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WSN Environmental Solutions

Alternative Waste Technology Facility, Lucas Heights

Preliminary Hazard Analysis

July 2009

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Appendices

Glossary

ADG	Australian Code for the Transport of Dangerous Goods
ALARP	As Low As Reasonably Practicable
AWT	Alternative Waste Technology
DEC	Department of Environment and Conservation
DoP	Department of Planning
EA	Environmental Assessment
EPA	Environment Protection Authority
ERPG	Emergency Response Planning Guidelines
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health Safety Executive
KPI	Key Performance Indicators
LHWRC	Lucas Heights Waste and Recycling Centre
MBT	Mechanical Biological Treatment
MSW	Municipal Solid Waste
PHA	Preliminary Hazard Assessment
PLL	Potential for Loss of Life (p.a.) expressed as fatalities per annum
PPE	Personal Protective Equipment
PRRC	Potential Risk Reduction Controls
QRA	Quantitative Risk Assessment
RRA	Risk Reduction Action
SEPP 33	State Environmental Planning Policy No.33

1. Introduction

WSN Environmental Solutions (WSN) is proposing to construct an Alternative Waste Technology (AWT) facility at the Lucas Heights Waste and Recycling Centre (LHWRC). The AWT facility includes an anaerobic digestion plant, which would generate biogas containing methane and other gases (primarily carbon dioxide). This generated gas would be piped to a renewable energy power plant comprising one or more biogas fuelled reciprocating engines.

GHD has been engaged to prepare a Preliminary Hazard Analysis (PHA) for the proposal, for inclusion in an Environmental Assessment (EA) under Part 3A of the *Environmental Planning and Assessment Act 1979*.

This report was prepared with background information, terms of reference and assumptions supplied by and agreed with WSN Environmental Solutions. The report is not intended for use by any other individual or organisation and, as such, GHD cannot accept liability for use of the information contained in this report, except for the purpose for which it was intended at the time of writing.

1.1 Objectives

The PHA objectives are:

- To demonstrate that the risks identified during and after the proposed development are acceptable in relation to the surrounding land use;
- To demonstrate that any residual risk will be appropriately managed; and
- To advise risk reduction strategies where unacceptable risks are identified.

1.2 Scope

This PHA includes a description of the proposed development, SEPP 33 screening of dangerous goods, a qualitative assessment and where required, subsequent quantitative risk assessment that reviews:

- Input/output materials storage, processing and handling;
- Primary items of the process; and
- Natural disasters, bushfires and flooding, as relevant.

2. Statutory Requirements

The current structure for project assessment is established by the *Environmental Planning and Assessment Act 1979* (the EP&A Act). This project is considered to be a major project under Part 3A of the EP&A Act, and therefore an EA is required to accompany the application to the Minister for Planning.

The Director-General’s Requirements for the EA require a PHA as per State Environmental Planning Policy No.33 – Hazardous and Offensive Development (SEPP 33). A PHA broadly examines the likely potential hazards that may occur as a result of a hazardous or offensive development.

SEPP 33 requires developments that are potentially hazardous to be the subject of a PHA to determine the risk to people, property and the environment at the proposed location and in the presence of controls. Should such risk exceed the criteria of acceptability, the development is classified as ‘hazardous industry’ and may not be permissible within most industrial zones in NSW.

For developments identified as potentially offensive the minimum criteria for such developments is meeting the requirements for licensing by the Department of Environment and Climate Change (DECC) (formerly Environment Protection Authority (EPA)). If a development cannot obtain the necessary pollution control licenses, then it may be classified as ‘offensive industry’, and may not be permissible within most industrial zones in NSW.

This PHA was prepared applying SEPP 33, and generally in accordance with the Department of Planning (DoP) (formerly Department of Urban Affairs and Planning) publications Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis (1992) (HIPAP 6) and Multi-Level Risk Assessment (1997).

This PHA considers risks associated with the development in terms of accidental loss scenarios and their potential for hazardous incidents. General handling of waste materials and emissions produced during normal operations are dealt with elsewhere in the EA.

The primary objectives of a PHA are to:

- Identify potential hazards associated with the proposal;
- Analyse the consequences of significant hazards on people and the environment, and the likelihood or frequency of these hazards occurring;
- Estimate the resultant risk to the surrounding land users and environment; and
- Analyse the safeguards to ensure they are adequate, and therefore demonstrate that the operation can operate within acceptable risk levels to its surroundings.

3. Methodology

3.1 General

A PHA is to provide sufficient information and assessment of risks to show that a project satisfies the risk management requirements of the proponent company and the relevant public authorities. Within this brief, the main objective of the PHA is to show that the residual risk levels are acceptable in relation to the surrounding land use, and that risk will be appropriately managed. This is done by systematically:

- Identifying intrinsic hazards and abnormal operating conditions that could give rise to hazards;
- Identifying the range of safeguards;
- Assessing the risks by determining the probability (likelihood) and consequence (effects) of hazardous events for people, the surrounding land uses and environment; and
- Identifying approaches to reduce the risks by elimination, minimisation and/or incorporation of additional protective measures.

With proper application, this method should demonstrate that the proposed facility can operate within acceptable risk levels in relation to its surroundings.

The PHA needs to be carefully and clearly documented with the assumptions and uncertainties of final design and operation defined.

3.2 Preliminary Risk Screening

The need for a PHA under SEPP 33 is determined by a preliminary risk screening of the proposed development. The preliminary screening methodology concentrates on the storage of specific dangerous goods classes that have the potential for significant off-site effects. Specifically the assessment involves the identification of classes and quantities of all dangerous goods to be used, stored or produced on site with an indication of storage depot locations. Details of the methodology are described in DoP's - Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines (1994).

3.3 Risk Classification and Prioritisation

Multi-Level Risk Assessment (1997) suggests the use of preliminary analysis of the risks related to a proposed development, to enable the selection of the most appropriate level of risk analysis in the PHA. The preliminary analysis, detailed in Section 6, includes risk classification and prioritisation using a technique adapted from the Manual for Classification of Risk due to Major Accidents in Process and Related Industries (IAEA, 1993).

3.4 Analysis and Assessment Levels

The hazard analysis and quantified risk assessment regime promoted in NSW relies on a systematic and analytical approach to the identification and analysis of hazards and the quantification of off-site risks to assess risk tolerability and land use safety implications. Two key objectives are emphasised in the implementation of this process:

- The systematic and analytical nature of the assessment process enables the nature of the hazards, risks, leading risk contributors and events to be identified and understood from design, operational and organisational viewpoints; and
- The quantification of off-site risks, where applicable, enables judgments to be made on location safety implications with regard to people, the biophysical environment and other land uses.

Multi-Level Risk Assessment (1997) prescribes three levels of risk assessment that can be undertaken. The choice of an appropriate technique is based on the results of preliminary screening, risk classification and prioritisation and the potential for significant off-site consequences arising from hazards identified for the proposed development.

Level 1 - This is a qualitative assessment using word descriptions to approximately assess and rank risks. This is used when risk screening, classification and prioritisation indicate no major off-site consequences, adequate controls exist, and surrounding land uses are not sensitive to the hazards posed.

Level 2 - A semi-quantitative assessment that utilises the hazards identified in Level 1 and provides a focused quantification of key potential off-site risk contributors to demonstrate that risk criteria will be met.

Level 3 - This involves a full quantitative risk assessment and is undertaken whenever the scale and nature of an activity creates a significant risk of a major accident. A full-scale analysis should also be carried out if partial quantification cannot sufficiently demonstrate that relevant criteria will be met.

The rationale for the multi-level risk assessment approach is that:

- Preliminary analyses that indicate minor land use safety outcomes may only require qualitative assessment (Level 1). The emphasis in such instances should be on the identification of key risk elements and optimising safety management controls, therefore fulfilling objectives of Level 1 above.
- Preliminary hazard analyses that indicate significant potential risk impacts to surrounding land uses should be subjected to a more detailed level of analysis including partial or total quantification (Levels 2 and 3). For such cases there should be increased emphasis on objectives of level 2 above, relating to land use safety and risk tolerability.

3.5 Qualitative Analysis

Qualitative analysis uses words and descriptive scales to determine the likelihood of each identified hazard and its consequences. This provides an estimate of the likely rate of occurrence of hazardous events and their severity, from which a measure of the risk may be obtained through a simple matrix format of the equation:

Risk = Likelihood x Consequence

The likelihood and consequence descriptors used in this assessment are shown in Table 3.1 and Table 3.2.

The risk associated with a proposed development is determined by combining the likelihood of the potentially hazardous events and the magnitude of their consequences. This is illustrated in Figure 3.1, which has been adapted from Australian/New Zealand Standard 4360:2004 Risk Management. The process of combining consequences and frequencies gives appropriate weight to the range between small consequence events (which are relatively frequent) and events of major consequence (which are very infrequent).

The hazard identification process for the AWT facility at Lucas Heights used the risk assessments conducted for the AWT facility at the Macarthur Resource Recovery Park as a basis, as the design for the AWT facility at Lucas Heights has been based on the AWT facility at the Macarthur Resource Recovery Park. Therefore the design and operational issues between the two sites are considered to be of similar nature. The original risk assessments for the AWT facility at the Macarthur Resource Recovery Park were completed in an independently facilitated workshop format in 2006. The participants included representatives of the facility operator/owner (WSN), the AWT facility design team (APT), and the project manager (GHD).

The risk assessment for the AWT facility at the Macarthur Resource Recovery Park was reviewed and modified by GHD design personnel to reflect any variations between the two sites.

The risk assessment framework (i.e. Table 3.1, Table 3.2, Figure 3.1) utilised in the risk assessments for the AWT facility at the Macarthur Resource Recovery Park, and thus the risk assessment for the AWT at Lucas Heights, is consistent with AS4360 and was agreed upon by the workshop participants at the time of the workshop in 2006.

