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ANAEROBIC DIGESTER PLANT HAZID REPORT

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CONFIDENTIAL

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TABLES

EXECUTIVE SUMMARY

This report documents the Hazard Identification (HAZID) Study which took place for the new anaerobic digestion (AD) plant at the Palm Paper mill in King's Lynn. The HAZID workshop was chaired by a HAZID Facilitator provided by WSP and recorded using a WSP HAZID excel worksheet.

A total of fifty-two scenarios were risk ranked. No scenarios were identified that were risk ranked as intolerable. Twenty-nine scenarios were identified as Tolerable if ALARP and twenty-three scenarios were identified as Broadly Acceptable.

The main hazards identified in the HAZID study are associated with loss of containment of biogas, which could result in fire and/or explosion from the methane component or toxic effects from the Hydrogen Sulphide (H_2S).

The new AD plant is close to the site boundary with the Highways Authority Depot. There were three scenarios identified that were considered to potentially have offsite fatalities, which were all risk ranked as Tolerable if ALARP. There are:

- Rupture of the existing 32 barg high pressure gas main caused by construction activities or the static loads of the new equipment, resulting in fire or explosion
- Flame out during flaring causing loss of containment of unburnt gas resulting in fire or explosion, if the flammable gas cloud is subsequently ignited
- Loss of containment from the 500 m^3 biogas storage tank resulting in toxic exposure to H_2S

Some aspects of the design are yet to be fully completed so were not able to be assessed. This included the off gas (CO_2) processing in the Biogas Treatment System (BGTS).

A key recommendation was the development of operating and maintenance procedures for the new AD plant and integrating these into the existing systems. This applied to many of the scenarios considered.

A total of thirty-three recommendations were raised during the workshop. Action tracking and close out is the responsibility of Palm Paper.

ABBREVIATIONS

Abbreviation	Definition
AD	Anaerobic Digestion
ALARP	As Low As Reasonably Practicable
BGTS	Biogas Treatment System
BLEVE	Boiling Liquid Expanding Vapour Explosion
COD	Chemical Oxygen Demand
COSHH	Control of Substances Harmful to Health
EPL	Eproplan
ETP	Effluent Treatment
GGSS	Green Gas Support Scheme
HAZID	Hazard Identification
IBS	Schlegel
LTA	Lost Time Accident
PPE	Personal Protective Equipment
SSSI	Site of Special Scientific Interest
UPS	Uninterruptable Power Supply
UXO	Unexploded Ordnance

1 INTRODUCTION

1.1 BACKGROUND

Palm Paper Ltd operate a paper mill in King's Lynn which prepares recycled print paper. The site intends to upgrade the effluent treatment plant to include an Anaerobic Digestion (AD) system, the preliminary design of which comprises three anaerobic reactors and a biogas treatment system to produce energy for use on site.

As part of the design development, a Hazard Identification (HAZID) study was undertaken.

1.2 STUDY OBJECTIVE

The aim of this HAZID review study is to gain information on the following:

- Identify potential safety, environmental and asset (commercial) hazards
- Identify the relevant safeguards which are in place to reduce the risk
- Evaluate the risk (severity and likelihood) for each identified hazard
- Make recommendations for improvements where current safeguards are deemed to be insufficient.

1.3 SCOPE

This HAZID considered the new AD plant, and included the following systems:

- Water supply and caustic dosing via the machinery house
- Three anaerobic reactors
- Desulphurisation plant (including nutrient and caustic dosing)
- Biogas storage
- Biogas flare system
- Biogas treatment system (BGTS)

The proposed layout and elevations are shown in Appendix B.

The study did not consider the existing facility except where the new plant may have an impact on it.

1.4 STUDY DOCUMENTATION

The documents referenced in the HAZID study are listed in Table 1-1.

Table 1-1 – HAZID Study Documentation

Document Type	Document Name	Document Number
P&ID	Desulphurisation	Q210015-4-DS-1,020-00
P&ID	IRC 1	X2160-IRC07327 IRC1
P&ID	IRC 2	X2160-IRC07327 IRC2
P&ID	IRC 3	X2160-IRC07327 IRC3
PFD	Palm Paper – King's Lynn P&ID Overview	N/A

Document Type	Document Name	Document Number
Layout	Optimising the existing WWTP via anaerobic treatment Elevation	LYNN PM7-1001-0000-BAU-1100-00
Elevation	Optimising the existing WWTP via anaerobic treatment Elevation	LYNN PM7-1001-0000-BAU-1101-00
Process Description	Upgrading of the operational wastewater treatment plant by means of an anaerobic stage. Palm Paper King's Lynn Application for permit	N/A

2 HAZID STUDY

2.1 METHODOLOGY

A high level review in the form of a HAZID was carried out on the AD plant.

Divide the project scope into nodes for the study

The purpose of this process is to break down the study into manageable sections. The study leader will provide guidance on node allocation and these nodes should be agreed prior to commencement of the study.

Identify possible hazard events

The HAZID consists of a brainstorming exercise guided by a checklist of potential hazards and relying on the study team's experience. A list of example hazards and prompts is provided in Table 2-1.

Identify possible causes

Potential high level causes of the hazard events should be identified.

Identify consequences

The consequences of the hazard events should be identified with respect to safety, environmental and asset (commercial) impacts. The focus should be on recording the most significant impacts. These consequences should be based on the absence of control measures (i.e. unmitigated).

Identify existing control measures

The existing control measures (i.e. those already incorporated into the design) should be identified. These safeguards can be engineered or based on operator action etc. However, use of generic safeguards such as training should be avoided.

Identify actions

Recommendations should be identified where suitable safeguards are absent or where the existing safeguards are deemed insufficient to reduce the risk to an acceptable level or as low as is reasonably practicable. These actions should only be assigned to a study team member and where necessary these actions should have an associated timescale for completion.

Assess risk

The risks associated with a hazard event can be assigned using a semi qualitative risk matrix, such as the one shown in Table 2-2.

Table 2-1 – HAZID Guidewords

Hazard Category	Prompts
Fire/Explosion Hazards	Flammable materials
	Tank Fire / Explosion
	Chemical reactions, Mixing of incompatible materials
	Physical Explosion
	Dust Explosion
	Warehouse Fires
	Runaway Reaction / Decomposition
	Internal Explosion e.g. loss of inerting
	BLEVE
	Oxidising substances
	Pyrophoric materials
	Fixed and Transient Ignition sources
Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)
	Inadequate washing / flushing
	Chemical reactions, Mixing of incompatible materials, including in drains and waste and water treatment
	Runaway Reaction / Decomposition
	Control system failure
	Ventilation system failure
	Human Error including draining, venting sampling, filling, loading / unloading
	Asphyxiation, confined spaces
Loss of Primary Containment	Material Selection
	Over Filling
	Process Deviation (Flow / Pressure / Level / temperature)
	Vibration
	Thermal Cycling / fatigue
	Ageing Plant
	Corrosion / erosion
	Structural / mechanical failure
	Impact – collision / dropped or swung objects
	Cryogenic Failure / Embrittlement

Hazard Category	Prompts
	Maintenance / cleaning/ containment
Working hazards	Gases under pressure, bottled gases
	Working/access at height
	Equipment overhead, lifting operations
	Hazardous equipment / surfaces
	Noise
	Radiation (ionizing, non-ionizing, EM)
	Chemicals, corrosive materials
	Biological hazards
Effects to the Environment	Loss of containment (substances that are dangerous to the environment)
	Firewater Run off (contamination, combustion products, unburned substances)
	Recovery (e.g. clean up chemicals)
	Catastrophic primary containment failure
	Non-catastrophic failure of primary containment (e.g. Tank shell leak),
	Failure of secondary containment including exceeding capacity
	Failure of Tertiary containment
	Tank overfill
	Tank floor failure / surface integrity failure
	Fire / Explosion
	Incompatible Materials
	Interaction within drainage system
	Human Error
	Release to Air / Smoke
	Release to water (marine)
	Release to water (fresh/estuarine)
	Release to Drinking water source (treatment/reservoir etc)
	Release to Groundwater
	Release to Soil/sediment
	Release to Habitat/species
	Release to SSSI/designated site
	Impact on built environment

Hazard Category	Prompts
External Hazards	Seismic event
	Extreme weather (hot, cold, storm)
	Flooding
	Lightning
	Vehicle impacts
	Aircraft crash
	Terrorism
	Vandalism / theft / third party interference
	Off-site / neighbouring fire / explosion
	Subsidence
	Historic Site specific Hazards e.g. Unexploded ordnance
Utilities	Electricity
	Water
	Compressed air
	Steam
	Natural Gas
	Control Systems
	Communication
	Other e.g. nitrogen

2.2 RISK RANKING

Risk ranking was undertaken using the risk matrix as shown in Table 2-2, with the definitions of the severity and likelihood presented in Table 2-3 and Table 2-4.

