ATTACHMENT I FOR THE EVIDENCE OF WALTER STARKE

AB Lime Limited

AB Lime Landfill Gas Management Plan

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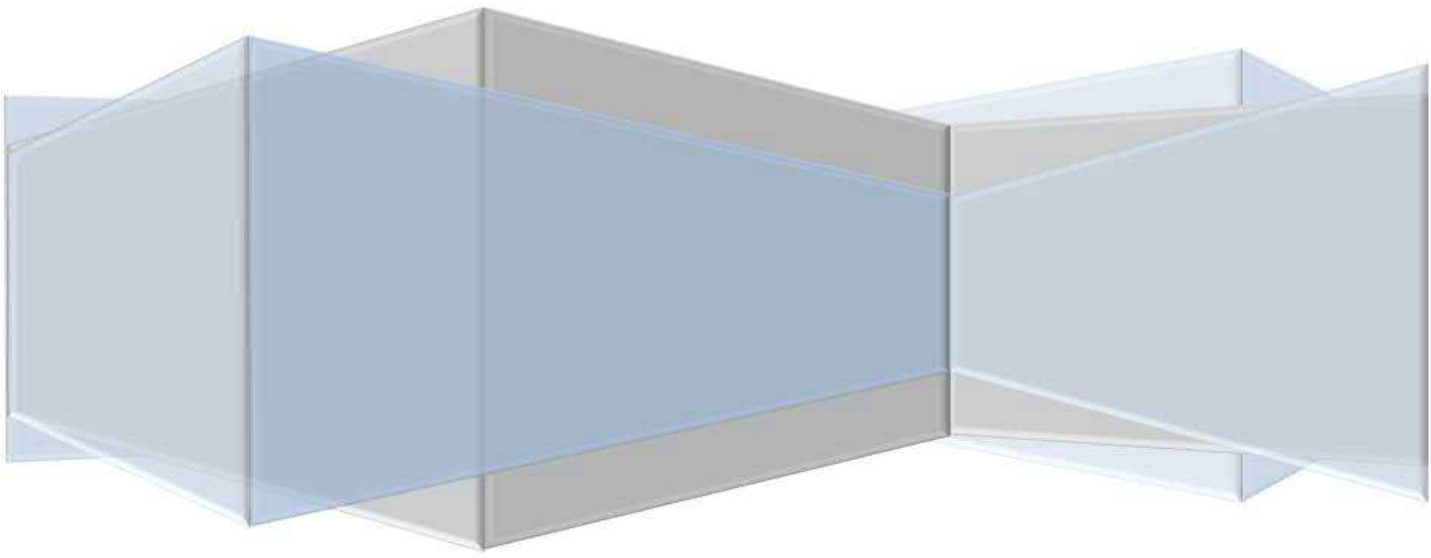
27 April, 2021

AB Lime Ltd

Draft for Consenting Purposes



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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
0	29 May 2020	Final Draft for Consenting Purposes	Walter Starke	Craig Redmond	Bruce Clarke	Vince Pace
1	27 April 2021	Response to Peer Review s92	Donne Wallace-Hunter	Craig Redmond	Bruce Clarke	Vince Pace

Contents

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs (on behalf of AB Lime Limited) is to provide a technical report for landfill management to assist with a resource consent application to increase the activities at AB Lime Landfill at 10-20 Kings Bend, Winton, in accordance with the scope of services set out in the contract between Jacobs and AB Lime (the Client).

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Introduction

1.1 Purpose/Objective of the Landfill Gas Management Plan

The purpose of the Landfill Gas Management Plan (LGMP) is to manage the effects of landfill gas in accordance with the corresponding legislative requirements outlined below in section 2. The LGMP covers the following matters:

i. To provide active LFG extraction throughout the active and post-closure phases

ii. To manage the maintenance of methane concentrations at the nearest site boundary not owned by the Consent Holder

iii. To provide for the treatment of recovered landfill gas by flaring in accordance with the NESAQ

iv. To manage surface emission concentrations above the area of the landfill surface for all future cells that contain permanent capping and temporary capping are maintained at less than 5000 ppm methane.

Maintenance:

v. To provide for maintenance of the landfill gas collection system

1.1.1 Management Plan Structure

The operation of AB Lime landfill and quarry requires a suite of environmental management and mitigation plans to operate the site. The Environmental Management Plan sets the overall framework for the operation of the site and is supported by a series of sub management plans focusing on specialist environmental areas to effectively run the landfill and quarry.

The Landfill Gas Management Plan is a sub management plan under this framework that manages the effects of landfill gas. Figure 1.1 below illustrates the relationship between the Landfill Gas Management Plan and the remainder of the AB Lime management plan framework.

This plan has been prepared in accordance with the certification and submission process outlined in section 1 of the AB Lime Environmental Management Plan.

Figure 1.1: AB Lime Management Plan Structure

2. Legislative Requirements

The legislative requirements of this Landfill Gas Management Plan outline the consent conditions that this plan is designed to assist with implementing.

2.1 Resource Consent Requirements

Table 2.1: Relevant Conditions for Consents related to the Landfill Gas Management Plan

Condition Number	Condition	Reference
Schedule 1 – General Conditions AUTH 201346, 201347, 201348, 201349, 201350, 201351		
23.	The consent holder shall prepare and maintain a Landfill Gas Management Plan (LGMP). The LGMP shall describe gas management for the landfill, including demonstrating how compliance with the relevant conditions of this consent will be achieved. The plan shall also achieve the following objectives:	
	vi. To provide active LFG extraction throughout the active and post-closure phases	Section 5.4., Section 9
	vii. To manage the maintenance of methane concentrations at the nearest site boundary not owned by the Consent Holder	Section 6
	viii. To provide for the treatment of recovered landfill gas by flaring in accordance with the NESAQ	Section 4.2.3, section 6.6
	ix. To manage surface emission concentrations above the area of the landfill surface for all future cells that contain permanent capping and temporary capping are maintained at less than 5,000 ppm as methane.	Section 6.5
	<u>Maintenance:</u> x. To provide for maintenance of the landfill gas collection system.	Section 6
Air Discharge Permit 201351		
2.	The discharge into air shall only be contaminants, including particulate matter, odour, combustion products and landfill gas, from a landfill as described in the application documents. The consent does not authorise the burning of solid waste at the site.	
16.	A landfill gas extraction system shall be installed and operated in accordance with the details supplied in the original consent application. The gas combustion system shall destroy at least 98% of non-methane organic compounds burned.	Section 4.2.3
17.	There shall be no visible emissions, excluding water vapour, light or heat haze, from any landfill gas flare.	Section 6.6
18.	Each gas extraction well shall be connected to the main gas extraction system within 12 months of placing wastes within the radius of influence of that well. Passive flares shall burn gas discharged from wells prior to connection to the gas extraction system. These temporary flares shall each have a continuous automatic ignition system, a flame arrestor and a backflow prevention device.	Section 4.2.3.3 & 4.3.2

Condition Number	Condition	Reference
19.	The enclosed principal landfill gas flare or other utilisation system shall have: a) A flame arrestor and backflow prevention device; b) A continuous automatic ignition system; c) An automatic isolation system to prevent the discharge of unburned landfill gas; d) Sampling ports of appropriate design for emission testing, including safe access to the sampling ports; e) A minimum combustion temperature of 750 degrees Celsius and a residence time in the combustion zone of at least 0.5 seconds; f) A permanent temperature indicator with visual readout at ground level.	Section 4.2.3
20.	a) The concentration of methane measured in monitoring probes outside the landfill footprint shall not exceed 1.25% by volume. b) The concentration of methane measured at the surface of landfill areas with temporary or permanent capping shall not exceed 0.5% by volume.	Section 6.3 & 6.5

2.2 Monitoring and Reporting the performance of the Landfill Gas Management Plan

Table 2.2: Monitoring and Reporting Requirements Related to the Landfill Gas Management Plan

Condition Number	Condition	Requirement	Relevant Regulatory Authority	Frequency	Date	Responsibility
Schedule 1 – General Conditions AUTH 201346, 201347, 201348, 201349, 201350, 201351						
29.	The EMP and sub-management plans (where applicable) shall include monitoring with respect to surface water, groundwater, leachate, landfill gas and nuisance. Each monitoring element shall include: i. Monitoring locations; ii. Monitoring parameters; iii. Monitoring frequency; iv. Detection limits; v. Reporting; vi. Trigger levels (for each monitoring location) for implementing contingency/remedial actions					
Air Discharge Permit 201351						

Condition Number	Condition	Requirement	Relevant Regulatory Authority	Frequency	Date	Responsibility
21.	A walk-over site inspection of the landfill shall be undertaken at least every week. Any evidence of possible landfill gas leaks, including odour, surface cracks, gas bubbles or vegetation damage, shall be investigated and appropriate remedial action shall be undertaken as soon as practicable.	Section 6.7	SRC	Weekly	Report yearly	AB Lime or their nominated consultant
22.	a) Methane concentrations shall be measured and recorded at least once each month in at least 7 monitoring probes located outside the landfill footprint, but within the consent holder's property, to demonstrate compliance with Condition 19(a). b) Methane concentrations shall be measured and recorded at least once each month at the surface of the landfill to demonstrate compliance with Condition 19(b).	Section 4.3.1 Section 6.5.1	SRC SRC	1x/month 1x/month	Report yearly Report yearly	AB Lime or their nominated consultant AB Lime or their nominated consultant
23.	Landfill gas shall be monitored at least once each month at each gas extraction well head and at each temporary flare station. The following parameters shall be measured and recorded: a) gas flow rate; b) gas composition (% methane, % oxygen, % carbon dioxide, % nitrogen, ppm carbon monoxide); c) gas temperature; d) gas pressure; and e) hydrogen sulphide concentration.	Section 6.2	SRC	1x/month	No reporting requirement	AB Lime or their nominated consultant
24.	Once a permanent landfill gas flare or other utilisation system is established, landfill gas shall be monitored. The following	Section 6.6	SRC	Continuous to ??	Report yearly	AB Lime or their

Condition Number	Condition	Requirement	Relevant Regulatory Authority	Frequency	Date	Responsibility
	parameters shall be measured and recorded at the following frequencies: a) Continuous monitoring: i. gas flow rate; ii. gas composition (% methane, % oxygen, % carbon dioxide, % nitrogen) iii. gas temperature; and iv. gas pressure b) Weekly monitoring: v. gas composition (ppm carbon monoxide). vi.					nominated consultant
25.	Once a permanent landfill gas flare or other utilisation system is established, landfill gas shall be monitored for the following parameters: a) hydrogen sulphide concentration shall be monitored at a frequency not less than once each month b) concentration of total non-methane organic compounds (NMOCs) shall be monitored annually.	Section 6.6	SRC	1x/month H_2S 1x/year NMOCs	Report yearly	AB Lime or their nominated consultant

2.2.1 Interaction Between Legislative Requirements and the Landfill Gas Management Plan

If there is a conflict between the management plan and the corresponding legislative requirements, including consent conditions, then the legislative requirements must prevail.

3. Background and Landfill Gas Generation

AB Lime operate an agricultural fertiliser and lime business, and a Class A landfill business approximately 4 km east of the Winton Township in Invercargill. As outlined by the Ministry for the Environment, *Class A landfills are, "sites in areas that reduce the potential for adverse effects on the environment, have engineered systems designed to provide a degree of redundancy for leachate containment, and collect landfill leachate and landfill gas"*[1].

A by-product of landfills is the generation of landfill gas which is created through the decomposition of organic waste in an anaerobic environment. The gas generated is predominantly methane and carbon dioxide which are greenhouse gases, and accordingly is managed to minimise its escape into the atmosphere.

As outlined by WasteMINZ NZ technical guidelines[2] if not managed appropriately, landfill gas can result in adverse effects such as:

- Explosions or fires due to gas release through cracks and fissures at the surface, or in confined spaces such as manholes, chambers and poorly ventilated areas of buildings on or adjacent to the site; and
- Asphyxiation of personnel entering trenches, manholes or buildings on or near the landfill site.
- Odour nuisance,
- Greenhouse effects of methane;
- Migration in surrounding sub-strata;
- Vegetation die off on the completed landfill surface and on adjacent areas.

Landfill gas capture is required for all areas of the landfill (including working and closed faces). Gas is captured through a piped network and is destroyed via a permanent flare or is utilised in a gas engine to produce electricity.

The gas management approach at AB Lime is to continue to increase the overall capture and destruction of landfill gas so that potential adverse effects on human health are minimised and additionally, that overall landfill operations are not impacted. Capturing gas also provides the landfill with the opportunity to generate a renewable energy resource.

3.1 Gas Composition

Landfill gas occurs as a result of decomposition of biodegradable material within a landfill, such as food, garden waste, paper, wood and cardboard.

Landfill gas consists of a mixture of carbon dioxide (approximately 40% to 60%), methane (approximately 35% to 60%), and trace gases including hydrogen sulphide, ammonia, hydrogen chloride, volatile organic compounds (VOC) and carbon monoxide.

Methane is a colourless and odourless gas, which is explosive in concentrations ranging from 5% (lower explosive limit – LEL) and 15% (upper Explosive limit (UEL) in air and flammable above 15% concentration. Carbon dioxide is also a colourless and odourless gas but is non-combustible. Both are 'green-house' gases, contributing to global warming. Trace gases within landfill gas are those that give the gas its characteristic odour.

[1] https://www.mfe.govt.nz/publications/waste/module-2-%E2%80%93-hazardous-waste-guidelines-landfill-waste-acceptance-criteria-and-4

[2] https://www.wasteminz.org.nz/wp-content/uploads/2016/04/Technical-Guidelines-for-Disposal-to-Land-9Aug18-FINAL.pdf

In addition to these environmental impacts, landfill gas control is also imperative to control or reduce short- and long-term safety hazards for operators associated with landfill gas building up as it is highly flammable, explosive and an asphyxiant gas[3].

3.2 Gas Generation

The amount of landfill gas that the landfill is likely to produce can be estimates using modelling as recommended in the WasteMINZ Guidelines (2018).

For the AB Lime landfill the modelling was based on a first order decay equation (Scholl Canyon Equation) developed by the US Environmental Protection Agency. The LandGEM version 3.02 model was used.

The results of the gas generation modelling are presented in Attachment 2. The results of the model can be used by AB Lime in their forward planning to determine:

- when a second principal flare is required;
- when and/or how many backup flares are necessary; and
- the viability of using landfill gas as a supplementary fuel source to coal in their limestone drying kilns.

The 2020 landfill gas modelling assumptions and salient points are as follows:

a) Three model runs were carried out for three maximum annual refuse acceptance rates:
   1) 100,000 tonnes/year
   2) 200,000 tonnes/year
   3) 300,000 tonnes/year

b) Actual historic placement rates and waste composition data were used for the years 2004 to 2018 with organics estimated to be 52% on average per annum;

c) That 35% of the refuse is putrescible or biodegradable, based on the information presented in the AB Lime Annual Report No. 5 dated 2019;

d) L_o or potential of methane generation per ton of waste of 100 m^3/hr;

e) With k or moisture content of landfill of 0.05 for years 2004 to 2009 and 0.1 from 2009 onwards since limited leachate recirculation has been used;

f) A gas collection efficiency of 10% in years 2004 to 2009 (when the landfill was operating without a principal flare) and 30% from 2009 to 2020. With these gas collection efficiency estimates the model has been calibrated to the volume of landfill gas being collected of 100 m^3/hr, as this is what is actually measured at the principal flare in Feb 2020;

g) From 2021 onwards the gas collection efficiency has been increased to 75%, based on the assumption that a combination of the following measures will be carried out:
   i. Improved cover and capping procedures, as described in the Landfill Operations Management Plan;
   ii. A reduced working face area, as described in the Landfill Operations Management Plan;
   iii. Minimising gas emissions through the existing oversteep slopes through appropriate capping of these slopes, as described in the Landfill Operations Management Plan;
   iv. Increased gas flow rates from gas extraction wells through improved operation and maintenance of the leachate collection pipework. It is envisaged that this will reduce the potential for storing

[3] https://www.wasteminz.org.nz/wp-content/uploads/2016/04/Technical-Guidelines-for-Disposal-to-Land-9Aug18-FINAL.pdf

excess leachate within the landfill that may interfere the gas extraction well, such as 'flooding' parts of the perforated section of the gas extraction well, (refer to the Landfill Leachate Management Plan);

v. Timely repair of leakage of landfill gas losses in cracks that may exist in the landfill capping, around the base of the wellheads, within the wellhead valves and monitoring ports, and in aboveground gas transmission/header pipework to the principal flare;

vi. Improved compaction efficiency of the waste, reducing the air-voids within the waste;

vii. Reduce the distance between the vertical landfill gas extraction wells;

viii. Continue to use horizontal collectors connected to the vertical gas extraction wells; and

ix. High rates of methane oxidation within the landfill and through the landfill capping system.

h) A 40/60 mixture of CO_2 and methane is used in the estimation. In reality, methane generation may vary from 30-65% and is very dependent on the types of waste being placed and the conditions of the landfill.

3.3 Gas Migration Pathways

Landfill gas can move through the ground either to the surface or towards the perimeter of the site taking the path of least resistance.

Once landfill gas is generated, it moves through the refuse and soil by both convection and diffusion. Convection is the movement of gas from an area of higher pressure to an area of lower pressure. Diffusion is the movement of gas from an area of higher concentration to an area of lower concentration. For landfills convection is typically the dominant method of gas migration.

The main potential hazard associated with off-site migration of landfill gas is the possibility of gas entering structures and being ignited, or possibly asphyxiation due to gas entering a confined space (e.g. a manhole) through cracks in foundations or utility services.

3.4 Factors Affecting Gas Production, Composition and Movement

Landfill gas may not be completely contained with a landfill. It can be discharged through the landfill surface or can potentially migrate through subsurface soils on adjacent property.

