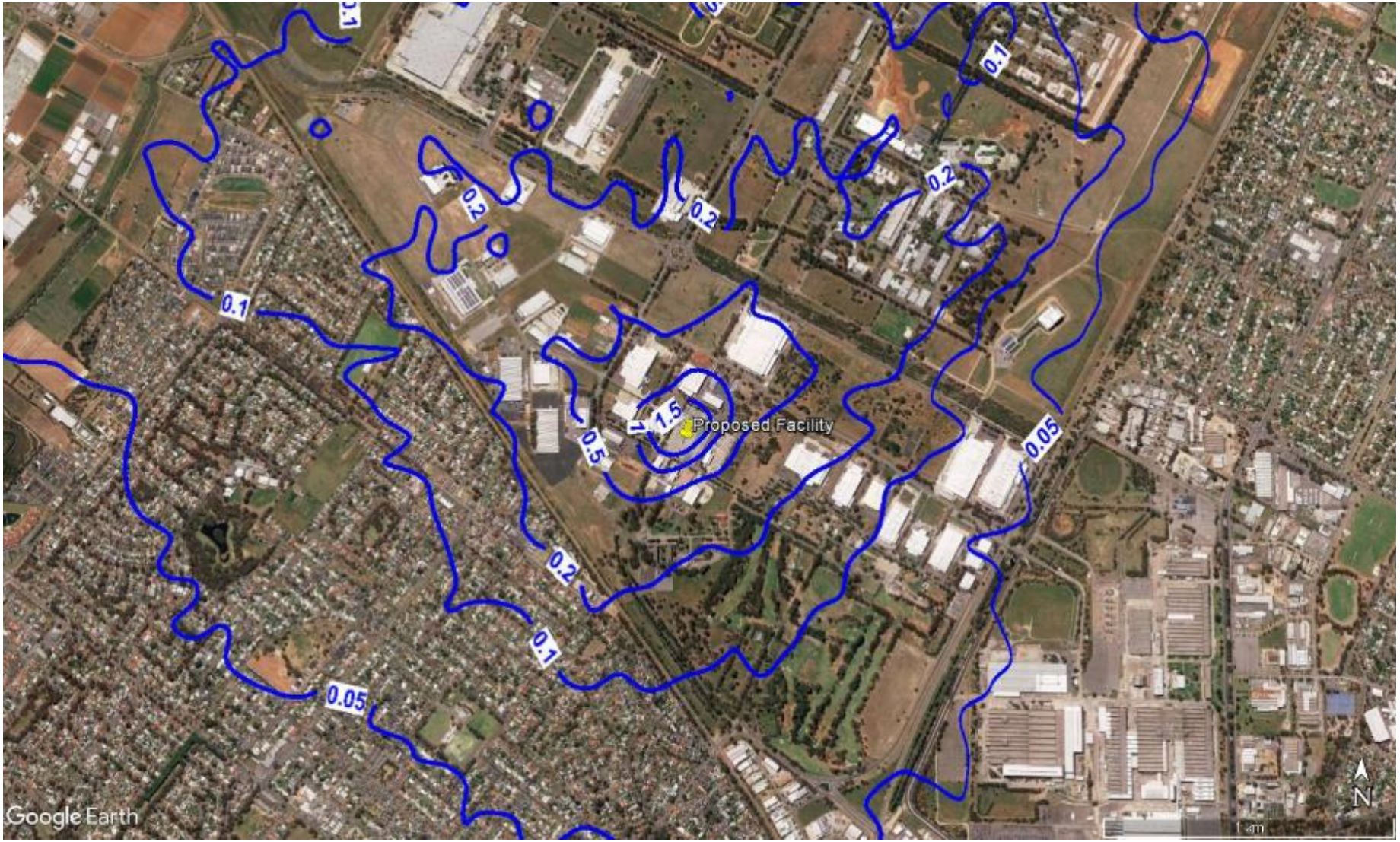

Figure 6: Routine Operations - Predicted 3-minute Average 99.9th Percentile Odour Concentrations (OU)

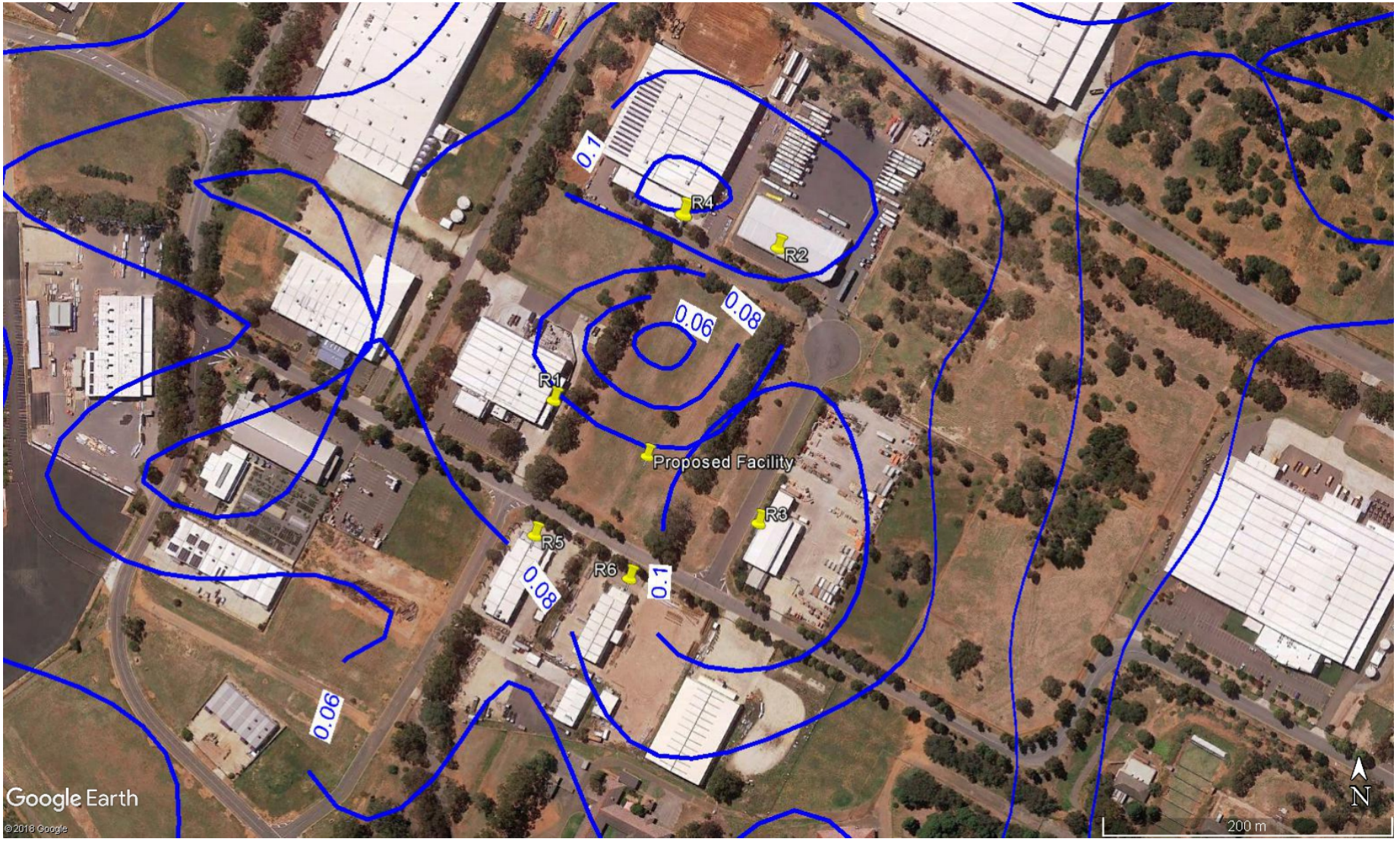

Figure 7: Routine and Upset Operations - 3-minute Average Maximum Predicted Concentrations in Isolation of H_2S

7. CONCLUSIONS

Air dispersion modelling has been completed to assess the potential air quality impacts associated with emissions from the proposed Plant operating under routine and full flaring operating scenarios.

Predicted GLCs have been estimated using the CALPUFF model and meteorological data generated by TAPM, in combination with meteorological monitoring data recorded at the nearest BoM monitoring station located at Elizabeth.

Where ambient monitoring data was available for compounds of interest, this has been used to determine the cumulative impacts of the proposed Plant.

The key findings of the air dispersion modelling are as follows:

- Predicted GLCs for all modelled compounds remain below the corresponding SA EPA standards across the modelled domain for both routine and full flaring operations, considered in isolation and cumulatively;
- The GLCs predicted at sensitive receptor locations remain below the relevant SA EPA standards for all pollutants and modelled scenarios;
- The maximum predicted 1-hour NO_2 GLC most closely approaches the relevant guideline, representing 92% of the 1-hour average NO_2 standard of 250 µg/m^3 when considered in isolation. This GLC is considered to be conservative given the assumptions applied to estimate NO_2 GLCs from predicted NO_x GLCs;
- The maximum 1-hour average NO_2 GLCs predicted at the nearby residences and golf course sensitive receptor locations represent no more than 36% (in isolation) and 40% (cumulatively) of the corresponding standard; and
- Odour concentrations are predicted to remain below the SA EPA criteria for routine operations across the modelled domain and are equal to less than 87% of the applicable criteria at the nearest sensitive receptor locations.
- H_2S concentrations are predicted to be below the SA EPA odour classification criteria across the modelled domain.

8. DISCLAIMER AND LIMITATIONS

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APPENDIX 1

CALPUFF INPUTS

CALPUFF Parameters

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
PRFDAT	CTDM/AERMET-type meteorological profile data file	PROFILE.DAT
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	8
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-01-01-01-0000-2009-02-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-02-16-00-0000-2009-04-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-04-03-00-0000-2009-05-18-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-05-18-00-0000-2009-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-07-03-00-0000-2009-08-17-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-08-17-00-0000-2009-10-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-10-02-00-0000-2009-11-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-11-16-00-0000-2009-12-31-23-0000.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**

METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2009
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	1
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2009
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+0900
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	7
NSE	Number of chemical species to be emitted	7
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1
INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	1
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	3
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	1
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	0
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0
INPUT GROUP: 3 -- Species List		

Parameter	Description	Value
CSPEC	Species included in model run	TR1
CSPEC	Species included in model run	TR2
CSPEC	Species included in model run	TR3
CSPEC	Species included in model run	TR4
CSPEC	Species included in model run	TR5
CSPEC	Species included in model run	TR6
CSPEC	Species included in model run	TR7
INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0.0
FNORTH	False northing at projection origin (km)	0.0
IUTMZN	UTM zone (1 to 60)	54
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	39
NY	Meteorological grid - number of Y grid cells	39
NZ	Meteorological grid - number of vertical layers	11
DGRIDKM	Meteorological grid spacing (km)	1
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 100.0, 200.0, 350.0, 500.0, 750.0, 1000.0, 2000.0, 3000.0, 4000.0, 5000.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	263.8390
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	6133.5530
IBCOMP	Computational grid - X index of lower left corner	17
JBCOMP	Computational grid - Y index of lower left corner	17
IECOMP	Computational grid - X index of upper right corner	23
JECOMP	Computational grid - Y index of upper right corner	23
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	17
JBSAMP	Sampling grid - Y index of lower left corner	17

IESAMP	Sampling grid - X index of upper right corner	23
JESAMP	Sampling grid - Y index of upper right corner	23
MESHDN	Sampling grid - nesting factor	10
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	0
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10
INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		

Parameter	Description	Value
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0
INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1
INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4

BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99

NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1

SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	1E-007
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1
INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	7
IPTU	Units used for point source emissions (e.g., 1 = g/s)	1
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0
INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6
INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0

NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0
INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0
INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0
INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0
INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	0
NRGRP	Number of receptor group names	0

APPENDIX 2

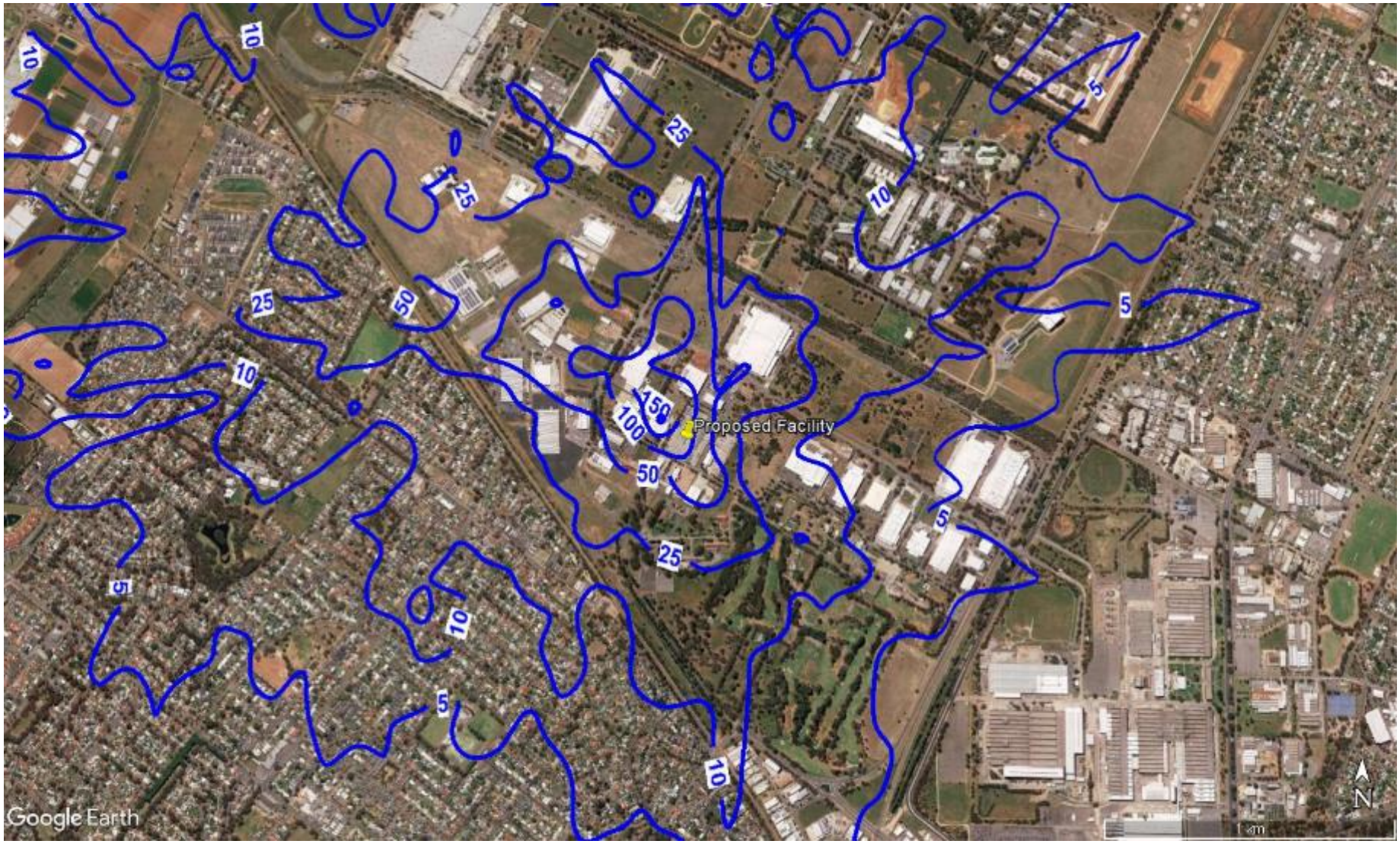
CONTOUR PLOTS

Scenario 1 (Normal Operations) – Annual Average Predicted Concentrations in Isolation of NO_2

Scenario 1 (Normal Operations) – 1-Hour Average Maximum Predicted Concentrations in Isolation of CO

Scenario 1 (Normal Operations) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO

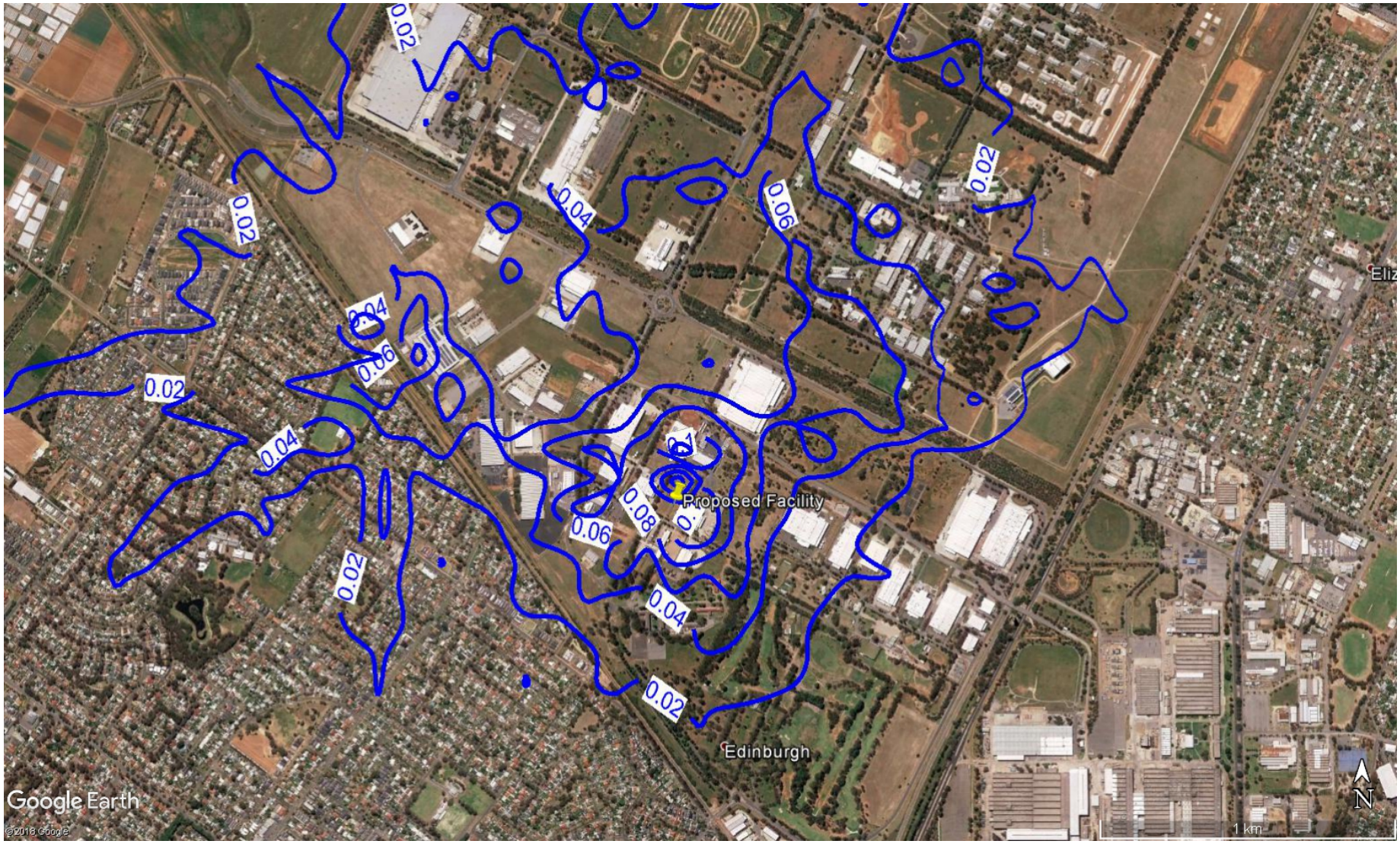
Scenario 1 (Normal Operations) – 1-Hour Average Maximum Predicted Concentrations in Isolation of SO_2



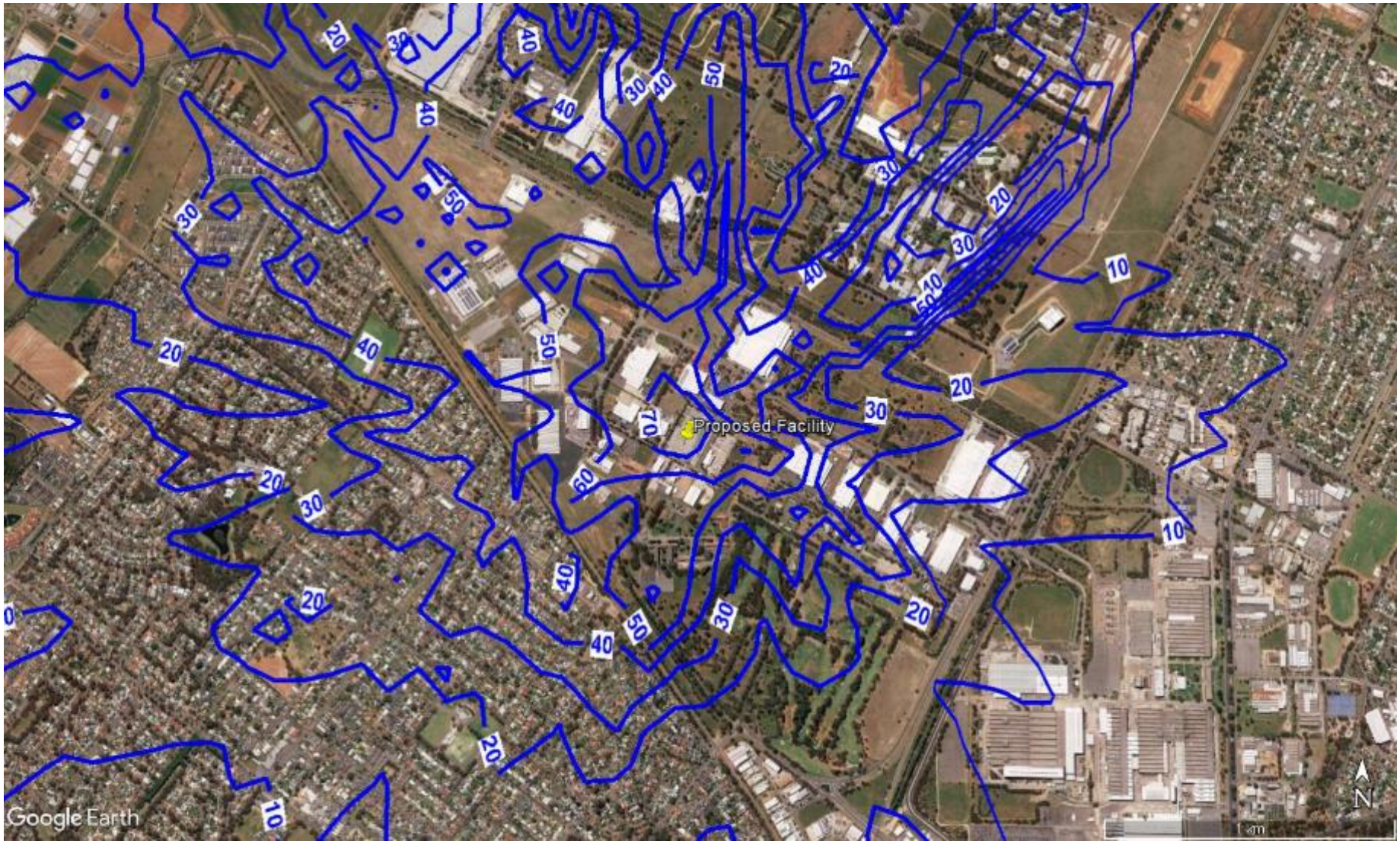
Scenario 1 (Normal Operations) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2

Scenario 1 (Normal Operations) – Annual Average Predicted Concentrations in Isolation of SO_2

Scenario 1 (Normal Operations) – 3-minute Average Maximum Predicted Concentrations in Isolation of H2S

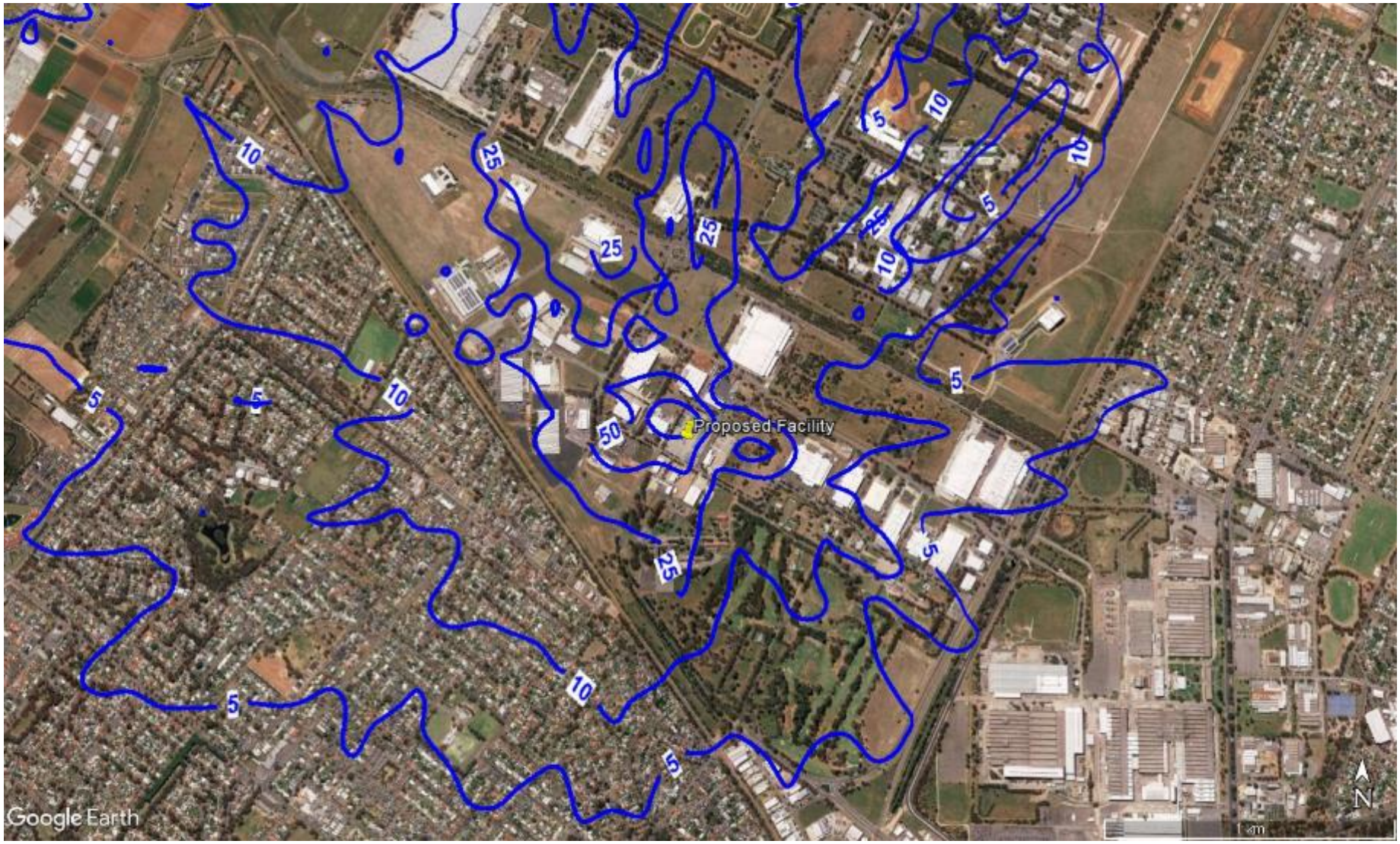


Scenario 2 (Upset Conditions) – 1-Hour Average Maximum Predicted Concentrations in Isolation of NO_2



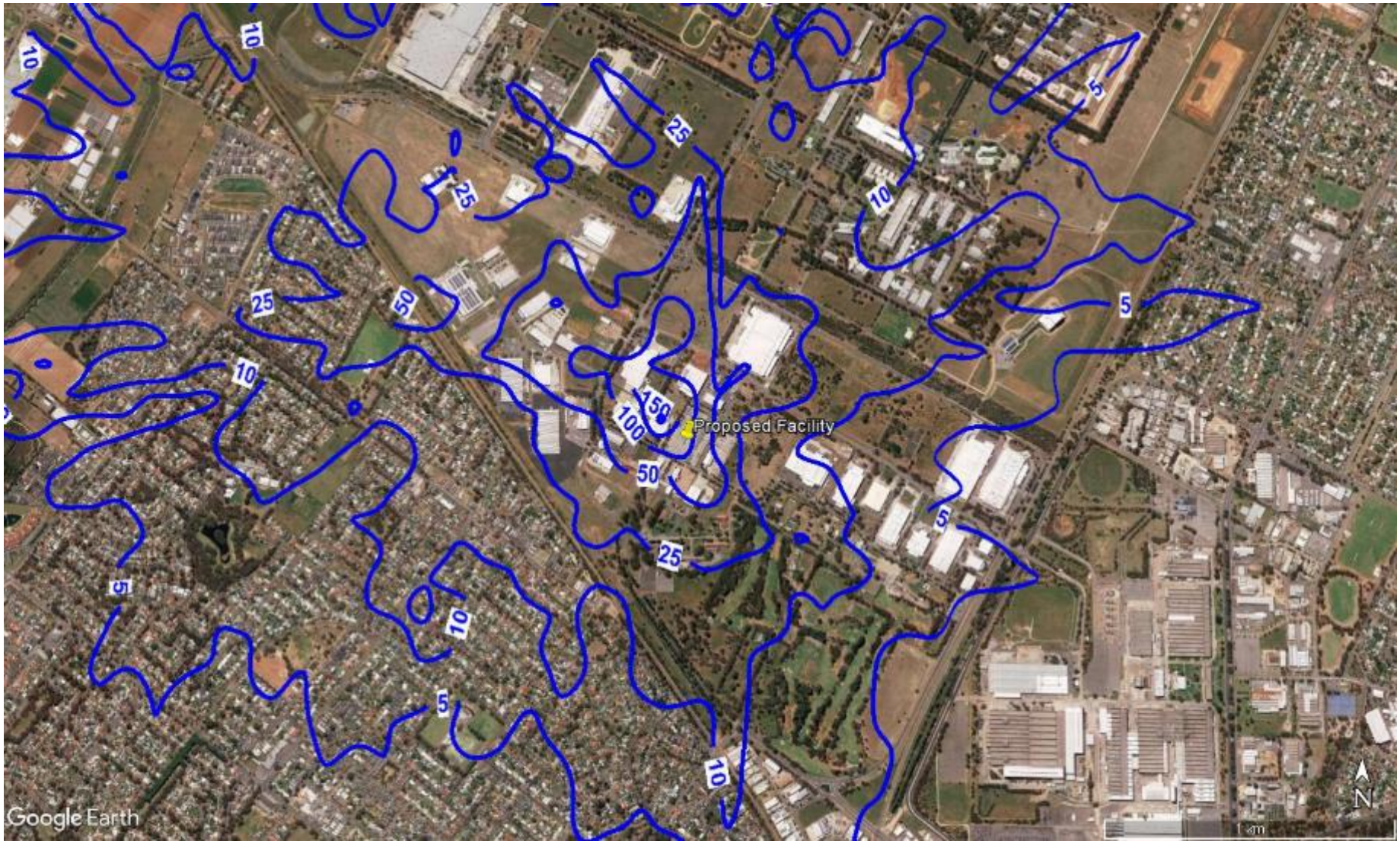
Scenario 2 (Upset Conditions) – Annual Average Predicted Concentrations in Isolation of NO_2

Scenario 2 (Upset Conditions) – 1-Hour Average Maximum Predicted Concentrations in Isolation of CO

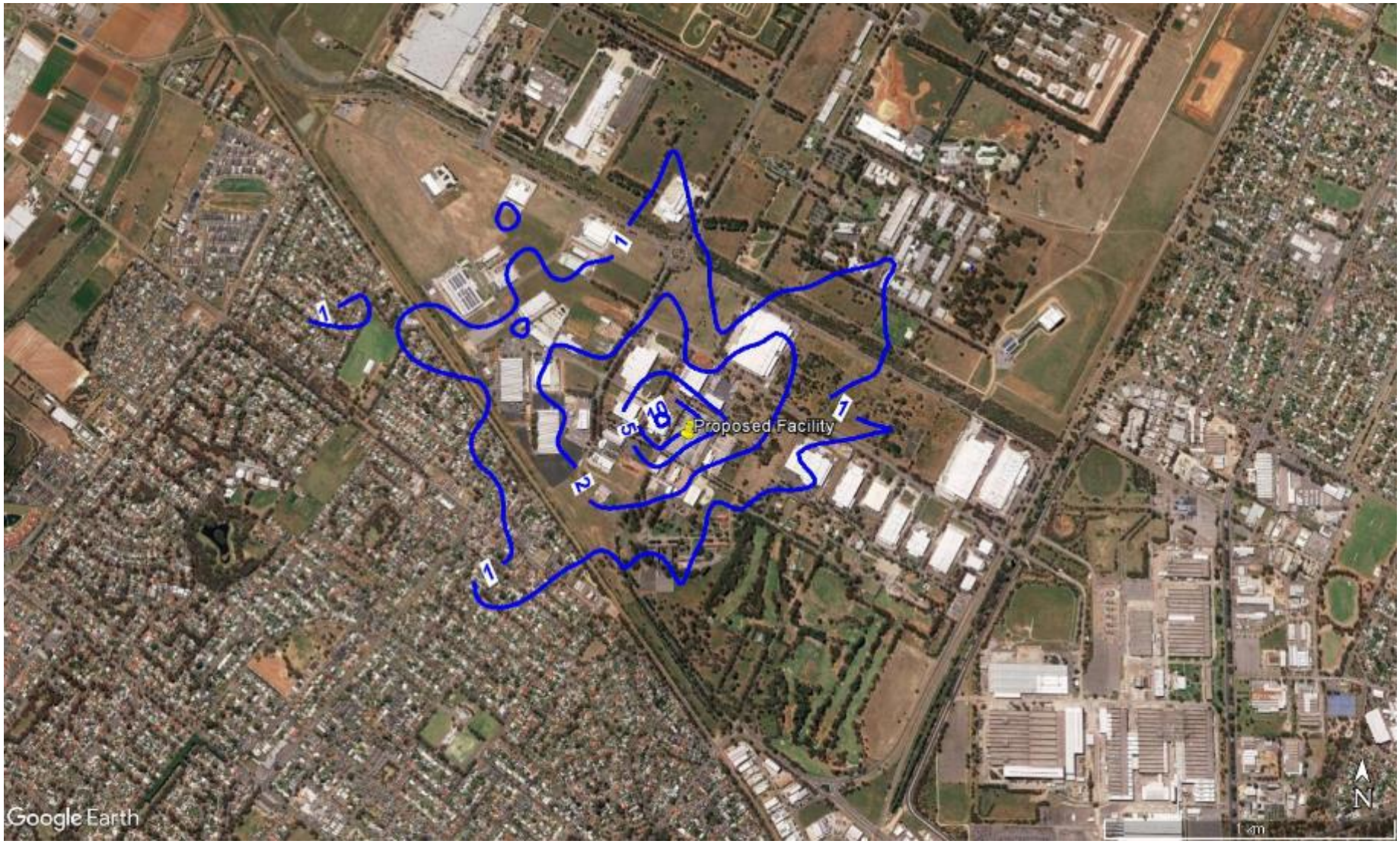


Scenario 2 (Upset Conditions) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO

Scenario 2 (Upset Conditions) – 1-Hour Average Maximum Predicted Concentrations in Isolation of SO_2

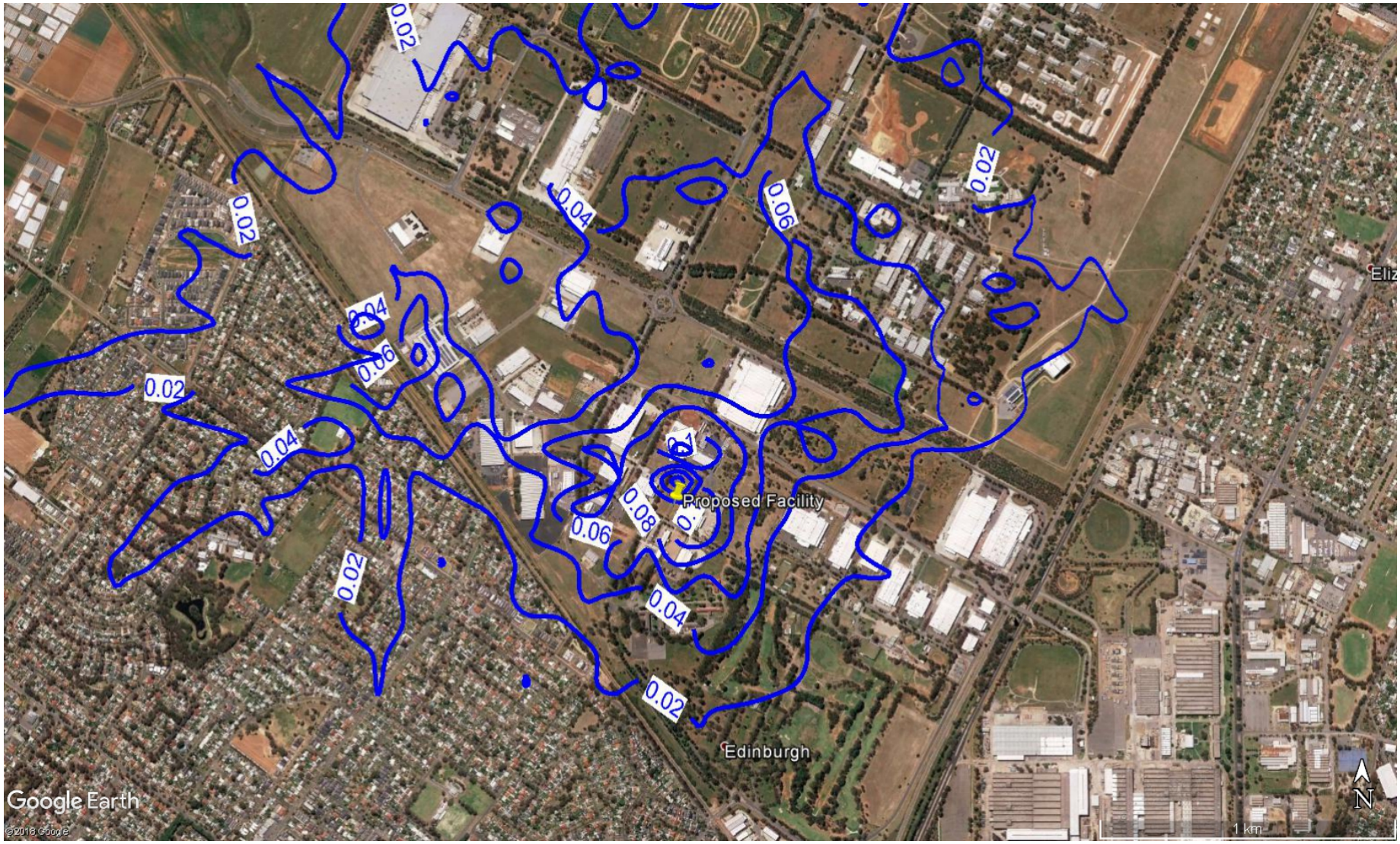


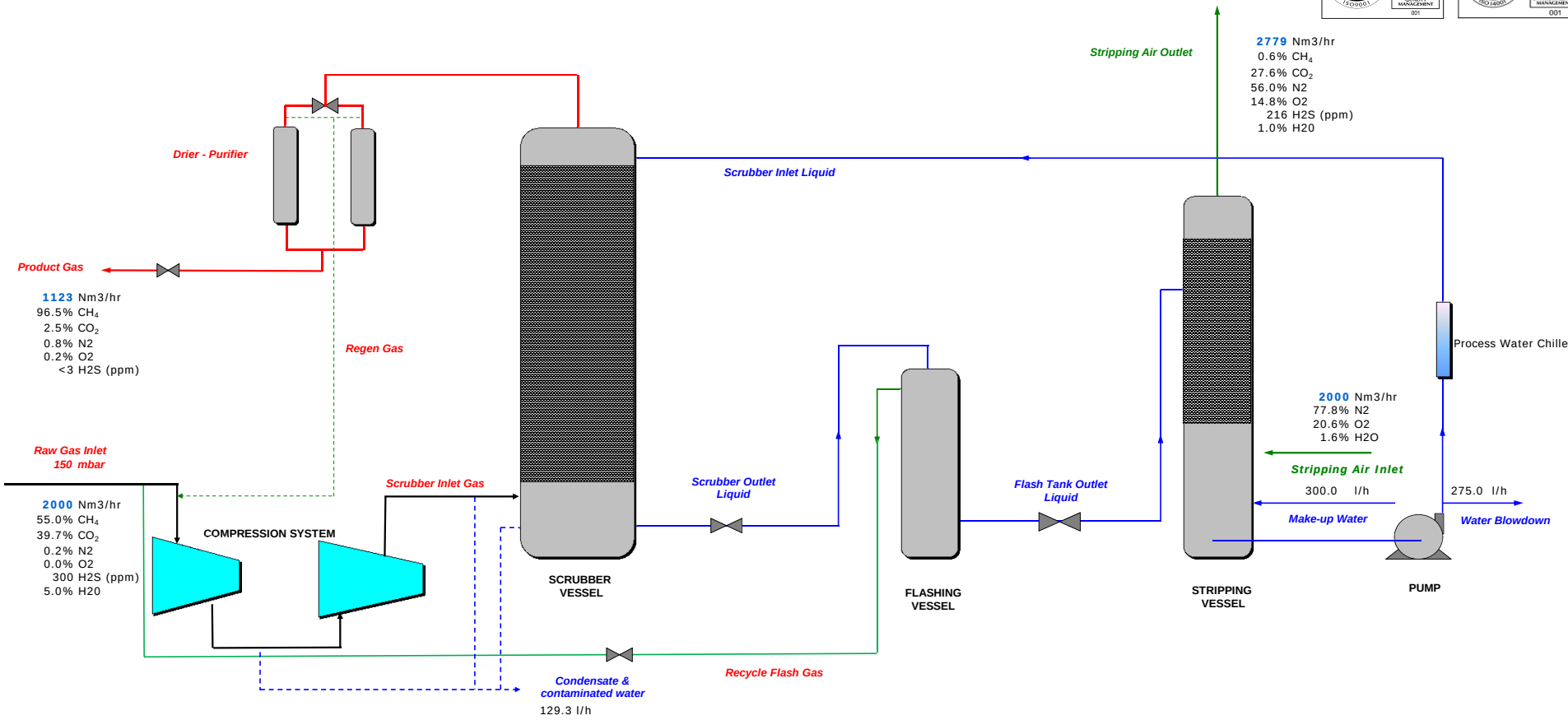
Scenario 2 (Upset Conditions) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2



Scenario 2 (Upset Conditions) – Annual Average Predicted Concentrations in Isolation of SO_2

Scenario 2 (Upset Conditions) – 3-minute Average Maximum Predicted Concentrations in Isolation of H2S





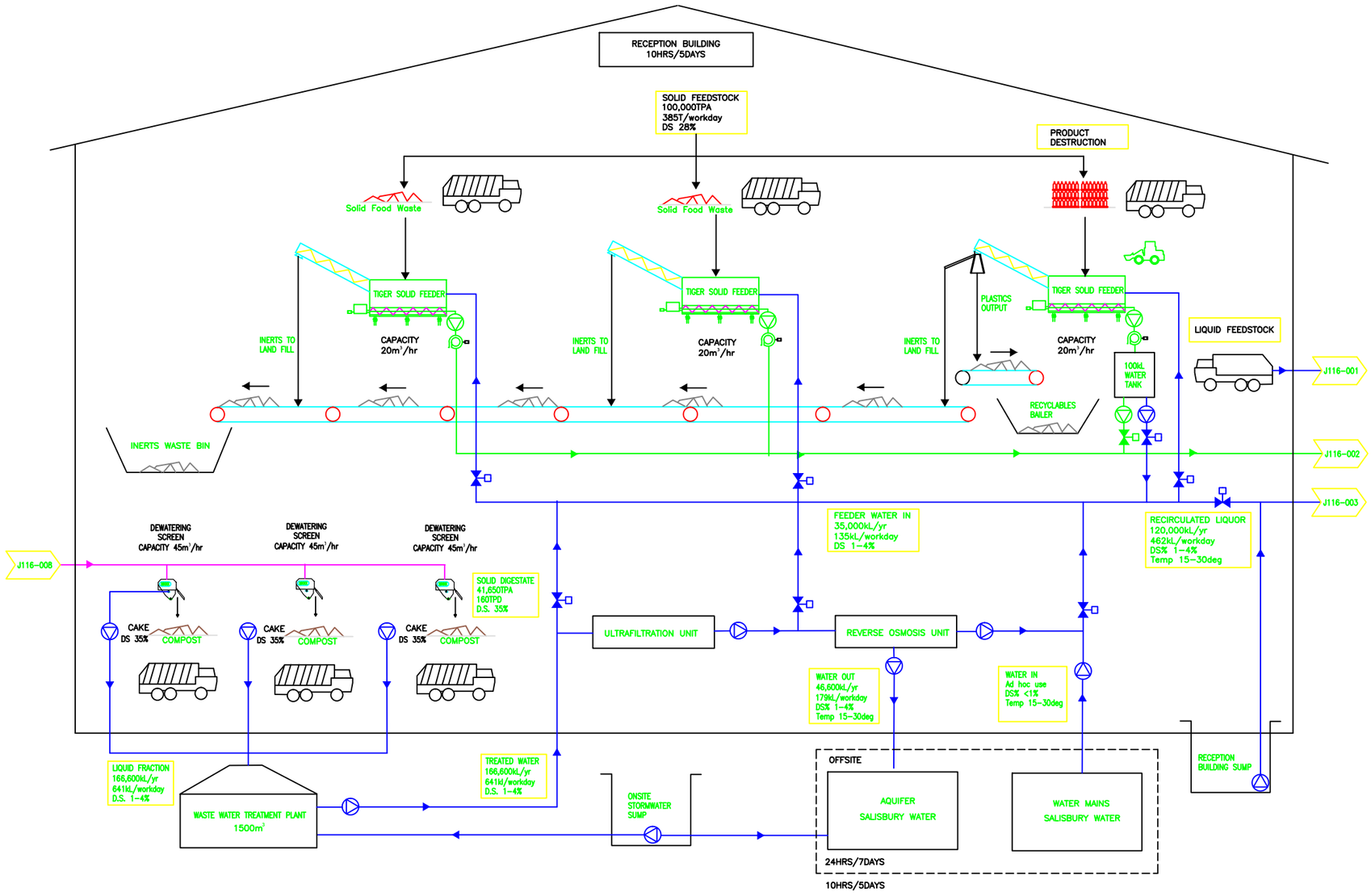
Notes.

1. The information provided in this diagram is typical and to be used for preliminary information only.
2. Make-up water, condensate & contaminated water and blowdown drains flows are average annual volumes, not instantaneous flows which may be considerably higher.
3. Effluent Air flow is estimate based on raw gas composition entered as design case within Performance & Utilities. Varying composition will effect effluent stream.
4. The composition of effluent air stream is shown as steady state in mass balance. Any downstream equipment needs to be sized with margin on flow and also composition to account for variances in stability, ramping, start-up/shutdown occurances. It is essential Greenlane are consulted for input on any downstream equipment selection.

Greenlane Totara
Biogas Upgrading System
Process Diagram

Revision Issued 11-Dec-13

DO NOT SCALE ~ IF IN DOUBT ASK | ALL DIMENSIONS IN MILLIMETRES



NOTES :-

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES (AOD) UNLESS NOTED OTHERWISE.

REV	DRWN	CHKD	APPD	DESCRIPTION	DATE
D					
C					
B					
A	JL	JO	HJ	PRELIMINARY ISSUE	19.11.18

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TITLE

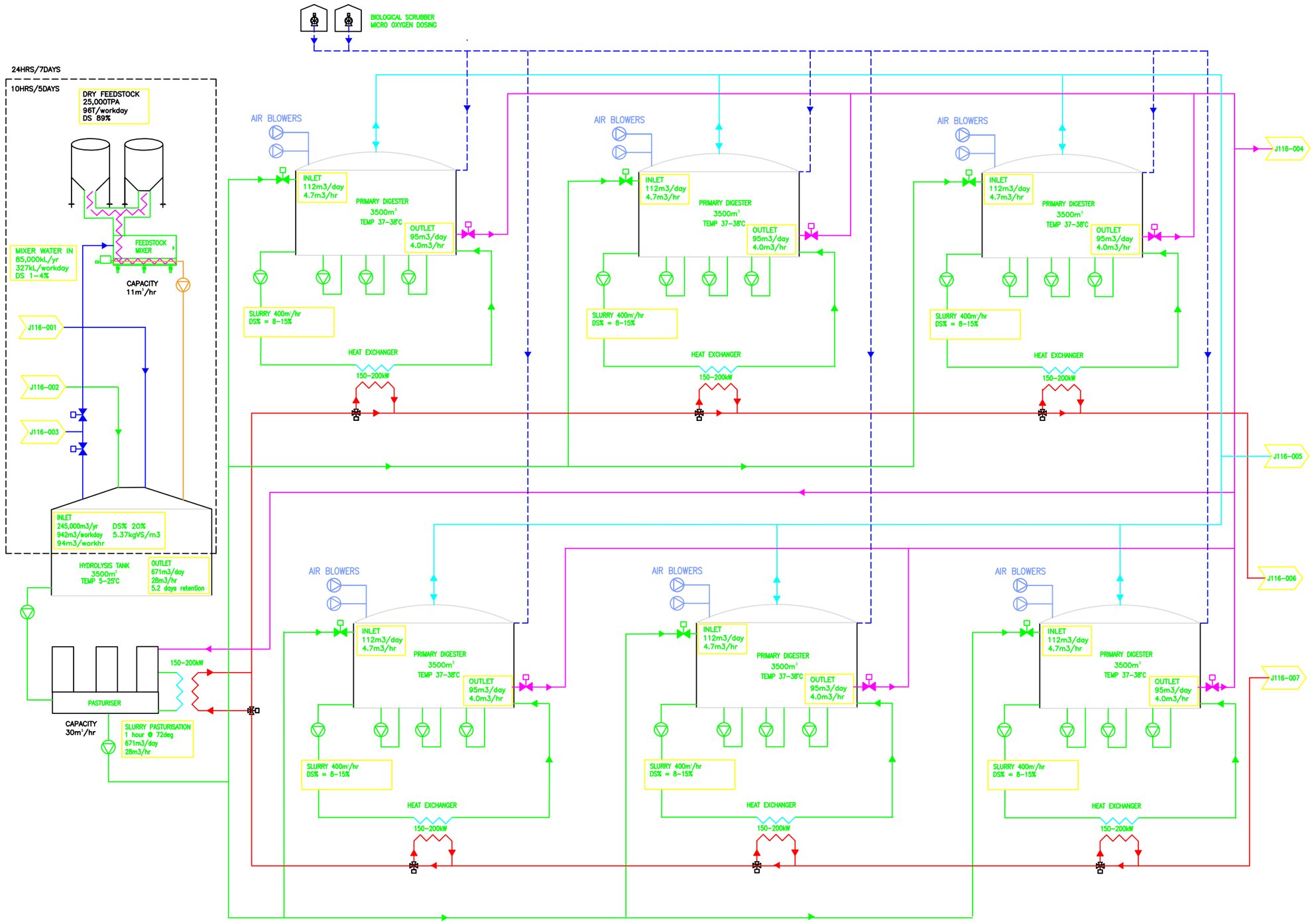
DELOREAN AD PLANT

CITY OF SALISBURY

PROCESS AND INSTRUMENTATION DIAGRAM

SCALE		DRG No.	REV.
NTS	A3	J116-PF-001	A

DO NOT SCALE ~ IF IN DOUBT ASK | ALL DIMENSIONS IN MILLIMETRES



NOTES :-

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES (AOD) UNLESS NOTED OTHERWISE.

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TITLE

DELOREAN AD PLANT

CITY OF SALISBURY

PROCESS AND INSTRUMENTATION DIAGRAM

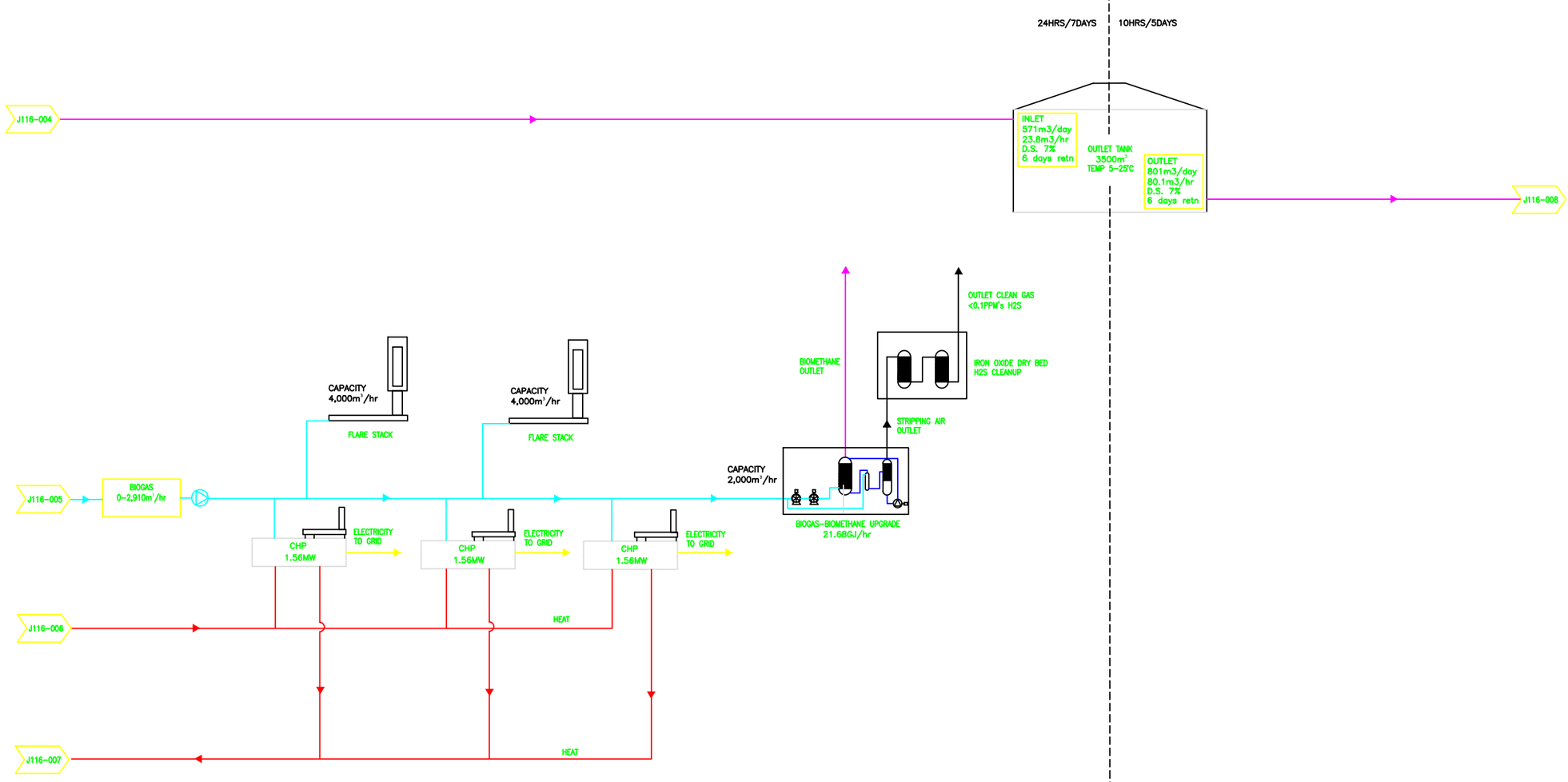
SCALE		DRG No.	REV.
NTS	A3	J116-PF-001	A

DO NOT SCALE ~ IF IN DOUBT ASK

ALL DIMENSIONS IN MILLIMETRES

NOTES :-

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES (AOD) UNLESS NOTED OTHERWISE.