Table 2-2 – Risk Matrix

Severity / Likelihood	1	2	3	4	5	6
A	Tolerable if ALARP	Tolerable if ALARP	Intolerable	Intolerable	Intolerable	Intolerable
B	Broadly Acceptable	Tolerable if ALARP	Tolerable if ALARP	Intolerable	Intolerable	Intolerable
C	Broadly Acceptable	Broadly Acceptable	Tolerable if ALARP	Tolerable if ALARP	Intolerable	Intolerable
D	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Tolerable if ALARP	Tolerable if ALARP	Intolerable
E	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Tolerable if ALARP	Tolerable if ALARP
F	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Tolerable if ALARP

Where:

- **Intolerable** represents high risk i.e.; action is needed to reduce the risk.
- **Tolerable if ALARP** represents medium risk i.e.; risks should be assessed to ensure they are as low as is reasonably practicable.
- **Broadly Acceptable** represents low risk i.e.; further risk reduction should be implemented if easily implemented or is required in order to adhere to good practice

Table 2-3 – Severity Criteria Definitions

Measure of Severity			
	Safety	**Environmental**	**Asset Loss**
1	First aid treatment	Non sensitive environmental impact	Event resulting in total loss up to £50,000
2	Single minor injury/ LTA	Sensitive environmental impact with localised damage, e.g.: -A mod leak from flange or valve -Small scale liquid spill	Event resulting in total loss between £50,000 and £100,000
3	Single severe injury or multiple minor injuries	Extensive environmental impact, e.g.: -A cloud of obnoxious vapour travelling beyond site boundary -Major breach of permitted emission limits with possibility of prosecution	Event resulting in total loss between £100,000 and 1 million
4	Permanent disability/ life changing injury or multiple severe injuries/ harm	Extensive environmental impact which can be restored, e.g.: -A vapour release with or without liquid fallout that exceeds discharge limits or cause temporary damage.	Event resulting in total loss between £1 million and 10 million
5	Fatalities (1-3)	Extensive environmental impact which can be restored in months, e.g.: -Liquid spill into a river or sea -A vapour release with or without liquid fallout that exceeds discharge limits or cause temporary damage. -Solid fallout (dust, soot, ash) -Liquid release significantly groundwater	Event resulting in total loss between £10 to 15 million
6	Multiple fatalities (>3) or fatality off site	Extensive environmental impact which can be restored in <5 years -Future impact with extensive damage to sensitive environment which can only be restored in a period of between 1 and up to 5 years.	Event resulting in total loss greater than £15 million

Table 2-4 – Likelihood Criteria Definitions

Frequency Categories		
A	10^{-1} per year	Event likely to occur several times in facility lifetime
B	10^{-2} per year	Event likely to occur once or twice in facility lifetime
C	10^{-3} per year	Similar event has occurred, or likely to occur several times in Company
D	10^{-4} per year	Similar event has occurred in Company
E	10^{-5} per year	Similar event has occurred in industry
F	10^{-6} per year	Similar event has not yet occurred in the industry, and would be a remote possibility

2.3 STUDY DETAILS

The workshop took place at the WSP Birmingham office on Wednesday 5th November and Thursday 6th November 2025 with some attendees online. The HAZID worksheet was presented to the team in person and online at all times.

2.4 ATTENDANCE

The list of attendees is shown in Table 2-5.

Table 2-5 – HAZID Attendees

Name	Role / Discipline	Company	5th November	6th November	Location
Hugo Siddle	Chairperson	WSP	Y	Y	In person
Amelia Collins	Scribe	WSP	Y	Y	In person
David Pinning (DP)	Head of Projects	Palm Paper Limited	Y	Y	In person
Peter Oughtibridge (PO)	Head of Technology	Palm Paper Limited	Y	Y	In person
Andrew Long (AL)	Effluent Treatment Plant Superintendent	Palm Paper Limited	Y	Y	In person
Daniel Thurston (DT)	Head of Electrical	Palm Paper Limited	Y	Y	Online
Mohammad Al-Azzawi	Project Engineer	Schlegel (IBS)	Y	Y	Online

Name	Role / Discipline	Company	5th November	6th November	Location
Heinz Goessling	Project Engineer	Econvert	Y	Y	Online
Mathias Fink	Project Engineer	Eproplan (EPL)	Y	Y	Online
Andreas Tiffner	Project Engineer (Automation)	Palm Group	Par	Y	Online

2.5 HAZID NODES

A list of HAZID nodes is presented in Table 2-6.

Table 2-6 – HAZID Nodes

Node	Node Name	Node Description
Node 1	Anaerobic Reactors	Wastewater is supplied into the machine house where it is held in a buffer tank and dosed with caustic. It is pumped to three anaerobic digestors which remove Chemical Oxygen Demand (COD) from the water and generate biogas. Wastewater then flows to the existing aerobic treatment plant
Node 2	Biological Desulphurisation	Biogas is scrubbed with caustic in the scrubber tower to remove H_2S (from 10,000 ppm to 100 ppm). The caustic is regenerated in the bioreactor from which sulphur sludge is removed.
Node 3	Biogas Storage and Treatment	Biogas is held in the gas storage tank before being diverted to gas treatment or flare. In gas treatment the biogas is dried and activated carbon filters remove any remaining H_2S. The gas is compressed before passing through membranes which separate the methane from CO_2. If the biogas does not meet specification or in the case of system upset, the biogas can instead be flared

3 CONCLUSIONS

3.1 KEY FINDINGS

A total of fifty-two scenarios were risk ranked. No scenarios were identified that were risk ranked as intolerable. Twenty-nine scenarios were identified as Tolerable if ALARP and twenty-three scenarios were identified as Broadly Acceptable.

The main hazards identified in the HAZID study are associated with loss of containment of biogas, which could result in fire and/or explosion from the methane component or toxic effects from the H_2S.

The new AD plant is close to the site boundary with the Highways Authority Depot. There were three scenarios identified that were considered to potentially have offsite fatalities, which were all risk ranked as Tolerable if ALARP. There are:

- Rupture of the existing 32 barg high pressure gas main caused by construction activities or the static loads of the new equipment, resulting in fire or explosion
- Flame out during flaring causing loss of containment of unburnt gas resulting in fire or explosion if the flammable gas cloud is subsequently ignited.
- Loss of containment from the 500m^3 biogas storage tank resulting in toxic exposure to H_2S

Some aspects of the design are yet to be fully completed so were not able to be assessed. This included the off gas (CO_2) processing in the BGTS.

A key recommendation was the development of operating and maintenance procedures for the new AD plant and integrating these into the existing systems. This applied to many of the scenarios considered.

A total of thirty-three recommendations were raised during the workshop. Action tracking and close out is the responsibility of Palm Paper.

The completed HAZID worksheet is shown in Appendix A.

3.2 ACTIONS

A total of 33 actions were identified during the HAZID study. Each was assigned an action owner, which was either named individual or the responsible supplier company.

The actions are listed in Table 3-1.

Table 3-1 – List of Actions

Action No.	Action	Most Severe Risk	HAZID Ref.	Action Owner
1	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	Tolerable if ALARP	1.02, 1.03, 1.07 2.01, 2.02, 2.04, 3.01, 3.02, 3.03, 3.09, 3.10, 3.14	PO

Action No.	Action	Most Severe Risk	HAZID Ref.	Action Owner
2	Ensure suitable lightning protection is provided as required	Broadly Acceptable	1.05	DP
3	Confirm requirement and location of safety showers and other measures to be implemented in the machine house and around the new AD plant area	Broadly Acceptable	1.06, 2.03	PO
4	Update the confined space register and risk assessment to include reactors, desulphurisation equipment and gas storage tank	Tolerable if ALARP	1.09, 1.10, 2.06, 2.07	PO
5	Investigate procedure and mitigation measures required for pellet removal operations including experience from other Palm Paper sites and use of experienced and competent third parties	Broadly Acceptable	1.11	PO
6	Review equipment and materials and ensure all are suitable for marine/ sea environment	Tolerable if ALARP	1.12	IBS, EPL
7	Review the requirement to pave the access road on opposite side of ETP to minimise the risk of impact to AD plant from mobile crane operations	Tolerable if ALARP	1.14	PO
8	Ensure suitable impact protection and lighting are installed where required	Broadly Acceptable	1.15	DP
9	Undertake GM 1 Pipeline integrity assessment to identify the risk and any mitigation measures required	Tolerable if ALARP	1.16	DP
10	Confirm scope of works for design of caustic transfer pipework. Review and implement required mitigation measures for caustic pipework e.g. use of double walled pipe with leak detection	Broadly Acceptable	1.18	PO
11	Drainage design to be confirmed with BHM including consideration of capacity, firewater run off and drain down rate of reactors	Tolerable if ALARP	2.11	DP
12	Confirm level controls on aeration tank noting potential for single point of failure e.g. level instrumentation	Broadly Acceptable	1.23	AL
13	Review location of control panels and pumps to minimise risk from flooding	Broadly Acceptable	1.23	IBS
14	Confirm requirement for UXO assessment	Tolerable if ALARP	1.24	DP
15	Confirm details of piling design and impacts	Broadly Acceptable	1.25	DP
16	Review the design for the reactor and biogas storage overpressure and under pressure relief valves for a loss of power scenario and implement suitable mitigation	Tolerable if ALARP	1.27	IBS
17	Undertake COSHH assessment on sulphur sludge	Tolerable if ALARP	2.08	PO