Table 3.1 Likelihood Descriptors

Assessment	Description
Almost certain	Expected to occur in most circumstances (>90%)
Likely	Likely to occur in the current period (50%-90%)
Possible	Possible to occur in the current period (10%-50%)
Unlikely	Unlikely to occur in the current period (<10%)

Table 3.2 Consequence Descriptors

Assessment	General Description	Financial /Legal	Political/ Reputation	Environment	Project	Performance	Safety
Catastrophic	Very high impact with catastrophic consequences	>$3M	Loss of Govt & community confidence Adverse National media awareness	Major prosecution under POEO Act (tier 1 or 2). Long-term &/or irreversible on & off-site impacts	Delays in excess of 10 months, significant resources impact	Corporate target missed by > 1 year. Continuous non-performance against >75% of KPI's Adverse quality problem	WorkCover notified immediately of eg fatalities, amputation of limb, person on life support, other immediately life threatening incidents Potential for prosecution
Severe	Material high impact with major consequences	$1M - $3M	Govt & community concern Adverse State wide media awareness	Prosecution under POEO Act (tier 2). Medium to long term significant on and off-site impacts.	Delays up to 5-10 months, serious resources impact	Corporate target missed by 6months-1year. Continuous non-performance against >50% of the KPI's Quality problem	WorkCover notified within one week, includes: lost time injury > 7 days, threat of violence at workplace, incident resulting in unsafe plant, fire, explosion, escape of gas or steam. Near miss fatality
Moderate	Noticeable impact with clearly visible consequences	$0.3M - $1M	Public awareness raised Negative media attention contained to local areas / surrounding neighbourhoods	Moderate impact to ecology or area of cultural heritage. Medium term, generally reversible on-site impacts.	Delays up to 3-5 months, moderate resources impact	Corporate target missed by 3m - 6m Continuous non-performance against 10-50% of KPI's Occasional Quality problem	Injury (or near miss) resulting in time away from work after the day of the incident Evacuation of confined space. Work-related illness
Minor	Some minor impact with unimportant consequences	<$0.3M	Public ignores	Minor impact to ecology or area of cultural heritage. Short- term reversible impacts contained to the site.	Delays up to <3 month, minimal resources impact, provider delay granted	Corporate target missed by <3months Occasional non-performance against KPI. Ad-hoc Quality problem	MTI - Injury (or near miss) requiring treatment by a doctor/paramedic; Evacuation of occupied confined space; Loss of isolation in during confined space entry FAI - Injury (or near miss) requires first aid & no further treatment at any time; Motor vehicle

LEVELS OF RISK

- Very High level of risk (1-3)
- High level of risk (4-7)
- Medium level of risk (8-11)
- Low level of risk (12-16)

	Minor	Moderate	Severe	Catastrophic
A/Certain	10	6	3	1
Likely	13	9	5	2
Possible	15	12	8	4
Unlikely	16	14	11	7

Figure 3.1: Risk Matrix

3.6 Quantitative Analysis

Quantitative analysis is conducted using numerical data values for both likelihood and consequences. This data has been gathered from a variety of sources including mathematical risk modelling, extrapolation from experimental studies or past data. A quantitative analysis can be used to estimate:

- Thermal radiation distances;
- Explosion overpressure; and
- Fatality risk levels.

3.7 Risk Assessment

Risk assessment involves comparing the level of risk found during the qualitative and quantitative analyses to previously established risk criteria, thereby ascertaining if that level of risk can be accepted or not. Such decisions take into account the wider context of the risk and include consideration of the tolerability of the risks borne by external parties.

Low and acceptable moderate risks can be allowed with minimal further treatment; however, they should be monitored and periodically reviewed to ensure they remain at this level. Higher-level risks should be treated using safeguards (see Section 3.8).

3.8 Risk Treatment

A complete range of safeguards should be incorporated into the design and operation of the proposed development as prevention or protection measures for higher-level risks. These measures may include plant design features, organisational safety controls, emergency and counter disaster principles and approval processes. Options should be evaluated on the basis of the extent of risk reduction and the extent of benefits or opportunities they create. In general, the cost of managing risks should be commensurate with the benefits obtained.

In identifying and implementing risk treatment options, the hierarchy of controls should be considered. The hierarchy of controls involves the principle of using a number of methods to manage a risk with emphasis on controlling the source of the hazard. The hierarchy includes *Elimination* > *Substitution* > *Engineering controls* > *Administrative controls* > *Personal protective equipment.*

- **Elimination:** The job is redesigned or the substance is eliminated so as to remove the hazard. However, the alternative method should not lead to a less acceptable product or less effective process.
- **Substitution:** Replace the material or process with a less hazardous one. For example, replace mercury thermometers with spirit thermometers.
- **Engineering controls:** Install or use additional machinery such as local exhaust ventilation to control the risk. Separating the hazard from operators by methods such as enclosing or guarding dangerous items of machinery. For example, use guards on compression testing machines.
- **Administrative controls:** Establish appropriate administrative procedures such as:
  - Job rotation to reduce exposure or boredom, or timing the job so that fewer workers are exposed.
  - Routine maintenance and housekeeping procedures.
  - Training on hazards and correct work procedures.
  - Perform risk assessments.
  - Increase safety awareness signage.
- **Personal protective equipment:** Provide suitable and properly maintained personal protective equipment (PPE) and training in its use.

3.9 Monitoring and Review

Risks and the effectiveness of control measures need to be continually monitored to ensure changing circumstances do not alter risk priorities. Factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect suitability or cost of various treatment options. Ongoing review is, therefore, essential to ensure that risk management activities remain relevant.

4. Facility Description

4.1 Location and Surrounding Land Uses

The LHWRC is located within the Sutherland Shire Local Government Area (LGA), which is in the southern region of the Sydney Metropolitan Region. The LHWRC extends over an area of 204.85 ha.

The project site is located in the south-eastern corner of the LHWRC, with access to the site off New Illawarra Road to Little Forest Road (see Figure 4.1). LHWRC is in a location that has access to several major roads, including New Illawarra Road, Heathcote Road and the M5 further to the north. Vicinity to these roads affords the facility efficient access to the majority of the Sydney Metropolitan Region.

Key:	1. ANSTO	4. North Engadine	7. Lucas Heights Conservation Area
	2. The site	5. Barden Ridge	8. Gun Club
	3. LHWRC	6. Ridge Sports Complex	9. Holsworthy Military Reserve

Figure 4.1: Regional context

The site is to the north of, and adjoining New Illawarra Road, and to the west of, and adjoining Little Forest Road (see Figure 4.2). The site has access to Little Forest Road, which connects with New Illawarra Road at the south-eastern corner of the LHWRC. This site has an area of 11 ha and is currently occupied by the facilities of the Police and Community Youth Club (PCYC). These facilities include mini-bike training and tracks.

Figure 4.2: Site Location

The site consists of two allotments known as:

- Lot 111 of DP 1050235, and
- Lot 1 of DP 233333.

Both of these lots front onto New Illawarra Road. The land is owned by ANSTO and leased to WSN. The AWT facility site is within the area previously identified in the 1999 LHWRC Master Plan as an area for "Recycling Resource Recovery". The site is on land that is zoned Special Uses – Waste Recycling (Zone 12 – Special Uses) within the Sutherland Local Environmental Plan 2006 (LEP 2006). As per the Master Plan the PCYC is intended to be relocated to the west of the Recycling Resource Recovery area (see Figure 4.3).

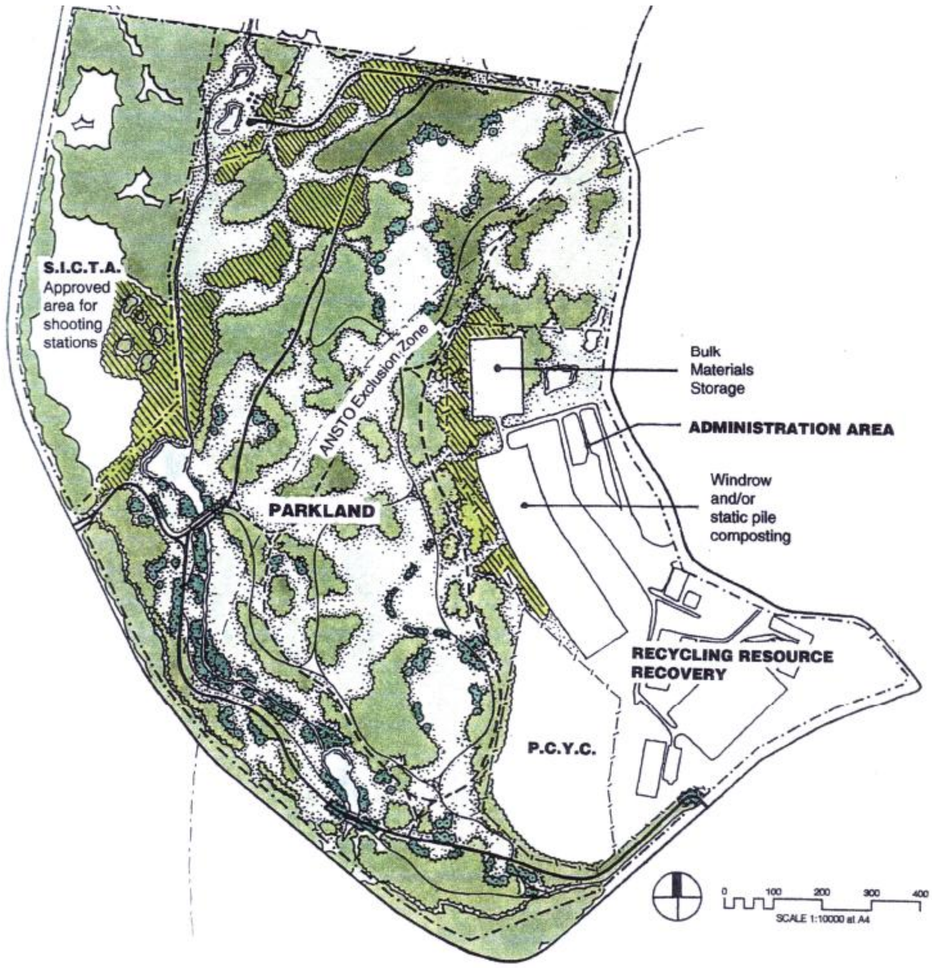

Figure 4.3: Approved LHWRC Masterplan

4.2 Surrounding Development

The site is surrounded by the following land uses:

- LH 1, the former Lucas Heights WRC, which has ceased operation and is currently being converted into a regional sporting facility - incorporating an 18-hole golf course, netball courts, hockey fields and an athletics stadium;
- Rehabilitated areas of the current LHWRC (including an area where the PCYC mini-bike track will be relocated);
- Power Plant (operated by Energy Developments Ltd (EDL));
- The Australian Nuclear Science and Technology Organisation (ANSTO) Technology Park - which incorporates Australia's only nuclear reactor;
- Holsworthy Military Reserve;
- Lucas Heights Conservation Area (LHCA);

- Residential development (approximately 2 km to the southeast at North Engadine and 2.6 km to the east at Barden Ridge);
- Sydney International Clay Target Association (SICTA); and
- Heathcote National Park.

4.3 Site Process Description and Layout

The AWT facility would include a mechanical biological treatment (MBT) plant to process up to 100,000 tonnes per annum of municipal solid waste (MSW) using the patented ArrowBio technology. The plant would use material separation technologies to recover recyclable materials from the municipal waste stream and anaerobic digestion to produce stabilised sludge/soil conditioner with market potential and biogas, suitable for electricity generation. It would divert an estimated 70% of the incoming material from landfill.

The MBT technology is similar to that currently being commissioned at WSN's Jacks Gully site (Ecolibrium^{TM} Mixed Waste Facility at the Macarthur Resource Recovery Park) in southwest Sydney and would incorporate the following:

Receival hall;

Receival of municipal solid waste and pre-treatment to remove large items not suitable for processing. Within the receival hall, a front end loader would be used to remove large items from the waste prior to putting it into a hopper that feeds the first plant conveyor that passes a manual sorting bay where car batteries, cardboard and other large items would be removed.

Processing building;

- *Material separation and recovery of recyclables;*

In the main processing building, the waste would be immersed in one of two vats of water. This would assist in separation of organics from the non-organic materials, such as recyclables. The organics would mainly dissolve in water to form a slurry, which would be preconditioned and pumped to the tank farm for biological treatment.

- *Mechanical treatment of municipal solid waste;*

Heavy inorganic components like glass, batteries, stones, aluminium and steel cans would sink to the bottom of the vat. A conveyor would then transfer these materials to the heavy materials line where a number of physical separation mechanisms including magnets (to recover ferrous metals), eddy current separators (to recover aluminium) and manual sorting (to recover glass) would be applied. The balance of the material would be collected in waste bins for landfill disposal.