REV	DRWN	CHKD	APPD	DESCRIPTION	DATE
D					
C					
B					
A	JL	JO	HJ	PRELIMINARY ISSUE	19.11.18

Biogass Renewables Pty Ltd
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ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

ROUND 5 CLARIFICATIONS

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
8/2/19	0	Issued	JL	JO	HJ

Response to Development Application Information Request

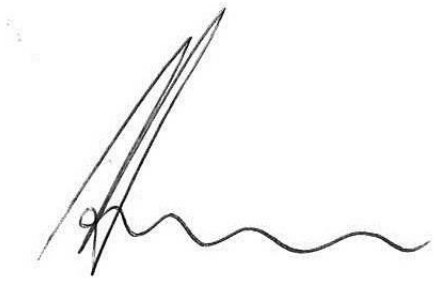
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



Hamish Jolly, Director
Biogass Renewables Pty Ltd
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RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	Previously it was indicated that 3 x Edina MWM TCG2020V16 units with a total generation capacity of 11MW(e) would be used; however Section 2.1.2 of the Air Quality Assessment mentions 3 x Jenbacher GE JC312 GS-NL D225 units with a total generation capacity of 1.6 MW(e). Provide clarification as to which generators will be utilised and the total generation capacity in MW.
	Delorean / Biogass	Confirming that the installed CHP co-generators will be 3 x 1.56MW(e) Edina MWM TCG2020V16 units with a total generation capacity of 4.68MW(e) not 11MW(e). The previously stated 3 x Jenbacher GE JC312 GS-NL D225 units was inadvertently included and has been updated in the ***Salisbury Anaerobic Digestion Plant Air Quality Assessment dated 5/2/2019***.
2	EPA	The additional information indicates that the biofilter feed will have a relative humidity of 85% (Section 2.3.2 of the Air Quality Assessment states 70%) and a maximum temperature of 45degC. The EPA's understanding is that a 95% RH and a maximum temperature of up to 37degC are more typical operating conditions. Provide examples of successful biofilters operating under the parameters submitted, including a statemen to flowrates and residence time.
	Delorean / Biogass	The previously stated biofilter relative humidity of 85% was included based on recommendations from odour consultant reports and discussions with the DWER in Western Australia in relation to the Richgro reference site. Clarifying that the stated 70% RH in the previous Air Quality Assessment was inadvertently included. Confirming that the design shall now comply with the 95% RH and a maximum temperature of 37degC to be consistent with the EPA South Australia's understanding and has been updated in the ***Salisbury Anaerobic Digestion Plant Air Quality Assessment dated 5/2/2019***. As stated in the previous response, this will be actively monitored with temperature and humidity sensors.
3	EPA	The EPA understands that the bio-methane upgrade plant would use an iron oxide scrubber system, which would guarantee 0.15mg/m3 maximum emission concentration and the safety flare is for destruction of any gas that may come from any part of the plant. It is noted that Table 1 "Flares" emissions data has changed from the previous submission data. Previously H2S emission at 5.2mg/m3 from the flares are now "below detection limit". If the flares are a bypass system, the

		EPA assumes that, given the unprocessed bio-methane hasn't changed, these numbers should still be the same. Clarify why Table 1 "Flares" emissions data changed from the previous submission data.
	Delorean / Biogass	As it is recognised that several changes have been made since initial correspondence with the EPA, a formal statement of key changes and justification has been provided in the ***Statement of Key Changes – Delorean dated 8/2/2019.*** The statement provides reasoning for the changes made to date and clarification on the final modelling.
4	EPA	It is noted that Table 2 of the Salisbury Anaerobic Digestion Plant Air Quality Assessment, prepared by Ramboll, dated 19 December 2018 (Air Quality Assessment), still doesn't include H2S odour ground level concentration (GLC) but has been include as a comment under Table 3. It is important to note that the H2S odour GLC from Schedule 2 of the Environment Protection (Air Quality) Policy 2016 (Air EPP) is 100th percentile (i.e. maximum not to be exceeded) and, being an industrial process, it is the criterion to be met, not the population-based Schedule 3 odour unit criteria. The criterion for H2S odour GLC is 0.15ug/m3, which is around odour threshold, hence why 94ug/m3 is vastly higher, perhaps in the hundreds of odour units range which is considerably different to what has been submitted in the odour unit plot (which indicates compliance with the Schedule 3 criteria, however this is not the correct criteria which is Schedule 2). Provide an assessment against the GLC H2S odour criteria and appropriately update all relevant sections of the Air Quality Assessment report.
	Delorean / Biogass	The EPA's feedback in relation to the Schedule 2 criteria has been well received and is understood. Following on from Response 3, an assessment against the GLC H2S odour criteria has been updated the *Air Quality Assessment*. The final modelling indicates H2S GLC maximum concentrations of 0.13ug/m3 and 0.13ug/m3 from the CHPs and Flares respectively and is below the acceptable Schedule 2 criteria of <0.15ug/m3. Additionally, please refer to the following supporting documentation: • ***Delorean Anaerobic Digestion Air Quality Assessment dated 5/2/2019*** • ***Appendix 1 – MWM Engine Data Sheet*** • ***Appendix 2 – Uniflare Emissions Specifications*** • ***Appendix 3 – Edina CHP Co-Generator Emissions Specifications*** • ***Appendix 4 – Exhaust Emissions Estimates*** • ***AD Facility Stack Commissioning 2015 (Doc No.: 1415-230)***
5	EPA	The response to question 4 contained in the letter from Hamish Jolly (Biogass Renewables) dated 20 December 2018, states a system is proposed that uses small amounts of air to remove H2S as elemental sulphur. However, "point d" states the sulphate is removed as a solid precipitate". It is noted that these do not correlate. Provide clarification and more detail as to the final precipitate of oxidised H2S; is it sulphur or sulphate.

	Delorean / Biogass	The biological removal of H2S is based on the biochemical oxidation of sulfide and can produce elemental sulfur (S) and/or sulfate (SO4). Both will precipiate out as a solid and be captured in the slurry removal system. The exact ratios of each will be determined by the exact reacted quantities from the air dosing.
6	EPA	The chemistry relating to this "biological desulphurisation" explained in response to question 4 in the letter from Hamish Jolly (Biogass Renewables) dated 20 December 2018 isn't supported with documentation. Provide published information that supports this methodology.
	Delorean / Biogass	In support of both Responses 5 and 6, please refer to page 707 of the attached published paper titled ***Microaeration for hydrogen sulfide removal during anaerobic treatment: a review (Krayzelova, L et. al.)*** for details on principals of biological removal of H2S using air (oxygen) dosing. In addition, please also refer to ***Appendix 5 – Richgro Weekly AD H2S Statistics*** for typical H2S concentrations in the biogas at the reference facility as a result of the air dosing system.
7	EPA	It is noted that most of the contour plots within the Air Quality Assessment do not have units nor are the nearest sensitive receivers identified. Provide updated contour plots with the missing metadata as detailed above.
	Delorean / Biogass	As requested, this has been updated in the ***Delorean Anaerobic Digestion Air Quality Assessment dated 5/2/2019.***
8	EPA	The provided process diagram (Greenlane Totara Biogas Upgrading System Process Diagram) indicates that all H2S entering the scrubber would be emitted to atmosphere from the stripper. Confirm that all H2S entering the scrubber and emitted to atmosphere from the stripper has been included (and therefore reflected) in the dispersion modelling.
	Delorean / Biogass	For the purposes of emissions modelling, 100% of H2S entering the Greenlane scrubber has been assumed to be emitted to atmosphere from the stripper. Confirming this has been included in the air dispersion modelling (worse-case).
9	EPA	The iron oxide in the purifiers (product gas line) would eventually all be converted to iron sulphide. The material is also likely to be odorous and requires approprate handling. Provide further details regarding handling and disposal of the iron sulphide.
	Delorean / Biogass	The SDS (attached) and Environmental Information (attached) of the proposed treatment material describes the material as a Quartz / Silica material and the disposal method by landfill. The testing results show that this material would qualify as less than an Intermediate waste when compared against the current classifications for Intermediate and Low Level Contaminated wastes for South Australia (Waste Disposal Information Sheet 2010 SA EPA). Disposal of material will be performed once per 18 – 24 months (dependant on exact H2S load in inlet gas). The sulphur is chemically bound to the iron (Iron Sulphide can be found naturally) and does not readily revert to Iron Oxide and elemental Sulphur without significant industrial processes being forced upon the material. Due to this, disposal shall be nominated as in landfill as a general waste. The specific disposal procedure shall be coordinated with the relevant waste disposal experts at the time. Both Cleanaway and Veolia have a number of personnel skilled in the safe and secure disposal of unusual products.

10	EPA	How would odour from the blow down water be managed to ensure that odour does not become a nuisance issue.
	Delorean / Biogass	All blow down water from the biomethane upgrade blow down shall be piped into the onsite Waste Water Treament Plant (WWTP) and recirculated back into the anaerobic digestion process alleviating any potential odour nuisance. Only treated process water meeting the applicable standards may exit the system for offtake to the Salibury aquifer.
11	EPA	Provide details of the operational criteria for blow down from the stripper.
	Delorean / Biogass	Please refer to the attached ***Greenlane Biogas Upgrading System: Process and Functional Description*** for details of the biomethane upgrade operation. As stated in section *2.2.4 Water Discharge*: *"Process water is discharged when the water blow-down valve opens. The frequency for blow-down is based on observed requirements for water changes necessary to keep the process water quality satisfactory. Flow values stated in other documentation are average annual values, not peak instantaneous."*
12	EPA	Provide details of the expected water quality in the blow down, particluarly with regard to residual H2S content.
	Delorean / Biogass	The blowdown water may contain some dissolved CO2 and H2S. Again, all blowdown water from the biomethane upgrade blow down shall be piped to the onsite WWTP for processing and recirculated back into the anaerobic digestion process alleviating any potential odour nuisance. Only treated process water meeting the applicable standards may exit the system for offtake to the Salibury aquifer. Please refer to the attached documentation for stripper water / blowdown water anaysis from various reference plants employing similar technolgoy as provided by Greenlane: • ***Typical Water Analysis from Upgrade units using two stage oil lubricated compressors*** –Totara (Orebro, Sweeden) • ***Stripping Water Analysis*** – RIM109 (UK) • ***Chemical Certificate of Analysis*** – RIM109 (UK) • ***Blowdown Water Analysis Report*** – Totara (Colorado, USA)
13	EPA	The fourth dot point on page 6 (Noise Mitigation Measures) of the Environmental Noise Assessment, AD Plant, Lot 505 Woomera Avenue, Salisbury, prepared by Herring Storer Acoustics (Document Rererence: 23621#3#18204) does not provide any certainty about what type of acoustic attenuation package, rated at 65 dB(A) at 1m, would be fitted to the generators. Provide details of the acoustic measures proposed to be implemented including the location of the measures on a plans, details of materials to be used (including type, length, height, thickness).
	Delorean / Biogass	For details on noise attenuation of the CHP co-generation unit rated at 65db(A) at 1m, please refer to the attached ***Noise Attenuation across a biogas generation unit*** provided by Edina.
14	EPA	Provide clarification if the noise from the compressors, the scrubber let down valve (between the scrubber and the flashing vessel) and the stripping vessel pump and fan have been incorporated into noise modelling.

	Delorean / Biogass	Please refer to the attached ***Statement of Key Changes – Delorean dated 8/2/2019.***

APPENDIX 1 – MWM ENGINE DATA SHEET

Edina Containerised CHP Range

TCG 2020V16 Natural Gas Australia

MWM
Energy. Efficiency. Environment.

Technical data

1560 kWel; 400 V, 50 Hz; Natural gas, MN = 80

Design conditions

Comb. air temperature / rel. Humidity:	[°C] / [%]	35 / 60
Altitude:	[m]	100
Exhaust temp. after heat exchanger:	[°C]	120
NO_x Emission (tolerance - 8%):	[mg/Nm³ @5%O_2]	500

Fuel gas data: [2]

Methane number:	[-]	80
Lower calorific value:	[kWh/Nm³]	10,17
Gas density:	[kg/Nm³]	0,79
Standard gas:	Natural gas, MN = 80	

Genset:

Engine:	**TCG2020V16**	
Speed:	[1/min]	1500
Configuration / number of cylinders:	[-]	V / 16
Bore / Stroke / Displacement:	[mm]/[mm]/[dm³]	170 / 195 / 71
Compression ratio:	[-]	13,0
Mean piston speed:	[m/s]	9,8
Mean lube oil consumption at full load:	[g/kWh]	0,2
Engine-management-system:	[-]	TEM EVO
Generator:	**Marelli MJB 500 LA4**	
Voltage / voltage range / cos Phi:	[V] / [%] / [-]	400 / ±10 / 1
Speed / frequency:	[1/min] / [Hz]	1500 / 50

Energy balance

Load:	[%]	100	75	50
Electrical power COP acc. ISO 8528-1:	[kW]	1560	1170	780
Engine jacket water heat:	[kW ±8%]	820	626	452
Intercooler LT heat:	[kW ±8%]	138	97	57
Lube oil heat:	[kW ±8%]			
Exhaust heat with temp. after heat exchanger:	[kW ±8%]	799	654	493
Exhaust temperature:	[°C]	426	449	479
Exhaust mass flow, wet:	[kg/h]	8665	6558	4507
Combustion mass air flow:	[kg/h]	8381	6340	4354
Radiation heat engine / generator:	[kW ±8%]	54 / 46	52 / 37	41 / 30
Fuel consumption:	[kW+5%]	3629	2795	1963
Electrical / thermal efficiency:	[%]	43,0 / 44,6	41,9 / 45,8	39,7 / 48,2
Total efficiency:	[%]	87,6	87,7	87,9

System parameters [1]

Ventilation air flow (comb. air incl.) with ΔT = 15K	[kg/h]	40700
Combustion air temperature minimum [5] / design:	[°C]	27 / 35
Exhaust back pressure from / to:	[mbar]	30 / 50
Maximum pressure loss in front of air cleaner:	[mbar]	5
Zero-pressure gas control unit selectable from / to: [2]	[mbar]	20 / 200
Pre-pressure gas control unit selectable from / to: [2]	[bar]	0,5 / 10
Starter battery 24V, capacity required:	[Ah]	430
Starter motor:	[kWel.] / [VDC]	15 / 24,0
Lube oil content engine / base frame:	[dm³]	265 / -
Dry weight engine / genset:	[kg]	6090 / 13290

Cooling system

Glycol content engine jacket water / intercooler:	[% Vol.]	35 / 35
Water volume engine jacket / intercooler:	[dm³]	151 / 20
KVS / Cv value engine jacket water / intercooler:	[m³/h]	46 / 30
Jacket water coolant temperature in / out:	[°C]	80 / 93
Intercooler coolant temperature in / out:	[°C]	40 / 44
Engine jacket water flow rate from / to:	[m³/h]	50 / 65
Water flow rate engine jacket water / intercooler:	[m³/h]	58 / 35
Water pressure loss engine jacket water / intercooler:	[bar]	1,6 / 1,4

3332371E8

1) See also "Layout of power plants"; 2) See also Techn. Circular 0199-99-2017; 5) In individual cases, the value may differ due to the final turbocharger design.

Frequency band f [Hz]	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k	12.5k	16k	L_{WA} [dB(A)]	S [m²]
Air-borne noise [3] $L_{wA,Tec}$ [dB(in)]	91	92	95	97	100	107	110	112	110	114	116	114	112	113	112	113	113	112	113	113	113	110	108	105	114	105	104	113	101	124	115
Exhaust noise [4] $L_{wA,Outlet}$ [dB(in)]					129			139			130			128			125			124			122			115					132	15,5

3) DIN EN ISO 3746; 4) DIN 45635-11 Appendix A (a3 dB); L_{WA}: Sound power level; S: Area of measurement surface (S_0=1m²)

APPENDIX 2: UNIFLARE EMISSIONS SPECIFICATIONS

UF10 2000 Emissions Page EA Compliant Stand Alone Flare Stack

Customer	**Biogass Renewable**			
Customer's reference	Delorean			
Our Reference No.	**UFQ**			
Machine type	**UF10-2000** High Temperature Enclosed Flare Stack			
Turndown Ratio	**5:1**			
Design Flow	**2000**	**Nm3hr**		
Design Turndown	**400**	**Nm3hr**		
Pilot System	Uniflare Fire Blaster			
Use environment	Site in open air with restricted access.			
Hazardous area classification in compliance with ATEX	Zone 2 in sphere 200 mm radius around all positive gas pipe connections			
Maximum design emissions Normalised at 0°C, 101.3 k Pa and 3% O2:	Carbon monoxide (CO)	50 mg Nm-3		
	Oxides of nitrogen (NOx)	150 mg Nm-3		
	Total volatile organic carbon as carbon	10 mg Nm-3		
	Non-methane volatile organic carbon	5 mg Nm-3		
Operation	Unattended Intermittent use			
Design Media	65%	Methane CH^4		
Design Burner Pressure	Minimum Burner inlet Pressure		60	mbarg
Thermal Rating	12.96	MW		
Destruction Efficiency CH4	>99.7%			
Destruction Efficiency H2S	>99.5%			
Design Combustion temperature	1000°C Fully refractory line with automated combustion control			
Minimum retention time	> 0.3 seconds			
Flare Stack Noise Limits	60 dBA@1m			
Booster Noise Limits	65 dBA@1m			
Control system	PLC controlled with Hardwired interface. Remote Start Stop. Status and Information available for Remote and site SCADA system.			
Safety systems	CE marked equipment Piltz PNOZ monitoring e-stop circuit Gas pressure protection IS barriers Local Isolators Flash back protected Flame arrestor Pressure and Temperature monitoring DSEAR and ATEX compliant			

Uniflare Limited
Unit 19
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KENILWORTH
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Registered in England Number 05689034

UF10 2000 Emissions Page EA Compliant Stand Alone Flare Stack

Design Calculation Page

CALCULATION OF RETENTION TIME					
CALCULATION OF COMPOSITION OF COMBUSTION PRODUCTS BS 5854					
per one volume of fuel @ 15° C and 1013 mbar					
Constitituent	Percentage in fuel	rel den	rel den fuel to air		
CH4	65%	0.554	0.3601		
CO2	35%	1.5198	0.53193		
	1	OK	0.89203		
STOICHIOMETRIC AIR PER UNIT VOLUME OF METHANE IS 9.55					
	biogas flow rate	2000	m3h-1 >	1300	m3h-1 CH4
	min air required	12415	m3h-1		
	excess air	200%			
	specific volume of air	0.819	m3 kg-1		
	mass flow rate of air	45476	kg h-1		
	mass flow rate of biogas	2178	kg h-1		
	total mass flow rate	47655	kg h-1		
fuel gases above their dew point have a specific volume similar to air at the relevant temperature					
	the volume of 1 kg of				
	flue gases at	1000	° C is		
		4	m3 kg-1		
	therefore the volume flow rate	181993	m3 h-1		
		51	m3 s-1		
	hot face diameter	1.605	m		
	area	2.02	m2		
	velocity	25.0	m s-1		
	height above flame	9	m		
	retention time	0.36	s		
	Retention time at sample port	0.32	s	Port 1m down from top	
	Heat release turn down ratio	5	:1		
	Combustion heat release full load	12.96	MW		
	Minimum heat release	2.59	MW	Created	RPB
EA Guidance on Landfill Gas Flaring 4.8.7 Page 24				Checked	MIJ

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APPENDIX 3 – EDINA CHP CO-GENERATOR EMISSIONS SPECIFICATIONS

THE QUEEN'S AWARDS FOR ENTERPRISE: 2014

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2015

Specialists in Power Generation

Edina

an EPAL company

Edina UK Ltd
Unit 12 & 13 Rugby Park
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Cheshire, SK4 3EJ
T: +44 (0) 161 432 8833
E-mail: info@edina.eu
Internet: www.edina.eu

18th January 2019

Biogass Renewables Pty Ltd
Ground Floor,
1205 Hay Street,
West Perth WA 6005

For the attention of: Joe Oliver

Our Reference: NA

Dear Joe

Re: H2S destruction across Bordertown biogas generation unit

Edina UK are the largest distributor of MWM gensets worldwide and have vast experience in the installation and long term operation of these units and have direct sales and technical support from their factory in Mannheim, Germany. MWM engines are German engineered and class leaders in electrical efficiency & reliability with low running costs.

We have been asked to comment on the level of H2S that could be found in the exhaust of a biogas generator in relation to the Delorean project. The project is to have a biogas generator rated at 1.56MWe electrical output.

H2S is produced by anaerobic digestion process and so is found in biogas. The level of H2S produced will depend primarily on the feedstocks being digested. As well as being odourous, H2S is a contaminant that is problematic to the longevity and operation of an engine. Within the combustion process the H2S is oxidised to SO2, which is an acidic compound, which contaminates the oil and can cause corrosion of the engine moving parts. This acidity and Sulphur can be followed through the deterioration of the lubricating oil through regular analysis. Hence the regular oil analysis will quickly indicate if a high-level of H2S is within the biogas.

MWM
Energy. Efficiency. Environment.

The combustion of H2S within the engine is nearly 100%. Any H2S within the exhaust will be due to "slip" of unburnt fuel passing through the engine during the period of "valve overlap". Hence the amount of H2S within the exhaust will be dependent on the amount of H2S within the fuel gas. Fuel gas slip (methane slip) is usually 1% with 2% as an absolute maximum. Higher values would obviously affect the engine performance/efficiency.

Because of the deleterious nature of H2S to the engine the anaerobic digestion plant will have at least one, and probably more, systems to reduce the H2S level. The Delorean project is reported to be very sensitive to potential odour and will have several H2S abatement processes. The digestion plant incorporates a controlled level of air addition to the gasholder to facilitate the biological oxidation of H2S to elemental Sulphur. This system is contained within the digestion plant. The design of this system should enable the H2S in the resultant biogas to a level of around 60ppm or lower. Subsequent to the biological system the plant is reported to have a biogas iron oxide scrubbing system. Within the scrubber the iron will react with the H2S to form inert Iron sulphide, which will remain within the scrubber. The scrubber supplier is to guarantee an H2S level in the biogas fed to the generator of less than 0.1ppm.

The detection of H2S within the exhaust is difficult due to its very low level. The low level is due to its combustion within the engine and the dilution with other combustion components. Generally on an exhaust analysis H2S is below the limit of detection, consequently it is not often monitored.

A typical limit of detection from an exhaust analysis would be expressed as the Method Detection Limit. This is the practical limit of detection for the test per unit volume of exhaust gas. For H2S this would be about 5mg/Sm3. Standard m3 is defined as dry gas, 0C and 1 atmosphere pressure.

To express this in terms of the actual exhaust gas at a typical 150C temperature, the H2S would be around 2ppm.

Since this is the limit of detection for the exhaust gas, a theoretical calculation can be made:

- If the biogas fed to a 1.56MWe generation set were to contain 200ppm of H2S.
  - This would be a feed rate of 200g of H2S per hour.
- Assume the slip of unburnt H2S is 2%.
  - This would release 4000mg of H2S into the exhaust.
- The exhaust flow at 150C from the generator would be around 9900m3/h.

Hence the H2S theoretical concentration in the exhaust would be 0.4mg/m3, or 0.27ppm.

The actual H2S in the exhaust stack is therefore significantly below the limit of detection of usual analytical methods.

Since the Delorian project has an H2S input of just <0.1ppm the theoretical concentration in the exhaust would be around 0.1ppb!

I trust this helps explain the difficulty in measuring H2S in an exhaust and why it is not usually considered a problem.

Yours faithfully
For and on behalf of EDINA UK LTD,

Ian Farr
Biogas Sales Manager

APPENDIX 4 – EXHAUST EMISSIONS ESTIMATES

H2S Emissions Estimates Delorean Project

CHP	Variable	Delorean	Formula & Conditions
Input	Capacity (MW)	1.56	
	H2S Molecular Weight (m)	34.1	
	Volume m3/hr (Vi)	720	
	ppm (Cpi)	0.1	
	mg/m3 (Cmi)	0.152	(Cpi x m)/22.4 @ STP 1atm 0degC
	mg/hr (Chi)	109.607	Cmi x Vi
	Destruction efficiency (p)	0.980	
Output	**volume m3/hr (Vo)**	**9900**	**@150degC**
	mg/hr (Cho)	2.192	Chi x (1-p)
	mg/m3 (Cmo)	0.00022	Cho/Vo
	ppm (Cpo)	**0.000145**	**(Cmo x 22.4)/m**
	ppb (Cbo)	0.145	Cpo x 1000

FLARE	Variable	Delorean	Formula & Conditions
Input	Capacity (m3/hr)	2000	
	H2S Molecular Weight (m)	34.1	
	Volume m3/hr (Vi)	2000	
	ppm (Cpi)	0.1	
	mg/m3 (Cmi)	0.152	(Cpi x m)/22.4 @ STP 1atm 0degC
	mg/hr (Chi)	304.464	Cmi x Vi
	Destruction efficiency (p)	0.995	
Output	**volume m3/hr (Vo)**	**181993**	**@1000degC**
	mg/hr (Cho)	1.522	Chi x (1-p)
	mg/m3 (Cmo)	0.0000084	Cho/Vo
	ppm (Cpo)	**0.0000055**	**(Cmo x 22.4)/m**
	ppb (Cbo)	0.0055	Cpo x 1000

APPENDIX 5 – RICHRO AD WEEKLY H2S STATISTICS

The following H2S data was obtained from the reference facility in *Jandakot, Western Australia* and provided courtesy of Richgro Garden Products by *Tony Doherty, Site Supervisor AD Plant*.

Richgro AD Weekly H2S Statistics

Ending Date	H2S (PPM)
22/02/2016	47
29/02/2016	35
7/03/2016	41
14/03/2016	30
21/03/2016	25
28/03/2016	23
4/04/2016	25
11/04/2016	24
18/04/2016	18
25/04/2016	15
2/05/2016	16
9/05/2016	27
16/05/2016	18
23/05/2016	32.1
30/05/2016	24.3
6/06/2016	24.3
13/06/2016	26.9
20/06/2016	37
27/06/2016	43
4/07/2016	53.5
11/07/2016	56.5
18/07/2016	39.5
25/07/2016	29
1/08/2016	30.3
8/08/2016	26.5
15/08/2016	26
22/08/2016	25
29/08/2016	27
5/09/2016	27
12/09/2016	25
19/09/2016	39
26/09/2016	59
3/10/2016	36
10/10/2016	32
17/10/2016	27
24/10/2016	22
31/10/2016	17
7/11/2016	12
14/11/2016	31
21/11/2016	27
28/11/2016	33
5/12/2016	29
12/12/2016	20
19/12/2016	7
26/12/2016	14
2/01/2017	43
9/01/2017	42
16/01/2017	17
23/01/2017	26
30/01/2017	29
6/02/2017	26
13/02/2017	34
20/02/2017	23
27/02/2017	53
6/03/2017	16
13/03/2017	10
20/03/2017	13

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EMISSION ASSESSMENTS

REPORT NUMBER: 1415-230

Richgro

AD Facility Stack Emissions Commissioning 2015

3 June 2015

ATTENTION: Mr Joseph Oliver

NATA

NATA Accredited Laboratory
Number: 17108
Accredited for compliance with ISO/IEC 17025. The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
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REVISION HISTORY		
Version Number	**Date Issued**	**Version Details**
1.0	3/06/2015	Final

Date: 3/06/2015

Attention: Mr Joseph Oliver

Client Address:
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STATEMENT OF LIMITATION

This assessment was restricted to the agreed-upon scope of work. No representations or warranties are made concerning the nature or quality of air, water or soil or any other substance on the inspected property, other than visual observations or measurements as stated within this report.

In preparing this report, Emission Assessments has relied upon certain verbal information and documentation provided by the client and/or third parties. Except as discussed Emission Assessments did not attempt to independently verify the accuracy or completeness of that information; but did not detect any inconsistence or omission of a nature that might call into question the validity of any of it. To the extent that the conclusions in this report are based in whole or in part on such information, they are contingent on its validity. Emission Assessments assume no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented or otherwise not fully disclosed or available to Emission Assessments.

Within the limitations of the agreed-upon scope of work, this assessment has been undertaken and performed in a professional manner, in accordance with generally accepted practices, using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied is made.

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1 ISSUE STATUS OF REPORT

This report is the first issue of data pertaining to the AD Facility Stack Emissions Commissioning 2015 sampling program. It is considered to be the final issue and most current.

2 INTRODUCTION

Emission Assessments Pty Ltd was requested by to conduct stack monitoring for Richgro as part of their AD Facility Stack Emissions Commissioning 2015.

In January 2013, Richgro (in conjunction with Biogas) was granted a DEC Works Approval for the construction of an Anaerobic Digestion Facility (AD Facility) adjacent to the existing aerobic composting Facility. In summary, this AD Facility receives mixed organic waste of varying proportions (including solid/liquid food waste and animal sourced liquid waste) which will be anaerobically digested to form two main by-products: digestate and biogas. The digestate will be used at the existing aerobic greenwaste composting shed, with an option to recycle the liquid stream in the AD Facility. The biogas is used to power a CHP plant (Combined Heat and Power plant) which uses a Generator to produce electricity. In cases of over production or poor quality, the gas is diverted away from the generator and burned in a flare.

It is a condition of the DER Works Approval (Number W5311/2012/1, dated 21st January 2013), that odour, air and noise monitoring be conducted during the commissioning phase of the AD Faciity. The purpose of the monitoring was to assess the emissions and potential impacts from the AD Facility.

Monitoring was conducted on the 15 April 2015 at Richgro's AD facility on 3 emission sources:

- Generator stack
- Flare stack
- BioFilter Inlet and Outlet

The Generator and Flare were tested at both full load (100%) and part load (50%) to simulate the variable operating conditions. The exact operating conditions were Flare 50% (220m^3/hr) and 100% (450m^3/hr); and Generator 50% (600KW) and 100% (1200KW).

In the absence of stated limits or performance criteria the results are simply stated and no further interpretation given.

3 SAMPLING LOCATION AND SAMPLING PLANE ASSESSMENT

To obtain the most representative sample possible, each sampling position/plane is assessed against criteria of the applied sampling methodology. Sampling points are then calculated to achieve this.

Generator stack: The sampling planes which were tested met *AS4323.1 "Selection of Sampling Positions"* and are considered to be ideal for the determinations for flow rate and isokinetic testing test parameters as detailed in AS4323.1.

Flare stack: It was noted that the location of the measurement site did not conform to the requirements outlined in AS4323.1. This states that the measurement site should be located a minimum of 2 stack diameters downstream of any potential disturbance; and a minimum of 6 stack diameters upstream of any potential disturbance. The measurement site is located 0.7m downstream of the outlet of the stack, which does not meet the recommended 2m distance downstream (internal stack diameter at the measurement site is 1.0m).However, when operating at 100% capacity, a preliminary flow traverse of the sampling plane proved that the flow profile met the criteria required for stack flow determination and isokinetic. Due to the burner design of the flare, operating less than 100% only partially uses the whole flare stack and severe stratification of the gas occurs.

4 SAMPLING METHODOLOGY

Details of the parameters/analytes sampled and the sampling methodology used to conduct the program are shown below.

Parameter/Analyte	Sampling Methodology	NATA Accredited Sampling	NATA Accredited Analysis
Sampling plane assessment	AS4323.1	Y	Y
Velocity, flow rate & temperature	USEPA Method 2	Y	Y
Oxygen (O_2)	USEPA Method 3A	Y	Y
Carbon Dioxide (CO_2)	USEPA Method 3A	Y	Y
Sulphur Dioxide (SO_2)	USEPA Method 6	Y	Y
Total Oxides of Nitrogen (NO_X)	USEPA Method 7E	Y	Y
Carbon Monoxide	USEPA Method 10	Y	Y
Total Volatile Organic Compounds (TVOCs)	USEPA Method 18	Y	Y
Hydrogen sulphide	USEPA Method 11	Y	Y
Odour	AS4323.3	Y	Y

4.1 Flow rate / velocity / temperature / moisture

Prior to initiating the sampling program, each source was evaluated for representativeness. The application of the "preliminary methods" involves an assessment of the sampling plane using established Australian Standards and USEPA Methods. The sampling plane of each source was evaluated daily to ensure that the most representative sample point selection had been employed. These methods must be applied correctly to ensure that sampling is conducted representatively across the sampling plane.

4.2 Gaseous parameters

Gaseous parameters were determined using a TESTO 350 electrochemical portable gas analyser. Gases were conditioned through a refrigerated process to eliminate moisture. The conditioned gas was then presented to the gas analyser and continuously data-logged for oxygen, carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxide and nitrogen dioxide.

4.3 Total Volatile Organic Compounds (VOCs)

Volatile Organic Compounds are sampled using a low flow technique (USEPA Method 18). The gases are passed through a sample probe to a moisture drop out and subsequently a carbon tube. At the end of testing the tube is recovered and refrigerated along with any condensate sample collected.

The collected sample media was analysed by NMI, a NATA-accredited laboratory using high resolution gas chromatography (HRGC) to report a suite of individual speciated VOCs, including benzene and toluene. Peak area methods were then used to calculate a result for Total Volatile Organic Compounds (TVOC), which were quantified as an n-hexane equivalent concentration.

4.4 Hydrogen sulphide

The sample is extracted from the emission source at a rate of 2L/min and passed through a series of midget impingers containing cadmium sulphate solution. Hydrogen sulphide is absorbed forming cadmium sulphide which is measured by iodometric titration.

4.5 Odour Concentration

The sampling and analysis of odour concentration was carried out in accordance with Australian Standard AS/NZS4323.3:2001 using NATA accredited methods. For each test a grab sample was taken by extracting stack gas into a nalophan bag, housed in a sealed container (odour barrel) under negative pressure.

After testing, samples were recovered and labelled with a unique number before sending to The Odour Unit a NATA accredited laboratory, for analysis. The odour samples were analysed by olfactometer testing using a multi-person panel, within 24 hours of collection. Results are expressed as odour units (ou) which is the concentration of odourant(s) that elicited a physiological response from the panel equivalent to that elicited by one Reference Odour Mass (ROM), evaporated in one cubic meter of neutral gas at standard conditions.

5 VARIATIONS TO PROTOCOLS

It should be noted that the Sulphur Dioxide concentrations reported have been adjusted to account for cross interference caused by high levels of Carbon Monoxide present in the stack gas. Both Pre and Post-test analyser calibrations passed but a slight calculated adjustment factor was used to account for the negative interference. For this reason, the results will have an increased level of uncertainty.

6 DEFINITIONS

6.1 Units of Measure

Parameter	Unit	Expanded Unit
Stack Velocity	am/s	Actual metres per second
	dsm/s	Dry standard metres per second
Stack Volume	dscm	Dry standard cubic metre
	acm	Actual cubic metre
Stack Concentration	mg/dscm	Milligrams per dry standard cubic meter
	g/dscm	Grams per dry standard cubic meter
	ppm	Parts per million
Stack Flowrate	dscm/min	Dry standard cubic metres per minute
	acm/min	Actual cubic metres per minute
Stack Emission rate	g/s	Grams per second
	g/g-mole	Gram per gram-mole

6.2 Practical Quantitation Limit

In this report, EAPL define the term 'practical quantitation limit (PQL)' as the lowest amount of an analyte which can be practically quantified by the analytical laboratory. The PQL is derived and reported by the analytical laboratory, and is laboratory-specific.

PQLs have various units depending on the analysis being conducted, including mg/L, ppm, mg.

6.3 Method Detection Limits

In this report, EAPL define the term 'method quantitation limit (MDL)' as the lowest stack concentration which can be reliably quantified by EAPL. This MDL is based on two parameters: the PQL reported by the analytical laboratory and the volume of stack gas sampled.

$$MDL = \frac{PQL}{Dry\ standard\ volume}$$

MDLs for stack concentrations are stated for individual sampling runs in the appropriate concentration unit, usually mg/dscm.

6.4 Standard Measurement Uncertainty

Method	Analyte	Uncertainty (±%)
USEPA Method 2	Velocity & Flow	3
USEPA Method 4	Moisture	4
USEPA Method 3A	Oxygen and Carbon dioxide	10
USEPA Method 6C	Sulphur Dioxide	**20***
USEPA Method 7E	Oxides of nitrogen	10
USEPA Method 10	Carbon monoxide	10
USEPA Method 11	Hydrogen Sulphide	15
USEPA Method 18	Total Volatile Organic Compounds (TVOCs)	20
AS4323.3	Odour	NA

***Uncertainty levels have doubled due to the calculated result adjustments to account for the carbon monoxide interference.**

6.5 Significant Figures

The following protocols are used for calculations and reporting data:

- All data generated from analytical laboratories are received to two significant figures.
- All calculations are performed on unrounded data.
- All particulate determinations are reported to two significant figures.
- All gaseous data is reported to two significant figures.
- Percentage concentrations are reported to one decimal place.

7 TABLES OF RESULTS

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Table 2: Summary Table for Bio-filter – Inlet and Outlet

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Table 3: USEPA Method 3A, 6C, 7E and 10 – Combustion gases, Run 1 and Run 2

Table 4: USEPA Method 11 – Hydrogen Sulphide, Run 1 and Run 2

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Table 6: AS4323.3 – Odour Concentration, Run 1 and Run 2

Flare Stack

Table 7: USEPA Method 3A, 6C, 7E and 10 – Combustion gases, Run 1 and Run 2

Table 8: USEPA Method 11 – Hydrogen Sulphide, Run 1 and Run 2

Table 9: USEPA Method 18 – Total VOCs, Run 1 and Run 2

Table 10: AS4323.3 – Odour Concentration, Run 1 and Run 2

Biofilter Stack – Inlet

Table 11: AS4323.3 – Odour Concentration, Run 1 and Run 2

Biofilter Stack – Outlet

Table 12: AS4323.3 – Odour Concentration, Run 1 and Run 2

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Chart 1: Generator Stack combustion gases, Run 1 and Run 2

Chart 2: Flare Stack combustion gases, Run 1 and Run 2

Table 1: Summary Table – Generator Stack and Flare Stack

Analyte	Units	Generator Stack		Flare Stack	
		Run 1 (50%)	Run 2 (100%)	Run 1 (50%)	Run 2 (100%)
Oxygen (O_2)	%	7.6	8.3	9.7	10.9
Carbon Dioxide (CO_2)	%	13.4	12.6	11	10.3
Carbon Monoxide (CO)	mg/dscm	580	590	45	16
	g/s	0.46	0.81	0.035	0.026
Sulphur Dioxide (SO_2)	mg/dscm	48	46	11	8.8
	g/s	0.038	0.062	0.0087	0.015
Total oxides of nitrogen*[1] (NO_X as NO_2)	mg/dscm	520	400	79	51
	g/s	0.42	0.54	0.062	0.084
Total VOCs (as n-hexane)	mg/dscm	<0.36	<0.37	<0.38	<0.35
	g/s	<0.00029	<0.00051	<0.018	<0.035
Hydrogen Sulphide	mg/dscm	<5.6	<5	<5.5	<5.2
	g/s	<0.0045	<0.0068	<0.0043	<0.0086
Odour Concentration	ou/dscm	1450	1720	215	279
	ou.m^3/s	1180*	2460*	174*	472*
Moisture (H_2O)	% vol.	2.1	4.4	3.1	1.5
Stack Flow	dscm/min	73	131	47	100
Stack Temperature	°C	130.1	145.1	1000	1000

***** Mass emission rate of odour concentration are expressed a wet value.

All concentration and mass emission data is referenced to STP (273.15K, 101.3kPa) and expressed as dry values.

Table 2: Summary Table for Bio-filter – Inlet and Outlet

	Units	Bio-filter Inlet		Bio-filter Outlet	
		Run 1	Run 2	Run 1	Run 2
Sampling Time	hh:mm	14:31	14:57	13:42	14:07
Date	dd/mm/yy	15/04/2015	15/04/2015	15/04/2015	15/04/2015
Stack Concentration	ou/dscm	2050	2440	724	789
Mass Emission Rate (Wet at STP)	o/u.m^3/s	8530	10200	1530	1670
Odour Character	-	Fatty acid / rancid	Fatty acid / rancid	Fatty acid / rancid	Fatty acid / rancid
Average Mass Emission Rate (Wet at STP)	o/u.m^3/s	9365		1600	
Bio-filter Odour Removal Efficiency	%	82.9%			

COMBUSTION GAS DATA: USEPA METHODS 3A, 6C, 7E, 10					
Logistical Information					
Job Number:	1415-230				
Company Name:	Richgro				
Sampling Program:	AD Facility Stack Emissions Commissioning				
Source Identification:	SI/MS				
Sampling Personnel:	Generator Stack				
Analyser Model:	Testo-350				
Analyser ID:	TESTO-02				
Analyser Calibrations					
		Zero (start)	Zero (end)	Span (start)	Span (end)
USEPA M3A Calibration:	% CO_2	0.0	0.0	4.6	4.5
	% O_2	0.0	0.0	17.8	18.1
USEPA M6C Calibration:	ppm SO_2	0.0	0.0	103.3	104.0
USEPA M7E Calibration:	ppm NO	-1.0	0.0	200.3	199.0
	ppm NO_2	-0.2	-0.1	45.1	45.0
USEPA M10 Calibration:	ppm CO	-0.3	-0.7	262.0	259.0
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Monitoring Date:	dd/mm/yy	15/04/2015		15/04/2015	
Start Time:	hh:mm	11:09		12:15	
Final Time:	hh:mm	11:39		12:45	
Sampling Duration:	minutes	30		30	
Average Stack Temperature:	°C	130.1		145.1	
Average Stack Velocity:	m/sec	12.3		22.0	
Moisture:	%	2.1		4.4	
Dry Standard Stack Flow Rate :	dscm/min	48		82	
Actual Stack Flow Rate:	acm/min	73		131	
Dry Gas Molecular Weight:	g/g-mole	30.44		30.35	
Sampling Concentrations					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Oxygen	% O_2	7.6		8.3	
Carbon Dioxide	% CO_2	13.4		12.6	
Sulphur Dioxide	ppm SO_2	16.8		15.9	
Nitrogen Oxide	ppm NO	174.5		123.6	
Nitrogen Dioxide	ppm NO_2	80.2		69.0	
Total Oxides of Nitrogen	ppm as NO_2	254.6		192.5	
Carbon Monoxide	ppm CO	460.4		473.7	
Reportable Data - USEPA Method 3A: Oxygen (O_2) and Carbon Dioxide (CO_2)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL % vol.**	**Stack Concentration % vol.**		**Stack Concentration % vol.**	
Oxygen (O_2)	0.01	7.6		8.3	
Carbon dioxide (CO_2)	0.01	13.4		12.6	
Reportable Data - USEPA Method 6C: Sulphur Dioxide (SO_2)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Sulphur dioxide (SO_2)	2.9	48	0.038	46	0.062
Reportable data - USEPA Method 7E: Oxides of Nitrogen (NO_X)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Nitrogen monoxide (NO)	1.3	230	0.19	170	0.23
Nitrogen dioxide (NO_2)	0.21	160	0.13	140	0.19
Total oxides of nitrogen (NO_X as NO_2)	2.3	520	0.42	400	0.54
Reportable Data - USEPA Method 10: Carbon Monoxide (CO)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Carbon monoxide (CO)	1.3	580	0.46	590	0.81
Comments					
1. Passed QA/QC checks					

USEPA METHOD 11: HYDROGEN SULPHIDE					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Generator Stack			
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Start Time:	hh:mm	11:08		12:13	
Final Time:	hh:mm	11:38		12:43	
Test duration:	minutes	30		30	
Standard Meter Volume:	dscm	0.029		0.029	
Average Stack Temperature:	°C	130.1		145.1	
Average Stack Gas Velocity:	m/sec	12.3		22	
Stack Moisture:	%	2.1		4.4	
Dry Standard Stack Flow Rate:	dscm/min	48		82	
Actual Stack Flow Rate:	acm/min	73		131	
Dry Gas Molecular Weight:	g/g-mole	30.44		30.35	
Emission Results					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**
Hydrogen Sulphide	5.6	<5.6	<0.0045	<5	<0.0068
Comments					
1. Passed QA/QC checks.					

USEPA METHOD 18: TOTAL VOCs					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Generator Stack			
Sampling Data					
		Run 1 (50% load)		**Run 2 (100% load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Start Time:	hh:mm	11:08		12:13	
Final Time:	hh:mm	11:38		12:43	
Test duration:	minutes	30		30	
Standard Meter Volume:	dscm	0.0274		0.0267	
Average Stack Temperature:	°C	130.1		145.1	
Average Stack Gas Velocity:	m/sec	12.3		22	
Stack Moisture:	%	2.1		4.4	
Dry Standard Stack Flow Rate:	dscm/min	48		82	
Actual Stack Flow Rate:	acm/min	73		131	
Dry Gas Molecular Weight:	g/g-mole	30.44		30.35	
Emission Results - Total VOCs					
		Run 1 (50% load)		**Run 2 (100% load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**
Total VOCs (as n-hexane)	0.36	<0.36	<0.00029	<0.37	<0.00051
Comments					
1. Passed QA/QC checks.					

AS4323.3: ODOUR					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Generator Stack			
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Time:	hh:mm	12:53		13:17	
Average Stack Temperature:	°C	130.1		145.1	
Average Stack Gas Velocity:	m/sec	12.3		22	
Stack Moisture:	%	2.1		4.4	
Dry Standard Stack Flow Rate:	dscm/min	48		82	
Wet Standard Stack Flow Rate:	scm/min	49		86	
Actual Stack Flow Rate:	acm/min	73		131	
Dry Gas Molecular Weight:	g/g-mole	30.44		30.35	
Emission Results - Odour Concentration					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Parameter		**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**	**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**
Odour concentration		1450	1180	1720	2460
Odour Results - Character, Intensity and Hedonic Tone					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Parameter		**Description**		**Description**	
Odour character		Gassy / exhaust / SO2 / slight sweet		Gassy / exhaust / SO2 / slight sweet	
Comments					
1. Passed QA/QC checks.					

COMBUSTION GAS DATA: USEPA METHODS 3A, 6C, 7E, 10					
Logistical Information					
Job Number:	1415-230				
Company Name:	Richgro				
Sampling Program:	AD Facility Stack Emissions Commissioning				
Source Identification:	SI/MS				
Sampling Personnel:	Flare Stack				
Analyser Model:	Testo-350				
Analyser ID:	TESTO-02				
Analyser Calibrations					
		Zero (start)	Zero (end)	Span (start)	Span (end)
USEPA M3A Calibration:	% CO_2	0.0	0.0	4.6	4.5
	% O_2	0.0	0.0	17.8	18.1
USEPA M6C Calibration:	ppm SO_2	0.0	0.0	103.3	104.0
USEPA M7E Calibration:	ppm NO	-1.0	0.0	200.3	199.0
	ppm NO_2	-0.2	-0.1	45.1	45.0
USEPA M10 Calibration:	ppm CO	-0.3	-0.7	262.0	259.0
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Monitoring Date:	dd/mm/yy	15/04/2015		15/04/2015	
Start Time:	hh:mm	16:25		17:38	
Final Time:	hh:mm	16:55		18:08	
Sampling Duration:	minutes	30		30	
Average Stack Temperature:	°C	1000.0		1000.0	
Average Stack Velocity:	m/sec	4.8		10.0	
Moisture:	%	3.1		1.5	
Dry Standard Stack Flow Rate :	dscm/min	47		100	
Actual Stack Flow Rate:	acm/min	225		470	
Dry Gas Molecular Weight:	g/g-mole	30.19		30.07	
Sampling Concentrations					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Oxygen	% O_2	9.7		10.9	
Carbon Dioxide	% CO_2	11.0		10.3	
Sulphur Dioxide	ppm SO_2	3.9		3.1	
Nitrogen Oxide	ppm NO	37.1		24.0	
Nitrogen Dioxide	ppm NO_2	1.3		0.7	
Total Oxides of Nitrogen	ppm as NO_2	38.3		24.7	
Carbon Monoxide	ppm CO	36.2		12.4	
Reportable Data - USEPA Method 3A: Oxygen (O_2) and Carbon Dioxide (CO_2)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL % vol.**	**Stack Concentration % vol.**		**Stack Concentration % vol.**	
Oxygen (O_2)	0.01	9.7		10.9	
Carbon dioxide (CO_2)	0.01	11		10.3	
Reportable Data - USEPA Method 6C: Sulphur Dioxide (SO_2)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Sulphur dioxide (SO_2)	2.9	11	0.0087	8.8	0.015
Reportable data - USEPA Method 7E: Oxides of Nitrogen (NO_X)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Nitrogen monoxide (NO)	1.3	50	0.039	32	0.054
Nitrogen dioxide (NO_2)	0.21	2.6	0.002	1.4	0.0024
Total oxides of nitrogen (NO_X as NO_2)	2.3	79	0.062	51	0.084
Reportable Data - USEPA Method 10: Carbon Monoxide (CO)					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Emission Rate (Dry) g/s**
Carbon monoxide (CO)	1.3	45	0.035	16	0.026
Comments					
1. Passed QA/QC checks					

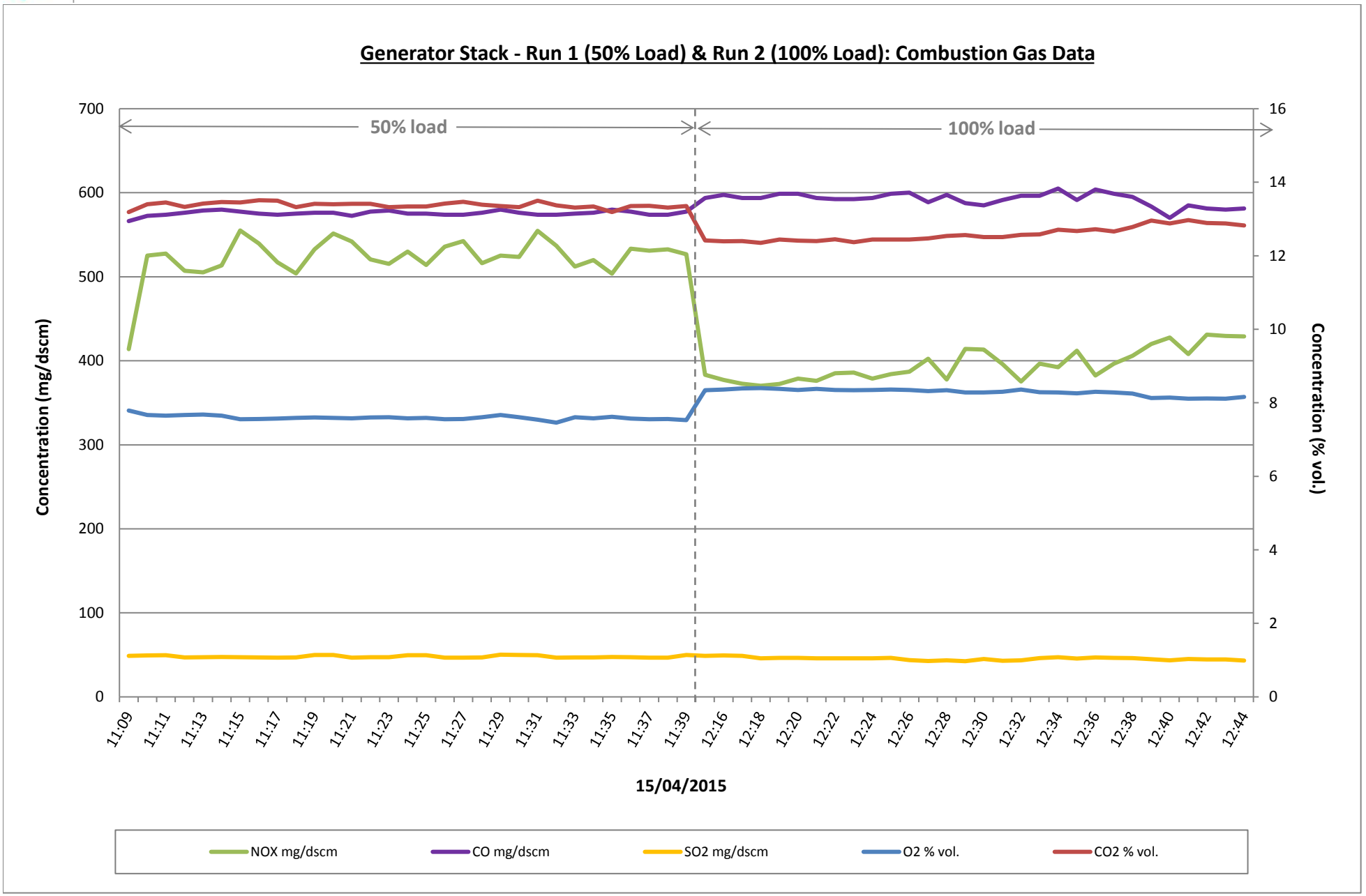
USEPA METHOD 11: HYDROGEN SULPHIDE					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Flare Stack			
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Start Time:	hh:mm	16:20		17:27	
Final Time:	hh:mm	16:50		17:57	
Test duration:	minutes	30		30	
Standard Meter Volume:	dscm	0.029		0.028	
Average Stack Temperature:	°C	1000.0		1000.0	
Average Stack Gas Velocity:	m/sec	4.8		10	
Stack Moisture:	%	3.1		1.5	
Dry Standard Stack Flow Rate:	dscm/min	47		100	
Actual Stack Flow Rate:	acm/min	225		470	
Dry Gas Molecular Weight:	g/g-mole	30.19		30.07	
Emission Results					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/s**
Hydrogen Sulphide	5.5	<5.5	<0.0043	<5.2	<0.0086
Comments					
1. Passed QA/QC checks.					

USEPA METHOD 18: TOTAL VOCs					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Flare Stack			
Sampling Data					
		Run 1 (50% load)		**Run 2 (100% load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Start Time:	hh:mm	16:20		17:27	
Final Time:	hh:mm	16:50		17:57	
Test duration:	minutes	30		30	
Standard Meter Volume:	dscm	0.0267		0.0286	
Average Stack Temperature:	°C	1000.0		1000.0	
Average Stack Gas Velocity:	m/sec	4.8		10	
Stack Moisture:	%	3.1		1.5	
Dry Standard Stack Flow Rate:	dscm/min	47		100	
Actual Stack Flow Rate:	acm/min	225		470	
Dry Gas Molecular Weight:	g/g-mole	30.19		30.07	
Emission Results - Total VOCs					
		Run 1 (50% load)		**Run 2 (100% load)**	
Analyte	**MDL mg/dscm**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/min**	**Stack Concentration mg/dscm**	**Mass Emission Rate (Dry) g/min**
Total VOCs (as n-hexane)	0.38	<0.38	<0.018	<0.35	<0.035
Comments					
1. Passed QA/QC checks.					