Action No.	Action	Most Severe Risk	HAZID Ref.	Action Owner
18	Ensure blower discharge pipework is insulated in appropriate areas	Broadly Acceptable	2.10	IBS
19	Include insulation and/ or trace heating on all vulnerable lines including caustic and nutrient dosing		2.12	IBS
20	Add to trace heating PPMs		2.12	DT
21	Review UPS requirements for trace and container heating		2.12	DP
22	Confirm pipe routing from the gas storage tank to the flare, noting the road layout and potential for vehicle impacts	Broadly Acceptable	3.03	IBS
23	Confirm suitability of flare exclusion zone when flare design finalised and supplier selected	Tolerable if ALARP	3.04	IBS
24	Confirm mitigation measures in place on gas storage tank to prevent air ingress from under pressure scenarios and formation of explosive atmosphere within the tank	Tolerable if ALARP	3.05	IBS
25	Confirm refrigerant gas to be used in the cold water plant for gas dryers. Consider non-hazardous alternatives	Broadly Acceptable	3.06	EPL
26	Confirm calibration gas to be used in the BGTS	Broadly Acceptable	3.07	EPL
27	Confirm confined space risk assessment requirements for inside the BGTS containers	Tolerable if ALARP	3.11	PO
28	Confirm pilot gas to be used for flare	Broadly Acceptable	3.13	IBS
29	Confirm action to be taken on detected and confirmed container ventilation failure	Broadly Acceptable	3.15	EPL
30	Confirm off gas design noting GGSS requirements and asphyxiation risks from loss of containment		3.16	PO
31	Confirm cooling medium to be used in the cold water plant for gas dryers. Consider non-hazardous alternatives		3.17	EPL
32	Confirm compression venting design including location of vent stack and any potential noise considerations	Tolerable if ALARP	3.18	EPL
33	Confirm water supply for the condensate trap	Tolerable if ALARP	3.19	IBS

Appendix A

HAZID WORKSHEETS

Node Number:	Node Name:	Cut points/Notes:	Design Intent:	Major Equipment Items:
1	Anaerobic Reactors	Inlet tie in with existing plant, outlet tie in with existing aerobic plant and outlet to desulph units	Waste water is supplied into the machine house where it is held in a buffer tank and dosed with caustic. It is pumped to three anaerobic digestors which remove COD from the water and generate biogas. Waste water then flows to the existing aerobic treatment plant	Machinery house, caustic storage vessel, wstewater buffer tank, pumps, anaerobic treatment reactors
2	Biological desulphurisation	Inlet of scrubber towers, outlet of desulphurisation	Biogas is scrubbed with caustic in the scrubber tower to remove H2S (from 10,000 ppm to 100 ppm). The caustic is regenerated in the bioreactor from which sulphur sludge is removed.	Scrubber towers, bioreactors, caustic storage, nutrient storage
3	Gas Treatment	Inlet of gas holder to flare and connection with grid	Biogas is dried and activated carbon filters remove any remaining H2S. The gas is compressed before passing through membranes which separate the methane from CO2. If the biogas does not meet specification or in the case of system upset, the biogas can instead be flared	Gas drying, blower, activated carbon filters, dust filters, compressors x2 (duty/standby), membranes Gas holder, flare stack

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
1	1.01	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Potential for loss of containment from waste water buffer tank and associated pipework and pumps	Potential for very low levels of flammable gas released into the machine house. Levels of gas will be higher if left stagnant. Nevertheless, it is considered unlikely it could reach LFL. No safety consequences			- High levels of active ventilation in the machine house - High tank throughput under normal conditions - Volume in the buffer tank is low						Note, there has been a previous incident of fire in machine house from air blower motors. This is outside the scope of the new AD plant, however the existing risk in the machine house is recognised and understood.
	1.02	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of biogas from reactors and associated pipework	Release of biogas (50 mbarg) into potentially manned areas. There are connections located close to ground level, however the lower levels of the reactor will be filled with wastewater. Release could also occur at roof level from pipework or lifting PRVs. If ignited, potential for flash fire. Potential for injuries	S	3	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available (not currently mandatory for general site access, see Action 1)	E	Broadly Acceptable	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	1.03	Fire/Explosion Hazards	Tank Fire / Explosion	Air ingress into reactor e.g. due to draining water for maintenance or due to loss of containment	If the reactor is drained of wastewater and there is air ingress, there is the potential for the formation of an explosive atmosphere with significant volumes of biogas. If ignited, potential explosion with multiple fatalities (< 3)	S	5	- Ignition control - reactor will be appropriately defined as a HAC zone, with equipment suitably ATEX rated - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Maintenance procedures will include measures for purging and venting	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	-	Fire/Explosion Hazards	Chemical reactions, Mixing of incompatible materials	No causes identified										
	-	Fire/Explosion Hazards	Physical Explosion	No additional causes identified										
	-	Fire/Explosion Hazards	Dust Explosion	No causes identified										
	-	Fire/Explosion Hazards	Warehouse Fires	No causes identified										
	-	Fire/Explosion Hazards	Runaway Reaction / Decomposition	No causes identified										
	-	Fire/Explosion Hazards	Internal Explosion e.g. loss of inerting	No additional causes identified										
	-	Fire/Explosion Hazards	BLEVE	No causes identified										
	-	Fire/Explosion Hazards	Oxidising substances	No causes identified										
	-	Fire/Explosion Hazards	Pyrophoric materials	No causes identified										
	1.04	Fire/Explosion Hazards	Fixed and Transient Ignition sources	Potential ignition sources on site including vehicles, non ATEX rated equipment	Potential ignition mechanism for loss of containment scenarios, see above.			HAC zones will be developed and appropriate controls implemented						Note - also applicable to nodes 2 and 3
	1.05	Fire/Explosion Hazards	Fixed and Transient Ignition sources	Lightning	Potential ignition during loss of containment or venting at the top of the reactor e.g. from PRVs located 3 m below tank roof level. Potential fire/ explosion. If personnel present potential for fatality (<3)	S	5	Informal policy/understanding on site for no roof access during lightning storms, however is not a formal policy (see Action 1).	F	Broadly Acceptable	Ensure suitable lightning protection is provided as required	2	DP	
	1.06	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of caustic from buffer tank, pumps or associated pipework. Caustic is piped over from the mill over a pipe bridge that runs over a public road and internal road and pathway	Potential operator/ member of the public exposure to caustic resulting in injury	S	4	- PPE, safety showers available to operators - Double walled, bunded tank - Double walled pipe construction - Leak detection	E	Broadly Acceptable	Confirm requirement and location of safety showers and other measures to be implemented in the machine house and around the new AD plant area	3	PO	Pipe bridge is approximately 9m high. Extremely unlikely to be impacted by any vehicles

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	1.07	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of biogas from reactors and associated pipework	Release of biogas (50 mbarg) into potentially manned areas. There are connections located close to ground level, however the lower levels of the reactor will be filled with wastewater. Release could also occur at roof level from pipework or lifting PRVs. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3)	S	5	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available which alarm at 6 ppm (not currently mandatory for general site access, see Action 1)	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	H2S risk is already present on site (but not at such high concentrations) so operators are trained and aware of the risks and mitigations required.
	-	Toxic/Asphyxiation Hazards	Inadequate washing / flushing	No causes identified										
	1.08	Toxic/Asphyxiation Hazards	Chemical reactions, Mixing of incompatible materials, including in drains and waste and water treatment	Ammonium carbamate stored in the adjacent room with connected floor drains to the caustic storage area	Potential mixing of caustic and ammonium carbamate resulting in the formation of ammonia gas. Potential toxic exposure to personnel. Potential injuries	S	3	- Both tanks are bunded, with small amounts of pipework external to bund minimising quantity which will flow to common drains. - Double walled pipe construction - Existing chemical handling procedures - neither chemical deliberately released to drain as part of normal procedure.	E	Broadly Acceptable				
	-	Toxic/Asphyxiation Hazards	Runaway Reaction / Decomposition	No causes identified										
	-	Toxic/Asphyxiation Hazards	Control system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Ventilation system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Human Error including draining, venting sampling, filling, loading / unloading	No additional causes identified										
	1.09	Toxic/Asphyxiation Hazards	Asphyxiation, confined spaces	Entry to reactors for maintenance (entry for planned inspection approx. every 5 years +, or for unplanned maintenance)	Inadequate atmosphere leading to potential asphyxiation and fatality (<3)	S	5	Existing site confined space entry procedures and permits, which define requirements for air testing, rescue provisions etc.	E	Tolerable if ALARP	Update the confined space register and risk assessment to include reactors, desulphurisation equipment and gas storage tank	4	PO	
	1.10	Toxic/Asphyxiation Hazards	Asphyxiation, confined spaces	Nitrogen required for purging operation (brought in via bottles)	Potential release of nitrogen with potential for asphyxiation and fatality (<3)	S	5	Refer to action 4 and action 1	E	Tolerable if ALARP	Update the confined space register and risk assessment to include reactors, desulphurisation equipment and gas storage tank	4	PO	Existing site purging operations are outsourced so this will be a new type of operation for Palm Paper
	1.11	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Removal of excess pellets into road tanker	Potential accumulation of small amounts biogas in the road tanker. This may be up to weekly operation. Potential exposure of road tanker or Palm Paper operator to H2S and potential injury.	S	3	Refer to action	E	Broadly Acceptable	Investigate procedure and mitigation measures required for pellet removal operations including experience from other Palm Paper sites and use of experienced and competent third parties	5	PO	Spillage of pellet not a significant environmental hazard
	1.12	Loss of Primary Containment	Material Selection	Plant located close to the sea	Potential for corrosion from salt in the atmosphere. Potential loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3).	S	5	Refer to action	E	Tolerable if ALARP	Review equipment and materials and ensure all are suitable for marine/ sea environment	6	IBS, EPL	
	-	Loss of Primary Containment	Over Filling	To be assessed in detail in HAZOP										
	-	Loss of Primary Containment	Process Deviation (Flow / Pressure / Level / temperature)	To be assessed in detail in HAZOP										
	-	Loss of Primary Containment	Vibration	No significant causes identified for AD plant, compared with existing vibration risks seen on site with rotating equipment.										