Light components like paper, cardboard, plastics, biodegradable organics (including food scraps) and unopened plastic bags would float in the vat and be scraped off the surface onto an inclined conveyor. Plastic bags would pass through a shredder/bag opener, and through a trommel, and the material that was inside the bags would re-enter the vats for processing.

Biological plant;

- *Biological treatment of municipal solid waste*

The slurry undergoes two processes in the biological tanks, orchestrated by naturally occurring micro-organisms. In the first acidogenic tank, fermentation is used to transform complex organic material into simpler organic acids and fatty acids. In the second acidogenic tank, the matter is heated to 35-40ºC, using hot water generated from exhaust gases from the on-site gas engines.

The slurry is then transported to the methanogenic fermentation tank for anaerobic degradation of the organic materials. In the methanogenic digester, pH and temperature are closely controlled to optimise the conversion of the products from the first stage to biogas rich in methane.

The products from this methanogenic stage are:

- Biogas;
- Wastewater, a portion of which is recycled to the waste pre-preparation tank (some is disposed of to the wastewater treatment plant); and
- A solid digestate.

- *Biogas production and electricity generation*

The biogas produced on-site is stored in an inflatable buffer tank, and is used for generating electricity in two 1 MW on-site gas engines. An on-site flare burns any excess gas that cannot be used by the engines. The waste heat from the engine exhausts passes through a heat exchanger, where it is used to heat water. The water is then used to heat the second stage acidogenic tank, as part of the co-generation cycle.

In the event that the biological plant shuts down, and during initial start-up, the acidogenic tank would need an external source of heat to bring it up to temperature. This would be provided by a hot water boiler, fired by either gas or diesel (subject to natural gas availability). The boiler may also operate at other times, depending upon heating requirements.

- *Stabilised sludge production*

The solid digestate component would be dewatered in a solid/liquid separator and the water component is recirculated back into the initial pre-sorting water vat. The digestate is then dewatered in a filter press or belt press. There is potential for this dewatered material to be blended in compost materials or sold as a quality stabilised sludge product. Any remaining water would be treated in the wastewater treatment plant in a sequencing batch reactor, and stored in separate tanks for industrial uses.

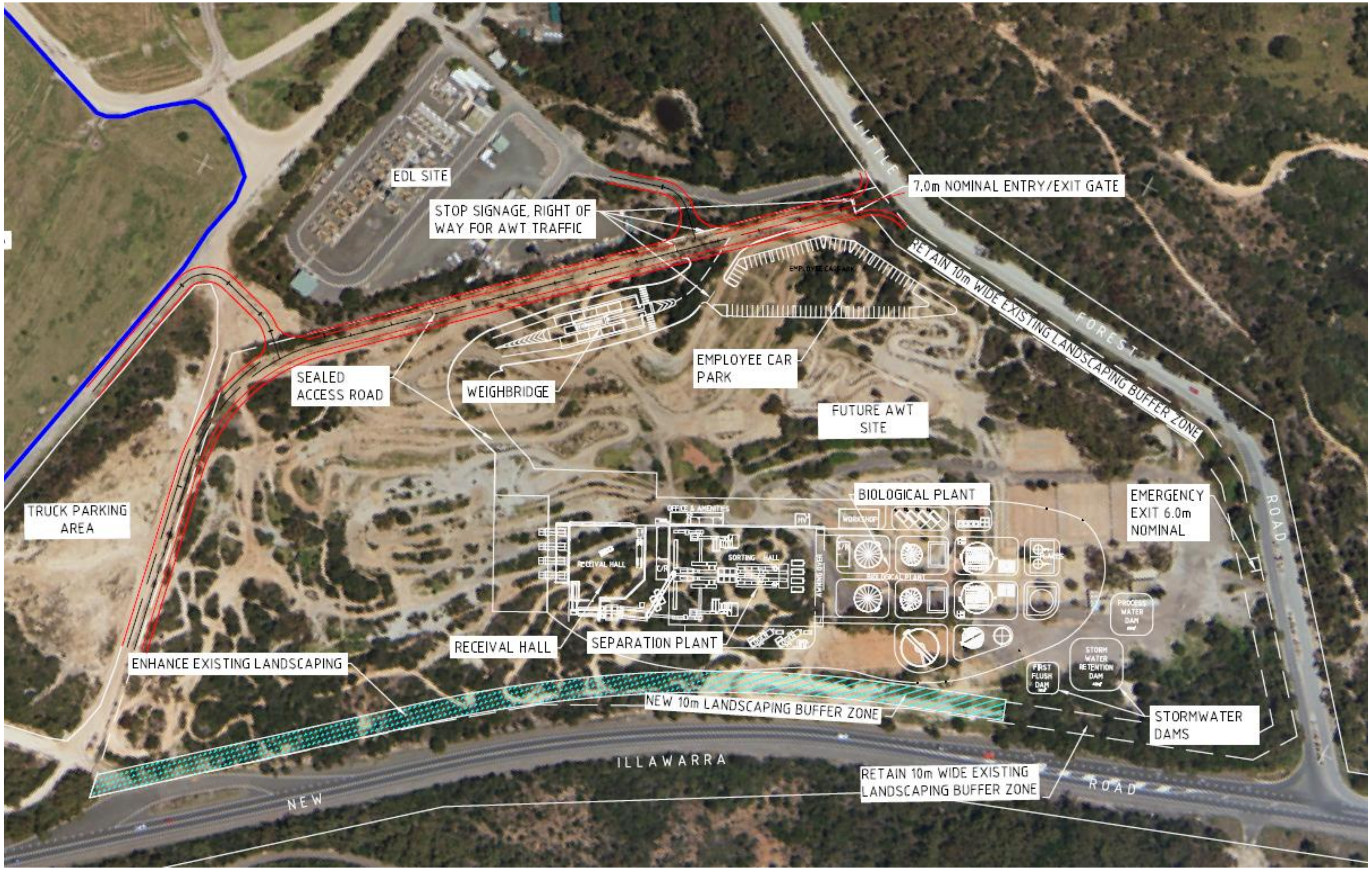

Figure 4.4: Aerial Site Layout

5. Preliminary Risk Screening

5.1 Dangerous Goods Storage Screening

A preliminary screening of the proposed development is required by SEPP 33, to determine if there is a need for a PHA. The methodology is described in DoP's Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines (1994).

The proposed inventories of hazardous substances and dangerous goods to be stored and utilised on site are listed below in Table 5.1. Some of these are defined as Dangerous Goods (DG) in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code).

Table 5.1 Dangerous Goods Storage Screening

Chemical	UN	Class	Packaging code	HazChem code	Quantity on site	Threshold
LPG (flare backup)	1075	2.1	-	2WE	<0.5m^3	16m^3 aboveground
Biogas - Methane 81%*	1971	2.1	-	2(S)E	1,000m^3	>1,000m^3 when stored 50m from site boundary
Diesel (boiler backup)	1202	3	PGIII	3(Z)	2.5m^3	15m^3 stored 10m from site boundary
Sodium Hydroxide Solution (50%)	1824	8	PGII	2R	1T	Class 8, PGII 25T
Hydrochloric Acid (33%)	1789	8	PGII	2R	1T	
Ferric Chloride (coagulant)	1773	8	PGIII	2X	25T	50T

* 100% methane has been used as the closest material match for the biogas.

In accordance with SEPP 33, all materials in Table 5.1 do not exceed the screening threshold for on site storage of dangerous goods. This is provided that the biogas and diesel are stored greater than 50m and 10m from the site boundary respectively. As a result of the biogas being near the outer limits of the potentially hazardous criteria as per SEPP 33, a preliminary hazard analysis (PHA) will be conducted in order to determine if it increases the risk to offsite land users, however it is noted that it is not required based on the dangerous goods screening.

If any changes are to occur in the type or quantity of those dangerous goods stored on site that do not currently exceed the threshold, it is recommended that the dangerous goods screening is repeated to ensure no thresholds are exceeded.

5.2 Transportation Screening

During operation, the AWT facility would increase the number of vehicles entering the surrounding network. Many of these vehicles will be trucks that will continually deliver material to the facility such as delivery of municipal solid waste to the receival hall. Workers and visitors to the site will also generate additional traffic on the surrounding road network.

Due to the small quantities of hazardous materials delivered to the site, it is expected that these vehicles would only make up a very small portion of the total vehicle movements.

The proposed movement of hazardous materials (both incoming and outgoing) is assessed in Table 5.2 against the transportation screening thresholds in Table 2 of Applying SEPP 33.

Table 5.2 Estimated Vehicle Movements of Dangerous Goods

Class Packaging Grp	Substance	Peak Weekly (Movements/Wk)	Threshold (Movements/wk)	Qty per load (Tonnes)	Threshold Load (Tonnes)
Class 2.1	LPG (UN 1075)	<1	>30	<0.5	2 (bulk) 5 (packaged)
Class 3	Diesel UN 1202	<1	>60	<2.5	10 (bulk)
Class 8	Sodium Hydroxide (50%) UN 1824	1	>30	1	2 (bulk) 5 (packaged)
	Hydrochloric Acid (33%) UN 1789	1		1	
	Ferric Chloride UN 1773	1		25	

As a requirement under SEPP 33, 'the proposed development may be potentially hazardous if the number of generated traffic movements (for significant quantities of hazardous materials entering or leaving the site) is above the annual or weekly cumulative vehicle movements'. If the transportation of dangerous goods exceeds the vehicle movement thresholds as established in Applying SEPP 33, Table 2, then a route evaluation study is required.

As the frequency of the dangerous goods deliveries is significantly below the thresholds, it is considered that the transport of dangerous goods to the AWT facility is not potentially dangerous and therefore does not require a route evaluation. However, if changes are to occur in the transport of dangerous goods, it is recommended that the screening process be repeated in order to determine if a route evaluation is required.

5.3 Level of Risk Assessment

According to SEPP 33, if any of the screening thresholds are exceeded then the proposed development should be considered potentially hazardous and a PHA is required. Also, if the quantities are close to the screening threshold values and the development site is near a sensitive receiver then the proposed development is also considered to be potentially hazardous and a PHA is required.

Based on the above assessment, the proposed development does not require a PHA as all materials, including transportation frequencies do not exceed the respective thresholds, thus are not considered as potentially hazardous as per SEPP 33. However, as the quantity of biogas is close to the threshold, and in order to demonstrate that the AWT facility would not pose additional risk to offsite land users, a PHA has been conducted.

6. Hazard Identification

6.1 General

Hazard identification represents a Level 1 or qualitative risk assessment and involves documenting all possible events that could lead to a hazardous incident. It is a systematic process listing potential causes and consequences (in qualitative terms). Reference is also made to proposed operational and organisational safeguards that would prevent such hazardous events from occurring, or should they occur, that would mitigate the impact on the plant, its equipment, people and the surrounding environment. This process enables the establishment, at least in principle, of the adequacy and relevancy of proposed safeguards.

The aim of the hazard identification study process is to highlight any residual risks associated with the interaction of the facility (as a whole) with the surrounding environment. A range of possible hazard scenarios were developed and ranked in terms of consequence and likelihood in consultation with the relevant stakeholders.