The distance that landfill gas can migrate is highly dependent on several factors including:

- Whether the landfill is lined or not and the type and quality of landfill base and sidewall liner;
- The type and compaction of the capping/cover on the landfill surface;
- The gas volume and pressure within a landfill;
- The configuration of the landfill;
- The geology and hydrogeology of the area; and
- The presence of man-made pathways such as underground services.

The composition and quantity of landfill gas is largely influenced by the type, volume and age of refuse in the landfill.

In addition, meteorological and environmental conditions will affect the rate of landfill gas emissions and migration. Landfill gas components can also be absorbed onto soil particles, transferred to water, or oxidised by methane consuming bacteria. These phenomena may also reduce emissions and migration of landfill gas.

3.5 Site Geology

The site geology at the AB Lime site is mainly limestone. In-site permeability testing carried out as part of the original resource consent application for the landfill in the early 2000s shows that the limestone has a permeability ranging from 1.24×10^{-8} to 2.94×10^{-6} m/s with an average of 3.30×10^{-7} m/s.

This is considered to be a relatively low permeability for the natural ground surrounding the landfill and therefore there is limited potential for significant lateral landfill gas migration from the site.

In addition to the relatively low permeable nature of the ground surrounding the landfill, other mitigation measures to minimise the risk of landfill gas migration are that the landfill has an engineered base and sidewall liner system and a landfill capping system that has been designed in accordance with good industry practice (see Landfill Operations Management Plan).

4. Design and Construction

4.1 Overall Scope of Works

4.1.1 Staged Development and Completion

The landfill will be developed in stages/areas with progressive development of gas controls within each area. The extent of each of these areas is expected to be generally as shown on the landfill staging plan contained in Attachment 3.

Installation of the landfill gas extraction system is conducted in accordance with current recognised good practice. The system is carried out as a staged development as landfilling progresses to control landfill gas migration odour emissions created by landfill gas emissions to the atmosphere.

4.1.2 Landfill Gas Extraction and Monitoring Works Overview

The overall gas extraction and monitoring works required for the development of the extension to the landfill include:

- Installation of landfill gas migration monitoring probes;
- Progressive installation and extension of gas extraction wells and gas control systems;
- Progressive installation of connection pipework, e.g. gas sub-header and gas header pipes;
- Connecting to the existing landfill gas principal flare and associated equipment installed in 2009;
- Landfill gas condensate controls; and
- Gas extraction well monitoring and tuning.

The overall monitoring network is further discussed in Section 6.1.2.

4.2 Materials

4.2.1 Landfill Gas Pipework Systems

All pipework will be medium of high-density polyethylene (MDPE or HDPE) or polyvinyl chloride (PVC). The pipework bedding material will be granular fill and all miscellaneous fitting, valves, etc. will comply with current NZ standards.

4.2.2 Landfill Gas Monitoring Probes

All pipework will be 50 mm diameter Class D UPVC screw jointed, constructed in a 100 mm diameter borehole. Granular backfill material will be used in the annulus between the 100 mm diameter borehole and 50 mm probe pipework. The granular backfill will be at least twice the slot size of the probe and miscellaneous fitting, valves, etc. will comply with current NZ standards.

4.2.3 Extraction Plant and Flares

The extraction plant and associated components will comply with the following standard:

- Resource Management (National Environmental Standards for Air Quality) Regulations 2004 and amendments;

- NZS 5261: 1996 The Installation of Gas Burning Appliances and Equipment;
- AS/NZS 60079.11:2000 Electrical Apparatus for Explosive Gas Atmospheres, Part 11: Intrinsic Safety "I";
- HB 13- 2000 Electrical Equipment for Hazardous Areas; and
- Health and Safety at Work Act and associated regulations.

The landfill operates using an enclosed principal flare that was installed in 2009. The enclosed flare was designed and monitored in accordance with the following:

- Flare arrestor and backflow prevention device, or similar (to prevent flashback);
- Automatic ignition system to provide a minimum 99% reliability;
- A destruction and removal efficiency of 99%;
- Minimum temperature of 750 ^{0}C for a retention time of at least 0.5 seconds;
- Operating range of the flare is 1000 m^3/hour;
- Appropriate sampling ports to enable verification of the destruction and removal efficiency and minimum temperature and retention time;
- A Programmable Logic Controller (PLC) maintains the operation and control of the flare; and
- The PLC will shut down and isolate the flare should it malfunction.

The Principal Flare Design – SKM 2009 report shows a general overview of the enclosed principal flare.

4.2.3.1 Flare Maintenance Checklist

Routine maintenance of the flare is carried out by AB Lime with the assistance of the specialist sub-contractor First Gas (or a similar qualified company).

For non-routine maintenance the flare manufacturer is either consulted or used to carry out the work.

The checks most frequently cited by manufacturers and operators include:

- Check the operation of condensate drop-out and disposal systems;
- Check the operation of slam-shut isolation valves and actuators;
- Check and lubricate the air dampers;
- Check the condition of the flare refractory lining;
- Clean flare arresters and filters;
- Check the ignition system operation and thermocouples;
- Check and clean the UV flame detector lens; and
- Check the PLC shutdown system and dialler operation (if fitted).

4.2.3.2 Site Walk-Over Inspections

The Environmental Manager or Environmental Technician will, during normal operation hours, inspect all operational flares at least twice daily, once at the start of the day and once late-afternoon before leaving the site.

Checks include:

- Visibility of plume from flare;
- Gas pressures are in normal operating ranges;
- Flare is operating;
- Continuous gas monitoring unit is operating correctly; and
- No odour around the flare site from leaks of pipe/flanges etc.

Where potential or actual nuisance is identified the Landfill Manager will be advised and shall investigate and organise to remedy or mitigate such nuisance.

4.2.3.3 Candle-Stick Flare and Operation

In the early stages of the landfill (mid-late 2000s) an open candle-stick flare operated at the site. Should there be a requirement to operate a candle-stick flare again it will be operated in accordance with the manufacturer's instructions and have the following:

- Flame arrester and backflow prevention devices or similar (to prevent flashback);
- Automatic ignition to provide a minimum 99% reliability; and
- Automatic shut-down and be isolated in the event of a malfunction.

4.3 Installation Schedule

4.3.1 Landfill Gas Migration Probes

Seven landfill gas migration probes were installed in July 2003. Attachment 1 shows a site plan showing the location of the probes.

If any new landfill gas migration probes are required, a design and installation plan will be submitted to Environment Southland for approval, prior to installing the probes.

4.3.2 Landfill Gas Extraction Well Installation

In general extraction wells are installed progressively within 6 months of filled areas greater than 10,000 m^2:

- On reaching the finished level of refuse filling;
- Where no refuse is to be placed for periods greater than 12 months and the refuse is more than 10 m deep; and
- Areas where landfill surface emission monitoring detects emissions above consent limits and other remedial actions to reduce the surface emission exceedances have failed (e.g. provide extra temporary capping around the extraction well head).

4.3.3 Early Extraction from Landfill Gas Extraction Wells

Gas extraction wells are installed as new cells/areas are filled. The use of remote lateral lines to a gas extraction well will ensure that gas extraction can commence within one month from the date of installation.

4.4 Placement and Construction of Gas Extraction Wells

4.4.1 General

For each stage of the landfill development it will be filled in a series of cells/areas generally in alignment with the leachate drainage pipework system from the northern part of the landfill to the southern part of the landfill.

Landfill gas extraction wells will be located in a grid pattern at approximately 50 m centres. Intermediate wells will be installed on the landfill as required. To maintain the efficiency of the gas collection system, gas well spacing may be reduced if the depth of refuse is less than 10 m, e.g. near the landfill sidewall liner.

Each well is connected with pipework, known as laterals, to a header system (or manifold) and then to a ring-main that connects to the permanent ground flare. The location of the landfill gas pipework in April 2020 is presented on a site plan contained in Attachment 4.

4.4.2 Construction

The position, method of construction, diameter and depth of every extraction well will be recorded at the time of installation.

4.4.3 In-Situ Extraction Wells

Gas extraction wells are installed in-place during early stage of cell/area filling to allow for early landfill gas extraction. These in-situ wells are progressively developed as stages are filled.

The in-situ vertical wells have horizontal landfill gas pipes connected to the vertical gas extraction pipes. More details are provided in the SKM 2009 Landfill Gas Design Report.

In-situ wells are connected to the gas extraction system via flexible pipework.

A site plan showing the locations of the in-situ gas extraction wells (as of April 2020) is contained in Attachment .

4.4.4 Retrospective Installation of Gas Extraction Wells

Fifteen gas wells were retrospectively installed by Texco Drilling and Piling Limited in the period November 2017 to April 2019.

The retrospective wells were installed to with the primary aim to improve landfill gas collection efficiency. Secondary benefits of these wells were the anticipated reduction in surface gas emissions, mitigate the potential for odour nuisances, and minimise the risk of perched leachate in the landfill.

The construction drawing for the retrospectively drilled wells is contained in Attachment 5.

A site plan showing the locations of the 15 retrospectively drilled wells is also contained in Attachment .

4.4.5 Landfill Gas Pipework

Gas extraction wells are connected by smaller diameter pipework to the larger diameter gas ring main that is connected to the principal flare. An articulated flexible joint is installed in the discharge pipework between the

extraction wellhead and the gas drawn-off reticulation (sub-header pipe) to allow for thermal expansion and settlement.

Current landfill gas pipework is located aboveground for easy or maintenance, for example, sagging pipes due to landfill settlement, or to get access to valves. Upon completion of the landfill the pipework may be buried in shallow trenches within the landfill cap.

The fall on all pipework is maximised where practicable to permit landfill gas condensate to flow to condensate collection points.

The gas collection pipework will have isolating valves and sample points installed at all branch lines as determined appropriate by the Landfill Manager.

The As-Built positions of the gas pipework will be clearly marked on site plans.

The installation of pipework will only be carried out by suitably qualified professional, such as First Gas or a similar qualified company.

4.4.6 Condensate Collection

Condensate collection points are installed at intervals along the pipework to minimise the risk of pipeline blockages from an accumulation of condensate. Gas condensate will be, as far as possible, collected at the leachate tank.

If condensate cannot be drained via the landfill gas ring-main, the second choice is to drain the condensate back into the extraction well from where it came (noting that this may limit the performance of the extraction well and this method of condensate disposal should therefore be used with caution).

4.4.7 Migration Probe Construction

Specialist drilling contractors will be engaged to undertake the construction of landfill gas migration probes on the landfill site.

The depth of the migration probes is determined by the groundwater levels in the area. Maximum probe depths are generally at least 2 m below the lowest expected groundwater table.

A typical migration probe construction detail is presented on the drawing contained in Attachment 1.

4.5 Record Keeping

The Landfill Manager (or delegate), will keep details of all gas design and construction activities carried out at the site and will provide these details to Environment Southland where requested. These records include:

- Engineering works including civil, mechanical and electrical works for the following specific items:
    a) PLC programmes and flow logistics;
    b) As-Built drawings;
    c) Bore logs;
    d) Locations of all main drains and other services; and
    e) Records of QA/QC inspections.
- Photographic record of the construction activity;

- The following records will also be provided in the Monitoring and Contingency Section:

  a) Monitoring activities and results (including non-standard results), investigations, actions and remedial works undertaken;

  b) Complaints and actions undertaken;

  c) Other incidents and actions undertaken;

  d) Fires;

  e) Accidents; and

  f) Other emergencies.

5. Gas Operations

5.1 General Operations

All processes at the landfill will be undertaken in accordance with this plan and the Landfill Operations Management Plan so that odours, noise, and other effects from landfill gas and site operations on the environment are minimised as much as reasonably practical and in compliance with the resource consent conditions.

5.2 Operating Hours

The landfill gas extraction and destruction system operates 24 hours per day.

The landfill permitted opening hours to receive refuse are Monday to Saturday, 8 am to 6 pm.

On occasion staff may be present outside the normal landfill opening hours to address items related to the landfill gas system.

5.3 Plant Operation

All equipment and plant at the landfill will be operated and maintained by appropriately trained staff in accordance with the manufacturer's instructions.

AB Lime's Environmental Manager or delegate, together with the assistance of the specialist sub-contractor First Gas (or a similar qualified company), will be responsible for the landfill gas equipment and plant operation and maintenance.

5.4 Landfill Gas Extraction Operation and Management

5.4.1 Extraction Wells

The Environmental Manager, delegate or the specialist landfill sub-contractor will monitor, inspect and tune all landfill gas extraction points no less than monthly and use that information to maximise landfill gas extraction rates from each well in a safe manner, while minimising the risk of landfill fires due to over-extraction.

The Environmental Manager, delegate or the specialist landfill sub-contractor will tune each well, or manifold, to optimise extraction rates and meet the following landfill gas quality target concentrations:

- Methane (CH_4): 45% - 65%;
- Carbon-dioxide (CO_2): 35% - 40%;
- Oxygen (O_2): 0% - 2%;
- Carbon-monoxide (CO): less than 100 ppm; and
- Temperature: less than 55 degrees Celsius.

The quantity of landfill gas extracted will be, at a minimum, the level required to achieve surface emission and migration standards, i.e. less than 0.5% methane or 5000 ppm methane, at any location on the landfill surface where there is Permanent Capping, and 1.25% methane at any landfill gas migration probe.

The Environmental Manager (or delegate) or the specialist landfill sub-contractor will notify all wells operating outside this range to the Landfill Manager.

5.4.2 Well Field Adjustment- Purpose and Objectives

The objective of the well field adjustment is to achieve a steady state of operation of the gas collection system by stabilising the rate and quality of extracted landfill gas.

Typical reasons for recovery of landfill gas and close control of the well field are:

- Meet environmental and regulatory compliance limits;
- Achieve and maintain effective surface gas emission control;
- Achieve and maintain effective subsurface gas migration control;
- Assist with proper operation and control of the recovery equipment (permanent ground flare or temporary candle-stick flare);
- Avoid well 'over-pull' and maintain a health anaerobic state within the landfill;
- Control of nuisance landfill gas odours;
- Prevent or control subsurface landfill gas fires; and
- Protect structures on and near the landfill.

Landfill gas field adjustment is partly subjective because it involves judgement calls based on simultaneous evaluation of several variables as well as general knowledge of site-specific field conditions and historical landfill gas concentration and flow rate trends.

Landfill gas field evaluation and adjustment consists of a collection of techniques which may be used to achieve a safe and steady state of gas field operation.

5.4.2.1 Typical Field Readings

The landfill gas extraction wells will be monitored once a month. The following will be recorded on pro-forma sheets:

- Name of person taking the readings;
- Date and time of each reading;
- Methane (CH_4) %;
- Carbon-dioxide (CO_2) %;
- Oxygen (O_2) %;
- Carbon-monoxide (CO) ppm;
- Hydrogen sulphide (H_4S) ppm;
- Balance gas (primarily N_2): %;
- Wellhead temperature (initial and adjusted) ^oC;
- System pressure (mBar);

- Atmospheric pressure (mBar);
- Wellhead gas flow (initial and adjusted) m^3/hr; and
- Wellhead valve position (initial and adjusted) m^3/hr.

Supplementary monitoring once to several times a week may be carried out using abbreviated form of field readings.

5.4.2.2 Well Field Adjustment Criteria

There are several criteria used in well field adjustment. The primary criteria used is the percentage of methane generated by each well.

Methane generation is an indicator of the healthy anaerobic state of the landfill and the proper operation of the landfill gas collection system. However, a decline in healthy productive state of the landfill is usually not immediately apparent from methane quality. Due to this several criteria must be considered at the same time.

The following are well field adjustment criteria and typical conditions for consideration:

- Methane generation rate;
- Temperature;
- Nitrogen (typically between 8% and 12%);
- General landfill gas ratios;
- Waste stream characteristics;
- Age of refuse;
- Oxygen quantity (typically below 1%, preferably less than 0.5%);
- Landfill cover/capping and its integrity in the proximity of the well;
- Depth of leachate within the landfill;
- Landfill construction factors including type of fill, size and shape of refuse mass, depth of fill, compaction of fill and leachate control methods);
- Seasonal, climatic, recent weather and other prolonged or extreme weather conditions such as droughts or floods;
- Proximity of the well to the side slope (within approximately 30 m may require conservative operation of the well);
- Landfill perimeter gas migration probes and surface emissions results; and
- Diurnal fluctuation (day to night) of atmospheric pressure.

5.4.2.3 Establishing Target Flows

For a given individual well, a target flow is established which will support stable methane and oxygen qualities while maximising the recovery of landfill gas.

Well adjustment is made in as small an increment as possible, preferably an increment of ten percent or less of the existing flow. There may be obvious conditions when this is not appropriate, such as when first opening a well or when serious over-extraction is recognised. Every effort should be made to make adjustments to operate as smooth as possible. Dramatic adjustments should be avoided.

Care must be taken to avoid over-extraction which may cause a subsurface fire. High well temperatures, typically over 60 ^{0}C, are an indication of aerobic activity and thus well over-pull. These effects may not be immediately apparent.

5.4.2.4 Well Field Optimisation

Every effort is made to continuously locate and correct or eliminate conditions (e.g. gas condensate, surging and blockage, settlement, etc.) which inhibit efficient operation of the gas collection system. This allows the monitoring and adjustment to be more effective.

5.4.3 Gas Extraction around the Working Face

The landfill working face shall be kept to a practicable minimum (<1000 m^2, see Landfill Operations Management Plan) and the Environmental Manager (or delegate) or the specialist landfill sub-contractor will as far as practicable maintain suction in the area surrounding the working face, to minimise gas odours. Note, other odour control measures around the working face include the use of daily cover and using a deodorising system, see also Landfill Operations Management Plan.