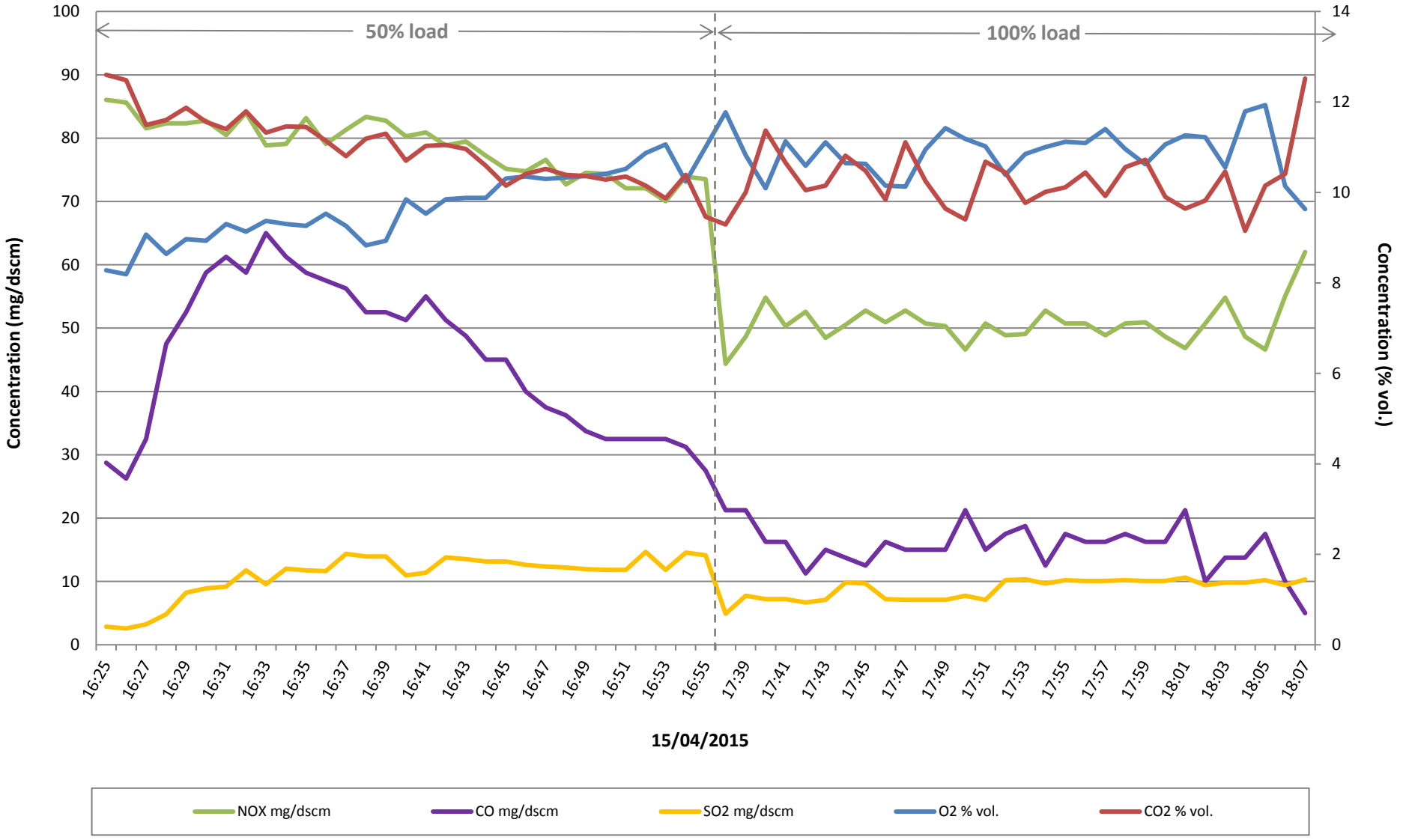
AS4323.3: ODOUR					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Flare Stack			
Sampling Data					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Time:	hh:mm	12:03		12:27	
Average Stack Temperature:	°C	1000.0		1000.0	
Average Stack Gas Velocity:	m/sec	4.8		10	
Stack Moisture:	%	3.1		1.5	
Dry Standard Stack Flow Rate:	dscm/min	47		100	
Wet Standard Stack Flow Rate:	scm/min	49		102	
Actual Stack Flow Rate:	acm/min	225		470	
Dry Gas Molecular Weight:	g/g-mole	30.19		30.07	
Emission Results - Odour Concentration					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Parameter		**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**	**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**
Odour concentration		215	174	279	472
Odour Results - Character, Intensity and Hedonic Tone					
		Run 1 (50% Load)		**Run 2 (100% Load)**	
Parameter		**Description**		**Description**	
Odour character		Gassy / SO2 / brick / burnt matches		Gassy / SO2 / brick / burnt matches	
Comments					
1. Passed QA/QC checks.					

AS4323.3: ODOUR					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Biofilter - Inlet			
Sampling Data					
		Run 1		**Run 2**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Time:	hh:mm	14:31		14:57	
Average Stack Temperature:	°C	25.0		25.0	
Average Stack Gas Velocity:	m/sec	7.4		7.4	
Stack Moisture:	%	1.5		1.5	
Dry Standard Stack Flow Rate:	dscm/min	246		246	
Wet Standard Stack Flow Rate:	scm/min	250		250	
Actual Stack Flow Rate:	acm/min	271		271	
Dry Gas Molecular Weight:	g/g-mole	28.85		28.85	
Emission Results - Odour Concentration					
		Run 1		**Run 2**	
Parameter		**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**	**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**
Odour concentration		2050	8530	2440	10200
Odour Results - Character, Intensity and Hedonic Tone					
		Run 1		**Run 2**	
Parameter		**Description**		**Description**	
Odour character		Fatty acid/rancid		Fatty acid/rancid	
Comments					
1. Passed QA/QC checks.					

AS4323.3: ODOUR					
Logistical Information					
Job Number:		1415-230			
Company Name:		Richgro			
Sampling Program:		AD Facility Stack Emissions Commissioning			
Sampling Personnel:		SI / MS			
Source Identification:		Biofilter - Outlet			
Sampling Data					
		Run 1		**Run 2**	
Date:	dd/mm/yy	15/4/2015		15/4/2015	
Time:	hh:mm	13:42		14:07	
Average Stack Temperature:	°C	22.0		22.0	
Average Stack Gas Velocity:	m/sec	3.7		3.7	
Stack Moisture:	%	1.5		1.5	
Dry Standard Stack Flow Rate:	dscm/min	125		125	
Wet Standard Stack Flow Rate:	scm/min	127		127	
Actual Stack Flow Rate:	acm/min	136		136	
Dry Gas Molecular Weight:	g/g-mole	28.85		28.85	
Emission Results - Odour Concentration					
		Run 1		**Run 2**	
Parameter		**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**	**Stack Concentration ou/dscm**	**Mass Emission Rate (Wet at STP) ou.m3/s**
Odour concentration		724	1530	789	1670
Odour Results - Character, Intensity and Hedonic Tone					
		Run 1		**Run 2**	
Parameter		**Description**		**Description**	
Odour character		Fatty acid/rancid		Fatty acid/rancid	
Comments					
1. Passed QA/QC checks.					


Generator Stack - Run 1 (50% Load) & Run 2 (100% Load): Combustion Gas Data
50% load
100% load
Concentration (mg/dscm)
Concentration (% vol.)
700
600
500
400
300
200
100
0
16
14
12
10
8
6
4
2
0
11:09
11:11
11:13
11:15
11:17
11:19
11:21
11:23
11:25
11:27
11:29
11:31
11:33
11:35
11:37
11:39
12:16
12:18
12:20
12:22
12:24
12:26
12:28
12:30
12:32
12:34
12:36
12:38
12:40
12:42
12:44
15/04/2015
NOX mg/dscm
CO mg/dscm
SO2 mg/dscm
O2 % vol.
CO2 % vol.

Flare Stack - Run 1 (50% Load) & Run 2 (100% Load): Combustion Gas Data



APPENDIX A

MPL – Analytical Report and Chain of Custody

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
enquiries@envirolabservices.com.au
www.envirolabservices.com.au

CERTIFICATE OF ANALYSIS 126723

Client:
Emission Assessments
Unit 6, 35 Sustainable Avenue
Bibra Lake
WA 6163

Attention: Stuart Inglis

Sample log in details:

Your Reference:	**1415-230**
No. of samples:	5 Liquid Samples
Date samples received:	20/04/2015
Date completed instructions received:	20/04/2015

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by:	1/05/15
Date of Preliminary Report:	Not Issued
Issue Date:	24/04/15

Results Approved By:

Jacinta Hurst
Laboratory Manager

Miscellaneous Inorganics						
Our Reference:	UNITS	126723-1	126723-2	126723-3	126723-4	126723-5
Your Reference	----------	1415230-001	1415230-004	1415230-007	1415230-010	1415230-017
Date Sampled	----------	15/04/2015	15/04/2015	15/04/2015	15/04/2015	15/04/2015
Type of sample		0.05M CdSO4	0.05M CdSO4	0.05M CdSO4	0.05M CdSO4	0.05M CdSO4
Date prepared	-	22/04/2015	22/04/2015	22/04/2015	22/04/2015	22/04/2015
Date analysed	-	22/04/2015	22/04/2015	22/04/2015	22/04/2015	22/04/2015
Hydrogen Sulfide*	mg/L	<2	<2	<2	<2	<2
Volume	mL	71	76	75	81	78

Method ID	Methodology Summary
Inorg-051	Sulphide determined titrimetrically based on APHA latest edition 4500 S2- F.

QUALITY CONTROL Miscellaneous Inorganics	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			22/04/2015	[NT]	[NT]	LCS-1	22/04/2015
Date analysed	-			22/04/2015	[NT]	[NT]	LCS-1	22/04/2015
Hydrogen Sulfide*	mg/L	2	Inorg-051	<2	[NT]	[NT]	LCS-1	100%
Volume	mL	1		<1	[NT]	[NT]	[NR]	[NR]

Report Comments:

INS: Insufficient sample for this test
NR: Not requested
<: Less than
NA: Test not required

NT: Not tested
PQL: Practical Quantitation Limit
>: Greater than

Quality Control Definitions

LCS: Laboratory Control Sample
RPD: Relative Percent Difference

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria:

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes and LCS: Generally 70-130% for inorganics/metals & 60-140% for organics is acceptable.

APPENDIX B

NMI – Analytical Report and Chain of Custody

REPORT OF ANALYSIS

Report No. RN1064703

Client	: EMISSION ASSESSMENTS PTY LTD	**Job No.**	: EMIS02/150417
	UNIT 6 / 35 SUSTAINABLE AVENUE	**Quote No.**	: QT-02018
	BIBRA LAKE WA 6163	**Order No.**	: PO1415-175
		Date Sampled	: 15-APR-2015
		Date Received	: 17-APR-2015
Attention	: STUART INGLIS	**Sampled By**	: CLIENT
Project Name	:		
Your Client Services Manager	: RICHARD COGHLAN	**Phone**	: (02) 94490161

Lab Reg No.	Sample Ref	Sample Description
N15/009484	.	CARBON TUBE 1415230-002 GENERATOR-TVOCS-R1 (50%) 15/04/2015
N15/009485	.	CARBON TUBE 1415230-005 GENERATOR-TVOCS-R1 (100%) 15/04/2015
N15/009486	.	CARBON TUBE 1415230-008 FLARE-TVOCS-R1 (50%) 15/04/2015
N15/009487	.	CARBON TUBE 1415230-011 FLARE-TVOCS-R1 (100%) 15/04/2015

Lab Reg No.		N15/009484	N15/009485	N15/009486	N15/009487	
Sample Reference	**Units**	.	.	.	.	**Method**
Dates						
Date extracted		22-APR-2015	22-APR-2015	22-APR-2015	22-APR-2015	
Date analysed		23-APR-2015	23-APR-2015	23-APR-2015	23-APR-2015	
Volatiles						
TVOC	ug	< 10	< 10	< 10	< 10	NGCMS_1120

Danny Slee, Section Manager
Organic - NSW
Accreditation No. 198

24-APR-2015

REPORT OF ANALYSIS

Report No. RN1064703

Client	: EMISSION ASSESSMENTS PTY LTD	**Job No.**	: EMIS02/150417
	UNIT 6 / 35 SUSTAINABLE AVENUE	**Quote No.**	: QT-02018
	BIBRA LAKE WA 6163	**Order No.**	: PO1415-175
		Date Sampled	: 15-APR-2015
		Date Received	: 17-APR-2015
Attention	: STUART INGLIS	**Sampled By**	: CLIENT
Project Name :			
Your Client Services Manager	: RICHARD COGHLAN	**Phone**	: (02) 94490161

Lab Reg No.	Sample Ref	Sample Description
N15/009488	.	CARBON TUBE 1415230-018 BLANK 15/04/2015

Lab Reg No.		N15/009488				
Sample Reference	Units	.				Method
Dates						
Date extracted		22-APR-2015				
Date analysed		23-APR-2015				
Volatiles						
TVOC	ug	<10				NGCMS_1120

Danny Slee, Section Manager
Organic - NSW
Accreditation No. 198

24-APR-2015

NATA
ACCREDITED FOR
TECHNICAL
COMPETENCE

Accredited for compliance with ISO/IEC 17025.
This report shall not be reproduced except in full.
Results relate only to the sample(s) tested.

This Report supersedes reports: *RN1064702*

APPENDIX C

The Odour Unit – Analytical Report and Chain of Custody

THE ODOUR UNIT (WA) PTY LTD

THE ODOUR UNIT

Showroom 1
16 Hulme Court
Myaree
WA 6154

Phone: +61 8 9330 9476
Facsimile: +61 8 9330 1868
Email: tschulz@odourunit.com.au
Internet: www.odourunit.com.au
ABN: 70 126 439 076

NATA

Accreditation Number: 14974

Form 06 - Perth Laboratory
Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	Emission Assessments	Telephone	(08) 9494 2958
Contact	Stuart Inglis	Facsimile	(08) 9494 2959
Sampling Site	Richgro Jandakot	Email	stuart@emissionassessments.com.au
Sampling Method	Drum & Pump	Sampling Team	Emission Assessments

Order details:

Order requested by	Stuart Inglis	Order accepted by	John Hurley
Date of order	April 2015	TOU Project #	W1789R.03
Order number	TBA	Project Manager	Clayton Hough
Signed by	TBA	Testing operator	Clayton Hough

Investigated Item	Odour concentration in odour units 'ou', determined by sensory odour concentration measurements, of an odour sample supplied in a sampling bag. Odour character is also assessed, however, AS4323.3:2001 and NATA accreditation do not cover the performance of this service. Where parties other than The Odour Unit perform the dilution of samples, the result that has been modified by the dilution factor is not covered by The Odour Units NATA accreditation. Sample collection using a hood or IFH (and calculation of the SOER) is not covered by The Odour Units NATA accreditation.
Identification	The odour sample bags were labelled individually. Each label recorded the testing laboratory, sample number, sampling location (or Identification), sampling date and time, dilution ratio (if dilution was used) and whether further chemical analysis was required.
Method	The odour concentration measurements were performed using dynamic olfactometry according to the Australian Standard 'Determination of Odour Concentration by Dynamic Olfactometry AS/NZS4323.3:2001. The odour perception characteristics of the panel within the presentation series for the samples were analogous to that for butanol calibration. Any deviation from the Australian standard is recorded in the 'Comments' section of this report.
Measuring Range	The measuring range of the olfactometer is $2^2 \leq \chi \leq 2^{18}$ ou. If the measuring range was insufficient the odour samples will have been pre-diluted. This is specifically mentioned with the results.
Environment	The measurements were performed in an air- and odour-conditioned room. The room temperature is maintained at 25°C or less, with temperature fluctuations of less than ± 3 °C.
Measuring Dates	The date of each measurement is specified with the results.
Instrument Used	The olfactometer used during this testing session was: ODORMAT SERIES V02 The software used during this testing session was: ODORMAT V3.0
Instrumental Precision	The precision of this instrument (expressed as repeatability) for a sensory calibration must be $r \leq 0.477$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V02: $r = 0.168$ (18th & 19th November, 2014) Compliance – Yes
Instrumental Accuracy	The accuracy of this instrument for a sensory calibration must be $A \leq 0.217$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V02: $A = 0.057$ (18th & 19th November, 2014) Compliance – Yes
Lower Detection Limit (LDL)	The LDL for the olfactometer has been determined to be 16 ou (four times the lowest dilution setting)
Traceability	The measurements have been performed using standards for which the traceability to the national standard has been demonstrated. The assessors are individually selected to comply with fixed criteria and are monitored in time to keep within the limits of the standard. The results from the assessors are traceable to primary standards of n-butanol in nitrogen.

NATA

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This report shall not be reproduced, except in full.

Date: Thursday, 16 April 2015

Report Number / Panel Roster Number: PER20150416

J. Hurley
State Manager WA

C. Hough
Authorised Signatory

THE ODOUR UNIT (WA) PTY LTD

Accreditation Number: 14974

Odour Sample Measurement Results

Sample Location	TOU Sample ID	Sampling Date & Time	Analysis Date & Time	Panel Size	Valid ITEs	Nominal Sample Dilution	Actual Sample Dilution (adjusted for Temperature)	Sample Odour Concentration (as analysed, in the bag) (ou)	Sample Odour Concentration (Final, allowing for dilution) (ou)	Odour Character
Generator 50% R1	PC15168	15/04/2015 @ N/A	16/04/2015 @ 12:53hrs	4	8	-	-	1,450	1,450	Gassy / exhaust / SO_2 / slight sweet
Generator 100% R2	PC15169	15/04/2015 @ N/A	16/04/2015 @ 13:17hrs	4	8	-	-	1,720	1,720	Gassy / exhaust / SO_2 / slight sweet
Flare 50% R1	PC15170	15/04/2015 @ N/A	16/04/2015 @ 12:03hrs	4	8	-	-	215	215	Gassy / SO_2 / brick / burnt matches
Flare 100% R2	PC15171	15/04/2015 @ N/A	16/04/2015 @ 12:27hrs	4	8	-	-	279	279	Gassy / SO_2 / brick / burnt matches

THE ODOUR UNIT (WA) PTY LTD

Accreditation Number: 14974

Odour Sample Measurement Results

Sample Location	TOU Sample ID	Sampling Date & Time	Analysis Date & Time	Panel Size	Valid ITEs	Nominal Sample Dilution	Actual Sample Dilution (adjusted for Temperature)	Sample Odour Concentration (as analysed, in the bag) (ou)	Sample Odour Concentration (Final, allowing for dilution) (ou)	Odour Character
Biofilter Inlet R1	PC15172	15/04/2015 @ N/A	16/04/2015 @ 14:31hrs	4	8	-	-	2,050	2,050	Fatty acid / rancid
Biofilter Inlet R2	PC15173	15/04/2015 @ N/A	16/04/2015 @ 14:57hrs	4	8	-	-	2,440	2,440	Fatty acid / rancid
Biofilter Outlet R1	PC15174	15/04/2015 @ N/A	16/04/2015 @ 13:42hrs	4	8	-	-	724	724	Fatty acid / rancid
Biofilter Outlet R2	PC15175	15/04/2015 @ N/A	16/04/2015 @ 14:07hrs	4	8	-	-	789	789	Fatty acid / rancid

THE ODOUR UNIT (WA) PTY LTD

Accreditation Number: 14974

Odour Panel Calibration Results

Reference Odorant	Reference Odorant Panel Roster Number	Concentration of Reference gas (ppm)	Panel Target Range for n-butanol (ppb)	Measured Concentration (ou)	Measured Panel Threshold (ppb)	Does this panel calibration measurement comply with AS/NZS4323.3:2001 (Yes / No)
n-butanol	PER20150416	50	$20 \leq \chi \leq 80$	1,450	35	Yes

Comments: None.

END OF DOCUMENT

BIOGASS RENEWABLES PTY LTD

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

(INCLUDING BIO METHANE UPGRADE PLANT)

FEBRUARY 2019

OUR REFERENCE: 23621-4-18204

Rochdale Holdings Pty Ltd A.B.N. 85 009 049 067 trading as:
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DOCUMENT CONTROL PAGE

ENVIRONMENTAL NOISE ASSESSMENT

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EDINBURGH - SOUTH AUSTRALIA
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Job No: 18204

Document Reference : 23621-4-18204

FOR

BIOGASS RENEWABLES PTY LTD

DOCUMENT INFORMATION			
Author:	**Paul Drew**	**Checked By:**	
Date of Issue :	**6th February 2019**		

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Revision	**Description**	**Date**	**Author**	**Checked**
1	**Report**	**17/10/2018**	**PD**	**GH**
2	**Addition of BioFilter Fan details**	**19/12/2018**	**PD**	
3	**Revised**	**9/11/2018**	**PD**	
4	**Additional noise sources / Bio Methane Upgrade Plant**	**6/2/2019**	**PD**	

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A Sound Power Levels

B Noise Contour Plots

1. INTRODUCTION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed Anaerobic Digestion (AD) facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The acoustic modelling and assessment is based on design data and plan layouts provided in October 2018 and previous measurement of the major noise sources at a similar facility in Jandakot, Western Australia.

An aerial image of the area surrounding Lot A505, 1-2 Gidgie Courtis shown in Figure 1.

Figure 1 - Site Location and Key receptors – Lot A505, 1-2 Gidgie Court, Edinburgh

The nearest residential area is 470m to the south-west, with another residential area located 1,400m to the east. The proposed site is within an Urban Employment zone, with General Industry surrounding the site. To the south-east are established sporting facilities including a golf course and shooting range.

Trucks of size ranging up to 25 tonne B-doubles will bring material to site, reversing into the facility Reception Hall via fast acting roller doors, which will be closed when not providing access to trucks (for odour control reasons). Trucks will be unloaded within the Reception Hall. Acoustically solid fences surround the digestion area and the truck access areas.

The major external noise sources are three generators, which are fitted with acoustic attenuation packages, two gas flares (generally on standby) and a number of gas and liquid pumps at the base of digestion tanks. Both flares would normally only operate if a number of generators were shut down. Trucks will generate noise within the site when entering and reversing, however truck movements will be at low speed and tipping will occur within the Receivals Hall, thereby limiting truck noise emission duration and level from the site.

A 3D diagram of the proposed facility layout is shown in Figure 2.

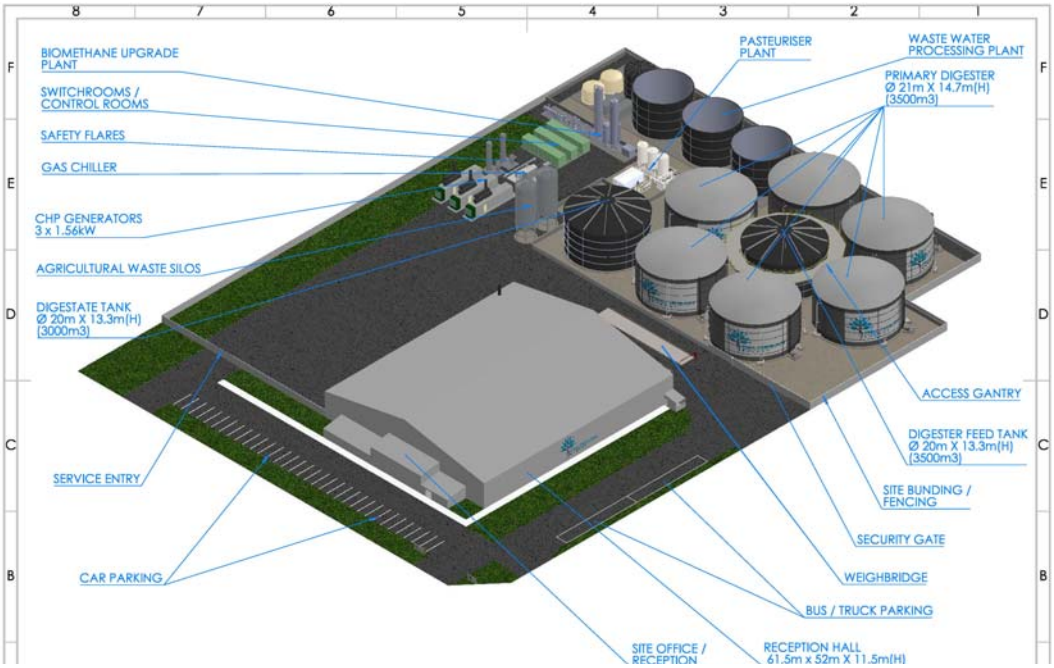


Figure 2 – AD Facility Layout

This assessment has been based on the following:

- The proposed site layout and equipment as shown in document "Lot 505 Assembly V5.pdf" issued 22nd May 2018.
- Previous noise measurements for the Richgro Jandakot AD Facility.
- Acoustic data for a similar Bio Methane Unit provided by the supplier.

2. ASSESSMENT CRITERIA

The proposed site is located within an Urban Employment Zone of the Salisbury Council Development Plan. The premises surrounding the proposed site at Lot A505, 1-2 Gidgie Court are used for automotive manufacturing (General Industry) or equipment hire (premises to the east of Gidgie Court). The premises on the western boundary (71 – 75 Woomera Avenue) is occupied by the North Adelaide Waste Management Authority, consisting of offices at the front (day hours) and recycling building currently operating 6am – midnight.

Residential areas are located to the south-west, 470m from the proposed site.

The Development Plan's interface between land uses principle of development control 7 states:

> *Development that emits noise (other than music noise) should include noise attenuation measures that achieve the relevant Environment Protection (Noise) Policy criteria when assessed at the nearest existing noise sensitive premises.*

Development Plan makes specific reference to the *Environment Protection (Noise) Policy 2007*.

The policy provides noise levels (L_{Aeq}) not to be exceeded at noise sensitive receivers, based on the principally promoted land use where the noise source and the noise receivers are located. The relevant criteria are:

Residential Zone

- 52 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 45 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#
- 60 dB(A) L_{Amax} between the hours of 10pm and 7am when measured;

At the nearest noise-affected premises in the City of Salisbury Residential zone in accordance with the *Environmental Protection (Noise) Policy 2007*.

Urban Employment Zone

- 59 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 50 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#

When measured and adjusted# at noise-affected premises in the City of Salisbury Urban Employment zone in accordance with the Environmental Protection (Noise) Policy.

The measured noise levels should be adjusted in accordance with the *Environmental Protection (Noise) Policy 2007* by the inclusion of a penalty for each characteristic where tonal/modulating/impulsive/low frequency characteristics are present.

The dominant noise sources at distance are the generators, which have significant acoustic attenuation packages and based on measurement at Richgro Jandakot will not have dominant noise characteristics at the residential area. Therefore no adjustment for noise characteristic applies for the proposed noise emissions to the residential area.

However some noise characteristics may be audible at the adjacent premises and appropriate adjustment are required.

3. METHODOLOGY

Noise levels were predicted using the acoustic software SoundPlan using the Concawe algorithm for Pasquill Class 6 climatic conditions. The sound power levels used in the acoustic modelling are tabulated in the Appendix A. Sound power levels were determined from measurement of a similar AD Plant at Jandakot, Western Australia.

The proposed AD facility is to operate continuously.

The AD facility operations consist of continuous operation of bio-filtration, digesters and associated pumps and fans, pasteuriser, biomethane upgrade plant, generators and safety flares (normally on standby). Intermittent noise will be generated on site by entry / exit of trucks and operation of high-speed roller doors.

Information relating to vehicle movements:

- A maximum (worst case scenario, otherwise could be as low as 35) of 50 trucks are likely to be entering site, comprised of:
    - Rigid trucks – 34 per day
    - Semitrailer trucks – 12 per day
    - B-double trucks – 4 per day
- All vehicles except for the B-double trailers will be loading/unloading within the receival shed.
    - B-doubles will take approximately 1 – 2 hours to fully unload

4. PREDICTED NOISE EMISSIONS

Predicted noise contour plots for 'worst case' winds for the proposed operations are shown in Appendix B.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are provided. The required heights are 3m adjacent the generators and adjacent the truck access area, as shown in plot 20W, Appendix B.

The generators and flares are capable of emitting noise exceeding the noise criteria at the adjacent premises. Noise mitigation by selection of attenuated generator package units rated at 65 dB(A) at 1m and provision of acoustic barrier walls around the generators and flare units is shown to attenuate noise emissions within acceptable levels.

TABLE 4.1 PREDICTED NOISE LEVELS

Receptor	Night 3 Generators		Night Two Flare Units		Day 3 Generators Trucks		Compliance
	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	
Residences							
Criteria	**45**	**45**	**45**	**45**	**52**	**52**	
R1: 20 Diruwa Drive, Salisbury North	27	27	24	24	36	36	Yes
R2: 60 Hogarth Rd, Elizabeth South	12	12	12	12	13	13	Yes
Adjacent Premises							
Criteria	**50**	**50**	**50**	**50**	**59**	**59**	
I1: 59-61 Woomera Ave (Coates Hire)	40	45^{t}	39	44^{t}	41	49^{ti}	Yes
I2: 4 Gidgie Crt	39	44^{t}	38	43^{t}	38	46^{ti}	Yes
I3: 3 Gidgie Crt	44	49^{t}	43	48^{t}	44	52^{ti}	Yes
I4: 71-75 Woomera Ave (NAWMA)	45	50^{t}	42	47^{t}	51	59^{ti}	Yes
I5: 76 Woomera Ave	42	47^{t}	40	45^{t}	51	59^{ti}	Yes
I6: 78 Woomera Ave	40	45^{t}	37	42^{t}	51	59^{ti}	Yes

The noise emissions for Night scenario two flares is dominated by pump noise, flare noise levels are relatively low compared to the overall predicted level. Characteristic adjustment for tonal noise only of 5 dB(A).

The noise emission for day scenario is conservative as trucks have been modelled at the passby emission level to consider busy periods where noise may be present for much of the 15 minute assessment period. Generally the L_{Aeq} noise level will be lower as trucks are only in the yard for short periods while entering or leaving the receival facility. Adjustments for tonal characteristic and impulsive characteristic have been applied, an adjustment of +8 dB(A) to the predicted noise level at the receptor premises.

5. NOISE MITIGATION MEASURES

The following noise mitigation measures are required to comply with the requirements of the Regulations:

- Fan selection and attenuation of the Bio-filter blower outlets to achieve a combined sound power of no more than 89 dB(A) external. This assessment is based on three fans, being "Fans Direct: SWS1-D51B Size 365-100% CS90 Fans, 23 kW with fan speed of 1370 rpm". Each fan discharge outlet to be fitted with 2D cylindrical podded silencer, minimum 1m gap (duct), 1D unpodded silencer.

- Section of 3m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the generators as shown in plot 20W, Appendix B.

- Section of 3.0m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the truck access area as shown in plot 20W, Appendix B.

- Generators to be fitted with acoustic attenuation package equivalent to those provided to generators at Richgro Jandakot site, rated at 65 dB(A) at 1m.

- Acoustic barrier walls to be installed around the generators and flare units as shown in plot 20W1, Appendix B. The walls may be constructed metal framing with roof sheeting or coolroom panel with a mass density of at least 10 Kg/m^2 for the combination. The wall on the western side of the generators and flare units should have a minimum mass density of 17 Kg/m^2 for the lower 5 meters, and if a lightweight construction, be a cavity wall type construction with minimum of 100mm between each side with 100mm acoustic insulation infil to assist in the control of lower frequency noise emissions. (90mm sandwich panel one side, 100mm channel with roof sheeting on the other side with 100mm fiberglass insulation infil for example). Concrete tilt-up panel would also be suitable.

- Bio Methane Upgrade Plant to be fitted with manufacturers proprietary acoustic enclosure, sound power of Bio Methane Unit including blower not to exceed 91 dB(A). Section of 4.5m high acoustic barrier wall between electrical buildings and alone east side of Bio Methane Plant as shown in Appendix B, plot 20W1

6. CONCLUSION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed AD facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are installed adjacent the generators and truck access area to ensure compliance at the adjacent premises to the west. The required heights of acoustic barriers are shown in plot 20W1, Appendix B.

APPENDIX A

Sound Power Levels

Acoustic Model Sound Power Levels

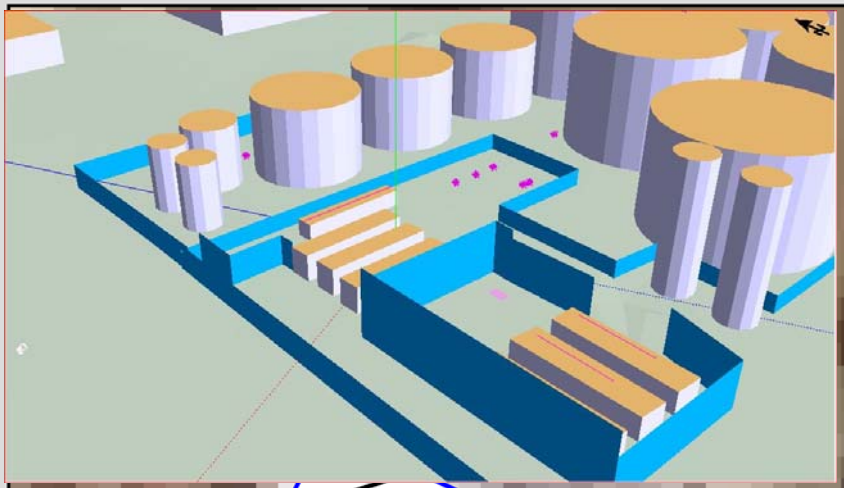
Sound Power in dB

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Generator 1	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 2	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 3	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Biofilter Blower	89.1	81	86	84	89	85	83	86	87	88	86	80	78	82	77	74	77	72	71	70	68	75	84	71	69	68	65
AD Flare 1 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
AD Flare 2 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
Digester Feed Tank - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digestate Feed Tank - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Process Water - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Inlet Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Pasteurizer - Outlet Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Bio-methane Blower	87	79	84	82	87	82	81	84	85	86	84	78	76	80	75	72	75	70	69	68	66	73	82	69	67	66	63
Bio-methane unit	88.2	86	88	86	85	90	84	80	85	78	83	81	80	82	81	78	77	78	76	74	74	74	73	69	67	66	63
Gas Chiller	87	79	84	82	87	82	81	84	85	86	84	78	76	80	75	72	75	70	69	68	66	73	82	69	67	66	63
25 Ton Truck	100.1	92	95	109	100	94	110	98	98	98	95	91	91	91	92	90	89	88	88	87	87	84	79	77	74	72	73
12 Ton Truck Moving	94.3	94	105	101	102	96	108	90	92	88	84	83	85	87	85	82	83	85	78	77	78	74	74	71	69	67	68

APPENDIX B

Noise Contour Plots



3.5m
3.0m
6.0m
7.5m
5.0m
7.5m
5.0m
3.0m
3.0m

Legend
Main building
Wall
Industrial sources
Line source
Area source

HERRING STORER ACOUSTICS

Ref: 18204 Run: 20W1
Date: 5/2/2019

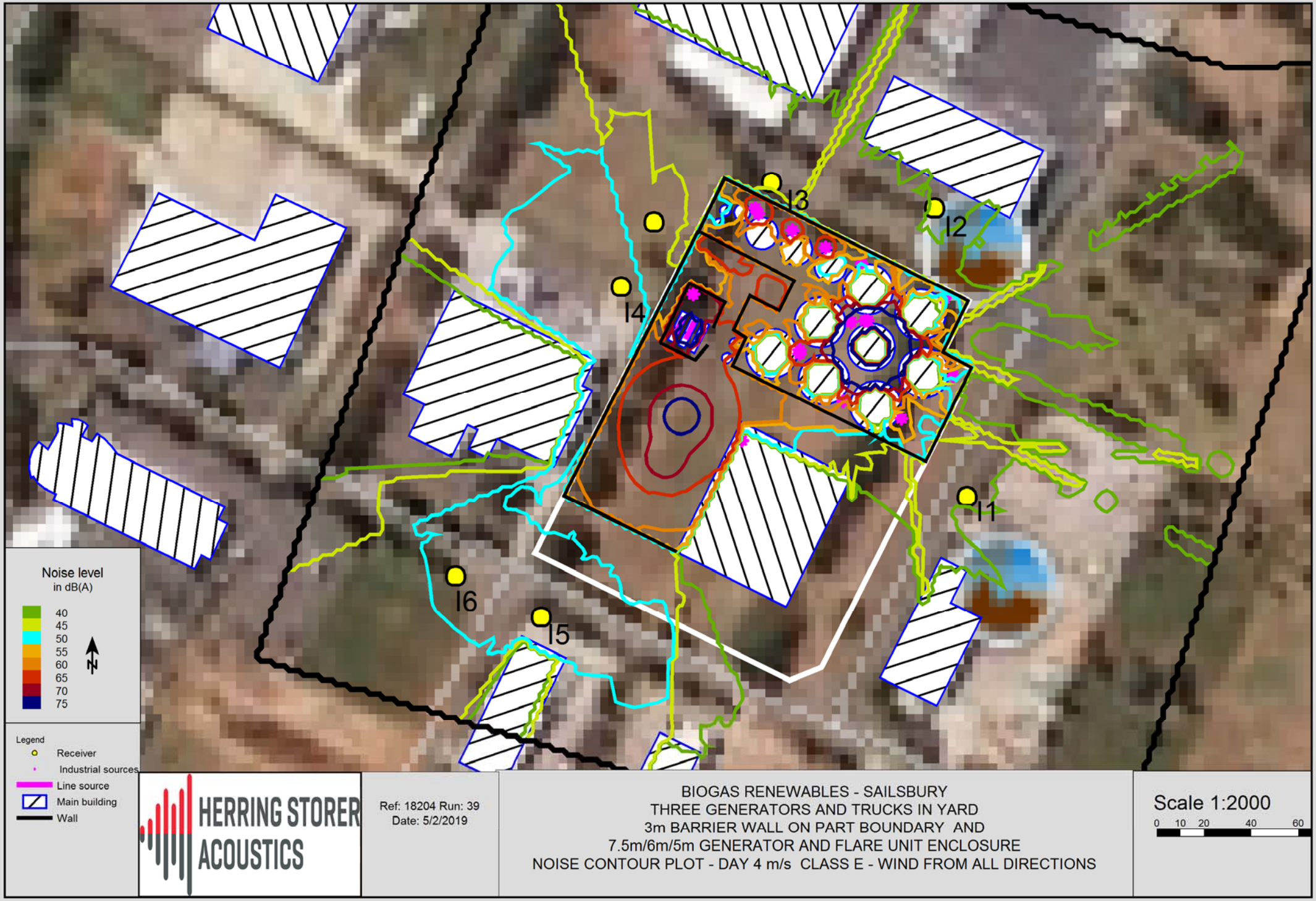
BIOGAS RENEWABLES - SAILSBURY
3m BARRIER WALL ON BOUNDARY AND
7.5m WALL ON WEST SIDE OF GENERATORS AND FLARE
UNITS, 5.0/6.0 m TO OTHER GENERATOR AND FLARE UNIT ENCLOSURE WALLS
3.5M WALL ON WEST SIDE OF BIO METHANE UPGRADE PLANT

Scale 1:1200
0 5 10 20 30


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources point
Line source
Main building
Wall
Area source
HERRING STORER ACOUSTICS
Ref: 18204 Run: 35
Date: 1/2/2019
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT, BU
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE - 45 dB(A)
Scale 1:2000
0 10 20 40 60


Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
Legend
Receiver
Industrial sources
Line source
Main building
Wall
Wyatt Rd
Sturton Rd
Tappa Rd
Kalurna Ave
Bolivar Rd
Oronga St
Parratta St
Carrin St
Illara St
Perry St
Arura Rd
Moronga St
Leila Ave
Camira Way
Kuipna Dr
Horwood Rd
Plough St
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
McCormack Crescent
Harold Rd
Diment Rd
West Ave
Tugger Way
Woomera Ave
Parling Ave
Kettering Rd
Willison Rd
Jeffries Rd
Goodman Rd
Bayer Rd
Grainger Rd
Philip Hwy
Edinburgh
R1
R2
I1
I2
I3
I4
I5
I6
HERRING STORER ACOUSTICS
Ref: 18204 Run: 37
Date: 5/2/2019
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources point
Line source
Main building
Wall
Area source
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 36
Date: 5/2/2019
BIOGAS RENEWABLES - SAILSBURY - NO GENERATORS, FLARING
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m ENCLOSURE TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE 45 dB(A)
Scale 1:2000
0 10 20 40 60


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 39
Date: 5/2/2019
BIOGAS RENEWABLES - SAILSBURY
THREE GENERATORS AND TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:2000
0 10 20 40 60

HERRING STORER ACOUSTICS

Ref: 18204 Run: 40
Date: 5/2/2019

BIOGAS RENEWABLES - SAILSBURY
3 GENERATORS OPERATING WITH TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS

Scale 1:15000
0 100 200 400

Intended for
Emissions Assessments Pty Ltd

Date
February 2019

BIOGASS RENEWABLES
SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

RAMBOLL

BIOGASS RENEWABLES
SALISBURY ANAEROBIC DIGESTION PLANT AIR QUALITY ASSESSMENT

Revision	**V4**
Date	**5/2/2019**
Made by	**Martin Parsons**
Checked by	**Ruth Peiffer**
Approved by	**Nick Houldsworth**

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1. INTRODUCTION

1.1 Background

Biogass Renewables Pty Ltd (Biogass) are proposing to develop an Anaerobic Digestion Plant (the Plant) at the parks precinct in Edinburgh, South Australia. The premises are located at A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, South Australia. The location of the proposed facility is shown in Figure 1, with the nearest sensitive receptors being on the perimeter of the plant boundary.

Emissions Assessments Pty Ltd (Emissions Assessments) requested Ramboll Australia Pty Ltd (Ramboll) undertake an air dispersion modelling assessment to determine the likely air quality impacts associated with routine operations and a flaring scenario for the Plant. This report presents the approach, methodology and results of air dispersion modelling for the Plant operating under each of the modelled scenarios. The maximum predicted ground level concentrations (GLCs) of the modelled compounds have been compared against the relevant ambient air quality criteria.

1.2 Overview of Process

The Plant will use organic waste to produce biogas (methane) through an anaerobic digestion process. The anaerobic digestion process is a fully enclosed system.

The organic waste (100,000 tonnes per annum [tpa] of food waste, 25,000 tpa of grain dust) is received, stored and pre-processed in a purpose built, sealed and fully enclosed negative pressure structure, before being pumped in a continuous process to a digester feed tank then onto one of six digester tanks, where it is stirred and agitated at intervals to encourage the release of biogas. An automated system regulates the necessary parameters such as pH and temperature. The digester breaks down the material to produce biogas, comprising approximately methane, carbon dioxide, water and hydrogen sulphide.

The biogas is collected under a fire resistant, double membrane dome on top of each digester. A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, known as biomethane.

The biomethane will then be fed to a power plant, which drives a generator to produce electricity for onsite use by Biogass. The digestion tanks harvest the steam and hot water from the power plant, which is used to stabilise the temperature of the biomass in the digestion and storage tanks.

Figure 1: General Location of the proposed Biogass Facility

1.3 Details of Process

An overview of the layout of the Plant is shown in Figure 2 with detailed description of the operation provided in the following sections.

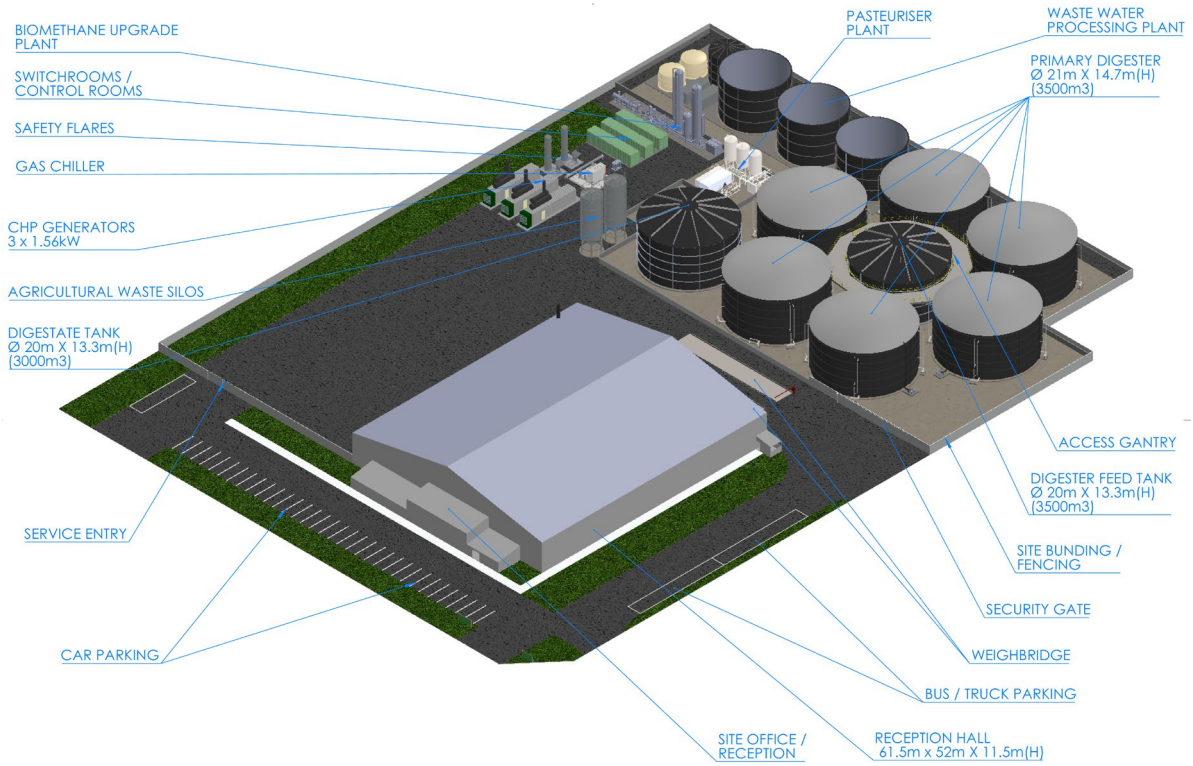

Figure 2: Layout of Plant

Source: Emissions Assessments

1.3.1 Receivals Hall

The waste is received in the receivals hall which is a 60 m x 52 m x 11.5 m high hooped roof building. The receivals hall is fitted with concrete bunkers, graded floor and drainage sump. The receivals hall will be under negative pressure and connected to the fully enclosed, single stack biofilter.

All vehicle entry points to process buildings will be via fast acting roller shutter doors which open and close on a pressure switch. All doors associated with process buildings will be connected to an alarm system which alerts operators in the event of doors being left open. Doors will only be opened for entry and exit of trucks with doors sealed before unloading occurs.

The solid and semi-solid waste will be deposited into graded bunkers with liquid waste pumped directly into a sump, for subsequent pumping to a liquid storage tank. Trucks are washed before departure with all wastewater draining to the sump for processing in the digestion system.

1.3.2 Staging Process (no emissions)

Blended and balanced feedstock is pumped in sealed pipes to a fully enclosed digester feed tank where it is mixed and warmed using heat from the Plant's biogas generators.

1.3.3 Anaerobic Digestion (no emissions)

Feedstock is pumped daily in sealed pipes from the digester feed tank to the primary digester tanks. These tanks are interoperable or can be isolated. The digesters are warmed using heat from the Plant's biogas generators. Biogas accumulates in the gas domes and can be positively displaced by pumping air between the gas dome's membranes.

1.3.4 Digestate Storage and Reuse (no emissions)

On a daily basis, digestate is pumped in sealed pipes to a digestate storage tank. The digestate will be unloaded onto offtake vehicles within the Receivals Hall for transport offsite.

1.3.5 Biogas Processing and Safety Flare

Biogas in the domes is positively displaced and drawn off in sealed gas pipes. The gas will then pass through a biomethane upgrade plant which will be used to upgrade the biogas to a methane-rich product gas, known as biomethane.

The entire gas management system is connected to an enclosed gas flare system comprising two flares. Gas can be directed to a flare at all gas storage and processing stages so as to bypass any equipment processing failure that may occur. The flare will only be operated on an emergency basis, or when one of the generators is not operating for routine maintenance (estimated 12 days per year), or in the unlikely event that all generators fail (worst case estimated 7 days).

1.3.6 Power and Heat Generation and Application

Clean methane gas, scrubbed and separated (carbon dioxide fraction removed) is compressed as fuel for three generators. Energy generated will be used to power the anaerobic digestion plant. The balance will supply 100% of Biogass' onsite energy requirements. Heat from the generator will be captured via a heat exchanger to heat the digester feed tank and the primary digesters.

2. ATMOSPHERIC EMISSIONS

2.1 Emission Sources

The atmospheric emissions sources included in the air dispersion modelling assessment for the Plant operating under routine conditions include:

- One biofilter stack, with emissions of concern being odour;
- Three gas fired reciprocating engines, with the emissions of concern being biomethane combustion products; and
- Emissions from the biomethane upgrade plant, consisting of hydrogen sulphide and odour.

The receivals hall was also considered as a potential emission source. However, as the hall will be fitted with fast acting roller shutter doors and will be under negative pressure and connected to the fully enclosed, single stack biofilter, potential emissions are considered to be negligible. The main doors will only open for vehicle entry for waste delivery and digestate transport. With fast door opening and closing times of 6 seconds, it is likely that the doors will be open for around 30 seconds per truck entry. Emissions monitoring at similar sites has indicated emissions from door openings and leakage from buildings with rapid roller shutter doors and comparable management practices are negligible. The receivals hall has not been included in the modelling assessment on this basis.

The full flaring scenario included in this assessment has considered the following atmospheric emission sources:

- Two enclosed flares, used when one or all of the generators are unavailable with the emissions of concern being biomethane combustion products.

2.1.1 Biofilter Emissions

The biofilter will use spongelite as the filter media. Air from the receivals hall will be humidified using misting nozzles running on timer, with a fan running inside the air extraction pipe. All biofilter fans will run on standard electric motor, with a spare which can be connected immediately in event of a failure.

2.1.2 Power Generation

The plant will incorporate three (3) x 1560 kW capacity Combined Heat and Power (CHP) co-generation units using MWM TCG2020V16 engines packaged by Edina.

Emissions associated with the generators include:

- Oxides of nitrogen (NO_x) consisting mostly of nitrogen oxide (NO) and a lesser concentration of nitrogen dioxide (NO_2). NO_x is formed primarily from the oxidation of fuel-bound nitrogen and nitrogen in the air;
- Hydrogen sulphide (H_2S) is produced by anaerobic digestion process and so is found in biogas. A H_2S destruction removal efficiency of 98% (worse-case) is specified by the supplier;
- Sulphur oxides (SO_x) which are predominantly in the form of sulphur dioxide (SO_2), formed from the oxidation of sulphur in the fuel; and
- Carbon monoxide (CO) formed from the incomplete combustion of the fuel.

Particulate matter (PM) and non-methane volatile organic emissions from the generators are considered to be negligible as the fuel source is a gaseous fuel with minor higher chain paraffins and as such, have not been included in the modelling assessment.

2.1.3 Enclosed Flares

Each enclosed flare will reach a height of 11.2 m and diameter of 1.6 m. The biogas is fed in at the bottom and combusted with the combustion temperature and efficiency controlled by a thermocouple near the top of stack, which adjusts the air inflow at the base of the stack via dampers. If the exhaust temperature is too high, the dampers are opened further and more air is drawn in and if too low, the dampers are restricted to restrict the air flow to maintain optimum combustion. Destruction removal efficiencies of 99.7% and 99.5% for methane and hydrogen sulphide (H_2S) respectively are guaranteed by the manufacturer as outlined in Appendix 4.

2.1.4 Biomethane Upgrade Plant

A biomethane upgrade plant will be used to upgrade the biogas to a methane-rich product gas, known as biomethane. Emissions of concern from the biomethane upgrade plant will include H_2S and odour.

2.2 Emissions Estimations

Emission estimates for all pollutants except H_2S for the power generation and flare were derived from stack monitoring data from a biogas production facility with a similar configuration located in Jandakot, Western Australia (as provided by Emissions Assessments). The emissions estimates for these pollutants and applied in this assessment have been derived from worst case concentrations, as measured when the reference plant was operating at 100% load and are considered conservative.

Concentrations of H_2S were below the detection limit for monitoring undertaken at the Jandakot facility. This is common due to the low concentrations typically found in the exhaust gas, as outlined in a letter from the manufacturer (Appendix 3). Biogass has indicated that they will be installing a H_2S scrubber upstream of the generators and flare and the theoretical input of H_2S will be at or below 0.1 ppm. For the purpose of the current assessment, emissions of H_2S were calculated based on a concentration of 0.1 ppm in the input gas and the stated destruction efficiencies for the generator and flare.

Emission estimates for the biomethane upgrade plant were derived from manufacturer's specifications. The manufacturer guarantees an emission limit below 0.1 ppm for H_2S.

The exhaust parameters and emission estimates for each of the modelled sources are provided in Table 1.

Table 1: Emission Parameters for the Plant

Parameter	Units	Bio Filter	CHP Power Generation x 3	Biomethane Upgrade	Flares x 2
Exhaust Parameters					
Operation		Continuous	Continuous	Continuous	< 12 days per year
Scenario		Routine and Flaring	Routine Only	Routine and Flaring	Flaring Only
Number		1	3	1	2
Coordinates	**UTM**	283634 mE, 6153412 mN	283603 mE, 6153437 mN 283607 mE, 6153435 mN 283611 mE, 6153433 mN	283640 mE, 6153473 mN	283611 mE, 6153455 mN 283615 mE, 6153453 mN
Height	**m**	14.5	14.5	14.5	11.2
Diameter	**m**	0.88	0.35	0.25	1.6
Temp	**Deg C**	22	150	15	1000
	K	295	423	288	1273
Measured Oxygen	**%**	NA	8.3	NA	10.9
Stack Moisture	**%**	1.5	4.4	NA	1.5
Volumetric Flow	**Nm^3/s Dry**	19.1	1.86	0.73	11.01
	Am^3/s	20.3	2.75	0.77	50.55
Exit Velocity	**m/s**	33.3	28.58	15.7	24.99
Emission Estimates					
OU	**$ou.m^3/s$**	1670	NA	105	NA
H_2S	**$mg/m^{3[1]}$**	NA	0.00033	0.15	0.00004
	g/s	NA	0.00000061	0.00011	0.00000042
NO_x	**$mg/m^{3[1]}$**	NA	400	NA	51
	g/s	NA	0.74	NA	0.56
SO_2	**$mg/m^{3[1]}$**	NA	46	NA	8.8
	g/s	NA	0.09	NA	0.1
CO	**$mg/m^{3[1]}$**	NA	590	NA	16
	g/s	NA	1.1	NA	0.18

Notes

1. Referenced to STP (273.15K, 101.3kPa) and expressed as dry values.

2.3 Non-Routine Emissions

Non-routine emissions from biogas plants (apart from the infrequent flaring) may potentially arise as a result of a malfunctioning of the flare, the air extraction system or the biofilter. For the Plant these will be addressed by the management practices outlined in the following sections.

2.3.1 Flaring

Flaring upset conditions may potentially occur if gas is vented via the flare without combustion occurring. The biogas plant flare system will mitigate this risk by configuring the ignition system to be battery powered with backup solar charging. The monitoring system also includes monitoring of the exhaust temperatures and exhaust gases, such that if combustion is not occurring an alarm will be activated to alert to the need for intervention.