6.2 Hazard Identification Tables

The hazard scenarios identified are presented in Appendix A. Each hazard scenario was evaluated in terms of consequence and likelihood using the scoring methodology from Table 3.1 and Table 3.2. A qualitative assessment of the resultant risk was then made using the risk matrix as provided in Figure 3.1. The hazards identified are a result of deviation from normal operations and the qualitative risk assigned to each scenario takes into account the inherent and proposed physical, operational and organisational safeguards designed to reduce the consequence and likelihood of these hazards.

It is important to understand that the selection of the qualitative consequence score for each hazard identified is based on the most likely consequence given the existing physical safeguards only. It does not consider the soft barriers such as control systems, training or standard operating procedures.

The likelihood score is an estimation of the likelihood of the nominated consequence occurring. Alternatively, the likelihood score may be considered as an estimation of the effectiveness of the inherent and proposed physical, operational and organisational safeguards.

Hazard identification was conducted using a desktop study approach based on information provided in the risk assessment workshops for the AWT at the Macarthur Resource Recovery Park held in 2006. Refer to Section 3.5 for more details.

7. Qualitative Risk Analysis

Many of the scenarios identified in the hazard identification (Appendix A) do not pose a credible risk off-site, or even on-site damage, fatality or injury. The scenario of fire or explosion of biogas was further investigated regarding the potential for off-site impacts.

7.1 Biogas Fire

Biogas will be produced at the AWT facility at a rate of approximately 90m^3 per tonne of waste processed. It is anticipated that the facility will be capable of processing 100,000 tonnes of municipal solid waste (MSW) per annum, therefore producing 10 million m^3 of biogas per annum.

Biogas produced by the anaerobic digesters would be captured and used to generate electricity, with minimal releases to the environment. Approximately 2 MW of electricity would be produced from the 100,000 tonnes per annum waste throughput.

The biogas will be stored in an inflatable double membrane buffer tank of 1000m^3 capacity and used for generating electricity in two 1 MW on-site gas engines. An on-site flare will burn any excess gas that cannot be used by the engines. The waste heat from the engine exhausts will pass through a heat exchanger, where it will be used to heat water. The water will then used to heat the second stage acidogenic tank, as part of the co-generation cycle.

The anticipated composition of biogas is to be approximately 81% methane and 17.5% carbon dioxide based on analysis of a similar operational facility. The biogas pressure in the outer annulus of the buffer tank is pressurised by blowers to maintain a constant pressure of 4.5 kPa on the inner membrane and thus ensuring a constant 4.5 kPa feed to the biogas engines. If the pressure rises then excess biogas is diverted to the flare. If the volume of gas available falls to less than 40% of the flow required to keep the engines running then the engines are shut down and the gas buffer tank is allowed to refill.

Pipes collecting biogas from the top of each of the anaerobic digesters will have an 80mm nominal diameter at the acetogenic digester and will progressively increase in size as more gas is collected from the digesters (acetogenic and methanogenic) closer to the biogas buffer tank up to a final common collection header size of 200mm. The pipe will be constructed of welded mild steel and will be painted on the outside.

The worst-case scenario considered is that of an ignited biogas release occurring at the biogas buffer tank. The buffer tank is considered to have the highest potential risk because of the volume of biogas held. Likely leak sources include piping connections and flanges. The potential for damage by impact from a vehicle crash on internal roads is also considered.

In order to minimise the potential for a biogas fire or explosion, the hierarchy of controls should be implemented (*Elimination > Substitution > Engineering controls > Administrative controls > Personal protective equipment)*. As the biogas is the product of the process, elimination is not possible, thus the most appropriate control method is the prevention of biogas leaks. A number of control methods are to be implemented in order to prevent the release of biogas from the process equipment, pipeline or buffer tank. Reference should be made to the Australian Standard, *AS1375 Industrial Fuel Fired Appliances Code* and *The Gas Supply (Gas Appliances) Regulation 2004*. Some preventative measures to be implemented on site include:

- Installation of bollards or alternative protection around the biogas buffer tank to prevent vehicle collisions with the tank and associated equipment;
- The biogas piping will be above ground running over the digesters to prevent vehicle collisions with the piping;
- A section of the biogas piping will be underground to cross the road. This section of piping will have a moisture separator to collect condensation from inside the gas pipe;
- All potential ignition sources should be eliminated from areas containing biogas; suitably zoned areas
- Signage should be placed in suitable locations to indicate the presence of flammable substances;
- Local exhaust and general room ventilation may both be essential in work areas to prevent accumulation of explosive mixtures;
- Handling equipment and tools must be grounded to prevent sparking;
- Depending on the odour properties of the biogas, an additive may be used to odorise the gas e.g. mercaptans in order to improve detection in case of a release;
- Permit to work systems for hot work;
- Specific materials of construction due to the flammable nature of the process output;
- Development of a maintenance regime; and
- Suitable emergency response procedures and equipment shall be available for the case of a leak and potential fires / explosions.

7.2 Impacts from Offsite

As noted previously ANSTO Technology Park, housing a nuclear reactor, is located on the opposite side of New Illawarra Rd from the AWT facility. As with the AWT facility, the nuclear facility must abide by Department of Planning (DoP) Guidelines, SEPP33 and therefore has demonstrated that the offsite fatality risks posed to surrounding land users is considered acceptable.

ANSTO undertake continuous environmental monitoring and there is close monitoring and management of all liquids, including waste water, airborne releases and solid wastes produced at ANSTO. All liquids released from ANSTO into the Sydney sewerage system must comply with a Trade Waste Agreement with Sydney Water.

In addition the design is fully compliant with all normal requirements for research reactor safety established by ARPANSA (the Australian Radiological Protection and Nuclear Safety Agency) and IAEA (the International Atomic Energy Agency) who both undertake regular inspection sof the site. Another Commonwealth agency, the Australian Safeguards and Non-Proliferation Office, part of the Department of Foreign Affairs, also monitors ANSTO.

8. Quantitative Risk Analysis

8.1 Biogas Fire

The worst-case scenario considered is that of an ignited biogas release from the biogas buffer tank or associated pipe work. This is considered to have the highest potential risk due to the volume of biogas and the likelihood of damage from surrounding activities. Modelling of a potential jet fire was performed for the following scenarios:

- Gas release from the complete rupture of the buffer tank and consequent jet fire.
- Gas release from a 100 mm flange leak in the 200 mm gas pipeline and consequent jet fire.
- Gas release from a 50 mm flange leak in the 200 mm gas pipeline and consequent jet fire.
- Gas release from a 25 mm flange leak in the 200 mm gas pipeline and consequent jet fire.

Biogas explosion scenarios were not considered as the open space of the site ensures limited potential for gas build up. The lack of confinement of the area means any overpressure resulting from an explosion would be low and it is unlikely to result in equipment damage or offsite impact.

The consequence analysis to determine the duration and magnitude of the potential jet fires and associated radiation levels are presented in Appendix B.

The heat radiation criteria used to identify various risk contours are shown in Table 8.1 and the surrounding land use criteria are shown in Table 8.2. Due to the proposed relocation of the PCYC facilities next to the AWT facility, the area has been classified as 'sporting complexes and active open space'.

Table 8.1 Effects of Heat Radiation [4]

Heat Flux (kW/m^2)	Effect
1.2	Received from the sun at noon in summer.
2.1	Minimum to cause pain after 1 minute.
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least 2nd degree burns will occur).
12.6	Significant chance of fatality for extended exposure (10%, Technica, 1988). High chance of injury. Thin steel may reach a thermal stress level high enough to cause structural failure.
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure. Unprotected steel will reach thermal stress temperatures that can cause failure.
35	Significant chance of fatality for people exposed instantaneously.

Source: *Hazardous Industry Planning Advisory Paper No. 4: Risk Criteria for Land Use Safety Planning*, D.o.Planning, Editor. 1997, Crown.

Table 8.2 NSW Individual Fatality Risk Criteria [4]

Land Use	Acceptable Criteria (risk in millions per year)
Hospitals, schools, childcare facilities, old age housing	0.5
Residential, hotel, motels, tourist resorts	1
Commercial developments	5
Sporting complexes and active open space	10
Industrial	50

Source: *Hazardous Industry Planning Advisory Paper No. 4: Risk Criteria for Land Use Safety Planning*, D.o.Planning, Editor. 1997, Crown.

The scenarios used in the biogas release and jet fire models are detailed in Table 8.3.

Table 8.3 Scenario Details

Scenario	Pressure (kPag)	Phase	Hole Size (mm)	Inventory of Release (m^3)	Failure Frequency (avg/yr)
25mm release	4.5	Pressurised gas	5	900	4.1×10^{-6}
50mm release	4.5	Pressurised gas	50	900	3.1×10^{-6}
100mm release	4.5	Pressurised gas	100	900	6.8×10^{-7}
Rupture	4.5	Pressurised gas	Rupture	1,000	4.4×10^{-6}

Assumptions used for the basis of the model included:

- The model was based on a release from a 200mm carbon steel pipeline;
- Failure rates of the pipeline were based on HSE data for offshore facilities (these equipment failure rates are considered conservative for this relatively small scale land based facility);
- Potential hole sizes included 25mm, 50mm, 100mm holes and a rupture scenario;
- The inventory is made of 100% methane;
- Release would occur for 1 hour prior to the source being contained;
- Release occurs at a height of 1m; and
- Results are based on weather conditions of 1.5F.

After modelling the scenarios as above in Table 8.3, it was found that there is no offsite risk for the AWT facility in terms of potential biogas release and consequential jet fire as the 50 x 10^{-6} risk contour corresponding to the industrial zone criteria does not exceed the site boundary. The risk contours are demonstrated in Figure 8.1.

Figure 8.1: Consequence Contours for Biogas Release & Jet Fire

In order to maintain compliance with the individual risk criteria of 50 x 10^{-6} per annum, for the neighbouring industrial area, it is recommended to fully implement the risk reduction measures as outlined in Appendix A.

The results of the consequence calculations for the scenarios are summarised in Table 8.4 below.

Table 8.4 Calculated Consequence Values

Scenario	25mm Release	50mm Release	100mm Release	Rupture
Gas Volume Flow (m^3/hr)	900	900	900	N/A
Release Duration (hr)	1	1	1	1
Jet Fire Length (m)	3	5	9	16
Jet Fire Diameter (m)	0.5	1	2	3
Distance to 23kW/m^2 (m)	At Flame End	At Flame End	At Flame End	15
Distance to 12.6kW/m^2 (m)	At Flame End	At Flame End	9	17
Distance to 4.7kW/m^2 (m)	At Flame End	5	12	24

8.1.1 Societal Risk and Risk to the Biophysical Environment

The Australian Standard AS1940-2004 The Storage and Handling of Flammable and Combustible Liquids states that "should alterations on the adjacent property result in a breach of the requirements for separation distance, the installation shall be modified or relocated to restore compliance or will be taken out of service".

It is important to note that the quantitative risk assessment is not assessing the impact on sensitive land users, and the site was assessed assuming industrial usage of the adjoining areas. The quantitative risk assessment was used to identify the potential zone of effect on the adjoining properties should a jet fire occur.