For vertical landfill gas extraction wells that are constructed as filling progresses, in-situ chimneys in the development will have gas tight covers fitted.

Lateral lines connected to the vertical gas extraction wells and remote extraction will be used to minimise gas escape around the working face as far as practicable.

5.5 Record Keeping

The Environmental Manager will keep a record of:

- Extraction well tuning results;
- Monthly inspection results;
- Well and gas reticulation installations;
- Up to date plan of extraction reticulation system;
- Exceedances;
- Contingency measures implemented;
- Calibration records; and
- Instrument prestart checks as per manufacturer specification.

6. Monitoring

6.1 General Landfill Gas Monitoring

The objectives of the landfill gas monitoring programme are to:

- Maintain protection of life and property from the hazards associated with landfill gas through monitoring of landfill gas volumes, composition and locations;
- Demonstrate that the gas extraction system and control measures are operating as designed;
- Demonstrate compliance with resource consent conditions; and
- Identify the need for and extent of remedial or mitigation measures to reduce effects on the environment.

6.1.1 Monitoring Schedule

The monitoring schedule for the landfill is presented in Table 6.1 below.

Surface emissions from the landfill are monitored in a pre-determined grid pattern over the intermediate and final capped areas of the landfill. In addition, surface emissions with be monitored at site specific features such as manholes, drainage channels and obvious cracks. Onsite buildings and the portable landfill office will also be monitored.

Subsurface gas migration from the site is to be monitored with a series of gas monitoring probes installed around the perimeter of the landfill. These are located between the landfill and onsite buildings. By monitoring at these locations, the safety of buildings and the risk of off-site migration can be managed.

Site weather conditions will be measured at Site 8.

Table 6.1: Landfill gas Monitoring Network

Site	Parameter	Location	Frequency
Gas Collection System	Damage/operation	Gas Collection Pipework	Monthly
Gas Extraction System	Gas flow, temperature, pressure, gas composition, damage/operation	Gas extraction wellheads	Monthly
Gas Treatment System	Gas flow, temperature, pressure, gas composition, damage/operation	Permanent Flare	Continuous
Surface Emissions	Methane	Grid pattern across intermediate & final covers, noted features such as cracks, drainage channels, onsite buildings & confined spaces.	Monthly
Subsurface Gas Monitoring Probes	Methane	Around landfill (see site plan in Attachment 1)	Monthly
Site 8	Wind Speed and Direction	Weather Station	At least hourly
Entire system	Damage/operation, odour, smoke, surface cracks, severe settlement or subsidence around wells, gas bubbles, liquid surging in the gas collection system or vegetation damage	Entire site	At least Weekly

6.1.2 Extraction Wells and Collection Pipework

The gas flow rate is to be monitored monthly at individual wellheads to assess well performance and optimise gas extraction. The landfill gas composition, pressure and temperature are monitored monthly at each wellhead to determine the quality of recovered landfill gas.

6.1.2.1 Gas Flaring System

Gas that enters the permanent gas flaring plant is monitored continuously for gas flow rate, pressure, and temperature and gas composition. This information will enable gas generation rates to be assessed and provide an indication of gas combustion efficiency.

6.1.2.2 Subsurface Gas Migration

Monitoring of the landfill gas monitoring probes along the perimeter of the landfill will enable the detection of subsurface gas migration and the determination of any gas migration patterns.

Methane concentration will be monitored on a monthly basis on each monitoring probe. The probes will be measured with a portable gas analyser and a log of readings and observations will be kept.

Attachment 1 contains copies of the stratigraphic and construction logs for the gas monitoring probes.

6.1.2.3 Site Weather Conditions

Site weather conditions including rainfall, wind velocity and direction, barometric pressure and temperature will be monitored continuously (at least once every hour). The information will be used to assist investigations and response to any odour complaints and interpretation of gas monitoring results.

6.1.2.5 Site Inspections

The purpose of routine site inspections is to ensure the safe and efficient operation of the landfill gas system to prevent equipment breakdowns and unscheduled maintenance. Repairs will be implemented as required. In addition to inspecting for damage and correct operation of equipment, the condition of the landfill surface is inspected and maintained. Any evidence of possible landfill gas leaks, including odour, smoke, surface cracks, severe settlement or subsidence around wells, gas bubbles, liquid surging in the gas collection system or vegetation damage will be investigated and appropriate remedial action taken as soon as possible.

The condition of the landfill gas system (extraction, collection and treatment) and landfill surface will be inspected at least once a week. A walkover site inspection log and site plan will be maintained, which will assist in recognising areas requiring corrective actions. Methane concentrations will be measured at least once a month at the surface of the landfill.

6.1.3 Equipment

Monitoring equipment is calibrated by independent contractors according to manufacturer's specifications.

Operating manuals for each item of equipment detail any daily or pre-operation calibration checks required.

6.1.4 Analytical Laboratory

If samples are taken for off-site analysis by an analytical laboratory, all chemical analysis will be carried out by an IANZ (Industry Accreditation New Zealand) or similar suitably qualified laboratory.

6.1.5 Training of Monitoring Staff

AB Lime staff members who carry out landfill gas monitoring (e.g. Landfill Technician) are trained using standard operating procedures. Monitoring will only be carried out by staff members who have been trained.

If contractors are used at any time for sampling or testing, they will be required to provide evidence of qualifications and/or experience and follow AB Lime's standard operating procedures.

6.1.6 Monitoring Records

AB Lime will maintain electronic records for gas monitoring. Hard copies of laboratory reports and field sheets are also kept.

A database will be maintained for all monitoring records and monitoring records will be provided to Environment Southland as per resource consent conditions requirements.

6.2 Extraction Well Monitoring

The Environmental Manager (or delegate) or specialist sub-contractor First Gas (or a similar qualified company) will monitor all extraction wells at least once and during a falling barometric pressure as far as practicable, unless a contingency event has occurred under which circumstances daily to weekly monitoring may be required on certain extraction wells.

Extraction well monitoring is undertaken using a portable landfill gas analyser in accordance with AB Lime standard operating procedure and equipment will be operated in accordance with the manufacturer's instructions.

Landfill gas extraction wells will be monitored monthly for:

- Gas flow rate (before and after adjustment of well head, if well head has been adjusted)
- Gas composition (% methane, % oxygen, % carbon-dioxide and ppm carbon-monoxide)
- Suction pressure (mBar)
- Gas temperature (^{0}C)
- Atmospheric air pressure (mBar)
- Any damage to the well head
- General operation of the well head (valves working properly, leakage around well head, surface water ponding around well head, etc.).

Records of all monitoring will be kept on site for analysis of historic trends of the landfill well head monitoring data.

Section 8 provides contingency measures for extraction well monitoring.

6.3 Migration Probe Monitoring

All migration probes will be monitored monthly in accordance with the AB Lime migration probe monitoring standard operating procedure (see Attachment 6) for:

- % methane;

- % oxygen;
- % carbon-dioxide; and
- Barometric pressure the day before, during and the day after monitoring.

Monitoring data along with any comments will be entered into the landfill gas migration probe monitoring database.

Within 1 week of the monthly migration probe monitoring the Environmental Technician will prepare a report summarising the monitoring rounds results for the Environmental Manager.

6.3.1 Interpretation of Results

If methane is detected in any migration probe the data will be reviewed by the Environmental Technician and the Environmental Manager who will discuss the monitoring results, identify any trends, potential problems and remediation options as required.

Trigger levels having been set to compare the monitoring data against. Unless otherwise stated in the relevant section of this report, the Environmental Manager will compare all monitoring data with the trigger levels set out in this report. Exceedance of trigger level requirement requires investigation and reporting and may require immediate remedial action.

6.3.1.1 Trigger Levels for Landfill Gas Migrate Probe Monitoring

Trigger levels are set at two levels, namely Trigger Level 1 or TL-1 (a lower response limit / warning level) and Trigger Level 2 or TL-2 (upper response limit / alarm level).

The TL-1 and TL-2 trigger levels for landfill gas migration probe monitoring are as follows:

- TL-1: 0.5% methane, i.e. 5000 ppm methane.
- TL-2: 1.25% methane, i.e. 12,500 ppm methane.

Exceedance of TL-1 warns of potential adverse effects, and potential future non-compliance with the resource consent conditions and results in a review of landfill management practices to identify and remedy the cause of the exceedance.

Exceedance of a TL-2 is a strong indication that significant adverse effects and breaches of consent conditions may already be occurring, or could have occurred, or are about to occur.

Responses to an exceedance of TL-1 and TL-2 are discussed in Section 8.

6.4 Structures and Confined Space Monitoring

All structures and confined spaces, e.g. stormwater monitoring chamber for the groundwater underdrain sampling location 13, located within 50 m of the landfill footprint where waste has been placed will be monitored on a monthly basis for methane, oxygen, carbon-dioxide and hydrogen sulphide.

6.4.1 Trigger Levels for Structures and Confined Space Monitoring

The trigger levels for structures and confined space monitoring will be:

- Methane: >0.25 %
- Oxygen: <19.5 %

- Hydrogen sulphide: >10 ppm

Responses to an exceedance of these trigger levels are discussed in Section 8.

6.5 Surface Emissions Monitoring

6.5.1 General

Monitoring of methane gas emissions from the surface of the landfill is undertaken to determine the rate at which gas is escaping from the permanently and temporary capped surface of the landfill and is used to:

- Provide assessment of landfill gas emissions to demonstrate compliance with the resource consent conditions (<5000 ppm or 0.5% methane);
- Provide assessment of landfill gas emissions to demonstrate compliance with the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (<5000 ppm or 0.5% methane);
- Assist when making decisions on the need for modifications to the gas extraction system in order to reduce potential odour nuisance and enhance gas extraction;
- Determine the need and locations of a landfill gas control system;
- Verify if an installed landfill gas control system is operating correctly; and
- Identify locations on the landfill surface where more detailed emission monitoring or surface remediation is required.

The Environmental Technician will conduct surface emission monitoring on a monthly basis over areas of the landfill that have had permanent capping and temporary capping placed.

The monitoring will be carried out in accordance with the AB Lime standard operating procedure for surface emission monitoring (see Attachment 6) using a calibrated and portable equipment such as a GES GasTec MK5 is a low-level hydrocarbon gas detector or similar suitable landfill gas monitoring equipment. For landfill gas surveys it is reasonable to assume that the all hydrocarbon detected is methane.

The surface emission monitoring will be carried out on a 50 m grid for the permanently capped areas of the landfill and a 25 m grid for the temporary/intermediate capped areas. A site plan showing a typical surface emission monitoring layout is contained in Attachment 7.

In addition to the surface emission grid monitoring testing should also be carried out:

- Around gas extraction well heads
- Along above ground or below ground landfill gas transmission/header pipework
- At cracks observed during the grid walk-over survey
- In areas where there is distress/dying of vegetation on the landfill surface cover

6.5.2 Interpretation of Surface Emission Monitoring

If methane is detected in during surface emission monitoring the data will be reviewed by the Environmental Technician and the Environmental Manager who will discuss the monitoring results, identify any trends, potential problems and remediation options as required.

6.5.2.1 Internal Trigger Level Exceeded (TL-1)

The AB lime internal trigger level (TL-1) for surface emission monitoring has been set as follows:

- For permanently capped areas: 0.05% or 500 ppm methane
- For temporary capped areas: 0.1% or 1000 ppm methane
- For discrete features, e.g. wellhead: 0.1% or 1000 ppm methane

6.5.2.2 Consent Compliance Level Exceeded (TL-2)

The AB lime consent compliance level (TL-2) for surface gas emission monitoring is 0.5% or 5000 ppm methane. For clarity, the TL-2 limit applies to the following parts of the landfill:

- For permanently capped areas: 0.5% or 5000 ppm methane
- For temporary capped areas: 0.5% or 5000 ppm methane
- For discrete features, e.g. wellhead: 0.5% or 5000 ppm methane

Responses to an exceedance of TL-1 and TL-2 are discussed in Section 8.

6.6 Flare Monitoring

A PLC continuously monitors the gas flare and its data is recorded on a data logger. The flare is monitored for:

- Temperature (^{0}C);
- Gas flow rate (m^3/hr);
- Gas composition (% methane, % oxygen, % carbon-dioxide, % nitrogen by calculation and ppm carbon-monoxide);
- Gas pressure;
- Pilot light activation; and
- Ignition system operation.

The inlet gas supply to the flare is monitored on a monthly basis, by appropriately qualified/experienced consultant for:

- Hydrogen sulphide (ppm); and
- Total Non-Methane Organic Compounds (NMOCs).

Monitoring results are forwarded to Environment Southland annually and this reporting requirements is in accordance with the resource consent conditions.

6.6.1 Daily Checks

The Environmental Manager (or delegate) will carry out the following daily checks:

- PLC data;

- Flare temperature;
- Pilot flame on the flare;
- Flare operation; and
- Security of flare compound (e.g. locked gate).

6.6.2 Weekly Checks

The Environmental Manager (or delegate) will carry out the following weekly checks:

- Condensate drains where fitted;
- Check ignition (correct sparking);
- Visual check on flare structure; and
- Visual leaks of the pipework extraction system.

6.6.3 Monthly Checks

The Environmental Manager (or delegate) will carry out the following monthly checks:

- Engage gas sub-contractor Ultra Gas or similar qualified company to check the landfill gas extraction system.

6.6.4 Six-Monthly Checks

The Environmental Manager (or delegate) will carry out the following six-monthly checks:

- Engage gas sub-contractor Ultra Gas or similar qualified company to calibrate the flare gas composition sensors.

6.6.5 Two-Yearly Checks

The Environmental Manager (or delegate) will carry out the following two-yearly checks:

- Engage gas sub-contractor Ultra Gas or similar qualified company to calibrate the flow meter.

6.7 Weekly Walk-Over Site Inspection of Landfill

The Environmental Technician will carry out a weekly walk-over site inspection of the landfill and record the presence/absence of the following:

- Any evidence of possible landfill gas leaks, including:
    - Odour nuisance;
    - Surface cracks or fissures in the landfill capping;
    - Gas bubbles;
    - Vegetation damage or stressed vegetation; and
    - Low points in the above-ground gas lines where gas condensate may collect.

The walk-over site inspection shall include:

- Interfaces between the permanently and temporary capped zones;
- Side slopes of the landfill;
- Around all gas extraction wells and well-head monitoring points;
- At junctions in the gas collection pipework;
- Pathways were pipework is buried in trenches;
- Leachate riser/clean out pipes; and
- Liquid discharge infrastructure (leachate recirculation techniques or condensate discharge).

6.8 Landfill Subsurface Fire

If large quantities of air are introduced into the landfill, either through damage or incorrect operation of the landfill gas extraction system, or inappropriate and/or insufficient landfill capping, subsurface combustion of the buried refuse may be ignited.

Subsurface fire situations are difficult to control or extinguish once started, present health and safety hazards, and can be costly to the landfill operator. Therefore, minimising the risk of a subsurface fire by good operation of the landfill gas collection system and maintenance of the landfill cover is the best course of action.

The presence of carbon-monoxide, carbon-dioxide and SO_2 (which is a product of H_2S combustion) are indicators of subsurface combustion within the landfill, as well as elevated temperatures measured at the gas extraction wells head.

6.8.1 Temperature Monitoring

Monitoring of landfill internal temperature is useful for establishing the risk of a or extent of a fire. Gas that enters the permanent gas flaring plant is monitored continuously for temperature.

Table 6.2: Landfill temperature and relating conditions

Temperature	Landfill Conditions
< 55°C	Natural Landfill Temperature
55 – 60° C	Elevated Biological Activity
60 – 70° C	Abnormally Elevated Biological Activity
> 70° C	Likelihood of Landfill Fire

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6.8.2 Gas Composition Monitoring

Gases within the waste are useful indicators of sub surface conditions and the potential for fire. Parameters monitored at the extraction well-head relating to the potential for fire include methane, oxygen, carbon monoxide and hydrogen sulphide.

Carbon monoxide is the most useful indicator of a subsurface fire. Gas that enters the permanent gas flaring plant is monitored continuously for gas composition.

Table 6.3: CO Concentration in relation to fire indication

CO Concentration (ppm)	Fire Indication
0 – 25	No fire indication

CO Concentration (ppm)	Fire Indication
25 – 100	Possible fire in area
100 – 500	Potential smouldering nearby
500 – 1000	Fire or exothermic reaction likely
> 1000	Fire in area

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The presence of oxygen at concentrations above 1% provides an indication that existing oxygen intrusion barriers (i.e. cover or capping) are not effective in keeping oxygen out and that additional cover is required.

Five percent (5%) oxygen and above can activate fire conditions.

6.8.3 Characterisation of a Fire

The ISWA Landfill operational guidelines refer to the classification of fires into 4 categories with corresponding levels of alert.

Table 6.4: ISWA Landfill Fire Alert Classifications

Category	Classification
Level 1 Alerts	Small fires – not involving landfill waste e.g. vehicle fires, equipment or office fires
Level 2 Alerts	Small waste fires – can be contained by on-site resources within 24 hours and fully extinguished in 48 hours. These typically involve less than 200m^3 of burning material
Level 3 Alerts	Medium size waste fires that can be contained in less than a week and that can be fully extinguished in less than 2 weeks. Typically, 200 to 5,000 m^3 of waste material involved
Level 4 Alerts	Large or deep-seated landfill fires that require more than 2 weeks to contain typically involving more than 5,000m^3 of burning waste

A contingency plan for landfill subsurface fires is presented in Section 8.

