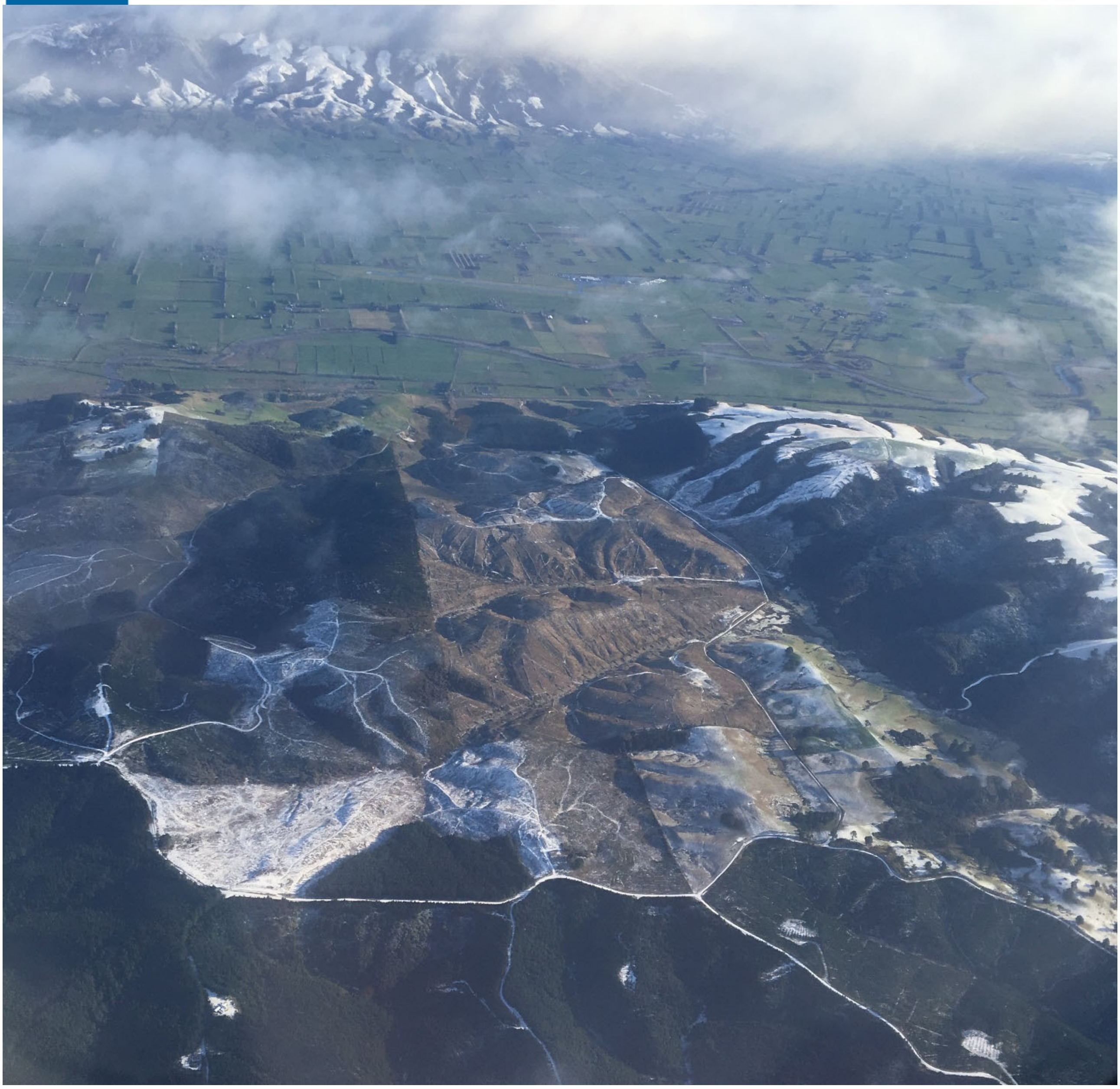
# Appendix 3: Landfill Concept Design Report



# Dunedin City Council

## Waste Futures - Smooth Hill Landfill

## Landfill Concept Design Report

August 2020

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# 1. Introduction

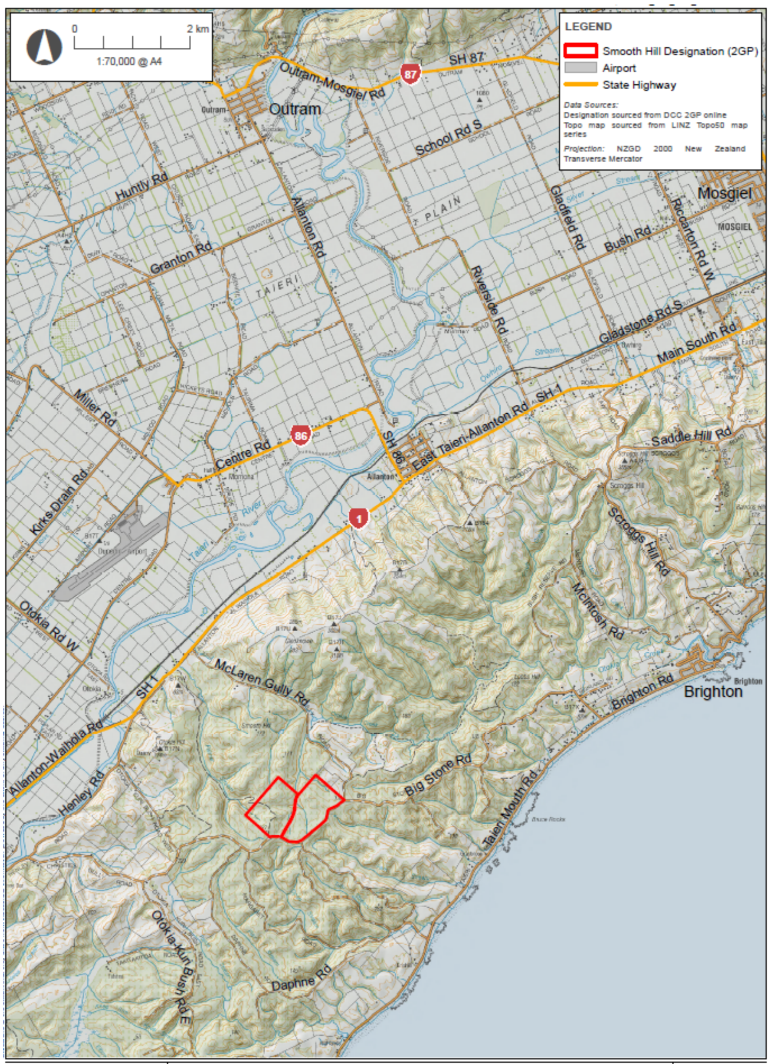
## 1.1 Introduction

The Dunedin City Council (Council) collects residential waste and manages the disposal of both residential and the majority of commercial waste for the Dunedin City area and environs.

The Council has embarked on the Waste Futures Project to develop an improved comprehensive waste management and diverted material system for Dunedin, including future kerbside collection and waste disposal options. As part of the project, the Council has confirmed the need to develop a new landfill to replace the Council's current Green Island Landfill, which is envisaged to reach full capacity around 2023.

The Council commenced a search for a new landfill location in the late 1980's and early 1990's and selected the Smooth Hill site in south-west Dunedin, shown in Figure 1 below, as the preferred option. At that time, the site was designated in the Dunedin District Plan, signalling and enabling its future use as a landfill site. The Council also secured an agreement with the current landowner, Fulton Hogan Ltd, to purchase the land. Over the following period, the Council extended the life of Green Island Landfill and further development of the Smooth Hill site has been on hold.

**Figure 1 – Site Location**



This report describes the engineering concept design of the proposed landfill. The design has been undertaken to a level to provide a basis for all specialist assessments of potential effects associated with the landfill development and operation, and to define the general works proposed. The concept design presented herein will be developed into a detailed design for construction purposes at some time in the future.

## 1.2 Landfill Purpose

As discussed later in this report, the landfill will be developed as a Class 1 Landfill and will only receive waste from commercial waste companies or bulk loads (not open to the public). The Council's waste reduction objectives and policies are that the waste stream will diminish over the lifespan of the landfill. However, population growth is likely to add to the waste stream over time. Therefore, the assumption has been made that the current average waste stream from the Council of 90,000 tonnes per year will be maintained for the life of the landfill. It is important to recognise that waste streams may vary significantly over time from this assumption and the concept design presented in this report allows the landfill design to be adapted in response to changes in waste stream volumes. This includes consideration of the need to allow for resilience in the landfill capacity for future events such as flooding, earthquakes, major redevelopment projects etc., all of which could result in a significant and unexpected volume of waste needing to be disposed of. This issue is discussed further in Section 3.7.1.

# 2. Site Description

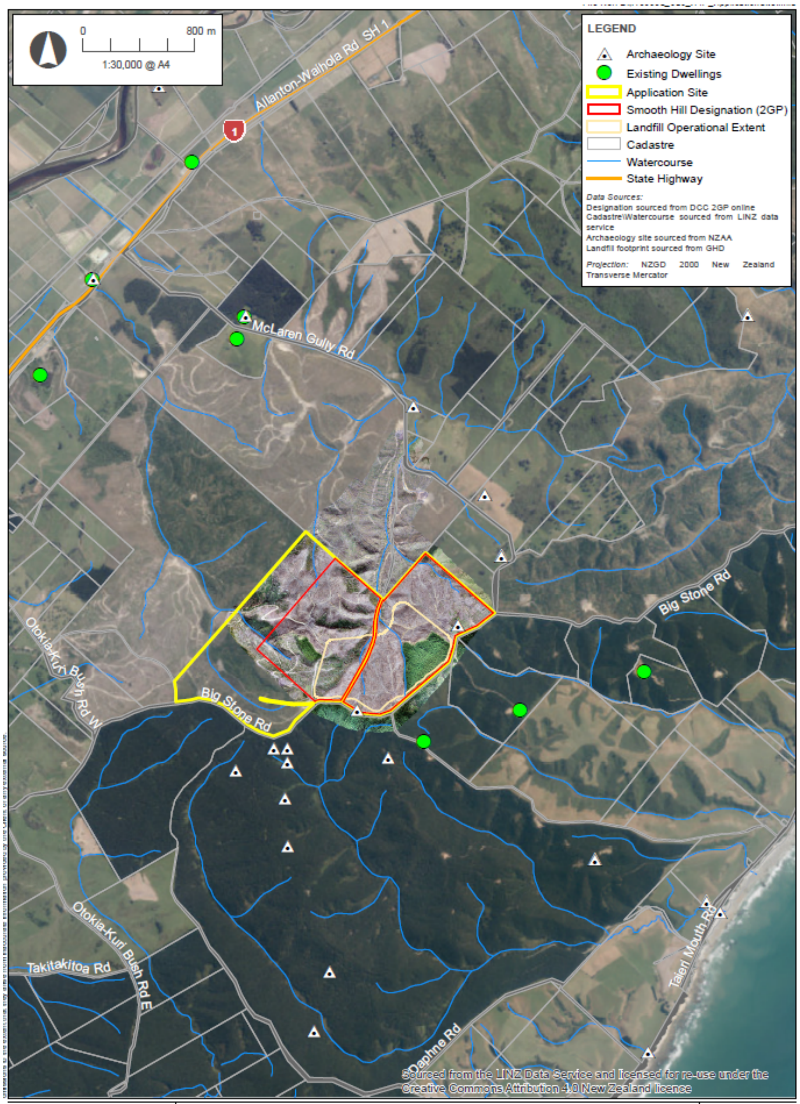
## 2.1 Site Location

The site is located approximately 28 km south-west of central Dunedin in the hills between State Highway 1 (SH1) and the coast. Access from SH1 is via McLaren Gully Road and Big Stone Road to the south-eastern boundary of the site. Both roads are currently unsealed. The site is bounded to the north and west by forestry land and to the north-east by pastoral farmland (Figures 1 and 2). Within the site, access is via a series of forestry roads and tracks. Most of the site has been logged and re-planted in the past 5 years although a large stand of Macrocarpa remain in the south-east part of the site (Figure 2) and areas of remnant native vegetation occur in the gully bottoms.

The archaeological remnants of two buildings have been identified within the site. The locations are shown on Drawing 51-12506381-01-C102 and discussed further in the Archaeology Report.

The site is currently un-serviced. Electricity and telephone line exist on SH1 and extend 1.1 km along McLaren Gully Road (from SH1) to two existing houses (shown on Figure 2.

**Figure 2 - Site Layout**



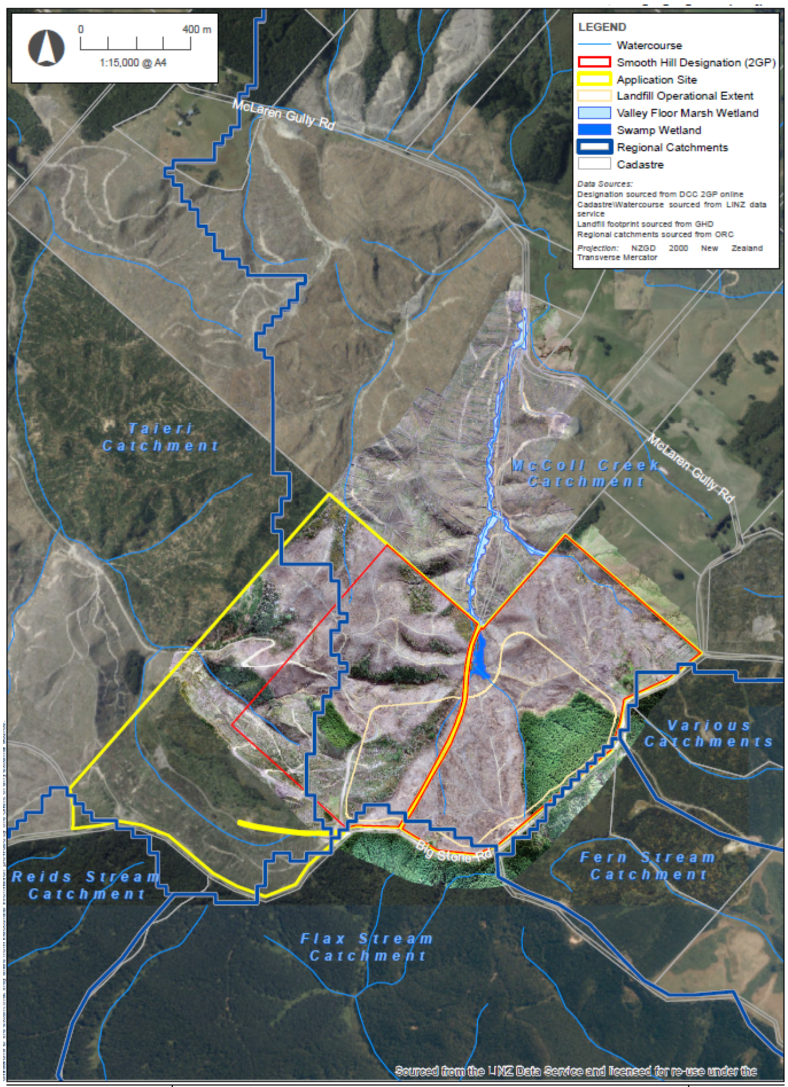
## 2.2 Topography and Geomorphology

The landfill site is located in a natural "amphitheatre", which is bisected by a larger central ridge and a smaller ridge in the south-western corner – both trending south to north – see Drawing 12506381-C103 Existing Contours. The site typically has side slopes of 20%. A south to north system of gullies passes through the site, which are dry most of the year with flowing water only after rainfall. The gullies coalesce into a single gully at the northern edge of the site, and join a permanent stream to the north of the site that passes under McLaren Gully Rd via a culvert. The stream then joins the Otokia Creek that ultimately flows to the coast near Brighton, approximately 10 km north-east of the landfill site

Big Stone Road runs along a ridge on the south-eastern edge of the site and is the catchment divide. To the south of Big Stone Road the land drains directly to the Pacific Ocean via a series of gullies and streams (from north to south Graybrook Stream, Fern Stream, Tutu Stream and Flax Stream – Figure 3).

The lowest elevation within the landfill site is the base of the gully at RL 100 rising to the ridgeline on Big Stone Road typically RL 140 to RL 150 and up to RL180 in the southwest corner of the site.

**Figure 3 - Surface Hydrology**



## 2.3 Site Ownership

The site is currently owned by Fulton Hogan Limited (FH). Council has an agreement with FH to purchase the designated land. In addition to the designated land purchase from FH, Council is also in discussions to purchase the land to allow the widening and upgrade of the SH1 junction, Maclaren Gully Road and Big Stone Road to the site entrance.

## 2.4 Climate

General climate data for the area derived from NIWA 2015 "*The Climate and Weather of Otago*" indicates the following for the site.

The climate of this region is temperate climate. Monthly rainfall is between 63 mm to 96 mm. Annual rainfall for the 2018 to 2019 period has been between 979 mm and 886 mm. The winter period of June to September is slightly dryer with rainfall between 42 mm and 47 mm per month. The wettest months are December and January.

Daily average temperatures across the year vary from 6.7 °C to 7.8 °C. Monthly average wind speeds are between 12.1 km/h to 15.7 km/h.

Soil moisture deficit occurs over the period of October to April. During the winter months there is little evapotranspiration.

### Table 1 Mean Monthly and annual rainfall at selected Otago locations[1]

*Table 6. Monthly and annual rainfall normal (a; mm), and monthly distribution of annual rainfall (b; %) at selected Otago locations, for the period 1981–2010.*

| Location | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alexandra | a | 48 | 36 | 29 | 24 | 28 | 31 | 19 | 23 | 19 | 31 | 31 | 47 | 363 |
| | b | 13 | 10 | 8 | 6 | 8 | 9 | 5 | 6 | 5 | 8 | 8 | 13 | |
| Balclutha | a | 78 | 68 | 62 | 50 | 68 | 62 | 50 | 43 | 48 | 61 | 53 | 71 | 713 |
| | b | 11 | 9 | 9 | 7 | 10 | 9 | 7 | 6 | 7 | 9 | 7 | 10 | |
| Clyde | a | 51 | 41 | 33 | 34 | 32 | 33 | 24 | 24 | 26 | 36 | 35 | 49 | 416 |
| | b | 12 | 10 | 8 | 8 | 8 | 8 | 6 | 6 | 6 | 9 | 8 | 12 | |
| Cromwell | a | 48 | 33 | 43 | 33 | 33 | 38 | 28 | 27 | 26 | 36 | 41 | 52 | 437 |
| | b | 11 | 8 | 10 | 8 | 7 | 9 | 6 | 6 | 6 | 8 | 9 | 12 | |
| Dunedin (Airport) | a | 69 | 63 | 56 | 48 | 60 | 47 | 46 | 40 | 42 | 58 | 50 | 72 | 652 |
| | b | 11 | 10 | 9 | 7 | 9 | 7 | 7 | 6 | 6 | 9 | 8 | 11 | |
| Dunedin (Btl Gardens) | a | 92 | 88 | 85 | 67 | 89 | 77 | 87 | 78 | 63 | 82 | 73 | 88 | 968 |
| | b | 9 | 9 | 9 | 7 | 9 | 8 | 9 | 8 | 7 | 8 | 8 | 9 | |

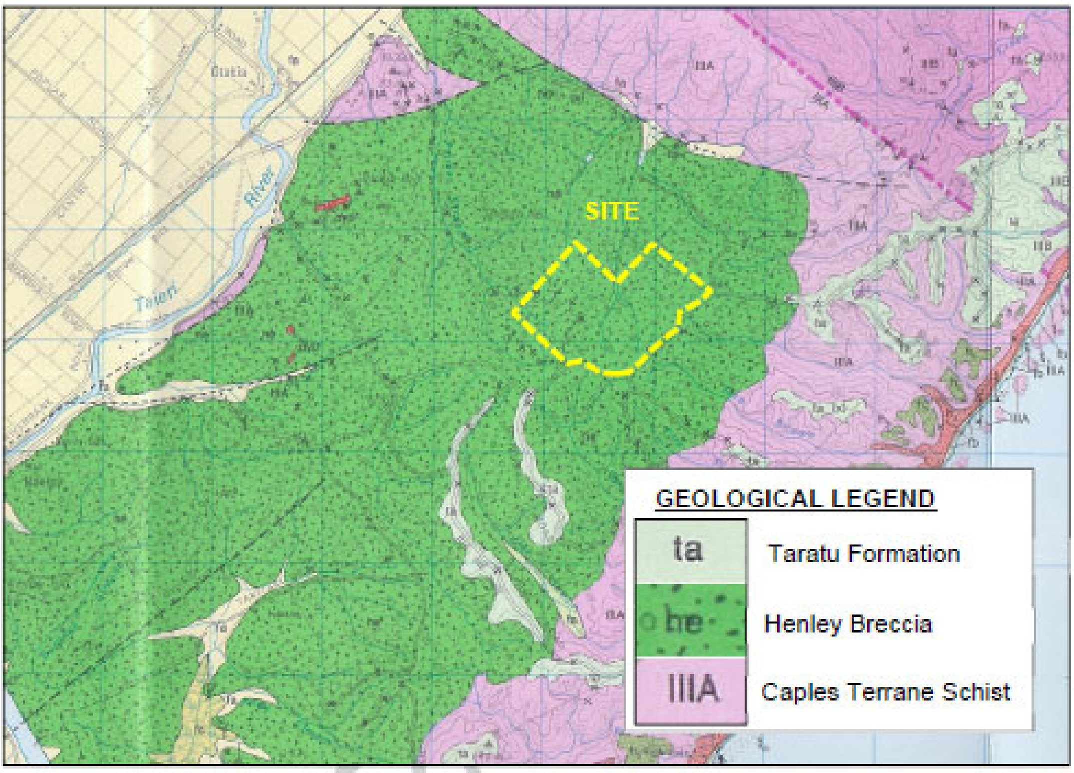
## 2.5 Site Geology

The available geological maps (Bishop [1994], and Bishop and Turnbull [1996]) show the site to be underlain by the Henley Breccia Formation. Although not shown on the geological map, borehole investigations show the Henley Breccia to be overlain by up to 5 m of topsoil, colluvium and loess, with deposits of alluvium in gullies. Bedding dips of 10-15° were measured in the Henley Breccia. Investigations have also encountered Taratu Formation deposits on hilltops in the south-western corner of the designation area.

A summary of the geology encountered during the ground investigation is presented in Section 3.4.1; and discussed in more detail in the Geotechnical Interpretive Report (GIR).

[1] Reproduced from NIWA 2015 "*The Climate and Weather of Otago*"

**Figure 4 - Geology Map**



# 3. Landfill Concept Design

## 3.1 Guidelines

The landfill is designed to meet the requirements of:

- WasteMINZ publication Technical Guidelines for Disposal to Land (2018 Edition)

  Resource Management (National Environmental Standards for Air Quality) Regulations 2004

## 3.2 Design Objectives

The objectives of the landfill design have been developed in consultation with DCC and are as follows:

- Capacity for the lifespan of the landfill to meet Council's waste management strategy while also allowing for unexpected events which may increase waste volumes in the future or the potential for a significant reduction in waste volumes allowing for the landfill footprint to be reduced.
- Containment of waste and leachate appropriate for a Class 1 landfill.
- Avoid contamination of groundwater and downstream surface water.
- Avoid (or minimise) migration of LFG from the site.
- Minimise amenity effects for surrounding rural-residential activities.
- Retain existing areas of indigenous vegetation/habitats and archaeological values where practicable to do so.
- A free draining final landform where ponding of surface water is avoided through grading towards the perimeter swale drains.
- Stable slopes.
- Access for maintenance, rehabilitation or monitoring purposes.
- Economically viable refuse placement capacity through optimisation of the footprint and height of the resultant landform.
- A final landform suitable for future light stock grazing and shallow rooted planting.

The landfill is designed to have staged construction to minimise affected site area and be progressively stabilised/capped.

## 3.3 Project Description

The project comprises the construction of a landfill with a capacity of approximately 6 million cubic metres to provide for the safe disposal of municipal solid waste for a period in excess of 35 years (up to 55 years). The landfill will be designed to accept municipal solid waste in accordance with acceptance criteria for a Class 1 landfill described in Appendix D of the *WasteMINZ (2018) Technical Guideless for Disposal to Land*. The overall project will comprise:

- All works associated with the development of an operating landfill on the identified footprint area including:
  - Earthworks to construct the required shape;
  - Construction of a low permeability lining system to prevent leachate seepage into the surrounding environment;

  - Construction of a leachate collection system above the low permeability lining system;
  - Stormwater control around the constructed landfill and other areas of the site with appropriate treatment and attenuation of stormwater before it leaves the site;
  - A landfill gas (LFG) collection system to collect LFG from the placed waste; and
  - A leachate management system, including (leachate storage, tanker loading facilities and leachate treatment facilities).
- LFG treatment by a LFG plant;
- Provision of water supplies for operational including firefighting (non-potable) and staff (potable) requirements;
- Provision of overhead power cables capable of HV transmitting electricity generated by future LFG engines;
- Construction and operation of a new landfill access road from McLaren Gully Road/Big Stone Road to the landfill operational area.
- Upgrade and sealing of McLaren Gully Road and Big Stone Road from State Highway 1 to the site entrance.
- Heavy vehicle movement on-site to operate the landfill, including excavators and bulldozers;
- Heavy vehicle movements to and from the site;
- Other vehicle movements for staff, contractors and possibly visitors;
- Operational infrastructure such as weighbridges and vehicle wheel wash;
- Facilities for site staff, including on-site wastewater disposal;
- Maintenance facilities for site plant and equipment;
- Landscaping and tree planting to minimise the visual impact of the facility; and
- Environmental monitoring systems.