9. Conclusions and Recommendations

It is concluded that the SEPP 33 threshold screening value for dangerous goods is not exceeded by any of the proposed dangerous goods to be stored at the AWT facility. Additionally, the transportation screening thresholds are not exceeded by any of the dangerous goods.

The qualitative risk assessment/hazard identification study identified one possible hazard scenario of high risk due to unacceptable potential consequences. This hazard involved the fire or explosion of the biogas. However, as demonstrated in the quantitative risk assessment, this hazard was not recognised to have the potential to impact offsite.

None of the other hazard scenarios identified had the potential to present an unacceptable risk to the surrounding land users. Adequate safeguards are required to ensure the risk scenarios that were identified are contained or at least controlled to an acceptable level.

When implementing safeguards for the protection against hazardous scenarios, the control hierarchy should be followed which involves *Elimination* > *Substitution* > *Engineering controls* > *Administrative controls* > *Personal protective equipment.*

The qualitative risk assessment identified control measures, safeguards and procedures that will be put in place, as well as recommending additional actions to reduce the level of risk associated with the development of the proposed AWT facility. These recommendations are summarised below and in the Hazard Identification in Appendix A.

The qualitative risk assessment has identified residual risk associated with the AWT facility. One of the most effective means of ensuring the ongoing safe operation of a facility is through implementing a comprehensive Safety Management System. Such a system will ensure that hazards associated with the site are identified and managed, so that all activities are undertaken in a safe manner.

9.1 Biogas Fire

Based on the results of the qualitative risk assessment for the biogas fire or explosion scenario, it was found that all objectives of Level 1 of the Multi-Level Risk Assessment (1997)[3] were met and that conducting a quantitative analysis (Levels 2 and 3) was not necessary. However, as the quantity of biogas is close to the threshold, and in order to demonstrate that the proposed AWT facility will not pose additional risk to offsite land users, a PHA was conducted.

It is concluded that although there exists a potential for a biogas fire or explosion to cause offsite effects, the scenario does not exceed any risk criteria as outlined in HIPAP 4. This was demonstrated by the application of the quantitative assessment process. It is considered that due to the operating pressure and sufficient engineering controls, the risk of a biogas fire or explosion is adequately minimised to as low as reasonably practicable (ALARP).

It is recommended that management procedures and design considerations be implemented to incorporate practices that would prevent risk scenarios occurring through:

- Installation of bollards or alternative protection around the biogas buffer tank to prevent vehicle collisions with the exposed piping and associated equipment;
- All potential ignition sources should be eliminated from areas containing biogas;

- Signage should be placed in suitable locations to indicate the presence of flammable substances;
- Local exhaust and general room ventilation may both be essential in work areas to prevent accumulation of explosive mixtures;
- Handling equipment and tools must be grounded to prevent sparking;
- Depending on the odour properties of the biogas, an additive may be used to odorise the gas e.g. mercaptans in order to improve detection in case of a release;
- Permit to work systems for hot work;
- Specific materials of construction due to the flammable nature of the process output;
- Development of a maintenance regime; and
- Suitable emergency response procedures and equipment shall be available for the case of biogas leak and potential fires / explosions.

10. References

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Appendix A

Hazard Register

HAZOP Register

Part Considered	
Part Considered	Receival Hall (& pre-sorting hall). Trucks drop from outside facility into pit. 3m pit, ‘sorting’ by front-end loader and excavator grab into hopper (no humans on pit or hopper). Hopper to conveyer. Conveyor to Trommel (120mm holes) (lower) drops to splitter – wet sorting or to land fill. Upper to hand sorting. Also control room (elevated), rest room etc

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
A.1	Hopper (15M3) – conveyor (VFD set) - trommel	High flow		Loaded by FE loader. VFD/VSD manually set (HMI-control room) clearing flow (hopper to conveyor).	Overflow – into receival hall.	Single direction conveyors (except hopper conveyor) that can be reversed to clear blockage. The conveyor can be manually directed inside or out (splitter). System shutdown if overload tripped.	Minor	Possible	Low	High flow (speed) – commercial. Low flow-residential.	No Further Action Required (NFAR)	
A.2	Receival Hall	High Pressure	Venting	Escaping gas	Release of odour causing gasses into atmosphere.	Negative pressure (to keep odour in). Water scrubbing. Controlled release.	Moderate	Possible	Low		NFAR	
A.3	Waste input	High temperature	Weather conditions	Low airflow	Discomfort to manual sorting		Minor	Possible	Low		NFAR	
A.4		Contamination	Hazardous goods	e.g. big: Car batteries e.g. small (through sorting)	Acid spill Gas leakage Personal injury	Large hazardous materials pre-sorted (by machines – FE loader & ‘excavator’ grab) Small hazardous materials go through sorting (drop through etc) Hazardous materials handling	Moderate	Possible	Low		Hazardous materials handling and emergency procedures to be developed	WSN
A.5	Conveyors	Access / ergonomics		Over-reaching Fall from heights	Personal injury	Walkways with rails on conveyors (12 deg max incline). Guards on conveyor to prevent human access.	Severe	Unlikely	Medium		NFAR	
A.6		Process Control	Start	Incorrect sequencing	High flow or low flow, blockages and overflow	Sequenced (processes) start	Moderate	Unlikely	Low		NFAR	
A.7		Size	Limits	Failure to remove large items in receival hall prior to loading hopper.	Process failure	Trips for materials too large to trommel	Moderate	Unlikely	Low		NFAR	

HAZOP Register												
Part Considered		Receival Hall (& pre-sorting hall). Trucks drop from outside facility into pit. 3m pit, 'sorting' by front-end loader and excavator grab into hopper (no humans on pit or hopper). Hopper to conveyer. Conveyor to Trommel (120mm holes) (lower) drops to splitter – wet sorting or to land fill. Upper to hand sorting. Also control room (elevated), rest room etc										
Id No.	**Element**	**Guide Word**	**Deviation**	**Possible Causes**	**Consequences**	**Safeguards**	**Cons-equence**	**Like-lihood**	**Rating**	**Comments**	**Action Required**	**Action By**
A.8	Receival Hall	Environmental impact	Ventilation	Escaping gas	Release of odour causing gasses into atmosphere.	Air extraction to water scrubber	Minor	Possible	Low		NFAR	
A.9		Environmental impact	Noise	Excessive noise	Public outrage	EIS./ EPA. Limit – 39 dBA	Moderate	Possible	Low		Mike / Peter to discuss EPA restrictions etc.	GHD
A.10		Commissioning	Procedures	Lack of procedure and testing	Process failure	Commissioning procedures	Minor	Possible	Low		Commissioning procedures to be developed	WSN, GHD
A.11		Safety equipment	Safety showers	Spills / hazardous substances	Personal injury	Amenities facilities under the control room	Moderate	Possible	Low		Consider safety showers & eye wash facilities located near personnel interaction conveyor forward of trommel	GHD

HAZOP Register	
Part Considered	Sort Building Bio Process hall Four points of receiving from receival hall Hydro-sorting. Wet separation – two lines. Vat (mixes with upper (large) and over magnet. Water evacuated. Inert material goes to land fill. Floating matter united with over 120mm – goes to 60mm sorting. Under goes to pipes. Over goes to hand sorting (textiles). Goes over magnet. Elevated control room oversees whole-room operation. No people on floor. People manning conveyors and 2 x forklift operators.

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
B.1	101-D-011-A1 Vat (300m3)	Level	Too high	Overloading Process breakdown	Overflow	Natural overflow Automatic sequencing of shut-down in event of process failure.	Minor	Possible	Low		NFAR	
B.2		Contamination	Hazardous/corrosive materials	Contaminated feed	Damage to plant	Epoxy coated	Minor	Possible	Low		NFAR	
B.3		Process Control	Critical variable monitoring	Variable feed loading	Level high and overflow	Control switches for level high and level low	Minor	Possible	Low		NFAR	
B.4		Maintenance	Access / Egress	Servicing required	Personal injury	Man holes – maintenance access pits. Auto draining sump.	Moderate	Possible	Low		NFAR	
B.5		Environmental	Seepage	Spillage of water into hall	Flood	Wash-down drainage systems, collection points (14), sumps, slopes etc	Minor	Possible	Low		NFAR	
B.6		Access / Egress	Emergency escape	Fire, bomb threat, toxic gas escape etc	Personal injury		Severe	Unlikely	Medium		Emergency procedures to be developed	WSN GHD
B.7		Safety equipment	Safety showers	Contact with hazardous substance	Personal injury		Severe	Unlikely	Medium		Review placement of hand-wash basins/ showers	
B.8		Commissioning	Procedures	Lack of procedure and testing	Process failure	Test with potable water to test for leaks. Pump to drain if required.	Severe	Unlikely	Medium		NFAR	
B.9		Shutdown	Emergency	System failure	Loss of productivity	Valves fail closed. Safe power down.	Severe	Unlikely	Medium		NFAR	

HAZOP Register												
Part Considered	Sort Building Bio Process hall Four points of receiving from receival hall Hydro-sorting. Wet separation – two lines. Vat (mixes with upper (large) and over magnet. Water evacuated. Inert material goes to land fill. Floating matter united with over 120mm – goes to 60mm sorting. Under goes to pipes. Over goes to hand sorting (textiles). Goes over magnet. Elevated control room oversees whole-room operation. No people on floor. People manning conveyors and 2 x forklift operators.											
Id No.	**Element**	**Guide Word**	**Deviation**	**Possible Causes**	**Consequences**	**Safeguards**	**Cons-equence**	**Like-lihood**	**Rating**	**Comments**	**Action Required**	**Action By**
B.10		Procedures	Confined space	Require entrance into vat for maintenance	Asphyxiation		Moderate	Unlikely	Low		Permit to work procedure to be established, as per legislation.	WSN
B.11	102-D-012-A1 (secondary)	As for 101-D-011-A1									As for 101-D-011-A1	
B.12	104-D-013-A1	Level	High		Overflow Blockages	Flow meter and level switch	Moderate	Possible	Low		NFAR	
B.13		High pressure	Blockages	Trommel screen clogged with waste.	Build-up of feed in process Overflow	Automatic wire brush for screen cleaning in trommel	Moderate	Possible	Low		NFAR	
B.14	105-D-014-A1 hydrocrusher, etc	Flow	Level	Failure of pumps in sumps.	Overflow	Equalising pipe between sumps for failure. Redundancy – 2 pumps per sump. 2 phase flow pumps.	Moderate	Possible	Low		NFAR	
B.15		Maintenance	Accessibility	Unable to easily access all parts of plant.	Personal injury	Elevated, all accessible. Forklift is able to access all areas (plant can be moved for access).	Moderate	Possible	Low		NFAR	
B.16		Contamination	Flammability	Combustion of plastic waste	Fire	Plastics are damp.	Moderate	Unlikely	Low		NFAR	
B.17		Utilities and services	Compressed air	Compressed air plant not calibrated	Personal injury Failure of plant	Inspection procedures as per legislation	Severe	Unlikely	Medium		NFAR	