2.3.2 Biofilter

Higher than normal emissions can occur through biofilters (or fugitive release from the receivals hall) due to failure of extraction motors, loss of power, loss of humidification of the inlet air and problems in the biofilter media, such as compaction of the bed, degradation in the efficiency and the need to perform maintenance such as replace the filter media. These will be managed as follows:

- The extraction system on all biofilters at the site will utilise standard motors, with one motor always kept onsite as a spare. The biofilter for this plant will use three fans. Loss of a motor will only reduce the extraction flow rate by 33% for a period anticipated for no more than 3 hours;
- The power supply for the pumps will be provided by onsite generators, and when not available, by mains power. Redundancy is therefore built into the power supply and a power failure event could only occur if the onset generators failed, and there happened to be a simultaneous mains power failure. The likelihood of these concurrent events is extremely low. Owing to the redundant design it is therefore expected that odour escape owing to power failure has negligible probability of occurring;
- The humidification system will be designed to ensure humidity for all inlet conditions is maintained at 95%; and
- The biofilter media is anticipated to last for 8 years. This is much longer than organic biofilter media as it does not suffer issues such as compaction and degradation in media performance. The media is anticipated to be replaced on an as-required basis, but not less than every 8 years. Monitoring of the stack emissions will be conducted to assess the performance of the biofilter. If a deterioration in performance below minimum standards is attributed to degradation of the media, all waste receivals will be held over pending a replacement of the media, a process of up to two days.

Given the above design and proposed management of the plant, the probability of non-routine emissions from the Plant occurring is considered to be negligible and as such, have not been included in the modelling assessment.

3. AIR QUALITY CRITERIA

3.1 Human Health

For ambient GLCs, the SA Environment Protection Authority (EPA) outlines state-wide standards in its Environment Protection (Air Quality) Policy 2016. The policy seeks to apply the standards at residential areas or places where people may congregate, such as beaches or picnic areas. The standards relevant to this assessment are listed in Table 2.

Table 2: SA EPA Environment Protection (Air Quality) Policy 2016 - Applicable Air Quality Standards

Pollutant	Averaging Period	Maximum Concentration ($\mu g/m^3$)[1]
CO	1-hour	31,240
	8-hour	11,250
NO_2	1-hour	250
	1-year	60
H_2S	3-minutes (odour)	0.15
	3-minutes (toxicity)	510
SO_2	1-hour	570
	1-day	230
	1-year	60

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.

3.2 Odour

The SA EPA has outlined state-wide standards for odour that are applicable to this study. The standards state that an activity cannot result in the number of odour units being exceeded for the number of persons (as specified in Table 3) over a 3 minute averaging time 99.9% of the time (based on evaluations at ground level using a prescribed testing, assessment, monitoring or modelling methodology for the pollutant and activity).

Table 3: SA EPA Environment Protection (Air Quality) Policy 2016 – Applicable Odour Standards

Number of people	Odour Units (OU) (3-minute average, 99.9% of time)
2000 or more	2
350 - 1999 (inclusive)	4
60 - 349 (inclusive)	6
12 - 59 (inclusive)	8
Single residence (fewer than 12)	10

4. EXISTING AIR QUALITY

In order to determine a background concentration to assess potential cumulative impacts for the purposes of this study, monitoring data from two SA EPA monitoring stations; Elizabeth (NO_2 and CO) and Northfield (SO_2). These locations were chosen as they are the nearest ambient air quality monitoring stations to the proposed site and the monitored values are considered to be generally representative of background concentrations.

Monitoring data collected at each site between 1 January 2015 to 31 May 2018 was utilised for the purpose of this assessment. No specific guidance for selection of an appropriate background concentration is provided by the SA EPA. The Environment Protection Authority Victoria (Vic EPA) State Environment Protection Policy (Ambient Air Quality) (SEPP (AQM)) (Gov. of Vic., 2001) recommends the 75th percentile concentration (concentration which is exceeded by 25% of concentrations for that averaging period) should be adopted as a background level. Correspondence with SA EPA personnel indicated this approach would be suitable to determine ambient background concentrations for use in this assessment.

A summary of the ambient concentrations measured at the Elizabeth and Northfield SA EPA monitoring stations is presented in Table 4.

Table 4 indicates that of the applicable pollutants, background concentrations are relatively low in the region.

Table 4: 75th Percentile and Annual Average Ambient Concentrations for CO, NO_2 and SO_2

Pollutant	Averaging Period	75th Percentile Concentration (µg/m^3)[1]	Annual Average (µg/m^3)[1]
CO[2]	1-hour	25	NA
	8-hour	25	
NO_2[2]	1-hour	10	
	24-hour	NA	8
SO_2[3]	1-hour	0	NA
	24-hour	0.14	
	Annual	NA	0.2

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. As measured at the Elizabeth SA EPA monitoring station.
3. As measured at the Northfield SA EPA monitoring station.

It is noted the annual average SO_2 concentration measured at the Northfield monitoring station is 0.2 µg/m^3, while the 75th percentile 1-hour average is zero; this is reflective of a large proportion of the hourly monitoring data being equal to zero.

5. MODELLING METHODOLOGY

5.1 Model Selection

The SA EPA has stipulated that unless prior agreement has been obtained, all air dispersion modelling should be completed using the CALPUFF air dispersion model using a meteorological dataset from 2009.

5.2 CALPUFF Model Set Up

The following model set up options within CALPUFF were used:

- Building downwash was included using the BPIP-Prime algorithms with site layout and elevation. The tanks, silos and receivals hall were included in the modelling;
- Grid spacings of 100 m over a 7 km x 7 km model domain were applied, centred approximately on the site;
- The TAPM prognostic meteorological model developed by CSIRO was used to generate a gridded meteorological dataset for the modelling domain. Monitored meteorological data from the Bureau of Meteorology (BoM) Elizabeth monitoring station were used with the TAPM output as inputs into the CALMET meteorological processor to develop a meteorological data file suitable for use in CALPUFF;
- No chemical transformation or deposition, except for the prediction of NO_2 (as discussed in Section 5.4);

A summary of the CALPUFF inputs applied in this assessment is provided in Appendix 2.

An annual wind rose generated by the CALMET meteorological processor for the proposed site location is presented in Figure 3, with the annual frequency of wind speeds presented in Table 5.

Table 5: Distribution of Wind Speeds for 2009 (CALMET-Generated Data)

Wind Speed	Calms	0.5–2.0 m/s	2.0-3.5 m/s	3.5-5.0 m/s	5.0-6.5 m/s	6.5-8.0 m/s	>8m/s
(%)	1.4	36.2	36	19.3	5.4	1.4	0.2

5.3 3 Minute Averaging Periods

A simple averaging-time scaling factor can be used to estimate short-term peak concentrations for applications. This adjustment primarily addresses the effect of meandering (fluctuations in the wind about the mean flow for the hour) on the average lateral distribution of material. The scaling factor used to adjust the lateral dispersion coefficient[1] for averaging time is the 1/5th power law:

$$Cl = Cs(60/tl)^{0.2}$$

where
Cl = Concentration for new averaging period;
Cs = Concentration for the 1-hour average period;
tl is the averaging time (min.) of interest

[1] Turner, D.B., 1970: Workbook of Atmospheric Dispersion Estimates. U.S. EPA Office of Air Programs Publication No. AP-26. Research Triangle Park, NC.

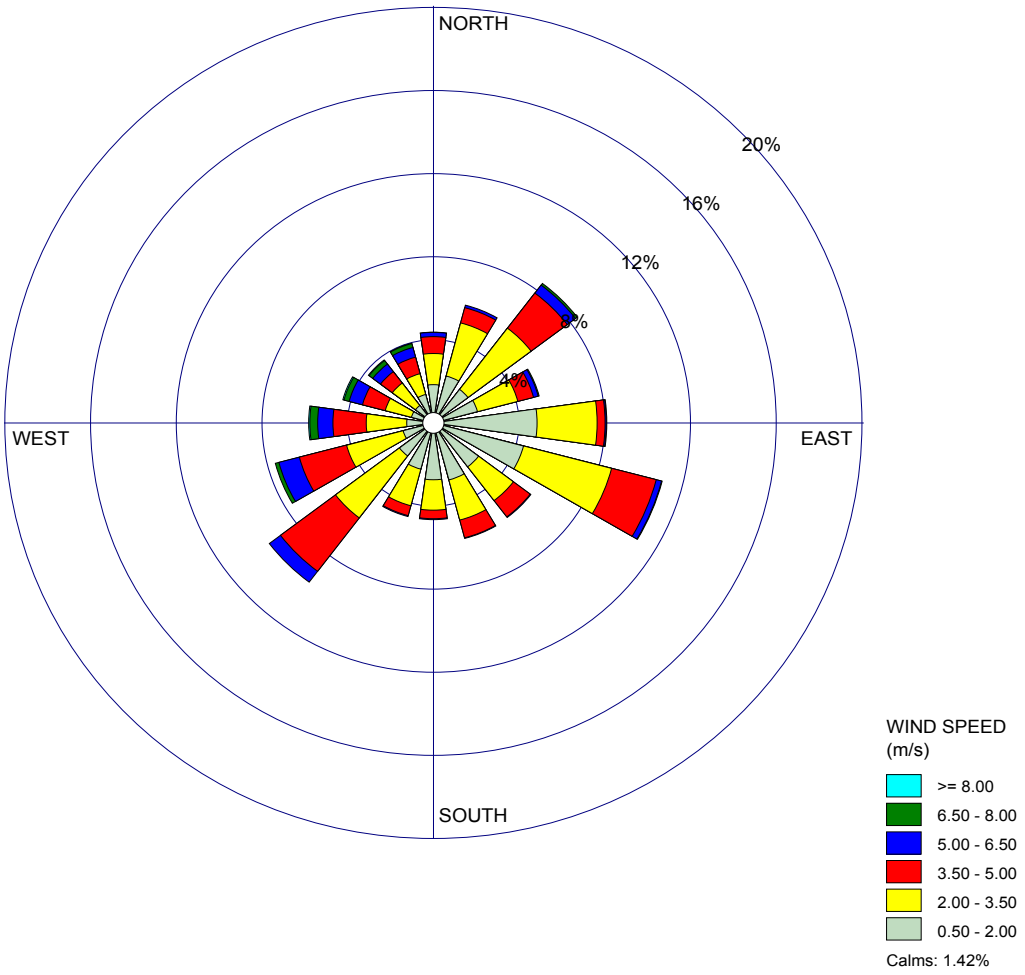

Figure 3: 2009 CALMET-Generated Annual Wind Rose

5.4 Treatment of Oxides of Nitrogen

A key element in assessing the potential environmental impacts from ground level NO_2 concentrations is estimating NO_2 concentrations from modelled NO_x emissions. The final NO_2 concentration is a combination of the NO emitted as NO_2 from the source stacks and the amount of NO that is converted to NO_2 by oxidation in the plume after release.

Generally, after the NO_x is emitted from the stack, additional NO_2 is formed as the plume mixes and reacts with the surrounding air. There are several reactions that both form and destroy NO_2, but the primary reaction is oxidation with ozone according to the following reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

This reaction is essentially instantaneous as the plume entrains the surrounding air. It is limited by the amount of ozone available and by how quickly the plume mixes with the surrounding air. Thus the ratio of NO_2 to NO_x increases as the plume disperses downwind.

In order to predict NO_2 concentrations, Ramboll has applied the US Environmental Protection Agency (USEPA) Ozone Limiting Method (OLM). This method assumes that ozone is the limiting reagent (i.e. the ozone concentration is less than the remaining NO_x concentration) and requires an NO_2 to NO_x in-stack ratio. In the absence of a site-specific in-stack ratio, it has been assumed

that 10% of NO_x emissions are NO_2 (a common assumption for gas combustion sources). Hourly average ozone concentrations for application in the OLM were obtained from the Elizabeth ambient air quality monitoring station.

The OLM approach is considered conservative over short-term averaging periods as it assumes the reaction between NO_x and ozone occurs instantaneously, when in reality this is likely to take place over a number of hours, during which time the plume is subject to dispersion.

6. MODELLING RESULTS

6.1 Ambient Air Quality Assessment

GLCs of the modelled compounds have been predicted for the following scenarios:

- Routine operations, with all three generators operating at maximum load and no flaring. This is considered conservative as the generators are typically sized to run at around 85% maximum load; and
- Full flaring scenario, with both flares operating at the maximum gas flow rate and no generator operation.

The results of the odour assessment for emissions from the biofilter and biomethane upgrade stacks are presented in Section 6.2.

The predicted GLCs for the Plant operating under routine conditions, both in isolation and cumulatively with background concentrations, are summarised in Table 6. The predicted GLCs are below their respective standards across the modelled domain. The maximum 1-hour average NO_2 GLC was predicted to be 61% of the respective guideline for operations in isolation and 65% of the guideline when considered cumulatively, with ambient background concentrations. The maximum predicted 1-hour average GLCs of NO_2 for routine operations in isolation are presented in Figure 4. This figure indicates that the highest predicted concentrations are expected to occur close to the site.

Further analysis of the maximum 1-hour average NO_2 predicted concentrations was undertaken at nine nominated receptor locations. Six of these represent the nearest commercial receptors surrounding the proposed Plant. A seventh receptor was located at the nearest residential receptor and an eighth at the residential receptor that was predicted to have the largest impact. Another was located at the nearby golf course. Table 7 presents the predicted 1-hour average NO_2 concentrations at these receptor locations, the highest being 128 µg/m^3 (cumulative concentration).

The maximum 1-hour average NO_2 GLCs predicted at the nearby residences and the golf course were not predicted to be any greater than 82 µg/m^3 (cumulative concentration), well below the corresponding SA EPA 1-hour average NO_2 standard of 250 µg/m^3. It is noted that the predicted NO_2 GLCs are considered conservative given the use of the OLM method (refer to Section 5.4), particularly for short-term concentrations close to the source.

The predicted GLCs for the Plant operating under the full flaring scenario are also summarised in Table 6. The predicted GLCs are all expected to remain well below their respective standards across the modelled domain when considered both in isolation and cumulatively with background concentrations.

The maximum 3-minute average H_2S concentration for both routine and upset operations is presented in Table 6. The maximum predicted 3-minute average H_2S concentration of 0.13 µg/m^3 complies with the SA EPA odour based standard for H_2S of 0.15 µg/m^3. A contour plot of H_2S concentrations predicted near the facility boundary is presented in Figure 5.

Contours of the predicted GLCs for all modelled compounds and averaging periods for both scenarios are presented in Appendix 1.

Table 6: Predicted Maximum GLCs for Routine Operations and Full Flaring

Compound	Averaging Period	Criteria	Background Concentration	Routine Operations (3 Generators, Biofilter and Biomethane Upgrade)				Full Flaring (2 Flares, Biofilter and Biomethane Upgrade)			
				Maximum Concentration		Cumulative Maximum Concentration		Maximum Concentration		Cumulative Maximum Concentration	
		µg/m³	µg/m³	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria
CO	1-hour	31,240	25	1,761	6%	1,786	6%	113	0.4%	138	0.4%
	8-hour	11,250	25	487	4%	512	5%	15	0.1%	40	0.4%
NO_2	1-hour	250	10	153	61%	163	65%	90	36%	100	40%
	Annual	60	8	5	8%	13	21%	0.5	1%	8	14%
H_2S	3-minute (odour)	0.15	NA	0.13	86%	NA	NA	0.13	86%	NA	NA
	3-minute (toxicity)	510	NA		0.03%		NA		0.03%		NA
SO_2	1-hour	570	0	144	25%	144	25%	113	20%	113	20%
	24-hour	230	0.14	20	9%	20	9%	4	2%	4	2%
	Annual	60	0.2	1.2	2.1%	1.4	2.4%	0.08	0.1%	0.3	0.5%

Notes:

1. Concentrations are referenced to 0 deg C and 101.3kPa.
2. Background concentrations are the 75th percentile 1-hour and 24-hour concentrations and annual average concentrations (as per Table 4).

Table 7: Predicted Maximum NO_2 GLCs for Routine Operations at Nominated Receptor Locations

Receptor	Description	Background Concentration	Maximum Concentration in Isolation		Cumulative Maximum Concentration	
		($\mu g/m^3$)	($\mu g/m^3$)	% of Criteria	($\mu g/m^3$)	% of Criteria
R1	Commercial Property on Boundary	10	153	61%	163	65%
R2	Commercial Property on Boundary		118	47%	128	51%
R3	Commercial Property on Boundary		101	40%	111	44%
R4	Commercial Property on Boundary		78	31%	88	35%
R5	Commercial Property on Boundary		109	44%	119	48%
R6	Commercial Property on Boundary		102	41%	112	45%
R7	Nearest Residential Receptor		54	22%	64	26%
R8	Residential Receptor with Maximum Impact		61	24%	71	28%
R9	Closest Part of Golf Course		72	29%	82	33%

Table 8: Predicted Maximum 3-Minute GLCs of H_2S for Routine and Upset Operations at Receptor Locations

Receptor	Description	Maximum Concentration in Isolation	
		($\mu g/m^3$)	% of Criteria
R1	Commercial Property on Plant Boundary	0.08	57%
R2	Commercial Property on Plant Boundary	0.11	71%
R3	Commercial Property on Plant Boundary	0.12	78%
R4	Commercial Property on Plant Boundary	0.13	86%
R5	Commercial Property on Plant Boundary	0.09	61%
R6	Commercial Property on Plant Boundary	0.10	67%
R7	Nearest Residential Receptor	0.03	17%
R8	Residential Receptor with Max Predicted Impact	0.07	47%
R9	Closest Part of Golf Course	0.08	52%

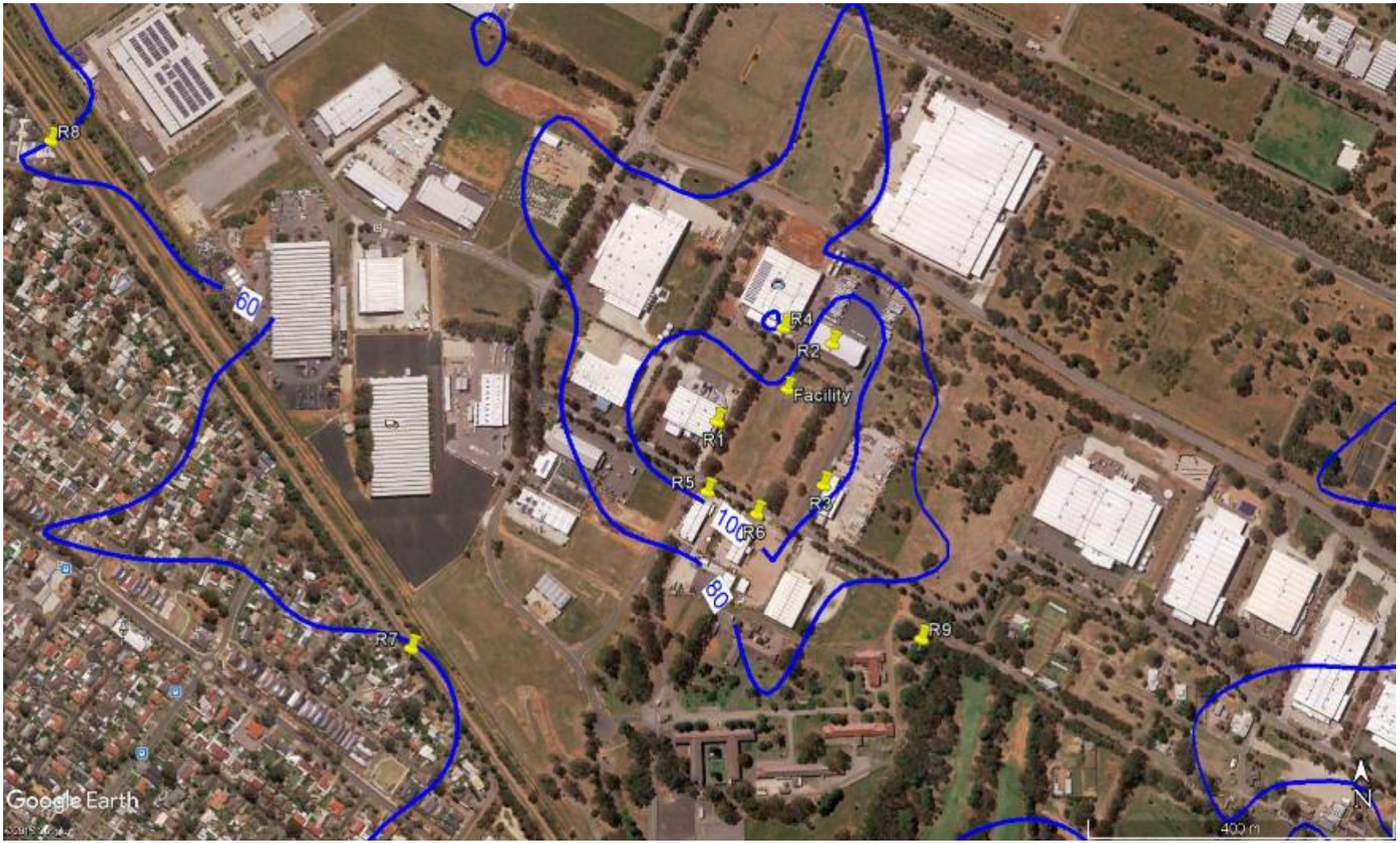

Figure 4: Routine Operations - Maximum Predicted 1-hour Average NO_2 GLCs (µg/m³) in Isolation

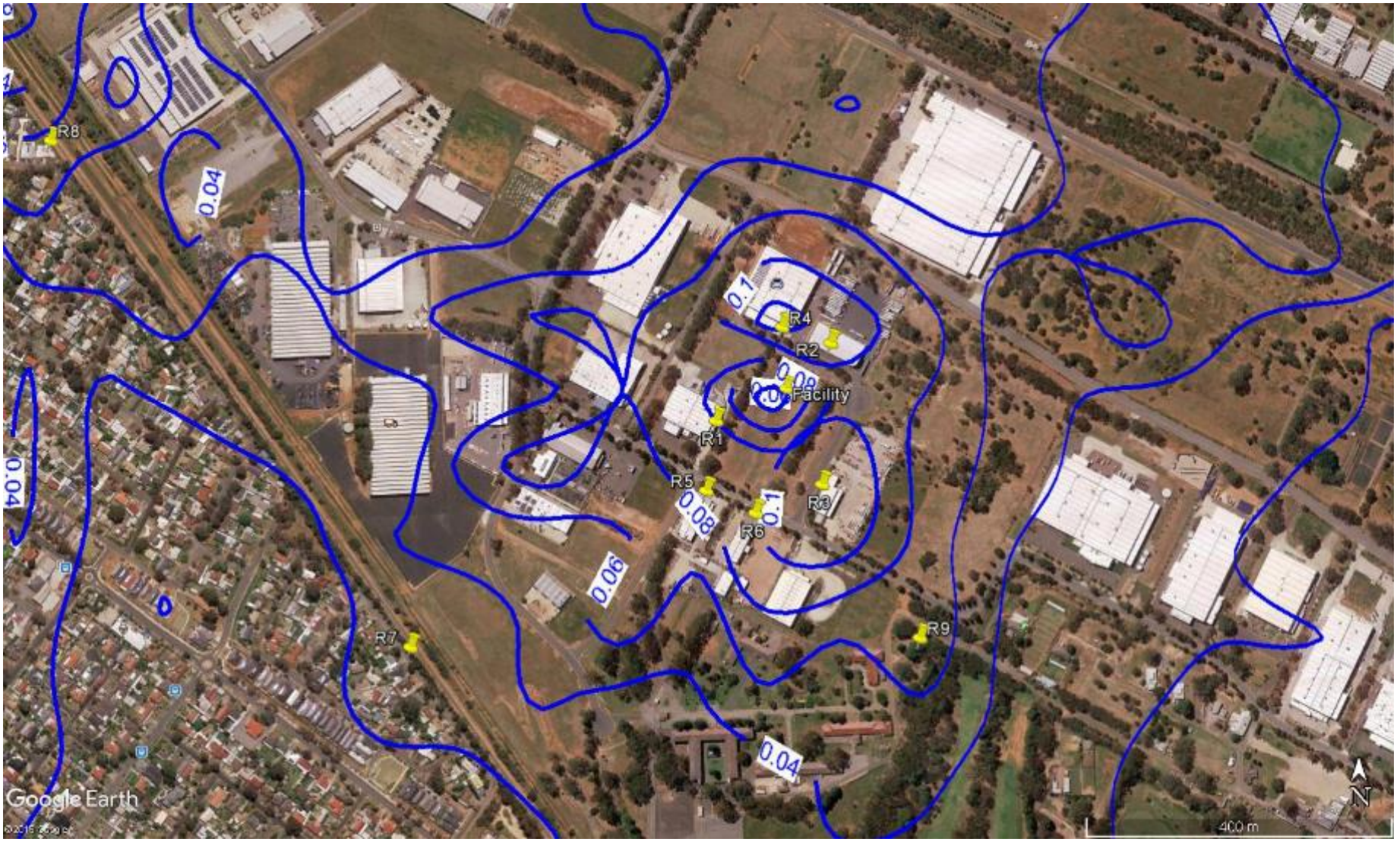

Figure 5: Routine and Upset Operations - 3-minute Average Maximum Predicted Concentrations in Isolation of H_2S (µg/m³)

6.2 Odour Assessment

The maximum predicted 99.9th percentile 3-minute average odour concentration for routine operations (considering emissions from the biofilter and biomethane upgrade stacks) is presented in Table 8. Contours of the predicted 99.9th percentile 3-minute average odour levels are presented in Figure 6.

The predicted odour levels remain below the SA EPA criteria of 2 OU throughout the modelled domain. Odour concentrations predicted to occur at the nearest residential and golf course receptor locations remain below 0.5 OU (Figure 6).

Table 9: 3-minute (99.9th Percentile) Predicted Odour Concentrations for the Biogas Plant

Compound	Averaging Period	Criteria	Maximum Predicted 99.9th Percentile
		(OU)	(OU)
Odour	3-minute (99.9th Percentile)	2	1.88

Table 10: 3-minute (99.9th Percentile) Predicted Odour Concentrations at Receptor Locations

Receptor	Description	Maximum Concentration in Isolation	
		(OU)	% of Criteria
R1	Commercial Property on Plant Boundary	1.81	91%
R2	Commercial Property on Plant Boundary	1.08	54%
R3	Commercial Property on Plant Boundary	0.79	40%
R4	Commercial Property on Plant Boundary	1.34	67%
R5	Commercial Property on Plant Boundary	1.59	80%
R6	Commercial Property on Plant Boundary	0.60	30%
R7	Nearest Residential Receptor	0.24	12%
R8	Residential Receptor with Maximum Impact	0.21	11%
R9	Closest Part of Golf Course	0.24	12%

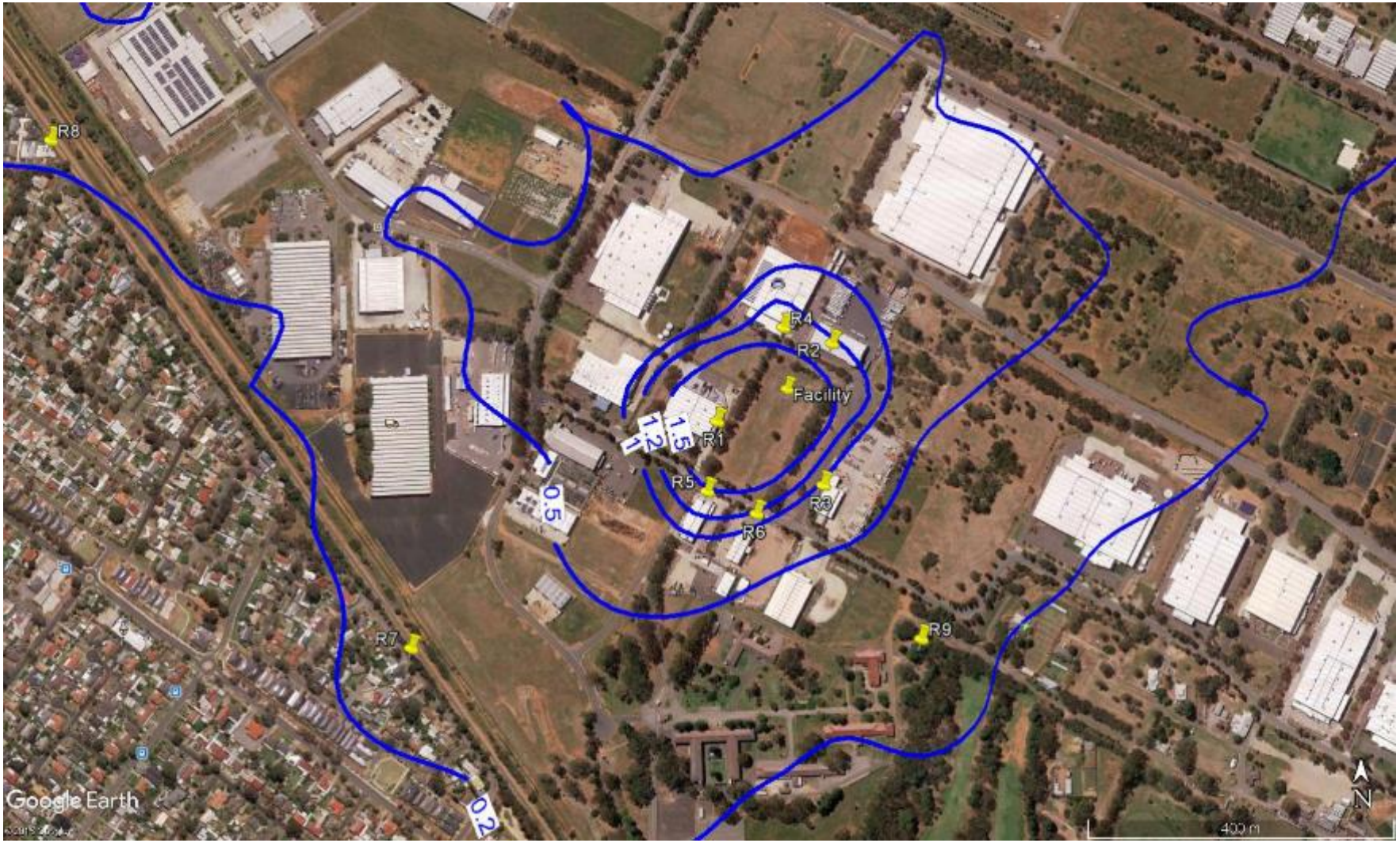

Figure 6: Routine Operations - Predicted 3-minute Average 99.9th Percentile Odour Concentrations (OU)

7. CONCLUSIONS

Air dispersion modelling has been completed to assess the potential air quality impacts associated with emissions from the proposed Plant operating under routine and full flaring operating scenarios.

Predicted GLCs have been estimated using the CALPUFF model and meteorological data generated by TAPM, in combination with meteorological monitoring data recorded at the nearest BoM monitoring station located at Elizabeth.

Where ambient monitoring data was available for compounds of interest, this has been used to determine the cumulative impacts of the proposed Plant.

The key findings of the air dispersion modelling are as follows:

- Predicted GLCs for all modelled compounds remain below the corresponding SA EPA standards across the modelled domain for both routine and full flaring operations, considered in isolation and cumulatively;
- The GLCs predicted at sensitive receptor locations remain below the relevant SA EPA standards for all pollutants and modelled scenarios;
- The maximum predicted 3-minute H_2S GLC most closely approaches the relevant standard, representing 86% of the odour based standard of 0.15 µg/m^3. This concentration was predicted to occur onsite;
- Odour concentrations are predicted to remain below the SA EPA criteria for routine operations across the modelled domain and are equal to less than 91% of the applicable criteria at the nearest sensitive receptor locations.

8. DISCLAIMER AND LIMITATIONS

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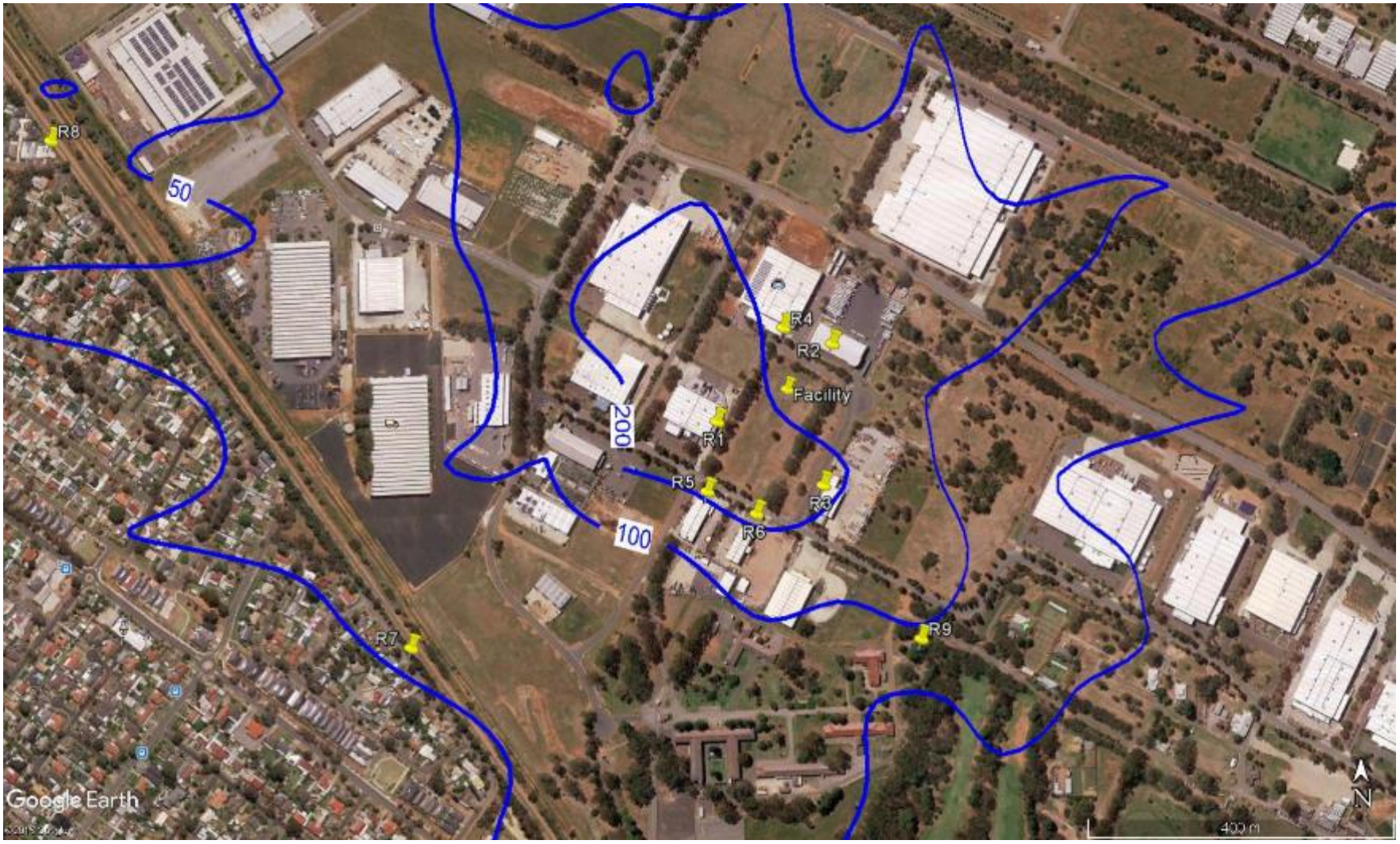
APPENDIX 1
CONTOUR PLOTS

Scenario 1 (Routine Operations) – Annual Average Predicted Concentrations in Isolation of NO_2 (µg/m^3)

Scenario 1 (Routine Operations) – 1-Hour Average Maximum Predicted Concentrations in Isolation of CO (µg/m^3)



Scenario 1 (Routine Operations) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO (µg/m³)

Scenario 1 (Routine Operations) – 1-Hour Average Maximum Predicted Concentrations in Isolation of SO_2 (µg/m³)

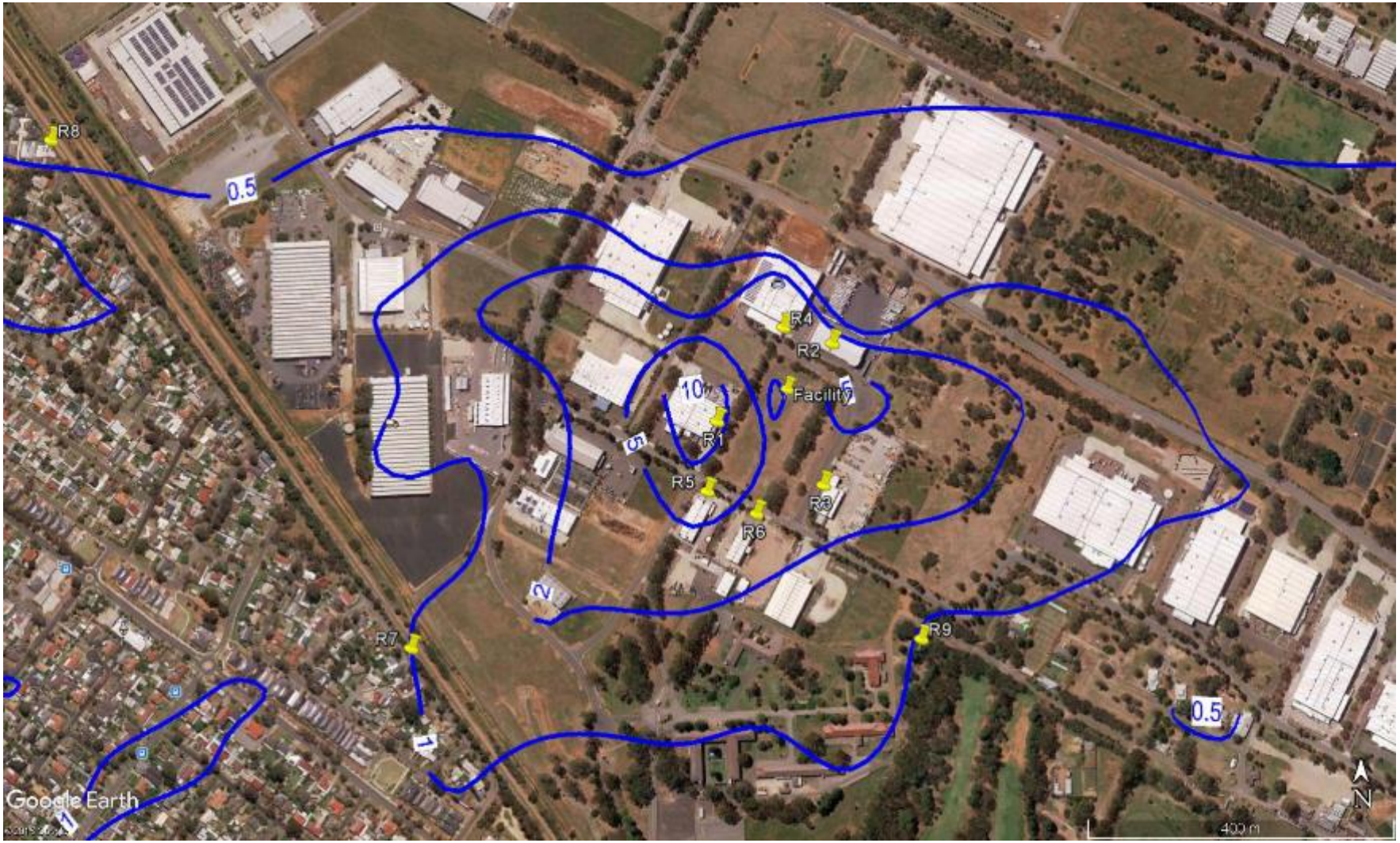
Scenario 1 (Routine Operations) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2 (µg/m^3)

Scenario 1 (Routine Operations) – Annual Average Predicted Concentrations in Isolation of SO_2 (µg/m^3)

Scenario 2 (Flaring) – 1-Hour Average Maximum Predicted Concentrations in Isolation of NO_2 (µg/m^3)

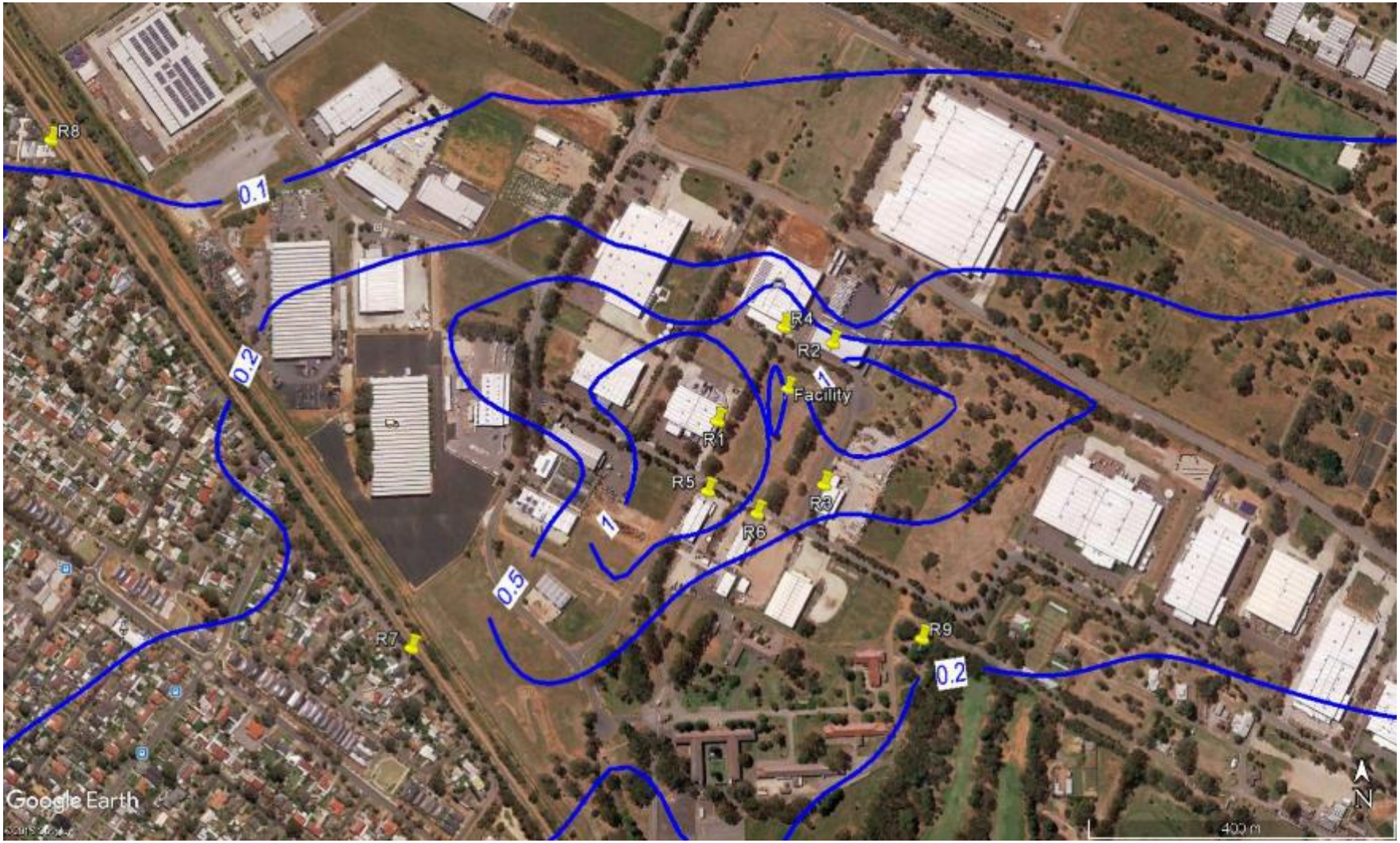
Scenario 2 (Flaring) – Annual Average Predicted Concentrations in Isolation of NO_2 (µg/m^3)

Scenario 2 (Flaring) – 1-Hour Average Maximum Predicted Concentrations in Isolation of CO (µg/m^3)



Scenario 2 (Flaring) – 8 Hour Average Maximum Predicted Concentrations in Isolation of CO (µg/m³)

Scenario 2 (Flaring) – 1-Hour Average Maximum Predicted Concentrations in Isolation of SO_2 (µg/m^3)



Scenario 2 (Flaring) – 24 Hour Average Maximum Predicted Concentrations in Isolation of SO_2 (µg/m^3)

Scenario 2 (Flaring) – Annual Average Predicted Concentrations in Isolation of SO_2 (µg/m^3)

Scenario 2 (Flaring) – 3-minute Average Maximum Predicted Concentrations in Isolation of H_2S ($\mu g/m^3$)

APPENDIX 2
CALPUFF INPUTS

CALPUFF Parameters

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
PRFDAT	CTDM/AERMET-type meteorological profile data file	PROFILE.DAT
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	8
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-01-01-01-0000-2009-02-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-02-16-00-0000-2009-04-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-04-03-00-0000-2009-05-18-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-05-18-00-0000-2009-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-07-03-00-0000-2009-08-17-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-08-17-00-0000-2009-10-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-10-02-00-0000-2009-11-16-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2009-11-16-00-0000-2009-12-31-23-0000.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**

METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2009
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	1
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2009
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+0900
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	7
NSE	Number of chemical species to be emitted	7
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1
INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	1
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	3
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	1
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	0
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0
INPUT GROUP: 3 -- Species List		

Parameter	Description	Value
CSPEC	Species included in model run	TR1
CSPEC	Species included in model run	TR2
CSPEC	Species included in model run	TR3
CSPEC	Species included in model run	TR4
CSPEC	Species included in model run	TR5
CSPEC	Species included in model run	TR6
CSPEC	Species included in model run	TR7
INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0.0
FNORTH	False northing at projection origin (km)	0.0
IUTMZN	UTM zone (1 to 60)	54
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	39
NY	Meteorological grid - number of Y grid cells	39
NZ	Meteorological grid - number of vertical layers	11
DGRIDKM	Meteorological grid spacing (km)	1
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 100.0, 200.0, 350.0, 500.0, 750.0, 1000.0, 2000.0, 3000.0, 4000.0, 5000.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	263.8390
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	6133.5530
IBCOMP	Computational grid - X index of lower left corner	17
JBCOMP	Computational grid - Y index of lower left corner	17
IECOMP	Computational grid - X index of upper right corner	23
JECOMP	Computational grid - Y index of upper right corner	23
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	17
JBSAMP	Sampling grid - Y index of lower left corner	17

IESAMP	Sampling grid - X index of upper right corner	23
JESAMP	Sampling grid - Y index of upper right corner	23
MESHDN	Sampling grid - nesting factor	10
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	0
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10
INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		

Parameter	Description	Value
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0
INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1
INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4

BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99

NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1

SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	1E-007
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1
INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	7
IPTU	Units used for point source emissions (e.g., 1 = g/s)	1
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0
INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6
INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0

NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0
INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0
INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0
INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0
INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	0
NRGRP	Number of receptor group names	0

APPENDIX 3
GENERATOR MANUFACTURER'S LETTER

THE QUEEN'S AWARDS FOR ENTERPRISE: 2014

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2018

Specialists in Power Generation

Edina

an EPAL company

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18th January 2019

Biogass Renewables Pty Ltd
Ground Floor,
1205 Hay Street,
West Perth WA 6005

For the attention of: Joe Oliver

Our Reference: NA

Dear Joe

Re: H2S destruction across Bordertown biogas generation unit

Edina UK are the largest distributor of MWM gensets worldwide and have vast experience in the installation and long term operation of these units and have direct sales and technical support from their factory in Mannheim, Germany. MWM engines are German engineered and class leaders in electrical efficiency & reliability with low running costs.

We have been asked to comment on the level of H2S that could be found in the exhaust of a biogas generator in relation to the Delorean project. The project is to have a biogas generator rated at 1.56MWe electrical output.

H2S is produced by anaerobic digestion process and so is found in biogas. The level of H2S produced will depend primarily on the feedstocks being digested. As well as being odourous, H2S is a contaminant that is problematic to the longevity and operation of an engine. Within the combustion process the H2S is oxidised to SO2, which is an acidic compound, which contaminates the oil and can cause corrosion of the engine moving parts. This acidity and Sulphur can be followed through the deterioration of the lubricating oil through regular analysis. Hence the regular oil analysis will quickly indicate if a high-level of H2S is within the biogas.

MWM
Energy. Efficiency. Environment.

The combustion of H2S within the engine is nearly 100%. Any H2S within the exhaust will be due to “slip” of unburnt fuel passing through the engine during the period of “valve overlap”. Hence the amount of H2S within the exhaust will be dependent on the amount of H2S within the fuel gas. Fuel gas slip (methane slip) is usually 1% with 2% as an absolute maximum. Higher values would obviously affect the engine performance/efficiency.

Because of the deleterious nature of H2S to the engine the anaerobic digestion plant will have at least one, and probably more, systems to reduce the H2S level. The Delorean project is reported to be very sensitive to potential odour and will have several H2S abatement processes. The digestion plant incorporates a controlled level of air addition to the gasholder to facilitate the biological oxidation of H2S to elemental Sulphur. This system is contained within the digestion plant. The design of this system should enable the H2S in the resultant biogas to a level of around 60ppm or lower. Subsequent to the biological system the plant is reported to have a biogas iron oxide scrubbing system. Within the scrubber the iron will react with the H2S to form inert Iron sulphide, which will remain within the scrubber. The scrubber supplier is to guarantee an H2S level in the biogas fed to the generator of less than 0.1ppm.

The detection of H2S within the exhaust is difficult due to its very low level. The low level is due to its combustion within the engine and the dilution with other combustion components. Generally on an exhaust analysis H2S is below the limit of detection, consequently it is not often monitored.

A typical limit of detection from an exhaust analysis would be expressed as the Method Detection Limit. This is the practical limit of detection for the test per unit volume of exhaust gas. For H2S this would be about 5mg/Sm3. Standard m3 is defined as dry gas, 0C and 1 atmosphere pressure.

To express this in terms of the actual exhaust gas at a typical 150C temperature, the H2S would be around 2ppm.

Since this is the limit of detection for the exhaust gas, a theoretical calculation can be made:

- If the biogas fed to a 1.56MWe generation set were to contain 200ppm of H2S.
    - This would be a feed rate of 200g of H2S per hour.
- Assume the slip of unburnt H2S is 2%.
    - This would release 4000mg of H2S into the exhaust.
- The exhaust flow at 150C from the generator would be around 9900m3/h.

Hence the H2S theoretical concentration in the exhaust would be 0.4mg/m3, or 0.27ppm.

The actual H2S in the exhaust stack is therefore significantly below the limit of detection of usual analytical methods.

Since the Delorian project has an H2S input of just <0.1ppm the theoretical concentration in the exhaust would be around 0.1ppb!

I trust this helps explain the difficulty in measuring H2S in an exhaust and why it is not usually considered a problem.

Yours faithfully
For and on behalf of EDINA UK LTD,

Ian Farr
Biogas Sales Manager

APPENDIX 4
FLARE DATA SHEET

UF10 2000 Emissions Page EA Compliant Stand Alone Flare Stack

Customer	**Biogass Renewable**			
Customer's reference	Delorean			
Our Reference No.	**UFQ**			
Machine type	**UF10-2000** High Temperature Enclosed Flare Stack			
Turndown Ratio	**5:1**			
Design Flow	**2000**	**Nm3hr**		
Design Turndown	**400**	**Nm3hr**		
Pilot System	Uniflare Fire Blaster			
Use environment	Site in open air with restricted access.			
Hazardous area classification in compliance with ATEX	Zone 2 in sphere 200 mm radius around all positive gas pipe connections			
Maximum design emissions Normalised at 0°C, 101.3 k Pa and 3% O2:	Carbon monoxide (CO)	50 mg Nm-3		
	Oxides of nitrogen (NOx)	150 mg Nm-3		
	Total volatile organic carbon as carbon	10 mg Nm-3		
	Non-methane volatile organic carbon	5 mg Nm-3		
Operation	Unattended Intermittent use			
Design Media	65%	Methane CH^4		
Design Burner Pressure	Minimum Burner inlet Pressure	60	mbarg	
Thermal Rating	12.96	MW		
Destruction Efficiency CH4	>99.7%			
Destruction Efficiency H2S	>99.5%			
Design Combustion temperature	1000°C Fully refractory line with automated combustion control			
Minimum retention time	> 0.3 seconds			
Flare Stack Noise Limits	60 dBA@1m			
Booster Noise Limits	65 dBA@1m			
Control system	PLC controlled with Hardwired interface. Remote Start Stop. Status and Information available for Remote and site SCADA system.			
Safety systems	CE marked equipment Piltz PNOZ monitoring e-stop circuit Gas pressure protection IS barriers Local Isolators Flash back protected Flame arrestor Pressure and Temperature monitoring DSEAR and ATEX compliant			

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Registered in England Number 05689034

UF10 2000 Emissions Page EA Compliant Stand Alone Flare Stack

Design Calculation Page

CALCULATION OF RETENTION TIME					
CALCULATION OF COMPOSITION OF COMBUSTION PRODUCTS BS 5854					
per one volume of fuel @ 15° C and 1013 mbar					
Constitituent	Percentage in fuel	rel den	rel den fuel to air		
CH4	65%	0.554	0.3601		
CO2	35%	1.5198	0.53193		
	1	OK	0.89203		
STOICHIOMETRIC AIR PER UNIT VOLUME OF METHANE IS 9.55					
	biogas flow rate	2000	m3h-1 >	1300	m3h-1 CH4
	min air required	12415	m3h-1		
	excess air	200%			
	specific volume of air	0.819	m3 kg-1		
	mass flow rate of air	45476	kg h-1		
	mass flow rate of biogas	2178	kg h-1		
	total mass flow rate	47655	kg h-1		
fuel gases above their dew point have a specific volume similar to air at the relevant temperature					
	the volume of 1 kg of				
	flue gases at	1000	° C is		
		4	m3 kg-1		
	therefore the volume flow rate	181993	m3 h-1		
		51	m3 s-1		
	hot face diameter	1.605	m		
	area	2.02	m2		
	velocity	25.0	m s-1		
	height above flame	9	m		
	retention time	0.36	s		
	Retention time at sample port	0.32	s	Port 1m down from top	
	Heat release turn down ratio	5	:1		
	Combustion heat release full load	12.96	MW		
	Minimum heat release	2.59	MW	**Created**	RPB
EA Guidance on Landfill Gas Flaring 4.8.7 Page 24				**Checked**	MIJ

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Chemical Certificate of Analysis

Client: Greenlane Biogas					
Site:					
Date Sampled: 7/6/16		Sample Location: RM109			
Contract No. R17752/1		PO No: TBC			
No.	Test Parameter	Result: Stripper Drain	Result: Borehole	Result: Buffer Tank	units
1	Calcium	52.40	53.90	53.10	mg/l Ca
2	Magnesium	71.20	74.60	72.20	mg/l Mg
3	Total Hardness	169.68	176.76	171.97	mg/l Ca
4					mg/l
5					mg/l
6					mg/l
7					mg/l
8					mg/l
9					mg/l
10					mg/l

Where: mg = milligram & µg = microgram and NAC = No Abnormal Change

Notes:

1. Samples tested in a UKAS accredited faciltiy

For Ritchie MacKenzie & Co. Ltd

Alex Shearer MSc

Project Engineer

Date Reported: 15/6/16

Ritchie Mackenzie & Co Limited, Broomhill Industrial Estate, Kirkintilloch, Glasgow G66 1TQ. Tel: 0141 776 6274.