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	-	Loss of Primary Containment	Thermal Cycling / fatigue	No causes identified										
	-	Loss of Primary Containment	Ageing Plant	No additional causes identified										
	1.13	Loss of Primary Containment	Corrosion / erosion	Potentially corrosive environments present e.g. H2S, condensate	Potential for increased corrosion. Potential loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3).	S	5	- Appropriate material selection - Existing maintenance management system (maximo). New plant will be integrated into the system	F	Broadly Acceptable				
	1.14	Loss of Primary Containment	Impact – collision / dropped or swung objects	Adjacent crane operations, e.g. replacement of equipment from aeration tanks	Potential for impact from load into reactors. Potential explosion with multiple fatalities (< 3)	S	5	- Major lifts involving cranes are contract lifts, with competent third party - Contractor selection and competence management	E	Tolerable if ALARP	Review the requirement to pave the access road on opposite side of ETP to minimise the risk of impact to AD plant from mobile crane operations	7	PO	
	1.15	Loss of Primary Containment	Impact – collision / dropped or swung objects	Vehicle impacts	Potential for impact from vehicle (e.g. pellet tanker, mobile crane, FLT) into reactors. Potential loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3).	S	5	- Concrete plinth higher than access road, minimising potential for vehicle impact - Existing on-site vehicle traffic policies enforced e.g. use of banksman, speed limits - Limited vehicle activity in the region around AD plant - Restricted access	F	Broadly Acceptable	Ensure suitable impact protection and lighting are installed where required	8	DP	
	1.16	Loss of Primary Containment	Structural / mechanical failure	Construction activities and future static loads close to existing LP and HP gas lines	Potential rupture of 32 barg gas pipeline resulting in explosion and multiple fatalities. Close to the site boundary and local authority depot. Potential for multiple site and public fatalities	S	6	Plant structures located as far as possible from the gas pipelines	E	Tolerable if ALARP	Undertake GM 1 Pipeline integrity assessment to identify the risk and any mitigation measures required	9	DP	
	-	Loss of Primary Containment	Cryogenic Failure / Embrittlement	No causes identified										
	-	Loss of Primary Containment	Maintenance / cleaning/ containment	No causes identified										
	-	Working hazards	Gases under pressure, bottled gases	No additional causes identified										
	-	Working hazards	Working/access at height	Managed though current Palm Paper safety management systems. No additional causes identified for AD plant.										
	-	Working hazards	Equipment overhead, lifting operations	No additional causes identified										
	-	Working hazards	Hazardous equipment / surfaces	No additional causes identified										
	-	Working hazards	Noise	No causes identified										
	-	Working hazards	Radiation (ionizing, non-ionizing, EM)	No causes identified										
	-	Working hazards	Chemicals, corrosive materials	No additional causes identified										
	1.17	Working hazards	Biological hazards	Bacteria in anaerobic system	Potential for illness	S	2	Existing site controls including PPE. Risks from anaerobic bacteria is less than those already existing on site in aerobic system.	C	Broadly Acceptable				
	1.18	Effects to the Environment	Loss of containment (substances that are dangerous to the environment)	Loss of containment of caustic from buffer tank, pumps or associated pipework. Caustic is piped over from the mill over a pipe bridge that runs over a public road and internal road and pathway	Potential pathway to groundwater or the river and environmental damage. If the release is from the pipe bridge, caustic will flow into surface drains or onto unmade ground. Surface drains route to a tank which is pumped to the river.	E	2	- Releases from within the machine house or onto concrete plinth area is within the site internal drainage system and will be directed back into process, no loss of containment to the environment - Double walled, bunded tanks - Double walled pipe construction - Leak detection - if leak identified contents of surface drains will be routed back into the process	E	Broadly Acceptable	Confirm scope of works for design of caustic transfer pipework. Review and implement required mitigation measures for caustic pipework e.g. use of double walled pipe with leak detection	10	PO	

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	1.19	Effects to the Environment	Loss of containment (substances that are dangerous to the environment)	Loss of containment of biogas from reactors and associated pipework, or from pellet removal activities	Release of methane and H2S to the environment. Greenhouse gas effect and acid rain. Volumes released unlikely to have significant environmental impact. Potential breach of limits for GGSS with financial penalty	E	1	- Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system	C	Broadly Acceptable				
	1.20	Effects to the Environment	Firewater Run off (contamination, combustion products, unburned substances)	Firewater runoff	Potential runoff to unmade ground and offsite locations. Potential environmenal impact.	E	2	Refer to action	B	Tolerable if ALARP	Drainage design to be confirmed with BHM including consideration of capacity, firewater run off and drain down rate of reactors	11	DP	
	-	Effects to the Environment	Recovery (e.g. clean up chemicals)	No causes identified										
	-	Effects to the Environment	Catastrophic primary containment failure	No additional causes identified										
	-	Effects to the Environment	Non-catastrophic failure of primary containment (e.g. Tank shell leak),	No additional causes identified										
	-	Effects to the Environment	Failure of secondary containment including exceeding capacity	No additional causes identified										
	-	Effects to the Environment	Failure of Tertiary containment	No additional causes identified										
	-	Effects to the Environment	Tank overfill	No causes identified										
	-	Effects to the Environment	Tank floor failure / surface integrity failure	No causes identified										
	-	Effects to the Environment	Fire / Explosion	No additional causes identified										
	-	Effects to the Environment	Incompatible Materials	No additional causes identified										
	-	Effects to the Environment	Interaction within drainage system	No additional causes identified										
	-	Effects to the Environment	Human Error	No additional causes identified										
	-	Effects to the Environment	Release to Air / Smoke	No additional causes identified										
	-	Effects to the Environment	Release to water (marine)	No causes identified										
	-	Effects to the Environment	Release to water (fresh/estuarine)	No additional causes identified										
	-	Effects to the Environment	Release to Drinking water source (treatment/reservoir etc)	No causes identified										
	-	Effects to the Environment	Release to Groundwater	No additional causes identified										
	-	Effects to the Environment	Release to Soil/sediment	No additional causes identified										
	-	Effects to the Environment	Release to Habitat/species	No causes identified										
	-	Effects to the Environment	Release to SSSI/designated site	No causes identified										
	-	Effects to the Environment	Impact on built environment	No causes identified										
	-	External Hazards	Seismic event	No causes identified										
	1.21	External Hazards	Extreme weather (hot, cold, storm)	Freezing external temperatures	Potential for freezing in instrument air supply causing air controlled valves to stick in the incorrect position. This has been know to occur on site. Consequences will be studied further in HAZOP			- Air dryers reduce the dew point to -40degC - Valves fail to safe position						
	1.22	External Hazards	Flooding	Potential for flooding from the river. Site is located in a flood risk zone below sea level	Potential for uncontrolled shut down of plant. Potential for pressure increase and PRVs to lift and vent biogas. (Note loss of containment consequences and safeguards have been covered above)	E	2	- Planning in place for flood events including controlled shut down. - EA flood alert system - Valves fail to safe position - Existing flood protection designed for 100 year flood event	E	Broadly Acceptable				