7. Reporting

Table 7.1 below provides a summary of the reporting requirements to Environment Southland. The minimum level of information for the gas monitoring reports also includes:

- Site plan where monitoring was undertaken;
- Time and date of monitoring;
- Meteorological conditions when monitoring was undertaken (including weather conditions and barometric pressure);
- Copy of raw data;
- Calibration certificates for instruments used and details of gas bump tests undertaken on the day of monitoring to verify instrument was functioning correctly; and
- Report of visual inspection of the cap, gas extraction or monitoring well (as applicable)

Table 7.1: Landfill Gas Monitoring and Management Reporting Requirements to Environment Southland

Site	Parameter	Detection Limit	Trigger Level		Monitoring Frequency	Report to SRC
			TL1	TL2		
Extraction wellheads	Methane	%	-	N/A	Monthly	Annual
	Carbon dioxide	%	-	N/A	Monthly	Annual
	Oxygen	%	-	N/A	Monthly	Annual
	Residual Nitrogen	%	-	N/A	Monthly	Annual
	Carbon Monoxide	ppm	-	N/A	Monthly	Annual
	Hydrogen Sulphide	ppm	-	N/A	Monthly	Annual
	Gas Flow Rate	m^3/hr	-	N/A	Monthly	Annual
	Gas Pressure	mBar	-	N/A	Monthly	Annual
	Gas Temperature	°C	-	N/A	Monthly	Annual
	Atmospheric pressure	mBar	-	N/A	Monthly	-
	Damage to well-head	-	-	Check functioning	Monthly	-
	Valve operation on well-head	-	-	Check functioning	Monthly	-
Permanent Gas Flare	Gas Flow Rate	m^3/hr	-	N/A	Continuous	Annual
	Gas Pressure	mBar	-	N/A	Continuous	Annual
	Gas Temperature	°C	-	N/A	Continuous	Annual
	Methane	%	-		Continuous	Annual
	Carbon dioxide	%	-		Continuous	Annual
	Residual nitrogen	%	-		Continuous	Annual
	Oxygen	%	-		Continuous	Annual
	Carbon monoxide	ppm	-		Continuous	Annual
	Hydrogen Sulphide	ppm	-		Monthly	Annual
	Total-Methane Organic Compounds	ppm	- -	>98% combustion	Monthly	Annual
Monitoring Probes	Methane	%	0.5%	1.25%	Monthly	Annual
	Carbon dioxide	%	-	N/A	Monthly	-
	Oxygen	%	-	N/A	Monthly	-
Site 8	Barometric Pressure		-	N/A	Continuous	Annual
	Wind Direction	o	-	N/A	Continuous	Annual
	Wind Velocity	m/s	-	N/A	Continuous	Annual
	Air Temperature	°C	-	N/A	Continuous	Annual
	Rainfall	mm	-	N/A	Continuous	Annual
Final cap	Methane	%	0.05%	0.5%	Monthly	Annual
Temporary Cap	Methane	%	0.1%	0.5%	Monthly	Annual
Well-heads, etc	Methane	%	0.1%	0.5%	Monthly	Annual
Site walk-over inspection				Gas leaks	Weekly	Annual
Landfill gas system	Operational/damage	-	Malfunction	N/A	Monthly	Annual
	Condensate		Malfunction	N/A	Monthly	-
Structures	Methane	%	>0.25%	N/A	Monthly	-
	Oxygen	%	<19.5	N/A	Monthly	-

	Hydrogen sulphide	ppm	>10 ppm	N/A	Monthly	-

8. Contingency Measures

8.1 Extraction Well Monitoring Contingency Measures

If the target gas composition levels cannot be achieved the Environmental Manager, with the assistance of the specialist subcontractor First Gas where appropriate, investigate the cause by reviewing:

- Trends is gas composition levels; and
- Recent surface landfill gas emissions results in the area

Depending on the outcome of this investigation the Environmental Manager will make a recommendation to the Landfill Manager.

Wells with well-head temperatures greater than 60 ^{0}C will be closed and monitored for carbon-monoxide. Neighbouring wells will be checked for temperature and carbon-monoxide concentration.

Concentrations of carbon-monoxide exceeding 100 ppm in wells will be monitored daily. If the concentration of carbon-monoxide continues to increase, then the extraction of the affected well shall be reduced or stopped.

If wells are closed, it is expected that the temperatures will fall to ambient levels as there is no extracted gas flow to provide heat. The well will be reopened after a few days with very low flow so true temperatures can be evaluated. Once the gas temperature falls below 40 ^{0}C and the concentration of carbon-monoxide is less than 100 ppm, the extraction flow will then be increased gradually over a period of several weeks with the well temperature being monitored regularly.

All wells being re-tested because of elevated gas temperatures (>50 ^{0}C) or having a carbon-monoxide level over 100 ppm and rising, shall be reported to the Landfill Manager as soon as practical.

8.2 Migration Probe Monitoring Contingency Measures

8.2.1 Internal Trigger Level Exceeded (TL-1)

The AB lime TL-1 for migration probe monitoring has been set at 0.5% or 5000 ppm methane.

Response if TL-1 is exceeded:

- Confirm that exceedance is 'real' and not an instrument error or 'rogue' result by:
    a) Carrying out a second and third monitoring round at the gas probe, with 2 hours between each monitoring round.
    b) Checking perimeter probe history.
    c) Check the landfill gas analyser.
    d) Conduct additional purging of landfill gas from the probe.
    e) Assess if the gas ratios are indicative of landfill gas or source of contamination.
- If exceedance is real:
    a) Immediately advise the Environmental Manager.
    b) Increase extraction on the nearest extraction wells and perform any repairs if necessary.

c) Conduct daily monitoring on the affected probes until results have returned below the TL-1 level on three consecutive occasions.

8.2.2 Consent Compliance Level Exceeded (TL-2)

The AB lime consent compliance level (TL-2) for migration probe monitoring is 1.25% methane.

In the event of an exceedance of the TL-2 in a migration probe the response will be as follows:

- Confirm that exceedance is 'real' and not an instrument error or 'rogue' result by:

  a) Carrying out a second and third monitoring round at the gas probe, with 2 hours between each monitoring round.

  b) Checking perimeter probe monitoring history.

  c) Check the landfill gas analyser.

  d) Conduct additional purging of landfill gas from the probe.

  e) Assess if the gas ratios are indicative of landfill gas or source of contamination.

- If exceedance is real:

  a) Immediately advise the Environmental Manager and Landfill Manager.

  b) Increase extraction on the nearest extraction wells and perform any repairs if necessary.

  c) Conduct daily monitoring on the affected probes until results have returned below the TL-1 level on three consecutive occasions.

  d) If the measures in items a) to c) above are unsuccessful the Landfill Manager will notify the SRC and Independent Peer Reviewer of the exceedance within 24 hours of the readings.

  e) Discuss with SRC and IPR and submit for their approval a remediation and monitoring plan, that must include as a minimum:

    - The vacuum/extraction of the auxiliary gas extraction system will be increased to mitigate effects;

    - Additional landfill gas extraction wells may be installed to mitigate effects; and

    - Additional landfill gas perimeter probes may be installed to assess the extent and likely source of landfill gas migration from the landfill to the landfill perimeter probe.

  f) Conduct daily monitoring on the affected probes until results have returned to below the TL-1 level on three consecutive occasions.

  g) Commence weekly monitoring on all probes.

  h) Advise any potentially affected neighbours if exceedances continue.

8.3 Structures and Confined Space Monitoring Contingency Measures

If the structures and confined space monitoring trigger levels (see Section 6) are exceeded the response will be as follows:

- Confirm that exceedance is 'real' and not an instrument error or 'rogue' result by:
  a) Carrying out a second and third monitoring round at the affected location, with 2 hours between each monitoring round
  b) Checking monitoring history at the affected location
  c) Check the landfill gas analyser
  d) Assess if the gas ratios are indicative of landfill gas or source of contamination.
- If exceedance is real:
  a) Isolate the area, advise affected staff and evacuate the area if required.
  b) Lockout electrical equipment and place signs of danger around isolated area.
  c) Immediately advise the Environmental Manager and Landfill Manager.
  d) Vent area either naturally or using forced air flow.
  e) Increase extraction on the nearest extraction wells and perform any repairs if necessary.
  f) Conduct daily monitoring in the affected locations until results have returned below 0.25% methane, oxygen levels are above 19.5% and hydrogen sulphide concentrations are below 10 ppm, on three consecutive occasions.
  g) Advise affected staff if exceedances continue.
  h) Investigate and report on remedial actions required.

8.4 Landfill Surface Emission Monitoring Contingency Measures

8.4.1 Internal Trigger Level Exceeded (TL-1)

The AB lime internal trigger level (TL-1) for surface emission monitoring has been set as follows:

- For permanently capped areas: 0.05% or 500 ppm methane
- For temporary capped areas: 0.1% or 1000 ppm methane
- For discrete features, e.g. wellhead: 0.1% or 1000 ppm methane

Response if TL-1 is exceeded:

- Confirm that exceedance is 'real' and not an instrument error or 'rogue' result by:
  a) Within a 5 m radius of the location where the TL-1 level is exceeded, carry out additional monitoring of a 1 m grid.

b) Carrying out a second and third monitoring round at the affected location, with 2 hours between each monitoring round.

c) Checking affected location monitoring result history.

d) Check the landfill gas analyser is operating correctly.

- If exceedance is real:

a) Immediately advise the Environmental Manager.

b) Assess if landfill capping/cover repair work is required near the affected location.

c) Assess if the gas extraction wellhead repair is required, or landfill capping/cover near wellhead.

d) Assess if leachate levels are high within the landfill and if leachate levels can be lowered in the landfill by pumping leachate from affected or nearby wells.

e) Increase gas extraction on the nearest extraction well(s).

f) Discuss with the Environmental Manager and Landfill Manager an appropriate strategy to minimise the risk that the compliance level (TL-2) will be exceeded.

g) Conduct surface emission monitoring on a daily basis until three successive monitoring rounds show results below the TL-1 criteria.

8.4.2 Consent Compliance Level Exceeded (TL-2)

The AB lime consent compliance level (TL-2) for surface gas emission monitoring is 0.5% or 5000 ppm methane. For clarity, the TL-2 limit applies to the following parts of the landfill:

- For permanently capped areas: 0.5% or 5000 ppm methane
- For temporary capped areas: 0.5% or 5000 ppm methane
- For discrete features, e.g. wellhead: 0.5% or 5000 ppm methane

In the event of an exceedance of the TL-2 limit in the permanently capped areas, the temporary capped areas or at distinct features the Environmental Manager, Landfill Manager, Jacobs (design consultants) and the specialist subconsultant First Gas (or similar qualified company) will prepare a more detailed programme of remedial works for the Landfill Manager approval.

Options for such a programme include:

- Repair and replace sections of the permanent or intermediate capping as required; and
- Installation of new gas extraction wells in the areas of concern and connection to the landfill gas extraction system as soon as practicable.

On completion of the remedial works the methane concentrations will be retested and a report submitted to the Landfill Manager summarising the actions undertaken and the re-testing results.

8.5 Gas Extraction System Shutdown Contingency Response

If the landfill gas extraction system is shut down for more than 24 hours the response will be as follows:

- Use the backup flares;
- Commence daily migration probe monitoring for methane, oxygen and carbon-dioxide until the system becomes operable;
- The Environmental Manager or specialist subcontractor First Gas (or similar qualified company) will prepare a report summarising the monitoring results, reasons for the shutdown and remedial actions taken to prevent recurrence of a similar shutdown event for the Landfill Manager, within one week of the shutdown;
- The report will be forwarded to SRC within two weeks of the extraction system shutdown;
- If the extraction system is likely to be shut down for an extended period that may lead to perimeter probe exceedances above the TL-2 level, alternative means of gas management will be investigated which may include temporary flares or temporary generators to run the extraction plant; and
- Temporary gas mitigation plans will be implemented in consultation with and approval from Environment Southland.

8.6 Gas Collection Pipework Contingency

If there are actual or suspected blockages in the above-ground gas collection pipework, the following will be observed:

- Only certified gasfitters are able to work on the gas collection pipework;
- Blockages are to be removed;
- Low points in the condensate pipes are to be raised;
- Condensate traps will be installed; and
- Condensate will be reintroduced into the landfill of piped to the leachate system.

8.7 Landfill Fire Contingency

Refer to AB Lime's specific Emergency Response Plan and Health and Safety Procedures. The Emergency Response Plan includes essential issues related to the landfill including:

- Site characteristics;
- Firefighting resources;
- Landfill fire alert levels (see Section 6);
- Incident command structure;
- Fire response actions and responsibilities;
- Firefighting methods;
- Landfill fire risk reduction strategies;
- Personal protective equipment;
- Personnel training; and

- The occurrence of a fire constitutes an incident and reporting is to be undertaken in accordance with the Health and Safety Procedure.

8.7.1 Contingency Plan

Table 8.1: Landfill Fire Responses

Contingency triggering event	Response guidelines
Smoke and odour detected	Advise **Site Management** immediately Immediate spotting of the fire Determine Fire Level 1 or 2
Level 2 fire	Advise **Site Management** immediately Management to Contact Emergency Services if necessary Shut off the landfill gas collection and management system Mobilize on site-firefighting resources – follow Emergency Response Plan and H & S procedures

9. Post Closure Landfill Gas Management

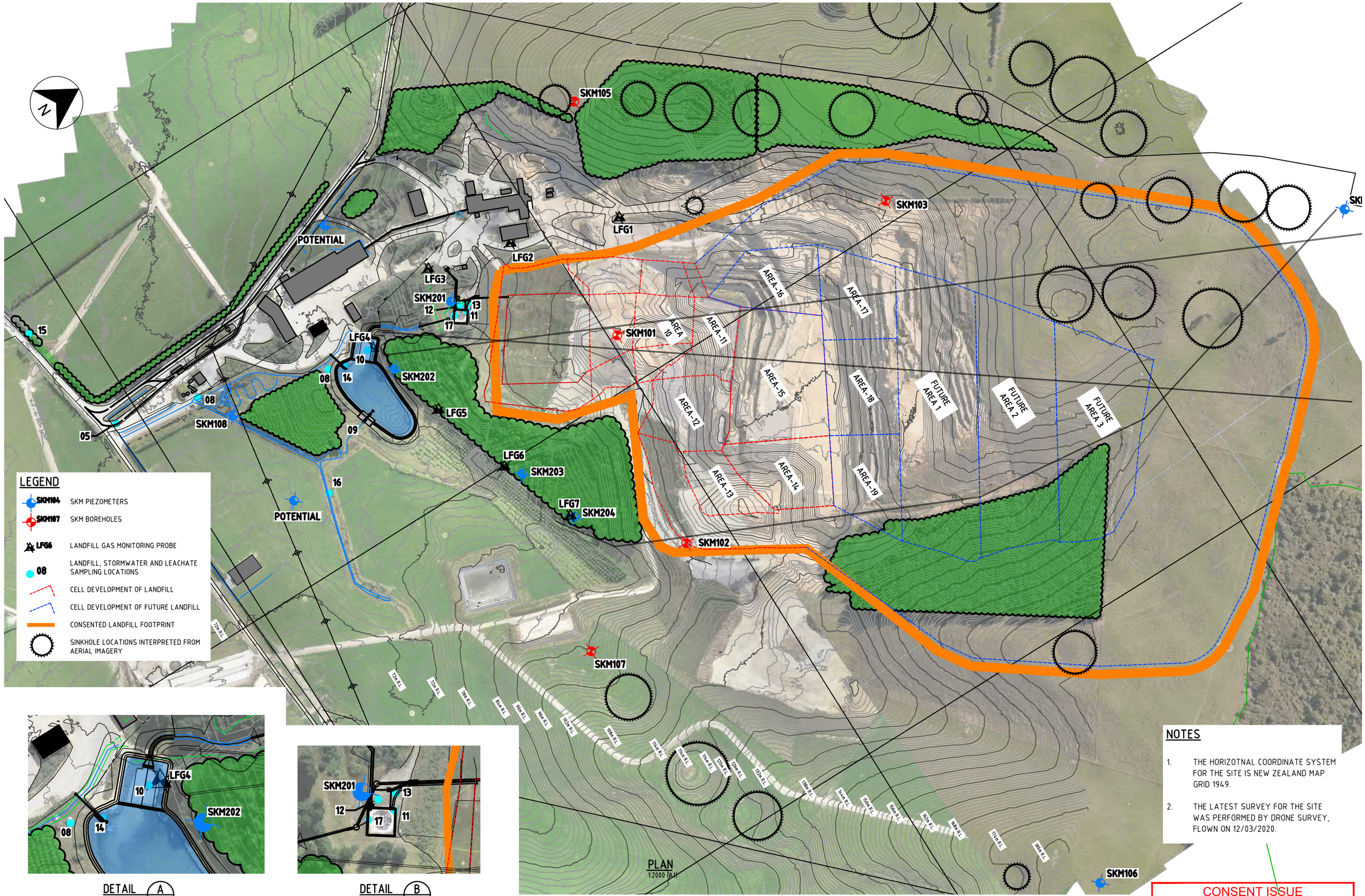
Post closure of the landfill, environmental monitoring will continue as per the monitoring and contingency section of this plan and will form part of an updated Landfill Concept, Landscape, Rehabilitation and Aftercare Plan.

As the landfill is restored and eventually closed the Trigger Levels and frequency of monitoring may be varied to match the changing environmental risk.

Any changes to the regime will be proposed through a change to the monitoring and contingency plan, which must be approved by Environment Southland.