The details of these works are described in subsequent sections of this report. Development of a landfill is essentially a long term construction project. The landfill will be developed in stages, with one stage being filled with waste while the next stage is constructed.

## 3.4 Geotechnical Design

The geotechnical design for the landfill is detailed in the Geotechnical Interpretative Report (GIR), (GHD, (2020). Smooth Hill Landfill Consenting - Geotechnical Interpretive Report, Reference 12506381). The factual results of the geotechnical investigation along with published and Client supplied geotechnical data is provided in the Geotechnical Factual Report (GFR).

### 3.4.1 Summary of Encountered Geology

**Topsoil**

A layer of topsoil was encountered at depths of up to 0.25 m bgl across most of the site; this will be classed as unsuitable material and removed from the landfill footprint.

**Shallow Slope Instability Features**

Debris was encountered in localised areas across the site during investigations and several small shallow slope instability features were noted around the site although not all were drilled or excavated. The debris associated with these features was generally encountered at the surface (occasionally with a thin veneer of topsoil), and extended to depths ranging between 0.4 m bgl to 2.7 m bgl.

Typically the debris comprised disturbed gravelly silt, silty sand, sand, silt and organic material such as tree roots and branches. Observations of the morphology of the features and composition of associated material and morphology suggests that these are shallow features associated with the loess with no obvious evidence of deeper-seated ground movement.

Slip debris will be classed as unsuitable material and removed from the landfill footprint and stored for daily or intermediate waste cover use.

**Alluvium**

Alluvium was encountered in the base of the gullies around the northern area of the site to depths of up to 2.7 m bgl. The alluvium typically comprised waterlogged sand, silt and gravel in varying amounts.

Alluvial soils will be classed as unsuitable material and removed from the landfill footprint and stored for daily or intermediate waste cover use.

**Loess**

Loess was encountered across most of the site to depths between 1.25 m to 4.1 m bgl and typically comprised silt, non-plastic to low plasticity, with varying amounts of clay, sand and fine gravel.

Laboratory testing was undertaken on loess samples from the site to investigate suitability as landfill liner or capping material. Completed laboratory testing of the loess indicates it can be compacted to achieve a permeability of $3x10^{-8}$ to $5x10^{-10}$ m/s, which is a relatively low permeability and desirable for a liner or capping material. However, loess soils typically become dispersive when disturbed and are prone to erosion from water flow and/or seepage. Completed dispersion testing on samples of loess collected at the site confirm that these materials are potentially dispersive (refer to test results provided in the GFR and GIR Section 6.2). This is an undesirable property for a landfill capping or liner material where long term integrity is important.

However, loess materials can be made non-dispersive through stabilisation by the addition of lime or bentonite. Completed lab testing (refer to Section 6.2 of the GIR) has shown the addition of 2.5% lime by weight results in a non-dispersive material and indicates that this type of material stabilisation may result in a material suitable for a landfill liner or capping layer.

Atterberg testing of the untreated loess indicates it plots on the A-Line of the Casagrande plasticity chart (refer to Section 6.2 of the GFR) suggesting that it has some plastic behaviour. Completed Atterberg testing on lime stabilised loess samples indicate the material remains on the A-Line. Further testing during detail design is required to confirm the effect of stabilisation on the plasticity of compacted loess and its ability to self-anneal. If used as a part of a liner system or a capping layer non-plastic behaviour and development of cracks would not be acceptable. The use of loess as a liner and capping material is discussed further in Section 3.10 of this report.

**Henley Breccia**

The Henley Breccia Formation encountered in exploratory holes comprised sandstone, siltstone, conglomerate, breccia with localised thin interbeds and lamination of organic mudstone / lignite.

Assessed strengths were variable both within lithologies and vertically and ranged from extremely weak to very weak in completely to highly weathered material to moderately strong in unweathered sandstones and breccia.

Throughout the depth of Henley Breccia Breccia Formation few defects were logged in boreholes. Logged defects were generally widely spaced bedding partings with occasional joints cross cutting bedding.

It is proposed to use excavated Henley Breccia as engineered fill beneath the base of the landfill to infill low areas and provide a base for the liner system.

### 3.4.2 Site Seismicity

As discussed in Section 2.2.3 of the GHD (2020) GFR, there are a number of identified faults within 100 km of the site. No faults are identified on the site in published data. In addition, no faults were identified on the site during the completed investigations for this project.

It should be noted that the faults described in Table 1 of the GFR are faults that are listed in the GNS Active Faults Database. However, the majority of those listed do not meet the definition of "Active" as defined by GNS Science (i.e. recurrence interval <2000 yrs). The closest active fault to the proposed landfill site, as defined in NZS 1170.5:2004, is the Alpine Fault, which is located 240 km to the northwest.

Whilst landfills are not specifically referenced in NZS 1170.5 2004 (and 1170.5 Section 1.1 specifically excludes slopes), the landfill has been assumed to have an Importance Level of 2 (IL2 - normal structures and structures not in other importance levels) to give some guidance as to possible design lifetimes and resultant return periods. For a design working life of 50 or 100 years, IL2 structures are required to be designed to resist earthquake loadings with return periods of 500 and 1000 years respectively.

The site investigation results show the ground conditions at the site should be classified as subsoil site class 'C' (shallow soil), as per NZS 1170.5.

For slope stability assessment under seismic load, the New Zealand Transport Agency Bridge Manual (NZBM) provides a method for determining a design ground acceleration, however, NZBM does not use design life and defines annual probability of exceedance (NZBM - Table 2.2). This table returns a design return period of 1/500 years. Seismic coefficients for preliminary geotechnical design for slope stability have been calculated using NZBM. Using this methodology, the peak ground accelerations (PGA) derived for the site are 0.24 g for damage control limit state (DCLS) or ultimate limit state (ULS) and 0.06 for service limit state (SLS) (¼ DCLS).

At detailed design stage, a site specific probabilistic seismic hazard assessment should be completed.

## 3.5 Formation Stability

Construction of the landfill will require both cutting into the existing valley landform and filling to create the desired landform. Based on the preliminary earthworks plan, a number of cross sections have been generated to analyse engineered cut and fill slopes comprising cuts into natural soils and rocks and engineered fill from site won material. The following stability scenarios have been considered:

- Static Stability – Target Factor of Safety 1.5
- Seismic Ultimate Limit State (ULS earthquake loading) – Target Factor of Safety 1.0
- Seismic Serviceability Limit State (SLS earthquake loading) – Target Factor of Safety 1.0

Slope stability analyses provided in the GIR for the proposed cut and fill design slopes indicate appropriate slope stability for the proposed design (refer to GIR Section 7).

As discussed in Section 3.4.1 of this report, a number of existing shallow areas of instability features have been identified on the site associated mostly with loess material. These features will either be removed during the landform excavation or do not intercept the landfill or associated structures. These features can be investigated further and slope stability modelling and hazard and risk assessment carried out during the detailed design of the works.

## 3.6 Landfill Stability

The overall form and design of the landfill must ensure the project is stable during development and in the operational period. The landfill is located in the head of a gully such that the final landform is buttressed against pre-existing hill sites on three sides. The northern end and low end of the landfill will have a 10 m high embankment constructed from engineered fill that will buttress the otherwise unsupported side of the landfill.

During development of the landfill, waste will be placed against this embankment at a stable slope. Placement of waste in the landfill to ensure waste stability during site development is a subject to be addressed during detailed design. Consideration also needs to be given to the interface friction angle at the base of the landfill between the waste and liner to protect against a base slide failure or a potential circular slip failure through the base. This will partly depend on the final liner system selected for the site. This is also a subject to be addressed during detailed design.

The overall stability of the landfill (stability of the bund with the full waste placement in the completed landfill) is presented in Section 7.6.4 of the GIR. The landfill stability for sections are presented in Tables 8 through 11 of the GIR and summarised below (Table 2). The calculated landfill stability values indicate the stability is appropriate. This issue requires further analysis and confirmation during detailed.

**Table 2 Landfill overall stability**

Table 3 Factors of Safety

| | Condition | Required FoS | Minimum Calculated FoS |
|---|---|---|---|
| 1 | Static (permanent) | 1.5 | 2.0 |
| 2 | Short Term Static (elevated water levels within landfill) | 1.3 | 1.7 |
| 3 | Serviceability Limited State Seismic | 1.0 | 1.6 |
| 4 | Ultimate Limited State Seismic | 1.0 | 1.0 |

## 3.7 Landfill Formation and Airspace

### 3.7.1 Landfill Footprint

The proposed landfill will occupy a portion of the designated site (approximately 44.5 Ha of the 87 Ha designated area). The landfill footprint and associated airspace development is based on a number of criteria including:

- The airspace is sufficient for disposal of up to 6 million cubic metres (equivalent to 5 million tonnes) of waste. Based on the assumed annual disposal rate of 90,000 tonnes per year the landfill has a design life of 55 years. However, as discussed earlier in this report, it is recognised that uncertainty exists regarding the future annual waste volumes that will be generated in the region and received at the landfill. This includes consideration of the need to allow for resilience in the landfill capacity for future events such as flooding, earthquakes, major redevelopment projects etc., all of which could result in a significant and unexpected volume of waste needing to be disposed of. It is also recognised that the Council will be working towards minimising waste as much as practicable. As described in Section 3.9, the landfill will be developed in five stages. This allows future flexibility in landfill development and ability to respond to future events. For example, a significant reduction in annual waste disposal rates may mean that the Stages 1 and 2 are sufficient for waste disposal over many decades and it is not necessary to develop stages 3 through 5 for the foreseeable future. Alternatively, an unexpected future event may result in an increase in waste volumes and the landfill has the capacity to cater for this type of event.

- Concerning a future reduction in annual waste volumes, the landfill is located in a gully system that is naturally bisected by a low central ridge. This ridge will be largely retained to segregate the landfill leachate collection systems into two halves – Stage 1 and 2, and Stage 3 through 5. The landfill liner drawing 51-12506381-01-C201 and 51-12506381-01-C204 show the retention of the natural ridge as a point of separation of Stages 2 and 3.
- The landfill has been located within the designation area to take advantage of the existing topography to the extent possible, minimising the amount of cut and fill necessary to form the base grade. Earthworks are however required to create planar surfaces for the placement of the landfill liner system.
- Development of the landfill design has been in consultation with the project team landscape architects. To the extent possible, the final cap profile has been developed to integrate with the surrounding landscape. The final surface profile is generally no more than 5 m above the adjacent ridge line formed by Big Stone Road. This will allow views of the landfill to be screened by trees.
- Development has also been in consultation with the project team ecologists. The footprint has been positioned to avoid areas within the designation identified as potential being of higher ecological value, including the western gullies as much as possible.
- As shown on Figure 51-12506381-01-C102, the archaeological remnants of two buildings have been identified within the site area. The remnants of one of these buildings will need to be removed as part of Stage 5 development. The remnants of the second building is located north of the area affected by the landfill development and will be retained in line with the recommendations contained in the Archaeology Report and incorporated into any future landfill visitor experience (see Archaeology Report).

### 3.7.2 Base grades

The base grade for the landfill liner will generally follow the broad gully profile and be from 4% for the flatter base and up to 25% for the inclined liner faces. Excavation and filling will be required across most of the site to form the sub grade and/or remove compressible/problematic soils. Depth of excavation will be typically be between 2 m and 10 m and include removal of all loess and some of the underlying weathered and unweathered rock.

All excavated soils (except for small amounts of unacceptable organic materials which will be stored and can be used as intermediate or daily cover) will then be used to form the landfill profile, liner and capping. Low-grade soils will be used for daily cover. The loess (together with modification discussed in Section 3.4.1) is an important source of low permeability material for the landfill liner and cap construction and will be won and stored on site for later use wherever possible. Underlying weathered rock will be used for engineered fill. Stockpiles will be located on the eastern side of the site (Drawing 51–12506381-01-C206). These are temporary structures, as all won materials will eventually be consumed by landfill development.

In some locations, engineered fill is required where the existing gullies are especially steep and need to be reduced by filling. The extent of the cut and fill to create the landfill base grade is shown on Drawing 51-12506381-01-C209.

In addition, a 10 m high toe embankment will be constructed at the northern low point of the landfill to facilitate placement of and retention of waste and contain leachate (to be removed through pumping). The location of the toe bund is shown on Drawing 51–12506381-01-C201.

Following excavation and filling, a 200 mm layer of selected soils will be placed where necessary to provide a construction base for the compacted clay layer of the landfill liner system.

The inclined faces will have 10 m wide benches at 10 m vertical intervals to facilitate sub stage construction of the liner. These benches are graded at 5% to facilitate leachate flow through the drainage media and restrict leachate head on the benches to less than 300 mm. The exact location of these benches will be determined at detailed design stage and therefore the design plans show the average inclined liner gradient of 20% (comprising a 25% grade for 10 m vertical height plus 10 m wide bench).

#### 3.7.3 Final Fill Profile

The final landfill capping landform is shown on Drawing 51-125306-01-C 202.

The lower elevation batter slopes immediately above the 10 m high toe bund will be constructed at 1V:4H with 10 m wide benches every 10 m vertical increase in height. These benches provide maintenance access and with a longitudinal grade of 2% and will include a swale drain to direct surface water flow to the perimeter stormwater drainage.

The upper portion of the final cap that is more visible, will be constructed at 1V:20H. As discussed above, the cap will rise from Big Stone Road to a maximum height of generally 5 m above the road to allow the top of the landfill to be effectively screened by planting on the Big Stone Road boundary. A small extent (a length of 150 m) of the final cap level will be up to 14 m above Big Stone Road where the road dips and fill in the landfill is required to achieve a grade in the perimeter swale drain. Engineered fill placed over this extent avoids potential for discharge from the landfill cap to flow to the southern catchment.

The entire final cap will shed water to the perimeter drainage swale that flows to the stormwater attenuation basin at the northern base of the landfill.

### 3.8 Overall Volumes

Drawings 51-12506381-01-C201, C202 and C203 show the landfill liner, final landfill cap and development stages. The overall landfill waste volume (net of daily cover and excluding the landfill cap) is approximately 6 million $m^3$ (equivalent to approximately 5 million tonnes of refuse). As discussed previously, at an assumed average waste disposal rate of 90,000 tonnes per year the landfill void will be consumed in 55 years.

The summary of the landfill void capacity is shown in Table 4.

**Table 4 Landfill capacity**

| | Volume |
|---|---|
| Gross void volume | 7,912,921 $m^3$ |
| less cover soils | 669,595 $m^3$ |
| less drainage layer | 129,599 $m^3$ |
| Net void | 7,113,727 $m^3$ |
| less daily cover | 927,877 $m^3$ |
| Net waste volume | 6,185,849 $m^3$ |
| Net Waste tonnage[Note] (@ 0.8 $t/m^3$) | 4,948,679 T |
| Expected life (years) | 55 |

Note: Waste tonnage may increase by 10% where additional waste to be placed due to waste settlement.

The bulk earthworks volumes in the landfill construction zone is shown in Table 5. The table indicates an apparent deficit of required fill/soils. However, the deficit occurs during the final stage of landfill development (Stage 5). Stage 5 may either not be constructed at all if the Council meets its waste minimisation targets; or constructed at some time in the distant future.

In the event that Stage 5 proceeds any shortfall at that time can be provided from a borrow area. Up to 800,000 $m^3$ of soil may be required and significant potential exists for borrow areas within the designation area. Detailed borrow area plans have not been developed at this time and resource consent for borrow areas is not being sought at this time.

**Table 5 Earthworks volumes**

| | | **Volume ($m^3$)** |
|---|---|---|
| **Total cut available** | | **1,969,975** |
| Total fill required | | 855,495 |
| Base liner soils required | | 345,600 |
| Final Cover soils required | | 669,600 |
| Daily cover required | | 927,900 |
| **Total soil required** | | **2,798,585** |
| | | |
| Deficit ($m^3$) | - | 828,620 |

## 3.9 Landfill Staging

The amphitheatre like setting for the landfill lends itself to phased development progressing in a clockwise fashion from east to west around a toe buttress constructed at the northern base of the amphitheatre. The landfill will be developed in five formal stages (Stages 1 to 5) where Stages 1 and 2 will be in the north-eastern portion of the landfill footprint separated by the natural ridge from Stages 3, 4 and 5 in the south-western portion. Each stage will be the full width of the landfill (from Big Stone Road to the toe buttress). (Refer to Drawing 51-12506381-01-C201).

The retention of the central ridge between Stages 1/2 and Stages 3/4/5 has a number of potential benefits:

- As discussed in Section 1.2, if future waste stream volumes reduce significantly, landfill development can be restricted to Stages 1 and 2.
- The risk of surface water from the southern area and associated gullies entering Stage 1 and 2 leachate collection systems during flood events is greatly reduced.

Each stage will be developed in turn sequentially in a number of sub-stages. The approach to construction is provided in Section 7 of this report. The actual filling procedure will be developed during detailed design and will need to consider the temporary stability of waste placement – as discussed in Section 3.6 of this report. Accordingly, the procedure discussed in Section 7 may change, however the requirement to cover waste with intermediate or final cover to minimise exposed waste will apply to any stage arrangement.

Allowing for 13%[2] daily cover and density of compacted waste of 0.8 t/$m^3$, the relationship of the void required for each tonne of waste is 1.25 $m^3$. Assuming the projected waste flow of 90,000 tonnes per annum, Table 6 provides a summary of the anticipated life of each stage (excludes final cap).

**Table 6 Landfill Development Filling Rates**

| Stage | Waste void net of daily cover[3] ($m^3$) | Waste Tonnage[4] (t) | Placement Period (Years) |
|---|---|---|---|
| 1 | 680,119 | 544,095 | 6 |
| 2 | 1,980,340 | 1,584,272 | 17.6 |
| 3 | 632,599 | 506,080 | 5.6 |
| 4 | 2,264,940 | 1,811,952 | 20.1 |
| 5 | 627,850 | 502,280 | 5.6 |
| **Totals** | **6,185,849** | **4,948,679** | **55** |

## 3.10 Lining System

### 3.10.1 Description

The purpose of a landfill lining system is to contain any leachate within the landfill and prevent it from entering the underlying soils or groundwater. It provides a low permeability containment system on which leachate is collected and removed from the landfill. For a Class 1 landfill the Technical Guidelines for Disposal to Land (WasteMINZ 2018) describe the following two lining systems, comprising from top to bottom:

- Type 1 lining system:
  - Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;
  - 1.5 mm HDPE geomembrane;
  - 600 mm compacted clay with a coefficient of permeability $k < 1 \times 10^{-9}$ m/s.

Or

- Type 2 lining system:
  - Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;
  - 1.5 mm HDPE geomembrane;

[2] Based on 150 mm of daily cover for each 1.0 m depth of compacted waste
[3]
[4] Tonnage is calculated as a percentage of volume and may vary where settlement allows additional tonnage to be placed.

- Geosynthetic clay liner (GCL);
- 600 mm compacted clay with a coefficient of permeability k < 1 x $10^{-8}$ m/s.

These two lining systems are considered to be equivalent and meet the needs of a Class 1 landfill. Either option may be selected for use during detailed design. As discussed in Section 3.4.1, the on-site loess material may be able to be used as the 600 mm compacted clay liner with appropriate stabilisation through the addition of lime to address dispersivity characteristics while retaining plastic characteristic and the ability to self- anneal during deformation.

Completed permeability testing of compacted laboratory samples indicate a permeability of less than $1x10^{-8}$ m/s is likely to be achievable for the Type 2 system for non-stabilised loess. Further permeability testing during detailed design will be required to confirm this can be achieved and the impact of adding lime (to address dispersivity issues), and possibly bentonite , to the loess.

For the purpose of this report and analysis completed elsewhere it has been assumed that a Type 2 lining system will be adopted. The proposed lining system is shown on Drawing 51-12506381-01-C207.

All components of the lining system work together to contain leachate within the landfill and minimise leachate seepage. The combined system functions as follows:

- For there to be any leakage through a lining system there has to be a “head” (depth) of leachate on top of the system to drive downward seepage. An effective drainage system above the main containment layers drains the leachate away before a significant depth of leachate can form above the containment layers, thus limiting the potential for any leakage. Leachate depth will be maintained at less than 300 mm through the leachate collection system comprising drainage media and adequately spaced leachate collection pipework.
- The primary containment layer is the HDPE geomembrane. This is used in both the Type 1 and Type 2 liner systems. Individual sheets are welded together and all welds tested for potential leaks. The HDPE geomembrane is practically impermeable and strict quality control measures are used to ensure integrity during placement. However, for the purposes of assessing environmental effects a minimum level of leakage through the membrane is assumed based on the assumption that multiple “pinhole” imperfections could occur. For the Type 2 liner system this leakage is mitigated through intimate contact with the underlying GCL or for Type 1 by the compacted clay layer. The number of assumed imperfections is stated in the Hydrogeology Report (GHD, 2020).
- For both Type 1 and Type 2 should there be a defect or damage in the HDPE, the underlying low permeability clay layer significantly restricts leakage that can occur. If the underlying layer includes a GCL (Type 2) then the bentonite (a very low permeability natural clay material in the GCL) swells when it becomes wet, filling the space between the HDPE and underlying 600 mm clay layer.
- Where a GCL is not used (Type 1), the underlying clay layer will be assessed or otherwise modified to meet a permeability requirement of < 1 x $10^{-9}$ m/s.
- Any potential seepage has to flow through the GCL and/or 600 mm of compacted clay liner before it enters the underlying ground and is therefore reduced to the flow rate through that layer. Intimate contact in the area of the HDPE hole is critical to prevent leachate flowing laterally and increasing the surface area through (the GCL or clay layer) which the leachate may travel.

Calculations regarding potential seepage through the liner system are discussed in the Hydrogeology Report (GHD, 2020). Anticipated leakage rates vary as the landfill is developed but remain very small at all times. The maximum leakage rate near the end of the landfill life is expected to be approximately 2 $m^3$/year.

## 3.11 Leachate Collection

Leachate is the liquid produced through waste degradation and rain water that percolates through the waste to the landfill liner, collecting dissolved and/or suspended matter from the waste as it passes through. A landfill is managed to minimise the volume of leachate that is produced. This is achieved by:

- Redirecting upslope surface water from entering the leachate collection system;
- Minimising the size of the active filling area where waste is exposed to rainfall;
- Covering areas with intermediate or final cover as soon as is practicable so that as much water as possible is shed into a stormwater collection system and minimising percolation of water through these layers into the underlying waste;
- A stormwater collection system that enables monitoring of stormwater from areas of intermediate cover or final cover and ability to redirect that contaminated surface water to the leachate system if found to be contaminated.
- Providing well managed stormwater systems to separate all stormwater flow from areas where waste is placed, and ensuring all site stormwater is diverted away from waste.

All stormwater that comes into contact with waste will be treated as leachate and will not be discharged to the stormwater system. Leachate generated within the landfill will flow to the leachate collection system at the base of the landfill from where it will be removed off site for treatment and disposal.

The leachate collection system will comprise:

- 300 mm thickness of drainage media overlying the leachate containment system (landfill liner);
- Perforated pipework on the base liner to collect leachate from the drainage media and transfer to the leachate sumps at the low point of the landfill liner;
- Leachate sump inside the landfill footprint at the base of the toe embankment containing high porosity media capable of attenuating leachate inflow arising from a rainfall event;
- Inclined leachate pumps and risers laid in each of the leachate sumps;
- Leachate riser pipe conveying leachate from the leachate pumps to the leachate storage tanks;
- Load out bay to fill leachate tanker trucks to transport the leachate to the DCC waste water treatment plant. The intention is to transition from trucking to a pipeline once leachate rates justify the change. This issue is discussed further in Section 5.1 and 5.4.

The leachate drainage plans and load out areas are shown on Drawings 51-12506381–01–C401 through C403.

## 3.12 Leachate Management System Design Requirements

The leachate collection system will be finalised during detailed design. The following are the design parameters that the leachate collection is required to meet;

- Under normal operating conditions the leachate head shall not exceed 300 mm in normal operating conditions.

- The perforated leachate pipework to convey the predicted leachate flow from a nominal 10% AEP rainfall event falling to a partially completed cell that has open liner, uncovered waste and capped waste. This flow to be accommodated in the voids within the leachate sump and voids in the waste – at the base of the landfill cell.
- Three leachate inclined pumps to be installed to each of the two leachate sump, where two pumps are capable of removing the accumulated leachate. The third pump is provided for pump maintenance and to provide additional pump capacity in emergencies.
- Leachate storage in the landfill waste and above ground storage to provide 48 hour storage capacity (plus additional storage in the leachate storage tank bund for emergency situations).
- Leachate tanks to be above ground with programmed inspection/maintenance regime.
- Leachate storage to be bunded to provide emergency storage for one leachate tank (should the tank fail)
- Leachate conveyance system to be PE pipe with welded joint system.

## 3.13 Final Cap

The primary purpose of the final cap on the landfill surface is primarily to shed precipitation to the surface water management system and thereby minimise seepage of water into the waste and the generation of leachate. In addition, the cap:

- Minimises the escape of LFG.
- Provides a barrier between the landfill waste and any future users of the site.
- Provides a suitable growing medium for appropriate vegetation.

The final cover is required to meet WasteMINZ 2018 Technical Guidelines for Disposal to Land for a Class 1 landfill. The proposed cap will include not less than 150 mm of topsoil, over 600 mm of clay with permeability less than $1x10^{-7}$ m/s that overlays a minimum of 500 mm intermediate cover.