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	1.23	External Hazards	Flooding	Overfill of the adjacent aeration or settling tanks	Potential for uncontrolled shut down of plant and damage to equipment e.g. electrical cabinets and control systems. Potential for pressure increase and PRVs to lift and vent biogas. (Note loss of containment consequences and safeguards have been covered above)	A	2	- Level control and level alarm in aeration tank	D	Broadly Acceptable	Confirm level controls on aeration tank noting potential for single point of failure e.g. level instrumentation	12	AL	This scenario has previously occurred but additional control measures have since been implemented
	-										Review location of control panels and pumps to minimise risk from flooding	13	IBS	
	-	External Hazards	Lightning	No additional causes identified										
	-	External Hazards	Vehicle impacts	No additional causes identified										
	-	External Hazards	Aircraft crash	No causes identified										
	-	External Hazards	Terrorism	No causes identified										
	-	External Hazards	Vandalism / theft / third party interference	No causes identified										
	-	External Hazards	Off-site / neighbouring fire / explosion	No causes identified										
	1.24	External Hazards	Historic Site specific Hazards e.g. Unexploded ordnance	Unexploded ordnance is a known concern in the area	Excavation and construction activities impacting UXO resulting in explosion and fatality	S	5	The AD plant location is on previously disturbed ground, so likelihood is low	E	Tolerable if ALARP	Confirm requirement for UXO assessment	14	DP	
	1.25	External Hazards	Subsidence	Effects from piling on the existing plant	Loss of structural integrity leading to collapse of structures and loss of containment (refer to previous causes). Potential for injury from structural collapse (risk ranked for physical injury form collapse)	S	4	- Preliminary piling design suggested no risk - Detailed piling and foundation design being undertaken by BHM who are experienced and competent structural engineers/ architects	F	Broadly Acceptable	Confirm details of piling design and impacts	15	DP	
	1.26	External Hazards	Subsidence	Subsidence	Subsidence has previously occurred on site at the settling tanks. Potential loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3).	S	5	- Preliminary piling design suggested no risk - Detailed piling and foundation design being undertaken by BHM who are experienced and competent structural engineers/ architects	E	Tolerable if ALARP	Confirm details of piling design and impacts	15	DP	
	1.27	Utilities	Electricity	Loss of power	Plant will shut down. Heating to the overpressure valves will stop. If this coincides with a period of low temperature, there is potential for freezing shut resulting in overpressure and loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in fatalities (<3).	S	5	Refer to action	E	Tolerable if ALARP	Review the design for the reactor and biogas storage overpressure and underpressure relief valves for a loss of power scenario and implement suitable mitigation.	16	IBS	
	1.28	Utilities	Electricity	Local loss of power to ETP	Continued feed of wastewater from the mill resulting in overfilling of the buffer tank This will be assessed in detail during HAZOP			Existing interlocking of control systems and high voltage network and process alarms						
	-	Utilities	Water	No causes identified										
	1.29	Utilities	Compressed air	Loss of compressed air	Valves move to failsafe position. No hazardous consequences expected, but will be assessed in detail during HAZOP.									
	-	Utilities	Steam	No causes identified										
	-	Utilities	Natural Gas	No causes identified										
	-	Utilities	Control Systems	No causes identified										New control system will be fully integrated into the site DCS
	-	Utilities	Communication	No causes identified										
	-	Utilities	Other e.g. nitrogen	No additional causes identified										

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
2	2.01	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of biogas from scrubber and associated pipework	Release of biogas (50 mbarg) into potentially manned areas. Biogas connection to scrubber at approx. 6 m. If ignited, potential for flash fire. Potential for injuries	S	3	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available (not currently mandatory for general site access, see Action 1)	E	Broadly Acceptable	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	2.02	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Air ingress into scrubber e.g. due to draining water for maintenance or due to loss of containment	If the bioreactor/ scrubber is drained there is the potential for the formation of an explosive atmosphere with significant volumes of biogas. If ignited, potential explosion with multiple fatalities (< 3)	S	5	- Ignition control - bioreactor and scrubber will be appropriately defined as a HAC zone, with equipment suitably ATEX rated - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Maintenance procedures will include measures for purging and venting	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	-	Fire/Explosion Hazards	Tank Fire / Explosion	No additional causes identified										
	-	Fire/Explosion Hazards	Chemical reactions, Mixing of incompatible materials	No causes identified										
	-	Fire/Explosion Hazards	Physical Explosion	No additional causes identified										
	-	Fire/Explosion Hazards	Dust Explosion	No causes identified										
	-	Fire/Explosion Hazards	Warehouse Fires	No causes identified										
	-	Fire/Explosion Hazards	Runaway Reaction / Decomposition	No causes identified										
	-	Fire/Explosion Hazards	Internal Explosion e.g. loss of inerting	No additional causes identified										
	-	Fire/Explosion Hazards	BLEVE	No causes identified										
	-	Fire/Explosion Hazards	Oxidising substances	No causes identified										
	-	Fire/Explosion Hazards	Pyrophoric materials	No causes identified										
	-	Fire/Explosion Hazards	Fixed and Transient Ignition sources	Refer to node 1										
	-	Fire/Explosion Hazards	Lightning	Refer to node 1										
	2.03	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of caustic from buffer tank, pumps or associated pipework.	Potential operator exposure to caustic resulting in injury	S	4	- PPE, safety showers available to operators - Tank and pump within collection tray - Leak detection	E	Broadly Acceptable	Confirm requirement and location of safety showers and other measures to be implemented in the machine house and around the new AD plant area	3	PO	
	2.04	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of biogas from scrubber and associated pipework	Release of biogas (50 mbarg) into potentially manned areas. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in potential fatalities (<3)	S	5	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available which alarm at 6 ppm (not currently mandatory for general site access, see Action 1)	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	H2S risk is already present on site (but not at such high concentrations) so operators are trained and aware of the risks and mitigations required.
	-	Toxic/Asphyxiation Hazards	Inadequate washing / flushing	No causes identified										

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	2.05	Toxic/Asphyxiation Hazards	Chemical reactions, Mixing of incompatible materials, including in drains and waste and water treatment	Nutrient dosing and caustic dosing located adjacent to each other.	Potential mixing of caustic and nutrients resulting in the formation of ammonia gas. Potential toxic exposure to personnel resulting in potential injuries	S	2	- Both tanks located in separate trays - Caustic is hard piped into tank, whilst nutrients are fed via IBC. Minimises risk of incorrect filling operation - Existing chemical handling procedures	F	Broadly Acceptable				
	-	Toxic/Asphyxiation Hazards	Runaway Reaction / Decomposition	No additional causes identified										
	-	Toxic/Asphyxiation Hazards	Control system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Ventilation system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Human Error including draining, venting sampling, filling, loading / unloading	No additional causes identified										
	2.06	Toxic/Asphyxiation Hazards	Asphyxiation, confined spaces	Entry to scrubber or bioreactor for maintenance (entry for planned inspection approx. every 2 years +, or for unplanned maintenance)	Inadequate atmosphere leading to potential asphyxiation and fatality (<3)	S	5	Existing site confined space entry procedures and permits, which define requirements for air testing, rescue provisions etc.	E	Tolerable if ALARP	Update the confined space register and risk assessment to include reactors, desulphurisation equipment and gas storage tank	4	PO	
	2.07	Toxic/Asphyxiation Hazards	Asphyxiation, confined spaces	Nitrogen required for purging operation (brought in via bottles)	Potential release of nitrogen with potential for asphyxiation	S	5	Refer to action 4 and action 1	E	Tolerable if ALARP	Update the confined space register and risk assessment to include reactors, desulphurisation equipment and gas storage tank	4	PO	Existing site purging operations are outsourced so this will be a new type of operation for Palm Paper
	2.08	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of sulphur sludge or scheduled maintenance e.g. replacing of flexible hose	Exposure to sulphur sludge resulting in skin or eye irritation	S	2	Existing chemical handling procedures	B	Tolerable if ALARP	Undertake COSHH assessment on sulphur sludge	17	PO	
	-	Loss of Primary Containment		Refer to node 1 (all guidewords)										
	2.09	Loss of Primary Containment	Ageing Plant	Degradation of polymers due to weathering	Loss of containment. Personnel exposure to H2S at up to 10,000 ppm local to the release but will slump towards ground level, resulting in potential fatalities (<3)	S	5	Material is insulated so is protected from temperature fluctuations and UV protected	E	Tolerable if ALARP				Note, plastic is preferred due to better resistance to corrosion compared with disadvantages of weathering potential.
	-	Working hazards	Gases under pressure, bottled gases	No additional causes identified										
	-	Working hazards	Working/access at height	Managed though current Palm Paper safety management systems. No additional causes identified for AD plant.										
	-	Working hazards	Equipment overhead, lifting operations	No additional causes identified										
	2.10	Working hazards	Hazardous equipment / surfaces	Blower discharge pipework is a hot surface (approx. 70 degC)	Potential burn injury	S	2	Refer to action	C	Broadly Acceptable	Ensure blower discharge pipework is insulated in appropriate areas	18	IBS	
	-	Working hazards	Noise	Blowers are equipped with acoustic hoods which reduce the exposure level to acceptable levels. No hazardous consequences.										
	-	Working hazards	Radiation (ionizing, non-ionizing, EM)	No causes identified										
	-	Working hazards	Chemicals, corrosive materials	No additional causes identified										
	-	Working hazards	Biological hazards	No additional causes identified										
	2.11	Effects to the Environment	Loss of containment (substances that are dangerous to the environment)	Loss of containment of caustic, nutrients or sulphur sludge. The desulphurisation area is located within the process drainage system	Potential overspill from plinth to unmade ground and offsite locations. Potential environmenal impact.	E	2	Refer to action	B	Tolerable if ALARP	Drainage design to be confirmed with BHM including consideration of capacity, firewater run off and drain down rate of reactors	11	DP	Action also applicable to nodes 1 and 3
	-	Effects to the Environment	Loss of containment (substances that are dangerous to the environment)	See node 1										