CHEMTRON
ADVANCED WATER TREATMENT SOLUTIONS

3500 Harry S. Truman Boulevard
St. Charles, MO 63301
(636) 940-5455

Water Analysis Report

Customer Name: CR&R **Date:** 06/27/17 **Tested By:** K. Ryder, N. Alvis
Contact Person: Dan Michalak **Report ID:** 062817-WA-1 **Prepared By:** K. Ryder, N. Alvis

Sample Background	**Sample ID #:**	**062717-CT-1**	**062717-CT-2**		
	Sample Description:	**City Makeup**	**Gas Scrubber**		
	City				
	State				
	Sample Date:	**06/26/17**	**06/26/17**		
Physical Properties	**Odor**	None	Spicy		
	Turbidity (NTU)	0.0	47.6		
	pH	6.36	6.28		
	Specific Gravity (g/mL)	0.999	1.000		
	Conductance (µS/cm)	811	848		
	TSS (mg/L)	0	122		
	TDS (mg/L)	380	500		
Other	**Total Hardness (mg/L as $CaCO_3$)**	180.2	156.4		
	Total Alkalinity (mg/L as $CaCO_3$)	109.1	98.3		
	Langelier Saturation Index (LSI)	-1.64	-1.82		
	Langelier Potential	Corrosive	Corrosive		
Anions (mg/L)	**Bicarbonate (as $CaCO_3$)**	109.1	98.3		
	Carbonate (as $CaCO_3$)	0.0	0.0		
	Hydroxide (as $CaCO_3$)	0.0	0.0		
	Chloride (Cl)	127.1	159.9		
	Phosphate (PO4)	< 0.1	< 0.1		
	Sulfate (SO_4)	35.7	39.3		
Cations (mg/L)	**Aluminum (Al)**	< 0.1	< 0.1		
	Antimony (Sb)	< 0.1	< 0.1		
	Barium (Ba)	0.11	0.12		
	Boron (B)	0.14	0.24		
	Calcium (CaCO3)	124.41	110.60		
	Chromium (Cr)	< 0.1	< 0.1		
	Cobalt (Co)	< 0.1	< 0.1		
	Copper (Cu)	0.27	0.26		
	Iron (Fe)	< 0.1	< 0.1		
	Lead (Pb)	< 0.1	< 0.1		
	Magnesium (MgCO3)	56.10	46.01		
	Manganese (Mn)	< 0.1	< 0.1		
	Molybdenum (Mo)	< 0.1	< 0.1		
	Nickel (Ni)	< 0.1	1.30		
	Phosphorus (P)	< 0.5	< 0.5		
	Potassium (K)	2.92	3.61		
	Silica (SiO2)	17.64	15.60		
	Sodium (Na)	55.29	82.78		
	Strontium (Sr)	< 1	< 1		
	Sulfur (S)	12.79	16.27		
	Zinc (Zn)	0.12	2.82		
	Zirconium (Zr)	< 0.1	< 0.1		
Additional Tests					

Greenlane® *Biogas Upgrading System*

RMT Series

Process & Functional Description

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1 Introduction

This document gives an overview of the Greenlane RMT Series of biogas upgrading systems, namely the **Rimu**, **Matai** & **Totara** range of plants. It provides a general description of the process and function. Specific manufacturer information relating to individual components is provided by Greenlane with operating & maintenance documentation at delivery of the equipment.

The Greenlane biogas upgrading system separates gaseous components produced by various digestion processes. The system interfaces between the digestion process and the gas consumer, generally either a gas pipeline or a vehicle refueling process.

The Greenlane system upgrades raw biogas through the removal of CO_2, H_2S, siloxanes and other soluble gases to produce primarily methane gas (~98%) which is clean and dry. The gas process comprises of gas compression, gas upgrading and gas drying operations.

The biogas compression system compresses the raw biogas to a pressure suitable for processing. The biogas upgrading system consists of a scrubbing vessel for water scrubbing (absorption of CO_2 and other soluble gases into water), a flashing vessel for methane recovery and a stripping vessel for regeneration of the process water. The drying system consists of a patented Pressure Swing/Temperature Swing adsorption (PSA/TSA) drier-purifier, which dries the upgraded gas after the scrubbing vessel making it suitable for use as a vehicle fuel. The Greenlane system eliminates virtually all H_2S from the product gas.

1.1 Features and Benefits

Design Features	Benefits
Patented processes	Greenlane achieves a methane gas dew point of -80°C. The product gas is compressible to 250 bar (g) without risk of hydrates or ice formation, even in the coldest climates. Residual hydrogen sulphide (H_2S) levels are reduced to ppb (part per billion) levels eliminating corrosive gas and minimising environmental effects by virtue of Greenlane patented technology.
Turndown	Turndown by compressor speed control means the system is energy efficient across a broad range of operating conditions.
Reliability	Greenlane rotary compressors eliminate compressor valves, rings and rod packing associated with reciprocating compressors. Fewer maintenance parts means less down time, high reliability and lower overall operating costs.
Compact	A simple enclosed module / skid mounted design means all parts are easily accessed from the skid boundary. Installation time is reduced.
Energy efficiency	Greenlane offers the highest methane gas production to energy utilisation ratio meaning energy costs are low.
Utilities	Greenlane offers low utilities consumption – important where water resources and effluent disposal is a concern.
Corrosion resistant materials	Process vessels and pipes with biogas and water contact are fabricated from stainless steel 316/316L, or GRP (Glass Reinforced Plastic).
Remote management	Web-based condition monitoring and diagnostic reporting from anywhere in the world is available coupled with full service contract options. This makes preventative maintenance effective, resulting in high availability and reliable operation.
Energy recovery	Recoverable heat can be up to 90% of the compressors main drive motor energy input, ideal for digester heating. High efficiency chiller options for low ambient operation via direct air cooling.

1.2 Performance Specifications

1.2.1 Inputs

Nominal design capacity of the Greenlane upgrading plants are based on an inlet pressure of 1,05 bar(a) and inlet gas temperature of 30°C. Operating capacity is automatically matched through use of variable speed drives which adjust the speed of the compressor and water pumps to match the actual design condition. The system is designed to operate with a gas inlet temperature ranging between 0°C and 40°C. Although the allowable gas composition is variable, it is typically (mol %) 50-65% CH_4 and 35-50% CO_2, with H_2S of up to 2500 ppm, as well as other traces of impurities. Inert gases such as air and nitrogen should be of very low quantity as their inclusion dilutes the product gas quality.

A client input via a 4-20mA signal determines the operating capacity.

1.2.2 Outputs

The system is designed to deliver product gas consisting of 97-98% CH_4, with H_2S less than 1 ppm and dew point of less than –80°C. On a new system dew points gradually improve over first 3 months of operation as the system is thoroughly dried and cycled. The upgrading plant does not remove inert gases such as nitrogen or oxygen, so if these gases are present in the raw gas they will reduce the product gas methane content.

Refer to the Performance & Utilities Data for details on capacities and utility information.

A full suite of electrical signal outputs is available for integration into a DCS (Distributed Control System) via a network connection (Ethernet).

Output capacity of the Greenlane biogas upgrading systems is determined by efficient speed control of the compressor and water pump motors.

1.2.3 Energy Recovery

Heat recovery is available for off skid process water heating. Recoverable heat can be up to 90% of the compressors' main drive motor energy input. Utilisation of recoverable energy depends on the system environment.

1.3 General Specifications

1.3.1 Design Standards

The mechanical and electrical systems are designed in accordance with the applicable codes for the region of installation. All systems for use in Europe are CE Marked with process vessels and piping designed in accordance with the Pressure Equipment Directive (PED). Instrumentation and electrical items in hazardous areas are ATEX certified.

For North America all process vessels are certified to ASME with piping to ANSI B31.3. Instrumentation and electrical meet local requirements such as CSA or UL.

1.3.2 Dimensions & Weight

Dimensions and weights: Refer to the General Arrangement Drawing.

1.3.3 Materials of Construction

Process vessels and piping in contact with raw biogas and product gas are fabricated from corrosion resistant materials such as stainless steel grade 316L or GRP (Glass Reinforced Plastic) to eliminate the risk of corrosion of vessels and pipe work. Valves and instrumentation have SS316L materials on process gas wetted surfaces.

All equipment must be securely mounted to a level concrete foundation. Both containerised and non containerised compression package options are available depending on client requirements. For non-containerised units, electrical control cabinets, VSDs and switchgear are free issued to the client for installing in a non hazardous, clean & dry area.

1.3.4 Additional Utilities & Safety Systems

Additional utilities required for the operation of the Greenlane biogas upgrading systems may include an odour reduction filter or similar for the treatment of the pungent stripper air/gas mixture, odourisation equipment of the product gas, a gas flare, gas vent, fresh water supply and treatment, effluent drainage, flow meters, purge gas (N_2), compressed air for instruments and calibration gases for the gas analysers. The client is responsible for providing these services as required to the upgrading equipment.

1.4 Greenlane AfterCare

Greenlane, through its Aftercare team, have a large dedicated team of installation, commissioning and service engineers spread around the world. Greenlane is able to provide full customer training and support via on site and classroom training of engineers, end users and maintenance personnel. Some of our services are listed below.

1.4.1 Site Assistance

Greenlane is able to offer and provide a site assistance package to ensure your plant is installed and operated correctly and most efficiently.

Our standard site assistance package is very flexible to meet individual client needs but normally would include:

- Installation Training
- Installation Checking
- Commissioning
- Performance Testing
- Operator Training

1.4.2 Maintenance Contracts

Greenlane is able to offer full maintenance contracts including supply of spare parts These can cover one off service to dedicated preventative maintenance plans covering life of plant. We can provide a service plan to best meet your needs.

1.4.3 Remote Monitoring and Remote Management

Our Aftercare team provides remote monitoring and management options for your Greenlane® Biogas upgrading plant. Monitoring & managing your upgrading plants operation will help ensure your plant is operating at its high efficiency as you require and expect. Hardware is installed for free with your new plant and different service plan choices are available. Refer to our Remote Monitoring and Management Document for more information.

2 Process Description

The Greenlane upgrading system consists of three main processes – the biogas process, the water process and the stripping air process

2.1 Biogas Process

Raw biogas is provided to the inlet isolation valve at the contract interface point.

The biogas flows through an inlet separator to the stage one compressor. Refer to Section 2.1.1 for details of compressor function. The compression process is two stage, complete with inter & after-cooling via water-cooled shell and tube heat exchangers. Temperature, pressure and level instrumentation monitor operation and provide control and safe operation. Discharge check valves are provided to prevent reverse flow of biogas when the system is stopped.

A condensate collector vessel and coalescing filter are provided following the stage 1 & stage 2 discharge coolers respectively. These devices collect and remove condensate and compressor lube oil from the biogas. The condensate collectors also act as receivers for the gas recovered from the flashing vessel. The coalescing filter discharge and scrubbing vessel weir decant drain lines are also connected to this collector vessel.

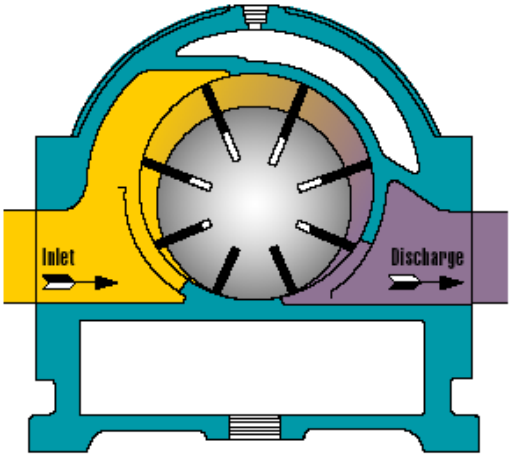
After compression, the biogas enters the bottom of the scrubbing vessel. Inside the vessel the biogas rises to the top, which is counter-flow to the process water flowing downwards. The water preferentially absorbs the more soluble gases such as CO_2 and H_2S. Product gas, which is now almost pure CH_4, exits from the top of the vessel. Packing balls and distributors inside the scrubbing vessel provide increased surface contact area between the gas and water to maximise absorption efficiency.

After the scrubbing vessel the product gas passes through a PSA/TSA adsorber. The molecular sieve media in the drier vessels adsorbs moisture and further purifies the product gas. The dried product gas passes through a filter and a pressure control valve, before being discharged at the skid boundary. The control valve maintains a steady set pressure at the scrubbing vessel, thus ensuring consistent CO_2 and H_2S absorption.

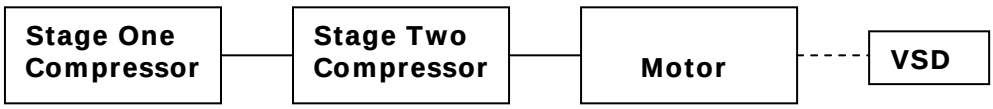
2.1.1 Gas Compression

The RMT series of upgrading plants utilise two stage rotary sliding vane compressors which are considered to be one of the most robust and reliable compressors on the market, ideally suited to dirty and corrosive gases such as wet biogas. The compressor has no valves which significantly reduces maintenance requirements and increases reliability and availability. Spare parts and service are hence low cost, quick and simple compared to other compression technologies such as reciprocating.

Vane compressors feature a one-piece rotor eccentrically mounted inside a water-jacketed cylinder. The rotor is fitted with blades that are free to move radially, in and out of longitudinal slots. These blades are forced out against the cylinder wall by centrifugal force, creating individual pockets of gas, which are compressed as the rotor turns.



The two compressor stages are directly coupled to a common motor, which has Variable Speed Drive (VSD) to enable efficient capacity control. Drive layout is as follows:



The compressors may be lubricated with biodegradable oil. The lubricating oil may be recovered in an oil separator and can normally be disposed by decomposition; i.e. anaerobic digestion.

More information on the compressor operation is provided in the RoFlo Operation & Maintenance manual which is provided with project documentation.

2.1.2 Compressor Cooling / Heat Recovery

Biogas is cooled in the stage 1 & stage 2 discharge coolers. These are shell & tube type heat exchangers with biogas in the tubes and cooling water in the shell. Manual valves are used to balance the water flow through the coolers to achieve optimum gas outlet temperatures. Manual isolation valves for the cooling water circuit are supplied.

[Option] Heat may be recovered from the compressor cooling water circuits by a remote system that normally comprises a plate heat exchanger and 3-way diverter valve with control or similar (client supply). Because full heat recovery cannot normally be relied on to provide sufficient cooling on a 100% continuous basis, a closed circuit water cooler can be provided to remove any excess heat or provide full cooling if required. Greenlane provides connection for client to utilize this heat source as required.

2.1.3 Gas Drying & Final Purification

After the biogas is upgraded in the scrubbing vessel, the water-saturated gas passes through a demister for removal of free moisture, and then to a Pressure Swing Adsorption/Temperature Swing Adsorption (PSA/TSA) adsorber that dries and purifies the final product gas. The gas dryer utilises dual vessels filled with several stages of adsorbent media. One vessel is always active, drying and purifying the product gas, with the other vessel regenerating or on stand-by. A dew point analyser monitors performance of the gas drying system. The vessels are switched when the dew point of the product gas reaches a pre-determined value.

2.1.4 Gas Pressure Control

A control valve located after the drier vessels controls and maintains gas pressure for the drying and scrubbing systems.

2.1.5 Gas Analysers

Gas analysers are installed at the outlet of the system to measure the quality of the product gas. Gas quality control criteria are determined by measuring CO_2, H_2S and dew point of the produced gas. If the gas does not meet specification it is sent to flare. Additional analysers or metering may be available as options on request.

2.1.6 Gas Vent

Gas venting by Pressure Safety Valves (PSV's) prevents excess pressure build up in the system. PSV venting is not part of normal operation, and only occurs during over-pressure situations. It must be ensured by the client that the gas is vented to a safe place.

2.2 Process Water

The process water pump draws regenerated water from the base of the stripping vessel delivering it to the top of the scrubbing vessel. A distributor at the top of the scrubbing vessel ensures the water flows evenly down the vessel to maximise absorption efficiency.

The water, with dissolved CO_2 and H_2S, is collected at the base of the scrubbing vessel and discharged. A control valve on the discharge line maintains scrubbing vessel water level. The water level is maintained to form a liquid seal that prevents gas from discharging into the process water line. The water discharged from the scrubbing vessel is saturated with dissolved CO_2 and H_2S. It is necessary to regenerate the water by stripping it of these dissolved gases.

After being discharged from the scrubbing vessel, the water flows to the flashing vessel. This vessel operates at an intermediate pressure, lower than the scrubbing pressure, but higher than the stripping pressure. Inside the flashing vessel CH_4 that was absorbed by the water in the scrubbing vessel is flashed off, thus minimising CH_4 slip. Recovered flash gas is fed back into the compressor. A back-pressure regulating valve on the flash gas line regulates the pressure in the flashing vessel. A control valve on the water discharge line controls the water level in the flashing vessel. The water level is maintained to form a liquid seal that prevents gas from discharging into the process water line.

The water discharged from the flashing vessel flows to the top of the stripping vessel. A hold-up device and distributor at the top of the stripping vessel ensures the water flows evenly to maximise stripping efficiency. The stripping vessel operates at approximately atmospheric pressure. In the stripping vessel atmospheric air passes upwards in counter-flow to the water falling downwards. Regeneration of the water takes place as the dissolved CO_2 and H_2S is released into the air stream. Packing balls inside the vessel provide increased surface contact area between the water and air, and maximises stripping efficiency. Make up water is added into the vessel as required, to maintain the water level.

The regenerated water at the discharge of the vessel is fed to the process water pump, and the process water cycle repeats.

2.2.1 Water Scrubbing Process

The scrubbing process upgrades the biogas quality by preferentially absorbing the undesirable gases such as CO_2 and H_2S into water. The elevated pressure in the scrubbing vessel facilitates gas absorption. The scrubbing process is designed to operate with chilled process water.

The scrubbing vessel incorporates a weir decant system that skims off and removes the top layer of liquid in the vessel. This layer may contain light hydrocarbon fractions, sulphur, fats and other contaminants. This liquid is discharged into the stage one condensate collector and is disposed of via the soiled water line. Although the liquid is mainly water, care is advised on the disposal because it may carry contaminants from the biogas, thus being potentially hazardous.

Due to the scrubbing vessel weir decant and water blowdown functions, a continuous supply of clean make-up water is required for process water replenishment. Included with the biogas plant is a dosing pump to allow treatment of the water system to maintain good water quality and highest plant efficiency.

2.2.2 Process Water Chilling

Process water temperature is maintained at approximately 7°C to maximise the absorption of CO_2 and H_2S gases in the scrubbing vessel. Cooling is typically achieved via a standard industrial water chiller, located in a safe area, which absorbs heat from the process water. A closed circuit glycol loop via a plate heat exchanger is provided for transferring heat from the process system.

[Option] Industrial water chillers are offered through Greenlane as an optional item. In conjunction with the water chiller, for installations subject to cold ambient conditions, an additional radiator can be supplied to provide direct air chilling and increase overall plant efficiency.

2.2.3 Make-up Water

Make up water must be free of active microbiology, solids that can deposit within the process system and other contaminants. Potable water is preferred, however clean process water may also be used. Care must be taken when choosing a water source that the mineral content (particularly chlorides) is not detrimental to stainless steel 316L.

It is the responsibility of the client to ensure that the process water system water quality is managed to avoid biological growth formation and/or scale build up, which can reduce the efficiency and capacity of the upgrading plant. Water quality, feedstock gas composition and other environmental factors at each site are always different.

Greenlane recommends the client to engage a water treatment specialist to provide analysis, advice and services, especially in cases where contamination or fouling is suspected. When process water quality is managed correctly the Greenlane upgrading plant should not foul or scale, and will provide consistant uninterrupted performance.

The Greenlane process operates at < 10°C water temperature and does not concentrate water-borne contaminants, so a zero or minimal water treatment regime is expected to provide reliable operation, given:

(i) the raw biogas feedstock is free of liquids at point of supply to the Greenlane plant
(ii) the recommended compressor oil is used
(iii) the stripping air supply is properly filtered

Refer to the Performance & Utilities Data for typical make up water quantity requirements. Values provided are based on average water consumption over a 7 day period of running with steady raw biogas production.

2.2.4 Water Discharge

Process water is discharged when the water blow-down valve opens. The frequency for blow-down is based on observed requirements for water changes necessary to keep the process water quality satisfactory. Flow values stated in other documentation are average annual values, not peak instantaneous flows.

2.2.5 Condensate

Water contaminated with oil and/or condensate is discharged from the condensate collector. An (optional) oil separator may be used to collect biodegradable lube oil that can be decomposed in the biogas digestion process. The separated water can then be disposed of with the process water blow-down stream as in Section 2.2.4.

2.3 Stripping Air

Air is drawn through an air filter and inverted U-bend before entering the base of the stripping vessel. The inverted U-bend prevents water from discharging through the stripping air inlet in the event of vessel flooding. Inside the vessel, the air is drawn upwards in counter-flow to the water flowing downwards. The air strips the dissolved CO_2 and H_2S out of the water and the air/gas mixture exits from the top of the vessel.

Stripping air/gas is discharged continuously during operation, regardless of the operating capacity. This stream contains air, CO_2, H_2S and other gases, and must be sent to a safe disposal point. The air/gas mixture is usually discharged to a biological filter, such as a carbon, earth or bio-filter. Greenlane may be able to assist with options for this equipment if required. Thermal Oxidiser options are also available.

2.4 Integral Safety Systems

Protection devices fitted to the Greenlane biogas upgrading system include:

- Pressure transmitter at compressor suction to protect the compressor and prevent gas inlet pressure falling below atmospheric pressure, thus protecting against the possibility to draw air into the process and create an explosive mix.
  Note: This device is secondary level protection. Primary level protection must be provided by the client, eg O_2 sensor following digesters.
- Pressure transmitter and a temperature transmitter fitted at compressor gas discharge to protect from over pressure and over temperature.
- Pressure relief valve fitted to gas line at discharge of compressor.
- Pressure relief valve fitted to gas line at scrubbing vessel discharge.
- Over speed protection is controlled by the Variable speed drive (VSD) units

3 System Control

3.1 Introduction

A Programmable Logic Controller (PLC) manages the Greenlane biogas upgrading system. The PLC is installed in a control cabinet, which is located in the designated non-hazardous electrical room within a container (containerised solutions). For non containerised solutions the electrical equipment is free issued to the client and must be installed in a non-hazardous, clean, dry and temperature controlled room, with cable schedule provided to client for them to provide site cabling.

Access to system control is either through the human machine interface (HMI) or the client's central control system (CCS) or SCADA. A Human Machine Interface (HMI) is provided which shows the current operating status and allows the operator to view process readings, the alarm and trip set points, and to reset any system trips. Pressure and temperature transmitters and other system instruments are connected to the PLC.

3.2 Program Logic Controller (PLC)

The Greenlane RMT Series utilise a Siemens S7, 300 series safety PLC. This PLC performs the following control functions:

- Provide the means for the operators to start and stop the system
- Perform safety functions by monitoring the system and causing it to go to a safe condition if any faults are detected
- Provide dynamic control of the process to ensure that the delivery of clean, dry product gas is optimised
- Interface for remote monitoring and diagnostics

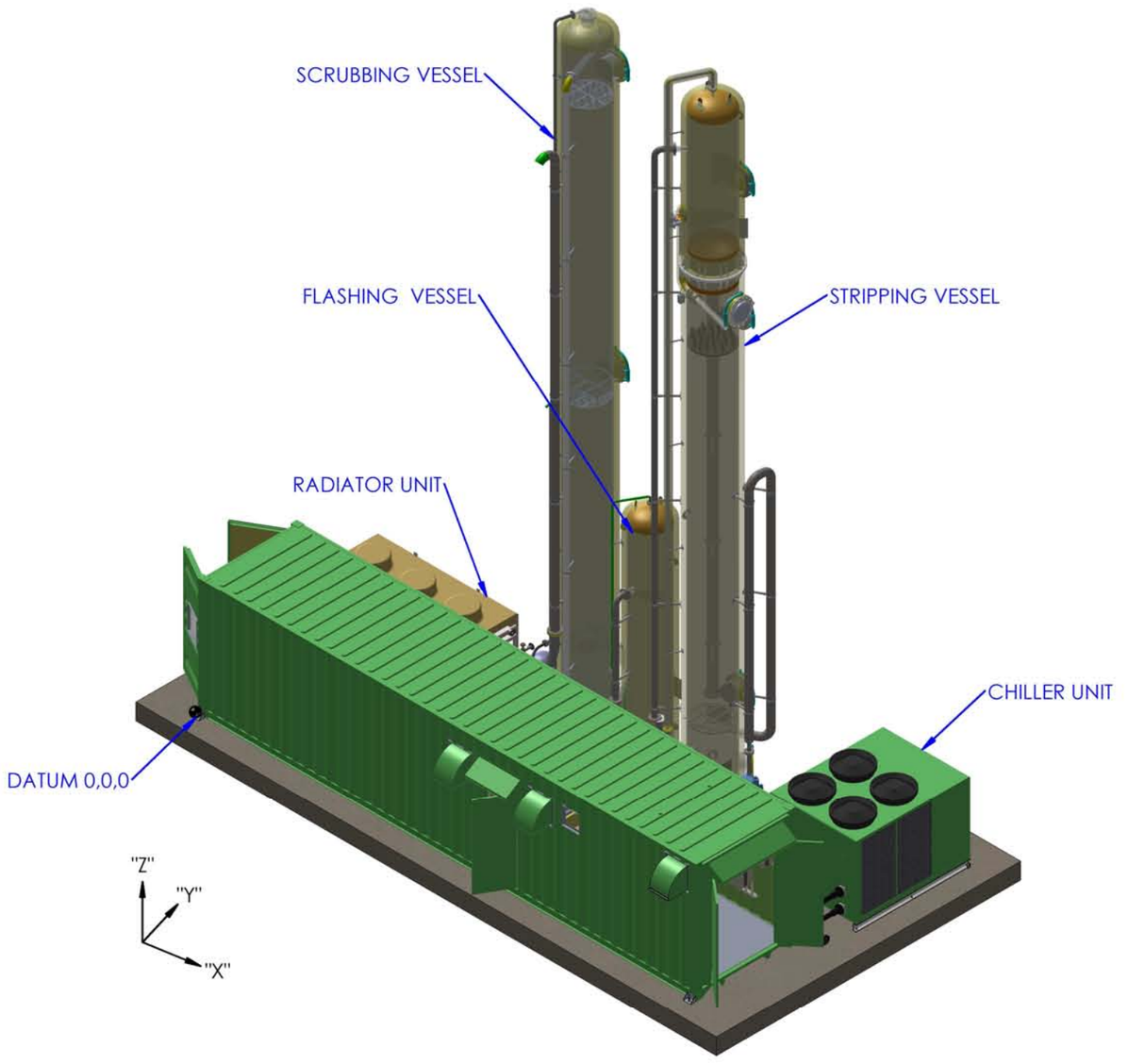
3.3 Human Machine Interface (HMI)

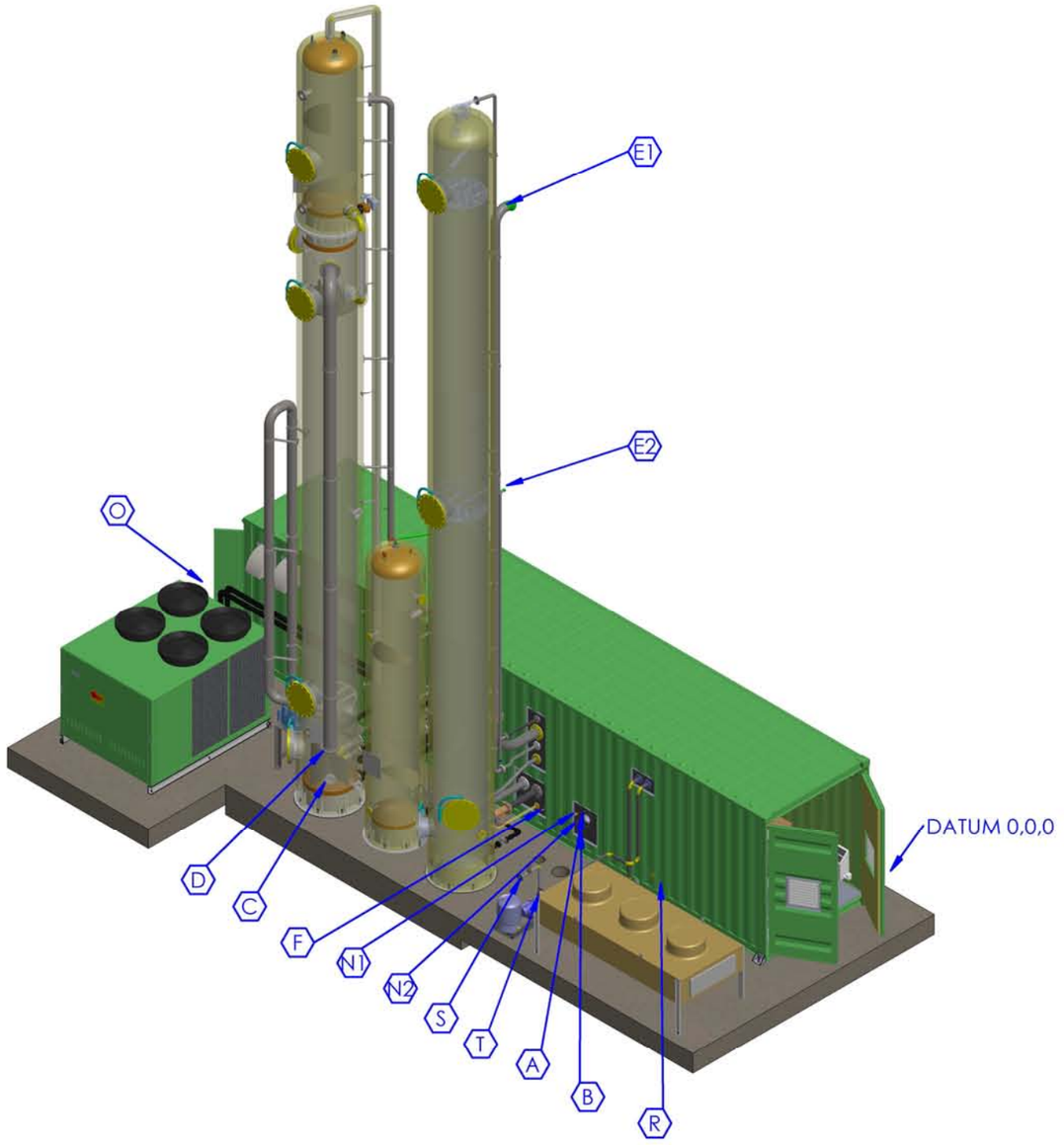
The HMI communicates with the PLC on a continual basis. It provides the following functions:

- Displaying monitored system process values
- Displaying package operating status
- Displaying event and alarm messages
- Providing a log of any alarm and trip messages, along with the time of occurrence
- Manual control of process and drain valves
- Manual entry of system alarm values (limited access)
- Manual entry of system trip values (controlled access)
- Resetting from a tripped state

3.4 Communication

Interface with the clients CCS or SCADA is via Ethernet TCP/IP protocol. Other forms of communication eg Profibus or Modbus are also available as priced option should client require communication in a different format. Communications list is available on request, which shows what is pre-configured in our PLC for data exchange with the client. Additional options from the standard plant that interface with the PLC are added to this list to match each specific project.





Description	Key	Size	Rate	X	Y	Z
Gas Inlet	A	DN150	CL150	4222	2396	783
Product Gas	B	DN50	CL150	4360	2396	533
Process Water Supply	C	DN80	CL150	7968	4636	812
Effluent Gas	D	DN200	CL150	7649	4955	1799
Safety Vent	E1	DN150	CL150	5375	2977	12857
Process Vent	E2	DN50	CL150	5183	3343	7401
Gas To Flare	F	DN15	CL150	5205	2404	493
Inert Gas	N1	DN15	Swagelok	4432	2417	609
Inert Gas	N2	DN15	Swagelok	4432	2417	780
Waste Water	O	DN50	CL150	12586	2794	83
Soiled Water Out	R	3/4"	CL3000	2497	2405	348
To Heat Recovery	S	40	CL150	3620	4561	960
From Heat Recovery	T	40	CL150	3106	4613	960

Note :
1. Drawing for indicative sales purpose only, Details will be finalised with tech. package following order.

PRELIMINARY

REV.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR SALES INFORMATION	15/09/2011	PM

Project name: RIMU
BIOGAS UPGRADING PLANT

Drawing name: -
GENERAL ARRANGEMENT
-

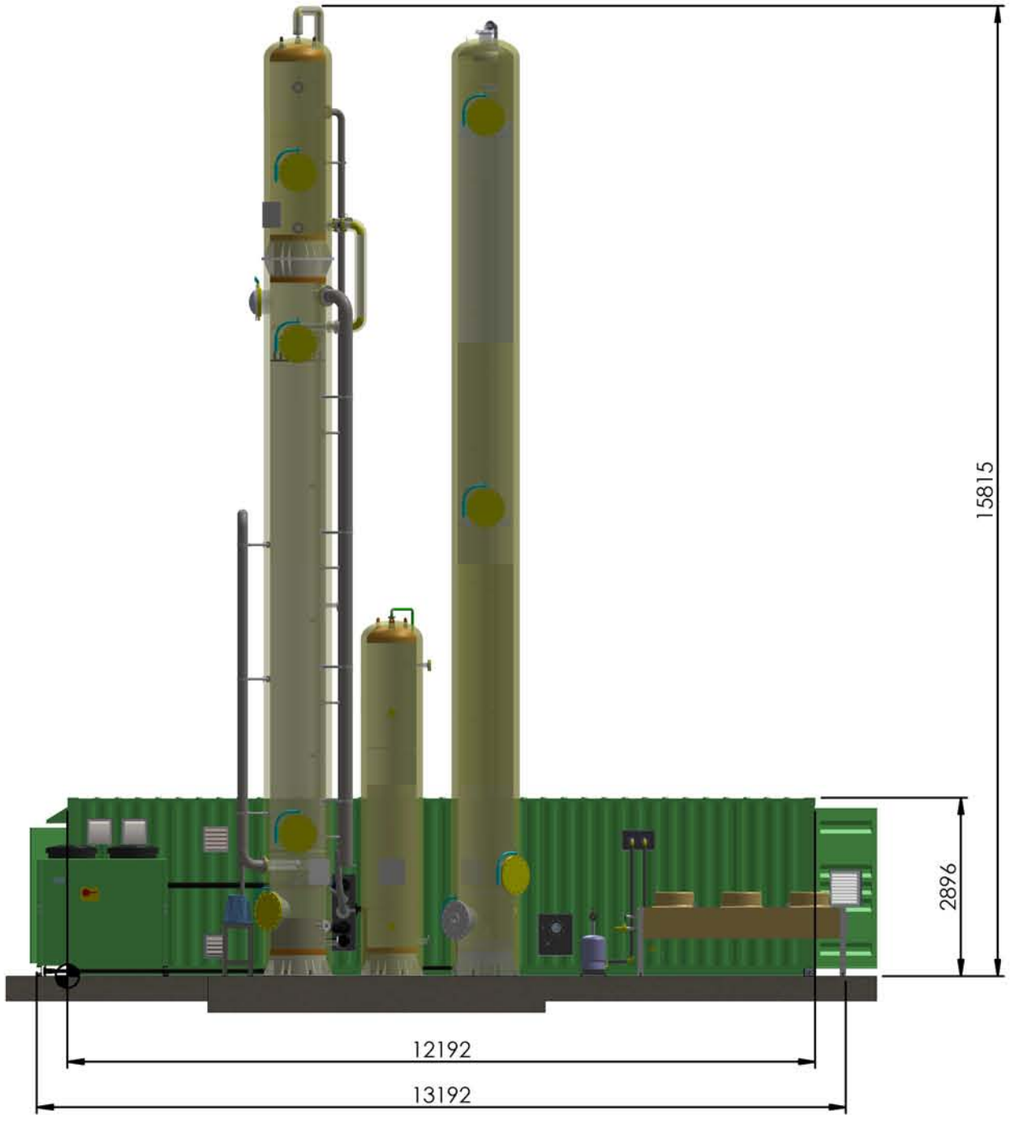
ALL DIMENSIONS IN MM

Drawn G.J. 10.08.11
Checked P. MCLEAY 16.09.11
Signed P. MCLEAY

Fabrication tolerances to comply with "Flotech General Standard for Dimensional Tolerances" unless specified otherwise on the drawing.

Drawing No. RIM104-000-00 -Sales

A3 | Scale: 1:100 | SHEET 1 OF 6 | Material: - | Weight: kg 154733.2 | Rev 0



PRELIMINARY

REV.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR SALES INFORMATION	15/09/2011	PM

Project name: RIMU
BIOGAS UPGRADING PLANT

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GENERAL ARRANGEMENT
-

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Drawn G.J. 10.08.11
Checked P. MCLEAY
Signed P. MCLEAY

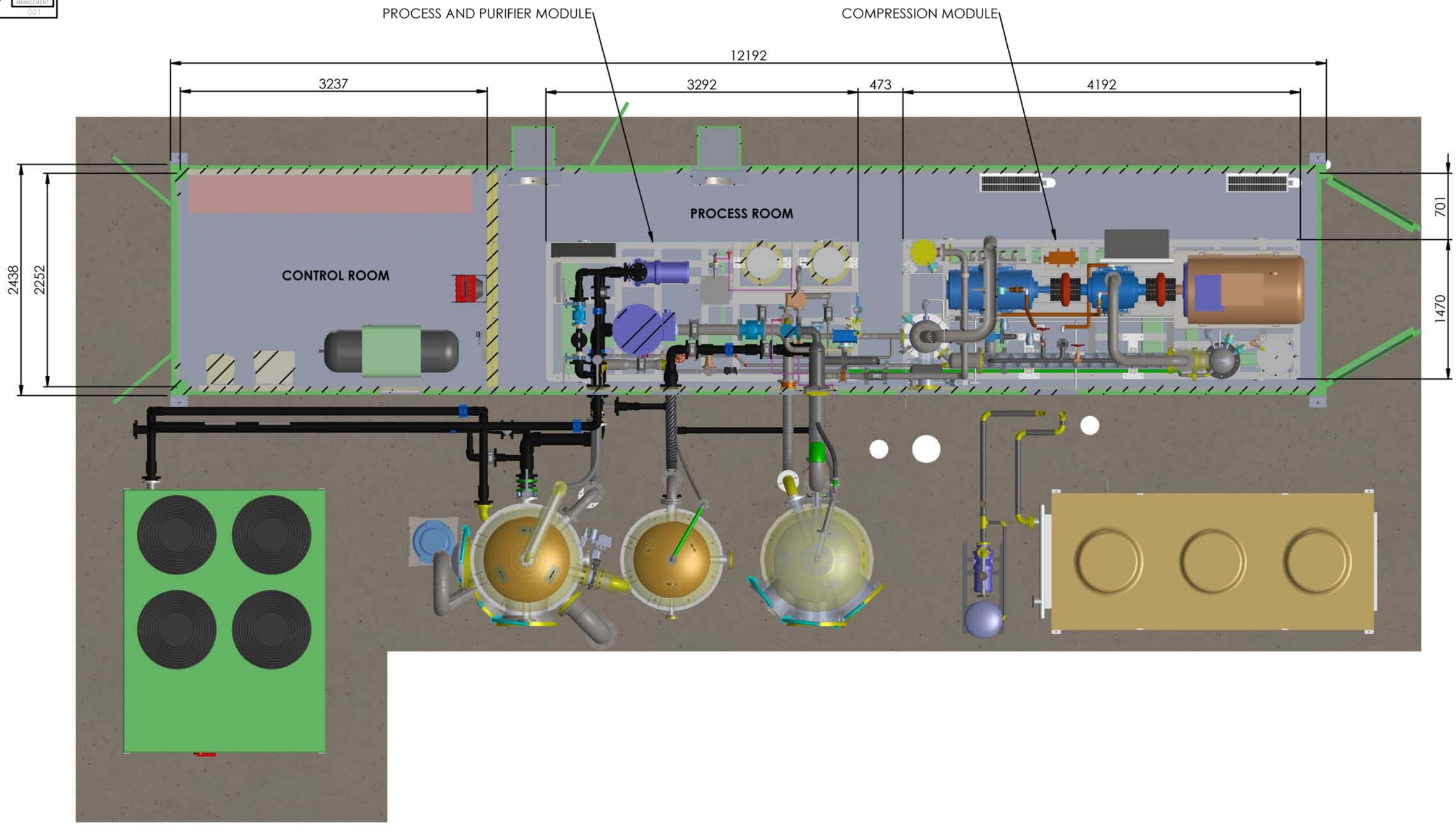
Drawing No: RIM104-000-00 -Sales

A3 | Scale: 1:100 | SHEET 2 OF 6

Material: -

Weight: kg 154733.2

Rev 0



PRELIMINARY

REV.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR SALES INFORMATION	15/09/2011	

Project name: RIMU
BIOGAS UPGRADING PLANT

Drawing name: -
GENERAL ARRANGEMENT
-

ALL DIMENSIONS IN MM

Drawn G.J. 10.08.11
Checked P. MCLEAY -
Signed P. MCLEAY

Fabrication tolerances to comply with "Flotech General Standard for Dimensional Tolerances" unless specified otherwise on the drawing.

Drawing No. RIM104-000-00-Sales

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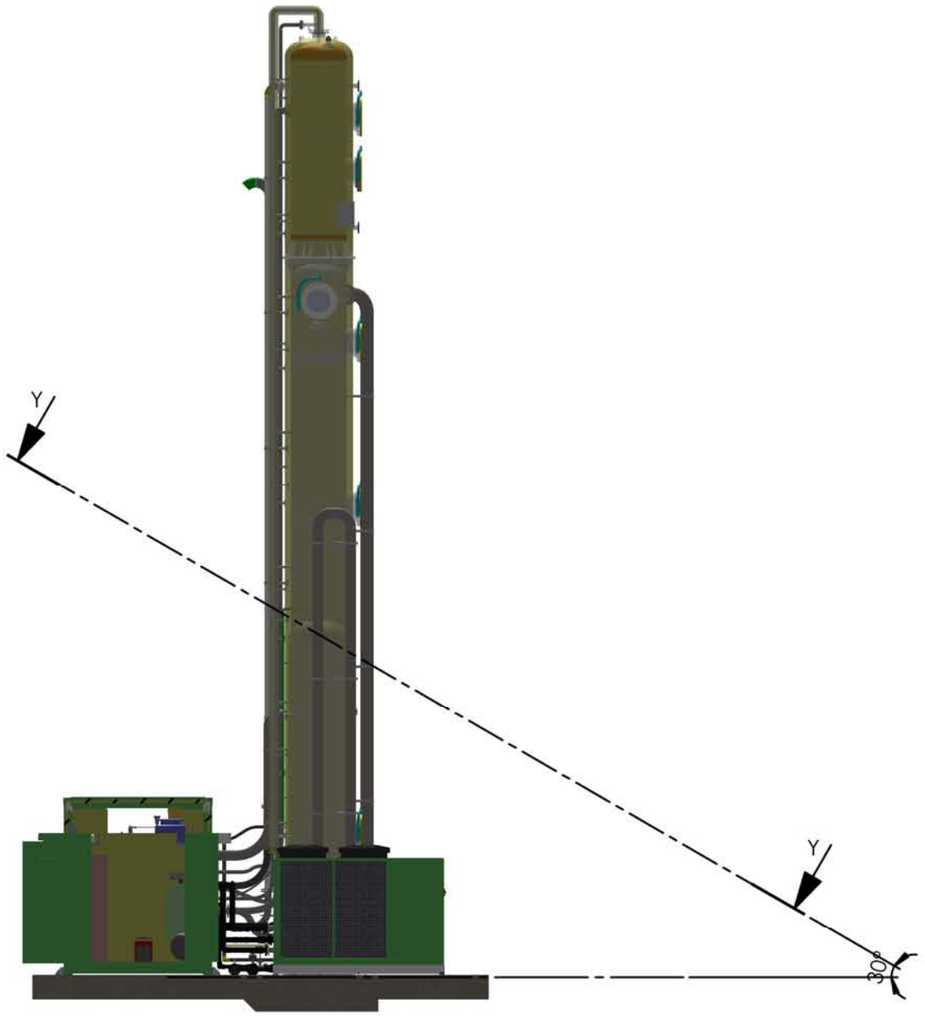

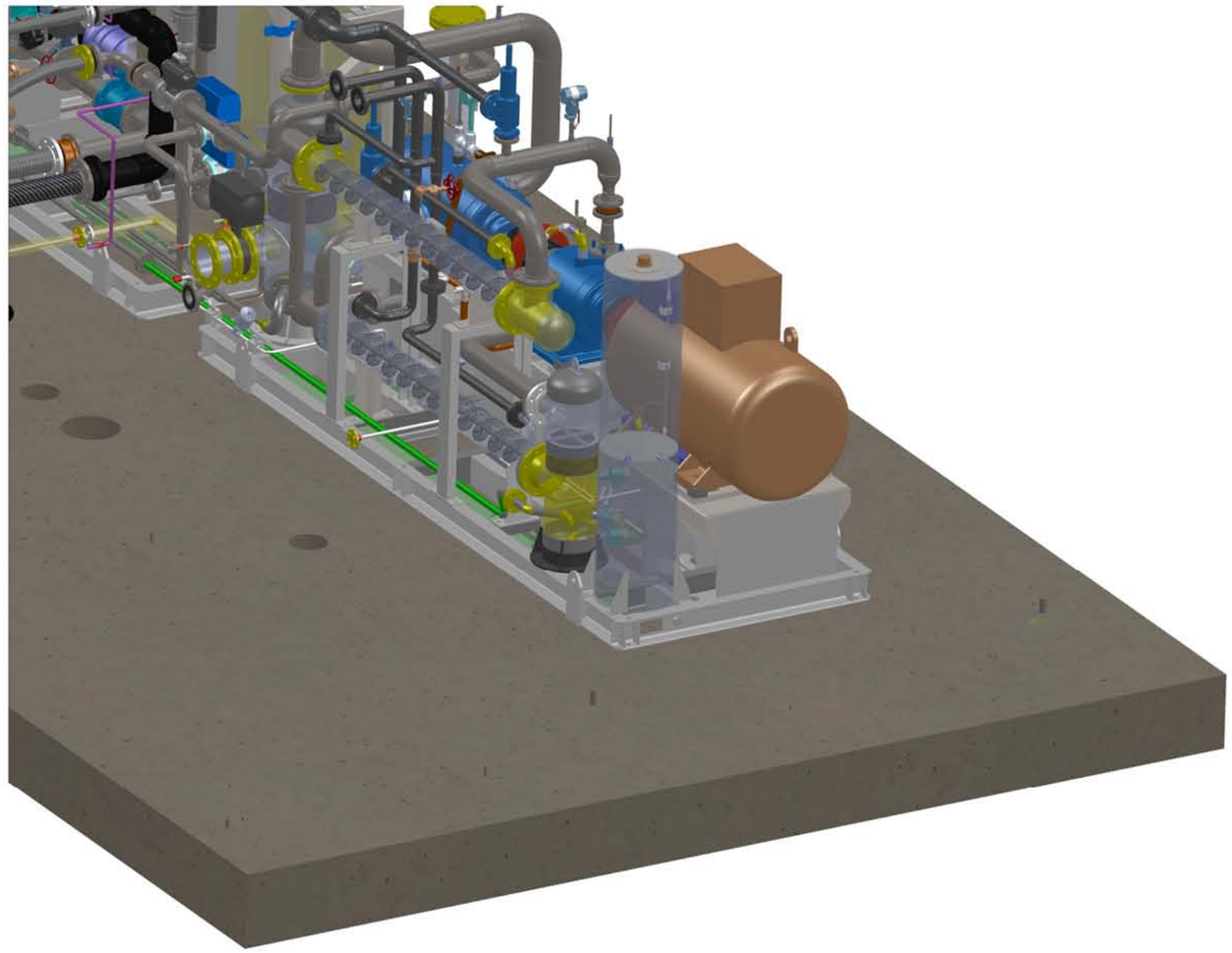

PRELIMINARY

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0	ISSUED FOR SALES INFORMATION	CC	P McL	17/3/2011

Project name: RIMU
BIOGAS UPGRADING PLANT

Drawing name: -
General Arrangement

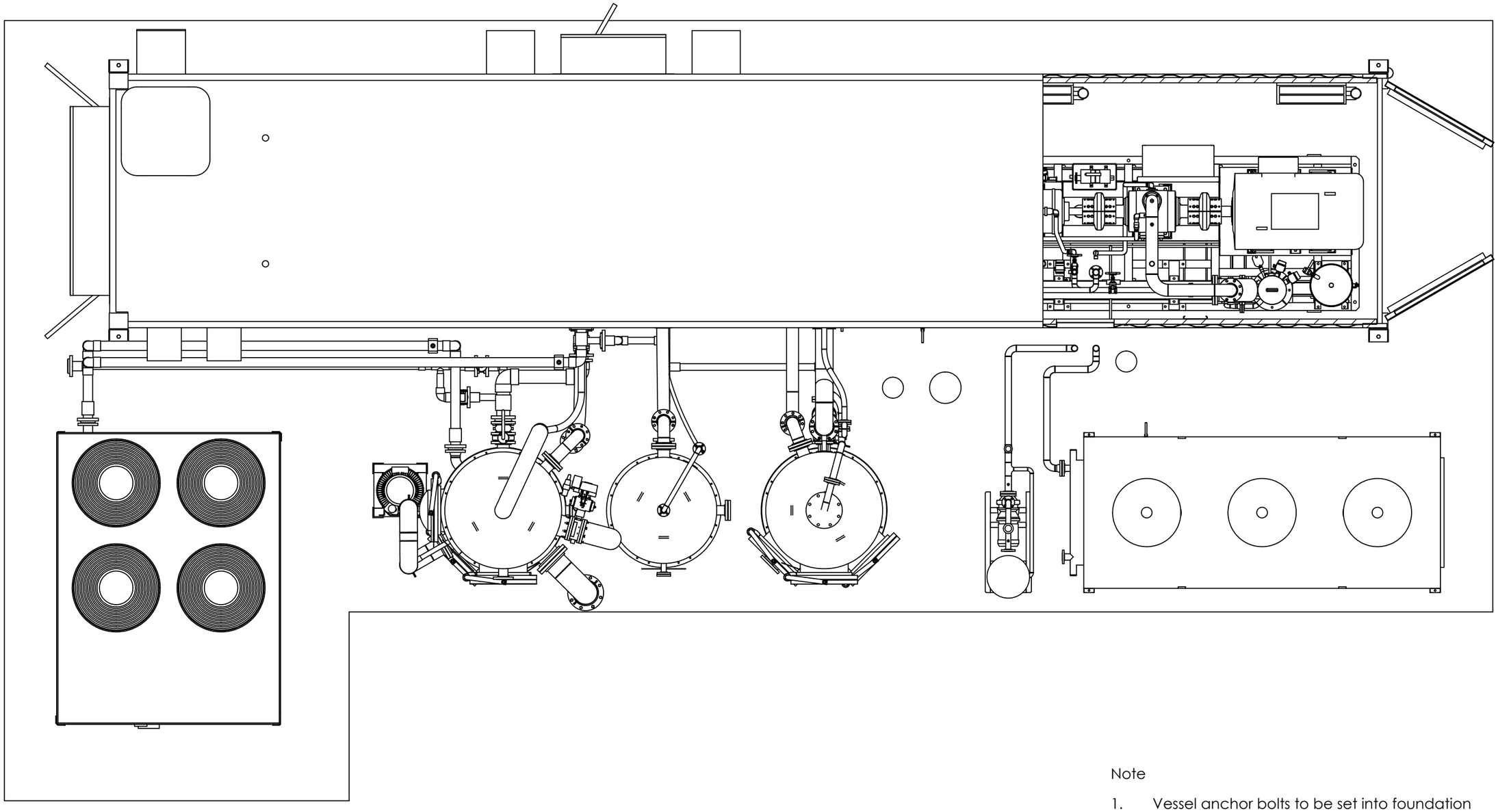
Fabrication tolerances to comply with "Flotech General Standard for Dimensional Tolerances" unless specified otherwise on the drawing.

ALL DIMENSIONS IN MM

Drawn	Carl Chu	17/03/2011
Checked	Peter Mcleay	17/03/2011
Signed	Peter Mcleay	17/03/2011

Drawing No.: RIM104-000-00 -Sales

A3 | Scale: 1:30 | SHEET 4 OF 6 | Material: - | Weight: 154733.2 | Rev 0



Note

1. Vessel anchor bolts to be set into foundation
2. Foundation bolts for container are to be installed once plant is set in place
3. Vessels, piping & foundation bolts have been designed using Standard Greenlane Design Criteria

PRELIMINARY

REV.	DESCRIPTION	DRAWN	APPROVED	DATE
0	ISSUED FOR SALES INFORMATION	J. W.	P McL	2/08/2012

Project name: RIMU
BIOGAS UPGRADING PLANT

Drawing name: -
General Arrangement

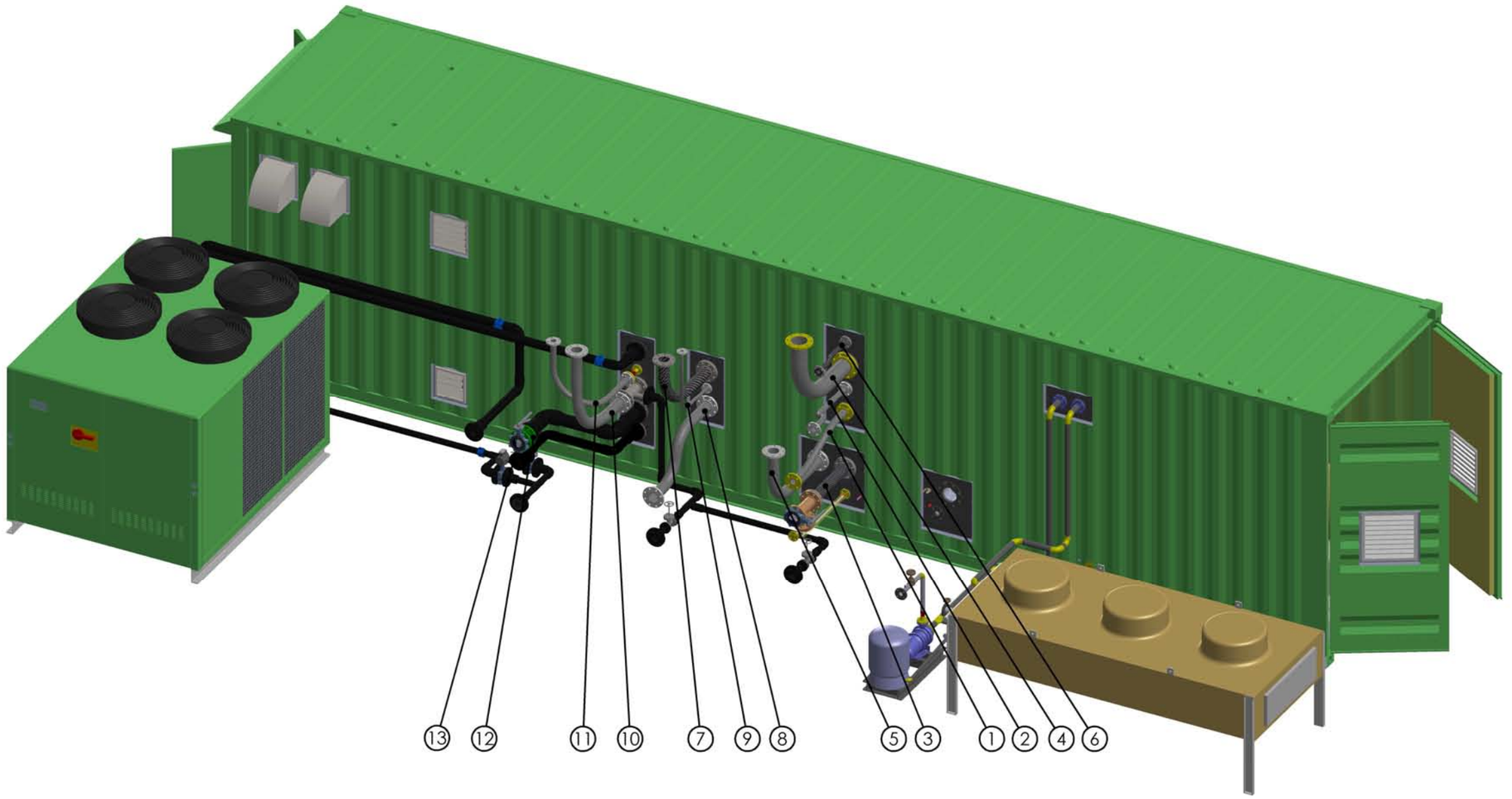
Fabrication tolerances to comply with "Flotech General Standard for Dimensional Tolerances" unless specified otherwise on the drawing.