As discussed in Section 3.10 of this report, it has been assumed that the loess material will be used for the 600 mm layer. Laboratory test data indicates a re-compacted permeability of $3 x10^{-8}$ m/s to $5 x10^{-10}$ m/s can be achieved for the non-stabilised loess. However, for cap placement it has been conservatively assumed that a field permeability of $5x10^{-8}$ m/s will be achieved.

It has also been assumed that lime stabilisation will be required for the loess to address the dispersivity issue of the non-stabilised loess.

The limited growing media in the final cap will be suitable for grass cover that will require regular mowing or light stock grazing or shallow rooted vegetation only.

## 3.14 Stormwater Control

### 3.14.1 Overall Stormwater Management

Stormwater management and control will be required during the construction, operation and closure phases of the landfill. Stormwater controls are shown on Drawings 51-12506381-01-C102, C301, C803 and C804. The management and control are required to mitigate adverse effects on water quality, increased runoff volume and the associated effects on the downstream receiving environment. The issues and associated control measures are discussed below.

Stormwater systems are required as part of the landfill operation to ensure that:

- Stormwater is diverted and separated from waste to avoid contamination – any stormwater that comes into contact with waste must be treated as leachate.
- To the extent practicable, erosion and transport of sediment from earthworks areas must be minimised. This is achieved through minimising exposed soil surfaces, installing cut-off drains to minimise flow over exposed earth surfaces, installing temporary measures where practicable to minimise the transport of sediment from earthworks areas, and stabilising these areas with vegetation or by other means as soon as practicable.
- Suitable conveyance systems (channels, pipes) are in place to carry the stormwater to suitable treatment devices to remove any sediment carried with the stormwater. These systems may comprise permanent systems (e.g. perimeter channels) or temporary systems as each stage is developed.
- Adequate treatment systems are in place to remove sediment from stormwater at all stages of development and operation of the landfill.

**Construction Phase**

A key issue during the construction phase is the exposed surface with the potential to generate suspension of sediments in runoff discharging to the downstream valley and Otokia Creek (with a minor contribution to Open Stream- see Section 3.16.

The construction phase controls will include:

**Preliminary works**

- Perimeter swale drain: A cut off channel will be provided around the perimeter of the immediate construction phase to intercept up gradient flows and divert these from entering the construction area. Further description of the swale drain is provided below.
- Attenuation basin: An attenuation basin will be constructed as part of the long-term management for the site managing increased runoff from the landfill site over its lifetime. All stormwater from the landfill (other than a small (9,000 $m^2$) area on the southern edge of the landfill adjacent to Big Stone Road – see 3.16) will report to this basin. This includes runoff from:
  - The Landfill extents;
  - Gullies outside the landfill footprint – but upslope of the attenuation basin;
  - The landfill facilities area;
  - The small area of the catchment upstream of the landfill (via the perimeter cut off drain and existing gullies prior to landfill footprint development);
  - pre-construction areas;
  - areas during construction;
  - areas with final cover and/or stormwater diverted from activity areas that has not come into contact with waste.

  The basin will be located at the downstream end of the landfill site and will be constructed at commencement of the landfill development works to manage increased flows associated with the exposed surface and to provide an additional level of treatment of runoff prior to discharge. Further description of the attenuation basin is provided in Section 3.15 below (see Drawing 51-12506381-01-C102 for location).
- Sediment control pond in landfill: A sediment control pond will be constructed at the immediate base of the excavation for each phase of the landfill and provide primary treatment of runoff removing sediment from discharges that then flow through to the attenuation basin. The typical anticipated layout of a sediment control pond for Stage 1

development is shown on Drawing 51-12506381-01-C803. These in-landfill sediment control ponds will remain in operation for the life of the various landfill stages until subsequent stage works require the footprint of that sediment control pond. Alternative sediment control ponds will be progressively installed for the subsequent development stage.

- Sediment control for Stockpile: The stockpiles are located in a small sub-catchment to the north of the main site area and the associated attenuation basin (51-12506381-01-C301). Stormwater runoff from the stockpile area will be managed through a separate stormwater control system ( 51-12506381-01-C206).
- Sediment control for access road development: The access road will be constructed at the commencement of the landfill development. A series of sediment control devices and practices will be installed for this temporary works in accordance with the requirements of the Otago Regional Council.
- Stage area limitation: Excavation will be carried out as required to limit the area exposed at any one time and following excavation surfaces will be protected as soon as possible. This may take the form of grassing /hydroseeding or the use of protective matting.
- Localised works will be site specific such as management measures for the road upgrade works, which may include the use of filter socks or temporary silt dams in channels while works are under construction and there is potential for elevated sediment concentrations in runoff.

**Operation Phase**

The operational phase involves the opening of new cells as required, the progressive relocation of access routes over the landfill footprint and application of cover soils once that portion of the cell is full.

The controls for the opening of new cells are similar to those outlined for the preliminary works (for Stage 1) including extension of the perimeter swale drain around the extent of the new works, development of new sediment control ponds and the development of drainage to the attenuation basin.

The key controls for the covering and closure of filled cells are the grading and surface drainage of the impermeable capping to the perimeter swale drain flowing to the attenuation pond and the establishment of a vegetative cover over the surface to reduce runoff volumes and stabilise the surface to control sediment discharges.

**Closure/Closed Phase**

This phase includes the final covering and closure of the landfill and the post-closure land use.

The closure phase controls will be similar to those for the cell closure discussed in the operational phase above with the addition of localised short term sediment control measures for the removal of long-term infrastructure such as hardstand areas and building platforms. Landfill capping and therefore closure of the cell will be progressive. It is expected that at any point in time, the final cap will be placed and vegetation established where the design levels are reached. Areas that are not finally capped are limited to the active portion of the landfill cell and areas that are not active and have not reached the design level will have intermediate cover placed.

The closed landfill will have an ongoing stormwater management requirement. This includes the ongoing drainage from the capping and the management of increased flows together with water quality monitoring. While this does not require the construction of additional control measures it does require the ongoing retention and maintenance of the perimeter swale drain and the attenuation basin.

A site specific stormwater management plan will be prepared which will form part of the overall operation plan for the landfill. The stormwater management plan will provide a more detailed assessment of management requirements, the measures to be adopted, and design of the controls. The plan will follow good practice and will utilise relevant guidelines best practice New Zealand guidelines, including Auckland Council GD05 for the sizing of ponds and the Environment Canterbury Erosion and Sediment Control Toolbox, for the identification of the most appropriate control measures taking in to account site specific conditions.

The following sections provide more information on specific aspects of the stormwater control systems.

#### 3.14.2 Landfill Stormwater Management Systems

The proposed landfill site is bounded by ridges on three sides and drains to the ephemeral gully at the north end of the site. The site is located at the head of the catchment and there is no significant external catchments that drain to and through the landfill site. This is a significant advantage for the site in terms of stormwater management.

The catchment reporting to the stormwater attenuation basin is 69.2 ha where the current surface at the time of the consent application is mainly cleared forestry, with vegetation existing in gullies and 8 ha of exotic macrocarpa forestry.

The stormwater collection and conveyance system at the landfill is based on:

- A perimeter swale drain around the final landfill footprint to collect stormwater flows from the limited land area up gradient of the landfill and the landfill cap and divert all stormwater to the attenuation basin at the toe of the landfill and is designed for a 1% AEP storm event. The perimeter drain will be constructed progressively as the landfill stages are developed. As there is no significant external catchment this drain will primarily be collecting stormwater from the interim and final landfill surfaces.
- A system of temporary stormwater drains on the landfill operational surface, as required to suit the current stage of operation, diverting all stormwater not impacted by contact with waste to the landfill perimeter drain.
- The final cap is graded to the perimeter swale drain. Where final capping slopes exceed 1V:10H, permanent contour drains discharging to the perimeter swale drains will be installed at 50 m centres. Prior to the establishment of the grass stabilised final capping, temporary contour drains will be installed to meet the requirements of the Canterbury Regional Council document Erosion and Sediment Control Guideline.
- During landfill construction and where soils are un-vegetated, clean water diversions will be installed and all sediment laden stormwater will pass through treatment ponds for the removal of sediment. As discussed above, these will be constructed progressively within the landfill footprint and the landfill is progressively developed. An example layout for Stage 1 is shown on Drawing 51-12506381-01-C803.
- All treated (for sediment only – any stormwater found to be contaminated by waste will be diverted to the leachate treatment system for disposal) and diverted stormwater will report to the attenuation basin at the northern boundary of the landfill. Along with the toe bund, the basin will be constructed at the commencement of the project development. The pond will provide additional water quality polishing as well as attenuate flows to the downstream catchment. In addition, in the event of a spill or leachate or other contaminants the pond will provide some emergency containment.

- Stormwater calculations and catchment flow assessments have utilised rainfall data derived from HIRDS V4 rainfall data and the NIWA Stream Explorer tool with (utilising the Regional Flood estimation method) with climate change allowances based on RCP TM61 rainfall intensity prediction software and in accordance with the requirements of the Otago Regional Council.

## 3.15 Attenuation Basin Design

The attenuation basin is designed to control flows from the catchment draining to it that currently discharge to the ephemeral stream. As noted previously, drainage is likely to be restricted to periods of rainfall. The preliminary design for the basin is shown on Drawings 51-12506381-01-C306 to C307.

The attenuation basin is designed to accommodate a 1% AEP storm event with allowance for climate change to the end of the 35 year consent period which provides for 4.6 degree centigrade rise in temperature. Stormwater channels provide 300 mm of free board above the 1% AEP. It will have less than 20,000 $m^3$ of stored water in a rain event (and is normally empty) and has a retained height of less than 4.0 m to the lined spillway crest and a total height of 4.8m. Other than the spillway, the attenuation basin embankment will have 1.0 m free board and 5.0 m width at the crest for maintenance access. This will attenuate flows and provides additional water treatment through a wet forebay, a waioro filter, as well as planting on the base of the dry main basin.

When flows occur through the basin most of the time discharge will occur via the low flow outlet. However, as added security to mitigate a leachate discharge, the low flow outlet pipe will be provided with an emergency shut off valve that can be closed to provide emergency storage if required. This then allows for water captured in the attenuation basin storage to test, monitor, treat or remove off site where necessary. This reduces the risk of discharging leachate contaminated stormwater to the receiving watercourse.

The base of the basin will be unlined to allow seepage of stormwater into the groundwater system. As described in the Hydrogeology Report, this will assist in mitigating groundwater recharge to the downstream area that will be impacted by the construction of the landfill.

## 3.16 Perimeter Drain Design

The perimeter swale drain is designed to accommodate a 1% AEP storm event. The minimum gradient of the swale drain is 1% (other than on the landfill toe embankment where flow volumes are minimal. Where the 1% AEP flow in the swale would exceed 0.8 m/s, scour protection will be applied to the design wetted surface of the swale drain. This limiting velocity is based on the use of loess in the channels and the maximum velocity for grassed swales will be confirmed during detailed design. Channel scour protections will vary dependant on the design velocity and will range from grass only channel, through reinforced earth (grass root matting) through to formal rock ballast rip-rap.

The swale drain will have a continuous gradient along the 1.2 km frontage of Big Stone Road from the high point at the south end of the landfill to the facilities area at the north and from there to the attenuation basin. To achieve this, the swale drain will be constructed on engineered fill to raise the swale 8 m above the road at this location being approx Ch360 on Channel 2 (see Drawing 51-12506381-01-C303 & 51-12506381-01-C304). Cross section and detail shown on Drawing 51-12506381-01-C3032. Slightly north of this location and where Big Stone Road is higher than the proposed swale drain, the drain will be constructed about 5 m lower than Big Stone Road. In both instances, the swale drain will have cross fall to the road boundary at a 1V:4H grade.

While the design directs all stormwater from the landfill and associated catchment to the attenuation basin, a small area of exception exists. Where the swale drain is higher than Big Stone Road (small section along southern edge of landfill – Area 1B shown on Drawing 51-12506381-01-C301), surface water that falls on the batter below the swale drain cannot flow into the swale drain. Flows from this area will be diverted from the landfill catchment to the catchment south-east of Big Stone Road (Open Stream catchment – see Section 3.16). This diversion in catchment has an area of 9,000 $m^2$ and anticipated flow rates of 67 l/s for a 10% AEP and 101 l/s for a 1% AEP. As the batter in question will be constructed wholly of engineered fill (see Drawing 51-12506381-01-C302), no waste will exist in this sub-catchment thereby avoiding the possibility for leachate to escape to this catchment.

The stormwater from this small sub-catchment will be collected in a swale drain along the base of the embankment and directed to the Big Stone Road swale system and Open Stream catchment via a culvert beneath Big Stone Road. The Open Stream catchment is comparatively large (at least 6 $km^2$) and the additional diversion catchment of 9,000 $m^2$ will make a very minor additional contribution (less than 0.01%). The flow to be diverted is calculated as 67 l/s for the 10% AEP and 101 l/s for the 1% AEP.

## 3.17 Subsoil Drainage and Groundwater

It is expected that there will be a number of groundwater seepages exposed within the landfill base when excavation to base grade levels has been completed. Springs/seepages remaining beneath a lining system can result in uplift pressures and cause a local failure of the lining system, and therefore they must be controlled and drained away.

To control groundwater beneath the landfill, a network of subsoil drains will be constructed beneath the lining system to be available to drain groundwater seepage under all stages of the landfill development. Subsoil drains also provide a collection system for any leachate seepage through the lining system. The groundwater drainage is therefore piped to a monitoring location at the toe of the landfill embankment. In the highly unlikely event that monitoring of the collected groundwater indicate unacceptable quantities of leachate, the groundwater can be extracted and treated as leachate. The proposed subsoil drain system will comprise:

- The base grade of the landfill will include ground water drainage that will gravitate to the low end of the landfill where it can be monitored and discharged to the attenuation basin.
- Seeps in the upper slopes will be tapped with additional drainage that feeds to the base grade drainage.
- The base grade drainage pipe will be perforated HDPE pipe in straight alignments to facilitate water jetting if required.
- The collection manhole will also be fitted with a small submersible pump to extract water for storage at the non-potable water supply reservoir located at the facilities area. This water will be used for vehicle cleaning and other maintenance purposes.
- The groundwater sump will be monitored for any leachate effects.
- The hydrogeology report estimates that groundwater seepage collected by the underdrain system will be very small reflecting the low permeability of the underlying geology. Groundwater flows could be up to 4 $m^3$/day (approx. 0.05 litres/second).

## 3.18 Perimeter Tree Planting

Landfill perimeter tree planting is proposed to provide visual screening along the exterior of the site and will also intercept dust from the site operation. A minimum 10 m wide strip has been provided to plant a mix of exotic and indigenous tree species along the site boundary with Big Stone Road and along the north eastern ridge within the site. All of the trees with the exception of Stages 4 and 5 can be planted at the commencement of the project. The trees along Stages 4 and 5 (Stage B mitigation planning) will be planted on constructed fill which will not be in place until approximately year 29.

The planting will consist of double staggered rows of pine adjoining the site boundary combined with mix of Kanuka (*Kunzea ericoides*) and Totara (*Podocarpus totara*) within the site.

# 4. Landfill Gas Management

Landfill Gas (LFG) collection and destruction is required by the National Environmental Standards for Air Quality 2004 to be provided in a landfill has a capacity of more than 1,000,000 tonnes of waste and the system must be in operation before 200,000 tonnes of waste is placed. With the predicted waste stream of 90,000 t /per annum, the gas collection and flaring system should be installed and operational within 2 years of commencement of the landfill operation.

LFG management is described in the Landfill Gas Design Report (Appendix A to this Report). In summary, the proposed LFG management system will incorporate the following elements:

- The lining and capping systems described earlier in this report will retain LFG within the landfill and prevent off-site migration.
- A LFG collection system comprising a network of collection wells and pipework.
- A destruction system using flaring with the opportunity to generate electricity once LFG quantities are sufficient.
- Monitoring to confirm the effectiveness of the system, including LFG monitoring boreholes/wells outside the waste boundary and regular surface monitoring of methane emissions from the completed cap.
- Buildings and structures on-site (but outside the landfill footprint) will be designed and constructed to minimise the risk of LFG entry and accumulation.
- Subsurface services on-site will be designed and constructed in accordance with relevant standards in relation to LFG as applicable (e.g. AS/NZS 2381.1.1:2005).
- Appropriate work, health and safety procedures will be developed and implemented in relation to situations where workers/site users may be at risk of being exposed to LFG emissions.

Gas collection systems can be installed in a number of a different ways. One option is the gas system will comprise vertical wells drilled into the waste after placement of the final capping. During landfill cell development and prior to the placement of the final cap, temporary horizontal landfill gas extraction pipes can be installed and connected to the gas extraction system. Other options for installation may be adopted.

The permanent wells will be pumped through near-surface and surface pipework to a gas destruction system that will be located at RL 125 on a terrace constructed on the north flank of the facilities area (see Drawing 51-12506381-01-C5701). This location is 15 m lower than Big Stone Road and the flare will be largely screened from Big Stone Road and beyond by tree planting and the topography.

Gas destruction will be provided initially by flaring. The landfill operator may however install “gas to energy” at its’ discretion. This plant, if fitted, will be located at the prepared terrace where the proposed flare is located. The *Landfill Gas Design Report* (Appendix A) details the residual discharges from flared LFG.

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# 5. Leachate Management

## 5.1 Leachate Quantities

Leachate is produced through decomposition of waste and where rainfall percolates through waste. Rates of generation are highest during operation where waste is being placed although this is mitigated as much as possible through careful management of the active landfill face. Flow rates through waste (including areas with daily cover) are further mitigated by absorption and evaporation. On completion of the landfill and application of the low permeability capping, leachate flows will be greatly attenuated such that the design flow will approach the average annual percolation rates.

In designing leachate management devices in the landfill, allowance for the peak flow condition is required to prevent discharge of leachate to the environment.

By far the most dominant contributor response to a single rainfall event, is flow to the leachate collection system from the exposed landfill liner before waste is applied (and before attenuation of the rainfall through the waste).

The percentage of rainfall and the reporting time for rainfall to reach the leachate collection system has been modelled using the Hydrologic Evaluation of Landfill Performance (HELP) software. The quantum of leachate produced annually is presented in the GHD report *Smooth Hill Landfill: Hydrogeological Assessment* (December 2019).

There are five pathways for rainfall infiltration to meet the leachate collection system – the derived time and total rainfall as a percentage of annual rainfall, for precipitation to reach the leachate collection system is tabled as follows:

**Table 7 Rainfall infiltration pathways**

| Pathway | Reporting time | % infiltration |
|---|---|---|
| Flow from open liner (with drainage layer) | 10 minutes | 95% |
| Flow through 14 m depth of open waste | 2 to 10 days | 67% |
| Flow through 14 m depth of open waste with daily cover | 2 to 10 days | 34% |
| Flow through Intermediate cap | >7 days | 29% |
| Flow through Final cap | >70 days | 26% |

Concept-level designs for the leachate collection system are shown on Drawings 51-12506381-01-C401 to 403. Leachate that reports to the leachate collection system, flows through pipework and drainage media to accumulate in the leachate sump at the low point of cells 1/2 and 3/4 where submersible pumps extract and deliver the leachate to above ground holding tanks.

Leachate will then be tankered off site until such time as a gravity pipeline will convey leachate to the council sewerage system connection in Brighton. This issue is discussed further in Section 5.4.

The in-cell leachate sumps provide storage for 10% AEP rain events through the voids within open graded aggregate that fill the sumps.

Additional storage for 1% AEP weather events is provided in the waste.

The Stage 1 sump is separated from Stage 2 sump with a clay berm that extends up the interface of the base of the Stage 1 / 2 cells (refer to Drawing 51-12506381-01-C208). The same applies to the Stages 3 / 4. The berm overlies the continuously laid landfill liner so that complications in the construction of the landfill liner are avoided. The berm is constructed to 2.5 m above the nominal liner level at the sump and 1.0 m above the liner at the interface between stages 1 / 2 and stages 3 / 4 to provide the required in-waste leachate storage volume and separation for the leachate management system from the surface water system. The bund therefore separates leachate from surface water from the as yet undeveloped landfill foot print.

When landfill development completes the landfill liner to the level of the landfill toe embankment (some 10 m above the base of the landfill), the risk of leachate loss to surface water is practically eliminated as leachate would need to saturate the waste for a depth of 10 m before being able to over top the bund and is therefore unlikely. Consequently the critical storage of leachate within the landfill cells is assessed for Stages 1 and 3 only.

The critical leachate flows relating to the leachate collection system infrastructure are summarised in the following table. The calculation sheets are provided in *Smooth Hill Landfill: Hydrogeological Assessment* (December 2019).

The leachate storage return periods stated in Table 9 provide for 10% AEP where leachate discharge is contained in other devices, AEP of 1% is used where there are no secondary devices that would otherwise contain leachate discharge.

### Table 8 Critical Leachate Storage Volumes

| Infrastructure | Storm return period (AEP) | Unit | Required capacity | Design capacity |
|---|---|---|---|---|
| Leachate collection pipework | 10% (TC 10 min) | l/s | 151 | 150 |
| Leachate sump storage | 10% (TC 2 hr) | $m^3$ | 267** | 240 |
| Emergency in waste storage (additional to the sump storage) | 1% (TC 2 hr) | $m^3$ | 214 | 790 |
| Total storage in landfill cell<br>. | | $m^3$ | 481 | 1,030 |
| Leachate storage tanks<br>(Stages 1-5)<br>(3 x 450 $m^3$ – 12.9 Dia x 3.5m high) | 10% (2 days) | $m^3$ | 1255 | 1350 |
| **Additional** (to above tank storage) leachate storage in emergency bund for leachate tanks<br>Based on bund base of 21 m wide x 55 m long and 1.5 m bund height | 1% (2 days) | $m^3$ | 862 | 992 |

Notes and assumptions

- ** The apparent discrepancy of the required storage over the actual storage in the leachate sump is not significant as the more than adequate additional capacity exists in the voids in the waste.
- Leachate collection pipework is 2 x 200 mm slotted HDPE @ 4% grade
- Leachate drainage media provides flow additional to pipe flow
- Porosity in leachate sump aggregate assumed as 30%

- Porosity in waste assumed as 30%
- Leachate pumps are assumed to be EPG Companies - SurePump™ Wheeled Sump Drainer Series 95 or similar with a 30 l/s capacity for each pump
- Leachate storage in the in-cell sump provides for 10% AEP event with the greater of 2 hours storage assuming pumps are not working, or the peak short storm duration flow (with pumps working).
- With combined cells (1 + 2 and 3 + 4 + 5) the in-cell leachate sump capacity is doubled as there are 2 sumps for each combined cell.

## 5.2 Leachate Quality

Leachate is generated from a Class 1 (municipal) landfill, due to the interaction of waste with infiltrating water and the release of liquids directly from the waste. Leachate can have varying quality, dependent upon the relative proportion of different waste types, landfill design, age of the landfill and local environmental setting. Typically, contaminant concentrations in leachate are highest when waste is exposed in an operating cell, and decrease with closure and as the landfill ages. Decomposition of putrescible material and the transition of the landfill waste from an aerobic to anaerobic state, and the generation of organic acids over time also plays a key role in determining leachate quality, influencing microbial reactions, solubility and physiochemical reactions of leachate constituents.

Decomposition of putrescible waste and the leachate generating environment is often defined as occurring in three stages:

1. Aerobic degradation, generating heat and producing organic compounds and carbon dioxide.
2. Anaerobic degradation where large organic molecules are broken down into simple compounds such as hydrogen, ammonia, water, carbon dioxide and organic acids.
3. Methanogenic degradation where organic acids break down to form methane gas and other products.

Table 9 outlines an upper quartile for the highest leachate constituent concentrations of eight New Zealand landfills, outlined in the Centre for Advanced Engineering Landfill Guidelines (CAE, 2000). For the purpose of this report and associated studies, this has been assumed to be the likely typical composition of leachate generated by the Smooth Hill landfill.

**Table 9: Upper quartile of the highest leachate constituent concentrations**

| Parameter | Upper Quartile Concentration – Class 1 Landfills (mg/L excluding pH)(1) |
|---|---|
| Aluminium | 7.9 |
| Ammoniacal Nitrogen | 705 |
| Arsenic | 0.17 |
| Boron | 12.3 |
| Cadmium | 0.0063 |
| Calcium | 378 |
| Chloride | 1730 |
| Chromium | 0.17 |
| Dissolved Reactive Phosphorus | 3.4 |

| | |
|---|---|
| Iron | 183 |
| Lead | 0.13 |
| Magnesium | 193 |
| Manganese | 5.4 |
| Nickel | 0.19 |
| Nitrate Nitrogen | 0.86 |
| pH | 8.1 pH Units |
| Potassium | 630 |
| Silica | 36 |
| Sodium | 1165 |
| Sulphate | 292 |
| Total Kjeldahl Nitrogen | 1220 |
| Zinc | 1.2 |
| Total VOC | 6.5 |
| Total SVOC | 4.4 |

1) Upper quartile of the highest leachate concentrations recorded in eight consented municipal solid waste (MSW) Class 1 Landfills in New Zealand (CAA, 2000).

## 5.3 Leachate Collection

As described in Section 3.14, leachate generation will be minimised through diversion of surface waters, minimising exposed waste cells and early placement of intermediate and final cover to landfill waste. The base liner will ensure containment of leachate within the landfill and minimise any discharge of leachate to the groundwater system (see Hydrogeology Report).