Attachment 1. Landfill Gas Migration Probes- Locations and Probe Design

DATE: 20/04/2021 13:35:43 NAME: HOBDAY, MIA
LOCATION: C:\users\hobdaym\appdata\local\projectwise\jacobs_anz_ie\d0213192\IZ000400-1000-NG-DRG-1008.dwg



LEGEND

- SKM104 — SKM PIEZOMETERS
- SKM107 — SKM BOREHOLES
- LFG6 — LANDFILL GAS MONITORING PROBE
- 08 — LANDFILL, STORMWATER AND LEACHATE SAMPLING LOCATIONS
- CELL DEVELOPMENT OF LANDFILL
- CELL DEVELOPMENT OF FUTURE LANDFILL
- CONSENTED LANDFILL FOOTPRINT
- SINKHOLE LOCATIONS INTERPRETED FROM AERIAL IMAGERY

DETAIL A
1:1000

DETAIL B
1:1000

PLAN
1:2000 (A1)

NOTES

1. THE HORIZOTNAL COORDINATE SYSTEM FOR THE SITE IS NEW ZEALAND MAP GRID 1949.
2. THE LATEST SURVEY FOR THE SITE WAS PERFORMED BY DRONE SURVEY, FLOWN ON 12/03/2020.

CONSENT ISSUE

REV	DATE	APP'D	REVISION
0	19.03.21	VP	CONSENT ISSUE - FOR HEARING
A	29.05.20	VP	CONSENT ISSUE

SCALES AT A1

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CLIENT	AB LIME LTD.		
PROJECT	LANDFILL INVESTIGATION		
DRAWN NBL	DRAWING CHECK KJ	REVIEWED CW DATE 19.03.2021	APPROVED VP DATE 19.03.2021
DESIGNED LJ	DESIGN REVIEW CW		

TITLE
GROUNDWATER, STORMWATER & GAS BOREHOLE LOCATIONS PLAN

SCALE	DRAWING No	REV
AS SHOWN	IZ000400-1000-NG-DRG-1008	0

A1

BOREHOLE LFG1

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	99.89 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	100.68 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5443082.8 N 2152830.9	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
1		SILT - Light brown clayey SILT, sl. sandy, occ. yellow brown fine to coarse angular limestone gravels, mod. plastic, firm, moist [COLLUVIUM].	98.9		Concrete seal
		- 1.98 m core loss from 0 to 2.83 m.			Bentonite seal
2			97.9		Blinding sand
3		LIMESTONE - Yellow brown biosparite LIMESTONE, sl. weathered to mod. weathered, very weak to mod. strong, very thin to thinly bedded with interbedded thin (<0.34 m) soft orange brown non-plastic clayey silt horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].	96.9		Filter sock
		- 0.91 m core loss from 2.83 to 4.66 m.			
		- silt horizons at 2.49 (0.34 m), 2.87 (0.09 m), 3.61 (0.14 m) and 4.56 (0.13 m).			
4		- fractures at 3.01 (0.12 m) and 3.19 m (0.14 m).	95.9		
5		LIMESTONE - Greenish grey biosparite LIMESTONE, mod. weathered, very weak to mod. strong, massive, skeletal fragments, trace black specks, occ. brown staining [FOREST HILL FORMATION].	94.9		
6			93.9		
7		- gradually becoming browner in colour.	92.9		
8		- 0.83 m core recovery from 7.46 to 8.83 m.	91.9		
9		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, thinly to medium bedded with interbedded thin (<0.04 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].	90.9		
		- soft horizons at 8.63, 8.71, 8.91 and 9.46 m.			
10		- fractures at 8.71 (0.11 m), 9.15 (0.15 m), 9.49 (0.08 m) and 10.23 m (0.06 m). Occ. black specks in fracture at 10.23 m.	89.9		
		- 0.54 m core recovery between 10.32 and 11.32 m.			
11			88.9		
		- soft horizon at 11.52, 11.66, 12.29 (0.12 m thick), 12.56 and 12.65 m.			Grade 7/14 Walton Park

DRILLING DETAILS

Drilled Depth:	25.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	12/07/03
Date Borehole Completed:	14/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG1

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	99.89 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	100.68 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5443082.8 N 2152830.9	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
		- fractures at 11.74, 12.17 (0.03 m), and 12.26 m (0.03 m).			gravel 50 mm Class E PVC piezometer
13		- fractures at 13.72 (0.04 m), 13.77 (0.08 m), 14.79 (0.08 m), 15.00 (0.10 m) and 15.30 m (0.08 m). Reddish brown staining & occ. black specks in cracks.	86.9		
14			85.9		
15		- soft horizons at 14.7 and 15.86 m.	84.9		
16		- fractures at 15.92 (0.05 m), 16.07 (0.03 m), 16.35 (0.03 m), 16.67 (0.06 m), 17.82 (0.09 m), 18.76 (0.06 m), 19.95 (0.19 m), 18.60 (0.05 m), 21.72 (0.02 m) and 22.25 m (0.02 m). Reddish brown staining in fractures at 15.92, 16.67 and 18.60 m.	83.9	▽	
17		- greenish grey staining at 16.38 (0.04 m) and 16.74 m (0.07 m).	82.9		
18		- soft horizons at 17.43, 17.55, 18.87, 20.91, 21.72, 22.25, 22.92, 23.17, 23.35 m. Reddish brown staining in soft horizon at 23.17 m.	81.9		
19			80.9		
20			79.9		20.3 m machine slotted screen (0.5 mm screen)
21			78.9		
22			77.9		
23			76.9		Backfill

DRILLING DETAILS

Drilled Depth:	25.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	12/07/03
Date Borehole Completed:	14/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG1

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	99.89 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	100.68 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5443082.8 N 2152830.9	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
25		EOH @ 25.0 m (target depth reached).	74.9		
26			73.9		
27			72.9		
28			71.9		
29			70.9		
30			69.9		
31			68.9		
32			67.9		
33			66.9		
34			65.9		
35			64.9		

DRILLING DETAILS

Drilled Depth:	25.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	12/07/03
Date Borehole Completed:	14/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG2

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	88.38 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	89.13 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442962.3 N 2152789.7	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
0		TOPSOIL - Brown clayey SILT, mod. plastic, firm, moist, trace reddish brown limonite inclusions [TOPSOIL].			Concrete seal
		SILT - Orange brown clayey SILT, mod. plastic, firm, moist, trace brown limonite inclusions [ALLUVIUM].			Bentonite seal
1			87.4		Blinding sand
2			86.4		
		- 1.42 m core loss from 0 to 2.68 m.			
3		- soft horizon at 2.85 m.	85.4		Filter sock
		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, very thin to thinly bedded with interbedded thin (<0.08 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].			
4			84.4		
		- soft horizons at 3.10, 3.28, 3.83, 4.01, 4.18, 4.50, 4.61, 4.89, 5.03 and 5.21 m.			
		- fractures at 3.88 (0.07 m), 5.38 (0.10 m), 5.78 m. Orange brown staining in cracks.			
5		- increase in black specks from 4.52 to 4.60 m.	83.4		
6			82.4		
		- soft horizons at 6.62, 6.72, 6.79, 7.01, 7.45, 7.73, 7.98 and 8.34 m.			
7			81.4		
		- greenish grey staining at 7.26 (0.08 m) and 7.48 m (0.03 m).			50 mm Class E PVC piezometer
8			80.4		Grade 7/14 Walton Park gravel
		- fractures at 8.68 (0.20 m) and 9.24 (0.12 m).		▽	
9		- increased black specks from 8.92 to 8.98 m.	79.4		
		- soft horizons at 9.20, 9.36, 10.20, 10.40 and 10.95 m.			
10			78.4		13.5 m machine slotted screen (0.5 mm screen)
11			77.4		

DRILLING DETAILS

Drilled Depth:	15.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	10/07/03
Date Borehole Completed:	11/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG2

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	88.38 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	89.13 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442962.3 N 2152789.7	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
13		- soft horizons at 12.35, 12.66 and 13.26 m. - fracture at 12.71 m (0.18 m). Orange brown staining & occ. black specks in crack.	75.4		
14		LIMESTONE - Greenish grey biomicrite LIMESTONE, mod. weathered, very weak, massive, skeletal fragments, trace black specks, occ. orange brown streaks [FOREST HILL FORMATION].	74.4		
15		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, medium bedded with interbedded thin (<0.06 m) soft horizons, skeletal fragments, trace black specks [FOREST HILL FORMATION]. - soft horizons at 14.18 and 14.63 m. EOH @ 15.0 m (target depth reached).	73.4		
16			72.4		
17			71.4		
18			70.4		
19			69.4		
20			68.4		
21			67.4		
22			66.4		
23			65.4		

DRILLING DETAILS

Drilled Depth:	15.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	10/07/03
Date Borehole Completed:	11/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG3

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	81.92 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	82.75 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442867.2 N 2152764.8	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
1		FILL - Greyish brown clayey SILT, occ. yellow brown and grey medium to coarse angular gravels (limestone chips and basaltic gravels) [FILL].	80.9		Concrete seal; Bentonite seal; Blinding sand
2		- greyish brown silt matrix washed away during drilling. LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, thin to medium bedded with interbedded thin (<0.08 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].	79.9		
3		- fractures at 1.72 (0.10 m), 1.85 (0.07 m), 2.01 (0.14 m), 2.29 (0.16 m), 2.62 (0.08 m) and 3.00 m (0.08 m). Reddish brown staining and occ. black pyrite specks in cracks.	78.9		Filter sock
4		- soft horizons at 2.45, 2.61, 3.08, 3.65, 3.87, 4.18, 4.38, 4.50 and 4.66 m. - 1.65 m core loss from 0 to 2.85 m.	77.9		
5			76.9		Grade 7/14 Walton Park gravel; 50 mm Class E PVC piezometer
6			75.9	▽	6.5 m machine slotted screen (0.5 mm screen)
7		- soft horizons at 6.36, 6.55, 6.65, 6.75, 6.93, 7.03, 7.22 and 7.31 m. - fracture at 6.85 m (0.37 m). Black staining in crack.	74.9		
8		EOH @ 8.05 m (target depth reached).	73.9		
9			72.9		
10			71.9		
11			70.9		

DRILLING DETAILS

Drilled Depth:	7.90 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	10/07/03
Date Borehole Completed:	10/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (1 hr).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG4

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	73.16 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	73.88 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442765.9 N 2152808.0	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
0		TOPSOIL - Brown clayey SILT, moist, firm, mod. plastic, rootlets [TOPSOIL].			Concrete seal
		SILT - Light brown clayey SILT, firm, plastic, moist, occ. brown limonite nodules, occ. reddish brown staining [ALLUVIUM].			Bentonite seal
1		- soft.	72.2		Blinding sand
		SILT - Light grey clayey SILT, firm, mod. plastic to plastic, moist, occ. brown limonite nodules, occ. orange brown streaks [ALLUVIUM].			
2		- 0.85 m core loss from 0 to 2.98 m. - soft from 1.65 to 2.08 m. - black staining from 1.83 to 3.28 m. - loss of core from 2.08 m.	71.2		Filter sock
3			70.2		
4		- decrease in orange brown staining.	69.2		Grade 7/14 Walton Park gravel
5			68.2	▽	50 mm Class E PVC piezometer
6		- loss of core from 4.26 m.	67.2		5.8 m machine slotted screen (0.5 mm screen)
		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, thin to thinly bedded with interbedded thin (<0.05 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].			
7		- soft horizons at 6.46, 6.58, 6.80, 6.88 and 7.03 m. - fracture at 6.95 (0.10 m). Reddish brown staining in crack. EOH @ 7.30 m (target depth reached).	66.2		
8			65.2		
9			64.2		
10			63.2		
11			62.2		

DRILLING DETAILS

Drilled Depth:	7.30 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	09/07/03
Date Borehole Completed:	09/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG5

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	75.65 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	76.47 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442791.9 N 2152906.9	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
0		SILT - Light brown clayey SILT, moist, firm to stiff, plastic, trace brown limonite nodules [ALLUVIUM].			Concrete seal
1		- orange brown and pale grey silty inclusions.	74.7		Bentonite seal; Blinding sand
2		SILT - Orange brown clayey SILT, moist, firm to stiff, non-plastic, trace brown limonite nodules and light grey silty inclusions [ALLUVIUM].	73.7		
		- 2.39 to 2.46 m, increase in limonitic nodules. - reddish brown streaks.			
3			72.7		Filter sock
4		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, medium bedded with interbedded thin (<0.02 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].	71.7		Grade 7/14 Walton Park gravel
5		- soft horizons at 4.36 and 5.06 m. - fractures at 4.45 (0.07 m), 4.65 (0.07 m) and 5.94 m (0.04 m). Reddish brown staining in cracks.	70.7		50 mm Class E PVC piezometer
6		LIMESTONE - Light greenish grey biomicrite LIMESTONE, unweathered to sl. weathered, weak to mod. strong, massive, skeletal fragments, trace black specks, occ. orange brown staining [FOREST HILL FORMATION].	69.7		5.8 m machine slotted screen (0.5 mm screen)
7		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, medium bedded, skeletal fragments, trace black specks [FOREST HILL FORMATION].	68.7	▽	
8		- horizontal tight and smooth undulating fracture with reddish brown staining. EOH @ 7.36 m (target depth reached).	67.7		
9			66.7		
10			65.7		
11			64.7		

DRILLING DETAILS

Drilled Depth:	7.36 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	07/07/03
Date Borehole Completed:	08/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (15 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG6

SINCLAIR KNIGHT MERZ

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Project:	AB Lime Borehole Installation	**Ground Elevation:**	73.38 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	74.16 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442821.1 N 2153001.7	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
0		TOPSOIL - Brown clayey SILT, moist, firm, non-plastic, trace black limonite inclusions, rootlets [TOPSOIL].			Concrete seal
		SILT - Greyish brown clayey SILT, firm, moist, mod. plastic, occ. black limonite inclusions, occ. reddish brown streaks [ALLUVIUM].			Bentonite seal
1		SILT - Orange brown clayey SILT, firm, moist, non-plastic, occ. black limonite inclusions, occ. reddish brown staining [ALLUVIUM].	72.4		Blinding sand
2			71.4		Filter sock
3		- decrease in black limonite inclusions, mod. plastic.	70.4		Grade 7/14 Walton Park gravel
4		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, very thin to thinly bedded with interbedded thin (<0.02 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].	69.4	▽	50 mm Class E PVC piezometer
5		- fractures at 4.32 (0.21 m) and 4.67 m (0.12 m). Orange staining in crack at 4.32 m.	68.4		3.5 m machine slotted screen (0.5 mm screen)
6		- soft horizons at 4.53 and 4.65 m. - 3.83 m lost core from 2.88 to 5.10 m. EOH @ 5.10 m (target depth reached).	67.4		
7			66.4		
8			65.4		
9			64.4		
10			63.4		
11			62.4		

DRILLING DETAILS

Drilled Depth:	5.10 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	06/07/03
Date Borehole Completed:	07/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (15 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

BOREHOLE LFG7

SINCLAIR KNIGHT MERZ

Sinclair Knight Merz Ltd.
25 Teed St, Newmarket
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Fax: +64 9 913 8901

Project:	AB Lime Borehole Installation	**Ground Elevation:**	76.00 mAMSL
Job Number:	AE02098.11	**Top of Casing Elev.:**	76.71 mAMSL
Location:	AB Lime Ltd, Winton, SOUTHLAND	**Drilling Method:**	HQ Core
Coordinates:	E 5442855.2 N 2153089.1	**Sampling Method:**	Core

Depth (mBGL)	Graphic Log	LITHOLOGICAL DESCRIPTION	Elevation (mAMSL)	Groundwater Level	Piezometer Construction Details
0		TOPSOIL - Brown clayey SILT, wet, non-plastic, very soft, rootlets [TOPSOIL].			Concrete seal
		SILT - Orange brown clayey SILT, moist, mod. plastic, firm to stiff, trace reddish brown streaks, trace brown limonitic inclusions [ALLUVIUM].			Bentonite seal
1			75.0		Blinding sand
		- increase in reddish brown streaks and brown limonite inclusions.			
2			74.0		Filter sock
		SILT - Greenish brown clayey SILT, moist, soft, non-plastic, trace brown limonite inclusions [ALLUVIUM].			
		LIMESTONE - Yellow brown biosparite LIMESTONE, unweathered to sl. weathered, mod. strong to strong, very thin to thinly bedded with interbedded thin (<0.07 m) soft horizons, skeletal fragments, trace black specks, occ. near vertical tight and undulating smooth fractures [FOREST HILL FORMATION].			
3			73.0	▽	Grade 7/14 Walton Park gravel
		- soft horizons at 2.38, 2.45, 2.97, 3.15, 3.53, 3.74, 3.94, 4.21 and 4.55 m.			
4		- fractures at 2.85 (0.10 m), 3.04 (0.11 m) and 4.07 m (0.14 m). Reddish brown staining in cracks.	72.0		50 mm Class E PVC piezometer
		- 0.4 m core loss from 1.85 to 3.0 m.			3.4 m machine slotted screen (0.5 mm screen)
5		EOH @ 5.0 m (target depth reached).	71.0		
6			70.0		
7			69.0		
8			68.0		
9			67.0		
10			66.0		
11			65.0		

DRILLING DETAILS

Drilled Depth:	5.00 mBGL
Bore Diameter:	HQ 96.0 mm
Date Borehole Started:	06/07/03
Date Borehole Completed:	06/07/03
Logged By:	D Jones
Drilling Company:	Webster Drilling & Exploration Ltd

COMMENTS

Bore developed by air surging until water was clear (45 min).

The stratification lines represent approximate boundaries. The transition may be gradual.