ALL DIMENSIONS IN MM

Drawn	Carl Chu	15/03/2011
Checked	Peter Mcleay	15/03/2011
Signed	Peter Mcleay	15/03/2011

Drawing No.: RIM104-000-00 -Sales

A3 | Scale: 1:40 | SHEET 5 OF 6 | Material: - | Weight: 154733.2 | Rev: 0



ITEM	DESCRIPTION	QTY	SIZE	RATE	LENGTH	P&ID LINE
	FLEXIBLE CONNECTIONS - ELAFLEX					
1	SCRUBBER GAS INLET FLEXIBLE CONNECTION	1	65NB	CL150	1141	570
2	SCRUBBER GAS OUTLET FLEXIBLE CONNECTION	1	50NB	CL150	1063	571
3	SCRUBBER WATER OUTLET FLEXIBLE CONNECTION	1	100NB	CL150	708	572
4	SCRUBBER GAS VENT FLEXIBLE CONNECTION	1	150NB	CL150	1532	573
5	SCRUBBER WATER IN CHILLED FLEXIBLE CONNECTION	1	100NB	CL150	1422	574
6	DRIER PROCESS VENT FLEXIBLE CONNECTION	1	40NB	CL150	1016	590
7	FLASHER GAS WATER IN FLEXIBLE CONNECTION	1	100NB	CL150	1337	565
8	FLASHER GAS WATER OUT FLEXIBLE CONNECTION	1	100NB	CL150	1364	566
9	FLASHER GAS OUT RECYCLE 2 FLEXIBLE CONNECTION	1	25NB	CL150	1928	567
10	STRIPPER WATER IN FLEXIBLE CONNECTION	1	100NB	CL150	1613	580
11	FLASHER 2 GAS OUT FLEXIBLE CONNECTION	1	50NB	CL150	1577	589
	EXPANSION JOINTS - ELAFLEX GREEN BAND					
12	STRIPPER WATER OUT CHILLED	1	50NB	CL150	130	587
13	STRIPPER WATER OUT TO PUMP	1	100NB	CL150	130	585

PRELIMINARY

REV.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR SALES INFORMATION	12/08/2011	PM

Project name: RIMU
BIOGAS UPGRADING PLANT

Drawing name: -
GENERAL ARRANGEMENT
FLEXIBLE CONNECTIONS - GENERAL ARRANGEMENT

ALL DIMENSIONS IN MM

Drawn	G.J.	10.08.11
Checked	P. MCLEAY	12.08.11
Signed	P. MCLEAY	12.08.11

Fabrication tolerances to comply with "Flotech General Standard for Dimensional Tolerances" unless specified otherwise on the drawing.

Drawing No. RIM104-000-00 -Sales

A3 | Scale: 1:50 | SHEET 6 OF 6 | Material: - | Weight: kg 154733.2 | Rev 0

PERFORMANCE AND UTILITIES DATA

Design Point - 600 Nm3/hr

Capacity		Rimu
Raw Gas Inlet Capacity*	Nm3/hr	600
Inlet Pressure	mbar	50
Inlet Temperature	degC	35

** Normal Conditions are defined as 0degC @ 1.013 bar(a)*

Cost		
Price of 1Kwh	AUD	0.08
Price of 1 m^3 of water	AUD	1.00
Price of 1 liter of oil	AUD	4.00
Operating hours per year	Hours	8350

Power Consumption		Rimu
Compressor Power Draw	kW	103.1
Water Pump Power Draw	kW	32.2
Stripping Air Blower Draw	kW	3.7
Drier/Purifier Heater - average over 24 hours	kW	2.1
Ancillaries	kW	0.8
Total Power	kW	**141.9**

Estimated Operating Cost		Rimu
Electricity cost	AUD /year	94762
Electrical energy per unit raw gas	kWh/Nm^3	0.236
Water cost	AUD /year	752
Lubrication oil cost	AUD /year	8901
TOTAL COST	AUD /year	104415
TOTAL COST per unit raw gas	AUD/ 1000 Nm^3	20.80

Utilities Consumption		Rimu
Lubrication oil for compressor	l/h	0.266
Compressed Air	5-7 bar(g), m^3/hr	3.0
Make-up Water	< 25°C (litres/hr)	90.0

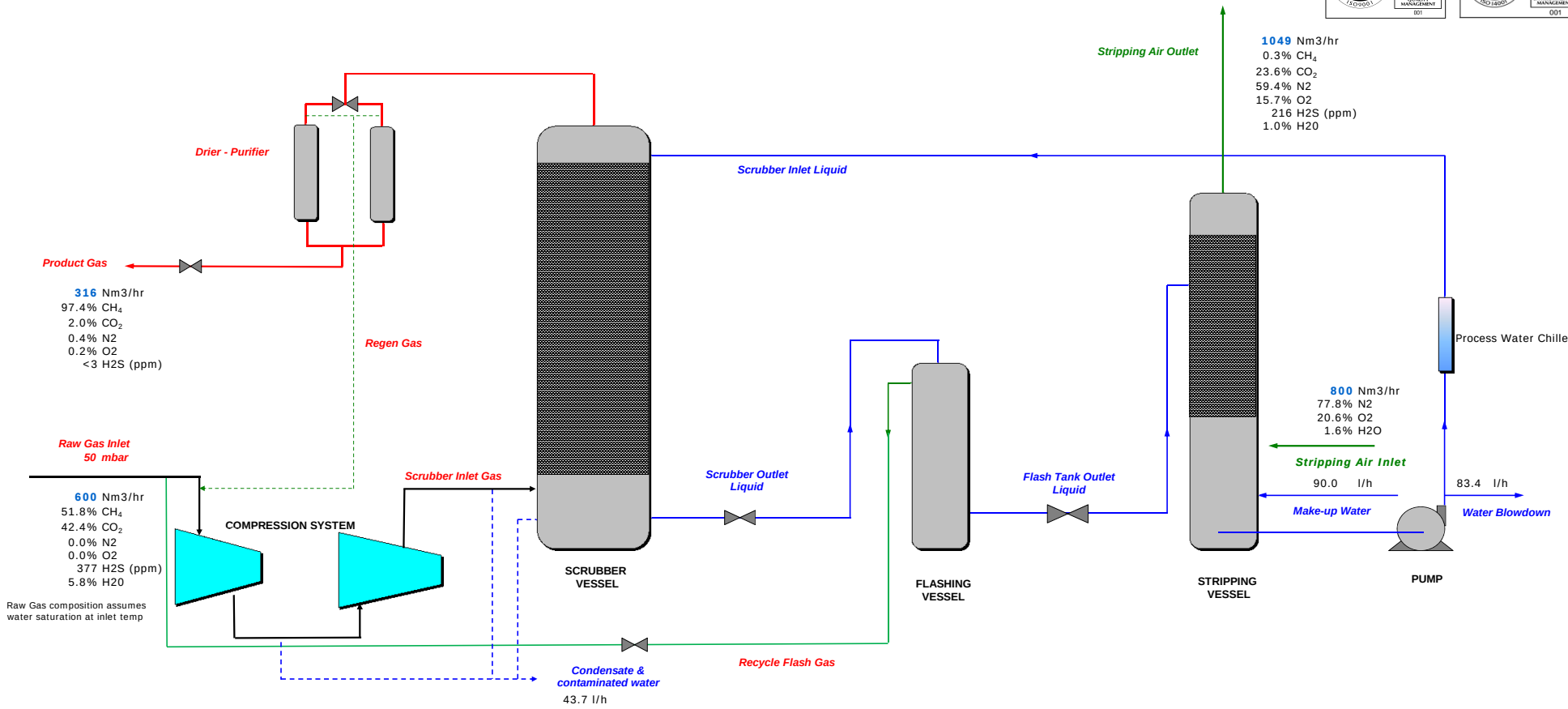
Effluent Streams		Rimu
Soiled Water & Blowdown Drains	l/h	127.0
Effluent Air, (Separated Gas)	m^3/h	1049

Optional Items		Rimu
Chiller power Draw*	kW	22.0
Chilled Water Recirculation Pump (kW)	kW	4.0
Radiator*	kW	4.0
Radiator Recirculation Pump	kW	1.3
Electrical energy per unit raw gas*	kWh/Nm^3	0.052
Odourising Unit	kg/yr	42.6

**20 degC average annual temperature*

Heat Recovery (Available)		Rimu
Heat Recovery*, available 55°C @ Max design capacity	kW	82.5

Revision Issued 11-Dec-13



Notes.

1. The information provided in this diagram is typical and to be used for preliminary information only.
2. Make-up water, condensate & contaminated water and blowdown drains flows are average annual volumes, not instantaneous flows which may be considerably higher.
3. Effluent Air flow is estimate based on raw gas composition entered as design case within Performance & Utilities. Varying composition will effect effluent stream.
4. The composition of effluent air stream is shown as steady state in mass balance. Any downstream equipment needs to be sized with margin on flow and also composition to account for variances in stability, ramping, start-up/shutdown occurances. It is essential Greenlane are consulted for input on any downstream equipment selection.

Greenlane Rimu Biogas Upgrading System Process Diagram

Revision Issued 11-Dec-13

Greenlane References Worldwide

Location (City/State, Country)	Capacity (Nm³/h)	Working Since	Feedstock	Use of upgraded biogas
Colorado, USA	3xTotara+ 7500	Commissioning 2014	Organic Waste	Pipeline injection
Vancouver, Canada	Kanuka 250	Commissioning 2014	Ag Waste	Pipeline injection
Scotland, U K	Matai 1200	Commissioning 2014	Ag Waste	Pipeline injection
Ayrshire, U K	2 Totara+ 5000	Commissioning 2014	Organic Waste	Pipeline injection
Widnes, Cheshire, UK	Totara 2000	Commissioning 2014	Organic Waste	Pipeline injection
Beccles; Suffolk UK	Totara 2000	Commissioning 2014	Organic Waste	Pipeline injection
Colorado, USA	Kanuka 300	Commissioning 2014	Organic Waste	Pipeline injection
Sao Pedro, RJ, Brazil	Matai 1200	Commissioning 2014	Municipal Solid Waste	CNG Vehicles (Cars)
Västerås, Sweden	Rimu 800	Commissioning 2014	Organic Waste	CNG Vehicles (Cars)
Perris, CA, USA	Totara 2000	Commissioning 2014	Organic Waste	CNG Vehicles (Trucks)
Beijing, China	Manuka 130	Commissioning 2014	Ag Waste	CNG Vehicles
Montreal, Canada	7xTotara+ 16000	Commissioning 2014	Municipal Solid Waste	Pipeline injection
Akureyri, Iceland	Kanuka 150	Commissioning 2014	Municipal Solid Waste	CNG Vehicles (Cars)
Kobe, Japan	2xKanuka 600	Commissioning 2014	WWTP	CNG Vehicles (Cars)
Alteno, Germany	Rimu 800	2014	Organic Waste	Pipeline injection
Oslo, Norway	Matai 1200	2013	Organic Waste	CNG Vehicles (Cars)
Zwickau, Germany	Rimu 750	2012	Crops/Liquid Manure	Pipeline injection
Canton, MI, USA	2xTotara+ 5400	2013	Municipal Solid Waste	Pipeline injection
Mörrum, Sweden	Kanuka 300	2013	Household waste	CNG Vehicles (Cars)
Anklam, Germany	2xTotara 4000	2012	Organic Waste	Pipeline injection
Vierverlaten, Netherlands	Totara+ 2200	2012	Organic Waste	Pipeline injection
Stockport, UK	Kanuka 300	2012	Organic Waste	Pipeline injection
Indiana, USA	Totara+ 2500	2012	Ag Waste	Gas grid and CNG Vehicles (Cars)
Borås, Sweden	Kanuka 300	2012	WWTP	CNG Vehicles (Cars)
Kobe, Japan	Kanuka 300	2012	WWTP	CNG Vehicles (Cars & Buses)
Skövde, Sweden	Rimu 800	2012	Organic Waste	CNG Vehicles (Cars & Buses)
Hitachi, Japan	2x CSFR 225	2012	WWTP	CNG Vehicles (Cars)
Hamilton, ON, Canada	Rimu 800	2011	WWTP	Pipeline injection
Gävle, Sweden	Kanuka 300	2011	WWTP	CNG Vehicles (Cars)
Dinteloord, Netherlands	Totara+ 2200	2011	Organic Waste	Pipeline injection
Dinteloord, Netherlands	Matai 1250	2011	Organic Waste	Pipeline injection
Fredericia, Denmark	Kanuka 300	2011	WWTP	Pipeline injection
Kouvola, Finland	Kanuka 300	2011	WWTP	Pipeline injection
Seelow, Germany	Totara 2000	2011	Crops/Liquid Manure	Pipeline injection
Stresow, Germany	Matai 1200	2011	Crops/Liquid Manure	Pipeline injection
Lidköping, Sweden	Totara 2000	2011	Organic Waste	CNG Vehicles (Cars)
Tarumi, Japan	2 x CSFR 330	2010	WWTP	CNG Vehicles (Cars)
Katrineholm, Sweden	Rimu 800	2010	Organic Waste	CNG Vehicles (Cars)
Didcot, Oxfordshire, UK	Manuka 130	2010	WWTP	Pipeline injection
Abbotsford, BC, Canada	Rimu 750	2010	Ag Waste	Pipeline injection
Västervik, Sweden	Manuka+ 130	2010	WWTP	CNG Vehicles (Cars)
Ueda, Japan	CSFR 100	2009	WWTP	CNG Vehicles (Cars)
Redvale, New Zealand	Manuka 80	2009	Municipal Solid Waste	CNG Vehicles (Cars)
Örebro, Sweden	Totara 2000	2009	Organic Waste	CNG Vehicles (Cars)
Lille (Marquette), France	Manuka+ 100	2009	WWTP	CNG Vehicles (Cars)
Motala, Sweden	Manuka 80	2009	WWTP	CNG Vehicles (Cars & Buses)
Katrineholm, Sweden	Manuka 80	2009	WWTP	CNG Vehicles (Cars)
Güstrow, Germany	5 x Totara 10 000	2009	Crops	Pipeline injection
Madrid, Spain	2 Totara 4 000	2009	Municipal Solid Waste	Pipeline injection, CNG Vehicles (Buses) & Power Gen
Seoul, Korea	CSFR 200	2009	WWTP	CNG Vehicles (Cars)
Kobe, Japan	2 x 330 = 660	2006	WWTP	CNG Vehicles (Cars & Buses)
Lille, France	2 x 600 = 1 200	2006	Municipal Solid Waste	CNG Vehicles (Buses)
Kobe, Japan	150	2004	WWTP	CNG Vehicles (Cars)
Trollhättan 2, Sweden	400	2000	WWTP	CNG Vehicles (Cars)
Reykjavik, Iceland	90	1999	WWTP	CNG Vehicles (Cars)
Kalmar, Sweden	90	1998	WWTP	CNG Vehicles (Cars)
Uppsala, Sweden	90	1998	WWTP	CNG Vehicles (Cars & Buses)
Linköping, Sweden	2 x 330 = 660	1997	Organic Waste	CNG Vehicles (Cars & Buses)
Bromma, Sweden	90	1997	WWTP	CNG Vehicles (Cars & Buses)
Trollhättan, Sweden	140	1995	WWTP	CNG Vehicles (Cars & Buses)
Sonzay, France	100	1994	WWTP	CNG Vehicles (Cars)
Lille (Marquette), France	100	1993	WWTP	CNG Vehicles (Cars)

GREENLANE BIOGAS: MANUKA -TOTARA+						
Model	**No**	**Plant location**	**Customer**	**Country**	**Capacity, Nm3/h**	**Project Ref:**
Totara/	1	Madrid	UTE - Madrid City	Spain	2000	P6013
Totara+	2	Madrid	UTE - Madrid City	Spain	2000	P6013
	3	Gustrow	Envitec	Germany	2000	P6003
	4	Gustrow	Envitec	Germany	2000	P6003
	5	Gustrow	Envitec	Germany	2000	P6003
	6	Gustrow	Envitec	Germany	2000	P6003
	7	Gustrow	Envitec	Germany	2000	P6003
	8	Örebro	SBI	Sweden	2000	P6012
	9	Lidköping	SBI	Sweden	2000	P6156
	10	Seelow	KTG	Germany	2000	P6282
	11	Anklam	Suikie Unie	Germany	2000	P6949
	12	Anklam	Suikie Unie	Germany	2000	P6949
	13	Dinteloord	Suikie Unie	Netherlands	2200	P6624
	14	Hold	Hold	-	2000	P6630
	15	Canton MI	Clean Energy	USA	2600	P6767
	16	Canton MI	Clean Energy	USA	2600	P6767
	17	Vierverlaten	Suikie Unie	Netherlands	2000	P6912
	18	Fair Oaks IN	Anaergia/UTS	USA	2500	P6878
	19	Montereal	BFI	Canada	2285	P6939
	20	Montereal	BFI	Canada	2285	P6939
	21	Montereal	BFI	Canada	2285	P6939
	22	Montereal	BFI	Canada	2285	P6939
	23	Montereal	BFI	Canada	2285	P6939
	24	Montereal	BFI	Canada	2285	P6939
	25	Montereal	BFI	Canada	2285	P6939
	26	Widnes Cheshire	ReFood	U K	2000	P7318
	27	Colorado	EDF Renewable Dev	USA	2500	P7337
	28	Colorado	EDF Renewable Dev	USA	2500	P7337
	29	Colorado	EDF Renewable Dev	USA	2500	P7337
	30	Beccles, Suffolk	FLI, Energ	U K	2000	P7353
	31	Perris	Perris	USA	2000	P7365
	32	Ayrshire	William Grants & Sons	U K	2500	P7427
	33	Ayrshire	William Grants & Sons	U K	2500	P7427
	34					
					72395	
Matai	1	Stresow	Envitec	Germany	1200	P6303
	2	Dinteloord	Suiker	Netherlands	1250	P6623
	3	Oslo	Cambi	Norway	1200	P7082
	4	Sao Pedro	Ecometano	Brasil	1200	P7097
	5	Scotland	Couper Angus	U K	1200	P7411
	6					
					6050	
Rimu	1	Zwickau	Envitec	Germany	800	P6190
	2	Abbotsford Farmer	Catalyst	Canada	750	P6192
	3	Katrineholm	SBI	Sweden	800	P6313
	4	Hamilton ON	CH2M Hill	Canada	800	P6692
	5	Skövde	Farmatic	Sweden	800	P6704
	6	Alteno	Schraden Biogas	Germany	800	P6730
	7	Västerås	SBI	Sweden	800	P7201
	8					
					5550	
Kanuka	1	Kouvola	Sarlin	Finland	300	P6511
	2	Fredericia	DONG	Denmark	300	P6653
	3	Gävle	SBI Ekogas	Sweden	300	P6687
	4	Colorado	EDF Renewable Dev	USA	300	P7299
	5	Kobe	Kobelco ECO-Solutions	Japan	300	P6831
	6	Mörrum	Västblekinge Miljö AB	Sweden	300	P6718
	7	Borås	Borås Miljö AB	Sweden	300	P6690
	8	Fairfield	Chesterfield	UK	300	P6983
	9	Akureyri	Nordurorka	Iceland	150	P7200
	10	Kobe	Kobelco ECO-Solutions	Japan	300	P7376
	11	Kobe	Kobelco ECO-Solutions	Japan	300	P7376
	12	Vancouver	CH Four- Seabreeze	Canada	250	P7461
	13					
					3400	
Manuka	1	Redvale	Waste Management	New Zeland	80	P5738
	2	Katrineholm	Svensk Biogas AB	Sweden	80	P6029
	3	Motala	Motala	Sweden	80	P6030
	4	Marquette	CUDL/Strabag	France	100	P6031
	5	Västervik	Västervik Biogas AB	Sweden	130	P6024
	6	Didcot	Centrica (Brittish Gas)	U K	130	P6048
	7	Beijing	CAU	China	130	P7255
	8	Linkoping	SBI International	Sweden	130	P6460
					860	
CSFR	**20**	Different places	Various	Various	5280	
	84	**Total plants**			**93535**	

Selected Reference List

Kanuka - Fredericia, Denmark

- Client: DONG Energy
- The first biogas upgrading plant to be installed in Denmark
- Kanuka evolved as a result of successful product development from the Manuka model
- **100 - 300 Nm³/h** raw biogas upgraded to pipeline quality gas
- Waste water treatment plant
- In operation 2011

Kanuka - Mäkikylä, Finland

- Client: Sarlin
- The first biogas upgrading plant to be installed in Finland
- **100 - 300 Nm³/h** raw biogas upgraded to pipeline quality gas
- Waste water treatment plant
- In operation 2011

Matai - Dinteloord, Netherlands

- Client: Suiker Unie
- First contract to supply Greenlane™ Biogas upgrading plants in the Netherlands. Suiker Unie has also ordered a Totara; both to be commissioned in 2011
- Matai, the second largest unit, suitable for commercial scale production of biogas
- **400 - 1250 Nm³/h** raw biogas upgraded to pipeline quality gas
- Organic waste
- In operation 2011

Totara - Lidköping, Sweden

- Client: Swedish Biogas International
- One of the major biogas upgrading plants in Sweden.
- Totara is the largest Greenlane Biogas upgrading plant in the current product range, suitable for large-scale and industrial production of biogas
- **650 - 2000 Nm³/h** raw biogas upgraded to vehicle fuel
- Organic waste
- In operation 2011

Rimu - Hamilton, Canada

- Client: CH2M Hill
- Canada's first WWTP biogas upgrading plant to be injecting into the gas grid
- Rimu is a midsized unit, suitable for medium scale and industrial production of biogas
- **250 - 800 Nm³/h** raw biogas upgraded to pipeline quality gas
- Waste water treatment plant
- In operation 2011

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Rimu - Abbotsford BC, Canada

- Client: Catalyst Power
- Canada's first biogas upgrading plant to be injecting into the gas grid
- **250 - 800 Nm³/h** raw biogas upgraded to pipeline quality gas
- Manure, agricultural waste, energy crops
- In operation 2010

Manuka+ - Didcot, Oxfordshire, UK

- Client: Centrica (British Gas) via Chesterfield
- The UK's first biogas upgrading plant using anaerobic digester waste as well as the first to inject biomethane in to the national gas grid
- Manuka+, the second smallest unit, is competitively priced and has been developed specifically for smaller communities
- **0 - 130 Nm³/h** raw biogas upgraded to pipeline quality gas
- Waste water treatment plant
- In operation 2010

Rimu - Katrineholm, Sweden

- Client: Swedish Biogas International
- The second Greenlane plant installed in this community, following a Manuka in 2009
- **250 - 800 Nm³/h** raw biogas upgraded to vehicle fuel
- Agricultural waste
- In operation 2010

Manuka - Katrineholm, Sweden

- Client: Svensk Biogas
- This self contained biogas upgrading system includes a fully unattended vehicle refuelling station, meeting the fuel needs of an estimated 330 cars
- Manuka, the smallest unit is competitively priced and has been developed specifically for small scale waste water and agricultural - applications
- **0 - 80 Nm³/h** raw biogas upgraded to vehicle fuel
- Waste water treatment plant
- In operation 2010

Manuka - Redvale landfill, New Zealand

- Client: Transpacific Industries Group
- This self contained biogas upgrading system is installed on a Landfill at the Redvale Energy Park. Upgraded gas is compressed to 250 BarG and then used to drive the rubbish collection trucks
- **0 - 130 Nm³/h** raw biogas upgraded to vehicle fuel
- Municipal Solid Waste
- In operation 2009

Matai - Stresow, Germany

- Client: EnviTec Biogas
- Greenlane's third contract with EnviTec Biogas, after the successful Installation of the Güstrow plant
- **400 - 1200 Nm³/h** raw biogas upgraded to pipeline quality gas
- Agricultural waste, energy plant
- In operation 2009

Manuka+ - Västervik, Sweden

- Client: Svensk Biogas
- One of the first small-scale biogas upgrading plants in Sweden
- **0 - 130 Nm³/h** raw biogas upgraded to vehicle fuel
- Waste water treatment plant, biowaste
- In production 2009

Totara - Örebro, Sweden

- Client: Swedish Biogas International
- One of the major biogas upgrading plants in Sweden, this was commissioned in temperatures approaching -30°C
- **600 - 2500 Nm³/h** raw biogas upgraded to vehicle fuel
- Agricultural waste
- In operation 2009

Totara - Güstrow, Germany

- Client: EnviTec Biogas
- The biggest plant of its kind in the world to date
- 5 x Totara, the biggest model in the current product range, to allow for consistently high rates of production of upgraded biogas
- **650 - 10 000 Nm³/h** raw biogas upgraded to pipeline quality gas
- Energy plants
- In operation 2009

Manuka - Marquette, France

- Client: City of Lille (CUDL)
- The first small-scale biogas upgrading project in France, Greenlane has been producing biogas at this site since 1993
- **0 - 80 Nm³/h** raw biogas upgraded to vehicle fuel
- Waste water treatment plant
- In production 2009

Totara - Madrid, Spain

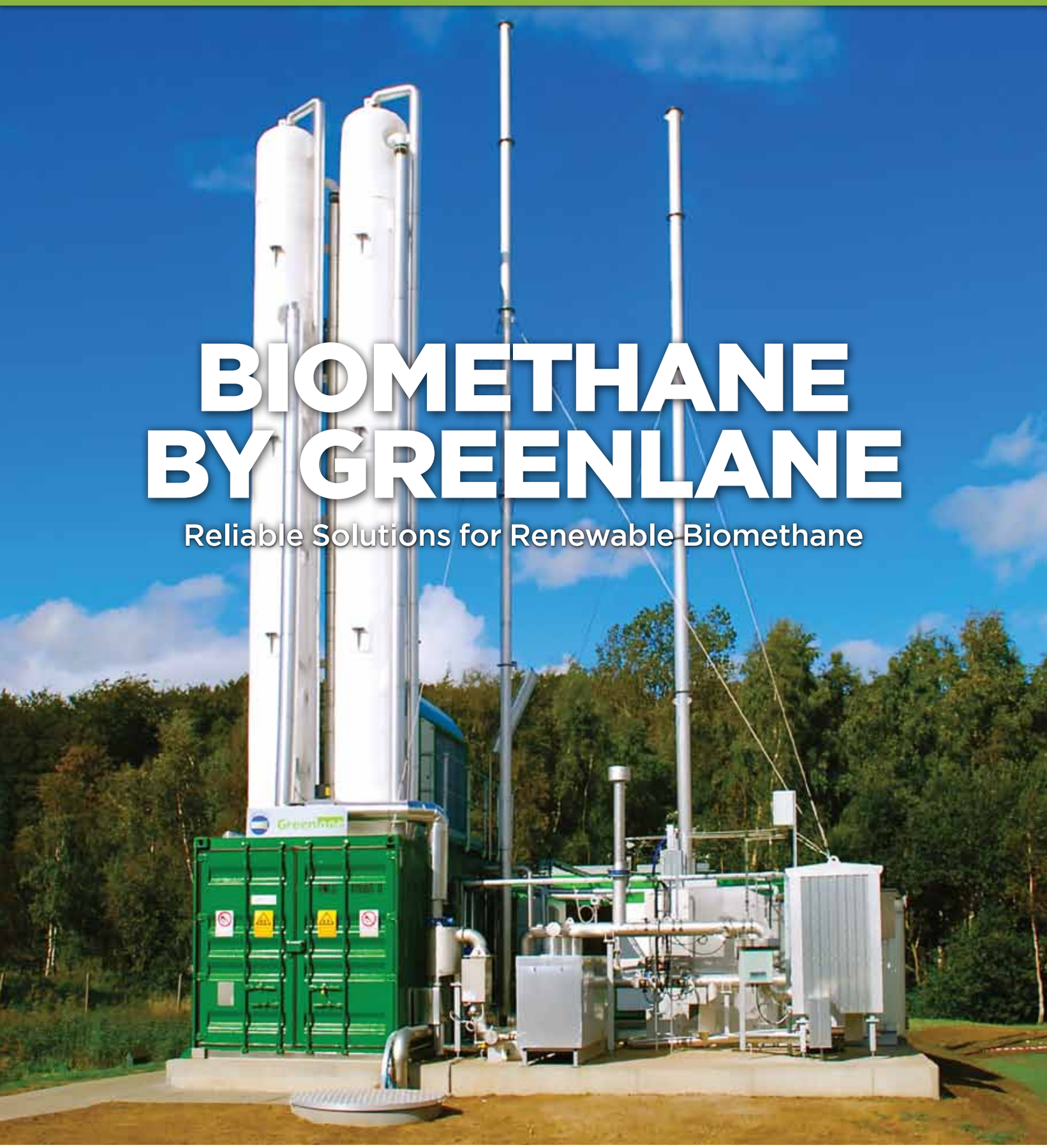
- Client: UTE Biometanización La Paloma
- At the time the contract was won, this was the largest biogas upgrading plant in the world
- 2 x Totara, the biggest models in the current product range, to allow for consistently high rates of production of upgraded biogas
- **1300 - 4 000 Nm³/h** raw biogas upgraded to vehicle fuel
- Municipal solid waste/household organic waste
- In operation 2007

Kanuka - Kobe, Japan

- Client: Kobelco Eco-Solutions
- The first commercial biogas upgrading project in Japan
- 2 x CSFR225 a legacy product, similar in size and capacity to the Kanuka model
- **100 - 450 Nm³/h** raw biogas upgraded to vehicle fuel
- Waste water treatment plant
- In operation 2007

Rimu - Lille, France

- Client: Linde
- The first industrial-scale biogas upgrading project in France
- France's first biogas upgrading plant to inject into the gas grid
- 2 x CSFR600 a legacy product, similar in size and capacity to the Rimu model
- **300 - 1200 Nm³/h** raw biogas upgraded for grid injection and bus refueling station
- Organic Waste
- In operation 2006



BIOMETHANE BY GREENLANE

Reliable Solutions for Renewable Biomethane

BIOGAS Greenlane

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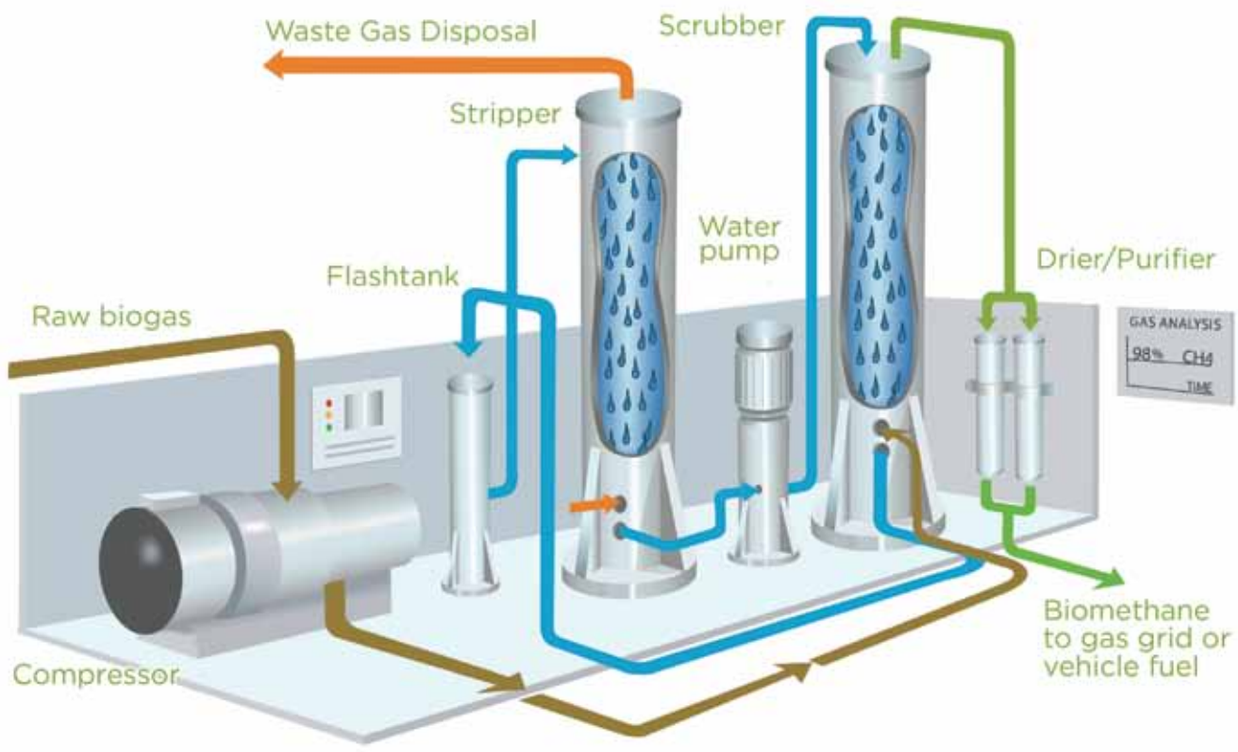
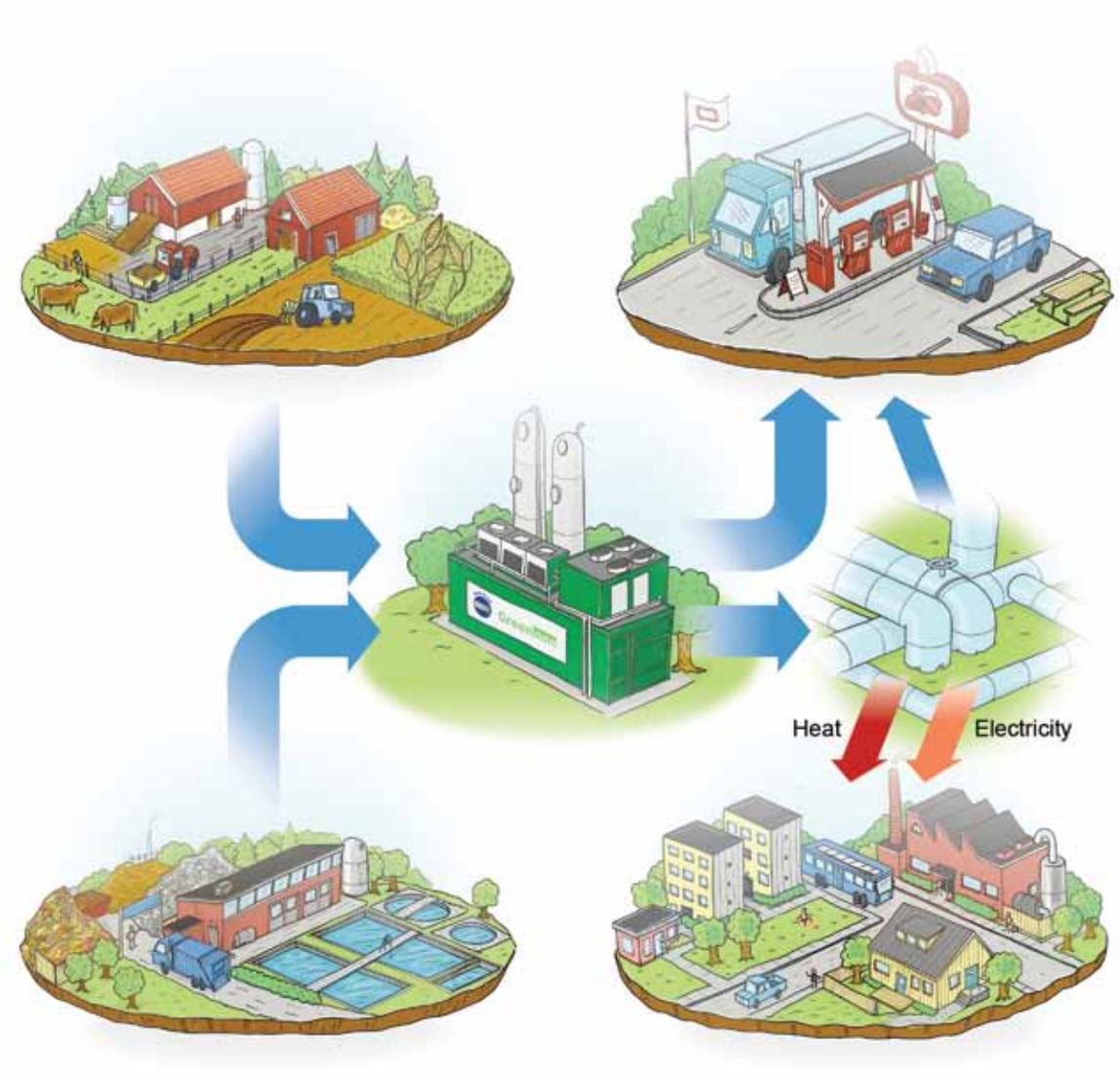


Green Technology – Clean Energy

Greenlane has the most environmentally friendly upgrading solution available. Plain water performs the majority of the work to upgrade biogas to purity levels that meet stringent specifications for national gas pipeline grids and vehicle fuel.

Carbon dioxide and hydrogen sulphide are separated under pressure by absorption into water, producing gas with methane content exceeding 97%. A patented drier-purifier "polishes" final gas quality while overall methane loss is 1 % or less. The heart of the system is a simple, robust and reliable compressor providing high availability with low operating costs.

PSA and water? Yes – Greenlane achieves its performance edge by exploiting "best of breed" technologies in combination. A water-based process and compressor gets most of the job done, followed by a patented PSA/TSA purifier that perfects delivered gas quality.



From Organic Waste to Cleaner Air

When organic waste from households, waste water treatment plants, manure and agriculture is broken down by micro-organisms, biogas is produced. For most efficient use this raw biogas is then upgraded to maximise its energy content.

Upgraded biogas, or biomethane, is a clean energy source. Biomethane is interchangeable with conventional natural gas thus can be injected into the natural gas grid, used to produce LNG, for power production or as a renewable vehicle fuel.

"We chose Greenlane Biogas because they are an established manufacturer with successful installations of upgrading plants throughout Europe and the world. In the specific situation and for this project the water scrubbing technology was the best solution."

Teun van der Weg, Project Manager at Suiker Unie, Holland

"We are very excited to be introducing Greenlane's gas upgrading technology to the North American landfill market. We believe their unique approach to biogas purification will enable increasingly cost-effective production of pipeline quality renewable natural gas which we can inject into the natural gas pipeline grid and distribute to our customers throughout North America."

Harrison Clay, President of Clean Energy Renewable Fuels, USA

"It is high time we also in Finland begin upgrading our biogas. I am delighted that we can start cooperation with Greenlane that will be the first commercial-scale biogas upgrading plant in Finland."

Kari Lammi, Director of Sarlin's Energy & Environment Department, Finland

Greenlane® – Proven and Standardised Technology

Greenlane® Biogas Upgrading Systems are offered as five standard modules that deliver biomethane of the highest quality. This product range spans the diverse needs of our clients; from small municipalities and farms to the larger models, designed for industrial biomethane facilities.

Model Name	Capacity Range		Estimated Plot Dimensions	Estimated Weight (Tonnes)	
	Nm3/h	SCFM	Length x Width	Shipping	Operating
Manuka	0 - 130	0 - 80	1 x std. 20' container	7	8
Kanuka	100 - 300	60 - 185	1 x std. 20' container	9	11
Rimu	250 - 800	155 - 500	1 x std. 40' container + towers	18	22
Matai	400 - 1200	250 - 745	1 x std. 40' container + towers	32	38
Totara	650 - 2500	405 - 1500	1 x std. 40' container + towers	40	48

- $NM^{3/h}$ = Normal Cubic Metres per Hour (Normal Conditions are defined as 0 °C, 1 bar (a))
- SCFM = Standard Cubic Feet per Minute (Standard Conditions are defined as 60 °F at 14.7 psia)

Above data is subject to change without notice. Specifications, estimated performance and utility consumption figures to be confirmed at time of order.

Strengths with Greenlane®

- Proven and patented technology
- Standardised modular design results in lower installed cost
- Energy efficient, low operating costs
- Clever, compact design with excellent maintainability
- High H_2S tolerance
- Less than 1 % methane slip
- Delivered biomethane exceeds 97 % CH_4
- Most reliable compression technology, highest availability
- Environmentally friendly – main process uses water
- Standard design – easy to install, manage and maintain

Greenlane Manuka & Kanuka upgrading plants utilise a **revolutionary new patented compression technology**, the 'Water Flooded Screw' (WFS). These high efficiency water lubricated rotary compressors require no gas pre-treatment or lubricating oil and have the lowest operating and maintenance costs. They are only available through Greenlane.

"We chose to team up with Greenlane Biogas primarily because of the environmental benefits of their technology. The upgrading process used in the Greenlane plants is water based, does not utilize any chemicals and is the most energy efficient available. They have also a solid track record of a proven, tried and tested technology used around the world."

Stephen McCulloch, Managing Director of Chesterfield Biogas, UK

AfterCare by Flotech – Insurance for our Customers

With more than 60 systems worldwide, it is AfterCare's responsibility to ensure reliability of Greenlane technology and profitability for our customers. With experience stretching back as far as 1990, we ensure that clients enjoy first class support to help keep Greenlane systems operating continuously. The AfterCare team is available every day and every hour; our aim is to provide the best service available!

AfterCare offers a full range of services to suit every installation. This includes installation assistance and start-up, training, optimisation and online analysis, as well as long term maintenance and spare parts support.

AfterCare on Request

Buy only the support and spare parts you need, when you need it.

AfterCare Service Agreement

AfterCare have standardised service and spare parts programs for your product. We are also available for emergency calls and phone based support to suit client needs.

AfterCare Performance based Service (Greenlane plants only)

A premium performance-based agreement, AfterCare ensures your plant is available for a specified amount of time throughout the year.

AfterCare Technical Hotline 24/7

We offer our customers a Customer Support Technical Hotline, available at all times.

AfterCare Remote Monitoring & Management Services

Remotely monitor and manage your plant on-line for increased profitability. Contact Flotech for detailed information.
www.greenlanebiogas.com/aftercare

AfterCare Service Team

"Greenlane's experience in Europe and Asia, along with the team they have been able to put together in North America, helped convince us that Greenlane has the experience to complete this project to our satisfaction and also support the plant during operation. We are pleased to have Greenlane as a partner for the Fair Oaks Dairy project."
Bernie Sheff, President of UTS Residual Processing, USA

"Greenlane Biogas has delivered several units to us, and they ensure our requirements for stable and smooth operating systems. They are also really interested in supporting our plants and to cooperate closely with us for system service and maintenance."
Peter Undén, Managing Director of Swedish Biogas, Sweden

Driving Energy Technology

Greenlane Biogas, part of the Flotech Group, has been the global leader in upgrading landfill and biogas for more than 20 years.

Our technology delivers environmentally friendly biomethane to replace fossil fuels in Europe, Asia, North America and the Pacific.

Greenlane's strategy is simple: We want to grow with our customers and create solutions for a sustainable society.

www.greenlanebiogas.com

BIOGAS Greenlane

A Flotech Group Company

THE QUEEN'S AWARDS FOR ENTERPRISE: 2014

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2018

Specialists in Power Generation

Edina

an EPAL company

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Unit 12 & 13 Rugby Park
Bletchley Road, Stockport
Cheshire, SK4 3EJ
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E-mail: info@edina.eu
Internet: www.edina.eu

20th January 2019

Biogass Renewables Pty Ltd
Ground Floor,
1205 Hay Street,
West Perth WA 6005

For the attention of: Joe Oliver

Our Reference: NA

Dear Joe

Re: Noise Attenuation across a biogas generation unit

Edina UK are the largest distributor of MWM gensets worldwide and have vast experience in the installation and long term operation of these units and have direct sales and technical support from their factory in Mannheim, Germany. MWM engines are German engineered and class leaders in electrical efficiency & reliability with low running costs.

We have been asked to comment on how the noise emitted from a generation set is attenuated by the packaging/containerisation, and how the noise specifications offered are achieved.

A containerized generation set is a gas fueled generator installed in an ISO like metal container for the purpose of a readily installed generation unit. In practice such a unit has four main point noise sources/breakout. These are:

- The container wall/roof
- The heat dump radiators, usually mounted on the roof
- The exhaust system, i.e. silencer also roof mounted
- The air inlet system.

Edina packages these units at our own factory near Belfast. However, items are bought in. The standard noise specification given is 75dB(A) at 1m measured as an average around the container at a height of 1.2m. To meet this specification all bought in items are specified to a lower noise specification than this. Typically, the radiators and the silencer (based on a supplied engine data sheet, would be specified at 68 -71 dB(A) at 1m to meet the standard

MWM
Energy. Efficiency. Environment.

specification. Obviously a lower overall noise specification would have a lower noise specified individual components.

For the actual container and inlet/outlet attenuation we purchase from acoustic specialists. We provide them with the noise spectrum of the engine as shown on the engine datasheet. Example shown below,

NOISE SOURCE *(unless Stated all levels below relate to 1 meter distance)*

Frequency Hz	63	125	250	500	1000	2000	4000	8000	
Plant Noise Level dB	98	101	107	102	101	100	95	99	Lp dB
A' Weighting	-26	-16	-9	-3	0	1	1	-1	dB
Unsilenced Lp dB(A)	72	85	98	99	101	101	96	98	dB(A)

Using this spectrum and the known attenuation provided by walls of different density and thickness a wall build up can be calculated.

Frequency Hz	63	125	250	500	1000	2000	4000	8000	
Unsilenced Lp dB(A)	72	85	98	99	101	101	96	98	Pa
Multi Set Correction	0	0	0	0	0	0	0	0	dB(A)
Combined Lp dB(A)	72	85	98	99	101	101	96	98	dB(A)
Attenuation									
Thickness / Density									
100 / 100kg	-29	-27	-35	-43	-49	-57	-61	-66	dB(A)
Additional Panelwork	0	0	0	0	0	0	0	0	dB(A)
Other	0	0	0	0	0	0	0	0	dB(A)
Silenced SPL dB(A)	43	58	63	56	52	44	35	32	dB(A)
Resultant Silenced Noise Level	65	dB(A)	Panel Type		SE H	Panel Notes Standard Build			

For a 'standard' 75 dB(A)@ 1m container the walls will comprise of 45 kg/m3 density rockwool, whereas for 65dB(A)@1m a 100kg/m3 density of rockwool is required. Density and/ or thickness will increase as greater attenuation is required.

For the inlet and outlet attenuation the air flow also has to be taken into account. Using the airflow required for cooling and combustion from the engine datasheet the necessary open area can be calculated, ensuring the air velocity is below that at which rain would be sucked into the container.

The attenuators are comprised of louvres and baffles. The length, distance between and thickness of the baffles controls their attenuating properties. For example, a 2.2m long attenuator is required for 65@1m on a 2020v12 (1.2MWe) whereas for 75 dB(a)@1m a 1.75m long attenuator will be enough. The distance between the baffles also decreases as the attenuation requirement lowers. Hence to keep the velocity low the overall size also increases on lower noise specs.

There are various calculations used in the design on every unit Edina supplies, based on the noise specification the client wants and the actual equipment within the container. Each container is actually bespoke and why no two are ever the same

I trust this helps explain some of the complexity with noise and designing a quiet generation unit.

Yours faithfully
For and on behalf of EDINA UK LTD,

Ian Farr
Biogas Sales Manager

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REVIEW PAPER

Microaeration for hydrogen sulfide removal during anaerobic treatment: a review

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Abstract High sulfide concentrations in biogas are a major problem associated with the anaerobic treatment of sulfate-rich substrates. It causes the corrosion of concrete and steel, compromises the functions of cogeneration units, produces the emissions of unpleasant odors, and is toxic to humans. Microaeration, i.e. the dosing of small amounts of air (oxygen) into an anaerobic digester, is a highly efficient, simple and economically feasible technique for hydrogen sulfide removal from biogas. Due to microaeration, sulfide is oxidized to elemental sulfur by the action of sulfide oxidizing bacteria. This process takes place directly in the digester. This paper reviews the most important aspects and recent developments of microaeration technology. It describes the basic principles (microbiology, chemistry) of microaeration and the key technological factors influencing microaeration. Other aspects such as process economy, mathematical modelling and control strategies are discussed as well. Besides its advantages, the limitations of microaeration such as partial oxidation of soluble substrate, clogging the walls and pipes with elemental sulfur or toxicity to methanogens are pointed out as well. An integrated mathematical model describing microaeration has not been developed so far and remains an important research gap.

Keywords Anaerobic digestion · Biogas · Elemental sulfur · Hydrogen sulfide removal · Microaeration · Sulfide oxidizing bacteria

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Abbreviations

ABR	Anaerobic baffled reactor
BTF	Biotrickling filter
CSTR	Continuous stirred tank reactor
DO	Dissolved oxygen
EGSB	Expanded granular sludge bed
FBR	Fluidized bed reactor
IC	Internal circuit reactor
MDU	Microaerobic desulfurization unit
ORP	Oxidation–reduction potential
PID	Proportional-integral-derivative
SCADA	Supervisory control and data acquisition
SOB	Sulfide-oxidizing bacteria
SOU	Sulfide-oxidizing unit

SRB	Sulfate-reducing bacteria
TN	Total nitrogen
UAF	Up-flow anaerobic filter
UASB	Up-flow anaerobic sludge blanket reactor
VFA	Volatile fatty acid

1 Introduction

Under anaerobic conditions, dissimilatory sulfate-reducing bacteria (SRB) use sulfate as the terminal electron acceptor for the degradation of organic compounds while producing hydrogen sulfide (H_2S). H_2S ends up in both the liquid effluent and biogas formed through the anaerobic digestion of organic material. High concentrations of hydrogen sulfide in biogas reduce its quality, since it causes corrosion of concrete and steel, compromises the functions of cogeneration units, produces emissions of unpleasant odors, is toxic to humans and generates emissions of sulfur dioxide during combustion. In addition, the presence of sulfide in the liquid phase causes corrosion of water transport systems and the accumulation of inert material in the sludge (e.g. metal sulfides). Moreover, sulfide is toxic to methanogens (already at concentrations above 50 mg L^{-1}) and may cause the inhibition of anaerobic processes (Buisman et al. 1990a; Hao et al. 1996; Hulshoff Pol et al. 1998; Khanal and Huang 2003b; Stucki et al. 1993; Zhou et al. 2007). For all of these reasons, the production of sulfide is a major problem associated with the anaerobic treatment of sulfate-rich wastewater and organic wastes.

Available methods for sulfide removal from biogas can be classified into physico-chemical and biological methods, as summarized in Table 1. Many commercial technologies are available on the market, such as SulfaTreat® (solid scavenger, iron sponge technology), SOXSIA® (sulfur oxidation and siloxane adsorption), THIOPAQ® (physical–chemical absorption with biological regeneration), DMT Sulfurex® (water scrubber), Sulfur-rite® (iron sponge technology), and Media-G2® (iron sponge technology).

Operation at high temperature and pressure, as well as the need for additional equipment and chemicals, make physico-chemical methods energetically demanding and expensive (Appels et al. 2008). In contrast, biological methods based on the biochemical oxidation of sulfide to sulfate, thiosulfate and elemental sulfur involve lower operational costs with lower or no need for chemical addition (Buisman et al. 1989; Syed et al. 2006). Biological removal of H_2S from biogas in closed anaerobic reactor (or digester) requires an electron acceptor. Therefore, a small amount of pure oxygen or air must be provided into the reactors for biological desulfurization.

Among the biological desulfurization methods, microaeration has recently gained growing attention. With microaeration, most authors refer to controlled dosing of small amount of air/oxygen into the liquid or gaseous phase of anaerobic digesters (Fig. 1). This method is reliable, simple and economically efficient. However, it has also some potential drawbacks such as partial oxidation of soluble substrate or clogging the walls and pipes with elemental sulfur which are discussed later in this manuscript. This contribution reviews the important aspects of biological removal of sulfide during anaerobic treatment. Particular attention is paid both to the basic principles of sulfide oxidation (microbiology, chemistry) and the technological factors influencing this process. The need for further developments of microaeration, such as mathematical modeling, is discussed as well. Furthermore, the challenges and advantages of biological oxidation of sulfide are described, including economic considerations.

2 Terminology

The action of dosing small quantities of air into the bioreactor is referred to by different terms in literature, such as "microaeration" (Duangmanee et al. 2007; Jenicek et al. 2008, 2010, 2013; 2014; Krayzelova et al. 2014a; Tang et al. 2004; Tartakovsky et al. 2011), "limited aeration" (Zhou et al. 2007; Zitomer and Shrout 2000), "aeration" (Bekmezci et al. 2011; Ikbal et al. 2003; Lohwacharin and Annachhatre 2010), "microoxygenation" (Díaz and Fdz-Polanco 2012; Díaz et al. 2011a, b; Fdz-Polanco et al. 2009; Ramos et al. 2012; Ramos and Fdz-Polanco 2013, 2014; Ramos et al. 2013, 2014b, c), "oxygenation" (Khanal and Huang 2003a, b; 2006; Khanal et al. 2003) or "moderate oxygenation" (van der Zee et al. 2007).