The leachate collection system includes 300 mm of granular drainage media with perforated pipes placed at centres designed to limit leachate head to 300 mm above the line during normal operational conditions, to be placed on the landfill liner (see Drawing 51-12506387-01-C207). However, as noted in Section 5.1, during low frequency/high intensity rainfall events the leachate level will be allowed to rise into the waste to allow for emergency short term storage. The drainage media will be protected with an overlying separation geotextile to limit soil fines that may clog the drainage media. Leachate drainage pipes will be extended to the edge of the landfill (up the landfill embankment bund to permit water jetting of the drainage collection pipework.

The leachate drainage pipes will be 200 mm ID smooth bore, slotted PE pipes designed to withstand the proposed waste load. The smooth bore pipes will extend the edge of the landfill to permit regular flushing of these pipes. At the minimum liner base grade of 4%, the capacity of each pipe is 75 l/s. Dual pipes will be installed at the toe of liner batters, however additional flow is available in the 300 mm deep drainage media that the pipes are laid in.

Leachate collected in the drainage pipework and media will report to a sump at the low end of the cell base where inclined leachate pipe risers will be installed to the surface of the landfill toe embankment.  These risers will have inclined pumps, to pump to leachate holding tanks at the site facilities area.

Penetrations to the landfill liner system by leachate pipes will be avoided through the use of HDPE inclined pump riser pipes connected to the leachate collection system.

The leachate pump system will have multiple pump risers pumps designed with one pump in redundancy. An emergency power supply will be installed at the facilities area to power the pumps should there be a fault in the overhead mains supply.

## 5.4 Leachate Storage and Management

### *Leachate Disposal*

Leachate disposal from the landfill will be to the Dunedin City Waste Water Treatment Plant (WWTP). During the initial period of landfill development, leachate volumes will be relatively modest and leachate will be stored on site and transported via road tankers to the Green Island WWTP facility. At an appropriate point of site development, a pipeline will be constructed from the site to the nearest connection into the WWTP system at Brighton, approximately 7.5 km to the north east of the site.This is not part of the application and will be considered at a later date.

The average leachate volumes to be removed off site are summarised below in Table 10. The following table also provides a summary of the truck movement determination if trucking was continued through the life of the landfill. However, as mentioned above, the intent is to change to a pipeline. Based on the below values the most likely time to change is after completion of Stage 1. Based on assumed filling rates this will be approximately 6 years after the landfill commences operation.

**Table 10 Average leachate removal by tanker**

| | | Stage 1 | Stage 1 - 2 | Stage 1 - 3 | Stage 1 - 4 | Stage 1 - 5 |
|---|---|---|---|---|---|---|
| **Total average annual leachate generation** ($m^3$) | | **29,978** | **48,107** | **58,503** | **75,045** | **87,283** |
| Total leachate predicted (as % of rainfall) | % | 36% | 32% | 30% | 29% | 28% |
| Average leachate per day | $m^3$ | 84 | 139 | 178 | 228 | 271 |
| Trucks per day (with 20 $m^3$ tanker) | No. | 4 | 7 | 9 | 11 | 14 |

Note that tanker truck numbers will increase to the point that the landfill operator will decide that installation of a gravity leachate discharge (to the DCC sewerage system) is financially viable. This may be at the end of Stage 1 or during the early development of Stage 2 of the landfill.

### *Leachate On-site Management*

While the leachate system is designed to limit the leachate head on the liner system to 300mm or less, the landfill leachate sump will be designed to accommodate storage of 10% AEP storm flows and provide for emergency storage for a 10% AEP in the landfill and waste for a period of 4 hours to not exceed a 1.0 m head on the nominal landfill base liner. This period allows issues with power supplies or pumps to be repaired before the storage is exceeded.

Storage for the 1% AEP is provided in the leachate sump at the base of the landfill and leachate storage tanks at the facilities area. This combined storage approach is used, as it is not practical to pump the whole storm flow to the leachate storage tanks. Bunds separating partial cells in the landfill will have levels designed to contain the 100 year storm event.

Leachate storage at the tanks in the facilities area will accommodate a 24 hour 10% AEP storm with additional storage for the 1% AEP in the tank farm bund. See Drawing 51-12506381-01-C403.

The critical leachate flow event is related to the temporary condition in the landfill development where the liner of a cell extension is installed and before waste is placed over this liner. Therefore there is no attenuation of the flow that waste would otherwise provide. As this condition exists at all stages of the landfill development – the storage tanks farm must be constructed in its entirety at commencement of the landfill operation.

The leachate storage tanks at the facilities area will be multiple 450 $m^3$ Timbertanks$^{tm}$ or similar that are around 13 m in diameter and 5 m high. The tanks will be contained in a lined depression to accommodate 150% volume of a ruptured tank and provide additional storage for a 1%AEP rainfall event. Surface water from the bund will have a valve arrangement to allow manual discharge to the surface water system following confirmation that there is no leachate in that rain water.

Once separately consented and constructed, the piped leachate drainage from the landfill to the Green Island WWTP via the existing Brighton network, will provide a flow rate for full discharge of the leachate from the tanks over the 24 hour period.

# 6. Ancillary Works

## 6.1 Operating Hours, Deliveries and Weighbridge

The landfill will be open for waste deliveries 7 days per week and up to 9.5 hours a day.

The proposed opening hours are as follows:

- Monday to Saturday 8.00 am - 5.30 pm
- Sunday 9.00 am - 5.30 pm
- Closed Christmas Day, Easter Friday and Anzac Day until 1pm

The landfill operator may commence operations 1 hour before and up to 1.5 hours after the opening hours to prepare for waste delivery in the morning and to close off the works at the end of the day. Staff or contractors may be on-site outside these hours for required work, monitoring or maintenance.

The site will only receive deliveries from commercial operators – general public access will be excluded to the site although the Council are considering inclusion of a visitor centre to allow public viewing of the site and education opportunities. Any centre will be located near the site entrance and securely separated from the site operations. .

Anticipated truck numbers to access the site are set out in the Traffic Assessment Report (GHD, 2020) and include the following during operational phases:

- Workers vehicles
- Delivery of waste
- Leachate transport (initial phase of operation only).

During the period of construction vehicle numbers will increase due to construction materials deliveries and additional site workers.

For delivery of waste, the expected waste flow is 90,000 tonnes per annum. The estimated number of truck movements has been calculated and presented in Table 11. This data indicates an average number of truck movement per day in the order of 10. This is an average number and allowing for daily variations during the year and leachate truck removal the total truck movements could be up to approximately 25 per day. Up to approximately 25 light vehicles may also travel to the site each day.

**Table 11 Total truck numbers per annum**

| Truck | Percentage of total deliveries | *Capacity of each truck)* *(t)* | Total carted for all trucks @ 100% capacity) (t) | Number of trucks if 100% capacity | Number of trucks if 80% capacity | Totals (t) |
|---|---|---|---|---|---|---|
| 6w | 10% | 10 | 3,982 | 398 | 498 | 3,982 |
| 8w | 20% | 15 | 11,947 | 796 | 996 | 11,947 |
| semi | 30% | 22 | 26,283 | 1,195 | 1,493 | 26,283 |
| T&T | 40% | 30 | 47,788 | 1,593 | 1,991 | 47,788 |
| **Totals** | | | **90,000** | **3,982** | **4,978** | **90,000** |

Trucks arriving at site will access the landfill through the proposed route from Big Stone Road. (see Drawings 51-12506381-01- C702) The site will be fenced and a main gate at the access point will provide security. Trucks will pass through the gate and be weighed at a weighbridge located inside the gate (see Drawing 51-12506381-01-C608 and C609 and C702).

Provision will be made for the weighbridge to be staffed with a kiosk installed between the incoming and outgoing weighbridges although other options and configurations for waste inspection may be utilised. This provides for manual/visual inspection of loads entering the site for compliance with the waste acceptance criteria for a Class 1 landfill described in Appendix D of the *WasteMINZ (2018) Technical Guideless for Disposal to Land*. If for any reason a truck load is rejected, a turning area is provided for the vehicle to leave the site. Following weighing, the truck will progress to the active landfill operational area for discharge via the internal access roads though the facilities area and across the landfill toe embankment. Once emptied to the landfill, trucks will pass through the wheel wash facility (see Drawing 51-12506381-01-C701 and C702 for optional locations) to ensure any tracked waste or sediment is removed before departing from the site via the weighbridge and main gate.

## 6.2 Site Roading

### 6.2.1 Access Road

#### *Description*

Access from SH1 is via the existing McLarens Gully Road to the junction with Big Stone Road (a distance of approximately 4.3km) Traffic then turns right onto the existing Big Stone Road for 350m to a proposed landfill access road junction (see Drawings 51-12506381-01-C611 to C612). A new access will be constructed from the junction to the site facilities and landfill – a distance of approximately 200m.

#### *Upgrades Required to Existing Roads*

An evaluation of anticipated traffic has been completed (see Integrated Transport Study, GHD 2020) and based on the study upgrades to the existing SH1/McLaren Gully Road junction are proposed. These will include:

- Upgrade of the SH1/McLaren Gully Road junction with the inclusion of a south bound left turn lane (Drawing 51-12606381-01-601).

- Inclusion of "flag lighting" for the SH1 junction.

Widening and upgrade of Maclaren Gully Road and Big Stone Road will be required up to the site access location. The legal roads and access to the weighbridge will be sealed.

The upgrade will not significantly affect stormwater volumes and the sealing of the road is likely to result in a reduction in sediment discharges in runoff. Design has therefore assumed that runoff will be managed via discharge to roadside channels similar to existing and that the same discharge points to watercourses will be retained so that the current drainage regime is not altered.

The concept level design for the road upgrades is shown on Drawings 51-12506381-01-C602 through C612 and indicates the following earthworks are required:

- Total cut volume up to 124,000 $m^3$
- Total fill volumes up to 109,000 $m^3$
- Cut slopes up to 4 m high.
- Embankments up to 6 m high

### *Internal Site Access*

The landfill main entry will have a lockable gate located at the entrances. Waste trucks will continue through the access road, loads assessed and weighed at the weighbridge and then to the landfill past the landfill facilities areas as shown on Drawings 51-12506381-01-C702. The wheel wash and weigh bridge will also be located in this area. Beyond this point the road will be unsealed. The leachate tanker trucks will enter the facilities yard to allow the trucks to fill with leachate before transporting the leachate to the DCC sewerage system for treatment at the Green Island WWTP

The design objective is for landfill access grades to not exceed 10% to be suitable for hauling full waste vehicles up-hill. The internal access roads will be constructed in a mix of cut and fill with slopes to be confirmed during detailed design. Fill embankments will be provided with fixed barriers to meet the requirements of the NZTA Safe System road safety approach.

Drainage for the new access road will be to roadside channels either side of the road in the location where it is in cut or at existing ground level and via sheet flow to the adjacent slope where the road is formed on a new embankment.

### *Tip Area Access and Perimeter Road*

An access track will be constructed around the final landfill perimeter next to the perimeter swale drain. The purpose of the track is to provide 4-wheel drive access to the perimeter of the landfill for monitoring and maintenance purposes. The track will be a gravel road.

The perimeter track will be progressively constructed along with the perimeter swale drain as the landfill stages are developed. Stormwater from the perimeter access will be directed to the swale drain.

As discussed earlier in this report, waste delivery and construction traffic will enter the landfill via the main gate

Once on the landfill toe embankment, the waste delivery trucks will access the base of the landfill for a bottom up waste placement. The existing ridge between Stages 2 and 3 is at the same level as the landfill toe embankment and this facilitates the construction of temporary access to the base of the landfill cells.

All landfill access roads will be unsealed.

Temporary aggregate access roads will be constructed on the landfill to provide passage of the waste delivery trucks. These temporary access roads will be amended regularly as the waste is placed and the level of the waste increased as the cell is progressively filled.

Surface run off from the access roads south of the intersection with the facilities area will discharge to the stormwater attenuation basin which will also provide a degree of treatment improving the quality stormwater discharges from the site. This attenuation basin also provides for the ability to manage a spill (should this occur) within the site and internal access roads closest to the landfill. Monitoring of water in the attenuation basin will be undertaken.

## 6.3 Site Facilities

Two main platforms will be created for the location of facilities: an upper area immediately to the north east of the landfill and west of the Big Stone Road access gate; and a lower platform to the north of the landfill (see Drawing 51-12506381-01-C701 and C702).

### 6.3.1 LFG Flare, Possible Future Energy Generation and Leachate Storage

The LFG flare and any future energy generation facility will be located on the lower platform area and workshop area where the elevation is ~RL125 (Drawing 51-12506381-01-C501, and C702).

Leachate storage tanks will be located on the upper platform (~RL135) to facilitate future gravity feed to the leachate load out platform and ultimately facilitate pumping to Brighton for discharge to the sewerage system at that location.

### 6.3.2 Site Office

An administration building will be provided for staff responsible for the operation of the landfill. It is anticipated that this would comprise the following or similar:

- Offices for landfill manager, construction manager, and others
- Offices for admin and accounts staff
- One office for laboratory, safety and compliance personnel
- Meeting room
- Lunch room/kitchen
- Toilet and shower facilities.

This would be located in a single storey building as shown on Drawing 51-12506381-01-C702. The precise location will be determined during detailed design. Parking will be provided adjacent to this building. As noted previously, this building and leachate storage will be located within the site security fence. If developed, public access/parking and a viewing platform/information boards will be provided east of this area and outside the security fence for public visitors. Access to the public area is from Big Stone Road.

### 6.3.3 Workshop and Staff Amenities

The layout of the workshop and facilities area is subject to detailed design. The following are indicative details to provide scale to the proposed facilities.

A workshop will be provided for plant and general maintenance. This may be a building of up to 20 m x 25 m with high access doors on the front to permit the large landfill plant to enter for maintenance and repair. Refuelling will occur at a dedicated location in the workshop compound where spill kits will be on hand. The workshop may have an associated store of equipment spares and essential landfill materials. This store would incorporate a toilet, shower, lockers and lunchroom.

A concreted equipment wash-down area with oil/sediment traps will be located near the workshop.

Water tanks will be provided to store non-potable water (from roofs or groundwater) for wheel wash, equipment cleaning and dust suppression requirements.  Potable water for drinking and showers will be tankered in. Wastewater from the toilets and showers will discharge to the leachate collection storage tanks for removal off site and disposal to the DCC sewerage system.

Additional small buildings will also be provided in this general area to house small plant, equipment, etc.

### 6.3.4 Wheel Wash

A wheel wash will be provided on the main access road for cleaning the wheels of all vehicles leaving the site as shown on drawing 51-12506381-01-C702. Beyond these points, the access road to the public roads will be sealed. The wheel wash will comprise a pressure under body spray wash with rumble bars through which the vehicles drive. Dirty water from the wheel wash will be captured in coarse sediment traps adjacent to the wheel wash and further treated in flocculation ponds before being recycled back to the wheel wash.  Discharges of excess water from the wheel wash recycle system are expected to be minimal and only occur during periods of heavy rainfall. This water will flow into the landfill stormwater system and will pass through the landfill stormwater attenuation basin.

## 6.4 Water Supply

### 6.4.1 Potable Water

Potable water for use of the landfill staff will meet the requirements of G12 of the Building Code and will be from water tankered to the site during the initial years of operation. A water supply pipeline from Brighton will be installed at the same time as the leachate pipeline after about 6 years of site operation.

### 6.4.2 Non-Potable Water

*Non-Potable Water Supply and Storage*

The non-potable water will be collected from the workshop roof and extracted from the ground water control system discussed in Section 3.17 above will be stored in large capacity tanks at the Facilities Area during the initial years of operation.  Water storage will also be provided to meet fire water supply requirements for the buildings at the facilities area in accordance with SNA PAS 4509:2008 (New Zealand Fire Service Firefighting Water Supplies Code of Practice) and the NZ Building code.

It is expected that after meeting fire supply requirements, daily demand for non-potable water may include the following.

**Table 12 Non-potable water use**

| Use | Estimated volume |
|---|---|
| Dust suppression (four applications per day) | 40 $m^3$ |
| Wheel wash (Daily requirement to supplement losses) | 5 $m^3$ |
| Machinery wash/vehicle wash (intermittent requirement) | 2 $m^3$ |
| **TOTAL daily non potable water use** | **47 $m^3$** |

The proposed water storage of non-potable water is four days maximum supply requirement and 200 $m^3$.

The annual catchment of the annual rainfall to the workshop building would produce approximately 300 $m^3$ per year. A typical single rainfall event of 15 mm precipitation would produce approximately 7.5 $m^3$ to flow to the tank. Although collection of roof water is beneficial, the supply volume is insufficient to meet the requirements for dust suppression over the summer season.

Groundwater collected from the landfill underdrains can also contribute to the water demands for the site. The Hydrogeology Report GHD, 2020) estimates groundwater flows of up to 4 $m^3$/day may be available, although it is noted that these seepage rates are likely to reduce with time following site development.

Therefore, rainfall and groundwater will not reliably meet the water demands for the site and will need to be supplemented by tanker water deliveries during the initial years of operation. However, as described above, after around 6 years of operation a water supply pipeline will be installed from Brighton to meet the site requirements.

### *Firefighting Water*

There are no pre-existing water sources on the site for fire water supply. The geology of the environs to the Smooth Hill landfill are such that the groundwater table is at the lower gully inverts and there is no continuous standing water in the lower gully and as such there is no reliable source for onsite fire water supply in addition to the supply discussed above.

First response firefighting water will be provided from on site storage tanks and delivered to a fire with a site dedicated 10 $m^3$ water tanker truck filled from a dedicated fire water supply tank of not less than 100 $m^3$. Other non-potable water tanks will be available for fire use; however, use of those tanks for other uses may make the storage in those tanks as unreliable.

Should helicopter monsoon buckets be used; water could be taken from the Taieri River approximately 3.5 km from the Site. Road based tankers can obtain emergency fire supply water from the same source being 6 km from the landfill west via McLaren Gully Road, 1.5 km south on SH1 and a short section of Henley Road to where it abuts the Taieri River.

## 6.5 Dust Suppression

Dust management and suppression will be an important part of mitigating and avoiding on-site and off-site effects associated with the construction and operation of the site. A range of measures are described in the Air Quality Report (GHD 2020) that will be implemented during construction and operation of the landfill to control dust emissions. As discussed above, it is noted that adequate water will need to be secured for this activity (estimated at up to 40 $m^3$ per day).

## 6.6 Services

Electricity, telecoms and data services are required at various locations on site. These will be arranged with the applicable service providers. Site telecommunications will use either mobile cell phone technology or a simplex radio system, and would involve small antennae and repeaters mounted on the site amenities buildings. If generated, electricity will be exported from the site at 11 kV or 33 kV by pylons and wires to be installed from SH1, along McLaren Gully Road/Big Stone Road and through the main vehicle access to the landfill.

# 7. Landfill Construction, Operation and Closure

## 7.1 Landfill Construction Activities

The landfill operation is effectively a long-term construction project dominated by earthworks and stormwater management. The bulk of these activities are completed progressively with waste being received over the projected life of the landfill. Therefore, the activities can be broadly divided into:

- Initial construction activities
- Ongoing operational and stage development activities
- Closure and aftercare activities

This construction methodology sets out the considerations and possible construction method to be used. At the time of preparation of this methodology, detailed design was not completed and the procurement model for construction not confirmed. Additionally the construction period has not been determined.

Accordingly, this should be considered a possible construction methodology and subject to confirmation following detailed design and delivery methodology for the landfill.

### 7.1.1 Initial construction activities

Initial construction activities occur prior to the landfill accepting its first waste. It is anticipated that these activities will take place over at least two construction seasons prior to the landfill accepting waste, with a construction season generally being defined as the period from October to April/May the following year.

Initial construction activities will include:

- SH1 and McLaren Gully Road/Big Stone Road upgrades.
- Access road from public road entrance to the site including site entrance and security fencing.
- Initial site clearance
- Construction of main offices and associated facilities.
- Construction of leachate storage tanks and load out.
- Construction of attenuation basin and toe berm.
- Construction of permanent stormwater controls around the initial stage of landfill development.
- Construction of sediment control measures.
- Formation of base grades for sub stage of Stage 1 of landfill.
- Placement of low permeability liner system and leachate collection system for sub stage of Stage 1 of landfill.
- Construction of wheel wash and weighbridge.
- Perimeter screening plantings.
- The landfill gas system will not be installed until 200,000 tonnes of waste is placed in the landfill. This is expected to be around 2 years after commencement of the landfilling.

### 7.1.2 Operational activities

Operational activities include:

- Waste filling.
- Placement of daily cover and intermediate cover as required. Materials will be stockpiled in the area indicated on Drawing 51-12506381-C206 or within the next sub stages of the landfill to minimise haul requirements.
- Stormwater management and maintenance works.
- Management of LFG and leachate systems.
- Environmental monitoring.
- Construction of the next landfill stage and other required construction work.

### 7.1.3 Closure and aftercare activities

Closure activities include placing the final capping layer on completion, establishing any final landscaping and removing any facilities and infrastructure that are not required during the aftercare period, or modifying such infrastructure for the aftercare period.

Aftercare activities include maintenance of the cap and stormwater systems, management and maintenance of the leachate and LFG systems and ongoing site and environmental monitoring.

The following sections describe these activities in further detail.

## 7.2 Initial construction activities

### 7.2.1 Earthworks

The five stages of the landfill are shown on drawing 51-12506381-01-C203. For completion, the landfill development requires earthworks involving 1.9 M $m^3$ of cut and 0.85 M $m^3$ of fill. Excess cut material will be consumed through the combined requirement for landfill liner (0.35 M $m^3$), final cover soils (0.67 M $m^3$) and daily cover (0.93 M $m^3$). It is envisaged that waste soils disposed to the landfill can be used as daily cover. Based on these assumptions, the required fill exceeds the cut material by approximately 0.9 M $m^{3.}$ However, as discussed in Section 3.8, this deficit is projected to occur late in the project's life and opportunities exist to develop on site borrow areas if the deficit occurs. The exact requirement for borrow volume is subject to the quantity of waste soils deposited and cannot be accurately predetermined for the life of the project at this time therefore all numbers at this time are indicative only. The Stage 1 earthworks will result in excess cut materials that will be required for further stages and will be stockpiled. This is discussed below.

Daily cover soils will be progressively excavated from future cut areas or stockpiled soils as the landfill develops.

The overall earthworks are typically limited to 5 m cut depth, although there will be deeper cuts on the ridges in Stage 3 and Stage 5 of up to 17 m. Loess soils will be excavated from beneath the landfill as they are both a viable source of landfill liner/cap and intermediate fill material. Excavated weathered breccia will be used for construction fill. Accordingly, the loess and breccia will be stored in separate stockpiles.

The breccia is generally sufficiently weak to be ripped and excavated although limited areas of blasting may be required.

### 7.2.2 Site Clearing

The landfill site is predominantly cleared forestry with replanted pine. Some native vegetation exists in the Stage 5 area and wetland species in the bottom of the gullies.

Clearing will only occur in the extent of the stage and associated sub stage that is under development. For the Stage 1 works, this will include the sub Stage 1A liner footprint (plus allowance for the subsequent sub stage), the landfill toe embankment, the facilities area and the access road from Big Stone Road. This extent is shown on drawing 51-12506381-01-C803 by way of example of how sub stages will be developed within any given stage.

Cleared vegetation suitable for the purpose will be chipped and stockpiled for later use as erosion control mulch. Stumps and poor quality organic material will be stockpiled clear of earthworks areas and water courses and allowed to decompose.

### 7.2.3 Topsoil Stripping

Topsoil will be required for placing on the final cap for establishment of vegetation. It is important that the topsoil is both removed from the base of the landfill and stored separately and appropriately in the stockpile area indicated on Drawing 51-12506-001-C206. Assuming a depth of 150 mm there could be up to 65,000 $m^3$ of topsoil that requires removal – although this will be progressively stripped, stockpiled and re-used over the life of the landfill.

### 7.2.4 Unsuitables

Small quantities of organic rich alluvial deposits may be excavated from the base of some of the gullies. This material, along with the insitu loess, requires removal from beneath the landfill as it is not suitable as a base grade for the liner system. Materials will be stockpiled separately for possible future use as a growing layer on the cap or for disposal in the landfill as a daily cover.

### 7.2.5 Subliner

The base liner bulk cut will be to at least 800 mm below the design level of the liner. This allows for the removal of rock (where this exists) and the placement of a soil layer that provides a suitable substrate to the placement of the high specification compacted clay liner. The subliner will generally be non-cohesive site won soils compacted to 95% standard compaction.

### 7.2.6 Landfill Toe Embankment

The toe embankment is key to the stability of the landfill. Due to its height, it also provides protection from leachate loss should leachate levels rise in the landfill for any reason.

The toe embankment will be installed in its entirety during the Stage 1 works to facilitate the construction of the stormwater attenuation basin, to utilise cut material from Stage 1 that would otherwise be stockpiled and to provide vehicle access to the future stages of the landfill to permit future development.

The toe embankment will be constructed from breccia material excavated as part of the Stage 1 works. This will be placed and compacted as engineered fill to meet the requirements of the detailed structural design for the embankment. The foundation soils for the embankment will be removed where they are outside the specifications due to organic content or moisture content.

The liner will be placed over the upstream face of the embankment to ensure leachate containment if leachate levels temporarily rise in the landfill.

### 7.2.7 Liner System Construction

#### *Compacted Clay Liner (CCL) Formation and Soil Modification*

The following section provides an approach to liner placement based on the assumption that a Type 2 liner system will be utilised – as described in Section 3.10 of this report. This is intended as an indicative description of the liner placement process. Detailed design may opt for a variant to this approach and design.