HAZOP Register												
Part Considered	Sort Building Bio Process hall Four points of receiving from receival hall Hydro-sorting. Wet separation – two lines. Vat (mixes with upper (large) and over magnet. Water evacuated. Inert material goes to land fill. Floating matter united with over 120mm – goes to 60mm sorting. Under goes to pipes. Over goes to hand sorting (textiles). Goes over magnet. Elevated control room oversees whole-room operation. No people on floor. People manning conveyors and 2 x forklift operators.											
Id No.	**Element**	**Guide Word**	**Deviation**	**Possible Causes**	**Consequences**	**Safeguards**	**Cons-equence**	**Like-lihood**	**Rating**	**Comments**	**Action Required**	**Action By**
B.18		Maintenance	Schedules	Daily maintenance requirements eg cleaning, not completed	Failure of process Breakdown of plant Decreased productivity	Maintenance procedures	Moderate	Possible	Low		Maintenance procedures and schedules to be developed and integrated with operating schedules.	WSN
B.19		Toxicity	Ventilation	Build up of toxic fumes	Asphyxiation	Natural airflow	Moderate	Possible	Low		To consider need for louvers	GHD
B.20		Physical damage	Collision	Impact of vehicle with plant and/or equipment	Personal injury Damage to plant	Passive controls – bollards etc. Traffic management plan.	Severe	Unlikely	Medium		NFAR	
B.21		Quality	Testing	Inadequate testing	Failure of plant	Systematic testing prior to commissioning (dry then wet)	Severe	Unlikely	Medium		Start up sequence to be developed (3 stage)	WSN Arrow GHD
B.22	105-D-015-A1 (tank farm)	High flow		Blockage	Overflow	Overflow into tanks and then into drain channel	Minor	Possible	Low		NFAR	
B.23		Low level		Blockage Insufficient flow	Pump damage	Switch to protect pumps	Minor	Possible	Low		NFAR	
B.24		Load	High	Too many solids	Overflow	Controlled overflow system	Minor	Possible	Low		NFAR	
B.25		Inspection and testing	Alarm	Inadequate testing	Failure of plant	Testing for start-up of moving equipment	Moderate	Possible	Low		Review need for visual as well as audible alarm	Arrow GHD
B.26		Procedures	Emergency	Pump failure		PSV, flow meter	Moderate	Possible	Low		NFAR	

HAZOP Register

Part Considered

Bio-Treatment Tank Farm

Outputs (to tank farm) Small less than 2.5 mm. Large to 28 mm Two systems to one re-watering sludge system. Effluent to 0.75mm screening. 4 x screens 0.5mm. balance tank (aerobic reactor). Polished water tank. 2 x dewatering systems (belt and screw press). (methanogenic output is like toothpaste).

Bio-gas (CH_4, 30% CO_2. 50mBar-2.5 KPa) to generators. Excess gas to gas holder & excess to flare.

Two lines.

1 – Hydrolysis (organics broken down into fatty acids and sugars)

2 - Acetogenic - Amino acids and fatty acids to CO_2 and acetic acid and Volatile fatty acids (VFAs).

3 - Acetogenic - Volatile fatty acids (VFA's) to CO_2 and hydrogen and acetic acid.

4 – Methanogenic – CH4 methane

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
C.1	106-D-021-A1P6 (acetogenic reactor 2)	Process control	Critical variance monitoring	Change in level of pH (normal pH of 7)	Decrease in productivity	Autobiological control (bugs). System monitoring Buffering	Moderate	Possible	Low		NFAR	
C.2		High flow		Blockage	Overflow	Level switch. Shut-down. Maximum out flow – valve open. Overflow system. Alarm.	Moderate	Possible	Low		NFAR	
C.3		Low flow		Blockage Insufficient flow	Decrease in productivity Process slow-down	Tank level indication (PLC)	Moderate	Possible	Low		NFAR	
C.4		Reverse flow	Control system failure	Blockage Pump	Negative pressure. Flammability.	PSV 106006 will not allow reverse flow (reactor 2). Two-way relief valve	Catastrophic	Unlikely	High		Vent height to be in accordance with AS code.	Arrow GHD
C.5		High pressure	Control system failure	Blockage Pump	Negative pressure. Flammability.	Water seal on overflow (isolates atmosphere from tank). Reactor 2. Small vapour space (235m3).	Severe	Unlikely	Medium		NFAR	
C.6		High pressure	Control system failure	Blockage Pump	Negative pressure. Flammability.	Release at 50mb Gas composition relatively constant.	Severe	Unlikely	Medium		Vent to be sized in accordance with code. Confirm if full-flow device.	Arrow GHD
C.7		Process control	Trips	Blockage System flooding	Overflow	Level switch PSV	Moderate	Possible	Low		NFAR	

HAZOP Register	
Part Considered	Bio-Treatment Tank Farm Outputs (to tank farm) Small less than 2.5 mm. Large to 28 mm Two systems to one re-watering sludge system. Effluent to 0.75mm screening. 4 x screens 0.5mm. balance tank (aerobic reactor). Polished water tank. 2 x dewatering systems (belt and screw press). (methanogenic output is like toothpaste). Bio-gas (CH_4, 30% CO_2. 50mBar-2.5 KPa) to generators. Excess gas to gas holder & excess to flare. Two lines. 1 – Hydrolysis (organics broken down into fatty acids and sugars) 2 - Acetogenic - Amino acids and fatty acids to CO_2 and acetic acid and Volatile fatty acids (VFAs). 3 - Acetogenic - Volatile fatty acids (VFA's) to CO_2 and hydrogen and acetic acid. 4 – Methanogenic – CH4 methane

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
C.8		Quality (ref retrieval hall)	Assurance		Contamination	Quality control of incoming feed.	Moderate	Possible	Low		NFAR	
C.9		Maintenance	Access	Insufficient access Frequent maintenance requirement	Personal injury Excessive down-time	CSTR vessel hydraulically driven. Requires little maintenance.	Moderate	Possible	Low		NFAR	
C.10		Load		Blockages	Overflow	Liquid level controls	Moderate	Possible	Low		NFAR	
C.11		Environmental	Odour	Escape of odorous gases	Public outrage	Sulphur 50-100ppm inside pipes (low level)	Moderate	Possible	Low		NFAR	
C.12		Commissioning	Requirements	Poor workmanship	Failure of plant Leakage	Mechanical, hydrostatic test. Charge with bugs.	Moderate	Possible	Low		Detailed commissioning procedure to be prepared.	Arrow WSN GHD
C.13		Quality	Testing and inspection	Failure to meet optimal temperature/PH	Decreased productivity	Biological testing	Minor	Possible	Low		Maintenance and testing procedures to be developed.	WSN
C.14	106-D-022-A1P6 (acetogenic reactor 1) Notes: Sludge recirculated to dewatering. Produces 100-200 m3 per day.	Same as per reactor 2.				Non-return valves Level switch Overflow system					Same as per reactor 2. NB Sludge recirculated to dewatering. Produces 100-200 m3 per day.	

HAZOP Register	
Part Considered	Bio-Treatment Tank Farm Outputs (to tank farm) Small less than 2.5 mm. Large to 28 mm Two systems to one re-watering sludge system. Effluent to 0.75mm screening. 4 x screens 0.5mm. balance tank (aerobic reactor). Polished water tank. 2 x dewatering systems (belt and screw press). (methanogenic output is like toothpaste). Bio-gas (CH_4, 30% CO_2. 50mBar-2.5 KPa) to generators. Excess gas to gas holder & excess to flare. Two lines. 1 – Hydrolysis (organics broken down into fatty acids and sugars) 2 - Acetogenic - Amino acids and fatty acids to CO_2 and acetic acid and Volatile fatty acids (VFAs). 3 - Acetogenic - Volatile fatty acids (VFA's) to CO_2 and hydrogen and acetic acid. 4 – Methanogenic – CH4 methane

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
C.15	106-D-023-A1P6 (methanogenic reactor 3) Notes: 40% sludge, water. Fluidised using slurry. 500m3/hour	Quality	Testing and inspection	Failure to meet optimal temperature/PH	Decreased productivity	PH adjustment Chemical Oxygen Demand monitoring	Moderate	Possible	Low		NFAR	
C.16		Low pressure	Control system failure	Loss of vertical velocity	Decreased productivity	Autobiological control Biological testing	Moderate	Possible	Low		NFAR	
C.17		High flow		Excess flow of coagulant etc into reactor	Decreased productivity	Detected in PH balance	Minor	Possible	Low		NFAR	
C.18		Fire / explosion	Inert atmosphere	Build up of flammable gas	Fire/explosion		Catastrophic	Unlikely	High	Vent valve sizing to be done as per code and modelling requirements	NFAR	
C.19		High pressure		Excess foam	Blockage of vent	Dedicated valve for biogas that is engineered to function with foam	Severe	Unlikely	Medium		NFAR	
C.20		Contamination	Water ingress	Evaporation	Corrosion Contamination	Self draining	Moderate	Possible	Low		NFAR	
C.21		Shutdown	Emergency	Power failure	Plant shuts down.	Process intrinsically safe at stop. Flare burns off excess (runs without power).	Severe	Unlikely	Medium		NFAR	
C.22		High flow		Build up of sludge	Blockage	Sludge evacuated using positive pumps.	Moderate	Possible	Low		NFAR	
C.23		Fire / explosion	Inert atmosphere	Build up of flammable gas	Fire/explosion		Catastrophic	Unlikely	High		Valves, flanges etc to be in accordance with AS.	Arrow GHD

HAZOP Register

Part Considered

Bio-Treatment Tank Farm

Outputs (to tank farm) Small less than 2.5 mm. Large to 28 mm Two systems to one re-watering sludge system. Effluent to 0.75mm screening. 4 x screens 0.5mm. balance tank (aerobic reactor). Polished water tank. 2 x dewatering systems (belt and screw press). (methanogenic output is like toothpaste).

Bio-gas (CH_4, 30% CO_2. 50mBar-2.5 KPa) to generators. Excess gas to gas holder & excess to flare.

Two lines.

1 – Hydrolysis (organics broken down into fatty acids and sugars)

2 - Acetogenic - Amino acids and fatty acids to CO_2 and acetic acid and Volatile fatty acids (VFAs).

3 - Acetogenic - Volatile fatty acids (VFA's) to CO_2 and hydrogen and acetic acid.