Table 1 The summary of physico-chemical and biological desulfurization methods others than microaeration

Physico-chemical methods	Reagent	Parameters	Situation	Additional comments	References
Precipitation	Iron chloride solution		Small scale anaerobic digester	For liquid sulfide	Kapdi et al. (2005)
					Petersson and Wellinger (2009)
Scrubbing	Sodium hydroxide	High pressure drop (high contact surface), long residence times	Lab-scale two-stage co-current contactor (scrubber)	For gaseous H_2S	Couvert et al. (2008)
				Large volume contactors	
Physical absorption	Water	Pressurizing of biogas	Counter-current packed column	High water consumpion	Kapdi et al. (2005)
				For simultaneous removal of H_2S and CO_2	Wellinger and Lindberg (1999)
Chemical absorption	Iron-chelated solutions	Room temperature Low gas pressure 1.2–2.2 bar	Lab-scale counter-current gas–liquid contactor	For gaseous H_2S	Horikawa et al. (2004)
	Sodium hydroxide			For gaseous H_2S	Petersson and Wellinger (2009)
				For very large gas volumes or high H_2S concentrations	
Chemical "dry" adsorption	Iron oxides, iron sponge	Temperature 25 °C Pressure less than 2 kPa	Lab-scale upward or downward flow gas–solid contactors (semi-batch)	For gaseous H_2S	Kohl and Nielsen (1997)
				limited regeneration ($1\times - 2\times$)	McKinsey Zicari (2003)
		Temperature 40 °C	Usually two reaction beds	Capacity 1000 Nm^3 gas h^{-1}	Petersson and Wellinger (2009)
		Atmospheric pressure		Limited regeneration	Wellinger and Lindberg (1999)
	Activated carbon (AC)	Temperature 50–70 °C Pressure 7–8 bar 300 mg H_2S per 1 g of AC	Usually two vessels for continuous system	For gaseous H_2S Limited regeneration Impregnation of AC needed	Bandosz (2002) Wellinger and Lindberg (1999)
Biological methods	**Electron acceptor**	**Dominant microorganisms**	**Situation**	**Additional comments**	**References**
Biochemical oxidation	Oxygen (pure O_2 or air)	SOB such as *Thiobacillus* sp., *Sulfolobus* sp.	Digester	For gaseous and liquid H_2S	Petersson and Wellinger (2009)
		SOB such as *Thiobacillus* sp., *Sulfolobus* sp.	Trickling filter with packing material	For gaseous H_2S	Petersson and Wellinger (2009)
		Thiobacillus sp.	Biological filter (combination of water scrubbing and biological oxidation)	For gaseous H_2S	Wellinger and Lindberg (1999)
		Thiobacillus sp.	Lab-scale fixed-film bioreactors	For gaseous and liquid H_2S	Gadre (1989)
					Jensen and Webb (1995)
	Nitrite		Lab-scale batch bioreactor	For liquid sulfide	Mahmood et al. (2007)
	Nitrite	Chemolitotrophic enrichment culture	Lab-scale batch bioreactor	For liquid sulfide	Cardoso et al. (2006)
		Pure culture of *Thiomicrospira* sp. *CVO*	Lab-scale batch and continuous bioreactor	For liquid sulfide	Gadekar et al. (2006)

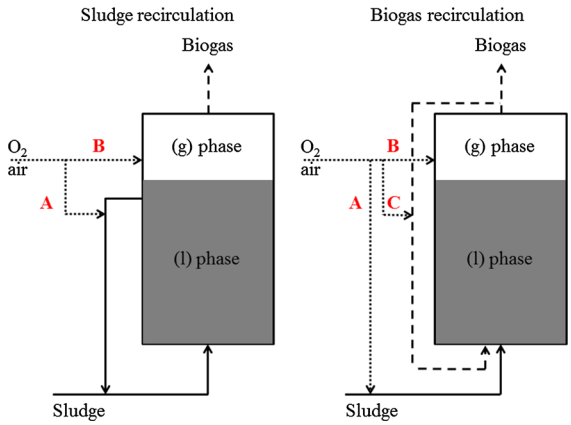

Fig. 1 The scheme of possible application of microaeration in anaerobic digesters with biogas and sludge recirculation: *A* dosage in the liquid phase, *B* dosage in the gas phase, *C* dosage in the biogas recirculation

The terms "microaeration" or "microoxygenation" reflect (in most cases) the gas used. I.e. when air is dosed into the anaerobic reactor, the process has been called "microaeration", and when pure oxygen is used, the term "microoxygenation" has been applied. However, this has not been a strict rule and not all authors follow it.

Besides, it should be noted that the terms "microaerobic" (Díaz and Fdz-Polanco 2012; Díaz et al. 2011a, b; Ramos et al. 2012, 2014b, c; Ramos and Fdz-Polanco 2013, 2014) or "microaerophilic" (Fdz-Polanco et al. 2009; Chu et al. 2005) are also applied to denote the reactor conditions (bulk liquid oxygen concentrations) as such, and at the same time referring to the act of oxygen dosage as "microoxygenation".

When referring to microaeration, the amount of oxygen is crucial. Several terms have been used when referring to the action of dosing oxygen to a culture. Authors were using the term "aeration/oxygenation" if the dose of oxygen was as high as 102–218 L O_2 L^{-1} feed (Bekmezci et al. 2011). For the amount of oxygen between 2.6 and 6.4 L O_2 L^{-1} feed (Lohwacharin and Annachhatre 2010) or 5.1 (Zhou et al. 2007), the authors used prefix "limited". Prefix "micro" was used when the amount of oxygen was 0.03–1.27 L O_2 L^{-1} feed (Díaz and Fdz-Polanco 2012; Díaz et al. 2010, 2011a, b; Fdz-Polanco et al. 2009; Jenicek et al. 2014; Krayzelova et al. 2014a; Rodriguez et al. 2012). However, van der Zee et al. (2007) used the prefix "moderate" for 0.74–0.94 L O_2 L^{-1} feed.

In this paper, the process of biological oxidation of sulfide is called "microaeration" if air was used for the oxidation of sulfide and "microoxygenation" if pure oxygen was used instead. As for the amount of air/oxygen dosed, we follow the criteria shown in Fig. 2. The term "microaerophilic" is used only to refer to microorganisms.

The concentration of dissolved oxygen (DO) is not a good control parameter for the microaeration process since the formation of elemental sulfur or sulfate proceeds at DO concentrations below 0.1 mg L^{-1}, which is the lowest detection limit of commonly available oxygen electrodes (Janssen et al. 1995). The oxidation–reduction potential (ORP) could make up a better control parameter to characterize microaerobic systems. However, a wide range of ORP values have been reported during microaeration: lower than −460 mV (Duangmanee et al. 2007); −320 to −270 mV (Nghiem et al. 2014); −265 mV (Khanal and Huang 2003b, 2006; Khanal et al. 2003); −230 to −180 mV (Khanal and Huang 2003a); 0 to −200 mV (Kobayashi et al. 2012); and higher than −150 mV (Xu et al. 2012). This large variation is probably caused by the uniqueness of each system and its operational conditions. Moreover, it is often not clear whether the results are expressed as ORP_H (with hydrogen electrode as reference) or as ORP_{Ag} (with argent chloride electrode as reference).

3 Principles of microaeration

To understand the effect of oxygen dosage, it is necessary to understand the nature of both biological and chemical oxidation of sulfide. The most important bioconversions involved in aerobic sulfide removal are (Buisman et al. 1990b; Chen and Morris 1972; Janssen et al. 1995; Kuenen 1975):

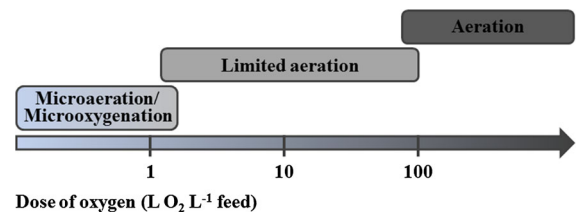

Fig. 2 The terminology for air/oxygen dosing based on the amount of oxygen dosed

$$2HS^- + O_2 \rightarrow 2S^0 + 2OH^- \quad \Delta G^\circ = -169.35\ \text{KJ mol}^{-1} \tag{1}$$

$$2HS^- + 4O_2 \rightarrow 2SO_4^{2-} + 2H^+ \quad \Delta G^\circ = -732.58\ \text{KJ mol}^{-1} \tag{2}$$

$$2HS^- + 2O_2 \rightarrow S_2O_3^{2-} + H_2O \quad \Delta G^\circ = -387.35\ \text{KJ mol}^{-1} \tag{3}$$

The biological removal of hydrogen sulfide (H_2S) is based on the biochemical oxidation of sulfide to elemental sulfur (S^0) or/and sulfate (SO_4^{2-}). Some authors (Díaz et al. 2011b; van den Ende and van Gemerden 1993) have also reported the production of thiosulfate ($S_2O_3^{2-}$). Sulfide serves as the electron donor while oxygen serves as the terminal electron acceptor. Under oxygen limiting (microaerobic) conditions, at oxygen concentrations below 0.1 mg L^{-1}, sulfur is the major end-product of the sulfide oxidation (Eq. 1), with a partial oxidation to thiosulfate (van den Ende and van Gemerden 1993). Sulfate is formed under sulfide limiting conditions and implies higher oxygen consumption per mole of sulfide (Eq. 2). Chemical oxidation of sulfide, resulting in the formation of mainly thiosulfate (Eq. 3) (Janssen et al. 1995) becomes important when biological activity of sulfide oxidizing bacteria is limited. This is the case especially in bioreactors highly loaded with sulfide. In such cases when oxygen is not consumed fast enough by sulfide oxidizing bacteria, the chemical oxidation of sulfide to thiosulfate becomes significant. From the economical point of view, sulfur formation is preferred, since it can potentially be recovered. Besides, the lower amount of oxygen needed for the oxidation to sulfur compared to sulfate implies lower energy consumption.

The formation of sulfur and sulfate can be controlled by the amount of oxygen supplied (Janssen et al. 1995). Theoretically, 0.5 mol O_2/mol S^{2-} is necessary for the oxidation of sulfide to elemental sulfur (Eq. 1). According to Janssen et al. (1995) a maximal sulfur production of 73 ± 10 % occurred at an O_2/S^{2-} consumption ratio in the range of 0.6–1.0 (mol L^{-1} h^{-1})/(mol L^{-1} h^{-1}) with 0.7 as the optimum. According to Alcántara et al. (2004), sulfur-producing steady states were achieved at O_2/S^{2-} ratio ranging from 0.5 to 1.5. The maximum elemental sulfur formation (85 % of the total influent sulfur) occurred at the ratio of 0.5. When the ratio was increased up to 2, sulfide was completely oxidized to sulfate. At O_2/S^{2-} as low as 0.15 mol/mol, the activity of sulfide-oxidizing severely decreased. According to the authors, it was probably related to an oxygen limitation in the culture which promoted sulfide accumulation in the reactor (Alcántara et al. 2004). At the ratios between 0.25 and 0.35 thiosulfate was detected in the culture. On the other hand, Díaz et al. (2011a) observed an increase in $S_2O_3^{2-}$ concentration when increasing oxygen rate from 9.3 to 14.1 L day^{-1}. This indicated a slight overdose of oxygen.

Munz et al. (2009) observed that in some cases, there is less than 0.5 mol O_2/mol S^{2-} necessary for successful oxidation of sulfide to elemental sulfur. Authors observed 91, 87, and 85 % of sulfide being converted to elemental sulfur at O_2/S^{2-} ratio of 0.015, 0.005, and 0.03 mol/mol, respectively. Also, they observed a strong effect of pH on the sulfide oxidation. The maximum elemental sulfur production decreased with increasing pH (from 85–91 to 53–59 % at pH 8 and 9, respectively).

According to Klok et al. (2013) biological oxidation of sulfide significantly depends on the concentration of sulfide. Sulfide oxidizing activity increased at sulfide concentrations from 0 to 0.15 mmoL L^{-1}. At concentrations from 0.3 to 1.0 mmoL L^{-1}, biological activity gradually decreased and increased again at sulfide concentrations from 1.0 to 5.0 mmoL L^{-1}. This was most likely the result of bacteria adaptation to high sulfide concentrations. Buisman et al. (1990a) observed that the contribution of chemical oxidation of sulfide was larger when sulfur loading rate increased.

4 Microorganisms involved in microaeration

Sulfide-oxidizing bacteria (SOB) are the main group involved in sulfide oxidation under microaerobic conditions. In general, SOB are photoautotrophs or chemolithotrophs. Photoautotrophs use CO_2 as the terminal electron acceptor while chemolithotrophs use oxygen (aerobic species) or nitrate and nitrite (anaerobic species). As microaeration always takes place in dark anaerobic fermenters, photoautotrophs cannot be involved in the process. Also, present paper focus on the dosing of limited amount of air or oxygen into an anaerobic reactor, therefore, chemolithotrophs using

nitrite or nitrate as an electron acceptor will not be discussed.

In terms of energy and carbon sources, SOB can be classified into four groups: (1) obligate chemolithotrophs, (2) facultative chemolithotrophs, (3) chemolithoheterotrophs, and (4) chemoorganoheterotrophs (Tang et al. 2009). Obligate chemolithotrophs need CO_2 as carbon source and an inorganic energy source. All known *Thiomicrospira* sp., many *Thiobacillus* sp., and at least one *Sulfolobus* sp. belong to this category (Kuenen and Veldkamp 1973; Matin 1978). Facultative chemolithotrophs can grow either chemolithoautotrophically with an inorganic energy source and CO_2 as carbon source, or heterotrophically with organic compounds as carbon and energy source. Some *Thiobacilli* sp., certain *Beggiatoa, Thiosphaera pantotropha*, and *Paracoccus denitrificans* are typical examples of facultative chemolithotrophic SOB (Friedrich and Mitrenga 1981; Nelson and Jannasch 1983). Chemolithoheterotrophs such as a few *Thiobacillus* sp. and some *Beggiatoa* strains generate energy from oxidation of reduced sulfur compounds. Chemoorganoheterotrophs can oxidize reduced sulfur compounds without deriving energy from them. *Thiobacterium*, *Thiothrix*, and some *Beggiatoa* sp. belong to this last group (Larkin and Strohl 1983).

As far as pH and temperature are concerned, the requirements of various SOB species are diverse. Growth at pH values in the range 1–9 and temperatures ranging from 4 to 90 °C have been reported (Tang et al. 2009). The majority of known chemolithotrophic SOB are mesophilic, *Thiobacillus* being the only genera encompassing both mesophilic and thermophilic environments. Other important thermophilic genera are *Sulfolobus* and *Thermothrix*.

The most cited species of SOB found for the oxidation of sulfide was *Thiobacillus* sp. (Alcántara et al. 2004; Annachhatre and Suktrakoolvait 2001; Maestre et al. 2010; Ravichandra et al. 2006) of *Hydrogenophilaceae* family (Luo et al. 2011), specifically *Thiobacillus denitrificans* (Krishnakumar et al. 2005; Lee and Sublette 1993; Ma et al. 2006; Ongcharit et al. 1990), *Thiobacillus nivellus* (Myung Cha et al. 1999), *Thiobacillus baregensis* (Vannini et al. 2008), *Thiobacillus thiooxidans* (Takano et al. 1997) and *Thiobacillus thioparus* (Vlasceanu et al. 1997). SOB of *Halothiobacillaceae* family were observed by Vannini et al. (2008) (*Halothiobacillus neapolitanus*) and Luo et al. (2011). Other SOB found to participate on the oxidation of sulfide were of genus *Thiomicrospira* (Gadekar et al. 2006), *Thiomonas* (Ng et al. 2004), *Thiothrix* (Cytryn et al. 2005; Maestre et al. 2010) with the specific species of *Thiothrix nivea* (Prescott et al. 2002), *Sulfurimonas* with the specific species of *Sulfurimonas denitrificans* (Maestre et al. 2010), and *Acidithiobacillus* with the specific species of *Acidithiobacillus thiooxidans* (Lee et al. 2006).

4.1 SOB found in anaerobic reactors subjected to microaeration

Most of SOB found in microaerobic reactors for biogas production belong to phylum *Proteobacteria* or, exceptionally to phylum *Actinobacteria*. *Halothiobacillus* sp., *Acidithiobacillus* sp., and *Sulfuricurvum* sp. were the most frequently cited species (Table 2). SOB were found almost exclusively in the headspace of the reactors or in the gas–liquid interphase suggesting that sulfide oxidation took place there.

Tang et al. (2004) observed a shift in the archaea population as the consequence of the introduction of microaeration. The size of *Methanosarcina* sp. population was reduced, while the size of *Methanoculleus* sp. population increased. In contrast, Ramos et al. (2014c) did not observe any particular impact on any of the archaeal populations while changing from anaerobic to microaerobic environment.

5 Technological and physical factors influencing microaeration

5.1 Oxygen dosing point and mixing method

5.1.1 Air dosing point

Number of authors compared the efficiency of microaeration when air is dosed into the headspace or into the liquid phase of anaerobic digesters (Fig. 1). When dosed into the headspace, oxygen can directly react with gaseous hydrogen sulfide and, therefore, the amount of air needed per given amount of hydrogen sulfide is minimized (Díaz et al. 2011b; Ramos et al. 2012). This is important, because dosing lower amount of air induce lower contamination of biogas by nitrogen. On the other hand, when air is overdosed in order to assure complete H_2S removal, the excess

Table 2 Sulfide oxidizing bacteria found in anaerobic reactors subjected to microaeration

Genus	Phylum	Location	Aeration gas	References
Acidithiobacillus thiooxidans	*Proteobacteria*	Bottom of biotrickling filter	Air	de Arespacochaga et al. (2014)
Arcobacter, Sulfuricurvum	*ε-Proteobacteria*	Headspace, liquid interphase	O_2	Ramos et al. (2014a)
Acidithiobacillus	*γ-Proteobacteria*			
Acinetobacter	*γ-Proteobacteria*	Headspace		
Rhodococcus	*Actinobacteria*			
Acinetobacter, Arcobacter, Sulfuricurvum	*Proteobacteria*	Microaerobic desulfurization unit	O_2	Ramos et al. (2013)
Halothiobacillus neapolitanus, Sulfurimonas denitrificans	*Proteobacteria*	Headspace	Air	Kobayashi et al. (2012)
Halothiobacillus, Thiofaba	*γ-Proteobacteria*	Headspace	O_2	Rodriguez et al. (2012)
Acidithiobacillus thiooxidans, Arcobacter mytili, Halothiobacillus neapolitanus, Thiomonas, Thiobacillus, Sulfuricurvum kujiense	*Proteobacteria*	Headspace (reactor with sludge recirculation)	O_2	Díaz et al. (2011b)
Halothiobacillus kellyi		Headspace (reactor with biogas recirculation)		
Arcobacter mytili				

oxygen will contaminate biogas (Díaz et al. 2010, 2011b).

When air is dosed into the sludge, the intense contact between oxygen and the liquid phase will facilitates non-specific oxidation of degradable organic compounds, i.e. some losses of oxygen. This will increase the necessary air dosage and, hence, the contamination of biogas by nitrogen. Potentially, certain part of organic load can be oxidized along with sulfide, but the decrease of methane yield due to this oxidation is usually negligible (Krayzelova et al. 2014a).

Dosing air into the liquid phase also causes the decrease of sulfide concentration in the liquid phase (Díaz et al. 2011b; Krayzelova et al. 2014a; van der Zee et al. 2007; Zhou et al. 2007). However, this decrease is usually only about 20–30 % (Krayzelova et al. 2014a) and cannot explain the large decrease in H_2S concentration in biogas. This implies that majority of H_2S oxidation takes place in the head space even if air is dosed into the liquid phase. Besides H_2S removal from biogas, the decrease of sulfide concentration in the liquid has the additional positive effect of decreasing sulfide toxicity towards methanogens.

5.1.2 Mixing method

The contact between oxygen and liquid phase is also intensified in digesters mixed by biogas recirculation. Analogically to dosing air into the liquid phase, this will increase the consumption of oxygen due to the reaction with organic compounds. Again, sulfide concentration in the liquid phase is decreased due to the intensified contact between oxygen and the liquid phase (Díaz et al. 2011a, b; Fdz-Polanco et al. 2009).

5.2 The location of sulfide oxidation and sulfur accumulation

For a proper design of microaeration, it is important to find out where the oxidation of sulfide occurs, i.e. whether it takes place in the biofilm covering the wall of the gas phase or in the liquid phase. Results from numerous microbial analyses (Table 2) revealed that SOB populations grow mainly on the walls of the headspace (Díaz et al. 2011b; Kobayashi et al. 2012; Ramos et al. 2014b; Rodriguez et al. 2012) or on the gas–liquid interphase Ramos et al. (2014b) suggesting that biological oxidation of sulfide takes place there.

The intensity of microaerobic processes strongly depended on the available surface area in the headspace. Ramos et al. (2014a) operated a pilot reactor with variable size of headspace to investigate where the process of biogas desulfurization predominantly took place. In this study, oxygen was injected into the liquid phase. Hydrogen sulfide was entirely removed from the biogas when the digester had 25 L headspace and little or no H_2S removal was observed when the size of headspace was minimized to almost 0 L. Moreover, the deposition of elemental sulfur in the headspace could represent a clear indication that the oxidation takes place there (Ramos et al. 2012). Kobayashi et al. (2012) observed the accumulation of microbial mats, containing elemental sulfur as the dominant component, on the inner walls of a reactor headspace including ceiling, wall, net, and catwalk. Also Ramos et al. (2014b) and Rodriguez et al. (2012) observed the elemental sulfur accumulation all over the walls of the headspace. This indicates that the headspace of a bioreactor may act as a "biofilter", where SOB can grow on all available surfaces. The sulfur mats also serve as additional support material where new microbial mats develop. Furthermore, scanning electron microscopy revealed that these sulfur mats were formed mostly by upward filaments (perpendicular to the gas–liquid interphase) creating a support with large specific surface. This may help SOB in the competition for oxygen (Kobayashi et al. 2012).

In contrast, Díaz et al. (2011b) observed only partial accumulation of elemental sulfur in the top of headspace and on the walls while Díaz et al. (2011b) and Ramos et al. (2014c) did not observe any accumulation of elemental sulfur in the headspace. These authors suggested that the elemental sulfur formed in their reactors has most probably fallen into the liquid effluent. However, this suggestion could not be proved and it remains unclear why sulfur deposition on headspace walls was not observed in these cases.

According to Krayzelova et al. (2014a), only 10 % of the produced elemental sulfur remained in the headspace of a UASB reactor, while 33 % left the reactor with the liquid effluent. In this case, the small headspace of UASB-type reactors was probably responsible for the modest depositions of sulfur in the headspace. Large range of elemental sulfur concentrations detected in the effluent samples was also observed by van der Zee et al. (2007).

Additionally, sulfur deposition in the headspace was not reported when oxygen was sparged in fine bubbles into the bioreactors (Khanal and Huang 2003a, 2006; Zitomer and Shrout 1998, 2000), thus increasing oxygen transfer to the bulk liquid phase. Under such condition, sulfide oxidation seemed to take place only in the liquid phase. Under this condition a significant consumption of oxygen for aerobic oxidation of organic matter was observed and SOB were found in the sulfur mats formed in headspace walls. This may indicate that oxidation of organic matter outcompeted the development of SOB in the liquid phase (Khanal and Huang 2006; Zitomer and Shrout 2000). The problems associated with elemental sulfur deposition on reactor walls and pipes will be discussed further.

5.3 Oxygen flow rate and biogas residence time in headspace

In general, bioreactors treating materials with low COD/S ratios, such as wastewater from brewery, sugar or paper industries (Table 3), produce large amounts of hydrogen sulfide. As a result of low COD/S ratios, these wastewater streams have been shown to require higher amounts of oxygen per volume of biogas (Zhou et al. 2007), in comparison to sewage sludge, agricultural wastes or manure. Normally, oxygen dosage (or equivalent air) between 0.3 and 3 % of produced biogas in the bioreactor is enough to achieve efficient biogas desulfurization (Table 3). However, oxygen rate of up to 12 % may be necessary if both gaseous and dissolved sulfide must be removed.

The residence time of biogas in the headspace is a key factor affecting sulfide removal efficiency, when providing oxygen/air injection into the headspace. Typically, removal efficiencies over 97 % were obtained with residence times over 5 h (Table 3). Schneider et al. (2002) found 88 % removal efficiency with a residence time of 2.5 h while it was lower than 40 % under 1.25 h. When the headspace was suppressed totally, the concentration of hydrogen sulfide in biogas produced with microaerobic treatment was similar to that found in unaerated digesters (Ramos et al. 2014a).

5.4 Removal of gaseous and dissolved sulfide and influence of pH

At pH around 7, at which anaerobic digestion typically occurs, $HS^-_{(d)}$ and $H_2S_{(d)}$ are the predominant sulfide species in the liquid phase [$pK_{a1} = 6.9$, Migdisov et al. (2002)]. The concentration of $H_2S_{(d)}$ increases when pH declines. Simultaneously, H_2S distributes between gas and liquid phases (dimensionless Henry's constant $H = c_G/c_L = 0.5$). Then, the value of pH influences sulfide distribution between liquid and gas phases and it is of particular importance when only $H_2S_{(g)}$ is removed by microaeration (i.e. by aerating the headspace). Assuming a constant amount of sulfur reduced by sulfidogenesis within the bioreactor, a lower pH results in a higher proportion of $H_2S_{(d)}$, a higher amount of $H_2S_{(g)}$ in the biogas to maintain the Henry's equilibrium and, consequently, requires a larger oxygen/air rate for efficient H_2S removal.

In those processes where sulfide removal occurs in the headspace, dissolved sulfide can be removed by increasing the contact between gas and liquid phases or by decreasing pH (to promote H_2S stripping). However, the required oxygen rate to remove both gaseous and dissolved sulfide species depends on the pH and the $Q_{biogas}/Q_{effluent}$ ratio (m^3 of biogas per m^3 of liquid effluent) in the bioreactor as shown in Fig. 3. Hence, at pH 7, the rate of oxygen needed to remove both gaseous and dissolved sulfide in digestion processes is lower than 1.3 times the rate necessary to remove exclusively gaseous sulfide with $Q_{biogas}/Q_{effluent}$ ratios larger than 15. This was confirmed by switching from sludge to biogas recirculation (Díaz et al. 2011a, b; Fdz-Polanco et al. 2009) at pH close to 7 and $Q_{biogas}/Q_{effluent} = 18$. By contrast, processes with $Q_{biogas}/Q_{effluent}$ ratios below 5, such as industrial wastewater treatment (Krayzelova et al. 2014a; Rodriguez et al. 2012), would require a much higher rate of oxygen to remove dissolved sulfide than it is needed for biogas desulfurization only, and this effect is larger when pH increases. Consequently, at high pH or low $Q_{biogas}/Q_{effluent}$, removing dissolved sulfide may affect the profitability whether by raising the costs of pure oxygen supply or by excessive biogas dilution by nitrogen if air is used. This negative effect on the costs can be partially neutralized if severe inhibition on digestion is prevented under microaerobic conditions, because a large increase in methane productivity was observed (Khanal and Huang 2006; Zitomer and Shrout 1998) in this case.

5.5 Reactor configurations

Over the years, microaeration has been tested in several different reactor configurations (Table 3). Reported configurations can be divided within two categories; a first one where oxygen/air is directly supplied into the reactor where the whole anaerobic digestion takes place, and, secondly, those configurations which comprise a chamber or separate unit where microaeration is performed.

5.5.1 Microaeration directly inside anaerobic digesters

Within the first category, microaerobic H_2S removal has been traditionally used in digesters treating agricultural wastes in Germany because of the simplicity of its application and the convenience for biogas exploitation (Schneider et al. 2002). However, the most reported and successful application, including full-scale operation, is the digestion of sludge from WWTP under microaerobic conditions. In fully-mixed sludge digesters (10 L–2100 m^3), microaeration can remove H_2S from biogas (2500–34,000 ppm_v) with efficiency higher than 97 % (Díaz et al. 2010; Fdz-Polanco et al. 2009; Jenicek et al. 2008, 2010, 2014; Ramos and Fdz-Polanco 2014). The lower efficiency found on full-scale microaerobic CSTR treating agricultural wastes, between 68 and 88 % (Kobayashi et al. 2012; Schneider et al. 2002), is probably the consequence of the low biogas residence time in the headspace in comparison to sludge digesters (see Sect. 5.3).

Recent research has broadened the usage of direct supply of oxygen to up-flow anaerobic sludge blanket (UASB) reactors, expanded granular sludge bed (EGSB) reactors, fluidized bed reactors (FBR) for the treatment of industrial wastewaters; particularly those from the brewery, sugar and paper industries that commonly present elevated sulfur load. The unaerated treatment of the wastewater of such industries resulted in a biogas with concentrations of H_2S higher than 20,000 ppm_v and up to 67,000 ppm_v, which was removed with efficiencies between 70 and 82 % under microaerobic conditions (Krayzelova et al. 2014a;

Table 3 The overview of anaerobic reactors where the use of microaeration has been reported

Reactor (volume in L)	OLR (g_{COD} L^{-1} day^{-1})	Feed (COD:S ratio)	Reactive (dosing point)	Reactive flow rate	O_2:biogas ratio (%)	O_2:$H_2S_{(g)}$ ratio (mol mol^{-1})
Fully-mixed digester (10)	2	Sludge (40)	Air (liquid)	1.6 L day^{-1}	1.7–9.2	1.3–7.4
UASB (3)	8	Synthetic brewery ww (95)	Air (liquid)	1 L day^{-1}	2.5	3.9
Fully-mixed digester (70)	2.3	Sludge (72)	O_2 (liquid)	ORP controlled (−320 to −270 mV)	n.a.	n.a.
Fully-mixed digester (7000)	1.5–2.2 g_{VS} L^{-1} day^{-1}	Sludge (–)	92–98 % O_2 (headspace or liquid)	5–34 Lm^{-3} day^{-1}	1	0.9–2
Fully-mixed digester (250)	1–1.9 g_{VS} L^{-1} day^{-1}	Sludge (–)	O_2 (headspace or sludge rec.)	1.8–19 L_{biogas} m^{-3}	0.33–0.5	1
Fully-mixed digester (250)	1.4–2.9 g_{VS} L^{-1} day^{-1}	Sludge (–)	O_2 (sludge rec.)	4.4–6.2 Lm^{-3} day^{-1}	0.44–0.62	1.9–2.8
Fully-mixed digester (338,000)	40–66 g_{manure} L^{-1} day^{-1}	Cow manure (–)	Air (headspace)	1 % of biogas rate	~1	1.8–4.4
Fully-mixed digester (265)	n.a.	Sludge (–)	O_2 (liquid)	0.16–0.46 LL_{feed}^{-1}	0.9–2.5	2.5–7
EGSB (4)	0.5–3.1	Synthetic vinasse (12)	O_2 (liquid)	0.37 L day^{-1}	4.7	1.7
Fully-mixed digester (250)	1.8–3.4	Sludge (48–93)	O_2 (headspace)	0.97 L day^{-1}	0.6–12	2–3.4
Fully-mixed digester (250)	2.4–4.7	Sludge (96–188)	O_2 (headspace or sludge rec.)	0.25 LL_{feed}^{-1}	1.4	1
Fully-mixed digester (250)	1.9–4	Sludge (143–310)	O_2 (sludge rec.)	0.25 LL $_{feed}^{-1}$	1.2–1.5	1–1.4
Fully-mixed digester (250)	1.9–4	Sludge (137–296)	Air (sludge rec.)	1.27 LL $_{feed}^{-1}$	1.2–1.5	1–1.4
Fully-mixed digester (2 × 1,500,000)	3.5	Sludge (–)	Air (sludge rec.)	n.a.	1.1	3.7
Fully-mixed digester (2,100,000)	3.5	Sludge (–)	Air (sludge rec.)	n.a.	2.9	5.5
Fully-mixed digester (250)	1.9–4.5	Sludge (152–369)	O_2 (headspace or sludge rec.)	2.6–4.8 L day^{-1}	1.3–2.4	0.7–1.3
Fully-mixed digester (11)	3.5	Sludge (–)	Air (sludge rec.)	1.1 L day^{-1}	2.1	n.a.
CSTR + SOU (92 + 1)	1.2	Sludge (690)	O_2 (liquid)	7.2 L day^{-1}	3	10–14
UASB (11)	2.8–12	Sulfite pulp mill ww. (45–60)	Air (liquid)	45–90 L day^{-1}	n.a.	n.a.
FBR (1.7)	3.5	Synthetic vinasse (144)	Air (liquid)	1.2–1.5 L day^{-1}	n.a.	440–560
UAF + SOU (4.5 + 2)	0.53–2.3 g_{TOC} L^{-1} day^{-1}	Synthetic ww. (9)	O_2 (liquid)	ORP controlled (−275 to −265 mV)	n.a.	n.a.
Fully-mixed digester (5)	1–8 g_{TS} L^{-1} day^{-1}	Synthetic waste (69)	Air	7.5 % of evolved gas	1–2.1	n.a.
Fully-mixed digester	n.a.	Agricultural waste (–)	Air (headspace)	n.a.	0.3–0.4	1.3–1.7

Gas residence time in headspace (h)	$H_2S_{(g)}$ conc. without microaeration (ppmv)	$H_2S_{(g)}$ removal efficiency (%)	$H_2S_{(d)} + HS_{(d)}^-$ removal efficiency (%)	Residual O_2 in biogas (%)	References
n.a.	13,000	≥99	68	n.a.	Jenicek et al. (2014)
n.a.	67,000	73	15	<0.1	Krayzelova et al. (2014a, b)
n.a.	6000	≥99	n.a.	1–1.8	Nghiem et al. (2014)

Table 3 continued

Gas residence time in headspace (h)	$H_2S_{(g)}$ conc. without microaeration (ppmv)	$H_2S_{(g)}$ removal efficiency (%)	$H_2S_{(d)} + HS^-_{(d)}$ removal efficiency (%)	Residual O_2 in biogas (%)	References
10	2500–4900	99	≈0	<0.1	(Ramos et al. 2014b)
8	3300–5000	99	n.a.	<0.1	Ramos and Fdz-Polanco (2014)
6	3400	90	≈0	<0.03	Ramos and Fdz-Polanco (2013)
1.4	2000–4000	68	n.a.	n.a.	Kobayashi et al. (2012)
7.6–0.2	3500	0–99	n.a.	1–2	Ramos et al. (2012)
2.4	25,000	72	40	4.1	Rodriguez et al. (2012), Lopes (2010)
7.1–8.6	3300–34,000	≥97	67–96	0.2–1	Díaz et al. (2011a)
6.3	13,000	≥98	88 (biogas recirculation)	0.6	Díaz et al. (2011b)
6.6	12,000	97.5	≈0	1–1.4	Díaz et al. (2010)
5.3	10,000	>99	≈ 0	1–1.4	Díaz et al. (2010)
n.a.	3300	99	n.a.	n.a.	Jenicek et al. (2010)
n.a.	5600	99	n.a.	n.a.	Jenicek et al. (2010)
5–8	9000–10,000	>99	≈0 (sludge recirculation)	0.3–4.8	Fdz-Polanco et al. (2009)
n.a.	34	92	n.a.	n.a.	Jenicek et al. (2008)
n.a.	1800–2600	>99	94	0.4–0.7	Duangmanee et al. (2007)
n.a.	5000–23,000	–	20–30	n.a.	Zhou et al. (2007)
n.a.	0.71 mg-S day^{-1}	>82	>52	n.a.	van der Zee et al. (2007)
n.a.	78,000	>99	99	n.a.	Khanal and Huang (2006)
n.a.	680	99	n.a.	n.a.	Ikbal et al. (2003)
2.5	2500	88	n.a.	n.a.	Schneider et al. (2002)

UASB up-flow anaerobic sludge blanket, *EGSB* expanded granular sludge blanket, *CSTR* continuous stirred tank reactor, *FBR* fluidized bed reactor, *SOU* sulfide oxidizing unit, *UAF* up-flow anaerobic filter, *n.a.* not available

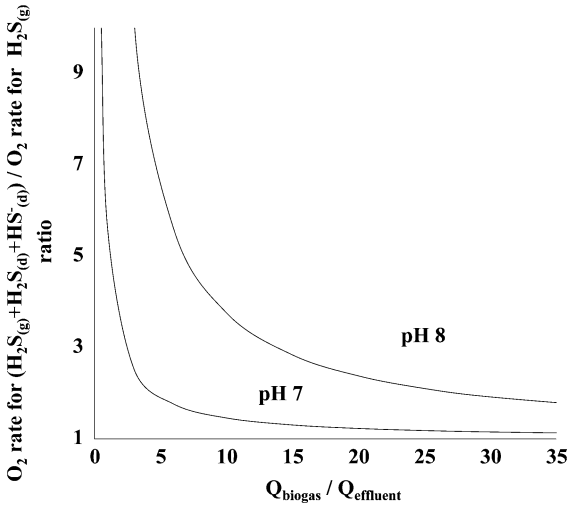

Fig. 3 Theoretical oxygen rate requirements for the microaerobic removal according to Eq. 1 assuming sulfide distribution obeys Henry's equilibrium. Oxygen rate to remove gaseous sulfide only is 1

Rodriguez et al. 2012; van der Zee et al. 2007; Zhou et al. 2007). Furthermore, microaeration can increase the performance of the organic matter removal as a result of the reduction of sulfide inhibition to methanogens (Rodriguez et al. 2012; Zhou et al. 2007). An innovative approach of microaeration is the application of water electrolysis within UASB reactors so that O_2 is produced directly in the reactor; H_2S can be removed and the production of H_2 and the electrical current significantly enhanced anaerobic digestion (Tartakovsky et al. 2011).

A novel, recently reported, configuration is the application of membranes as a tool to provide required microaeration for sulfur oxidation. Membranes were already conceived many years ago as a way to provide bubble-less aeration in fermentation processes (Cote et al. 1988). However, only scarce reports are available where membranes are used as a way to provide aeration with the objective of sulfide oxidation. In principle, membranes could be used to transfer oxygen to the headspace or to the liquid phase of an anaerobic reactor. This would be accomplished by providing the flow of oxygen or air on one side of the membrane, and exposing the other side to the biogas in the headspace or the liquid phase of the reactor. Alvarez (2014) studied the use of silicon tubing as a way to provide microaeration to the headspace of an anaerobic reactor. Mass transfer coefficients for the different gases involved were determined (CH_4, CO_2, H_2S, O_2, N_2). The formation of a biofilm over the membrane surface was observed on the biogas side, similar to that formed on the surfaces of the headspace of anaerobic reactors subjected to microaeration. On the other hand, Camiloti et al. (2013, 2014) reported the application of silicone tubes for the microaeration of the liquid phase of anaerobic reactors for wastewater treatment. In this case, a biofilm containing SOB was also formed, which was identified as responsible for a large part of the sulfur oxidation. The application of membranes with selective permeability for oxygen represents a great opportunity, since they may partially reduce the dilution of the biogas with nitrogen, when air is used as oxygen source. Moreover, membranes preventing methane permeation would be required to avoid emissions of this gas to the atmosphere.

5.5.2 Microaeration in separate compartments

In the second category, a microaerobic unit (or compartment) is added to the process, thus maintaining the core anaerobic digestion unaerated. This allows the utilization of higher O_2 rates and avoids the accumulation of elemental sulfur in the headspace of the anaerobic digester. Hence, anaerobic baffled reactors (ABR) can be designed with a final compartment where microaeration is performed to remove the H_2S produced in the initial chambers under anaerobic conditions (Bekmezci et al. 2011; Fox and Venkatasubbiah 1996). In a similar way, the sulfide-rich liquor and biogas, or the biogas alone, produced during anaerobic digestion can be treated in a sulfide oxidation unit (SOU) where microaeration is performed. When liquid and biogas were introduced into the SOU, increasing the ORP to around −265 from the natural anaerobic level of −290, H_2S was removed with efficiency higher than 99 % (Khanal and Huang 2006). Alternatively, the raw biogas produced in the digester can be treated in a SOU, inoculated with anaerobic sludge, which simulates the microaerobic conditions within the headspace of digesters. In this way S^0 can be easily removed without affecting the digester (Ramos et al. 2013).

5.6 Microaeration process control

A variable oxygen rate is necessary in most reactors, as the consequence of feed composition/rate variations

resulting in the varying production of sulfide. Besides, residual oxygen in the biogas must meet the requirements of the biogas utilization technology that will be employed afterwards. Oxygen content below 1 % is required for fuel cells and below 3–0.5 % (after carbon dioxide removal) for vehicle fuels or injection of upgraded biogas into the natural gas grid (Petersson and Wellinger 2009). Optimal process control is the key to the successful microaeration in such cases. Oxygen supply can be controlled to cope with the changes of H_2S concentration and biogas flow (Ramos and Fdz-Polanco 2014). Proportional-integral-derivative (PID) controller was used to control the oxygen flow rate according to the H_2S concentration in biogas (Ramos and Fdz-Polanco 2014). Oxygen flow rate was set according to the difference (e) between the measurement and target H_2S concentration. H_2S concentration in biogas dropped below the set-point (0.01 %) in a time range from 4.0 to 5.5 h, subsequently stabilizing at zero, while oxygen content remained around 0.05 %. The microoxygenation level was optimal since it kept the removal efficiency above 99 % with a minimum oxygen concentration in biogas. The flow of biogas was another parameter used for the control of H_2S concentration in biogas and for the control of oxygen supply in this paper. Approximately 3.5 and 5.0 L of O_2 per 1 m^3 of biogas was needed to successfully remove 0.33 and 0.5 % of H_2S from biogas, respectively. The average H_2S removal efficiency was 99 % with 0.08 % of oxygen in biogas. Ramos and Fdz-Polanco (2014) suggested that biogas production could be an efficient regulating parameter under variable organic loading rate and steady sulfur load, while under non-steady sulfur load, H_2S concentration should be used as a regulating parameter instead.

When using biogas production as a control parameter, there is a danger that overdosing by air would increase apparent biogas production which would induce the increase of air dosage. Therefore this strategy would only work in the case when the changes in biogas flow are considerably greater than the potential overdose by air. This was the case of the study by Ramos and Fdz-Polanco (2014).

ORP has also been used for the control of oxygen dosing, in a chemostat (Khanal and Huang 2003a) and a UAF system (Khanal and Huang 2003b, 2006; Khanal et al. 2003). In general, oxygen injection was automatically turned on whenever the reactor ORP was 10 mV below the target value. Pure oxygen was injected to the reactor until ORP was raised to 10 mV above the target level. During the operation of the chemostat, a target ORP value of −230 mV (50 mV above the anaerobic ORP level of −280 mV) almost completely removed the dissolved and gaseous sulfide (Khanal and Huang 2003a). In the UAF, the target ORP value of −265 mV (25 mV above the ORP level of −290 mV) was set, which provided a dissolved sulfide removal over 98.5 %,by converting it mainly to elemental sulfur with a production of small amount of thiosulfate (Khanal and Huang 2003b, 2006; Khanal et al. 2003). ORP as a tool for controlling microoxygenation was also used by Nghiem et al. (2014). In their case, an ORP probe was connected to a supervisory control and data acquisition (SCADA) system to control the digester. SCADA system was set to control valve dosing oxygen to maintain ORP level between −310 and −290 mV (the natural ORP level was −485 mV). Under such conditions, H_2S concentration decreased from over 6000 mg L^{-1} to just 30 mg L^{-1}.

No study was published that would use sulfide concentration in the liquid phase as the control parameter for the dose of air into the microaerobic reactor. This is most probably because the relation between H_2S concentration in biogas and in the liquid phase is not straightforward and large variations in H_2S concentrations in biogas often correspond to small or negligible variations in the liquid phase. This would largely depend on the oxygen dosing point (see chapter 5.1). However, even if air is dosed directly into the liquid phase, the changes in H_2S concentrations in liquid phase are relatively small compare to the changes in H_2S concentrations in biogas.

6 Mathematical modelling of sulfide oxidation

Mathematical modelling is an important tool which can provide valuable information that can help to understand the behavior of complex systems. There are many papers describing the kinetics of chemical oxidation of sulfide. The basic relation for the kinetic model can be expressed as follows (O'Brien and Birkner 1977):

$$R_{chem.ox.} = k_m \cdot (S_{H_2S})^{\alpha} \cdot (S_{O_2})^{\beta} \quad (4)$$

Table 4 The kinetic parameters of chemical oxidation of sulfide described by the Eq. 4

k (min^{-1})	α	β	c (S^{2-}) (mmoL L^{-1})	c (O_2) (mmoL L^{-1})	References
17.46	1.02	0.80	0–5.00	0.15	Klok et al. (2013)[a]
0.1165	1.00	1.00	0.04–0.10	Saturated (25 °C)	Luther et al. (2011)
0.57	0.41	0.39	0.16–9.38	0.003–0.266	Buisman et al. (1990a)
0.055	0.38	0.21	0.09–0.30	0.16–0.62	Wilmot et al. (1988)
67.6	1.15	0.69	0.05–0.20	0.60	Jolley and Forster (1985)
1.44	1.02	0.80	0.02–1.21	0.21–1.10	O'Brien and Birkner (1977)

[a] Measured in the gas phase

where $R_{chem.ox.}$ is the sulfide oxidation rate (mmoL L^{-1} min^{-1}), k_m is the rate constant (min^{-1}), S_{H_2S} is the H_2S concentration (mmoL L^{-1}), S_{O_2} is the O_2 concentration (mmoL L^{-1}), α is the reaction order with respect to the sulfide concentration (–), and β is the reaction order with respect to the oxygen concentration (–).

The summary of available kinetic parameters and the tested range of sulfide and oxygen concentrations are shown in Table 4. The parameters vary significantly across the literature. Different researchers used different analytical methods to determine sulfide and sulfide oxidation rate, and used different buffer solutions. Reported experiments were also conducted at different sulfide and oxygen concentrations ranging from 0 to 9.38 and 0 to 1.10 mmoL L^{-1}, respectively. The reaction order of oxygen very likely depends on sulfide concentration (Buisman et al. 1990a). Due to the uniqueness of each system, it is very hard to summarize the results and to make a unified conclusion.

Sharma et al. (2014) proposed the following kinetic expression for chemical oxidation of sulfide:

$$R_{chem.ox.} = k_m \cdot (S_{H_2S})^{\alpha} \cdot \frac{S_{O_2}}{K_{O_2} + S_{O_2}} \quad (5)$$

with k_m being 4.46 h^{-1}, α 0.56, and K_{O_2} 1.30 mg L^{-1}. H_2S oxidation rate was independent of the O_2 concentration at the O_2 concentration above 5 mg L^{-1}, which they explained by Monod type equation.

Nielsen et al. (2004) included the effect of pH and temperature in their model of chemical oxidation of sulfide:

$$R_{chem.ox.} = \frac{k_0 + k_1 \cdot K_1/S_{H^+}}{1 + K_1/S_{H^+}} \cdot (S_{S^{2-}})^{\alpha} \cdot (S_{O_2})^{\beta} \cdot \theta^{T-20} \quad (6)$$

where $S_{S^{2-}}$ is the concentration of total sulfide (g m^{-3}), k_0 and k_1 are the rate constants for the

Table 5 The kinetic parameters of biological oxidation of sulfide to elemental sulfur

b_{SOB} (day^{-1})	μ_{SOB} (day^{-1})	$K_{s,S^{2-}}$ (mg S^{2-} L^{-1})	K_{s,O_2} (mg O_2 L^{-1})	Y_{SOB} (mg × mg^{-1} S^{2-})	Dominant microorganisms	References
n.a.	0.67	11.00	0.0002	0.0900 (x = VSS)	SOB from activated sludge	Xu et al. (2013)
0.130	n.a.	n.a.	n.a.	0.0380 (x = COD)	SOB of *γ-Proteobacteria* and *Halothiobacillaceae* class	Munz et al. (2009)
0.034	8.64	63.68	n.a.	0.0006 (x = ATP)	*Thiomicrospira* sp.	Gadekar et al. (2006)
n.a.	n.a.	8.96	n.a.	0.0891 (x = protein)	*Thiobacilli* sp.	Alcántara et al. (2004)
n.a.	7.20	0.32	n.a.	0.0969 (x = protein)	Pure culture of *Thiobacillus thioparus*	De Zwart et al. (1997)

n.a. not available

oxidation of H_2S and HS^-, respectively [(g S m^{-3})$^{1-\alpha}$ (g O_2 m^{-3})$^{-\beta}$ h^{-1}], θ is the Arrhenius constant, T is the temperature (°C), and K_1 is the first dissociation constant for H_2S ($\approx 1.0 \times 10^{-7}$). The reaction order α and β were 0.9 and 0.2 respectively, θ was 1.06, and k_0 and k_1 fluctuated from 0.02 to 0.08 and from 0.25 to 1.00, respectively. The rate constants varied significantly and should be employed with caution. Moreover, the rate equation is valid within the pH and temperature intervals of 6–9 and 5–25 °C, respectively (Nielsen et al. 2004).

For biochemical oxidation of sulfide, Monod-type equation for substrate utilization should be used as follows (Xu et al. 2013):

$$\frac{dS_{S^{2-}}}{dt} = -\frac{\mu_{SOB}}{Y_{SOB}} \cdot \frac{S_{S^{2-}}}{K_{s,S^{2-}} + S_{S^{2-}}} \cdot \frac{S_{O_2}}{K_{s,O_2} + S_{O_2}} \cdot X_{SOB} \quad (7)$$

where μ_{SOB} is the maximum specific growth rate (h^{-1}), Y_{SOB} is the yield coefficient for SOB (g VSS g^{-1} S^{2-}), $K_{s,S^{2-}}$ and K_{s,O_2} are sulfide and oxygen affinity constants (kg m^{-3}), $S_{S^{2-}}$ and S_{O_2} are sulfide and oxygen concentrations (kg m^{-3}), and X_{SOB} is the concentration of SOB (kg m^{-3}).

Xu et al. (2013) presented an integrated model describing sulfur cycle processes of sulfate reduction, sulfide oxidation and sulfur bioreduction. They found out that the ratio of oxygen to sulfide is a key factor for controlling elemental sulfur formation.

Kinetic data for biological oxidation of sulfide found in the literature are summarized in Table 5. However, these kinetic studies were made in aerobic environments. It has been reported that the maximum specific activity for sulfide oxidation by SOB is different under aerobic and anaerobic conditions (McComas et al. 2001), i.e. 23.7 and 8.6 mg HS^- $g_{protein}^{-1}$ min^{-1}, respectively. Yu et al. (2014) studied the microbial community structures in a biological desulfurization reactor under microaerobic conditions (0.02–0.33 mg L^{-1}). The results indicated that the microbial community functional compositions and structures were dramatically altered with elevated dissolved oxygen levels. Genes involved in sulfate reduction processes significantly decreased at relatively high dissolved oxygen concentration (0.33 mg L^{-1}), while genes involved in sulfur/sulfide oxidation processes significantly increased in low dissolved oxygen concentration conditions (0.09 mg L^{-1}) and then gradually decreased with continuously elevated DO levels. Therefore, the oxidation of sulfide under microaerobic (oxygen limited) conditions must be further studied.

Botheju et al. (2009) developed a model of oxygen effect in anaerobic digestion, however, the model focused on aerobic oxidation of soluble carbon and inhibition of strict anaerobic organisms, not on sulfide oxidation. Biomass dependent first order hydrolysis kinetics was used to relate increased hydrolysis rate to oxygen induced increase in biomass growth rate (Botheju et al. 2009, 2010). An integrated model describing the effects of microaeration on biological and chemical oxidation of sulfide in anaerobic digestion has not been addressed yet. Therefore, mathematical modelling remains a research gap in microaeration.

7 Adverse effects of oxygen in anaerobic treatment

7.1 Oxygen toxicity to methanogens

Strict absence of oxygen has previously been considered as vital for anaerobic digestion, because of the toxicity of oxygen to methanogens (Zehnder 1988). Later, methanogens were shown to be tolerant to certain oxygen concentrations or protected by facultative anaerobic bacteria in both granular (Guiot et al. 1992; Kato et al. 1993a, b; Shen and Guiot 1996) and suspended sludge (Estrada-Vazquez et al. 2003). Methanogens in granular sludge appear to be more tolerant to the presence of oxygen than methanogens in flocculent sludge. Based on the multilayer structure of anaerobic granular sludge, facultative anaerobes are predominant in the periphery of the granules, while oxygen-sensitive methanogens are located in the deeper layers, protected from the exposure to air (Guiot et al. 1992; Shen and Guiot 1996). In most studies, no significant oxygen inhibition (Díaz et al. 2010, 2011b; Fdz-Polanco et al. 2009; Jenicek et al. 2011a, 2014; Krayzelova et al. 2014a; Nghiem et al. 2014; Ramos and Fdz-Polanco 2014; Tang et al. 2004; Zhou et al. 2007) of methanogens was observed during microaeration. Only two studies (Jenicek et al. 2010; Zitomer and Shrout 2000) reported slightly lower specific methanogenic activity in microaerobic reactor compared to anaerobic reactor.

7.2 Explosion risks of methane/oxygen mixtures

In general, mixing oxygen or air with biogas is undesirable because of the increased explosion risks of methane/oxygen mixture. However, the amount of oxygen dosed in microaerobic digestion is very small and it is quickly consumed. Therefore, it is far from the flammable range, which is typically 85–95 % of air and 5–15 % of methane by volume (Appels et al. 2008; Wase and Forster 1984). The leakage of biogas in air should be considered as the higher threat compare to the mixing of a small amount of air/oxygen with biogas. During microaeration, the amount of oxygen or air in biogas should never reach these values. Most authors mentioned almost no or very limited amount of oxygen detected in biogas during microaeration (Krayzelova et al. 2014a; Ramos and Fdz-Polanco 2013, 2014). Nonetheless, the explosion risk is always present when working with biogas and should not be underestimated.

7.3 Partial oxidation of organic substrate

When oxygen is present in anaerobic treatment methanogenic substrates or methane can be partially oxidized. However, the oxygen dosing rate typically applied during microaerobic removal of sulfide (0.001–0.01 kg m^{-3} day^{-1}) and organic loading rate (ORL) of digesters expressed in COD in the same oxygen units (1–10 kg m^{-3} day^{-1}) are three orders of magnitude different. Therefore, the amount of oxidized substrate cannot be significant. Some authors observed lower methane production in microaerobic reactors compare to anaerobic reactors caused probably by an aerobic degradation of organic matter (Khanal and Huang 2003a; Kobayashi et al. 2012; Ramos and Fdz-Polanco 2013; Rodriguez et al. 2012). However, most authors report no or negligible decrease of methane production due to microaeration (Díaz et al. 2010, 2011a, b; Fdz-Polanco et al. 2009; Jenicek et al. 2010; Krayzelova et al. 2014a; Nghiem et al. 2014). In these cases the dose of oxygen was not controlled according to the sulfide content (or it was controlled very roughly by ORP). Therefore, oxygen was apparently overdosed or digesters were in unbalanced conditions which contributed to the decrease of methane production.

The partial oxidation of organic compounds in anaerobic digester can improve the efficiency of volatile suspended solids removal (VSS). The evaluation of side-effects of microaerobic sulfide removal during anaerobic digestion showed the decrease in VSS/TSS ratio of the digested sludge in all experiments with microaerobic conditions, due to its better VSS degradation (Jenicek et al. 2008).

7.4 Clogging the walls and pipes of microaerobic reactor with elemental sulfur

According to some authors, microaeration takes place solely or almost solely in reactor headspace (Díaz et al. 2011b; Kobayashi et al. 2012; Ramos et al. 2014b; Rodriguez et al. 2012). The whitish deposition of elemental sulfur on the walls and pipes can clog the system resulting in headspace overpressure and biogas leakage. de Arespacochaga et al. (2014) operated a biotrickling filter with a solid oxide fuel cell for on-site electricity and thermal energy production. Around 70 % of H_2S removal was done by partial oxidation to elemental sulfur which increased the pressure drop over the column, reduced the availability of the treatment line, and eventually led to a fuel cell shutdown. A cleaning interval of less than 14 months is necessary to minimize microaeration costs (Ramos et al. 2014b). Ramos et al. (2014b) opened their microaerobic reactors, cleaned the surface of its headspace, removed the liquid interface, and restarted microaeration. Hydrogen sulfide removal was not affected, however, it was not clear which mechanism (biological or chemical oxidation) played the main role in this set-up. The collection of elemental sulfur is a remaining challenge in microaeration technology and requires further research, especially in full-scale applications.

7.5 Dilution of biogas by nitrogen from air

By using air for microaeration, nitrogen will remain and dilute biogas. This is especially challenging when biogas with low amount of methane (around 50 %) is produced, e.g. from lignocellulose (Chandraa et al. 2012), because then, even small dilution of biogas may complicate its further use in cogeneration unit. Celis (2012) reported that when extremely high H_2S concentrations (around 12,000 ppm) must be removed, the concentration of N_2 to increased up to 20 % in biogas. It caused a decrease of methane concentration below 50 % and such concentration is

too low for most cogeneration units. However, the replacement of air by oxygen solved the nitrogen dilution of biogas without affecting digestion and desulfurization efficiency.