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	-	Effects to the Environment		Refer to node 1 (all guidewords)										
	2.12	External Hazards	Extreme weather (hot, cold, storm)	Low ambient temperature	Potential freezing of caustic and nutrient dosing lines. Blockage of lines resulting in loss of chemical dosing. Consequences for loss of chemical dosing will be assessed in detail during the HAZOP.			Machinery container is heated			Include insulation and/ or trace heating on all vulnerable lines including caustic and nutrient dosing	19	IBS	Action also applicable to node 1
	-										Add trace heating to relevant PPMs	20	DT	
	-										Review UPS requirements for trace and container heating	21	DP	
	-	External Hazards		Refer to node 1 (all guidewords)										
	-	Utilities	Water	Loss of cooling water and sealing water to be assessed in detail during the HAZOP										
	-	Utilities	Electricity	See node 1										Pressure relief for scrubber is via reactor relief valves
	-	Utilities	Control Systems	See node 1										
	-	Utilities	Compressed air	See node 1										
	-	Utilities	Steam	No causes identified										
	-	Utilities	Natural Gas	No causes identified										
	-	Utilities	Communication	No causes identified										
	-	Utilities	Other e.g. nitrogen	No additional causes identified										
3	3.01	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of biogas from storage tank (500 m^3 capacity). Worst case is failure of the membrane resulting in loss of tank inventory.	Release of biogas (50 mbarg) into potentially manned areas, with potentially significant volumes of biogas. If ignited, potential flash fire or explosion. Potential for site and public fatalities.	S	6	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available (not currently mandatory for general site access, see Action 1) - HAC to be completed to confirm HAC zones with appropriately rated ATEX equipment	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	3.02	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of biogas from BGTS.	Release of biogas (10-16 barg) within the container. If ignited, potential for jet fire or confined explosion. Potential for fatalities (<3)	S	5	- Container is ventiliated - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available (not currently mandatory for general site access, see Action 1) - HAC to be completed to confirm HAC zones with appropriately rated ATEX equipment	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	3.03	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of biogas from flare system pipework. Pipework is routed from gas storage area over/under a roadway to the proposed gas flare location	Release of biogas (50 mbarg) into potentially manned areas. If ignited, potential for flash fire. Potential for injuries	S	3	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available (not currently mandatory for general site access, see Action 1) - Valves and flame arrestors located in flare safety zone with personnel access restricted	E	Broadly Acceptable	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	-										Confirm pipe routing from the gas storage tank to the flare, noting the road layout and potential for vehicle impacts	22	IBS	

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	3.04	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Flare flame out	Unburnt gas released to atmosphere. This could be full gas output during start up or emergency shut down. If ignited, potential for flash fire. Potential for fatality, which may be offsite as the flare is located close to the boundary fence line	S	6	- Flame out detection - Ignition redundancy - Wastewater can be bypassed around AD system to reduce biogas generation - Flare safety zone with personnel access restricted	E	Tolerable if ALARP	Confirm suitability of flare exclusion zone when flare design finalised and supplier selected	23	IBS	
	3.05	Fire/Explosion Hazards	Tank Fire / Explosion	Underpressure and potential air ingress into gas storage tank	Potential asset damage and damage to membrane. Potential formation of explosive atmosphere within the storage tank. If ignited, potential explosion. Potential for fatalities	S	6	BGTS blower has a shut off on low pressure in the inlet of the biogas treatment system	E	Tolerable if ALARP	Confirm mitigation measures in place on gas storage tank to prevent air ingress from underpressure scenarios and formation of explosive atmosphere within the tank	24	IBS	
	-	Fire/Explosion Hazards	Fixed and Transient Ignition sources	See node 1										
	-	Fire/Explosion Hazards	Lightning	See node 1										
	-	Fire/Explosion Hazards	Dust Explosion	Potential for dust formation and explosion from the activated carbon filters was discussed by the team and not considered credible										
	3.06	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of refrigerant gas R454b	Potential release of flammable gas in vicinity of treatment container. Potential fire and operator injury	S	3	- Plant is located outside providing natural dispersion and ventilation - Existing maintenance management system (maximo). New plant will be integrated into the system - Small volumes of refrigerant (approx. 60 L)	F	Broadly Acceptable	Confirm refrigerant gas to be used in the cold water plant for gas dryers. Consider non hazardous alternatives	25	EPL	
	3.07	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of containment of calibration gases (preliminary design for calibration gas contains methane, N2, O2, CO2 and H2S)	Potential release of flammable gas in vicinity of treatment container. Potential fire and operator injury	S	4	- Plant is located outside providing natural dispersion and ventilation - Existing maintenance management system (maximo). New plant will be integrated into the system - Small volumes of calibration gas (preliminary design - 10l consumption)	F	Broadly Acceptable	Confirm calibration gas to be used in the BGTS	26	EPL	
	3.08	Fire/Explosion Hazards	Loss of containment with ignition (e.g. Flammable materials and mists, Gases /vapours)	Loss of water lock in the condensate pit e.g. due to evaporation, leakage	Potential release of flammable gas from the condensate pit vent, likely in the vicinity of the storage tank. If ignited potential fire and operator fatality	S	5	Level control and alarm in the condensate pit. Automatic top up on low level.	E	Tolerable if ALARP				
	-	Fire/Explosion Hazards	Chemical reactions, Mixing of incompatible materials	No causes identified										
	-	Fire/Explosion Hazards	Physical Explosion	No causes identified										
	-	Fire/Explosion Hazards	Warehouse Fires	No causes identified										
	-	Fire/Explosion Hazards	Runaway Reaction / Decomposition	No causes identified										
	-	Fire/Explosion Hazards	Internal Explosion e.g. loss of inerting	No causes identified										
	-	Fire/Explosion Hazards	BLEVE	No causes identified										
	-	Fire/Explosion Hazards	Oxidising substances	No causes identified										
	-	Fire/Explosion Hazards	Pyrophoric materials	No causes identified										

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	3.09	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of biogas from storage tank (500 m^3)	Release of biogas (50 mbarg) into potentially manned areas. Personnel exposure to H2S at up to 100 ppm (under normal conditions or 10,000 ppm under emergency conditions) local to the release but will slump towards ground level, resulting in fatalities. Potential for offsite impact	S	6	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available which alarm at 6 ppm (not currently mandatory for general site access, see Action 1)	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	H2S risk is already present on site (but not at such high concentrations) so operators are trained and aware of the risks and mitigations required.
	3.10	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of biogas from BGTS up to activated carbon filters.	Release of biogas (50 mbarg) into potentially manned areas. Personnel exposure to H2S at up to 100 ppm (under normal conditions, 300 ppm under upset conditions) local to the release but will slump towards ground level, resulting in fatalities	S	5	- BGTS up to activated carbon filters is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available which alarm at 6 ppm (not currently mandatory for general site access, see Action 1) - Gas detection in containers	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	3.11	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment after compression	Release of biogas at 10-16 barg inside container. Potential oxygen displacement and asphyxiation. Containers not normally manned but personnel may be present during walkaround inspections	S	5	- Gas detection in containers which initiates shut down and venting - Containers ventilated - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system	E	Tolerable if ALARP	Confirm confined space risk assessment requirements for inside the BGTS containers	27	PO	
	3.12	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of biogas from flare system pipework. Pipework is routed from gas storage area over/under a roadway to the proposed gas flare location	Release of biogas (50 mbarg) into potentially manned areas. Personnel exposure to H2S at up to 100 ppm (under normal conditions or 10,000 ppm under emergency conditions) local to the release but will slump towards ground level, resulting in fatalities.	S	5	- Plant is located outside providing natural dispersion and ventilation - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Personal gas detectors available which alarm at 6 ppm (not currently mandatory for general site access, see Action 1) - Valves and flame arrestors located in flare safety zone with personnel access restricted	E	Tolerable if ALARP	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	3.13	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Flare flame out	Unburnt gas released to atmosphere. This could be full gas output during start up or emergency shut down. Personnel exposure to H2S at up to 100 ppm (under normal conditions or 10,000 ppm under emergency conditions) local to the release but will slump towards ground level, resulting in fatalities.	S	5	- Flame out detection - Ignition redundancy - Wastewater can be bypassed around AD system to reduce biogas generation - Flare safety zone with personnel access restricted	F	Broadly Acceptable	Confirm pilot gas to be used for flare	28	IBS	
	3.14	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Changeout of activated carbon	Exposure to carbon dust with sulphur, potential lung and skin damage	S	3	Refer to action	D	Broadly Acceptable	Develop site operating and maintenance procedures for new AD plant including requirements for PPE, personal gas detection, access requirements etc.	1	PO	
	3.15	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of calibration gases (preliminary design for calibration gas contains methane, N2, O2, CO2 and H2S)	H2S content of calibration gas is very low. Preliminary design indicates 0.1% by volume. Potential release of gas within the container. Containers not normally manned but personnel may be present during walkaround inspections	S	5	- Gas detection in containers - Containers ventilated - Permit to work, safe systems of work implemented on site - Existing maintenance management system (maximo). New plant will be integrated into the system - Existing gas bottle handling procedures	F	Broadly Acceptable	Confirm action to be taken on detected and confirmed container ventilation failure	29	EPL	