4 – Methanogenic – CH4 methane

Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
C.24		Materials of construction	Structures	Failure to identify correct vessels/pipes in an emergency	Personal injury Damage to plant		Severe	Unlikely	Medium		Confirm colour for gas coding	Arrow GHD
C.25		Environmental impact	Vapour emissions	Inert air	Build up of gases		Moderate	Possible	Low		Confirm need of sniffers around top of tank.	Arrow GHD
C.26		Commissioning	Procedures	No process	Plant failure		Moderate	Possible	Low		Full detailed commissioning programme to be written	Arrow GHD
C.27	106-D-024-A1P6 (balance tank)	High flow		Blockage System flooding	Overflow	Sequence can be altered and sludge evacuated. Overflow to drain and bunded area.	Moderate	Possible	Low		NFAR	
C.28		Natural hazards	Thunderstorm	Lightening strike	System overload (power surge) Plant failure		Severe	Unlikely	Medium		Consider need for lightning protection	GHD
C.29	106-D-025-A1P6 (polishing tank, polished water tank) Notes: 6 hour cycle	Level	High	Blockage System flooding	Overflow	High level switch. Overflow system.	Minor	Possible	Low		NFAR	
C.30							Minor	Possible	Low			
C.31	106-D-027-A1P4 Notes: coagulant,	Flow		Power failure	System shut-down	Overflow system. Valves fail closed.	Moderate	Possible	Low		NFAR	

HAZOP Register												
Part Considered	Bio-Treatment Tank Farm Outputs (to tank farm) Small less than 2.5 mm. Large to 28 mm Two systems to one re-watering sludge system. Effluent to 0.75mm screening. 4 x screens 0.5mm. balance tank (aerobic reactor). Polished water tank. 2 x dewatering systems (belt and screw press). (methanogenic output is like toothpaste). Bio-gas (CH_4, 30% CO_2. 50mBar-2.5 KPa) to generators. Excess gas to gas holder & excess to flare. Two lines. 1 – Hydrolysis (organics broken down into fatty acids and sugars) 2 - Acetogenic - Amino acids and fatty acids to CO_2 and acetic acid and Volatile fatty acids (VFAs). 3 - Acetogenic - Volatile fatty acids (VFA's) to CO_2 and hydrogen and acetic acid. 4 – Methanogenic – CH4 methane											
Id No.	Element	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
C.32		Load	Loss of containment	Leakage of flocculant	Fire Slip hazards	Polymer. Minimal fire hazard.	Moderate	Possible	Low		NFAR	
C.33		High pressure	Control system failure	Power failure	System shut-down	Feeding pump closes in closed position	Moderate	Possible	Low		NFAR	
C.34		Contamination	Isolation	Blockage System flooding	Overflow Flooding	Overflow contained in bunded area	Moderate	Possible	Low		NFAR	
C.35		Access		Fall into vat	Personal injury	Physical barriers. Light activated trips	Moderate	Possible	Low		NFAR	
C.36		Commissioning	Requirements	Blockage	Failure of plant Leakage	Test for leakage prior to commissioning. Pipes to be constantly flushed to keep pipes clear. Flush lines to stop sludge plugs forming.	Moderate	Possible	Low		NFAR	
C.37	106-D-026-A1-P4 (screw-press dewatering)	Shutdown	Emergency	Power failure	Plant shuts down.	Valves shut down in closed position.	Moderate	Possible	Low		NFAR	
C.38		Flow	Low	Continual flow over time	Cavitation	Level control Flow meter monitors and alarm sounded.	Moderate	Possible	Low		NFAR	
C.39		High load		Blockage System flooding	Overflow	Overflow system	Moderate	Possible	Low		NFAR	
C.40		Maintenance	Isolation	Required system shut-down	Process break-down	Sequenced start, stop and cleaning	Moderate	Possible	Low		NFAR	

CHAZOP Register											
Part Considered	PLC connected to HMI server (no redundancy). Operator Interface Unit (PCs) – some/limited redundancy. PLC at main building (no redundancy). Remote dial-in set up at Bio-treatment area. Twisted pair cable. Ethernet connection. Two power supplies. Separate to plant gen. System compatible with treatment plant. Can monitor HMI. Engine running (standard for biogas within/compliant to AS). Compost plant connected to same backbone. Instruments connected to same backbone by separate cables. Simple ESD functions. Reporting back to control system. Plant can withstand 6 hour stop. Local data-logging with server. Servicing through network (monitoring not control). CITEC OIU , RAID 6 requested. Trend monitoring. Video monitoring (x 3) IP enabled. Archiving in HMI server. Any OIU can be used for engineering configuration. Operating manager and assistant (1 person operating). SCADA server. Armoured optical fibre cable. Self-sustaining generators										
Id No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
D.1	Loop control	Intermittent signal	Wiring damage Undesirable fauna	Plant shutdown Electrical failure	Design of system Pest eradication program	Moderate	Possible	Low		Loss of signal spec to be developed. Programmer to carry out programme validation.	Arrow Ludan
D.2	Security		Internal sabotage External sabotage	Process failure	Password protection.	Severe	Possible	Medium			
D.3	Trips / alarms		Multiple alarms	Operator error	Priority alarms.	Minor	Possible	Low			
D.4	Tuning parameters	Modification control	Inadequate planning and change management	Process failure	Process validation and site commissioning	Moderate	Possible	Low		To be documented. Hand-over documents and training to be given	Arrow Ludan
D.5	Standards	Documentation	Lack of network knowledge	Unable to complete maintenance	Working Functional Description	Severe	Unlikely	Medium		Functional description to be completed (95% complete) and transferred to client for review (draft for review in December).	Arrow Ludan
D.6	Loss of power supply	Failure mode	OIU disconnected from plant control	Plant operation without control	PLC can run independently. NB loss of information – no operator intervention.	Moderate	Possible	Low		Failure modes/effects to be specified in functional description – long-term loss.	Arrow Ludan
D.7	Order of tuning	Commissioning First start up	Lack of testing	System failure	Simulation test for IO in Israel. Additional test on-site prior to start-up.	Moderate	Possible	Low			
D.8	Shared control between multiple devices	Common mode failures	PLC and CPU down.	SCADA system down	HMI independent of PLC.	Moderate	Possible	Low			
D.9	System loading	Controller memory	PLC sizing versus IO programming needs	Memory corruption	Non-volatile RAM. CPU has back-up battery (5 year life).	Moderate	Possible	Low			
D.10	System loading	Controller memory	PLC sizing versus IO programming needs	Memory corruption	PLC is suitably sized for IO and plant needs	Moderate	Possible	Low			

CHAZOP Register	
Part Considered	PLC connected to HMI server (no redundancy). Operator Interface Unit (PCs) – some/limited redundancy. PLC at main building (no redundancy). Remote dial-in set up at Bio-treatment area. Twisted pair cable. Ethernet connection. Two power supplies. Separate to plant gen. System compatible with treatment plant. Can monitor HMI. Engine running (standard for biogas within/compliant to AS). Compost plant connected to same backbone. Instruments connected to same backbone by separate cables. Simple ESD functions. Reporting back to control system. Plant can withstand 6 hour stop. Local data-logging with server. Servicing through network (monitoring not control). CITEC OIU , RAID 6 requested. Trend monitoring. Video monitoring (x 3) IP enabled. Archiving in HMI server. Any OIU can be used for engineering configuration. Operating manager and assistant (1 person operating). SCADA server. Armoured optical fibre cable. Self-sustaining generators

Id No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
D.11	Memory Performance	Corruption Failure mode	Loss of power	Plant control disruption	Internal watchdog timer in CPU (Non SIL rated). PLC does not freeze.	Moderate	Possible	Low			
D.12	Power		Lightning/ surges/ over-voltages	System failure	Earthing. Separation. Separate earth in control room for instrumentation only. Possible use of VFD with harmonics built in. Screen	Moderate	Possible	Low		Investigate surge protection specification Confirm UPS hours Proactive – filtering shielding	Arrow Ludan
D.13	Application programs	QA	Logic faults	Incorrect plant operation	Functional specification. Design basis for each module. Operating procedure.	Moderate	Possible	Low		Functional specification/QA check system Backup PLC and HMI server.	Arrow Ludan
D.14	Network communications	Inputs and outputs			Implicit in HMI. System handshaking between HMI and PLC.	Moderate	Possible	Low		Computer status monitoring. Link monitoring	Arrow Ludan
D.15	Performance phase	Interactions with other loops			Regular process logic for loops	Moderate	Possible	Low		List essential and non-essential loops after review of draft	WSN
D.16	Abnormal operations	Emergency operations	Instrumentation failure Power loss Signal loss	Control system function impaired	Failsafe system. Instrument signal goes to low-energy. Process failure. Fail closed for valves. Instrument signals go to fail notification - fail off.	Severe	Unlikely	Medium		Check all failsafe nodes of control system with process description	Arrow Ludan WSN GHD
D.17	Loop control	Testing	Untested loops	Unexpected loop actions	Line by line level simulation.	Severe	Unlikely	Medium			
D.18	Processing failure	Software		Plant control lost	DVD back-up and hard disk to be provided at hand-over.	Moderate	Possible	Low			

CHAZOP Register	
Part Considered	PLC connected to HMI server (no redundancy). Operator Interface Unit (PCs) – some/limited redundancy. PLC at main building (no redundancy). Remote dial-in set up at Bio-treatment area. Twisted pair cable. Ethernet connection. Two power supplies. Separate to plant gen. System compatible with treatment plant. Can monitor HMI. Engine running (standard for biogas within/compliant to AS). Compost plant connected to same backbone. Instruments connected to same backbone by separate cables. Simple ESD functions. Reporting back to control system. Plant can withstand 6 hour stop. Local data-logging with server. Servicing through network (monitoring not control). CITEC OIU , RAID 6 requested. Trend monitoring. Video monitoring (x 3) IP enabled. Archiving in HMI server. Any OIU can be used for engineering configuration. Operating manager and assistant (1 person operating). SCADA server. Armoured optical fibre cable. Self-sustaining generators

Id No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
D.19	Processing failure	Power	Lightning/ surges/ over-voltages	System failure	24 volt DC. Fuse terminal to connect instruments. 24 volts for solenoids. Pneumatic operated valves on site.	Moderate	Possible	Low			
D.20	Emergency			System failure	Spare installed IO (actual +20%)	Moderate	Possible	Low			
D.21	Processing failure	Power	Lightning	System failure		Moderate	Possible	Low		Lightning protection – spec to be determined	GHD
D.22										Control equipment environment spec	GHD
D.23										Set spares list (PLC memory to be determined). Critical spares list to be confirmed.	Arrow
D.24	Safety requirements				Explosion proof enclosure to be used	Moderate	Possible	Low			
D.25					Trending spec developed. Includes training (to include competency based level of assessment).	Moderate	Possible	Low			
D.26	Reliability level	Low reliability	Reliability of equipment Plant stops		Vulnerability spec – reliable system (reliability spec mutually agreed)	Moderate	Possible	Low			
D.27					Clear equipment standard.	Moderate	Possible	Low			
D.28	Technology advance	Old technology	Disused technology or operating system		Upgradeable systems	Moderate	Possible	Low			
D.29	System fault status indication	Fault/ no indicator	Setup and programming		Fault diagnosis inherent in HMI and PLC.	Moderate	Possible	Low			
D.30					ELV/HV/LV separation to be done to AS.	Moderate	Possible	Low			

CHAZOP Register	
Part Considered	PLC connected to HMI server (no redundancy). Operator Interface Unit (PCs) – some/limited redundancy. PLC at main building (no redundancy). Remote dial-in set up at Bio-treatment area. Twisted pair cable. Ethernet connection. Two power supplies. Separate to plant gen. System compatible with treatment plant. Can monitor HMI. Engine running (standard for biogas within/compliant to AS). Compost plant connected to same backbone. Instruments connected to same backbone by separate cables. Simple ESD functions. Reporting back to control system. Plant can withstand 6 hour stop. Local data-logging with server. Servicing through network (monitoring not control). CITEC OIU , RAID 6 requested. Trend monitoring. Video monitoring (x 3) IP enabled. Archiving in HMI server. Any OIU can be used for engineering configuration. Operating manager and assistant (1 person operating). SCADA server. Armoured optical fibre cable. Self-sustaining generators