Attachment 2. Landfill Gas Generation Modelling (2020)

Predicted Landfill Gas and Methane Generation for 100,000 tonnes per annum of waste(k= 0.05 and 0.1)

Year	Total Landfil gas (m3/year)	Total Landfill gas (m^3/hour)	Collection Efficiency (%)	Landfill gas collected (m^3/hour)	Methane collected (m^3/hour)	Methane(m3/year) as per model	k
2005	118282	14	10	1	1	70969	0.05
2006	331851	38	10	4	2	199110	0.05
2007	547059	62	10	6	4	328235	0.05
2008	786286	90	10	9	5	471772	0.05
2009	984493	112	10	11	7	590696	0.05
2010	2018693	230	30	69	41	1211216	0.1
2011	2229819	255	30	76	46	1337891	0.1
2012	2424152	277	30	83	50	1454491	0.1
2013	2611735	298	30	89	54	1567041	0.1
2014	2630841	300	30	90	54	1578504	0.1
2015	2647286	302	30	91	54	1588372	0.1
2016	2719910	310	30	93	56	1631946	0.1
2017	2742842	313	30	94	56	1645705	0.1
2018	2781251	317	30	95	57	1668751	0.1
2019	2860021	326	30	98	59	1716012	0.1
2020	2931294	335	30	100	60	1758776	0.1
2021	2995785	342	75	256	154	1797471	0.1
2022	3268593	373	75	280	168	1961156	0.1
2023	3515441	401	75	301	181	2109265	0.1
2024	3738798	427	75	320	192	2243279	0.1
2025	3940899	450	75	337	202	2364540	0.1
2026	4123768	471	75	353	212	2474261	0.1
2027	4289235	490	75	367	220	2573541	0.1
2028	4438956	507	75	380	228	2663373	0.1
2029	4574429	522	75	392	235	2744657	0.1
2030	4697009	536	75	402	241	2818206	0.1
2031	4807925	549	75	412	247	2884755	0.1
2032	4908286	560	75	420	252	2944971	0.1
2033	4999096	571	75	428	257	2999458	0.1
2034	5081264	580	75	435	261	3048759	0.1
2035	5155613	589	75	441	265	3093368	0.1
2036	5222887	596	75	447	268	3133732	0.1
2037	5283759	603	75	452	271	3170255	0.1
2038	5338838	609	75	457	274	3203303	0.1
2039	5388676	615	75	461	277	3233205	0.1
2040	5433771	620	75	465	279	3260262	0.1
2041	5474574	625	75	469	281	3284745	0.1
2042	5511495	629	75	472	283	3306897	0.1
2043	5544902	633	75	475	285	3326941	0.1
2044	5575130	636	75	477	286	3345078	0.1
2045	5602482	640	75	480	288	3361489	0.1
2046	5627230	642	75	482	289	3376338	0.1
2047	5649624	645	75	484	290	3389774	0.1
2048	5669886	647	75	485	291	3401932	0.1
2049	5688221	649	75	487	292	3412932	0.1
2050	5704810	651	75	488	293	3422886	0.1
2051	5719821	653	75	490	294	3431893	0.1
2052	5733403	654	75	491	295	3440042	0.1
2053	5745693	656	75	492	295	3447416	0.1
2054	5756813	657	75	493	296	3454088	0.1
2055	5766875	658	75	494	296	3460125	0.1

Predicted Landfill Gas and Methane Generation for 200,000 tonnes per annum of waste(k= 0.05 and 0.1)

Year	Total Landfil gas (m3/year)	Total Landfill gas (m^3/hour)	Collection Efficiency (%)	Landfill gas collected (m^3/hour)	Methane collected (m^3/hour)	Methane(m3/year) as per model	k
2005	118282	14	10	1	1	70969	0.05
2006	331851	38	10	4	2	199110	0.05
2007	547059	62	10	6	4	328235	0.05
2008	786286	90	10	9	5	471772	0.05
2009	984493	112	10	11	7	590696	0.05
2010	2018693	230	30	69	41	1211216	0.1
2011	2229819	255	30	76	46	1337891	0.1
2012	2424152	277	30	83	50	1454491	0.1
2013	2611735	298	30	89	54	1567041	0.1
2014	2630841	300	30	90	54	1578504	0.1
2015	2647286	302	30	91	54	1588372	0.1
2016	2719910	310	30	93	56	1631946	0.1
2017	2742842	313	30	94	56	1645705	0.1
2018	2781251	317	30	95	57	1668751	0.1
2019	2860021	326	30	98	59	1716012	0.1
2020	2931294	335	30	100	60	1758776	0.1
2021	2995785	342	75	256	154	1797471	0.1
2022	3826489	437	75	328	197	2295893	0.1
2023	4578141	523	75	392	235	2746884	0.1
2024	5258263	600	75	450	270	3154958	0.1
2025	5873664	671	75	503	302	3524198	0.1
2026	6430502	734	75	551	330	3858301	0.1
2027	6934349	792	75	594	356	4160609	0.1
2028	7390249	844	75	633	380	4434149	0.1
2029	7802764	891	75	668	401	4681659	0.1
2030	8176024	933	75	700	420	4905614	0.1
2031	8513763	972	75	729	437	5108258	0.1
2032	8819362	1007	75	755	453	5291617	0.1
2033	9095879	1038	75	779	467	5457527	0.1
2034	9346082	1067	75	800	480	5607649	0.1
2035	9572475	1093	75	820	492	5743485	0.1
2036	9777324	1116	75	837	502	5866395	0.1
2037	9962679	1137	75	853	512	5977608	0.1
2038	10130396	1156	75	867	520	6078237	0.1
2039	10282152	1174	75	880	528	6169291	0.1
2040	10419466	1189	75	892	535	6251680	0.1
2041	10543713	1204	75	903	542	6326228	0.1
2042	10656137	1216	75	912	547	6393682	0.1
2043	10757862	1228	75	921	553	6454717	0.1
2044	10849906	1239	75	929	557	6509944	0.1
2045	10933192	1248	75	936	562	6559915	0.1
2046	11008552	1257	75	943	566	6605131	0.1
2047	11076740	1264	75	948	569	6646044	0.1
2048	11138439	1272	75	954	572	6683064	0.1
2049	11194267	1278	75	958	575	6716560	0.1
2050	11244782	1284	75	963	578	6746869	0.1
2051	11290490	1289	75	967	580	6774294	0.1
2052	11331849	1294	75	970	582	6799109	0.1
2053	11369271	1298	75	973	584	6821563	0.1
2054	11403133	1302	75	976	586	6841880	0.1
2055	11433772	1305	75	979	587	6860263	0.1

Predicted Landfill Gas and Methane Generation for 300,000 tonnes per annum of waste(k= 0.05 and 0.1)

Year	Total Landfil gas (m3/year)	Total Landfill gas (m^3/hour)	Collection Efficiency (%)	Landfill gas collected (m^3/hour)	Methane collected (m^3/hour)	Methane(m3/year) as per model	k
2005	118282	14	10	1	1	70969.21	0.05
2006	331851	38	10	4	2	199110.41	0.05
2007	547059	62	10	6	4	328235.40	0.05
2008	786286	90	10	9	5	471771.84	0.05
2009	984493	112	10	11	7	590696.01	0.05
2010	2018693	230	30	69	41	1211216.09	0.1
2011	2229819	255	30	76	46	1337891.26	0.1
2012	2424152	277	30	83	50	1454491.25	0.1
2013	2611735	298	30	89	54	1567041.26	0.1
2014	2630841	300	30	90	54	1578504.37	0.1
2015	2647286	302	30	91	54	1588371.84	0.1
2016	2719910	310	30	93	56	1631945.92	0.1
2017	2742842	313	30	94	56	1645705.07	0.1
2018	2781251	317	30	95	57	1668750.74	0.1
2019	2860021	326	30	98	59	1716012.30	0.1
2020	2931294	335	30	100	60	1758776.33	0.1
2021	2995785	342	75	256	154	1797470.83	0.1
2022	4384384	501	75	375	225	2630630.34	0.1
2023	5640840	644	75	483	290	3384504.24	0.1
2024	6777729	774	75	580	348	4066637.55	0.1
2025	7806429	891	75	668	401	4683857.29	0.1
2026	8737235	997	75	748	449	5242340.81	0.1
2027	9579463	1094	75	820	492	5747677.60	0.1
2028	10341542	1181	75	885	531	6204925.23	0.1
2029	11031100	1259	75	944	567	6618660.00	0.1
2030	11655038	1330	75	998	599	6993022.69	0.1
2031	12219600	1395	75	1046	628	7331760.07	0.1
2032	12730437	1453	75	1090	654	7638262.33	0.1
2033	13192662	1506	75	1130	678	7915597.03	0.1
2034	13610900	1554	75	1165	699	8166539.86	0.1
2035	13989337	1597	75	1198	719	8393602.31	0.1
2036	14331762	1636	75	1227	736	8599056.92	0.1
2037	14641600	1671	75	1254	752	8784959.93	0.1
2038	14921953	1703	75	1278	767	8953171.93	0.1
2039	15175627	1732	75	1299	780	9105376.45	0.1
2040	15405161	1759	75	1319	791	9243096.79	0.1
2041	15612852	1782	75	1337	802	9367711.31	0.1
2042	15800779	1804	75	1353	812	9480467.18	0.1
2043	15970822	1823	75	1367	820	9582492.92	0.1
2044	16124683	1841	75	1381	828	9674809.63	0.1
2045	16263902	1857	75	1392	835	9758341.23	0.1
2046	16389873	1871	75	1403	842	9833923.76	0.1
2047	16503856	1884	75	1413	848	9902313.66	0.1
2048	16606992	1896	75	1422	853	9964195.40	0.1
2049	16700314	1906	75	1430	858	10020188.31	0.1
2050	16784755	1916	75	1437	862	10070852.79	0.1
2051	16861160	1925	75	1444	866	10116695.91	0.1
2052	16930294	1933	75	1450	870	10158176.48	0.1
2053	16992849	1940	75	1455	873	10195709.65	0.1
2054	17049452	1946	75	1460	876	10229671.07	0.1
2055	17100668	1952	75	1464	878	10260400.63	0.1

2004 Modelling

1. Placement rate of 60,000 tonnes per annum with first placemetn 2004
2. 2005 - 2009 a k value of 0.1 used as leachate recirculation not in place
3. 2010 to 2039 k value of 0.15 used
4. Landfill operated for 35 year conentt period
5. 50/50 ration of methane and CO2

2009 Modelling

1. for 2004 to 2007 actual placemetn rates used, from 2008 to 2039 60,000 tonnes/annum used
2. 70% of waste placed assumed to be organinc
3 Lo valume of 170 m3 per tonne
4. 2004 -2009 a collection effciency of 55% and k value of 0.1
5 2010 to 2039 a collectio efficiency of 75% and k value of 0.15
6. 50/50 mixture of CO2 and methane
7. Ran model for 0.1 k value first then again for 0.15 for all years. Selcted 2005 to 2009 results for 0.1 and 50% removal and then from 2010 at 0.15 and 70 %

2020 Modelling

Run 1

3. Max placement rate from 2020 is 300,000 tonnes per annum
4. 35 year consent period to 2055
5. Placement rates 2004 to 2019 as per data supplied by AB Lime
6. 52 % organics to 2013 and 35 % organics since 2013
7. k0.05 for first 5 years then .1
8. Methane /CO2 ratio 60/40
9. From 2021 up to total of 300,000 tonnes per annum which of organics is 105,000 tonnes/yr

10 Lo of 100 m3/tonne

11. 2004 -2009 a collection effciency of 55% and k value of 0.1
12. 2010 to 2055 a collection efficiency of 75%

Run 2

As above execpt collection efficiency for years 2005 to 2009 reduced to 10% and remainder to 2020 to 30%

Run 3

From 2020 at 100,000 tonnes placement per annum

Run 4

From 2020 at 200,000 tonnes placement per annum

Run 1 A

K at 0.1 and 0.15

Run 3A

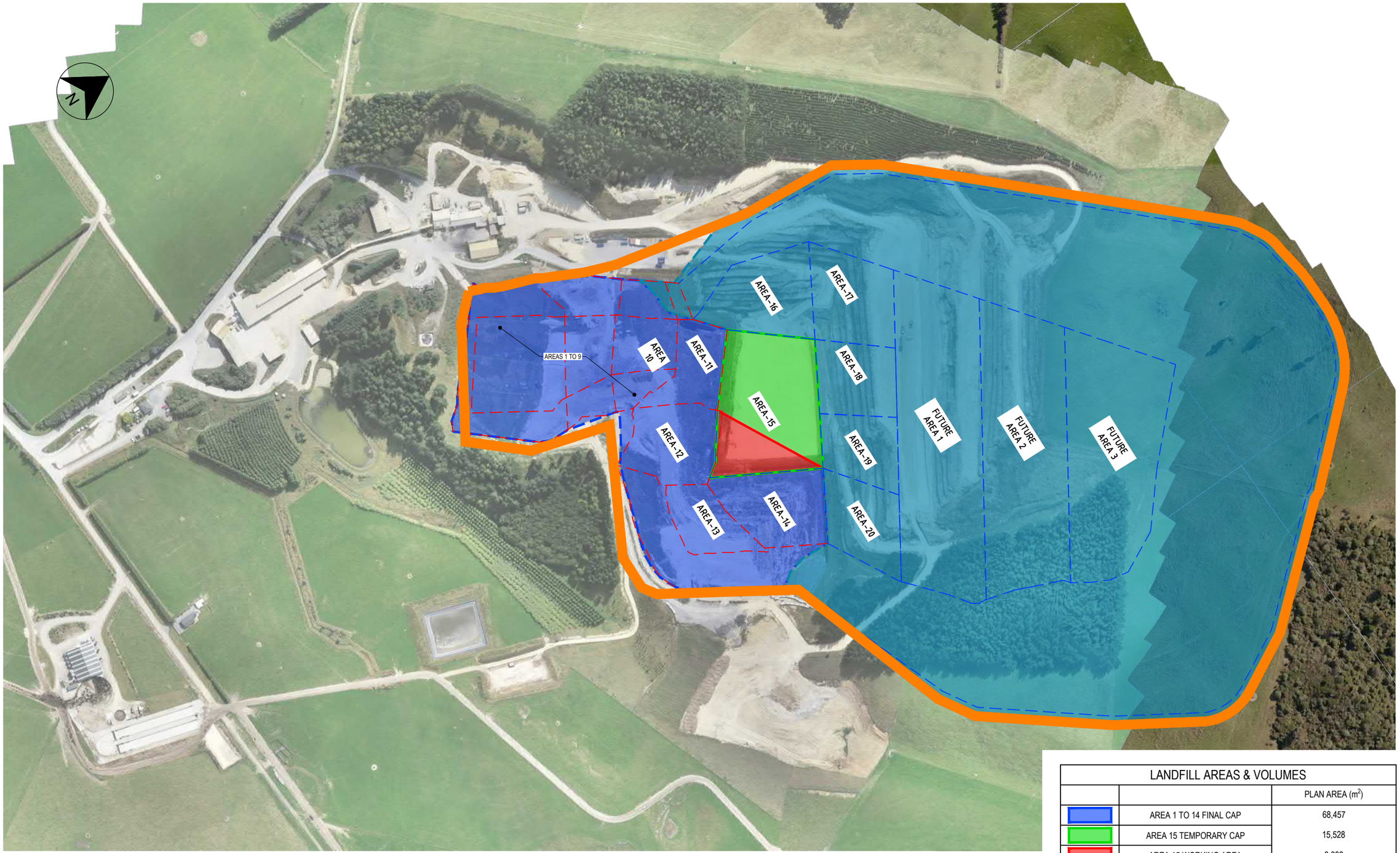
K at 0.1 and 0.15

Run 4A

K at 0.1 and 0.15

Year	Placement tonnes	% Organics	Tonnes organic in model
2004	27,914.09	52	14515
2005	51,762.75	52	26917
2006	54,607.80	52	28396
2007	62,753.19	52	32632
2008	55,825.95	52	29029
2009	49,572.60	52	25778
2010	48,647.91	52	25297
2011	49,045.95	52	25504
2012	50,462.73	52	26241
2013	47,974.00	35	16791
2014	47,823.20	35	16738
2015	58,173.30	35	20361
2016	50,505.10	35	17677
2017	53,670.53	35	18785
2018	61,560.00	35	21546

Attachment 3. Site Plan- Locations of Future Areas of Waste Filling



LANDFILL AREAS & VOLUMES		
		PLAN AREA (m^2)
	AREA 1 TO 14 FINAL CAP	68,457
	AREA 15 TEMPORARY CAP	15,528
	AREA 15 WORKING AREA	3,882
	AREA 16 TO FUTURE AREA 3 LANDFILL	296,157

CONSENT ISSUE

REV	DATE	APP'D	REVISION
A	29.05.20	VP	CONSENT ISSUE

SCALES AT A1

AB LIME

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CHRISTCHURCH CENTRAL 8013
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Tel: +64 3 940 4900
Fax: +64 3 940 4901
Web: www.jacobs.com

CLIENT: AB LIME LTD.
PROJECT: LANDFILL INVESTIGATION

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
NBL	KJ	CW	VP
DESIGNED	DESIGN REVIEW	DATE 29.05.20	DATE 29.05.20
WS	BC		