8 Additional advantages of microaeration

8.1 Enhancement of hydrolysis

Since hydrolysis is often considered as the bottleneck of the anaerobic digestion of solid materials (Myint et al. 2007), improving this limiting step can improve the whole process (Botheju and Bakke 2011). An adequate microaeration intensity can significantly enhance the hydrolysis of carbohydrate and protein in food waste by 21–27 and 38–64 %, respectively (Xu et al. 2014). A sufficient microaeration strategy should be employed during the early period of digestion to enhance the hydrolysis of easily biodegradable organics, promote acidogenesis, and avoid the accumulation of lactic acid (Zhu et al. 2009). Johansen and Bakke (2006) studied the effects of microaeration on hydrolysis of primary sludge and observed 50–60 % increase in the rate of the hydrolysis of carbohydrates and proteins. The extra hydrolyzed products were oxidized to carbon dioxide or incorporated into new biomass. The increase of soluble proteins due to microaeration was also observed by Diak et al. (2013) together with the increase of ammonia. Microaeration effectively solubilized COD, and improved the subsequent degradation of COD. However, the increase of carbohydrates was not observed. On the other hand, Nguyen et al. (2007) reported no enhancement of hydrolysis by microaeration, but the applied amount of air per kilogram of total solids per day was 10× lower than in the study of Johansen and Bakke (2006).

Moreover, microaerobic assays presented shorter lag-phase than the anaerobic assays in the study conducted by Díaz et al. (2011c). This resulted in faster production of methane during the first steps of the cellulose degradation. The maximum methane production in the anaerobic assay was observed on day 19 while in the microaerobic assay it was observed before day 15.

8.2 Better recovery from shock loading or serious decrease of pH

Wang et al. (2014) described that microaeration was a promising strategy to handle shock loading in anaerobic treatment of coal gasification wastewater. The recovery time was shortened from 23 to 11 days under natural condition. Ramos and Fdz-Polanco (2013) subjected microaerobic digester to a hydraulic overload. Microaeration improved the biogas quality and oxygen seemed to contribute to a stable digestion system, which increased the ability to deal with overloads. Also Jenicek et al. (2010) observed faster methanogenic bacteria recovery after the inhibition caused by overloading. Aero-tolerant methanogenic culture was added to anaerobic digester to improve the recovery time after organic overload or toxicity upset (Tale et al. 2015). In contrast to the anaerobic enrichment, the aerated enrichments were more effective, resulting in faster recovery of methane and COD removal rates.

After a shock-load of sucrose, the pH in the complete-mix methanogenic reactors recovered more quickly under microaeration conditions (Zitomer and Shrout 1998). Aeration may prevent pH decreases in other highly loaded systems since volatile acids were potentially oxidized and carbon dioxide and hydrogen were stripped out. O'Keefe et al. (2000) observed no adverse effect of aeration on the microbial activities in anaerobic digester.

8.3 Better sludge quality

Microaeration also appeared to improve the quality of the digested sludge in the way of lower foaming potential and better dewaterability (Jenicek et al. 2011a, b, 2014). The extent of foaming problems was lower in microaerobic digester compare to anaerobic digester.

8.4 Production of elemental sulfur

As mentioned previously, there is a lack of technology available to recover elemental sulfur from bioreactors where microaeration is applied. However, if this technology were to be developed, the elemental sulfur could be used in bioleaching processes (Tichý et al.

1994) or for the autotrophic sulfur-oxidizing denitrification (Krayzelova et al. 2014b; Zhou et al. 2011). The biologically produced elemental sulfur has some distinctly different properties as compared to "normal" inorganic (orthorhombic) sulfur (Kleinjan et al. 2003). The density of biologically produced sulfur is lower and the particles have hydrophilic properties whereas orthorhombic sulfur is known to be hydrophobic with higher density. Due to this, the biologically produced sulfur could be more available and suitable for microorganisms compared to the chemically produced one. More information about biologically produced elemental sulfur can be found in the papers by Janssen et al. (2009) and Kleinjan et al. (2003).

9 Economic considerations

When considering microaeration to remove sulfide, air is, at least initially, the most economical alternative; however, biogas dilution with nitrogen (1–8 %) when air is employed may result in a lower performance of biogas combustion or higher costs during biogas upgrading to remove nitrogen. In fact, a recent economic evaluation revealed that the utilization of concentrated oxygen (92–98 %) presented higher net present value (NPV5 and NPV20) than the utilization of pure oxygen or air to substitute the current addition of $FeCl_3$ to the anaerobic digesters of a full-scale WWTP producing 550 m^3 h^{-1} of biogas. This alternative presented the lowest operational costs per cubic meter of biogas treated (0.0019 EUR) compared to air, pure oxygen supply and the addition of $FeCl_3$ (0.0027 EUR, 0.0039 EUR and 0.0100 EUR, respectively) (Díaz et al. 2015).

10 Needs for further research

Microaeration as a method for biogas desulfurization has been gaining attention over the past years and it has been often used in full-scale digesters in agricultural applications [personal communications with plant operators and Schneider et al. (2002)]. However, some theoretical and practical aspects of microaeration still remain unclear and need further research. This is important both for introduction of microaeration into new fields (high rate digesters for wastewater treatment) and for optimization of microaeration in current application (agricultural digesters).

10.1 Mechanism of sulfide oxidation

There is still discussion to what extend bacteria are responsible for the oxidation of sulfide under microaerobic condition. It is clear that both biotic and abiotic processes run in parallel (Buisman et al. 1990a), but the rates of these processes in microaerobic digesters are not well quantified yet.

Moreover, the exact metabolic pathway of sulfide oxidation under microaerobic condition is not well defined. It is not clear yet, what is the role of intermediate sulfur species such as sulfite, thiosulfate, polysulfide, and polythionates. It is also not clear, to what extend can be elemental sulfur repeatedly reduced to sulfide and how this process contributes to the overall oxygen consumption and reduction of methane yield.

10.2 Control of microaeration

To maximize the efficiency of microaeration, precise control of air dosing is needed. In the current applications, microaeration often cannot cope with sudden changes of sulfide concentration in biogas induced e.g. by the start of intermittent mixing (personal communication with plant operators). It can be expected that similar problems will take place in high-rate digesters should microaeration be introduced for them too.

The spatial control of microaeration, i.e. the spatial distribution of the formation of elemental sulfur is even more pressing problem. In current applications, most of sulfur forms on the walls of reactor's headspace (Kobayashi et al. 2012; Ramos et al. 2012, 2014b; Rodriguez et al. 2012) and is expected to continually fall of into the liquid effluent (Ramos et al. 2014c). However, partial or complete clogging of biogas piping has also been reported (de Arespacochaga et al. 2014). When introduced into high-rate digesters such as UASB, IC or EGSB, formation of sulfur will partially take place in the three-phase separators of these reactors (Krayzelova et al. 2014a) which may seriously impair the function of the digester. Therefore, new methods for controlled safe sulfur formation in dedicated compartments of the

digesters should be developed. The application of biomembranes (biofilm grown on the surface of membrane modules) for air delivery is one of the promising options (Alvarez 2014). This technique would facilitate sulfur formation directly on the surface of these membranes and thus preventing the clogging of three-phase separators.

10.3 Microbiology

There are several reports describing the microbiological composition of microaerobic biofilms, but there has been very little systematic work on this topic. Most of the knowledge on SOB microbiology is derived from studies with pure SOB cultures (De Zwart et al. 1997) or environments different from microaerobic digesters such as activated sludge biotrickling filters etc. (Alcántara et al. 2004; Munz et al. 2009; Xu et al. 2013).

10.4 Mathematical modelling

Microaeration as a method for biogas desulfurization in anaerobic digestion has not been modelled yet and remains an important research gap. Although, there are a few papers describing sulfate reduction and sulfide oxidation (Xu et al. 2013), the conditions of limited amount of oxygen are specific and require its own modelling approach.

11 Conclusions

Although the interest in microaeration for hydrogen sulfide removal from biogas in full-scale has been steadily growing, only over 40 papers on this topic have been published during the last decade. Interestingly, while microaeration has been widely applied in full-scale anaerobic digesters for solid substrates (biogas plants), microaeration in anaerobic reactors for wastewater treatment such as UASB reactor has been rarely studied or applied.

The following highlights were extracted from recent literature:

- The accumulation of elemental sulfur and the growth of SOB biofilm have been most often observed in the headspace (or on the gas–liquid interphase) of anaerobic bioreactors, as the result of microaeration taking place in the gas phase. However, there are reports showing that microaeration can take place also in the liquid phase.
- The residence time of biogas in the headspace and available surface area are the key factors affecting the efficiency of hydrogen sulfide removal through sulfur oxidation in the headspace.
- Intensified contact between oxygen and anaerobic biomass may improve the removal of dissolved sulfide, decrease the amount of oxygen in biogas and increase the rate of hydrolysis. This effect can be facilitated when the reactor is mixed by biogas or when air/oxygen is dosed into the liquid phase.
- An integrated mathematical model describing microaeration has not been developed so far. Such model would greatly improve the understanding of the process and research on this topic is of high priority.

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RIM109 – 13/05/2016 :

Make-Up Water :

Our Ref: PAC38890 **Your Ref: Greenlane Biogas - 13-5-16**
Date Taken: 12/05/2016 **Date Received: 13/05/2016** **Date Started: 13/05/2016** **Date Completed: 20/05/2016**

Test performed	Test result	Units of Measure	Method of Detection	Theoretical Limits Of Detection
			Lab Ref. C40810	*LabCom ID* 644,517
Client Ref. default., Greenlane Biogas - Bore Hole - RIM 109 - Please also test for Dissolved CO2, Sulfate, Sulfite, CSB and TnB.				
Ammonium (as NH4)	**0.04**	mg/l		0.01mg/l
Chloride	**44**	mg/l		0.1mg/l
COD	**<1**	mg/l		1mg/l
Dissolved CO2	**2.5**	mg/l		1mg/l
pH	**7.97**	-		-
Sulphate (as SO4)	**57**	mg/l		1mg/l
Sulphide	**<0.01**	mg/l		0.01mg/l
Total Alkalinity (as CaCO3)	**296**	mg/l		1mg/l
Total Hardness (as CaCO3)	**501**	mg/l		1mg/l
Total Nitrogen	**<3**	mg/l		3mg/l

Stripping Water

Our Ref: PAC38890 **Your Ref: Greenlane Biogas - 13-5-16**
Date Taken: 12/05/2016 **Date Received: 13/05/2016** **Date Started: 13/05/2016** **Date Completed: 20/05/2016**

Test performed	Test result	Units of Measure	Method of Detection	Theoretical Limits Of Detection
			Lab Ref. C40809	*LabCom ID* 644,516
Client Ref. default., Greenlane Biogas - Stripper Drain - RIM 109 - Please also test for Dissolved CO2, Sulfate, Sulfite, CSB and TnB.				
Ammonium (as NH4)	**2.15**	mg/l		0.01mg/l
Chloride	**39**	mg/l		0.1mg/l
COD	**29**	mg/l		1mg/l
Dissolved CO2	**70**	mg/l		1mg/l
pH	**6.71**	-		-
Sulphate (as SO4)	**69**	mg/l		1mg/l
Sulphide	**<0.01**	mg/l		0.01mg/l
Total Alkalinity (as CaCO3)	**250**	mg/l		1mg/l
Total Hardness (as CaCO3)	**493**	mg/l		1mg/l
Total Nitrogen	**<3**	mg/l		3mg/l

Stripper Water from TOTARA Orebro :

Process water from Stripper
Calculated flow Örebro [Totara]; 1,8 l/m

- pH 6,63
- 17,2 degrees C
- Chloride 19,2 mg/l
- Sulfate 89,6 mg/l
- Sulfite <0,10 mg/l
- Ammonium 0,22 mg/l
- Nitrogen 0,17 mg/l
- CSB 70 mg/l O2
- TnB 2,3 mg/l O2

Gustrow 24/09/2009 :

1. Process water in & Stripper blowdown water analysis.

kiwa
Partner for progress

Kiwa Control GmbH
FB Umweltanalytik
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14770 Brandenburg
Tel.(03381) 3408-0
Fax (03381) 340822

Kiwa Control GmbH
FB Umweltanalytik
Am Weidenbruch 22
18196 Kessin
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www.kiwa.de

FLOTECH
NAWARO Bioenergiepark Güstrow
Am Langen Bruch 1

D-18273 Güstrow

Prüfbericht **09-49418-2058**

Auftraggeber:	FLOTECH NAWARO Bioenergiepark Güstrow D-18273 Güstrow, Am Langen Bruch 1
Berichtsdatum:	01/10/09
Prüfziel:	Untersuchung von Trinkwasser Investigation of drinking water
Referenz-Nr.:	Trinkwasser einer Anlage auf dem Firmengelände NAWARO
Probenbeschreibung:	Wasser
Probennehmer:	Kiwa Control GmbH
Probeneingangsdatum:	24/09/09
Leistungszeitraum:	24/09/09 - 01/10/09
Prüfort:	Kiwa Control GmbH, FB Umweltanalytik 18196 Kessin, Am Weidenbruch 22

Dorab

		Makeup water	Blowdown water
Nr: Probenkennzeichnung:		09.2058-1 Einlauf	09.2058-2 Auslauf
Vor-Ort-Parameter			
Farbe qualitativ Colour		farblos Colourless	lt. weißl. light white
Geruch qualitativ Odour		ohne None	lt. fremd. Some
Trübung qualitativ Turbidity		keine None	schwach ** slightly
pH-Wert DIN 38404-C5 pH		7,4	7,3
Elek. Leitfähigkeit(20°C) DIN EN 27888-C8 Conductivity	µS/cm	497	510
Sauerstoff DIN EN 25814-G22 O_2	mg/l	3,17	5,60
Temperatur DIN 38404-C4 Temp.	°C	17,7	14,6
Summenparameter			
TOC Total Organic Carbon DIN EN 1484 (H3)	mg/l	8,22	17,0
Metalle und Halbmetalle			
Calcium EN ISO 11885-E22	mg/l	110	109
Chrom EN ISO 11885-E22	mg/l	<0,001	<0,001
Eisen Iron EN ISO 11885-E22	mg/l	0,32	<0,050
Kupfer Copper EN ISO 11885-E22	mg/l	0,033	0,001
Magnesium EN ISO 11885-E22	mg/l	16	16
Mangan ese EN ISO 11885-E22	mg/l	<0,010	<0,010
Nickel EN ISO 11885-E22	mg/l	0,079	<0,002
Zink EN ISO 11885-E22	mg/l	0,51	<0,020
sonstige Parameter			
Freies Chlor Free chlorine DIN 38408-G4	mg/l	<0,03	<0,03
Gesamt-Chlor Entirely chlorine DIN 38408-G4	mg/l	0,03	0,03
Schwefel Sulphur EN ISO 11885-E22	mg/l	<0,050	<0,050

Nr: Probenkennzeichnung:		09.2058-1 Einlauf	09.2058-2 Auslauf
mikrobiol. Parameter *			
Koloniezahl, 36°C 1) DIN EN ISO 6222, K5	KBE/ml		
Koloniezahl, 22°C 2) DIN EN ISO 6222, K5	KBE/ml		

< entspricht Bestimmungsgrenze)
(1) TVO (BRD) - Verordnung zur Novellierung der Trinkwasserverordnung vom 21. Mai 2001
1) Trinkwasserverordnung/ Gußverfahren
2) Trinkwasserverordnung/ Gußverfahren
*) Analyse Fremdlabor
** flockige Schwimmstoffe

Mit freundlichen Grüßen

i.A. M. Mü.

Dr. A. Plantikow
Laborleiterin

Typical Water Analysis from Upgrade units using two stage oil lubricated compressors

Data taken from Totara Upgrade Unit

Total Volume 0,19 m3/h (=3,3 l/m) continuous daily produced waste water consisting of three fractions;

Process water from Stripper
Calculated flow Örebro [Totara]; 1,8 l/m

- pH 6,63
- 17,2 degrees C
- Chloride 19,2 mg/l
- Sulfate 89,6 mg/l
- Sulfite <0,10 mg/l
- Ammonium 0,22 mg/l
- Nitrogen 0,17 mg/l
- CSB 70 mg/l O2
- TnB 2,3 mg/l O2

Condensate from Biogas
Calculated flow Örebro [Totara]; 1,4 l/m

- pH 5,3
- 16,9 degrees C
- Chloride 15,1 mg/l
- Sulfate 66 mg/l
- Sulfide 0,18 mg/l
- Ammonium 56 mg/l
- Nitrogen 44 mg/l
- CSB 36,1 mg/l O2
- TnB 41,8 mg/l O2

Oil poluted water from compressor
Calculated flow 200 l/day=0,14 l/m

8/2/2019

Dear EPA South Australia,

Statement of Key Changes – J116 Delorean Project

As requested, a summary of key changes to the design of the Delorean Anaerobic Digestion Project are detailed in this statement and I hereby confirm that all key changes have been reflected in the latest emissions modelling.

Previously, the air dispersion modelling had used base data obtained from the reference facility in Jandakot, Western Australia during commissioning in 2015 and documented in ***Richgro AD Facility Stack Emissions Commissioning 2015 (Report No: 1415-230).***

Initially, the H2S emissions data was previously used at the Limit of Detection (LOD) of 5mg/m3 and 5.2mg/m3 for the CHP and Flare respectively. This high limit was stated by the laboratory when analysing the samples and is not deemed representative of the proposed site.

It is noted that no H2S was detected during testing, hence the emissions modelling inputs for the CHP and Flare were previously changed to *"below detection limit*" which more adequately represents predicted H2S values (close to or at zero) given the relationship with the corresponding odour units measured and modelled from the sources.

More accurate emissions data has since been obtained and remodelled rather than using the LOD or *"below detection limits"*. Key changes to the latest design and modelling are as follows:

- ***Air Dispersion Modelling Data (CHP & Flare)*** - H2S emissions data has been obtained from the preferred CHP and Flare suppliers including emissions flow rates and destruction efficiencies. These inputs have been used to estimate the H2S emissions from the site are reflected in the latest air dispersion modelling to ensure accuracy of simulated results.

- ***Air Dispersion Modelling Data (Iron Oxide H2S Scrubber)*** – The *Schlumberger Iron Oxide Scrubber* guaranteeing <0.1ppms H2S was previously added *downstream* of the Biomethane Upgrade Unit (BMU) to treat only the exhaust gas from the BMU. The final design has been updated with the scrubber moved *upstream* of all generation and flaring equipment, scrubbing biogas to <0.1ppms immediately after digestion. The H2S is further reduced via combustion destruction (>98% and >99.5% for CHP and Flare respectively) prior to a final dilution step. The biological H2S scrubber (air dosing unit) is still factored into the design as previously mentioned.

- ***Noise Modelling Data*** – All potential noise emitting sources have been reviewed and the assessment now incorporates additional noise elements of the BMU, Pasteuriser, Chiller and Tank Mixing Pumps which were previously inadvertently omitted. Delorean / Biogass is committed to ensuring that the proposed anaerobic digestion plant meets all of the EPA requirements and will ensure that that recommended measures outlined

in the updated ***Environmental Noise Assessment prepared by Herring Storer dated 6/2/2019*** will be undertaken prior to commissioning of the facility.

I hope that this statement adequately addresses the EPA's questions and if you have any further questions, please don't hesitate to get in touch.

Kind regards,

Joseph Oliver
General Manager
Biogass Renewables Pty Ltd

Office: +61 (0)8 6147 7577
Mobile: +61 (0)412 378 018
Email: joseph.oliver@biogass.com.au
1205 Hay St, West Perth, Western Australia 6005

ANAEROBIC DIGESTION BIOENERGY PROJECT

EPA SOUTH AUSTRALIA

RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

ROUND 6 CLARIFICATIONS

DELOREAN ENERGY SA ONE (IN ASSOCIATION WITH BIOGASS RENEWABLES PTY LTD)

Date	Revision	Revision Comment	Prepared	Reviewed	Approved
26/02/2019	0	Issued	JL	JO	HJ

Response to Development Application Information Request

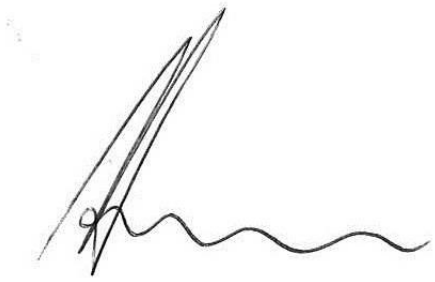
To whom it may concern,

It is acknowledged that the EPA South Australia has been in contact with DeLorean Energy SA ONE Pty Ltd regarding the development of the Anaerobic Digestion bioenergy facility being constructed by Biogass Renewables Pty Ltd in Edinburgh, South Australia.

Biogass Renewables Pty Ltd works towards ensuring compliant and fit-for-purpose design that meets all applicable requirements of approving authorities.

We hope the attached information provides adequate responses to the information requested by the EPA.

Best regards,



Hamish Jolly, Director
Biogass Renewables Pty Ltd
Ground Floor, 1205 Hay St
West Perth WA 6005
hamish.jolly@biogass.com.au
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RESPONSE TO DEVELOPMENT APPLICATION INFORMATION REQUEST

DeLorean Energy Pty Ltd (DeLorean) in association with Biogass Renewables Pty Ltd (Biogass) submits the following information to address the information requested by the EPA South Australia (EPA) in relation to the proposed project:

Response Details	
Respondent	DeLorean Energy SA One (in association with Biogass)
Proposal	Construction of a new Anaerobic Digestion Bioenergy Plant
Location	A505 DP68296, Hundred Munno Para, 1-2 Gidgie Court, Edinburgh, SA 5111
Development Number	361 / L007 / 18

Response		
No.	**Respondent**	**Commentary**
Plant / Equipment and Process		
1	EPA	The EPA has reviewed the *Biogass Renewables Salisbury Anaerobic Digestion Plant Air Quality Assessment*, prepared by Ramboll, dated February 2019. It is the EPA's understanding that the H2S input to the CHP and Flare are both based on the scrubber manufacturer's guarantee 0.1ppm level. The biomethane H2S theoretical levels before the scrubber are presumably the same 60ppms based on the Richgro information. Regardless of that, the EPA does not understand how the modelled ground level results in 0.13ug/m3 which is above that for Blue lake Milling (0.116ug/m3) when the input to the CHP and Flares are considerably higher at Blue Lake Milling (i.e. 60ppms c.f. 0.1ppms) when the destruction efficiencies are the same. Also, given how close this predicted GLC is to the Schedule 2 odour GLC for H2S, and the H2S input is based on a weekly average from Richgro data (noting the odour GLC for H2S is a 3 minute average) the EPA requires clarification as to the confidence in the 0.1ppm guaranteed limit for the scrubber. Provide clarification in regards to how the modelled ground level H2S results in 0.13ug/m3 which is above that for Blue Lake Milling (0.116ug/m3) when the inputs into the CHP and Flares are considerably higher at Blue Lake Milling (i.e. 60ppm c.f. 0.1ppm) when the destruction efficiencies are the same.
	Delorean / Biogass	Confirming that the modelling results show that the GLC for the Delorean project (0.13ug/m3) is higher than that of the Bordertown project (0.116ug/m3) even though that the biogas is at 0.1ppms H2S and 60ppms H2S respectively. It is important to note that these are two distinctly different projects with different designs and parameters. To clarify, the key differences between the two projects from an odour emissions perspective are as follows: • Delorean incorporates a H2S scrubber upstream of all generation and flaring equipment that is performance guaranteed to reduce the H2S in the biogas to <0.1ppms whereas the Bordertown site does not have this. • Delorean incorporates a Biomethane Upgrade plant (BMU) which does not have a destruction efficiency compared to the CHP (98%) and flare (99.5%). • Delorean's nearest receptor is closer to the site boundary than that of Bordertown's, increasing the predicted GLC.

2	EPA	Given the H2S input is based on a weekly average from the Richgro data (noting the odour GLC for H2S is a 3 minute average) provide clarification to as the confidence in the 0.1ppm guaranteed limit for the scrubber.
	Delorean / Biogass	The scrubber uses a proprietary iron oxide filter medium provided by the preferred supplier *Schlumberger*. The unit is performance guaranteed by the supplier to output biogas with a H2S content of <0.1ppms. It is noted that although zero H2S output is expected, it cannot be performance guaranteed by any supplier. Data from reference facilities utilising this technology were provided to the EPA in the Delorean response dated 20/12/2018. Please refer to the attached document ***RE: SulfaTREAT Biogas H2S Adsorbent Scrubber Performance*** provided by *Schlumberger* confirming the <0.1ppms H2S performance guarantee.
3	EPA	Please update the fourth dot point on page 6 (Noise Mitigation Measures) of the *Environmental Noise Assessment, AD Plant, Lot 505 Woomera Avenue, Salisbury*, prepared by Herring Storrer Acoustics (Document Reference: 23621#3#18204) to include the acoustic measures proposed to be implemented including the location of the measures on a plans, details of materials to be used (including type, length, height, thickness) in order for the overall operation to achieve the noise criteria specified in the EPA's letter dated 20 July 2018.
	Delorean / Biogass	It is understood that this information was not reflected in the previously submitted noise report. This has now been incorporated and is reflected in the updated ***Environmental Noise Assessment, AD Plant, Lot 505 Woomera Avenue, Salisbury dated 26/02/2019*****,** prepared by Herring Storrer Acoustics (Document Reference: 23621#3#18204).

Schlumberger Australia Pty Ltd

ABN: 74 002 459 225
Level 5, 256 St Georges Terrace
Perth Western Australia 6000
Tel: (61) 8 9420 4800
Fax: (61) 8 9420 4757

22nd February 2019

Attn: Jonathan Luu
Biogass Renewables Pty Ltd
Ground Floor, 1205 Hay St, West Perth
Western Australia 6005

RE: SulfaTREAT Biogas H_2S Adsorbent Scrubber Performance

Dear Jonathan,

Thank you for your request. We are happy to support you on your upcoming renewables project. We confirm that the system design detailed in our proposal, reference PS.Q.19.03, will remove H_2S from the biogas to the required outlet specification

Schlumberger will warrant that, in the absence of mal operation outside the design operating conditions provided by Biogas Renewables Pty Ltd, SULFATREAT 2242 Plus will remove H_2S from the biogas to the defined outlet concentration (<0.1 ppmv) for not less than the warranted days from first admission of process gas.

Schlumberger Purification Solutions are the market leader in H2S removal technologies & we have hundreds of biogas and odor control applications globally using our family of SULFATREAT adsorbents. We are the world's leading Sulfur removal company with over 1500 applications treating 3 trillion standard cubic feet of gas per day.

Should you have any questions please do not hesitate to contact me directly.

Best Wishes,

Dr Stewart Thompson
Schlumberger Production Technologies
Level 5, 256 St Georges Terrace
Perth, WA, Australia, 6000
Email: SThompson03@slb.com
Mobile: +61 4 3840 9933

BIOGASS RENEWABLES PTY LTD

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA

(INCLUDING BIO METHANE UPGRADE PLANT)

FEBRUARY 2019

OUR REFERENCE: 23621-5-18204

Rochdale Holdings Pty Ltd A.B.N. 85 009 049 067 trading as:
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DOCUMENT CONTROL PAGE

ENVIRONMENTAL NOISE ASSESSMENT

AD PLANT

LOT A505, 1-2 GIDGIE COURT
EDINBURGH - SOUTH AUSTRALIA
(INCLUDING BIO METHANE UPGRADE PLANT)

Job No: 18204

Document Reference : 23621-5-18204

FOR

BIOGASS RENEWABLES PTY LTD

DOCUMENT INFORMATION			
Author:	**Paul Drew**	**Checked By:**	
Date of Issue :	**26th February 2019**		

REVISION HISTORY				
Revision	**Description**	**Date**	**Author**	**Checked**
1	**Report**	**17/10/2018**	**PD**	**GH**
2	**Addition of BioFilter Fan details**	**19/12/2018**	**PD**	
3	**Revised**	**9/11/2018**	**PD**	
4	**Additional noise sources / Bio Methane Upgrade Plant**	**6/2/2019**	**PD**	
5	**Addition of Edina Attenuation Package Information**	**26/2/2019**	**PD**	

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APPENDICIES

A Sound Power Levels

B Noise Contour Plots

1. INTRODUCTION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed Anaerobic Digestion (AD) facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The acoustic modelling and assessment is based on design data and plan layouts provided in October 2018 and previous measurement of the major noise sources at a similar facility in Jandakot, Western Australia.

An aerial image of the area surrounding Lot A505, 1-2 Gidgie Courtis shown in Figure 1.

Figure 1 - Site Location and Key receptors – Lot A505, 1-2 Gidgie Court, Edinburgh

The nearest residential area is 470m to the south-west, with another residential area located 1,400m to the east. The proposed site is within an Urban Employment zone, with General Industry surrounding the site. To the south-east are established sporting facilities including a golf course and shooting range.

Trucks of size ranging up to 25 tonne B-doubles will bring material to site, reversing into the facility Reception Hall via fast acting roller doors, which will be closed when not providing access to trucks (for odour control reasons). Trucks will be unloaded within the Reception Hall. Acoustically solid fences surround the digestion area and the truck access areas.

The major external noise sources are three generators, which are fitted with acoustic attenuation packages, two gas flares (generally on standby) and a number of gas and liquid pumps at the base of digestion tanks. Both flares would normally only operate if a number of generators were shut down. Trucks will generate noise within the site when entering and reversing, however truck movements will be at low speed and tipping will occur within the Receivals Hall, thereby limiting truck noise emission duration and level from the site.

A 3D diagram of the proposed facility layout is shown in Figure 2.

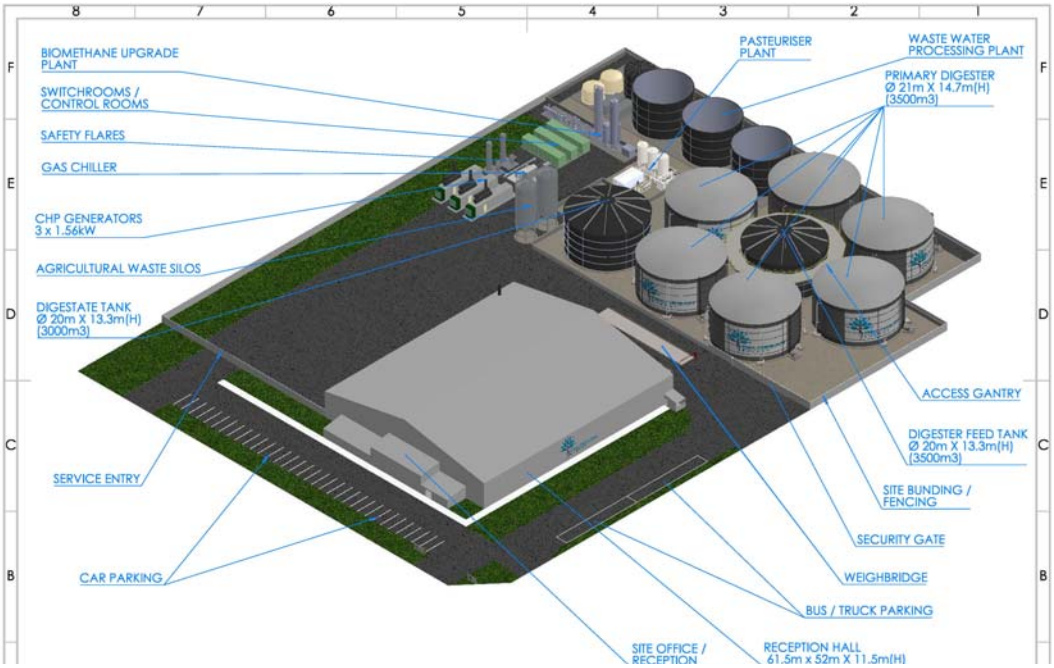


Figure 2 – AD Facility Layout

This assessment has been based on the following:

- The proposed site layout and equipment as shown in document "Lot 505 Assembly V5.pdf" issued 22nd May 2018.
- Previous noise measurements for the Richgro Jandakot AD Facility.
- Acoustic data for a similar Bio Methane Unit provided by the supplier.

2. ASSESSMENT CRITERIA

The proposed site is located within an Urban Employment Zone of the Salisbury Council Development Plan. The premises surrounding the proposed site at Lot A505, 1-2 Gidgie Court are used for automotive manufacturing (General Industry) or equipment hire (premises to the east of Gidgie Court). The premises on the western boundary (71 – 75 Woomera Avenue) is occupied by the North Adelaide Waste Management Authority, consisting of offices at the front (day hours) and recycling building currently operating 6am – midnight.

Residential areas are located to the south-west, 470m from the proposed site.

The Development Plan's interface between land uses principle of development control 7 states:

> *Development that emits noise (other than music noise) should include noise attenuation measures that achieve the relevant Environment Protection (Noise) Policy criteria when assessed at the nearest existing noise sensitive premises.*

Development Plan makes specific reference to the *Environment Protection (Noise) Policy 2007*.

The policy provides noise levels (L_{Aeq}) not to be exceeded at noise sensitive receivers, based on the principally promoted land use where the noise source and the noise receivers are located. The relevant criteria are:

Residential Zone

- 52 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 45 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#
- 60 dB(A) L_{Amax} between the hours of 10pm and 7am when measured;

At the nearest noise-affected premises in the City of Salisbury Residential zone in accordance with the *Environmental Protection (Noise) Policy 2007*.

Urban Employment Zone

- 59 dB(A) Leq between the hours of 7am and 10pm when measured and adjusted#
- 50 dB(A) Leq between the hours of 10pm and 7am when measured and adjusted#

When measured and adjusted# at noise-affected premises in the City of Salisbury Urban Employment zone in accordance with the Environmental Protection (Noise) Policy.

The measured noise levels should be adjusted in accordance with the *Environmental Protection (Noise) Policy 2007* by the inclusion of a penalty for each characteristic where tonal/modulating/impulsive/low frequency characteristics are present.

The dominant noise sources at distance are the generators, which have significant acoustic attenuation packages and based on measurement at Richgro Jandakot will not have dominant noise characteristics at the residential area. Therefore no adjustment for noise characteristic applies for the proposed noise emissions to the residential area.

However some noise characteristics may be audible at the adjacent premises and appropriate adjustment are required.

3. METHODOLOGY

Noise levels were predicted using the acoustic software SoundPlan using the Concawe algorithm for Pasquill Class 6 climatic conditions. The sound power levels used in the acoustic modelling are tabulated in the Appendix A. Sound power levels were determined from measurement of a similar AD Plant at Jandakot, Western Australia.

The proposed AD facility is to operate continuously.

The AD facility operations consist of continuous operation of bio-filtration, digesters and associated pumps and fans, pasteuriser, biomethane upgrade plant, generators and safety flares (normally on standby). Intermittent noise will be generated on site by entry / exit of trucks and operation of high-speed roller doors.

Information relating to vehicle movements:

- A maximum (worst case scenario, otherwise could be as low as 35) of 50 trucks are likely to be entering site, comprised of:
    - Rigid trucks – 34 per day
    - Semitrailer trucks – 12 per day
    - B-double trucks – 4 per day
- All vehicles except for the B-double trailers will be loading/unloading within the receival shed.
    - B-doubles will take approximately 1 – 2 hours to fully unload

4. PREDICTED NOISE EMISSIONS

Predicted noise contour plots for 'worst case' winds for the proposed operations are shown in Appendix B.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are provided. The required heights are 3m adjacent the generators and adjacent the truck access area, as shown in plot 20W, Appendix B.

The generators and flares are capable of emitting noise exceeding the noise criteria at the adjacent premises. Noise mitigation by selection of attenuated generator package units rated at 65 dB(A) at 1m and provision of acoustic barrier walls around the generators and flare units is shown to attenuate noise emissions within acceptable levels.

TABLE 4.1 PREDICTED NOISE LEVELS

Receptor	Night 3 Generators		Night Two Flare Units		Day 3 Generators Trucks		Compliance
	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	Noise Level L_{Aeq}	Adjusted Noise Level L_{Aeq}	
Residences							
Criteria	**45**	**45**	**45**	**45**	**52**	**52**	
R1: 20 Diruwa Drive, Salisbury North	27	27	24	24	36	36	Yes
R2: 60 Hogarth Rd, Elizabeth South	12	12	12	12	13	13	Yes
Adjacent Premises							
Criteria	**50**	**50**	**50**	**50**	**59**	**59**	
I1: 59-61 Woomera Ave (Coates Hire)	40	45^{t}	39	44^{t}	41	49^{ti}	Yes
I2: 4 Gidgie Crt	39	44^{t}	38	43^{t}	38	46^{ti}	Yes
I3: 3 Gidgie Crt	44	49^{t}	43	48^{t}	44	52^{ti}	Yes
I4: 71-75 Woomera Ave (NAWMA)	45	50^{t}	42	47^{t}	51	59^{ti}	Yes
I5: 76 Woomera Ave	42	47^{t}	40	45^{t}	51	59^{ti}	Yes
I6: 78 Woomera Ave	40	45^{t}	37	42^{t}	51	59^{ti}	Yes

The noise emissions for Night scenario two flares is dominated by pump noise, flare noise levels are relatively low compared to the overall predicted level. Characteristic adjustment for tonal noise only of 5 dB(A).

The noise emission for day scenario is conservative as trucks have been modelled at the passby emission level to consider busy periods where noise may be present for much of the 15 minute assessment period. Generally the L_{Aeq} noise level will be lower as trucks are only in the yard for short periods while entering or leaving the receival facility. Adjustments for tonal characteristic and impulsive characteristic have been applied, an adjustment of +8 dB(A) to the predicted noise level at the receptor premises.

5. NOISE MITIGATION MEASURES

The following noise mitigation measures are required to comply with the requirements of the Regulations:

- Fan selection and attenuation of the Bio-filter blower outlets to achieve a combined sound power of no more than 89 dB(A) external. This assessment is based on three fans, being "Fans Direct: SWS1-D51B Size 365-100% CS90 Fans, 23 kW with fan speed of 1370 rpm". Each fan discharge outlet to be fitted with 2D cylindrical podded silencer, minimum 1m gap (duct), 1D unpodded silencer.

- Section of 3m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the generators as shown in plot 20W, Appendix B.

- Section of 3.0m high acoustic barrier fence (0.48mm BMT or greater density) on the adjacent common boundary to the truck access area as shown in plot 20W, Appendix B.

- Generators to be fitted with acoustic attenuation package equivalent to those provided to generators at Richgro Jandakot site, rated at 65 dB(A) at 1m. Refer acoustic design details provided by Edina (20/1/2019) Appendix C, consistent with the acoustic attenuation of the Richgro units.

- Acoustic barrier walls to be installed around the generators and flare units as shown in plot 20W1, Appendix B. The walls may be constructed metal framing with roof sheeting or coolroom panel with a mass density of at least 10 Kg/m^2 for the combination. The wall on the western side of the generators and flare units should have a minimum mass density of 17 Kg/m^2 for the lower 5 meters, and if a lightweight construction, be a cavity wall type construction with minimum of 100mm between each side with 100mm acoustic insulation infil to assist in the control of lower frequency noise emissions. (90mm sandwich panel one side, 100mm channel with roof sheeting on the other side with 100mm fiberglass insulation infil for example). Concrete tilt-up panel would also be suitable.

- Bio Methane Upgrade Plant to be fitted with manufacturers proprietary acoustic enclosure, sound power of Bio Methane Unit including blower not to exceed 91 dB(A). Section of 4.5m high acoustic barrier wall between electrical buildings and alone east side of Bio Methane Plant as shown in Appendix B, plot 20W1

6. CONCLUSION

Emission Assessments Pty Ltd commissioned Herring Storer Acoustics to carry out an acoustic assessment on behalf of Biogass Renewables Pty Ltd. The assessment is of noise emissions from a proposed AD facility at Lot A505, 1-2 Gidgie Court, Edinburgh South Australia. The purpose of the assessment is to establish whether the proposal complies with the requirements of the Salisbury Council Development Plan, and *Environment Protection (Noise) Policy, 2007*.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at residential areas. Maximum noise emissions will also comply with the requirements at residential areas.

The predicted noise levels after adjustment for noise characteristic are shown to comply with the regulation requirements at the adjacent industrial premises, providing acoustic barrier fences are installed adjacent the generators and truck access area to ensure compliance at the adjacent premises to the west. The required heights of acoustic barriers are shown in plot 20W1, Appendix B.

APPENDIX A

Sound Power Levels

Acoustic Model Sound Power Levels

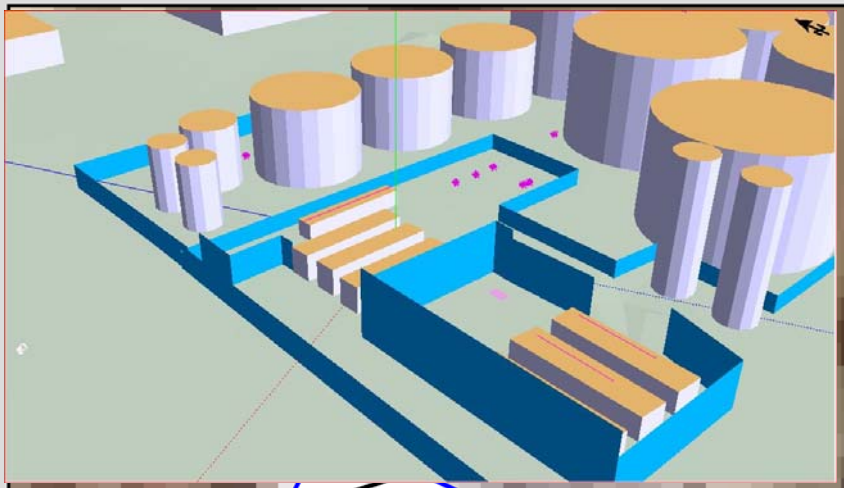
Sound Power in dB

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Generator 1	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 2	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Generator 3	95.8	93	96	93	92	98	91	88	92	86	91	89	88	89	89	86	85	85	84	82	82	82	81	76	74	73	70
Biofilter Blower	89.1	81	86	84	89	85	83	86	87	88	86	80	78	82	77	74	77	72	71	70	68	75	84	71	69	68	65
AD Flare 1 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
AD Flare 2 100%	93.6	110	106	102	105	102	94	103	99	97	85	86	84	83	78	78	78	77	78	78	75	71	69	68	67	64	61
Digester Feed Tank - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digestate Feed Tank - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Process Water - Pump 1	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 2	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 3	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Process Water - Pump 4	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Dome Fan	97.3	83	84	83	79	81	73	75	78	81	78	78	89	98	86	89	84	84	83	78	75	74	71	66	64	61	56
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Transfer Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41

Description	L_{WA}	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Digester - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Inlet Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Pasteurizer - Outlet Pump	85.1	79	83	83	77	78	72	71	75	74	71	72	72	72	70	74	79	76	77	75	71	71	68	62	63	63	53
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Pasteurizer - Mixer	73	67	70	71	65	65	60	59	63	62	58	59	60	60	58	62	67	64	65	63	59	59	56	50	51	51	41
Bio-methane Blower	87	79	84	82	87	82	81	84	85	86	84	78	76	80	75	72	75	70	69	68	66	73	82	69	67	66	63
Bio-methane unit	88.2	86	88	86	85	90	84	80	85	78	83	81	80	82	81	78	77	78	76	74	74	74	73	69	67	66	63
Gas Chiller	87	79	84	82	87	82	81	84	85	86	84	78	76	80	75	72	75	70	69	68	66	73	82	69	67	66	63
25 Ton Truck	100.1	92	95	109	100	94	110	98	98	98	95	91	91	91	92	90	89	88	88	87	87	84	79	77	74	72	73
12 Ton Truck Moving	94.3	94	105	101	102	96	108	90	92	88	84	83	85	87	85	82	83	85	78	77	78	74	74	71	69	67	68

APPENDIX B

Noise Contour Plots



3.5m
3.0m
6.0m
7.5m
5.0m
7.5m
5.0m
3.0m
3.0m

Legend
Main building
Wall
Industrial sources
Line source
Area source

HERRING STORER ACOUSTICS

Ref: 18204 Run: 20W1
Date: 5/2/2019

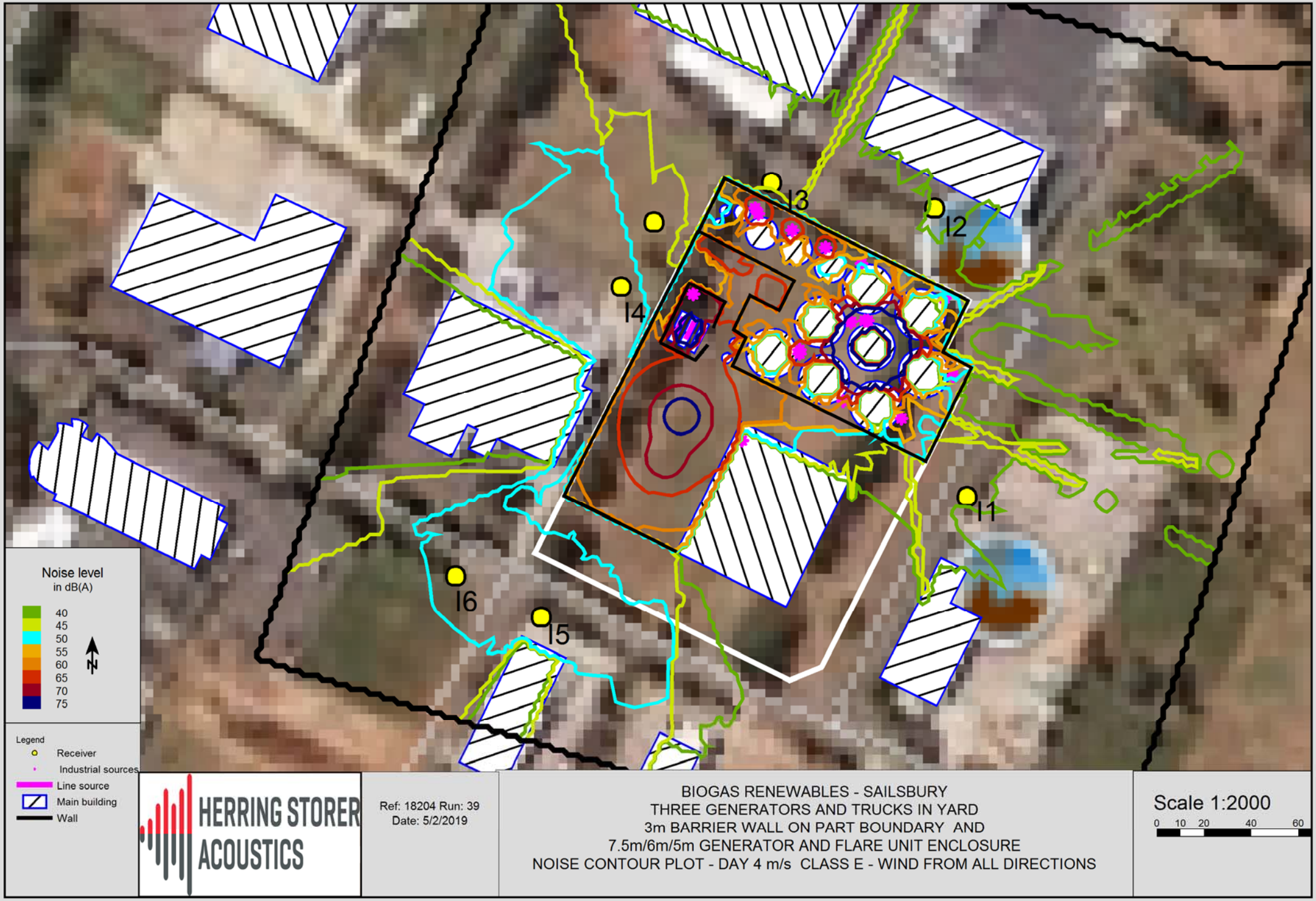
BIOGAS RENEWABLES - SAILSBURY
3m BARRIER WALL ON BOUNDARY AND
7.5m WALL ON WEST SIDE OF GENERATORS AND FLARE
UNITS, 5.0/6.0 m TO OTHER GENERATOR AND FLARE UNIT ENCLOSURE WALLS
3.5M WALL ON WEST SIDE OF BIO METHANE UPGRADE PLANT

Scale 1:1200
0 5 10 20 30


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources point
Line source
Main building
Wall
Area source
HERRING STORER ACOUSTICS
Ref: 18204 Run: 35
Date: 1/2/2019
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT, BU
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE - 45 dB(A)
Scale 1:2000
0 10 20 40 60


Noise level
in dB(A)
10
15
20
25
30
35
40
45
50
Legend
Receiver
Industrial sources
Line source
Main building
Wall
Wyatt Rd
Sturton Rd
Tappa Rd
Kalurna Ave
Bolivar Rd
Oronga St
Parratta St
Carrin St
Illara St
Perry St
Arura Rd
Moronga St
Leila Ave
Camira Way
Kuipna Dr
Horwood Rd
Plough St
Traverse Ave
Quadrant Ave
Latitude Rd
Tangent Ave
McCormack Crescent
Harold Rd
Diment Rd
West Ave
Tugger Way
Woomera Ave
Parling Ave
Kettering Rd
Willison Rd
Jeffries Rd
Goodman Rd
Bayer Rd
Grainger Rd
Philip Hwy
Edinburgh
R1
R2
I1
I2
I3
I4
I5
I6
HERRING STORER ACOUSTICS
Ref: 18204 Run: 37
Date: 5/2/2019
BIOGAS RENEWABLES - EDINBURGH
NIGHT SCENARIO - 3 GENERATORS, NO TRUCKS, ONE FLARE UNIT
3m BARRIER WALL ON PART BOUNDARY
ACOUSTIC BARRIER WALLS TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
Scale 1:15000
0 100 200 400


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources point
Line source
Main building
Wall
Area source
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 36
Date: 5/2/2019
BIOGAS RENEWABLES - SAILSBURY - NO GENERATORS, FLARING
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m ENCLOSURE TO GENERATORS AND FLARE UNITS
NOISE CONTOUR PLOT - NIGHT 3 m/s CLASS F - WIND FROM ALL DIRECTIONS
LIGHT BLUE DOTTED LINE 45 dB(A)
Scale 1:2000
0 10 20 40 60


I3
I2
I4
I1
I6
I5
Noise level
in dB(A)
40
45
50
55
60
65
70
75
N
Legend
Receiver
Industrial sources
Line source
Main building
Wall
HERRING STORER
ACOUSTICS
Ref: 18204 Run: 39
Date: 5/2/2019
BIOGAS RENEWABLES - SAILSBURY
THREE GENERATORS AND TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS
Scale 1:2000
0 10 20 40 60

HERRING STORER ACOUSTICS

Ref: 18204 Run: 40
Date: 5/2/2019

BIOGAS RENEWABLES - SAILSBURY
3 GENERATORS OPERATING WITH TRUCKS IN YARD
3m BARRIER WALL ON PART BOUNDARY AND
7.5m/6m/5m GENERATOR AND FLARE UNIT ENCLOSURE
NOISE CONTOUR PLOT - DAY 4 m/s CLASS E - WIND FROM ALL DIRECTIONS

Scale 1:15000
0 100 200 400

APPENDIX C

Edina Noise Attenuation Package

THE QUEEN'S AWARDS FOR ENTERPRISE: 2014

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2018

Specialists in Power Generation

Edina

an EPAL company

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Bletchley Road, Stockport
Cheshire, SK4 3EJ
T: +44 (0) 161 432 8833
E-mail: info@edina.eu
Internet: www.edina.eu

20th January 2019

Biogass Renewables Pty Ltd
Ground Floor,
1205 Hay Street,
West Perth WA 6005

For the attention of: Joe Oliver

Our Reference: NA

Dear Joe

Re: Noise Attenuation across a biogas generation unit

Edina UK are the largest distributor of MWM gensets worldwide and have vast experience in the installation and long term operation of these units and have direct sales and technical support from their factory in Mannheim, Germany. MWM engines are German engineered and class leaders in electrical efficiency & reliability with low running costs.

We have been asked to comment on how the noise emitted from a generation set is attenuated by the packaging/containerisation, and how the noise specifications offered are achieved.

A containerized generation set is a gas fueled generator installed in an ISO like metal container for the purpose of a readily installed generation unit. In practice such a unit has four main point noise sources/breakout. These are:

- The container wall/roof
- The heat dump radiators, usually mounted on the roof
- The exhaust system, i.e. silencer also roof mounted
- The air inlet system.

Edina packages these units at our own factory near Belfast. However, items are bought in. The standard noise specification given is 75dB(A) at 1m measured as an average around the container at a height of 1.2m. To meet this specification all bought in items are specified to a lower noise specification than this. Typically, the radiators and the silencer (based on a supplied engine data sheet, would be specified at 68 -71 dB(A) at 1m to meet the standard

MWM
Energy. Efficiency. Environment.

specification. Obviously a lower overall noise specification would have a lower noise specified individual components.

For the actual container and inlet/outlet attenuation we purchase from acoustic specialists. We provide them with the noise spectrum of the engine as shown on the engine datasheet. Example shown below,

NOISE SOURCE *(unless Stated all levels below relate to 1 meter distance)*

Frequency Hz	63	125	250	500	1000	2000	4000	8000	
Plant Noise Level dB	98	101	107	102	101	100	95	99	Lp dB
A' Weighting	-26	-16	-9	-3	0	1	1	-1	dB
Unsilenced Lp dB(A)	72	85	98	99	101	101	96	98	dB(A)

Using this spectrum and the known attenuation provided by walls of different density and thickness a wall build up can be calculated.

Frequency Hz	63	125	250	500	1000	2000	4000	8000	
Unsilenced Lp dB(A)	72	85	98	99	101	101	96	98	Pa
Multi Set Correction	0	0	0	0	0	0	0	0	dB(A)
Combined Lp dB(A)	72	85	98	99	101	101	96	98	dB(A)
Attenuation									
Thickness / Density									
100 / 100kg	-29	-27	-35	-43	-49	-57	-61	-66	dB(A)
Additional Panelwork	0	0	0	0	0	0	0	0	dB(A)
Other	0	0	0	0	0	0	0	0	dB(A)
Silenced SPL dB(A)	43	58	63	56	52	44	35	32	dB(A)
Resultant Silenced Noise Level	65	dB(A)	Panel Type		SE H	Panel Notes Standard Build			

For a 'standard' 75 dB(A)@ 1m container the walls will comprise of 45 kg/m3 density rockwool, whereas for 65dB(A)@1m a 100kg/m3 density of rockwool is required. Density and/ or thickness will increase as greater attenuation is required.

For the inlet and outlet attenuation the air flow also has to be taken into account. Using the airflow required for cooling and combustion from the engine datasheet the necessary open area can be calculated, ensuring the air velocity is below that at which rain would be sucked into the container.

The attenuators are comprised of louvres and baffles. The length, distance between and thickness of the baffles controls their attenuating properties. For example, a 2.2m long attenuator is required for 65@1m on a 2020v12 (1.2MWe) whereas for 75 dB(a)@1m a 1.75m long attenuator will be enough. The distance between the baffles also decreases as the attenuation requirement lowers. Hence to keep the velocity low the overall size also increases on lower noise specs.

There are various calculations used in the design on every unit Edina supplies, based on the noise specification the client wants and the actual equipment within the container. Each container is actually bespoke and why no two are ever the same

I trust this helps explain some of the complexity with noise and designing a quiet generation unit.

Yours faithfully
For and on behalf of EDINA UK LTD,

Ian Farr
Biogas Sales Manager