The landfill liner can be installed to the extent that waste will be placed for the following 18 months. The landfill liner could then be extended annually with provision to continue filing 6 months past a 12 month design period (should the 12-month capacity be achieved at the start of winter). Installation of the landfill liner over winter cannot achieve the required quality and will not occur.

The liner formation will be constructed to provide a minimum transverse gradient of 2% and longitudinal gradient of 4% on the landfill base. These gradients will direct leachate to the sump where inline pumps will transfer the leachate to the leachate storage tanks.

The composite liner consists of (bottom to top) structural soil foundation (subliner as described above), compacted clay liner (CCL), flexible membrane liner (FML) textured both sides and a protective non-woven geotextile underlying the leachate collection system. A geosynthetic clay liner (GCL) will be placed under the FML on the base of the landfill (not side liners). The FML will be coloured white on the upper side to reduce thermal wrinkle development.

The composite liner will be overlaid with the leachate collection system. The interface friction values of the composite liner will undergo laboratory testing when the material suppliers are identified and accurate product information is obtained. As discussed in Section 3.6, laboratory friction test results will need to be reviewed during detail design with respect to the waste placement plan and liner/waste slope stability.

Suitably modified loess soils could be used for liner and capping development and will be set aside in stockpiles as part of the bulk earthworks. Initial testing reported in this document (Section 3.4.1) indicates that lime stabilisation of the loess material addresses dispersivity characteristics of the material. This issue will require further investigation and confirmation during detailed design. At this time it is assumed that any liner will conform to the requirements for a Class 1 landfill set out in the Technical Guidelines for Disposal to Land (WasteMINZ 2018).

#### *Synthetic Liner Installation*

Filter fabric, GCL and FML will be installed to the manufacturer’s specifications progressively as the composite liner is constructed. GCL shall not be applied where there is risk or rainfall before the FML can be placed over the GCL.

Joints in the synthetic liners shall have laps and application of sealants in accordance with the manufacturer’s specifications. The FML will be double seam welded and pressure tested prior to acceptance. Hot bead edge welding is only permitted where destructive test samples are taken from the FML liner.

In all instances, synthetic liner will be anchored in trenches at the top of the slope or intermediate benches as appropriate.

#### *Leachate Collection System*

Following acceptance of the composite landfill liner, the leachate collection system will be installed on the base of the landfill. The protective filter fabric will be applied to the FML prior to any work commencing on the leachate collection system.

All pipework will be polyethylene and joints butt welded and de-beaded internally. Electrofusion welding will only be accepted in exceptional circumstances. Perforated sections of the leachate pipework will be slot cut radially. All other leachate pipework rising to the edge of the landfill liner will be anchored and provided with removable caps for flushing purposes.

Drainage media will be applied over the prepared base liner as a single layer using low bearing pressure delivery vehicles and spreading equipment. Trafficking over the exposed synthetic liner will not be permitted.

The leachate drainage media will be protected from contamination with an overlay of a non-woven geofabric.

Leachate pump risers, pumps, delivery pipes, storage and loading facilities will be installed prior to placement of waste in the landfill. The leachate storage system and the load-out bay have containment systems installed to capture and retain any leachate spillage. This will be operational prior to placement of waste in the landfill.

***Groundwater Management System***

For much of the landfill site, groundwater within the underlying breccia is many metres below the base of the landfill. Seepage is however anticipated towards the landfill toe, and at the junction of the landfill base and the sidewalls. Accordingly, groundwater drainage will be installed prior to the construction of the CCL.

The groundwater drainage will be designed to withstand the design loads and will be polyethylene with joints butt-welded and de-beaded internally. Electrofusion welding will only be accepted in exceptional circumstances. Perforated sections of the pipework will be slot cut radially. The perforated drainage pipework will be encased in open graded aggregates and the entire drain encased in filter fabric.

The loess soils are known to be easily erodible – therefore any drainage pipework will have filters applied to prevent soil particle loss to the drainage. The drainage pipework that extends under the landfill toe embankment will not be perforated and will not have filter material encasing the pipe bedding, but will have anchor blocks to prevent longitudinal flow of water through the bedding.

While significant amounts are not anticipated, any seepage in the side batters to the landfill will have secondary drainage pipework extending from the main groundwater drainage to the point of seepage. The specification for this secondary drainage will be the same as for the main groundwater drainage.

The groundwater drainage will report to an access manhole immediately before discharging to the attenuation basin. This allows flushing of the pipework and monitoring of the discharge. This monitoring manhole may have an electrical pump to divert ground water to tanks at the landfill facilities area for non-potable use as dust suppressant, wheel wash and equipment wash down.

### 7.2.8 Likely Machinery Requirements during the Construction Phases

Construction phases will be recurring every 2 to 5 years during the life of the landfill and are likely to require the following equipment (or similar):

- Vegetation chipper x 1
- Excavators x 4 (20 to 30 tonne)
- Scrapers x 2
- Moxy x 1
- Bulldozers (D6 equiv) x 2

- Padfoot roller x 1
- Grader x 1
- Vibrating smooth drum roller x 2
- Water cart
- Delivery trucks (come and go – only 1 stationed on site)

#### 7.2.9 Stockpiles

The proposed stockpile location is shown on Drawing 51-12506381-01-C206. Excavated material is likely to be mostly stored within the landfill footprint for re-use in the next phase of development. The stockpile area will be used for longer term storage, as required. This may include:

- Surplus excavated materials until they are needed for landfill operations or final capping;
- Low permeability loess material;
- Topsoil
- Unsuitables

The stockpiles will have appropriate sediment control measures which may include the use of soils stabilisers, biodegradable cover or silt fences for the smaller stockpiles or sediment retention ponds and cut off drains for the larger stockpile areas. Stockpiles will be track rolled and trimmed to regular shapes and those not expected to be reworked within 1 month will have mulch or hydroseeding applied.

The stockpile will be no higher than 20m.

### 7.3 Operational Activities

#### 7.3.1 Waste Composition

The Landfill will be a Class 1 Landfill suitable to accept municipal solid waste, and hazardous materials that meet the leachability (TCLP) limits from Ministry for the Environment (MfE) 2004:*Module 2: Hazardous Waste Guidelines* – Class A. Generally cleanfill and bulk green waste is not expected to be disposed at the landfill as these wastes are expected to be diverted from the waste stream and managed at facilities closer to Dunedin. It is however expected that some cleanfill or greenwaste will be comingled with other waste or may from time to time be deposited in the landfill. Contaminated soils that meet the acceptance criteria will be accepted. As previously described, daily cover will generally be won from excess earthworks spoil as the landfill base is progressively developed.

The waste composition for waste disposed to Green Island Landfill for the period 1 July 2017 to 30 June 2018 has been assumed to represent the waste characterisation for the Smooth Hill Landfill.

Waste will be co-mingled in the body of the landfill but is expected to include the following as outlined in Table 13:

**Table 13 Waste Types**

| Waste Stream | Likely % of waste tonnage |
|---|---|
| General Waste | 92% |
| Special/Hazardous Waste | 8% |

Waste minimisation is expected to occur off-site, with the Council responsible for determining the likely operations model for achieving waste minimisation (i.e. kerbside collection to transfer station – waste segregation and recycling and reuse – to landfill). As discussed above, at this time it has been assumed that Council will minimise compostable material from being disposed to the landfill to preserve void space and reduce landfill gas generation.

Special and hazardous wastes will require specific handling and deposition into the landfill in accordance with hazardous waste guidelines and as set out in the landfill management plan. Special waste is likely to include biosolids from DCC Waste Water Treatment Plants, with a review of DCC's long-term biosolids strategy being undertaken in 2020/21 with a view to informing expenditure in the 2021 Long Term Plan.

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### 7.3.2 Waste Placement

Incoming waste will be inspected and weighed at the weighbridge and trucked to the landfill tip area through the main landfill access road. At commencement of the landfilling with waste, the base of Stage 1 will be some 10 m below the level of the toe embankment crest. The natural land formation between Stages 2 and 3 has the same level as the toe bund. This will be utilised to create a temporary access to the base level of Stage 1. Access roads on the landfill will be amended as the waste level rises.

Initial layers of waste applied to the prepared liner and leachate collection system will be bagged waste or selected waste that has no protrusions that could penetrate the FML. This initial waste placement will be pushed out over the leachate blanket. Landfill machinery will not be permitted to traffic over the leachate blanket unless there is at least 1.0 m thickness of waste. Compaction will not commence until the waste is greater than 2.0 m thick.

At commencement of the Stage 1 landfilling, a low bund will be installed at the interface of Stages 1 and 2 to provide support for the toe slope of the waste and to direct leachate to the leachate collection sump. This bund will also direct surface water from earthworks to the sediment retention pond and avoid entry to the leachate collection system.

Daily cover will be applied at the end of each day's waste placement.

#### Daily Cover

Landfill daily cover could be 150 mm of site won or imported soils. Acceptable imported soils may include contaminated soils that are non-odorous and meet the waste TCLP acceptance criteria for landfill waste, or construction and demolition waste. Daily cover will be placed at the end of each working day such that there are no uncovered areas of waste while the site is not operating. The operating cell of the landfill will be limited to around 300 $m^2$ to provide for not less than 1.0 m compacted depth of waste to be placed to avoid excessive percentage of cover soils to waste. Artificial daily covers are also an option that is available for consideration.

#### Intermediate Cover

Intermediate cover will be placed where waste will not be overlaid with fresh waste for more than 3 months. The cover soils will be low permeability loess stripped from subsequent landfill stages or stockpiles placed in compacted layers not less than 300 mm thick and with hydroseed applied. The cover shall be graded to the stormwater system where possible to allow runoff of uncontaminated water and reduction in leachate generation. Intermediate cover will be stripped before placement of fresh waste.

### 7.3.3 Likely Machinery Requirements during Operational Phase

In addition to the waste delivery trucks, the following machinery or similar are likely to be required for the operational phase of the project:

- Excavators x 2
- Bulldozer x1
- Reuse compactor x 1
- Water cart x 1
- 6W truck x 1

## 7.4 Closure and Aftercare Activities

Prior to the end of the life of the landfill a Landfill Closure Plan will be prepared to detail the activities required for closure of the landfill and the aftercare period. In general terms, the following issues will be addressed.

The final capping system will be constructed progressively after filling in any area as the final waste level is reached. Cap construction will generally comprise:

- Excavating soils from the soil stockpiles and placing in layers on the landfill cap in accordance with the design.
- Placing an upper topsoil and/or growth layer from materials stockpiled on site.
- Constructing surface contour drains to manage stormwater falling on the landfill cap, including connections to the perimeter drainage systems.
- Establishing vegetation

Equipment used for capping works will be similar to those identified above for construction phases, as described in Section 7.2.8.

On completion the stockpile sites will be graded to conform to the adjacent topography and revegetated and any stormwater systems disestablished.

The balance of the site will have permanent stormwater features finalised. This includes:

- Contoured swales on the landfill cap
- Perimeter swale
- Attenuation basin.

All facilities not required during the landfill aftercare period will be removed.

Aftercare activities comprise:

- Ongoing operation and maintenance of the LFG extraction and treatment system
- Ongoing operation and maintenance of the leachate collection, treatment and disposal system
- Maintenance of the site stormwater systems

- Maintenance of the landfill cap, including filling any areas that may have been subject to differential settlement, repair of any surface erosion and maintenance of vegetation as required
- Maintenance of any remaining site infrastructure, including fences
- Ongoing environmental monitoring as required by consents
- Any reporting required by consents
- Responding to contingent events as set out in the Landfill Closure Plan.

# 8. Hazards and Contingent Events

During the construction/operational phase of the landfill a range of potential extreme events may occur that are outside the design scenarios. A number of different scenarios and potential response actions have been considered in the following section of the report.

## 8.1 Extreme Weather

Extreme weather events include very high rainfall episodes beyond the design criteria assumed in this report; very high wind events; and high snow fall events that prevent landfill operation.

For issues relating to extreme rainfall, in most cases the proposed stormwater treatment systems, leachate management systems and attenuation basin are designed to manage a 1%AEP event and limit potential environmental effects. Responses that may be required following extreme events include:

- Take immediate steps to prevent/minimise discharge of waste or leachate to the stormwater system and downstream receptors.
- Advise relevant authorities of any breach of any consent conditions.
- Investigate whether downstream effects have occurred and plan remedial actions.
- Undertake water analysis and prepare remedial action plan for approval of the consent authority.
- Treat or remove contaminated water as required by the consents or consent authority.
- Repair on-site infrastructure.

. In the event extreme snowfall event or extensive wind-blown damage may prevent access to the weighbridge or to the active waste cell for an extended period (more than 1 day). Actions that may be required include:

- Gaining access for site staff using 4WD vehicles as soon as possible.
- Once the site is accessed, reviewing all key stormwater, leachate management and landfill gas management components to ensure ongoing operation.
- Advise relevant authorities in regard to breach of any consent conditions.
- Take immediate steps to prevent/minimise discharge of waste or leachate to the environment.
- Coordinate the accumulation of waste at waste transfer station or re-direct waste to an appropriately classed disposal facility (i.e. Kate Valley Landfill or AB Lime Landfill).
- Provide portable weigh station on the emergency access or record waste deliveries based on estimation.
- Remove excess snow and or import aggregate to re-open access to the active waste cell.

## 8.2 Earthquake

Section 3.4 of this report provides an overview of the seismic risk associated with this location. This has been taken into account in the design of the landfill and will continue to be addressed through detailed design. An unlikely event larger than anticipated seismic event occurs it may result in:

- Instability of the permanent landfill face.

- Instability of any internal working face.
- Instability of the landfill toe bund.
- Lateral displacement of the waste pile.
- Possible excessive strains and/or rupture of the landfill lining system.
- Tearing on the landfill capping.
- Landslips elsewhere around the site and landfill access road (discussed further in Section 8.5).

Following a significant earthquake the following actions should be undertaken:

- Inspect the landfill and surrounds for any visible sign of land damage, or damage to the lining system where observable.
- If identified, inform the relevant authorities and instigate an investigation program to determine the extent of any damage and necessary remedial actions.
- The lining system is of particular significance and damage may not be observable. Shallow waste slope failure could allow the waste to be removed to inspect the condition of the liner. If this is not possible, the groundwater collection system should be monitored weekly to identify any potential leakage of leachate from the waste through the liner.
- If there is a rupture of the composite liner – there is likely to be a direct report to the groundwater collection system and a quick response observed by monitoring. In such a case, the groundwater collection system is separated into four discrete systems and flows from the affects system can be re-directed to the leachate collection system should leachate content exceed acceptable levels.
- A rupture of the FML where the CCL is intact is likely to have a more moderate impact and the effects to the ground water collection system would be monitored and action taken as above where the effects of the discharge exceed acceptable levels as agreed with the Otago Regional Council.
- Tearing of the landfill capping may require the removal of expelled waste to the active cell and repair of the capping construction.
- Leachate breakout from the capping may occur through minor capping failures. Remedy may include excavation of chimneys into the waste to direct the surface discharge to the landfill and leachate collection system and repair of the landfill cap.

## 8.3 Leachate Discharge to the environment from above ground systems

The event considered here is a “sudden” discharge.  Any failure and leakage of the liner is considered a long-term event and would be identified through monitoring of the groundwater underdrain system and /or downstream groundwater monitoring wells.

A sudden leachate discharge to the environment could occur as the result of a number of events:

- Failure of the leachate rising main between the landfill and the storage tanks.
- A leachate tank and bunding failure.
- Spillage from a leachate tanker during filling.
- Spillage from a tanker during filling or transport through the site.

- In the longer term, rupture of the proposed pipeline between the site and Green island WWTP (not considered further here as will be the subject of a future resource consent application if needed).

The leachate riser pipes will be butt-welded PE and are resilient to movement and impact. The leachate storage tank farm is provided with emergency containment to accommodate a tank failure. The leachate load out bay is provided with storage of the tanker capacity to retain spillage should that occur.

The landfill and the facilities area gravitates to the stormwater system that reports all flows to the attenuation basin. Any leachate discharge to the environment from equipment failure would ultimately enter the attenuation basin. The low flow discharge pipework from this basin has stop valves to retain spillage (particularly in events not associated with a significant rainfall event). This arrangement allows stormwater to be monitored and either released to the environment if acceptable or held and re-directed to the leachate management system if not.

If a spillage occurred outside the catchment that drains to the attenuation basin (i.e. the landfill access road and public roads) it would involve a leachate tanker accident where typical environmental spill response mitigation associated with the spillage of any trucked hazardous substance would be need to be implemented.

## 8.4 Landslip

As discussed in Section 3 the site area is currently susceptible to shallow failures associated with the loess deposits that occur across the site.  A number of existing landslips have been identified on site and will need to be investigated and addressed during the detailed design process. Reactivation of existing features or development of new landslips may occur on site – most likely in response to extreme weather events or a seismic event.  In general, such events may not impact operations unless they damage site infrastructure or block access routes. Actions to be taken involve general and well understood civil engineering practices.

## 8.5 Attenuation basin dam failure

The attenuation basin is normally “dry” unless flows exceed the nominal base groundwater flow. Water depth in the basin during operation is limited to 1.0 m depth of retained water up to a 10% AEP event. The structure is designed to attenuate up to a 1% AEP through the piped system and excess to that flow will have safe passage over the stabilised overflow.

During a 1% AEP event, the attenuation basin will retain 3,300 $m^3$ of water.  The maximum height of the retaining structure is 4.8 m (from crest to lowest downstream natural surface level). Consequences of failure and appropriate emergency measures will need to be addressed during detail design.

## 8.6 Landfill Fire

Landfill fires potentially fall into three different categories:

- Surface waste fires
- Underground waste fires
- Fires in surrounding scrub/trees.

Underground landfill waste fires are typically very slow burning and by their underground nature are not a significant threat to the surrounding environs. However, they difficult to extinguish and emphasis must be placed on prevention. In regard to surface fires and fires in the surrounding scrub/tress the emphasis is on first response fire attendance and prohibition of ignition sources and spark arrest to machinery will be set out on the landfill management plan. Provision of fire water supply is discussed in Section 6.4 above.

### *General procedures*

- When discovered, personnel must advise site management or nominated chief warden immediately, no action is to be taken without notifying another person, unless in immediate danger.
- Information to be provided to the fire warden includes: location of fire, type of fire, whether any person is trapped, injured or involved, any action taken so far.
- If possible – remove any machinery or equipment or shut down. Shut down any obvious fire hazards e.g. gas lines. Remove personnel from the area. Operators not to alight from plant or equipment unless safe to do so.
- Communications officer or chief warden representative will contact the emergency services if necessary, other personnel are not to unless instructed to prevent duplication and confusion of information.
- Control of the landfill is delegated to the most senior warden present who will direct evacuation if needed and liaise with emergency services.

Landfill fire management may include:

- Excavate out any waste on fire and smothering with inert soil material or similar. Use on site water cart and fire truck.
- Switch off power supply and LFG gas lines if there is subsequent risk.
- Site manager to direct plant operators for best approach to each individual incident.
- Plant and equipment should be moved to a safe distance away from the area.
- All fire water will be treated as leachate and managed accordingly.
- Personnel must not enter landfill area during a fire event unless instructed or accompanied by emergency services or onsite personnel with the relevant PPE (breathing apparatuses).

The on-site water tanker truck will be fitted with pressure pump and hoses to apply water until the Fire Service arrives to the site. It is important to not assume that the fire is extinguished.

Underground fires can occur deep within the waste through a combination of hot-spot development and pockets of LFG. While extinguishing these fires utilises a similar approach to that described above, access can be problematic and may require re-excavation of waste to achieve.

Fires in the surrounding brush/trees may ultimately result in a surface waste fire and damage to other infrastructure. A firebreak will be maintained around the site to limit the risk of a nearby brush fire spreading to the site.

# 9. Alternatives Considered

## 9.1 Landfill Designation Location

The Council commenced a search for a new landfill site to succeed the existing Green Island landfill in the late 1980s. The process and recommendations are documented in the Council report “A Future Landfill for Dunedin” (DCC April 1993). Thirty-two potential landfill sites were initially considered with respect to ecological, physical, social and economic factors. The initial selection process reduced the number of sites from 32 to 11. The 11 sites were then assessed against a range of criteria documented in the Beca Stevens 1992 report “Dunedin City Council Refuse Landfill Study – Site Selection Report” (Beca 1992A). Following this study and considerable consultation with a range of stakeholders including Tangata Whenua, consensus was reached by the Council that:

- In the immediate future the extension of Green island would be evaluated in detail; and
- Smooth Hill was the preferred future landfill site and would be investigated further to confirm the viability of that site.

Beca then completed an environmental impact assessment of the proposed Smooth Hill site in October 1992 (Beca, 1992B). The Beca report concluded that the site is technically suitable for a landfill with a capacity of approximately 55 years at filling rates estimated at that time. On the strength of the Beca (1992B) report; Council resolved to proceed with negotiations to purchase the Smooth Hill property and appropriate designation of the Smooth Hill site as a landfill site. These processes were completed over the following year, and the designation remains in effect.

Since that time, Green Island has continued to be Dunedin’s primary municipal solid waste landfill operation. However, current resource consents for the operation expire in 2023 and while the potential exists to extend the consents for a limited period, the Council decided to resume investigation and enabling of the Smooth Hill landfill option as part of the wider Waste Futures 2023 Project (that develops a comprehensive waste management and diverted material system for Dunedin).

In 2018 and 2019 the Council facilitated initial review of the Smooth Hill site followed by a feasibility assessment including: landfill filling plans; financial models; and landfill feasibility in terms of engineering, economics, environment, social and cultural aspects. The findings are summarised in the Stantec Report “DCC Waste Futures 2023 – Landfill Feasibility Workstream” (Stantec Feb 2019).

The Stantec feasibility report concluded that Smooth Hill has the capacity to accommodate current waste quantities to 2063 and beyond and further investigation did not identify any barriers to development – effectively confirming the 1992 study findings.

Based on these confirmatory findings Council approved proceeding to apply for resource consents for Smooth Hill and completing associated studies, including this design report.

Therefore, the Council have been through an extensive process of site selection in the early 1990s with wide ranging consultation with respect to the selection of the Smooth Hill site – concluding in the site being designated as a future landfill location. The recent 2019 work has confirmed that the Smooth Hill site remains a viable and the preferred location for a Class 1 landfill to replace the Green Island landfill.

## 9.2 Landfill Size and Footprint

The designation area is significantly larger than required for the landfill (i.e. 87 ha compared to a landfill footprint of approximately 44.5 ha) and allows some flexibility in landfill location as well as co-siting of appurtenant facilities and structures. As discussed in Section 2 of this report, the topography of the site is a natural amphitheatre and the landfill has been sited to take advantage of the natural landform to the extent possible.

During the design process, technical input from a range of experts has been used to help guide the design process and minimize environmental and social effects to the extent possible. Adjustments made to the landfill footprint and final form based on this input include:

- Avoidance of the "Western Gully" by the landfill footprint and appurtenant facilities. Initial ecologically studies identified this area as having higher ecological values (Drawing 51-12506381-01-C102 for location of gully).
- Restricting the final landfill cap elevation to no more than 5m above the adjacent landform to allow screening by tree planting.
- Adjustment of the landfill footprint adjacent to Big Stone Road to allow for appropriate landscape plantings to screen the landfill from road users and adjacent properties.

The 2019 Stantec report targeted a landfill waste volume of 6,000,000 $m^3$ for the landfill. A similar landfill waste volume has been developed as part of this study. Current Dunedin annual waste disposal rates are in the order of 90,000 tonnes per year. If these rates are maintained the landfill has a life of approximately 55 years. However, uncertainty exists over future rates of disposal. Issues include:

- The Council is looking to divert waste to recycling where possible, as well as promote waste minimisation. This is likely to result in a long-term reduction in landfill waste per head of population.
- This may be offset to some extent by population growth in the Dunedin area. Furthermore, the landfill may accept waste from other districts, increasing the annual rate of waste disposal.
- Significant region wide unexpected events can result in spikes in waste disposal rates.

Given the uncertainty regarding future requirements, the landfill has been developed to allow future adaption. As discussed in Section 2 of this report, a key adaptive approach is that the landfill can be developed in two distinct phases. If waste volumes reduce significantly, Stage 1 and 2 of the landfill may be sufficient for many decades and development of Stages 3 through 5 can be delayed long into the future.