TITLE: LANDFILL CAPPING STATUS WHEN AREA 15 IS ACTIVE PLAN

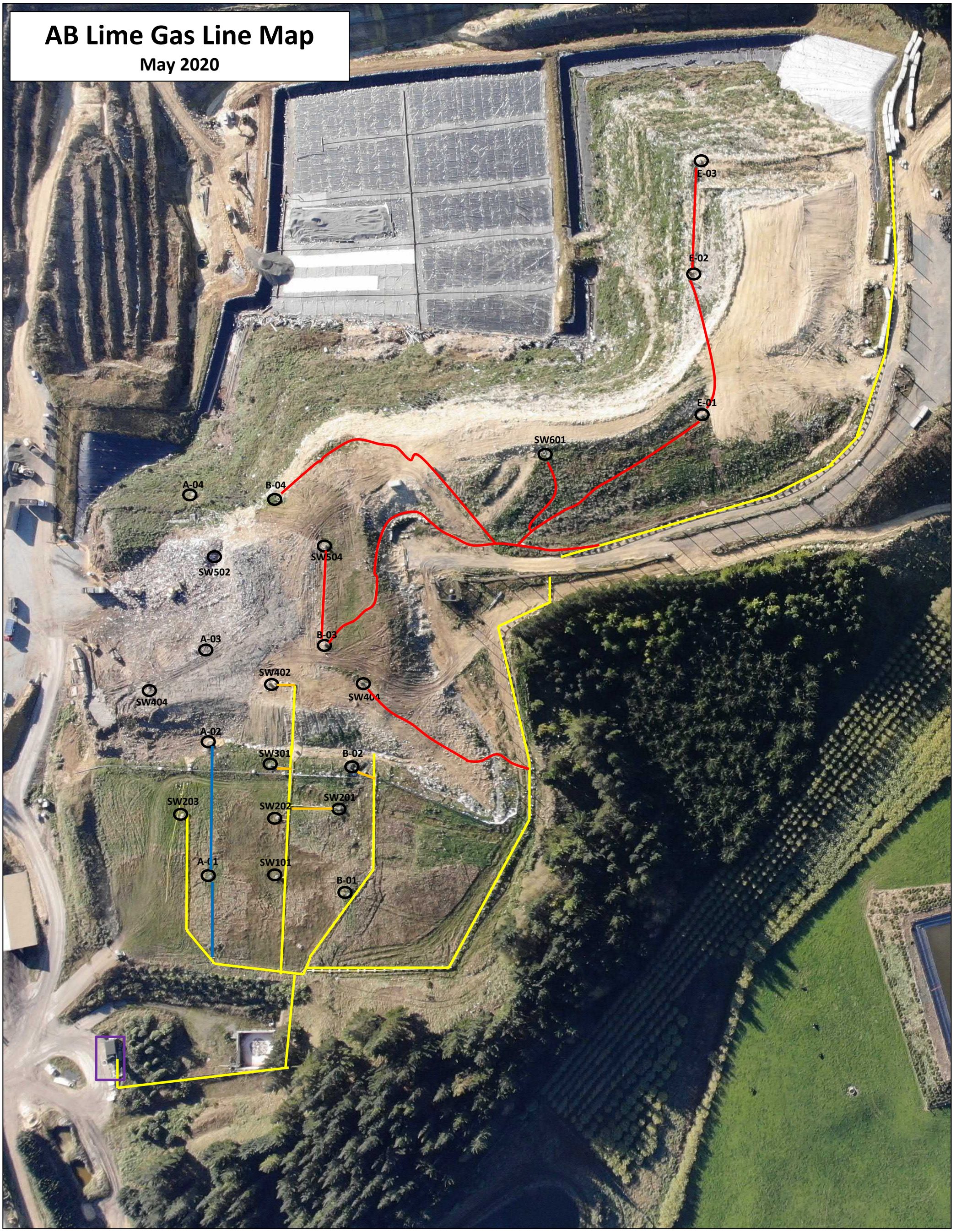
SCALE	DRAWING No	REV
AS SHOWN	IZ000400-1000-NG-DRG-1013	A

A1

Attachment 4. Site Plan- Landfill Gas Extraction Wells and Above-Ground Pipework

AB Lime Gas Line Map

May 2020



Legend

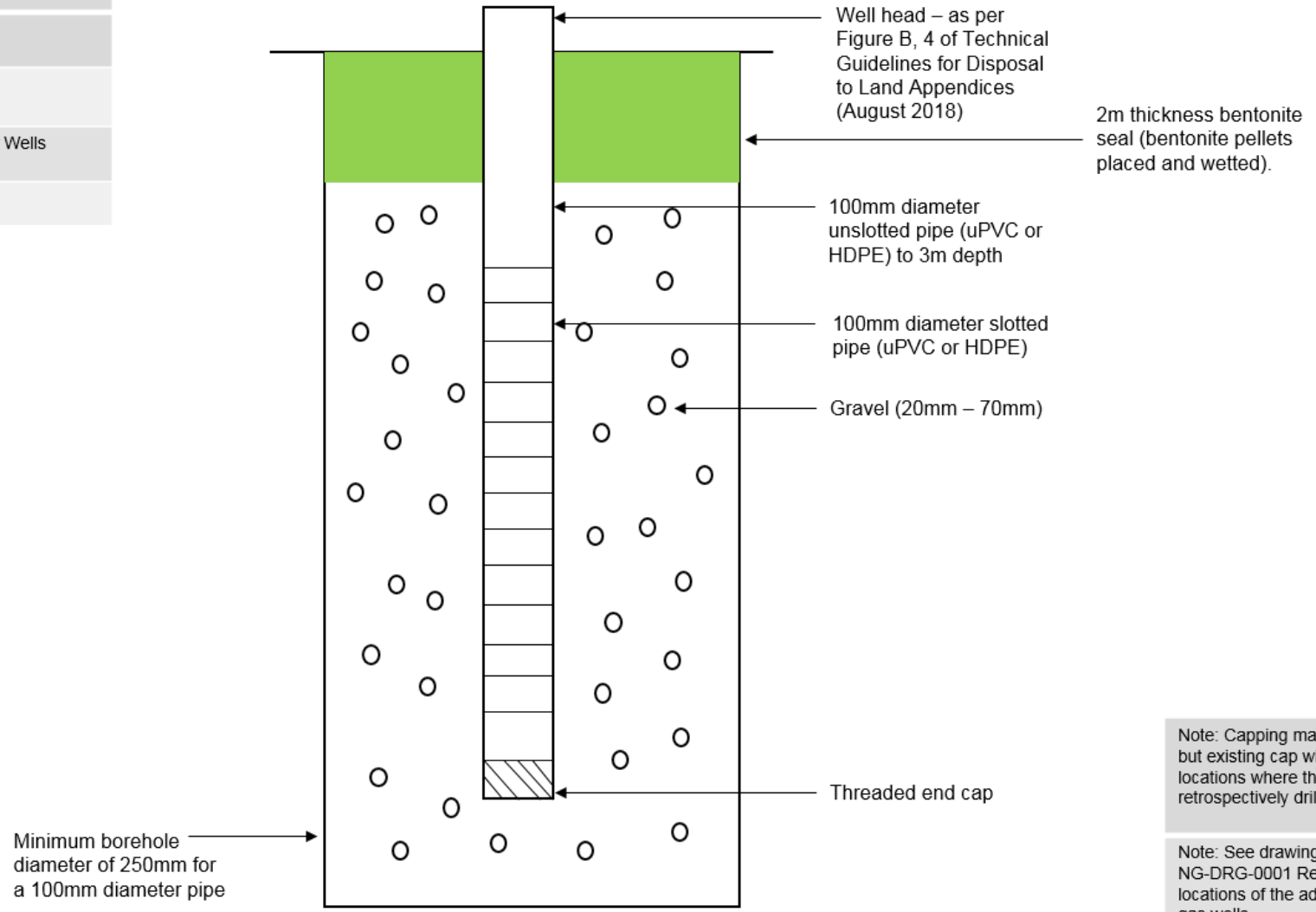
- Above Ground Main Gas Line (200mm)
- Below Ground active gas line
- Temporary 65mm gas lines
- Smaller pipe connections off main line to well
- Gas Well Head
- Flare

AB LIME

Attachment 5. Landfill Gas Extraction Well (100 mm diam)-Retrospectively Drilled

JACOBS

Project	AB Lime Cell 3 Design
Project No.	IZ000400
Work Package	A.P4.EV.LFG
Task	100mm Diameter Wells Specification
Element	Well Design



Note: Capping material not shown in drawing but existing cap will be in place in the locations where the wells will be retrospectively drilled

Note: See drawing number IZ000400-LFG-NG-DRG-0001 Rev 1 for the proposed locations of the additional 100mm dia. landfill gas wells

Attachment 6. Procedures- Monitoring of Migration Probes and Surface Gas Emissions

AB Lime Ltd

LANDFILL GAS MONITORING PLAN

- Final
- 28 May 2012

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1. Introduction

1.1. Background

Environment Southland has issued an air discharge permit to AB Lime Ltd (Consent No. 201351) which requires landfill gas monitoring at the surface of the landfill and at perimeter monitoring wells. This monitoring plan is designed to provide for compliance with the air discharge monitoring requirements of the consent. In addition to meeting consent requirements AB Lime also wishes to manage on-site and off-site risks and to investigate gas collection efficiencies at the landfill.

Procedures for monitoring perimeter and surface and perimeter landfill gas at AB Lime landfill are provided in Section 5 of this document. Field data sheets (FDS) are provided in the appendices to record monitoring that is required as conditions of the consent, and include perimeter monitoring of methane (FDS1), findings of surface walk-over inspections (FDS2), and surface methane monitoring (FDS3).

1.2. Discharge Permit Conditions for Landfill Gas Monitoring

The air discharge permit issued to AB Lime defines conditions related to discharge of odour, dust, and landfill gas from the landfill. The discharge permit addresses the need to monitor landfill gas from the gas collection system that is ultimately collected and burned in the flare, as well as the uncollected, or fugitive, landfill gas that is discharged through the surface or through the sides of the landfill. This document concerns the monitoring of fugitive landfill gas emissions only. The conditions in the air discharge permit related to the discharge and monitoring of fugitive landfill gas include:

> *"19. (a) The concentration of methane measured in monitoring probes outside the landfill footprint shall not exceed 1.25% by volume)*
>
> *(b) The concentration of methane measured at the surface of landfill areas with intermediate or final cover shall not exceed 5.0% by volume*
>
> *...*
>
> *20. A walk-over site inspection of the landfill shall be undertaken at least every week. Any evidence of possible landfill gas leaks, including odour, surface cracks, gas bubbles or vegetation damage, shall be investigated and appropriate remedial action shall be undertaken as soon as practicable.*
>
> *21. (a) Methane concentrations shall be measured and recorded at least once each month in at least 10 monitoring probes located outside the landfill footprint, but*

within the consent holder's property, to demonstrate compliance with Condition 19(a).

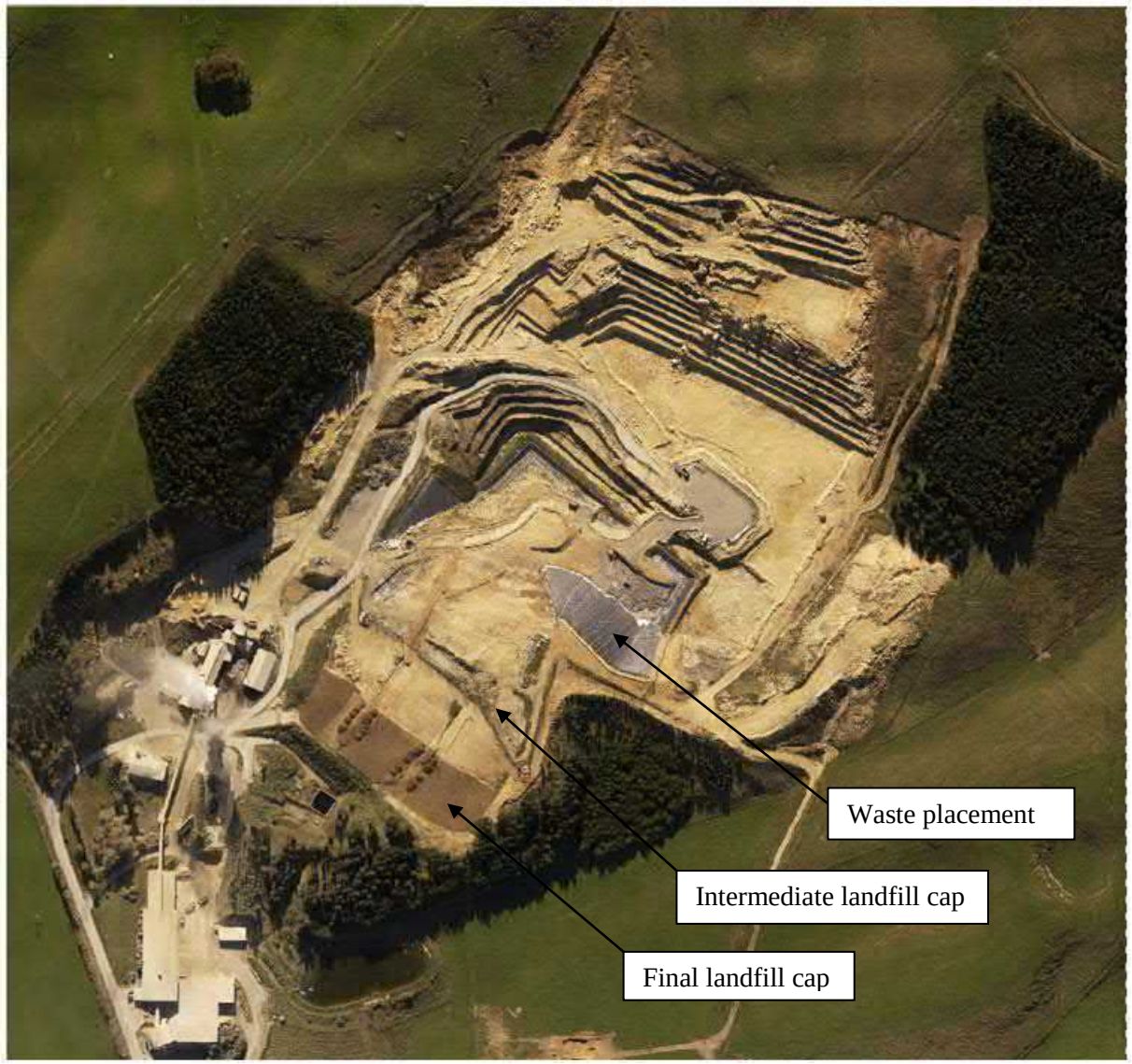
(b) Methane concentrations shall be measured and recorded at least once each month at the surface of the landfill to demonstrated compliance with Condition 19(b)."

2. Site Description

The AB Lime landfill was opened in 2004 in land that had previously been quarried. The landfill is a high quality engineered landfill with a geomembrane liner. Leachate is collected and taken to a nearby wastewater treatment plant, although leachate recirculation may be introduced at some point. The landfill has some intermediate capping and final capping in the southern part of the landfill. The landfill's gas collection system is an active system with vertical and lateral wells feeding an enclosed flare, which has been burning around 100 m^3 of landfill gas per hour.

The landfill typically receives between 40,000 and 50,000 tonnes of waste per year. Due to the continuing operation of the quarry, more land for further landfill cells is being made available, so that the landfill will be able to operate at this rate of placement for several decades. Being a relatively new and dry landfill, with ongoing refuse placement and limited final capping, the level of landfill gas production has not yet peaked.

- **Figure 1 Aerial Image of AB Lime Landfill (as of April 2012)**



3. Landfill Gas Emissions to Air

3.1. Background

Landfill gas is a natural by-product of the anaerobic decomposition of organic waste in a landfill. The composition and rate of landfill gas generation are dependent on the types of waste and the level of microbial activity within the waste. Landfill gas is generally composed of 50-55% methane (CH_4), 45-50% carbon dioxide (CO_2), less than 5% nitrogen (N_2), and less than 1% non-methane organic compounds (NMOCs). Methane is typically the contaminant of greatest concern, as it is the dominant component of landfill gas, has the potential to accumulate to levels where it can become an explosive hazard, and is a potent greenhouse gas.

3.2. Influence of Climate and Meteorology

Barometric pressure and precipitation can have significant effects on landfill gas migration. Increased barometric pressure will result in decreased landfill gas venting until the pressure within the landfill rises above the atmospheric pressure. Conversely, falling atmospheric pressure will result in increased venting of landfill gas until equilibrium is reached.

Temperature can affect the rate of landfill gas production, as the bacteria responsible for decomposition of waste and generation of landfill gas are temperature dependent. The bacteria are able to survive below freezing, but can also function well at temperatures up to 65°C. Generally, warmer temperatures promote a greater rate of landfill gas production. Higher temperatures also promote volatilisation and other chemical reactions within the waste, so trace gas components of landfill gas tend to increase with higher temperatures.

Landfill gas emitted from the surface of the landfill will disperse downwind. Stronger winds will result in greater dispersion of the surface emissions, while periods of calm winds will tend to result in greater accumulation of landfill gas, and therefore higher measurements of landfill gas components such as methane.

AB Lime has installed a meteorological station on site to collect data for wind speed and direction, temperature, barometric pressure and precipitation which are recorded continuously as 15-minute averages. This data will be consulted prior to monitoring to determine, to the degree practicable, “worst case” conditions likely to result in higher rates of landfill gas, including low atmospheric pressure and low wind speeds.

4. Monitoring Approaches

4.1. Perimeter Monitoring

Perimeter monitoring for landfill gas is designed to measure potential horizontal migration of gas from the landfill. A perimeter monitoring network consists of permanent probes installed around the perimeter of the landfill to measure subsurface concentrations of landfill gas. The perimeter monitoring wells must be located outside the existing waste disposal footprint but within the boundary of the landfill property. The depths of the wells must be to the same depth as the landfill waste, and ideally below the depth of the lowest seasonal groundwater level. Currently six perimeter monitoring probes have been established and are in operation, and the number will be increased to at least ten probes as the landfill expands.

The monitoring probes consist of a length of pipe with a perforated section over the sampling length. The portion of the well above the surface should be capped and sealed, with a sampling port for attaching the sample inlet tubing for the landfill gas monitor.

Monitoring of the probes should be undertaken at a time when landfill gas is most likely to migrate. Because subsurface gas pressures are considered to be at a maximum during the afternoon hours when barometric pressure tends to drop, monitoring should either be conducted in the afternoon or whenever the barometric pressure is low. The monitoring should include, at a minimum, both methane concentrations and barometric pressure, although most landfill gas monitors also provide for measurement of oxygen and carbon dioxide. Prior to monitoring the probe should be purged with a vacuum pump to provide a representative sample of gas. The monitoring probes should remain sealed between monitoring periods.