Node	Ref.	Hazard Category	Guideword	Cause(s)	Consequence	Cat	S	Safeguards	L	Risk	Action	Action No.	Action Owner	Comments
	3.16	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of off gas (CO2 with traces of methane)	Design yet to be confirmed however loss of containment may present asphyxiation risk and breach of GGSS limits. Refer to action						Confirm off gas design noting GGSS requirements and asphyxiation risks from loss of containment	30	PO	
	3.17	Toxic/Asphyxiation Hazards	Loss of containment (toxic substances)	Loss of containment of cooling medium in the gas dryer	Potential toxic or environmental consequences to be confirmed Refer to action						Confirm cooling medium to be used in the cold water plant for gas dryers. Consider non hazardous alternatives	31	EPL	
	-	Toxic/Asphyxiation Hazards	Inadequate washing / flushing	No causes identified										
	-	Toxic/Asphyxiation Hazards	Chemical reactions, Mixing of incompatible materials, including in drains and waste and water treatment	No causes identified										
	-	Toxic/Asphyxiation Hazards	Runaway Reaction / Decomposition	No causes identified										
	-	Toxic/Asphyxiation Hazards	Control system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Ventilation system failure	No causes identified										
	-	Toxic/Asphyxiation Hazards	Human Error including draining, venting sampling, filling, loading / unloading	No causes identified										
	-	Toxic/Asphyxiation Hazards	Asphyxiation, confined spaces	No causes identified										
	-	Loss of Primary Containment		Refer to node 1 (all guidewords)										
	-	Working hazards	Gases under pressure, bottled gases	No causes identified										
	-	Working hazards	Equipment overhead, lifting operations	Lifting operations e.g. for maintenance, activated carbon changeout, pump repairs would be managed under the same lifting procedures and controls as those already existing on site No additional risk from new AD plant										
	-	Working hazards	Hazardous equipment / surfaces	No causes identified										
	3.18	Working hazards	Noise	Process upset on compression system	Venting of 16 barg gas which can produce noise	S	2	Refer to action	B	Tolerable if ALARP	Confirm compression venting design including location of vent stack and any potential noise considerations	32	EPL	
	-	Working hazards	Radiation (ionizing, non-ionizing, EM)	No causes identified										
	-	Working hazards	Chemicals, corrosive materials	No causes identified										
	-	Working hazards	Biological hazards	No causes identified										
	-	Effects to the Environment		Refer to node 1 (all guidewords)										
	-	External Hazards		Refer to node 1 (all guidewords)										
	3.19	Utilities	Water	Loss of water supply for the condensate trap	Potential release of flammable gas from the condensate pit vent, likely in the vicinity of the storage tank. If ignited potential fire and operator fatality	S	5	Level control and alarm in the condensate pit and operator intervention.	E	Tolerable if ALARP	Confirm water supply for the condensate trap	33	IBS	
	3.20	Utilities	Electricity	Local loss of power	Unable to light flare, see 3.04 and 3.13									
	-	Utilities	Compressed air	See node 1										
	-	Utilities	Control Systems	See node 1										
	-	Utilities	Steam	No causes identified										
	-	Utilities	Natural Gas	No causes identified										
	-	Utilities	Communication	No causes identified										
	-	Utilities	Other e.g. nitrogen	No causes identified										

Appendix B

SITE DRAWINGS

E - DUCT Ø 90 L = 45.70m

GL +3,00

E - DUCT Ø 90 L = 45.70m

E - DUCT Ø 90 L = 45.70m

A

C

Gas flare

Gas tank 500 V= m3

D

A

GL +1,20

Desulphurization

GL −1,60

Activated carbon filters

Biogas treatment system

Biogas treatment system

Anaerobic reactors Ø 9.00 m

E - DUCT Ø 90 L = 54.60m

PLANUNGSGRENZE IBS / BMW

PE-HD Ø 150 59.70m

3 x Ø100 21.10m

4 x Ø100 23.40m

2 x Ø100 5.00m

B

B

FRESHWATER PIPE DN 600

GL +1,50

SCUM PIPE ST 1+2 DN 150

RETURN SLUDGE PIPE ST 1+2 DN 500

DISCHARGE PIPE ST 1+2 DN 600

STAIRWAY

GL +2,10

Lean gas system

GL +1,50

E

STAIRWAY

WL +7,00

AERATION TANK UNIT 4

H234

POL DN 100

RETURN SLUDGE PIPE ST 1 DN 500

RETURN SLUDGE PIPE ST 2 DN 500

3.42

E

INLET PIPE ST 2 DN 700

FRESHWATER PIPE DN 600

DISCHARGE PIPE ST 1+2 DN 600

PIPE BRIDGE

WL +7,00

AERATION TANK UNIT 3

H233

MACHINERY HOUSE

H 220

WL +7,00

AERATION TANK UNIT 2

H232

WL +7,00

AERATION TANK UNIT 1

H231

GL +0,70

GL +0,50

132 KV-TRACE

GL +0,50

STORAGE TANK

H 225

D

132 KV-STATION

H 221

HIGH VOLTAGE

H 221

GL +0,70

GL +0,00

GL −1,60

GL +0,00

90.40

6.80

41.80

H242

SETTLING TANK 2

FRESH WATER INTAKE PIPE DN 500

GL +2,10

WL +4,50

SETTLING TANK 2

H 242

SCUM PIPE

DN 150

RETURN SLUDGE PIPE

DN 500

INLET PIPE

DN 700

DISCHARGE PIPE ST 2

DN 600

FRESH WATER INTAKE PIPE DN 500

GL +3,30

SCUM PIPE ST 1+2 DN 150

RETURN SLUDGE PIPE ST 1+2 DN 500

INLET PIPE ST 1 DN 700

DISCHARGE PIPE ST 1

DN 600

OVERFLOW ST 1

DN 700

GL +1,00

INLET PIPE ST 2

DN 700

INLET PIPE ST 1

DN 700

GL +3,30

41.80

H241

SETTLING TANK 1

INLET PIPE

DN 700

WL +5,70

RETURN SLUDGE PIPE

DN 500

SCUM PIPE

DN 150

SETTLING TANK 1

H 241

WL +5,70

GL +2,00

LA DEPOT ACCESS ROAD

AERATION TANK H230

MACHINERY HOUSE H220

46.30

10

21.10

132 KV – SUBSTATION H221

2.10

0 50m 100m

Scale 1:200

41.80

SETTLINGS TANKS H240

V = 2 x 5565 m3

A = 2 x 1320 m2

21.40

52.25

AERATION TANK H230

V_{total} = 4 x 5100 m3 = 20400 m3

2 8.00 2

STORAGE TANKS H225

26.00

MACHINERY HOUSE H220

7.50

STREET

2 8.20 5.70 5 12.05

132 KV – SUBSTATION H221

149.69

MILL SITE ZERO (MSZ) = 5,00 m AOD

(LOCAL REFERENCE FRAME) (ABOVE ORDANCE DATUM)