# 10. Limitations

This report: has been prepared by GHD for Dunedin City Council and may only be used and relied on by Dunedin City Council for the purpose agreed between GHD and the Dunedin City Council as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than the Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Smooth Hill Landfill Project arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Dunedin City Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

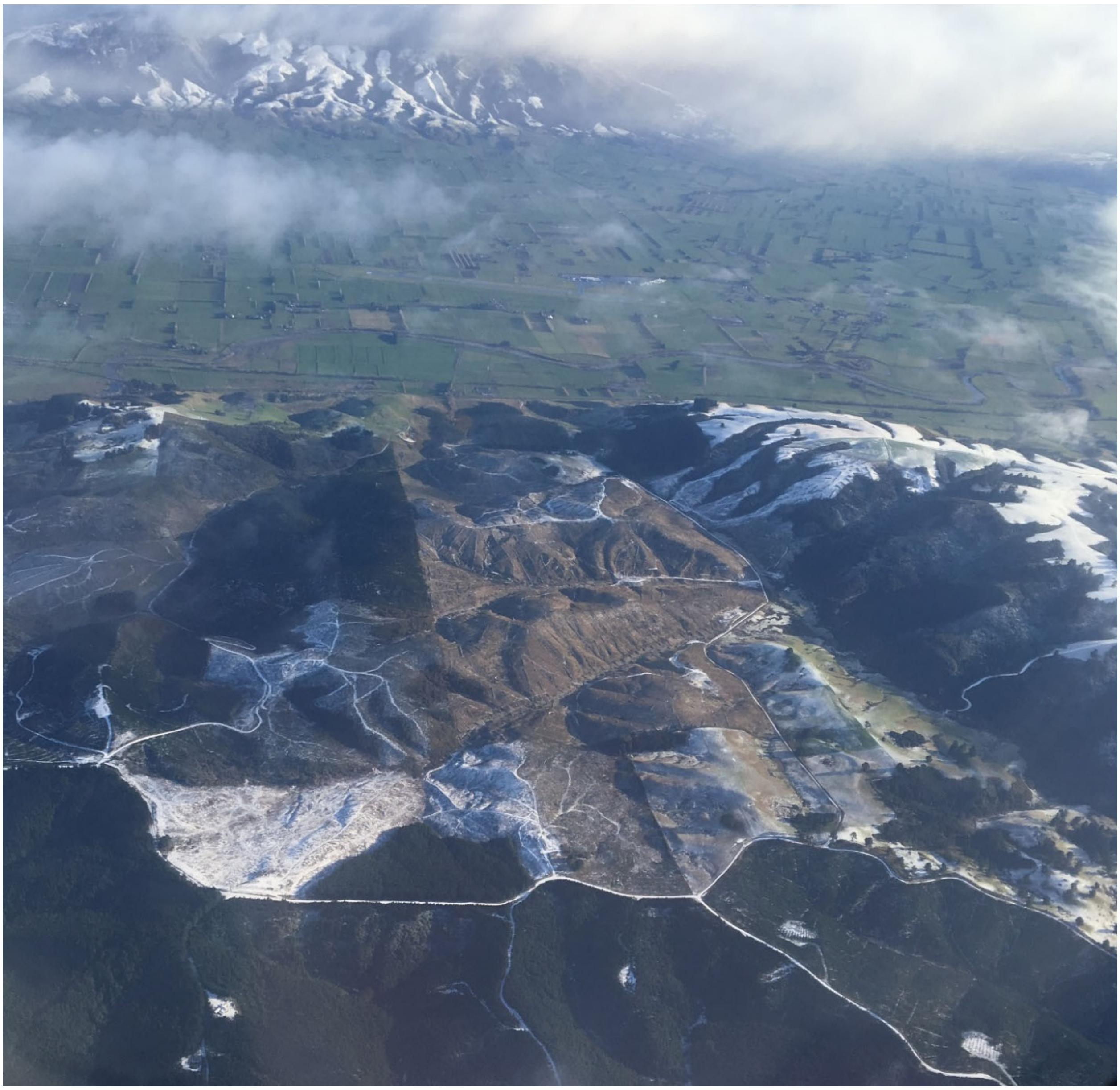
The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of vegetation and topography. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

# Appendices

# **Appendix A** – Landfill Gas Assessment and Concept Landfill Gas Management Measures



# Dunedin City Council

## Waste Futures - Smooth Hill Landfill

## Landfill Concept Design Report

## Appendix A - Landfill Gas Assessment and Concept Landfill Gas Management Measures

August 2020

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# Attachments

# 1. Introduction

## 1.1 Purpose of this report

The purpose of this report is to document the assessment of Landfill Gas (LFG) related impacts and appropriate LFG management measures for the proposed Smooth Hill Landfill (the Landfill). This report is an appendix to the GHD (2020a) *Landfill Concept Design Report* (the Design Report) and should be read in conjunction with that report for information on the background to the project and the site setting amongst other relevant matters.

## 1.2 Scope of works

GHD undertook the following scope of works for the Landfill as part of this report:

- Reviewed relevant background information, including relevant legislation and guidance
- Developed a parameters, assumptions and justifications table for a LFG emissions model
- Developed a LFG emissions model based on the parameters adopted
- Developed Conceptual Site Models (CSMs)
- Completed a preliminary LFG Risk Assessment (RA)
- Identified potentially appropriate LFG management measures
- Prepared concept designs and supporting basis for an active LFG collection, treatment and destruction system, and perimeter monitoring bore network
- Prepared a report (this report) to document the works completed

## 1.3 Assumptions

During the preparation of this report, GHD has made a number of assumptions as identified through the text of this report and its appendices. These assumptions include (but are not limited to) the following:

- The assumptions adopted for the LFG emission model are adequate to produce a reasonable LFG emissions output model scenario for the purposes of this assessment.
- The assessment of LFG related risks is a subjective process and that one individual's tolerance for risk may be quite different to another individuals. The preliminary LFGRA completed as part of this report was completed by GHD personnel experienced in LFG management. Therefore, it is based on GHD's tolerance to the identified risks. This may be different to DCC (or other parties) tolerance to the same risks.
- The assessment of LFG related risks is only valid for the circumstances prevailing at the time of assessment.
- The concept designs proposed for the LFG system and the bore network as part of this assessment are to be considered as indicative only. The future contractors would provide more refined designs prior to construction or an alternative design and construction method that results in similar outcomes.
- GHD considers that the guidelines and information that have been adopted in this report in relation to assessing and managing LFG at the site were appropriate for that purpose.
- Where timeframes are discussed in this report, these timeframes are based on landfilling waste at the rate of 90,000 t/annum and commencing in 2022. The actual date waste

deposition commences may be several years later.  However, for the purpose of this report 2022 has been used as a base date for modelling and reference purposes.

## 1.4 Introduction to landfill gas

## 1.5 What is LFG?

LFG is a complex mixture of different gases produced by the degradation of biodegradable waste materials deposited within landfill sites. The emission rate and chemical composition of LFG varies depending on many factors including waste type, time, moisture content, temperature, etc. During the anaerobic phase, when decomposition of biodegradable waste materials occurs in the absence of oxygen, methane and carbon dioxide are the major constituents of the LFG generated (although numerous other gases may also be present at low concentrations).

The timescale for the evolution of significant quantities of LFG typically varies from three to twelve months following waste deposition, and can continue for well over 30 years following the termination of waste landfilling activities.

LFG can cause health, safety, amenity and environmental impacts due to the gases it contains. Under certain conditions, LFG can:

- Be flammable and explosive
- Present an asphyxiation (suffocation) hazard
- Be toxic to humans, flora and fauna
- Be odorous
- Be corrosive
- Contribute to greenhouse gas emissions
- Contribute to photochemical smog

Due to its potentially hazardous nature, LFG must be appropriately assessed and managed at landfill sites.

## 1.6 LFG legislation

Under the National Environmental Standards for Air Quality (Air Quality NES) Regulations 2004, a Class 1 landfill, such as the Smooth Hill landfill, requires control and flaring of LFG where the landfill has a total potential capacity of not less than 1 million tonnes and contains not less than 200,000 tonnes of waste (refer to Section 5.2 for more details). The Smooth Hill landfill exceeds this criteria and the LFG system is required to be installed and operational before 200,000 tonnes of waste is deposited in the landfill.

## 1.7 How is LFG typically assessed and managed?

The typical approach to assessing the significance of LFG related risks at a landfill site is to:

- Identify potential physical hazards that may be associated with LFG emitted from the landfill site.
- Review relevant site information in relation to LFG.
- Estimate potential future rates of LFG emissions from the landfill site.
- Develop CSMs for potential LFG emissions from the landfill site.
- Prepare an assessment of LFG related risks.

Following the completion of the tasks above, potentially appropriate LFG management measures for the site are identified.

GHD has adopted the approach above for the site. Further information on these tasks (as relevant to the site) is provided in the following sections.

In terms of potential impacts of combusted LFG on nearby receptors this issue has been addressed in the Air Quality Assessment report (GHD 2020).

# 2. Proposed landfill site

## 2.1 Existing Environment

Section 2 of the GHD (2020a) *Landfill Concept Design Report* (the Design Report) for the landfill provides an overview of the existing site environment including the site geology. Of relevance to this report is any potential sources of ground gas within the existing environment – either natural or man-made. The site geology is summarised in the Design Report with a more detailed discussion provided in the Geotechnical Factual Report and Geotechnical Interpretive Report (GHD 2020b & GHD 2020c). The site's geology is summarised as follows:

- The site consists of a series of relatively steep, generally dry, gullies that drain towards the north. The lower reaches of some gullies are infilled with relatively recent alluvial deposits that contain significant amounts of organic material. These deposits have the potential to generate gas. However, it should be noted that all such deposits will be removed from beneath the landfill and appurtenant structures during site development. Excavated materials are likely to be used as intermediate or daily cover during waste placement in the landfill.
- The site is underlain by the Henley Breccia formation, which comprises predominantly sandstone, siltstone, conglomerate, breccia with localised thin interbeds and laminations of organic mudstone / lignite. The latter has the potential for gas generation. However, it comprises a small percentage of the overall rock mass. Furthermore, permeability testing (GHD 2020b) indicates the Henley Breccia generally has a very low permeability and the likelihood of gas movement through this formation would be low. In addition, the Henley Breccia is overlain by several metres of low permeability loess.

## 2.2 Landfill Overview

As identified in the Design Report, the proposed landfill site will have a capacity of approximately 6 million cubic metres (equivalent of 5 million tonnes) of waste and will be designed to provide for the safe disposal of municipal solid waste and an average of 15% hazardous waste for a period in excess of 35 years.

Key LFG aspects of this site will include:

- Construction of a low permeability lining system to prevent leachate seepage into the surrounding environment.
- Construction of a leachate collection system above the low permeability lining system.
- Stormwater control around the constructed landfill and ultimate treatment of stormwater before it leaves the site.
- A leachate management system, including (leachate storage, tanker loading facilities and ultimately a pipeline to convey leachate to the municipal wastewater treatment plant).
- A LFG collection system (including pipes and wells) to collect LFG from the landfilled waste within two years of commencement of landfilling.
- A perimeter environmental monitoring network including wells for landfill gas monitoring
- LFG treatment and destruction by a LFG plant.
- At some time in the future an LFG energy plant may be installed at the site. However, this is not part of the current work scope.

The Design Report provides an overview of the landfill construction methodology and operation including a summary of the anticipated waste types and tonnages in Sections 3 and 7. This includes a description of how the landfill will be constructed and how waste will be placed in the landfill during operations. In general the landfill will be a Class 1 landfill suitable for accepting Municipal Solid Waste and hazardous materials that meet the leachability (TCLP) limits from MfE 2004: Module 2: Hazardous Waste Guidelines. Class A contaminated soils that meet this limit will be accepted. It is possible that green waste will be predominantly diverted from the waste stream as part of the domestic waste collection process. However, at this time this has not been confirmed. Furthermore, some amount of green waste will remain in the waste stream even with diversion.

# 3. Landfill gas emission model

## 3.1 Overview

In order to develop an understanding of the potential magnitude of LFG emission rates at the site over time, GHD developed a LFG emission model for a landfilling period of 55 years, which is consistent with the total design capacity of the site (see Section 2 of the Design report).

The model used for this exercise was the USEPA's (2005) Landfill Gas Emissions Model (LandGEM) Version 3.02. This model was adopted as it is the most commonly used LFG emission model in New Zealand, according to the Ministry for the Environment (2001) A Guide for the Management of Closing and Closed Landfills in New Zealand.

A modelling parameters, assumptions and justifications table (refer to Appendix A) was developed to document the relevant parameters, assumptions and justifications that were adopted for the model. The modelling output is provided in Appendix B and summarised in the following sub-sections.

## 3.2 Model outputs

The estimated LFG emission rates for the model are shown on Figure 3-1.**Error! Reference source not found.** below. Noting that the LandGem model presents the LFG emission rate outputs as $m^3$/LFG/year, GHD converted these rates into $m^3$/LFG/h in this report for consistency with typical industry practice (refer to Appendix B).

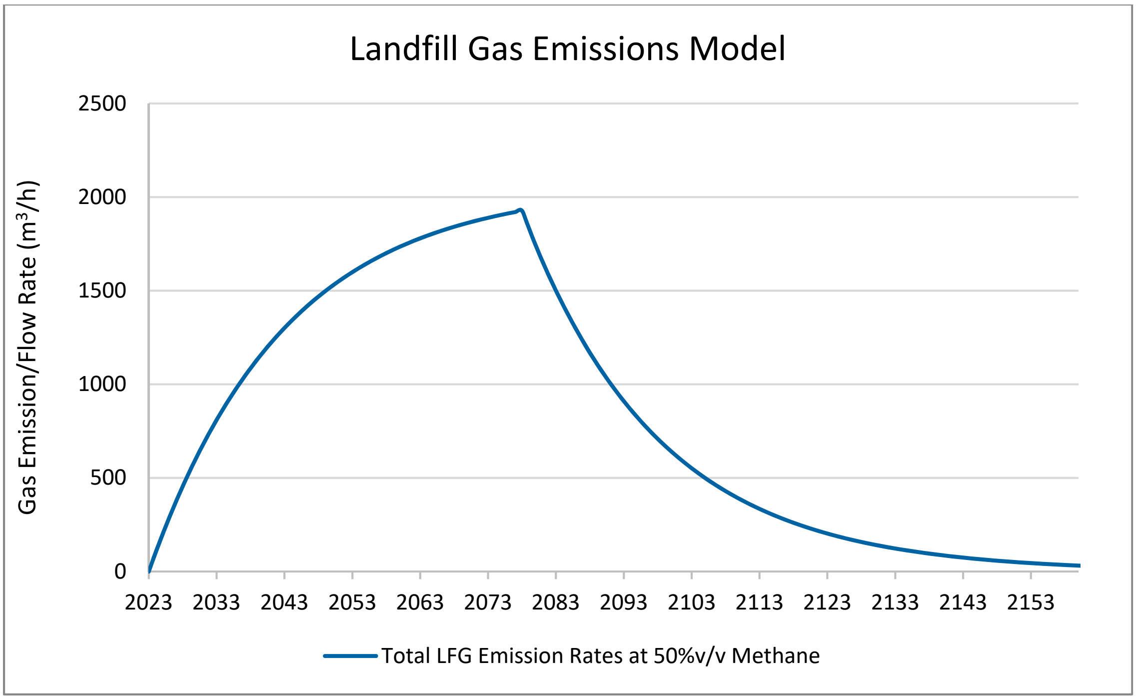


**Figure 3-1 LFG emission model outputs**

Figure 3-1 shows the following:

- The proposed landfill is expected to start generating LFG in 2023 and will continue to do so for many years after landfilling of waste has ceased in 2078.
- The LFG emission rate at the proposed site will peak in 2078 at 1,927 $m^3$/LFG/h and will steadily decrease every year post 2078.

- The LFG emission rate will be greater than 250 m$^3$/LFG/h (i.e. moderate to large generation rates[1]) between 2026 and 2118 (93 years).
- The LFG generation rates will be greater than 100 m$^3$/LFG/h at 50% v/v methane (i.e. theoretically sufficient to operate a flare according to the EPA VIC (2015)) from 2024 to 2137 (114 years).

Based on the magnitude and longevity of the estimated emission rates, it is considered that active[2] LFG management using flares and/or engines will likely be required at the site for many decades to appropriately manage the LFG emitted.

[1] According to EPA Victoria (Australia) (2015) *BPEM, Siting, design, operation and rehabilitation of landfills*, Section 6.7.1 on page 35

[2] i.e under vacuum

# 4. Preliminary landfill gas risk assessment (LFGRA)

## 4.1 Overview

GHD undertook a preliminary evaluation of the risks associated with LFG at the site using a source, pathway, receptor approach. The purpose of this task was to assist with understanding potential LFG related risks at the site and what LFG management measures may be appropriate.

It is noted the outcome of the LFGRA is based on the assumption that the site's surrounding environment would remain unchanged from the present day to the time for which the LFGRA has been completed (i.e. 2047 as identified in Section 6 – it is recognised that the landfill will have a longer operational life than this.  However, from a risk assessment basis, this year is considered a reasonable point in time to assess landfill gas risks as a number of LFG related risks are typically present during the operational period of a landfill. Furthermore, this year approximately reflects the likely term of any resource consent).

Due to the site not yet being operational, and no monitoring data being available, GHD has completed a preliminary LFGRA at this time. This is documented in the following sections. The LFGRA should be updated once the LFG monitoring data from Stage 2 is available.

## 4.2 Source, pathways and receptors

### 4.2.1 Source

The primary source of the LFG at the site is the waste materials that will be landfilled at the site, specifically the organic and biodegradable components, which are likely to generate LFG under appropriate anaerobic conditions.

The key factors that need to be considered include the type of LFG emissions (i.e. methane and carbon dioxide), the total quantities of LFG emitted and the period over which the LFG emissions would occur. Other aspects to consider include:

- The lower reaches of some gullies at the landfill are infilled with relatively recent alluvial deposits containing significant amounts of organic materials that have the potential to generate gas. However, it is noted these deposits will be removed from beneath the landfill footprint and appurtenant structures during site development for reuse as landfill cover when the site is operational.
- The site's geology consists of localised thin interbeds and lamination of organic mudstone/lignite that has the potential to generate gas. However, it is noted that this is a small percentage of the overall rock mass and the Henley Breccia generally has a very low permeability and the likelihood of gas movement through the rock mass would be low.
- Groundwater elevation is generally deep within the breccia unit (~ 20 m below ground level).
- Constructed landfill cells at the site would have been lined with a Flexible Membrane Liner (FML) and Compacted Clay Liner (CCL) or similar – see Section 3 of the Design Report.
- The site will have a leachate management system installed and will be operational upon commencement of landfill operations.

- The LFG emission model (refer to Section 60) suggests that the LFG emission rate will be approximately 1,439 $m^3$/h during 2047.
- It is anticipated that the site will have an active LFG collection and treatment system installed and operational within two years of landfilling operations commencing (i.e. by 2025). This system would be progressively expanded across the waste mass with time.
- The carbonaceous shale deposit located at the site may be another alternative source of ground gas at the site (Victoria University of Wellington 2016), albeit that they comprise a relatively small amount of the rock mass and the rock mass has a very low permeability.
- It is anticipated that the landfill stages that have been filled by 2047 (Stages 1 and 2) will be covered by intermediate and/ or final cover at that time.

### 4.2.2 Pathways

There are a number of potential emission pathways that LFG could be emitted from the landfilled waste including the following:

- Through the landfill's surface and associated penetrations
- Through the subsurface geology (unsaturated zone)
- Through the subsurface geology (saturated zone – leachate and groundwater)
- Through subsurface services
- Through the proposed LFG collection and treatment/destruction system

It is noted that:

  - There are currently no subsurface services along Big Stone Road on the southern boundary of the landfill. It has been assumed that this will continue to be the case in 2047.
  - The surface water management infrastructure (e.g. stormwater drains and groundwater drainage) may act as release points or barriers to subsurface LFG movement in these locations. The landfill management plan will address worker safety and confined space entry procedures where LFG may be present.

### 4.2.3 Receptors

There are a number of potential receptors that have been identified for LFG emitted from the site including the following:

- On-site and off-site workers
- On-site visitors
- On-site subsurface services
- On-site buildings and structures
- Off-site residents
- Off-site buildings and structures
- Off-site visitors
- On-site and off-site flora
- On-site and off-site fauna
- On-site and off-site air
- Global climate

- Groundwater

GHD has identified all residential, industrial and commercial properties within 3.5 km of the site in existence at the time this report was prepared. There are currently a number of rural residential properties northwest of the site between 1.5 and 2.5 km from the landfill footprint. Three rural residences are also located southeast of the site, within 1 km of the landfill footprint. The nearest sensitive receptor (a residential property) is 731 Big Stone Road, approximately 380 m from the landfill footprint. In this report it has been assumed from a LFG risk perspective that this property will continue to remain the nearest sensitive receptor in 2047. It is recognised that the District Plan allows for dwellings to be potentially erected on surrounding properties that are closer to the landfill footprint than 731 Big Stone Road. The closest properties to the landfill footprint where dwellings could be constructed are to the south and south east of the landfill. -These properties are currently operated as forestry blocks and it is considered unlikely that dwellings would be erected upon them, or if they were, that any such dwellings would be closer than 380 m to the (operational) landfill site, between now and 2047.

## 4.3 Conceptual site models

Based on the identification of source-pathway-receptor linkages between LFG emitted from the site and the adjacent environment, as described above, GHD have developed a visual representation of the preliminary conceptual site models (CSMs). The CSMs represent a period in the site's future life (assuming it was approved) when filling in Stages 1 and 2 had been completed (refer drawing 51-12506381-01-C203). This is estimated to be approximately 24 years[3] after landfilling operations have commenced at the site i.e. 2047. The CSMs are provided in Appendix C.

## 4.4 Sensitivity of receptors

Following consideration of the source, pathways and receptors, GHD considers that the relative sensitivities of the identified receptors are as illustrated in Figure 4-1 below.

[3] Based on 90,000 tonnes per annum of waste placement

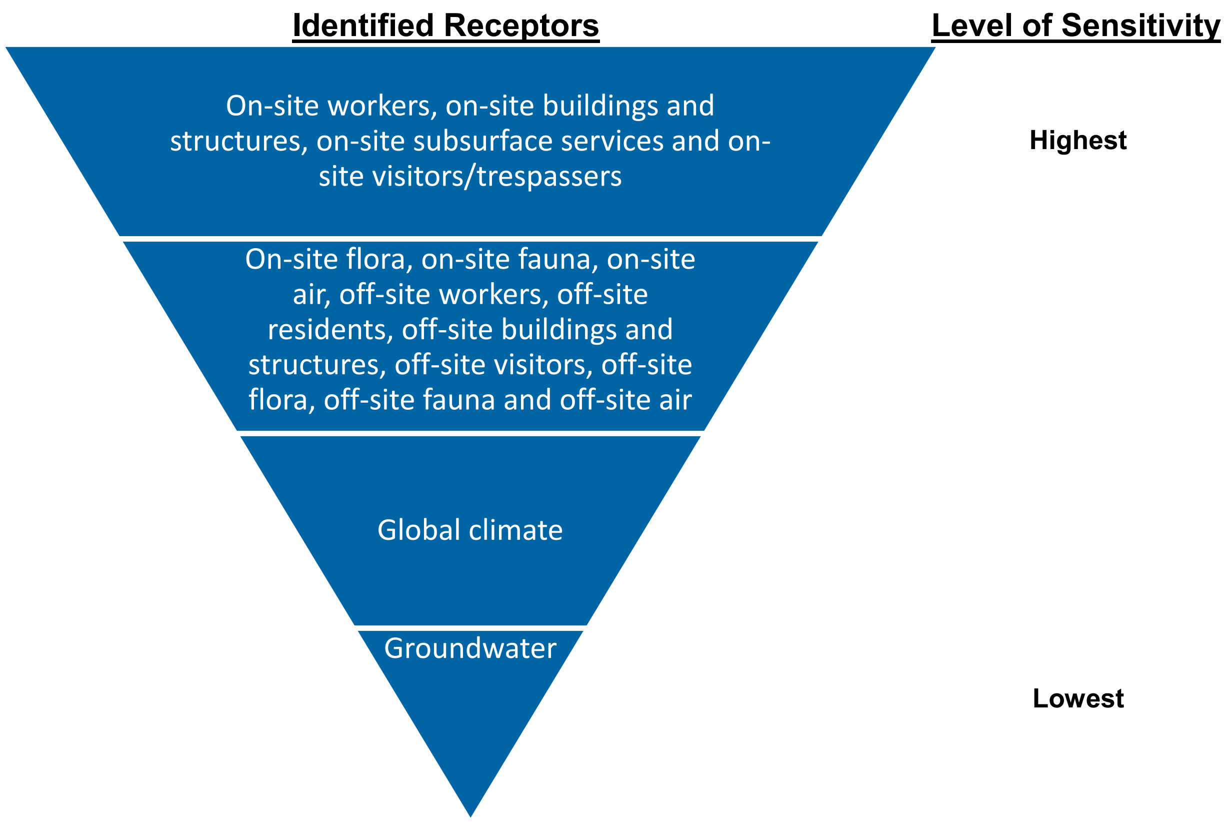


**Figure 4-1 Relative sensitivities of identified receptors**

## 4.5 Potential impacts upon receptors

As highlighted in Section 1.5, LFG can cause health, safety, amenity and/or environmental impacts upon receptors due to the gases it contains. The available information (including the site CSMs) suggests that there are a number of potentially complete source-pathway-receptor linkages between the LFG emitted by the site and the receptors identified in Section 4.2.3. Should these linkages be complete, they have the potential to result in a range of LFG related impacts upon these receptors.

GHD undertook a preliminary assessment of the potentially complete source-pathway-receptor linkages and potential impacts to receptors with consideration of the LFG emission model. This process identified key risks, which are summarised in the following section.

## 4.6 Key risks

The key risks associated with LFG at the site during 2047 are considered to be as follows

- Impact upon on-site workers and visitors.
- Impact upon on-site buildings and structures
- Impact upon future on-site subsurface services

Risks presented to other potential receptors are currently considered to be of a lower significance.

## 4.7 Summary

Given the key risks identified above and the magnitude and longevity of the estimated emission rates identified in Section 3.2, a range of LFG management measures will likely be required at the site for many decades to appropriately manage the LFG emitted. These LFG management measures include active LFG management (i.e. collection and combustion), regular monitoring and appropriate waste covering and containment systems.

To assist with the development of these management measures, GHD has reviewed the relevant regulatory documents / guidelines for LFG management at landfills in New Zealand. The key points of note in relation to these documents are provided in the following section.