4.2. Surface Monitoring

Monitoring for landfill gas at the surface of the landfill provides a qualitative indication of whether high levels of landfill gas are escaping from the landfill surface or whether the landfill gas collection system is working well to minimise emissions. Surface monitoring also provides confirmation that methane concentrations do not pose an inhalation or explosive hazard. AB Lime's discharge consent requires methane concentrations to be below 5% (the lower explosive limit for methane) above the surface of the landfill.

There are several techniques for monitoring surface emissions of landfill gas. These include:

- Visual inspection of landfill surface for areas of distressed vegetation, evidence of capping cracking, and detection of landfill gas odours.
- Instantaneous surface monitoring (ISM), in which the surface is traversed in a prescribed pattern using a portable flame ionisation detector (FID). Methane is sampled with a wand or

funnelled inlet at 50mm to 100mm above the ground surface. Readings are recorded at regular intervals, and areas of elevated concentrations are noted.

- Integrated surface sampling (ISS), in which a sample is continuously drawn into a Tedlar bag using a sample pump whilst traversing the surface of the landfill in a prescribed pattern. The sample is then measured with an FID or other analytical instrument. This method does not provide measurement at the same spatial resolution as the ISM method, although if performed properly it can provide a representative sample of the landfill as a whole. The sample may also be sent to a laboratory for analysis of trace organic components if required.
- Flux Box Testing – flux boxes are containers such as an open-ended box or drum cut lengthways, with the open end embedded into the landfill surface. Flux boxes may be used to determine mass emissions (i.e.m^3/hr) of landfill gas as opposed to ambient concentrations at the surface of the landfill (i.e., ppm of methane). However, flux boxes require specific design and operation to produce reliable results.

A combination of the above methods may be used to provide a comprehensive analysis of gases emitted through the landfill surface. For the purpose of showing compliance with AB Lime's discharge permit for monitoring of surface methane, a combination of visual inspections and ISM are recommended.

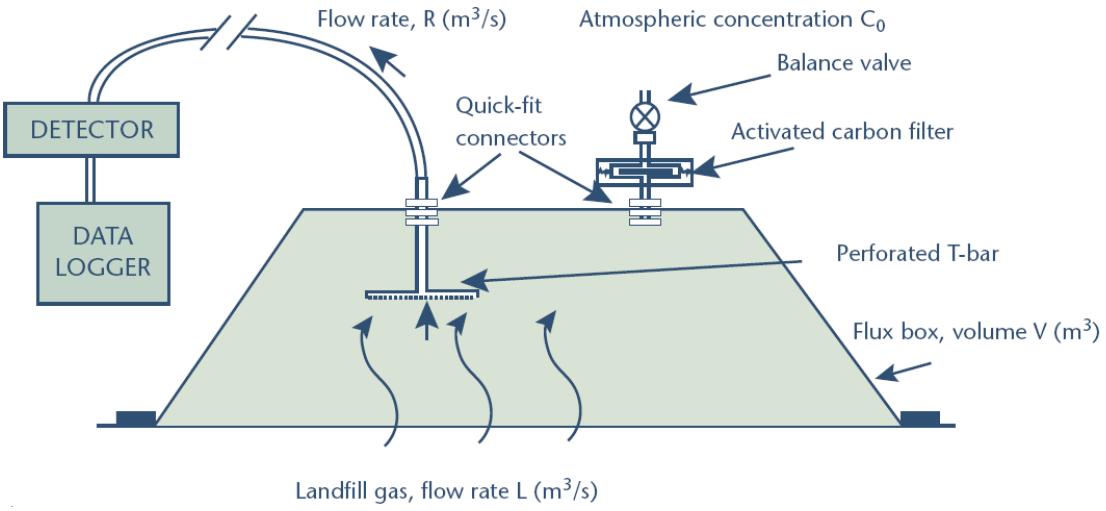
4.3. Surface Flux Monitoring

AB Lime may also wish to measure the emission rate, or flux, of landfill gas to estimate the efficiency of landfill gas collection. Monitoring of surface concentrations with ISM provides measurement of methane concentrations near the landfill surface. However this monitoring cannot be used to determine actual emission rates. Flux box surveys are needed in order to quantify the rate of emission at a particular location. By taking measurements at a number or representative locations, it is possible to calculate an emission rate of methane for the overall capped surface of the landfill.

Flux boxes comprise an enclosed chamber, such as a box open at the base or a metal drum cut in half lengthwise that is placed over a portion of the landfill surface and allowed to collect gas that is being emitted from the surface. Figure 2 provides an example schematic of a flux box. The rate at which methane enters the confined space is measured via a sample line with a FID or equivalent monitoring instrument, and a flux for that location is calculated. Measurement at a location may be conducted over typically an hour, and repeated at other designated locations. The individual measurements from all the locations are then aggregated to estimate the emission rate for the whole site or for a specific zone within the site. However, as landfill gas fluxes can vary widely with time depending on weather conditions, as well as with location over the landfill surface, relating the flux box measurements to an overall landfill emission rate requires a carefully designed study.

Guidance on designing a flux box monitoring program can be found from the UK Environment Agency[1] *Guidance on Monitoring Landfill Gas Surface Emissions* (2010).

- **Figure 2 Schematic of a Flux Box for Surface Methane Emissions Measurement**



[1] http://publications.environment-agency.gov.uk/PDF/GEHO0311BTOL-E-E.pdf

5. Monitoring Procedures

5.1. Monitoring Personnel

Monitoring personnel shall be AB Lime staff or contractors who have been trained in the operation of landfill gas monitoring equipment in use at the landfill.

5.2. Monitoring Frequency

The methane concentrations in the perimeter monitoring probes located outside the landfill footprint are required to be monitored at least monthly as a condition of 21(a) of the resource consent.

The methane concentrations at the surface of the landfill are required to be monitored at least monthly as a condition of 21(b) of the resource consent, and a surface visual inspection is required once per week.

5.3. Probe Monitoring Procedure

A suitable gas monitor (e.g., Landtec GEM-2000 or equivalent) for measuring methane (CH_4), carbon dioxide (CO_2), oxygen (O_2) and static pressure of the gas in the perimeter monitoring probes. Readings will be recorded on field data sheet FSD1 (Appendix A). All data recorded and stored shall be uploaded to a PC after the monitoring is complete.

Upon arriving at the probe, monitoring personnel will:

1. Record weather conditions, including wind speed and direction, temperature and barometric pressure.
2. Record the probe identification number, date, time and name of monitoring personnel on the field data sheet.
3. Connect the gas inlet port of the GEM-2000 to the monitoring probe's sample port.
4. Open the valve connecting the probe sample port to the GEM-2000 inlet port, and record the static pressure /vacuum in the probe.
5. Activate the pump on the GEM-2000 and operate until at least two probe volumes have been pumped out of the probe.
6. Once readings have stabilised, record the methane, CO_2 and O_2 concentrations and time on the field data sheet.

7. Close the valves on the probe and disconnect the tubing to the GEM-2000.

8. Repeat at other perimeter monitoring locations until all perimeter probes have been monitored.

9. Download all data from the GEM-2000 onto a PC for stsorage.

5.4. Surface Walkover Procedure (Visual Inspection)

AB Lime's discharge consent requires surface visual inspections on at least a weekly basis. The weekly surface inspection entails a walkover of the site to identify any zones or features where a relatively high concentration of methane can be detected. Items to look for include cracks or fissures in the capped surface of the landfill, distressed vegetation, and detection of landfill gas odour. Any findings of the visual inspection that suggest elevated emissions of landfill gas should be confirmed by measurement with a FID. The results of the inspection will be recorded on field data sheet (FDS2 in Appendix B).

Monitoring personnel will use a recent and to-scale site plan/drawing with the following information and locations indicated:

a) The location of the final capping;

b) The location of intermediate capping;

c) The active portion of the landfill where waste is being placed;

d) The location of waste that has been placed but does not yet have any intermediate capping;

e) The location of landfill gas extraction wells;

f) The location of leachate clean out pipes (understood to be located on the eastern embankment of the of the landfill);

g) The location of active waste placement, i.e. the working face; and,

h) The location of the buried waste footprint, i.e. where the landfill capping layer meets the sidewall geomembrane layer constructed in the buried anchor trench.

5.5. Surface Methane Monitoring

AB Lime's discharge consent requires surface monitoring with an FID to determine methane concentrations on at least a monthly basis. The landfill surface will be traversed in a systematic manner with a FID to measure methane concentrations as close to the surface of the landfill as is

practicable. At the time of this writing, AB Lime has acquired a Crowcon Gas-Tec landfill gas monitor for instantaneous surface monitoring (ISM).

The traversing of the landfill surface must follow a prescribed path in order to ensure that the entire surface is covered and to allow relative ease in comparing monitoring results over time. The monitoring path should be designed so as to cover the capped surface of the landfill in a prescribed pattern. For example, the perimeter of the landfill may be initially traversed with the FID, followed by a grid pattern at 10-20 metre spacing over the landfill surface. This monitoring path will need to be updated over time to include future expansion of the landfill. Figure 3 provides an example of the landfill monitoring path over the existing surface of the landfill with permanent capping.

Ideally the monitoring should be carried out in low wind or calm weather conditions. However, should wind appear to interfere with the readings a wind breaker device should be used.

Areas of elevated surface methane concentrations in excess of 0.5% (5,000 ppm) should be noted and the time, location, and methane concentration being recorded in the field data sheet or monitoring log. Many landfill gas monitors (including the Crowcon Gas-Tec monitor) incorporate a global positioning system to assist mapping the measured methane concentrations. In this case each reading should include a concentration, time and date stamp, and GPS coordinates where the readings were acquired.

Weather checks shall be performed as part of the ISM procedure, and include recording the wind speed and direction, temperature, barometric pressure, and cloud cover during the monitoring period.

- **Figure 3 Example of Landfill Walk Path for Instantaneous Surface Monitoring**

The landfill gas monitor must be calibrated to appropriate methane standards on at least a 6-monthly schedule as per manufacturer instructions. The Crowcon Gas-Tec monitor has multiple measurement scales of 0-100ppm, 0-1,000 ppm, and 0-10,000 ppm, providing a maximum measurement range of 0-1% methane. If surface concentrations exceed 1% methane, then another monitoring instrument must be used (for example, the GEM-2000 landfill gas monitor used for the perimeter probe monitoring can measure up to 100% methane, and may be used to measure high surface concentrations of methane). Care should be taken when methane concentrations are high, as explosive conditions may result.

5.6. Reporting

A report of monitoring activities and summary of monitoring results will be prepared and submitted to Environment Southland annually. The monitoring reports will include:

- A summary of the weekly surface inspections, including observations of cracks in landfill capping surface and odour;
- A summary of monthly surface methane measurements, including location(s) and magnitude of maximum observed methane concentrations; and,
- A summary of methane concentrations measured at each perimeter monitoring probe.

Any monitoring of methane in excess of the permitted concentrations of the consent, either at the landfill surface or at the perimeter monitoring wells, will be reported to Environment Southland no later than one month after the exceedance. The report will include the location and measured methane concentration of the exceedance as well as documentation of date, time, barometric pressure, temperature and general weather conditions at the time of exceedance.

Appendix A Perimeter Monitoring Field Data Sheet

AB Lime Perimeter Probe Monitoring Field Data Sheet (FDS1)

Date:_____Atmospheric Pressure (millibar):_____ Air Temperature (°C):_____

Assessor:_____ Instrument ID:_____ Weather Conditions:_____

Perimeter Monitoring Probe ID	Time	Probe Static Pressure (Pa)	CH_4 (ppm or %)	CO_2 (%)	O_2 (%)	General Comments

Appendix B Weekly Surface Walkover Inspection Field Data Sheet

AB Lime Weekly Surface Inspection Field Data Sheet (FDS2)

Atmos. Pressure (millibar):_____ Wind Speed (m/s):_____ Wind Direction:_____ Air Temperature (°C):_____

Weather Conditions:_____

Date:_____ Time: (Start)_____(Finish)_____ Assessor:_____

Instructions: During weekly surface walkover inspections, note the location of any surface cracks, locations of distressed vegetation, odour, or any other issues relevant to landfill performance on the map, and describe the nature of the fault on the following table.

- **Table 1 Weekly Surface Inspection Field Data Sheet (Indicate nature of issue or fault)**

Location of issue or fault (Identify on map)	Comment (Discernable odour, surface cracking, distressed vegetation, other)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

Appendix C Monthly Surface Monitoring Field Data Sheet

AB Lime Monthly Surface Monitoring Field Data Sheet (FDS3)

Atmos. Pressure (millibar):_____ Wind Speed (m/s):_____ Wind Direction:_____ Temperature (°C):_____

Weather Conditions (cloud cover, rain, etc.):_____

Date:_____ Time: (Start)_____(Finish)_____ Assessor:_____

Instructions: Traverse the surface of the landfill with handheld monitor as near to the surface as is practicable (<5cm). Indicate path of surface monitoring on the aerial photo at left. Note any occurrences of elevated methane concentrations in excess of 0.5% (5,000 ppm) and indicate the measured methane concentrations and times of measurement in the following table.

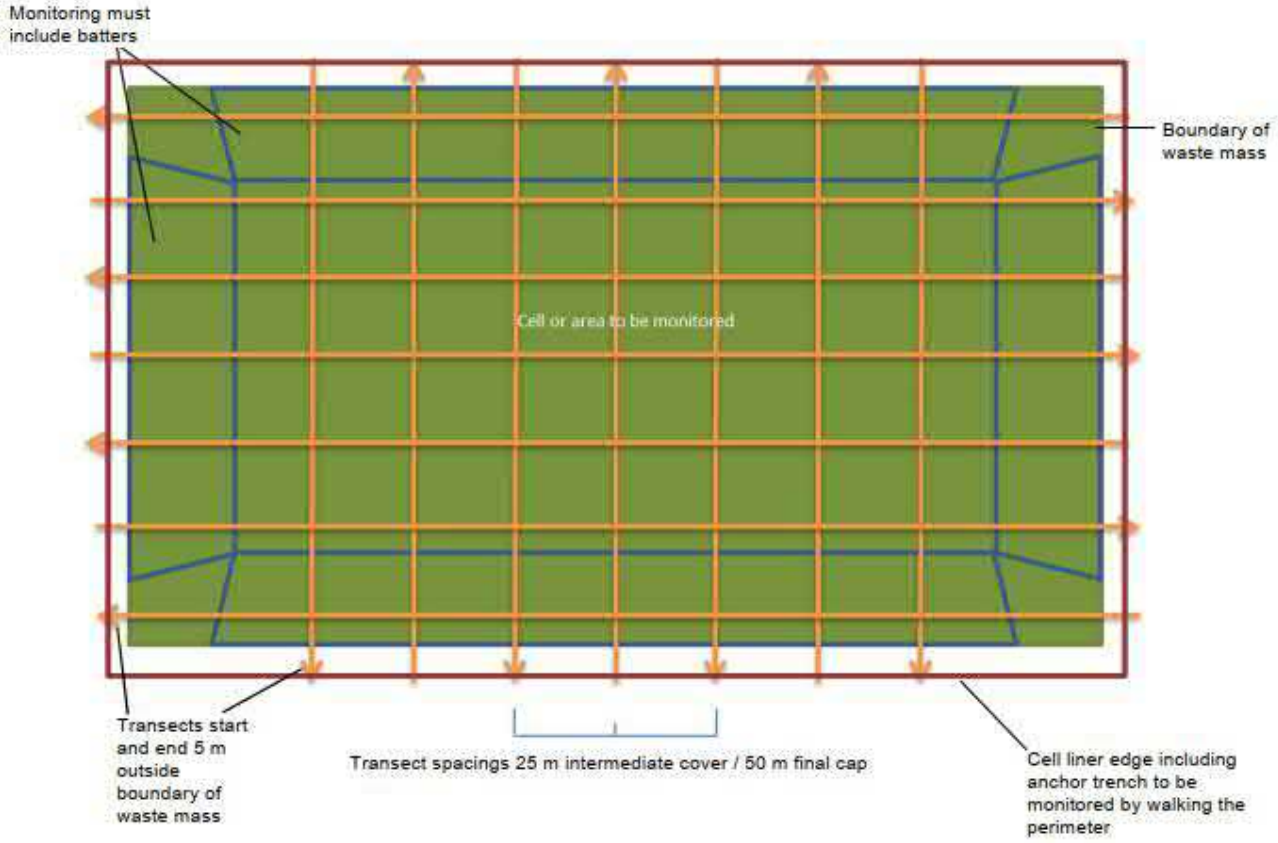
- **Table 2 Monthly Instantaneous Surface Monitoring Field Data Sheet (Record areas of elevated methane concentration)**

Monitoring Location (Identify location on map)	Time of measurement	Methane Concentration (ppm)	Comment (discernable odour, etc.)

Attachment 7. Example of a Site Plan for Gas Surface Emissions

4. Surface emissions should be monitored continuously along each transect at a height of approximately 50 mm above the surface of each cell of the landfill. Data should be logged regularly i.e. every few seconds. Where equipment has an automatic data logging capability, this should be used. The transects should be spaced at 25 m intervals for intermediate cover and 50 m intervals for final caps.
5. Monitor at normal walking speed along the transects parallel to the landfill boundary. Typically, two sets of transects should be started from two boundaries at right angles to each other so the transects cross in a grid pattern (see figure 1). Each transect should start and finish approximately five metres beyond the waste boundary.

Figure 1: Transect diagram for undertaking a walkover survey



Source:

Landfill gas fugitive emissions monitoring guideline

EPA VICTORIA | Environment Protection Authority Victoria

Publication 1684, February 2018

Guideline