REVISION	COMMENT	DATE	NAME

21.08.2025	LYNN PM 7	1001	0000	BAU	1100	00
DATE	PROJECT / FIELD	SUBJECT	VE	FIELD	DR. NO.	REV.

PAPER MILL LYNN PM 7

WATER TREATMENT PLANT

SUBJECT OPTIMIZING THE EXISTING WWTP VIA ANAEROBIC TREATMENT

DESIGN PRELIMENARY DESIGN

KIND OF PLAN LAYOUT

SCALE 1:200

SIZE 1189x841

ENGINEER SCHLEGEL Consulting Engineers 80639 Munich, Germany (+49 89) 17 90 2-0

DATE 15.05.2025

CHECKED Al-Azzawi

DRAWN Tamang

CHECKED Al-Azzawi

DATE

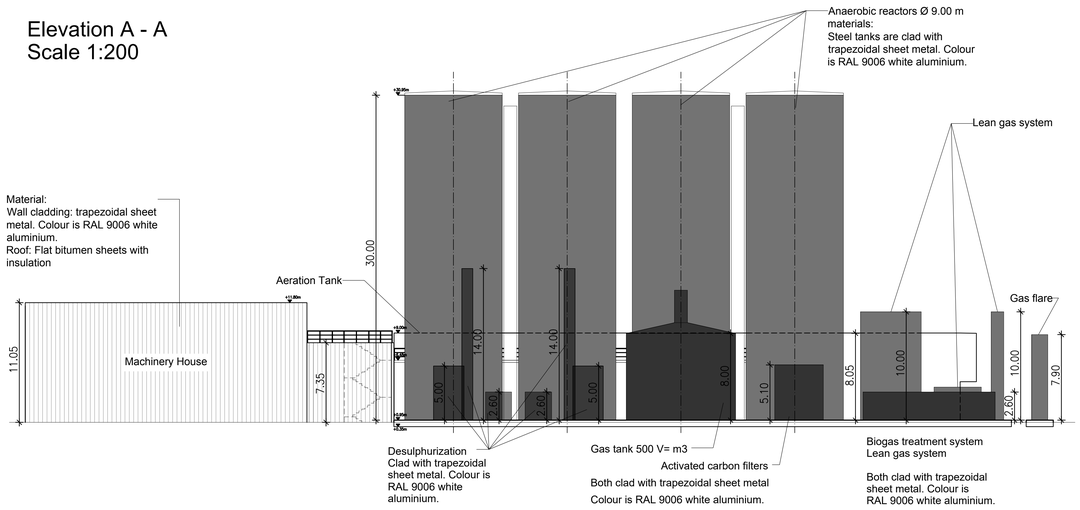
CLIENT PALM PAPER LIMITED

King`s Lynn

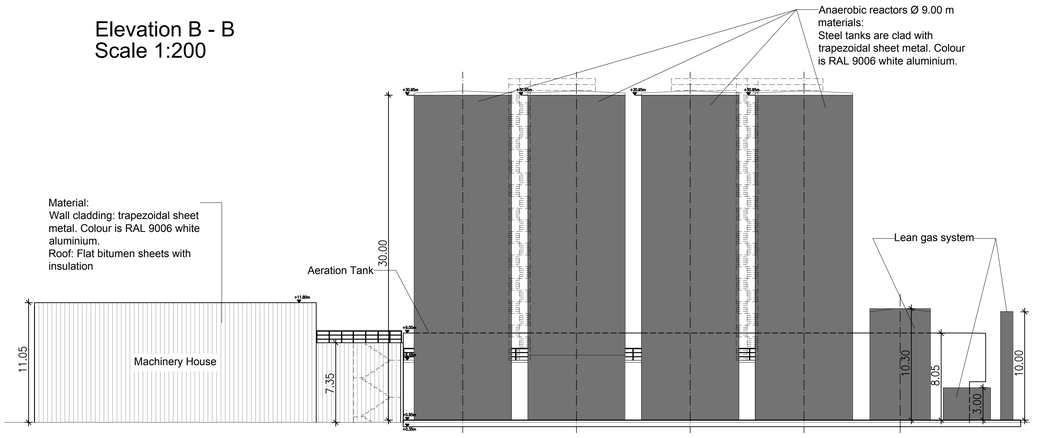
Norfolk PE30 5EJ

DATE

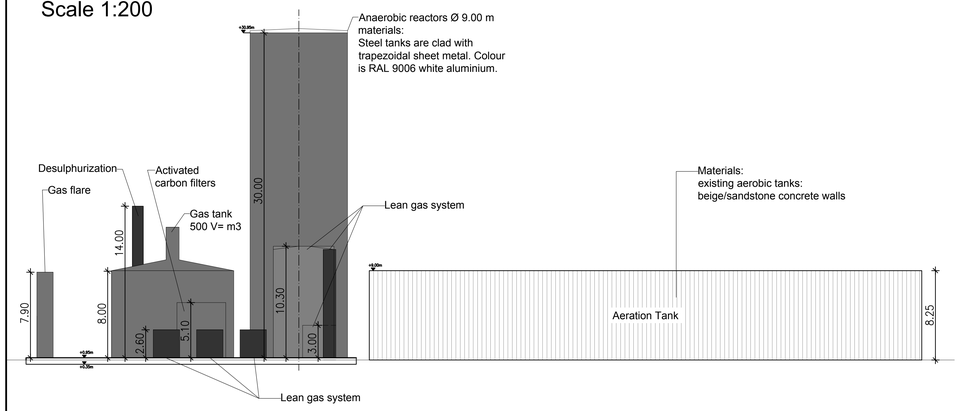
Elevation A - A
Scale 1:200



Elevation B - B
Scale 1:200



Elevation C - C
Scale 1:200



Elevation D - D
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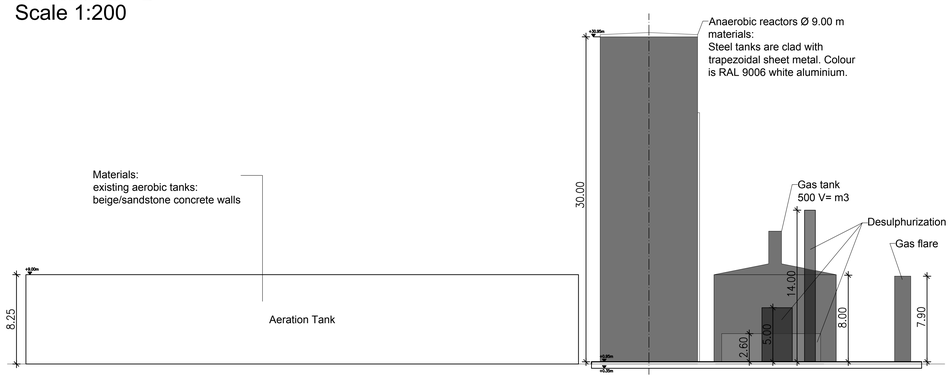

Elevation E - E
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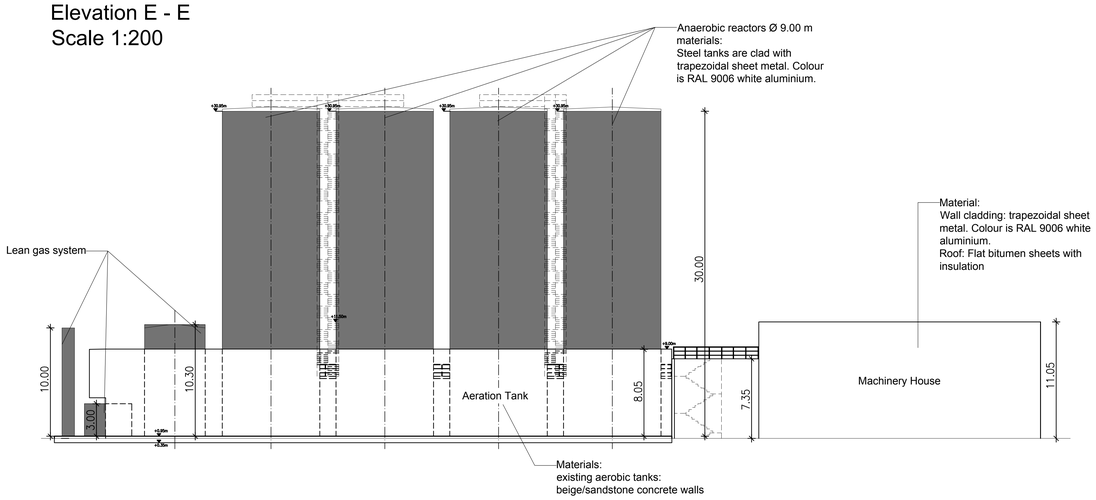

0 50m 100m

Scale 1:200

MILL SITE ZERO (MSZ) = 5,00 m AOD
(LOCAL REFERENCE FRAME) (ABOVE ORDANCE DATUM)

REVISION	COMMENT	DATE	NAME

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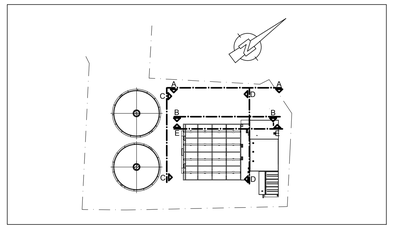
21.08.2025	LYNN PM 7	1001	0000	BAU	1101	00



PAPER MILL LYNN PM 7
WATER TREATMENT PLANT

SUBJECT: OPTIMIZING THE EXISTING WWTP VIA ANAEROBIC TREATMENT

DESIGN: PRELIMENARY DESIGN

KIND OF PLAN: ELEVATIONS

SCALE: 1:200
SIZE: 1189x841

ENGINEER: SCHLEGEL Consulting Engineers
80639 Munich, Germany (+49 89) 17 90 2-0

DATE: 15.05.2025
CHECKED: Al-Azzawi
DRAWN: Tamang
CHECKED: Al-Azzawi

CLIENT: PALM PAPER LIMITED
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