# 5. Regulatory documents and guidelines

## 5.1 Overview

There are two key documents in relation to LFG management in New Zealand. These are:

- The National Environmental Standards for Air Quality (Air Quality NES) Regulations 2004
- Waste Management Institute New Zealand (WasteMINZ) (2018) Technical Guidelines for Disposal to Land

Furthermore (although considered of lesser direct relevance) the following two documents exist:

- Climate Change Response Act 2002
- Ambient Air Quality Guidelines 2002 update

To assist with the development of potentially appropriate LFG management measures for the site, GHD has reviewed these four documents and identified the key points of note within them in relation to LFG management at the site. These points of note are presented in the following sections

## 5.2 The National Environmental Standards for Air Quality (Air Quality NES) Regulations 2004

The Air Quality NES Regulations 2004 are regulations made under the Resource Management Act 1991, which aims to set a guaranteed minimum level of health protection for all New Zealanders. This includes controlling greenhouse gas emissions at landfills. The following clauses of the Air Quality NES apply to the site with regards to LFG management.

### Clause 25: Application of regulations 26 and 27

*(1) Regulations 26 and 27 apply to a landfill if—*

*(a) the landfill—*

*(i) has a total capacity of not less than 1 million tonnes; and*

*(ii) contains not less than 200 000 tonnes of waste; and*

*(iii) is or is likely to be accepting waste; and*

*(b) the waste in or to be included in the landfill is likely to consist of 5% or more (by weight) of matter that is putrescible or biodegradable.*

*(2) However, regulations 26 and 27 do not apply to a landfill until 8 October 2007 if the landfill—*

*(a) has a total capacity of not less than 1 million tonnes of waste; and*

*(b) on 8 October 2004—*

*(i) contains not less than 200 000 tonnes of waste; and*

*(ii) is accepting waste; and*

*(c) does not operate a gas collection system.*

*(3) Regulations 26 and 27 do not apply to a cleanfill.*

### Clause 26: Control of gas

*(1) No person may allow the discharge of gas to air from a landfill.*

*(2) Subclause (1) does not apply if the landfill has a system for the collection of gas from the landfill—*

> *(a) That is designed and operated to ensure that any discharge of gas from the surface of the landfill does not exceed 5 000 parts of methane per million parts of air; and*
>
> *(b) In which the gas is—*
>
> > *(i) flared in accordance with regulation 27; or*
> >
> > *(ii) used as a fuel or for generating electricity.*

### Clause 27: Flaring of gas

*(1) If gas collected at a landfill is destroyed by flaring,—*

> *(a) The system for the principal flare or flares must—*
>
> > *(i) comply with the requirements in subclause (2); or*
> >
> > *(ii) achieve at least the same effect as the system in subclause (2); and*
>
> *(b) The system for the backup flare must—*
>
> > *(i) comply with the requirements in subclause (3); or*
> >
> > *(ii) achieve at least the same effect as the system in subclause (3).*

*(2) The system for a principal flare must—*

> *(a) have a flame arrestor; and*
>
> *(b) have an automatic backflow prevention device, or an equivalent device, between the principal flare and the landfill; and*
>
> *(c) have an automatic isolation system that ensures that, if the flame is lost, no significant discharge of unburnt gas from the flare occurs; and*
>
> *(d) have a continuous automatic ignition system; and*
>
> *(e) have a design that achieves a minimum flue gas retention time of 0.5 seconds; and*
>
> *(f) be designed and operated so that gas is burned at a temperature of at least 750°C; and*
>
> *(g) have a permanent temperature indicator; and*
>
> *(h) have adequate sampling ports to enable emission testing to be undertaken; and*
>
> *(i) provide for safe access to sampling ports while any emission tests are being undertaken.*

*(3) The system for a backup flare must have—*

> *(a) a flame arrestor; and*
>
> *(b) an automatic backflow prevention device, or an equivalent device, between the backup flare and the landfill; and*
>
> *(c) an automatic isolation system that ensures that, if the flame is lost, no significant discharge of unburnt gas from the flare occurs; and*
>
> *(d) a continuous automatic ignition system.*

*(4) A principal flare must be operated at all times unless it has malfunctioned or is shut down for maintenance.*

*(5) A backup flare must be operated if, and only if, a principal flare is not operating.*

## 5.3 WasteMINZ (2018) Technical Guidelines for Disposal to Land

The WasteMINZ (2018) Technical Guidelines for Disposal to Land, dated August 2018 (WasteMINZ guidelines) provides technical guidance relating to the siting, design, operation and monitoring of landfills in New Zealand, including LFG management. The key points outlined in the WasteMINZ Guidelines regarding LFG management are as follows:

- The base of an extraction well to be typically targeted at least 5 metres above the liner of the landfill
- LFG well spacing of 50 to 70 metres
- LFG well spacing of no greater than 30 metres from the edge of the waste mass
- Pipework and extraction equipment to be designed for gas flows of the maximum landfill gas emission throughout the design life of the pipework system
- Utilisation equipment to be designed for the maximum collected landfill gas throughout the design life of the landfill gas management system
- The upper 2 to 5 metres of the well riser should be non-perforated to prevent air entrainment
- Landfill gas monitoring should be undertaken at all landfill sites, primarily to determine whether gas production is giving rise to a hazard or nuisance.

## 5.4 Climate Change Response Act 2002

The Climate Change Response Act 2002 provides a legal framework, which requires New Zealand to meet its obligations relating to climate change. An amendment of the Act in 2008 put in place the Emissions Trading Scheme (ETS) to reduce domestic emissions, including emissions from landfill. The Climate Change Response Act 2002 requires landfill operators to report and surrender emissions units in proportion to calculated methane emissions from the biodegradation of organic waste from their landfills.

In 2019, an additional amendment of the Act was undertaken to include emissions reduction targets for 2050. Specifically for methane, the following targets were established in a calendar year:

- 10% less than 2017 emissions by the calendar year beginning on 1 January 2030.
- 24% to 47% less than 2017 emissions by the calendar year beginning on 1 January 2050 and for each subsequent calendar year.
- GHD considers that the installation and operation of the active LFG collection and treatment system may assist in meeting the emission reduction targets identified above by reducing the discharges associated with this facility.

## 5.5 Ambient Air Quality Guidelines 2002 Update

The New Zealand ambient air quality guidelines (2002 update) (Ambient Air Quality Guidelines) outlines the ambient air quality guideline values for New Zealand, and provides guidance on how to use these values to manage air quality under the Resource Management Act 1991. The guideline values are the minimum requirements that outdoor air quality should meet in order to protect human health and the environment. If these guideline values are exceeded appropriate measures should be implemented to improve air quality. Air quality potential impacts and mitigation measures are discussed further in the Air Quality Report (GHD 2020).

## 5.6 International guidance

It is noted that there is a range of international guidance available in relation to LFG assessment and management in Australia, the United Kingdom, Canada, the United States of America and elsewhere. Where information or guidance has been limited in the New Zealand documents identified above, GHD has applied other relevant international guidance. The international guidance that has been considered in such cases is identified in Section 9.

# 6. Suggested LFG management measures

Based on the outputs of the works presented in the preceding sections of this report, the following management measures are considered to be appropriate for the LFG emitted by the site:

- Installation and appropriate construction quality assurance (CQA) of a low permeability basal and sidewall lining system. It is anticipated that all landfill cells will incorporate this measure and that it will consist of FML and CCL[4] or similar (see section 3 of the Design report) which will reduce the likelihood of subsurface LFG emissions.
- Installation, appropriate CQA and operation of a leachate management system at the site. Leachate pumping systems to be designed and operated in accordance with relevant standards in relation to LFG as applicable (e.g. *AS/NZS 2381.1.1:2005*).
- Regular covering of waste with appropriate daily and intermediate cover materials. It is anticipated that daily cover will be applied at the end of each day's waste placement and intermediate cover will be placed on areas where further waste will not be placed for one month[5].
- Progressive capping and rehabilitation of the site with a low permeability landfill cap over the site's lifetime. It is anticipated that a final cap that meets the WasteMINZ 2018 Technical Guidelines for Disposal to Land for a Class 1 landfill will be installed at the site[6].
- Progressive installation, operation and monitoring of an active LFG collection, treatment and destruction system (i.e. gas wells, pipework, manifolds, flares and/or engines) that is suitable for the quantity of LFG emitted by the site as development progresses. It is anticipated that LFG management will commence after two years of landfill operations. Emissions from the combustion of LFG at the flares and/or engines must meet the requirements of the Air Quality NES and the ambient air quality guidelines at agreed locations. Emission issues are discussed further in the Air Quality Report (GHD 2020).
- Appropriate design, installation and validation of buildings and structures and subsurface services (for example in accordance with *AS/NZS 2381.1.1:2005* if relevant) on-site to prevent LFG entering and/or accumulating within them.
- Design, installation and implementation of an appropriate LFG monitoring network and program. This network and program should be reviewed and potentially updated on an ongoing basis as conditions change at/adjacent to the site over time.
- Completion of a detailed LFGRA prior to waste filling occurring and on-going review and update of that document as conditions change at/adjacent to the site over time. This detailed LFGRA should further consider / investigate organic mudstone / lignite as a source of ground gas at the site
- Development and implementation of appropriate work, health and safety procedures for on-site workers who may be at risk of being exposed to LFG emissions.

In this report, GHD has developed concept designs for:

- An active LFG collection and treatment/destruction system

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[4]GHD (2019a) Waste Futures Phase 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design Report, Section 3.9
[5] GHD (2019a) Waste Futures Phase 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design Report, Section 7.3.2
[6] GHD (2019a) Waste Futures Phase 2 – Work stream 3 Smooth Hill Landfill, Landfill Concept Design Report, Section 3.12

- A perimeter LFG monitoring bore network

The basis for the concept designs and the concept designs themselves are provided in the following sections.

# 7. Concept design of active LFG collection and treatment/destruction system

## 7.1 Overview

The overarching goals for LFG management at the proposed landfill are as follows:

- To optimise the overall quantity of LFG collected from the deposited waste and thereby reduce potentially adverse outcomes (such as fugitive emissions and LFG related odour).
- To comply with the LFG related requirements of the Air Quality NES.
- To comply with the LFG related recommendations of the WasteMINZ Guidelines and the Ambient Air Quality Guidelines.
- To address the prioritised risks identified from by the preliminary LFGRA.

As such, the emphasis of the concept design for the LFG collection and treatment/destruction system (the system) is on the environmental control of LFG as opposed to LFG utilisation for electricity (although it is noted that this may be possible).

## 7.2 Design goals

The design goals for the system are presented in Table 7-1. They have been considered in the development of the concept design of the system (as relevant).

**Table 7-1 Design goals for proposed LFG collection and treatment/destruction system**

| Design criteria/requirements | Goal |
|---|---|
| Environmental | 1. Meet any required noise emission levels at all times.<br>2. Minimise potential brush/forest fire risks (on and off-site).<br>3. Not cause significant dust or odour emissions.<br>4. Enable the site to be monitored in accordance with WasteMINZ Guidelines.<br>5. Allow leachate monitoring and possible extraction to occur at individual vertical LFG wells.<br>6. Reduce fugitive emissions of LFG from the landfill |
| Legal/Statutory | 1. Comply with the relevant requirements of the Air Quality NES<br>2. Comply with the LFG related recommendations of the WasteMINZ Guidelines and the Ambient Air Quality Guidelines |
| Operational | 1. Be able to be readily and practically and economically operated, monitored and maintained. |

| Design criteria/requirements | Goal |
|---|---|
| Technical | 1. Be of suitable capacity to manage the anticipated rate of LFG collected allowing for any uncertainties with consideration to the peak LFG emission rate of approximately 1,927 $m^3$/h.<br>2. Minimise condensate collection within the pipework and ensure adequate drainage of condensate from the pipework.<br>3. Minimise the likelihood of damage due to settlement.<br>4. Minimise the likelihood of subsurface landfill fires developing due to air being drawn into the landfilled waste mass.<br>5. Appropriate interface with existing and potential future (where anticipated) site infrastructure.<br>6. Minimise the likelihood of vandalism/damage/interference.<br>7. Minimise the likelihood of bushfire related damage (both by and to the LFG collection and treatment/destruction system). |

## 7.3 Concept design

Based on the information presented in this report, particularly Section 7.1 and Section 7.2, GHD developed a concept design and associated details of the concept system post closure of the landfill. These are shown on the drawings provided in Appendix C. The reason that the system is shown at closure is so that the complete system can be shown rather than just a portion of it. It is noted that the system would be constructed progressively and follow the filling of the site.

## 7.4 Key elements of system

The key elements of the system are as follows:

- A primary flare (elevated type) and a backup flare (candlestick type) to combust the collected LFG.
- Ability to utilise LFG fuelled engine(s) to combust the collected LFG if there proves to be enough LFG collected to allow this in the future. A typical engine example is the GE Jenbacher JMS 320 GS-B.L provided in Attachment D.
- LFG collection pipework (extraction wells, condensate drainage points, interconnecting pipework) that will be progressively expanded across the site in line with filling activities.
- Main condensate pots to be installed in key locations (to be assessed during the detailed design). These vessels could be self-draining into the landfilled waste mass or pumped out.
- Horizontal LFG wells to be installed during filling to optimise LFG collection, with vertical wells to be installed post filling.
- Individual LFG extraction wells (whether horizontal or vertical) to be installed and connected to manifold structures where they can be individually monitored and adjusted as required. Certain LFG extraction wells uphill of the relevant manifolds may require condensate ‘J-traps’ to be installed (to be assessed during detailed design).

- Approximately 203 vertical LFG extraction wells to be installed at approximately 50 metre centres between each individual wells. 52 of the wells along the boundary are to be installed no greater than 30 metres from the waste footprint boundary (i.e. edge of the waste mass) in accordance with the recommendations of the WasteMINZ Guidelines.
- Individual vertical LFG extraction wells to have wellheads at the ground surface at the point of penetration through the final cap. The wellheads would allow the well to be monitored and adjusted for LFG. Additionally, the wellheads would also allow leachate to be monitored and extracted by a surface operated portable pump or a submersible pump installed in the well, if required. The pipework for the proposed vertical LFG extraction wells to be 160 mm outer diameter (OD) and wells to be installed to a target depth of at least 5 metres above the base of the landfill to minimise the risk of penetrating the proposed liner system as recommended by the WasteMINZ Guidelines.
- Temporary horizontal LFG collection lines to be installed as the landfill is progressively filled.

## 7.5 Key assumptions for active LFG collection and treatment/destruction system

In addition to the assumptions detailed elsewhere in this report, GHD adopted the following key assumptions during the development of the concept design for the system:

- A specialist LFG consultant and contractor will ultimately complete detailed design of the system and install, operate, monitor and maintain it.
- A drill rig employed by the specialist LFG contractor would be capable of safely installing the vertical LFG extraction wells into the landfilled waste mass at the site to the required depths and diameters.
- The horizontal and vertical wells would be installed by a specialist LFG contractor in general accordance with the concept design drawings
- The horizontal wells would be progressively expanded across the site during landfilling operations.
- The installation of vertical wells would typically occur once intermediate cover and/or final cap is placed in areas filled to the required height. This would be assessed and confirmed at the relevant time.
- The specialist LFG contractor will carefully consider the required screening depths of the gas wells prior to their installation. The specialist LFG contractor will ensure that the wells:
  - Are not screened in the earthen cover materials.
  - Are installed so as to minimise the likelihood of causing air ingress into the waste.
  - Are installed so as to minimise the likelihood of interference with the installed horizontal wells.
- Only preliminary consideration has been given to potential environmental and safety issues associated with the construction and operation of the proposed system These issues should be further reviewed and addressed during the detailed design stage.

# 8. Concept design of perimeter LFG monitoring bore network

## 8.1 Overview

Based on the overarching goals for LFG management at the site identified in Section 7.1 and the outputs of the works presented in the preceding sections of this report, GHD developed a concept design for a preliminary perimeter LFG monitoring bore network (bore network) for the site.

This concept design was developed with consideration of the guidance provided in EPA Victoria (2015) Best Practice Environmental Management: Siting, design, operation and rehabilitation of landfills (BPEM). The BPEM was selected as the principal point of reference for the design of the bore network as detailed guidance on this matter is not provided in the WasteMINZ Guidelines.

The BPEM outlines various points of note in relation to the design of perimeter LFG monitoring bore networks. Some points of note are provided below:

*The aim of a LFG monitoring bore network is to intercept any LFG escaping laterally from a landfill site and identify its location. As such, LFG monitoring bores must be installed at appropriate locations, drilled to depths suitable to intercept all gas movement paths, constructed appropriately to intercept gas and should be determined based on the findings of a LFGRA.*

*The following are key design factors:*

- *Bore location and spacing*
- *Bore depth*
- *Bore construction design*
- *Bore installation CQA*

*Typically it is expected that a LFG monitoring bore network will:*

- *Target sensitive receptors such as dwellings*
- *Encircle the entire landfilled waste mass*
- *Be installed into the local geology (not into waste or fill materials)*

*EPA recommends that LFG monitoring bores are sited at least 20 metres from the boundary of the landfilled waste, to ensure validity of the LFG monitoring data subsequently obtained.*

GHD subsequently considered the BPEM guidance and developed a preliminary concept for the bore network as discussed in the following sections.

## 8.2 Design goals

The design goals for the bore network are presented in Table 8-1. These were considered in the development of the concept design of the bore network (as relevant).

**Table 8-1 Design goals for proposed perimeter LFG monitoring bore network**

| Design criteria/requirements | Goal |
|---|---|
| Environmental | 1. To not cause significant dust or odour emissions. |

| Design criteria/requirements | Goal |
|---|---|
| | 2. To enable the LFG to be monitored in accordance with the LFG related recommendations of the WasteMINZ Guidelines and BPEM |
| Legal/Statutory | 1. To comply with the LFG related recommendations of the WasteMINZ Guidelines and BPEM |
| Operational | 1. To be able to be readily and practically accessed, monitored and maintained.<br>2. To not obstruct other on-site operations / activities.<br>3. To appropriately interface with existing and potential future (where anticipated) site infrastructure. |
| Technical | 1. To be able to intercept any LFG escaping laterally from the site and identify its location.<br>2. To be installed at appropriate locations, drilled to depths suitable to intercept all gas movement paths, constructed appropriately to intercept gas and be determined based on the findings of a LFGRA.<br>3. To target sensitive receptors such as dwellings.<br>4. To encircle the entire landfilled waste mass.<br>5. To be installed into the local geology (not into waste or fill materials).<br>6. To be sited at least 20 metres from the boundary of the landfilled waste.<br>7. To minimise the likelihood of vandalism/damage/interference. |

## 8.3 Concept design

Based on the information presented in this report, GHD developed two concept designs for the preliminary bore network prior to commencement of the landfilling operations at the site. The reason that the bore network is shown prior to filling is such that background monitoring data can be obtained prior to filling works commencing to assist with confirming potentially naturally present ground gas concentrations at the site. It is noted that the bore network may need to expand with time at the site for example due to monitoring results obtained and/or changes to adjacent receptors.

These concept designs are shown on the drawings provided in Appendix C with associated explanation of their basis provided in the following sections.

## 8.4 BPEM bore network

As identified above, the BPEM document provides detailed guidance in relation to the design and spacing of perimeter LFG monitoring bores. The BPEM contains a table[7] that outlines default bore spacings based on the type of geology in which the landfill site is located and the

[7] Table B.2: Recommended landfill gas monitoring bore spacing

proximity of 'development' to the site boundary. These defaults can be amended by the findings of a LFGRA.

Therefore, GHD's first step in developing the preliminary bore network was to identify how many LFG bores may be required if no LFGRA had been completed and Table B.2 was adopted verbatim.

This step identified that the required bore spacings would be as per Table 8-2 below, assuming that the maximum bore spacing from Table B.2 was adopted and on the understanding that the bedrock at the site is breccia (i.e. fissure of fracture flow dominated strata).

**Table 8-2 BPEM recommended LFG monitoring bore spacing for fissure or fracture flow-dominated permeable strata**

| Site description | Maximum bore spacing (m) |
|---|---|
| Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); no development within 250 metres | 50 |
| Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 250 metres | 50 |
| Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 150 metres | 20 |

The BPEM recommended LFG bore monitoring network resulted in 63 LFG monitoring bores being required around the site. Given the site's local environs, the findings of the preliminary LFGRA and other works completed in this report, this number of wells is considered to be excessive by GHD. Therefore, GHD developed a refined preliminary bore network design with a reduced number of monitoring bores. The reduced LFG monitoring bore network is discussed in the following section.

## 8.5 Preliminary LFG monitoring bore network

As identified above, based on the LFGRA completed in this report, GHD reviewed the BPEM bore network and developed what is considered to be a more reasonable bore network for the site at this time. This preliminary bore network:

- Increased the bore spacing (greater than 50 m) from the BPEM bore network on the northern, western, south-western and south-eastern boundaries due to a lack of current and perceived lack of future receptors for LFG in those areas within 250 metres of the waste footprint boundary.
- Adopts a bore spacing of 50 metres along part of the southern boundary of the site due to one current off-site receptor approximately 380 metres south of the waste footprint boundary.
- Adopts a bore spacing of 20 metres along the north-eastern boundary due to proposed on-site receptors (buildings) in that area within 150 metres of the waste footprint boundary.
- This resulted in a bore network of 32 LFG monitoring bores being needed around the site. GHD considers that this preliminary system is more reasonable at this time based on the available information. It is noted that additional bores may be required in the future based on monitoring results.

## 8.6 Key assumptions for perimeter LFG monitoring bore network

In addition to the assumptions detailed elsewhere in this report, GHD adopted the following key assumptions during the development of the concept design for the preliminary bore network:

- A specialist consultant will ultimately develop a detailed design for the LFG bores.
- A specialist drilling contractor will ultimately install the LFG monitoring bores.
- The suggested LFG bore locations are readily and safely accessible with a drilling rig and under DCC control.
- A drill rig employed by the specialist drilling contractor would be capable of safely installing the LFG bores at the identified locations and to the appropriate depths and diameters.
- The LFG bore network would be installed and monitored on a minimum monthly frequency for LFG at least 12 months prior to the placement of waste in order to obtain background ground gas data for the site prior to filling.
- Only preliminary consideration has been given to potential environmental and safety issues associated with the construction and operation of the proposed system. These issues should be further reviewed and addressed during the detailed design stage.