Id No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Comments	Action Required	Action By
D.31					Audible/visible alarms in control room.	Moderate	Possible	Low			
D.32	Safety requirements		Fire	System failure	Fire indication system located in control room. Critical areas identified and shut-down procedure identified.	Moderate	Possible	Low		Investigate need for smoke and fire alarms to be integrated into control system. Review procedures.	GHD

CHAIR Register									
Part Considered	AWT Facility								
ID	Guideword	Problem / Cause	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Action / Control Measures Recommended (Risk Mitigation)	Resp.
E.1	Size	Size of equipment	Too big	Modular connections. Trommel 40t (less than 6m wide). 6m in height.	Moderate	Possible	Low		
E.2	Heights	Working at heights	Fall from height	Supports to be built prior to installation. Scissors	Severe	Unlikely	Medium		
E.3	Depths	Confined space	Asphyxiation	Nil identified at this stage for during construction	Moderate	Possible	Low		
E.4	Position	Misalignment		Cross-check for misalignment.	Moderate	Possible	Low		
E.5	Environmental conditions	Extremes of heat	Heat stroke	Build in winter/spring. Day time construction only. PPE.	Moderate	Possible	Low		
E.6	Energy	Low/ high energy		Provision for low energy. Subcontractors to bring high energy.	Moderate	Possible	Low		
E.7	Timing	Too late	Program delay	Identified long-lead time items.	Moderate	Possible	Low		
E.8	Timing	Extended delays	Delays from construction work	LDs and clear scope.	Moderate	Possible	Low	Subcontractors availability to be confirmed	GHD
E.9	Environmental conditions	Poor lighting		No planned night work	Moderate	Possible	Low	If night work required, permissions to be sought for lighting.	WSN
E.10	Heights	Working at heights	Fall from height	PPE, SWMS, JSA, separation	Severe	Unlikely	Medium		
E.11	Natural hazards	Earthquake		Formal study conducted	Minor	Unlikely	Low		
E.12	Environmental impact	Runoff	Waterway contamination/ pollution	Construction EMP	Moderate	Possible	Low		
E.13	External safety interfaces	Traffic	Personal injury Motor vehicle crash	TMP within site.	Severe	Unlikely	Medium		
E.14	Security		Vandalism Sabotage	Fully secure site 24x7	Moderate	Possible	Low		
E.15	Natural hazards	Hazardous fauna Brown snakes	Personal injury	Plan in place.	Moderate	Unlikely	Low		
E.16	Hazardous substances		Personal injury	MSDS Response plan	Moderate	Possible	Low		
E.17	Environmental impact	Effluent	Waterway contamination	Portable toilets in construction	Moderate	Unlikely	Low		
E.18	Personal protection		Personal injury	SWMS, temporary safety showers for welding, signage	Moderate	Possible	Low		

CHAIR Register									
Part Considered	AWT Facility								
ID	Guideword	Problem / Cause	Consequences	Safeguards	Cons-equence	Like-lihood	Rating	Action / Control Measures Recommended (Risk Mitigation)	Resp.
E.19	External safety interfaces	Members of the public	Personal injury Public liability	Exclusion zones, signage, guards	Moderate	Possible	Low		
E.20	Environmental conditions	High wind	Damage to plant	Tie-downs for wind loading	Moderate	Possible	Low		
E.21	Inspection testing and certs		Weld failure	Test certs, Non-Destructive Testing on welding, material books on plant, resin testing. Supervision, visual inspection of weld.	Severe	Unlikely	Medium	Confirm appropriate testing level	GHD

Appendix B

Consequence Analysis

Consequence Modelling

A part of the risk assessment process involves generating consequences for the release events identified. The steps involved in determining consequences are:

- Determine release conditions based upon materials involved, process conditions and available inventory etc;
- Based on release conditions, determine the types of events which will occur (eg jet fire, toxic cloud, evaporating pool etc);
- Calculate the extent of the consequences; and
- Establish the impact of the consequence (e.g. proportion of people killed when exposed to a toxic dose)

The consequences are calculated using empirically derived models, which can then be used to determine which release cases generate offsite effects and should be included in the risk model. The level at which fatal consequences are considered to occur will directly influence the risks.

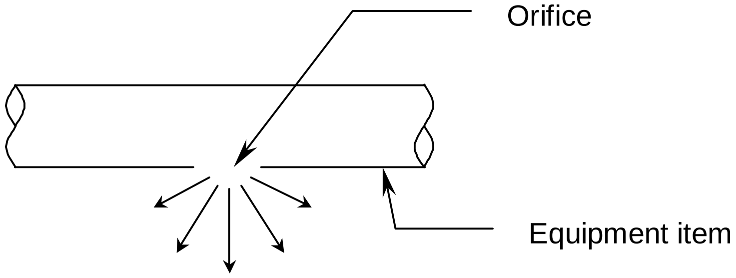
This Appendix discusses basic concepts and theory behind the various consequence models used in the analysis. The models discussed are:

- Discharge Modelling;
- Dispersion;
- Flammable Effects:
  - Jet Fire;
  - Flash Fire;

B.1 Discharge Modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure or static head is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, eg, vapour or liquid, velocity of release etc. Figure B 1 illustrates an example scenario.

Figure B 1 Typical Discharge



The discharge can be considered to have two stages; the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.

The conditions at the orifice are calculated by assuming isentropic expansion, i.e., entropy before release = entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate ($\dot{m}$) and discharge velocity (u_0) are then given by:

$$\dot{m} = C_d A_o \rho_o \sqrt{-2(H_0 - H_i)}$$

And $$u_0 = C_d \sqrt{(-2(H_0 - H_i)}$$

Where

- C_d = Discharge coefficients;
- A_o = Area of the orifice;
- ρ_o = density of the material in the orifice;
- H_o = Enthalpy at the orifice; and
- H_i = Enthalpy at initial storage conditions.

The discharge parameters passed forward to the dispersion model are as follows:

- Release height (m) and orientation;
- Thermodynamic data: release temperature (single phase) or liquid mass fraction (two-phase), initial drop size;
- Other data;
  - For instantaneous release: mass of released pollutant (kg), expansion energy (J)
  - For continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s).

B II. Dispersion

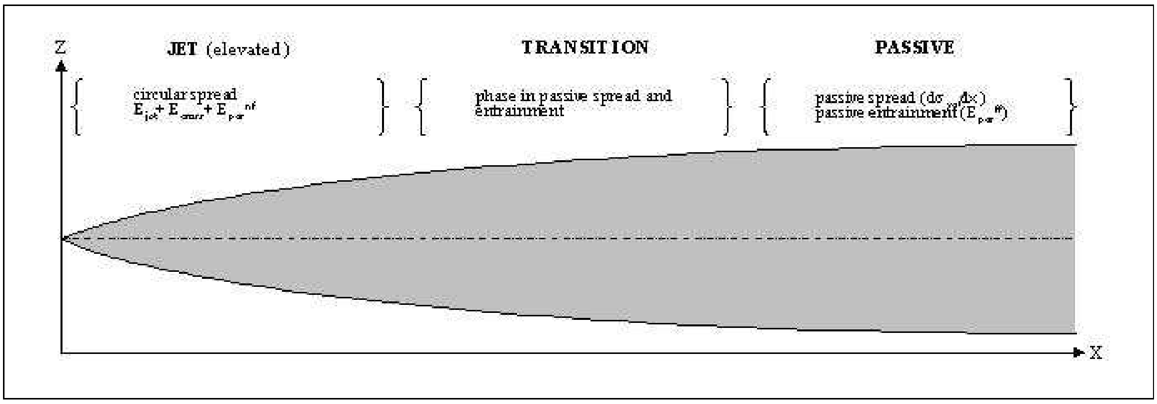
When a leak occurs, the material will be released into the atmosphere. Upon being released it will start to disperse and dilute into the surrounding atmosphere. The limiting (lowest) concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

The consequence modelling package PHAST utilises the Unified Dispersion Model (Witlox *et al*, 1999). This models the dispersion following a ground level or elevated two phase un-pressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation.

B II.1 Jet Dispersion

For a continuous, pressurised release, the material is released as a jet, i.e., high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure B 2 below shows a typical release and the various phases involved.

Figure B 2 Jet Dispersion



The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the mixing is turbulent and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

- Material released, specifically molecular weight;
- Discharge conditions including phase(s) of release, velocity etc; and
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).

B II Flammable Effects

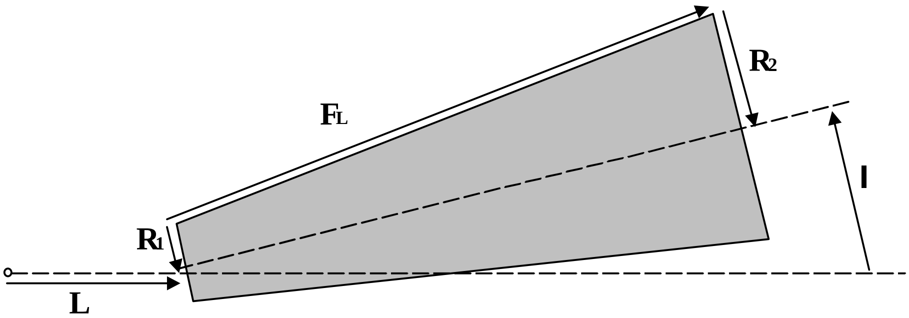
If the release is of a flammable material, it is possible for the release to be ignited. The type of fire which results (eg jet, pool, explosion etc) depends on the physical properties of the release and whether the ignition is immediate or delayed. The various flammable effects are discussed below.

B III.1 Jet Fire

Jet fires are a result of high momentum releases. If a flammable release is ignited instantaneously, a jet fire will result. The flame will have a degree of 'lift off' as the flammable mixture has to dilute to be within the flammable limits. This section briefly discusses the model used for jet fires as well as key parameters in the calculation.

The jet fire calculation utilises the Chamberlain model (Chamberlain 1987). In this model, jet fires are modelled as a conical flame, with the ignited portion lift off, inclination and shape being determined by the material being released, the pressure at which it is being released and the hole size that it is being released through. These release parameters are the main inputs to the jet fire radiation calculations. Figure B 3 below shows a graphical representation of the jet fire model.

Figure B 3 Truncated Cone Jet Fire Model



Where;

L = Lift off;

I = Flame Inclination;

R_1 = Flame Base Radius;

R_2 = Flame End Radius; and

F_L = Flame Length.

The jet fire calculations model radiation from the entire surface of the ignited portion of the jet. This includes radiation from the cone forming the body of the flame, as well as from the ends of the cone. The amount of radiation that a nearby receiver is exposed to is determined by its distance from the flame surface, as well as by the orientation of the flame relative to the receiver. The key parameters in the calculation of the radiation exposure of a receiver are therefore the flame lift off, the flame inclination, and the dimensions of the ignited portion of the jet (i.e. flame length and end radii).

B III.3 Flash Fire

Flash fires are transient in nature and are the product of delayed ignition of a dispersing cloud in an unconfined environment. In a delayed ignition from vertical release the fireball formed dies back to a steady state jet flame from the source.

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2	A. Montgomery	D Gamble		FINAL DRAFT		15/01/09
3	A. Montgomery	D Gamble		D Gamble		27/01/09
4	F. Freeman	D Gamble		D Gamle		31/07/09

* Denotes signature on original document