# 9. Reliance


- British Columbia: Ministry of Environment (2010) Landfill Gas Management Facilities Design Guidelines, March 2010
- Dunedin City Council (2019) 2nd Generation District Plan (2GP). Retrieved from https://www.dunedin.govt.nz/council/district-plan/2nd-generation-district-plan
- EPA Victoria (2015), Best practice environmental management - Siting, design, operation and rehabilitation of landfills, EPA Victoria Publication 788.3, August 2015
- GE Power & Water (2013a) Jenbacher Type 3 Technical Specifications
- GE Power & Water (2013b) JMS 320 GS-BL, Biogas 1.063kW el.
- GHD (2020a) Waste Futures Phase 2 – Work Stream 3 Smooth Hill Landfill, Landfill Concept Design Report (DRAFT)
- GHD (2020b) Waste Futures Phase 2 – Work Stream 3, Smooth Hill Consenting – Geotechnical Factual Report
- Ministry for the Environment and Ministry of Health (New Zealand) (2002) Ambient Air Quality Guidelines, 2002 Update
- Ministry for the Environment (New Zealand) (2004) Module 2: Hazardous Waste Guidelines, Landfill Waste Acceptance Criteria and Landfill Classification
- Ministry for the Environment (2001) A Guide for the Management of Closing and Closed Landfills in New Zealand
- Ministry for the Environment (2019) Climate Change Response (Zero Carbon) Amendment Act
- Resource Management (National Environmental Standards for Air Quality) Regulations 2004, July 2017
- NIWA (2015) The Climate and Weather of Otago, 2nd edition
- Victoria University of Wellington (2016) Geology of Dunedin
- WasteMINZ (2018a), Technical Guidelines for Disposal to Land, August 2018
- WasteMINZ (2018b), Technical Guidelines for Disposal to Land: Appendices, August 2018
- Windsor Engineering (2019) Biogas Flare – GF1000

# 10. Limitations

This report: has been prepared by GHD for Dunedin City Council and may only be used and relied on by Client for the purpose agreed between GHD and the Client as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than the Client and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Smooth Hill Landfill Project arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Client and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

# Attachments

# **Appendix A** – Landfill gas model parameters, assumptions and justifications table

| | | | |
|---|---|---|---|
| Client | Dunedin City Council | | |
| Prepared by | Fabrice Cheong (03/09/2019) | Checked by | Matt Welsh (04/09/2019) |
| Subject | Proposed Smooth Hill Landfill - Parameters, Assumptions and Justification Table for Landfill Gas Model (LandGEM 3.02) | Job no. | 12506381 |
| Revision | 1 | Date | 17 March 2020 |

| **Model Parameter** | **Model Assumption** | **Justification** |
|---|---|---|
| Methane generation rate (k values) | Methane generation rate (k value): 0.05 year$^{-1}$ | A value of 0.05 year$^{-1}$ has been selected based on the typical k-values used in New Zealand landfills outlined on pages 27 to 28 of WasteMINZ (2018) *Technical Guidelines for Disposal to Land: Appendix B*.<br><br>It is noted that a site specific k-value can be calculated and applied using the Pierce et al (2005) formula identified on page 27 of the WasteMINZ (2018) *Technical Guidelines for Disposal to Land: Appendix B*. GHD calculated this value to be 0.0164 year$^{-1}$ (refer to Attachment 1 for calculations).<br><br>GHD subsequently reviewed the calculated k-value against the k-values presented on pages 27 to 28 of the WasteMINZ (2018) *Technical Guidelines for Disposal to Land: Appendix B* and those presented on page 16 of the US EPA (2005) *LandGEM version 3.02 User's Guide* default values. GHD concluded that the calculated k-value was likely to be too low for the site based on the guidance in these documents and the calculated k-value was therefore discarded in favour of the value of 0.05 year$^{-1}$ identified above. |
| Potential methane generation capacity ($L_o$) | Potential methane generation capacity ($L_o$ values): 100 $m^3$/Mg | The adopted value is based on the lower value for a typical NZ landfill identified on page 26 of Appendix B of WasteMINZ (2018) *Technical Guidelines for Disposal to Land: Appendix B* (i.e. 100 $m^3$/tonne) and the inventory emission *(i.e. 100 $m^3$/Mg)* for a conventional landfill as outlined on page 16 of the US EPA (2005) *LandGEM version 3.02 User's Guide*, which is based on the US EPA (1998) *Compilation of Air Pollutant Emission Factors, AP-42, Vol. 1: Stationary Point and Area Sources.* |

| Model Parameter | Model Assumption | Justification |
|---|---|---|
| | | GHD notes that 1 Mg is the same as one metric tonne. |
| Nonmethane organic compound concentration (NMOC) (ppmv) | NMOC: Inventory Co-disposal – 2,400 ppmv | The adopted NMOC value is the inventory default where co-disposal of hazardous waste has occurred (or is proposed to be done in the case of this site) (i.e. 2,400 ppmv). The adopted value is based on page 17 of the US EPA (2005) *LandGEM version 3.02 User's Guide.*<br>WasteMINZ (2018) *Technical Guidelines for Disposal to Land: Appendix B* provides no New Zealand specific value for this parameter. |
| Methane content (% by volume) | Methane content: CCA – 50% by volume (default) | The adopted value is the model default value as identified on pages 17 to 18 of the US EPA (2005) *LandGEM version 3.02 User's Guide* default values.<br>This value is commonly used in greenhouse gas estimation for landfill sites in GHD's experience. |
| Estimated years of landfilling (calendar year) | The landfill commenced landfilling operations in 2023 and will cease in 2077 (55 years) | Based on a total airspace design capacity of 55 years as per Section 3.2.1 of GHD (2019) *Waste Futures Phase 2 – Workstream 3 Smooth Hill Landfill: Landfill Concept Design Report* to estimate the maximum LFG emissions that may be generated at the final stage of the landfill (i.e. worst case scenario). |
| Quantity of waste landfilled per calendar year (tonnes) | 2023 90,000<br>2024 90,000<br>2025 90,000<br>2026 90,000<br>2027 90,000<br>2028 90,000<br>2029 90,000<br>2030 90,000<br>2031 90,000<br>2032 90,000<br>2033 90,000 | Projected waste inflow estimated from weighbridge records at Green Island landfill (Council's current landfill site) and as confirmed with Council as per Council (Alice Grace) e-mail *'RE: Smooth Hill - incoming waste and truck numbers'* dated 12 June 2019 |

| Model Parameter | Model Assumption | | Justification |
| --- | --- | --- | --- |
| | 2034 | 90,000 | |
| | 2035 | 90,000 | |
| | 2036 | 90,000 | |
| | 2037 | 90,000 | |
| | 2038 | 90,000 | |
| | 2039 | 90,000 | |
| | 2040 | 90,000 | |
| | 2041 | 90,000 | |
| | 2042 | 90,000 | |
| | 2043 | 90,000 | |
| | 2044 | 90,000 | |
| | 2045 | 90,000 | |
| | 2046 | 90,000 | |
| | 2047 | 90,000 | |
| | 2048 | 90,000 | |
| | 2049 | 90,000 | |
| | 2050 | 90,000 | |
| | 2051 | 90,000 | |
| | 2052 | 90,000 | |
| | 2053 | 90,000 | |
| | 2054 | 90,000 | |
| | 2055 | 90,000 | |
| | 2056 | 90,000 | |
| | 2057 | 90,000 | |

| Model Parameter | Model Assumption | | Justification |
|---|---|---|---|
| | 2058 | 90,000 | |
| | 2059 | 90,000 | |
| | 2060 | 90,000 | |
| | 2061 | 90,000 | |
| | 2062 | 90,000 | |
| | 2063 | 90,000 | |
| | 2064 | 90,000 | |
| | 2065 | 90,000 | |
| | 2066 | 90,000 | |
| | 2067 | 90,000 | |
| | 2068 | 90,000 | |
| | 2069 | 90,000 | |
| | 2070 | 90,000 | |
| | 2071 | 90,000 | |
| | 2072 | 90,000 | |
| | 2073 | 90,000 | |
| | 2074 | 90,000 | |
| | 2075 | 90,000 | |
| | 2076 | 90,000 | |
| | 2077 | 90,000 | |

## Attachment 1 – K-value calculation

Average annual rainfall (r) Dunedin (Airport) approximately 5.5 km north west of the site based on NIWA (2015) *The Climate and Weather of Otago*, Page 16, Table 6 = 652 mm = 0.652 m

$K = 0.016e^{(0.04r)}$

$K = 0.016e^{(0.04 \times 0.652)}$

$K = 0.0164\ year^{-1}$

# **Appendix B** – Landfill gas model and calculations

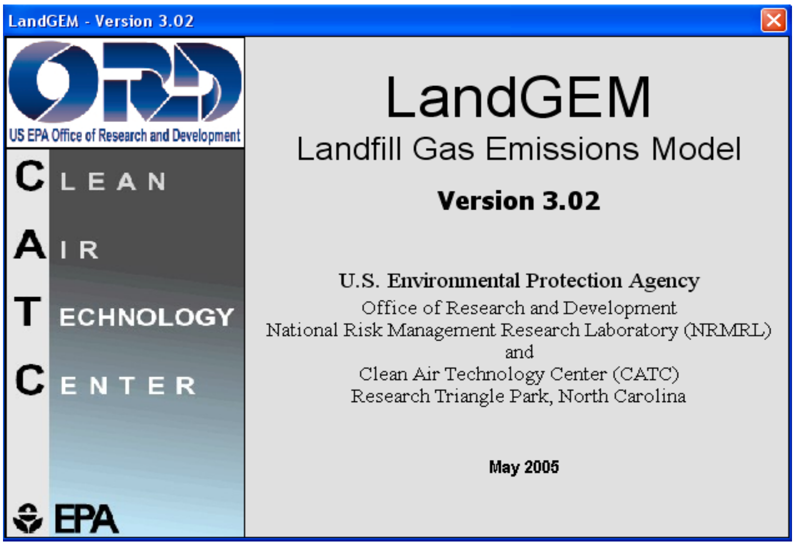
| | |
|---|---|
| **Project** | Smooth Hill Landfill Approval for Consent |
| **Subject** | 55 Year Scenario LFG Generation Model |
| **Revision** | 1 |
| **Prepared by** | Fabrice Cheong |
| **Checked by** | Matt Welsh |
| **Date** | 10/12/2019 |

| Year | Total LFG | LFG Generation Potential<br>Total LFG Generation Rates at 50%v/v Methane |
|---|---|---|
| | m3/year | m3/h |
| 2023 | 0 | 0 |
| 2024 | 880067 | 100 |
| 2025 | 1717212 | 196 |
| 2026 | 2513530 | 287 |
| 2027 | 3271010 | 373 |
| 2028 | 3991548 | 455 |
| 2029 | 4676945 | 534 |
| 2030 | 5328914 | 608 |
| 2031 | 5949087 | 679 |
| 2032 | 6539014 | 746 |
| 2033 | 7100169 | 810 |
| 2034 | 7633957 | 871 |
| 2035 | 8141711 | 929 |
| 2036 | 8624702 | 984 |
| 2037 | 9084137 | 1036 |
| 2038 | 9521165 | 1086 |
| 2039 | 9936879 | 1134 |
| 2040 | 10332319 | 1179 |
| 2041 | 10708473 | 1222 |
| 2042 | 11066281 | 1262 |
| 2043 | 11406639 | 1301 |
| 2044 | 11730398 | 1338 |
| 2045 | 12038366 | 1373 |
| 2046 | 12331315 | 1407 |
| 2047 | 12609977 | 1439 |
| 2048 | 12875048 | 1469 |
| 2049 | 13127191 | 1498 |
| 2050 | 13367037 | 1525 |
| 2051 | 13595186 | 1551 |
| 2052 | 13812208 | 1576 |
| 2053 | 14018645 | 1599 |
| 2054 | 14215015 | 1622 |
| 2055 | 14401807 | 1643 |
| 2056 | 14579490 | 1663 |
| 2057 | 14748506 | 1682 |
| 2058 | 14909280 | 1701 |
| 2059 | 15062213 | 1718 |

| Year | Total LFG | LFG Generation Potential<br>Total LFG Generation Rates at 50%v/v Methane |
|---|---|---|
| | m3/year | m3/h |
| 2060 | 15207687 | 1735 |
| 2061 | 15346066 | 1751 |
| 2062 | 15477697 | 1766 |
| 2063 | 15602907 | 1780 |
| 2064 | 15722011 | 1794 |
| 2065 | 15835307 | 1806 |
| 2066 | 15943077 | 1819 |
| 2067 | 16045590 | 1830 |
| 2068 | 16143105 | 1842 |
| 2069 | 16235863 | 1852 |
| 2070 | 16324097 | 1862 |
| 2071 | 16408029 | 1872 |
| 2072 | 16487866 | 1881 |
| 2073 | 16563811 | 1890 |
| 2074 | 16636051 | 1898 |
| 2075 | 16704768 | 1906 |
| 2076 | 16770134 | 1913 |
| 2077 | 16832312 | 1920 |
| 2078 | 16891457 | 1927 |
| 2079 | 16067651 | 1833 |
| 2080 | 15284022 | 1744 |
| 2081 | 14538612 | 1659 |
| 2082 | 13829555 | 1578 |
| 2083 | 13155080 | 1501 |
| 2084 | 12513499 | 1428 |
| 2085 | 11903208 | 1358 |
| 2086 | 11322682 | 1292 |
| 2087 | 10770468 | 1229 |
| 2088 | 10245186 | 1169 |
| 2089 | 9745523 | 1112 |
| 2090 | 9270228 | 1058 |
| 2091 | 8818114 | 1006 |
| 2092 | 8388049 | 957 |
| 2093 | 7978959 | 910 |
| 2094 | 7589821 | 866 |
| 2095 | 7219661 | 824 |
| 2096 | 6867554 | 783 |
| 2097 | 6532619 | 745 |
| 2098 | 6214020 | 709 |
| 2099 | 5910958 | 674 |
| 2100 | 5622678 | 641 |
| 2101 | 5348456 | 610 |
| 2102 | 5087609 | 580 |
| 2103 | 4839483 | 552 |
| 2104 | 4603459 | 525 |
| 2105 | 4378946 | 500 |

| Year | Total LFG | LFG Generation Potential<br>Total LFG Generation Rates at 50%v/v Methane |
|---|---|---|
| | m3/year | m3/h |
| 2106 | 4165382 | 475 |
| 2107 | 3962234 | 452 |
| 2108 | 3768993 | 430 |
| 2109 | 3585177 | 409 |
| 2110 | 3410326 | 389 |
| 2111 | 3244003 | 370 |
| 2112 | 3085791 | 352 |
| 2113 | 2935295 | 335 |
| 2114 | 2792139 | 319 |
| 2115 | 2655965 | 303 |
| 2116 | 2526432 | 288 |
| 2117 | 2403216 | 274 |
| 2118 | 2286010 | 261 |
| 2119 | 2174520 | 248 |
| 2120 | 2068467 | 236 |
| 2121 | 1967587 | 224 |
| 2122 | 1871627 | 214 |
| 2123 | 1780346 | 203 |
| 2124 | 1693518 | 193 |
| 2125 | 1610924 | 184 |
| 2126 | 1532358 | 175 |
| 2127 | 1457624 | 166 |
| 2128 | 1386535 | 158 |
| 2129 | 1318913 | 150 |
| 2130 | 1254589 | 143 |
| 2131 | 1193402 | 136 |
| 2132 | 1135199 | 130 |
| 2133 | 1079835 | 123 |
| 2134 | 1027171 | 117 |
| 2135 | 977075 | 111 |
| 2136 | 929422 | 106 |
| 2137 | 884094 | 101 |
| 2138 | 840976 | 96 |
| 2139 | 799961 | 91 |
| 2140 | 760947 | 87 |
| 2141 | 723835 | 83 |
| 2142 | 688533 | 79 |
| 2143 | 654953 | 75 |
| 2144 | 623010 | 71 |
| 2145 | 592626 | 68 |
| 2146 | 563723 | 64 |
| 2147 | 536230 | 61 |
| 2148 | 510078 | 58 |
| 2149 | 485201 | 55 |
| 2150 | 461537 | 53 |
| 2151 | 439028 | 50 |

| Year | Total LFG | LFG Generation Potential<br>Total LFG Generation Rates at 50%v/v Methane |
|---|---|---|
| | m3/year | m3/h |
| 2152 | 417616 | 48 |
| 2153 | 397249 | 45 |
| 2154 | 377875 | 43 |
| 2155 | 359446 | 41 |
| 2156 | 341915 | 39 |
| 2157 | 325240 | 37 |
| 2158 | 309378 | 35 |
| 2159 | 294289 | 34 |
| 2160 | 279937 | 32 |
| 2161 | 266284 | 30 |
| 2162 | 253297 | 29 |
| 2163 | 240944 | 27 |




# Summary Report

**Landfill Name or Identifier:** Smooth Hill Landfill Gas Generation - 55 Years

**Date:** Friday, 29 November 2019

**Description/Comments:**

**About LandGEM:**

First-Order Decomposition Rate Equation:

$$Q_{CH_4} = \sum_{i=1}^{n}\sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10}\right) e^{-kt_{ij}}$$

Where,

$Q_{CH4}$ = annual methane generation in the year of the calculation *($m^3$/year)*

i = 1-year time increment

n = (year of the calculation) - (initial year of waste acceptance)

j = 0.1-year time increment

k = methane generation rate (*year$^{-1}$*)

$L_o$ = potential methane generation capacity (*$m^3$/Mg*)

$M_i$ = mass of waste accepted in the $i^{th}$ year (*Mg*)

$t_{ij}$ = age of the $j^{th}$ section of waste mass $M_i$ accepted in the $i^{th}$ year (*decimal years*, e.g., 3.2 years)

LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available. Further guidance on EPA test methods, Clean Air Act (CAA) regulations, and other guidance regarding landfill gas emissions and control technology requirements can be found at http://www.epa.gov/ttnatw01/landfill/landflpg.html.

LandGEM is considered a screening tool — the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate. Defaults for estimating emissions for this type of operation are being developed to include in LandGEM along with defaults for convential landfills (no leachate or liquid additions) for developing emission inventories and determining CAA applicability. Refer to the Web site identified above for future updates.

## Input Review

LANDFILL CHARACTERISTICS

| | | |
|---|---|---|
| Landfill Open Year | **2023** | |
| Landfill Closure Year (with 80-year limit) | **2077** | |
| *Actual Closure Year (without limit)* | ***2077*** | |
| Have Model Calculate Closure Year? | **No** | |
| Waste Design Capacity | | *megagrams* |

MODEL PARAMETERS

| | | |
|---|---|---|
| Methane Generation Rate, k | **0.050** | *year $^{-1}$* |
| Potential Methane Generation Capacity, $L_o$ | **100** | *$m^3$/Mg* |
| NMOC Concentration | **2,400** | *ppmv as hexane* |
| Methane Content | **50** | *% by volume* |

GASES / POLLUTANTS SELECTED

| | |
|---|---|
| Gas / Pollutant #1: | **Total landfill gas** |
| Gas / Pollutant #2: | **Methane** |
| Gas / Pollutant #3: | **Carbon dioxide** |
| Gas / Pollutant #4: | **NMOC** |

WASTE ACCEPTANCE RATES

| Year | Waste Accepted | | Waste-In-Place | |
|---|---|---|---|---|
| | *(Mg/year)* | *(short tons/year)* | *(Mg)* | *(short tons)* |
| 2023 | 90,000 | 99,000 | 0 | 0 |
| 2024 | 90,000 | 99,000 | 90,000 | 99,000 |
| 2025 | 90,000 | 99,000 | 180,000 | 198,000 |
| 2026 | 90,000 | 99,000 | 270,000 | 297,000 |
| 2027 | 90,000 | 99,000 | 360,000 | 396,000 |
| 2028 | 90,000 | 99,000 | 450,000 | 495,000 |
| 2029 | 90,000 | 99,000 | 540,000 | 594,000 |
| 2030 | 90,000 | 99,000 | 630,000 | 693,000 |
| 2031 | 90,000 | 99,000 | 720,000 | 792,000 |
| 2032 | 90,000 | 99,000 | 810,000 | 891,000 |
| 2033 | 90,000 | 99,000 | 900,000 | 990,000 |
| 2034 | 90,000 | 99,000 | 990,000 | 1,089,000 |
| 2035 | 90,000 | 99,000 | 1,080,000 | 1,188,000 |
| 2036 | 90,000 | 99,000 | 1,170,000 | 1,287,000 |
| 2037 | 90,000 | 99,000 | 1,260,000 | 1,386,000 |
| 2038 | 90,000 | 99,000 | 1,350,000 | 1,485,000 |
| 2039 | 90,000 | 99,000 | 1,440,000 | 1,584,000 |
| 2040 | 90,000 | 99,000 | 1,530,000 | 1,683,000 |
| 2041 | 90,000 | 99,000 | 1,620,000 | 1,782,000 |
| 2042 | 90,000 | 99,000 | 1,710,000 | 1,881,000 |
| 2043 | 90,000 | 99,000 | 1,800,000 | 1,980,000 |
| 2044 | 90,000 | 99,000 | 1,890,000 | 2,079,000 |
| 2045 | 90,000 | 99,000 | 1,980,000 | 2,178,000 |
| 2046 | 90,000 | 99,000 | 2,070,000 | 2,277,000 |
| 2047 | 90,000 | 99,000 | 2,160,000 | 2,376,000 |
| 2048 | 90,000 | 99,000 | 2,250,000 | 2,475,000 |
| 2049 | 90,000 | 99,000 | 2,340,000 | 2,574,000 |
| 2050 | 90,000 | 99,000 | 2,430,000 | 2,673,000 |
| 2051 | 90,000 | 99,000 | 2,520,000 | 2,772,000 |
| 2052 | 90,000 | 99,000 | 2,610,000 | 2,871,000 |
| 2053 | 90,000 | 99,000 | 2,700,000 | 2,970,000 |
| 2054 | 90,000 | 99,000 | 2,790,000 | 3,069,000 |
| 2055 | 90,000 | 99,000 | 2,880,000 | 3,168,000 |
| 2056 | 90,000 | 99,000 | 2,970,000 | 3,267,000 |
| 2057 | 90,000 | 99,000 | 3,060,000 | 3,366,000 |
| 2058 | 90,000 | 99,000 | 3,150,000 | 3,465,000 |
| 2059 | 90,000 | 99,000 | 3,240,000 | 3,564,000 |
| 2060 | 90,000 | 99,000 | 3,330,000 | 3,663,000 |
| 2061 | 90,000 | 99,000 | 3,420,000 | 3,762,000 |
| 2062 | 90,000 | 99,000 | 3,510,000 | 3,861,000 |

WASTE ACCEPTANCE RATES (Continued)

| Year | Waste Accepted | | Waste-In-Place | |
|---|---|---|---|---|
| | *(Mg/year)* | *(short tons/year)* | *(Mg)* | *(short tons)* |
| 2063 | 90,000 | 99,000 | 3,600,000 | 3,960,000 |
| 2064 | 90,000 | 99,000 | 3,690,000 | 4,059,000 |
| 2065 | 90,000 | 99,000 | 3,780,000 | 4,158,000 |
| 2066 | 90,000 | 99,000 | 3,870,000 | 4,257,000 |
| 2067 | 90,000 | 99,000 | 3,960,000 | 4,356,000 |
| 2068 | 90,000 | 99,000 | 4,050,000 | 4,455,000 |
| 2069 | 90,000 | 99,000 | 4,140,000 | 4,554,000 |
| 2070 | 90,000 | 99,000 | 4,230,000 | 4,653,000 |
| 2071 | 90,000 | 99,000 | 4,320,000 | 4,752,000 |
| 2072 | 90,000 | 99,000 | 4,410,000 | 4,851,000 |
| 2073 | 90,000 | 99,000 | 4,500,000 | 4,950,000 |
| 2074 | 90,000 | 99,000 | 4,590,000 | 5,049,000 |
| 2075 | 90,000 | 99,000 | 4,680,000 | 5,148,000 |
| 2076 | 90,000 | 99,000 | 4,770,000 | 5,247,000 |
| 2077 | 90,000 | 99,000 | 4,860,000 | 5,346,000 |
| 2078 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2079 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2080 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2081 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2082 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2083 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2084 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2085 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2086 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2087 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2088 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2089 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2090 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2091 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2092 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2093 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2094 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2095 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2096 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2097 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2098 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2099 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2100 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2101 | 0 | 0 | 4,950,000 | 5,445,000 |
| 2102 | 0 | 0 | 4,950,000 | 5,445,000 |

## Pollutant Parameters

| | Gas / Pollutant Default Parameters: | | | User-specified Pollutant Parameters: | |
|---|---|---|---|---|---|
| | Compound | Concentration (*ppmv*) | Molecular Weight | Concentration (*ppmv*) | Molecular Weight |
| Gases | Total landfill gas | | 0.00 | | |
| | Methane | | 16.04 | | |
| | Carbon dioxide | | 44.01 | | |
| | NMOC | 4,000 | 86.18 | | |
| Pollutants | 1,1,1-Trichloroethane (methyl chloroform) - HAP | 0.48 | 133.41 | | |
| | 1,1,2,2-Tetrachloroethane - HAP/VOC | 1.1 | 167.85 | | |
| | 1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC | 2.4 | 98.97 | | |
| | 1,1-Dichloroethene (vinylidene chloride) - HAP/VOC | 0.20 | 96.94 | | |
| | 1,2-Dichloroethane (ethylene dichloride) - HAP/VOC | 0.41 | 98.96 | | |
| | 1,2-Dichloropropane (propylene dichloride) - HAP/VOC | 0.18 | 112.99 | | |
| | 2-Propanol (isopropyl alcohol) - VOC | 50 | 60.11 | | |
| | Acetone | 7.0 | 58.08 | | |
| | Acrylonitrile - HAP/VOC | 6.3 | 53.06 | | |
| | Benzene - No or Unknown Co-disposal - HAP/VOC | 1.9 | 78.11 | | |
| | Benzene - Co-disposal - HAP/VOC | 11 | 78.11 | | |
| | Bromodichloromethane - VOC | 3.1 | 163.83 | | |
| | Butane - VOC | 5.0 | 58.12 | | |
| | Carbon disulfide - HAP/VOC | 0.58 | 76.13 | | |
| | Carbon monoxide | 140 | 28.01 | | |
| | Carbon tetrachloride - HAP/VOC | 4.0E-03 | 153.84 | | |
| | Carbonyl sulfide - HAP/VOC | 0.49 | 60.07 | | |
| | Chlorobenzene - HAP/VOC | 0.25 | 112.56 | | |
| | Chlorodifluoromethane | 1.3 | 86.47 | | |
| | Chloroethane (ethyl chloride) - HAP/VOC | 1.3 | 64.52 | | |
| | Chloroform - HAP/VOC | 0.03 | 119.39 | | |
| | Chloromethane - VOC | 1.2 | 50.49 | | |
| | Dichlorobenzene - (HAP for para isomer/VOC) | 0.21 | 147 | | |
| | Dichlorodifluoromethane | 16 | 120.91 | | |
| | Dichlorofluoromethane - VOC | 2.6 | 102.92 | | |
| | Dichloromethane (methylene chloride) - HAP | 14 | 84.94 | | |
| | Dimethyl sulfide (methyl sulfide) - VOC | 7.8 | 62.13 | | |
| | Ethane | 890 | 30.07 | | |
| | Ethanol - VOC | 27 | 46.08 | | |

## Pollutant Parameters (Continued)

| | Gas / Pollutant Default Parameters: | | | User-specified Pollutant Parameters: | |
|---|---|---|---|---|---|
| | Compound | Concentration (*ppmv*) | Molecular Weight | Concentration (*ppmv*) | Molecular Weight |
| Pollutants | Ethyl mercaptan (ethanethiol) - VOC | 2.3 | 62.13 | | |
| | Ethylbenzene - HAP/VOC | 4.6 | 106.16 | | |
| | Ethylene dibromide - HAP/VOC | 1.0E-03 | 187.88 | | |
| | Fluorotrichloromethane - VOC | 0.76 | 137.38 | | |
| | Hexane - HAP/VOC | 6.6 | 86.18 | | |
| | Hydrogen sulfide | 36 | 34.08 | | |
| | Mercury (total) - HAP | 2.9E-04 | 200.61 | | |
| | Methyl ethyl ketone - HAP/VOC | 7.1 | 72.11 | | |
| | Methyl isobutyl ketone - HAP/VOC | 1.9 | 100.16 | | |
| | Methyl mercaptan - VOC | 2.5 | 48.11 | | |
| | Pentane - VOC | 3.3 | 72.15 | | |
| | Perchloroethylene (tetrachloroethylene) - HAP | 3.7 | 165.83 | | |
| | Propane - VOC | 11 | 44.09 | | |
| | t-1,2-Dichloroethene - VOC | 2.8 | 96.94 | | |
| | Toluene - No or Unknown Co-disposal - HAP/VOC | 39 | 92.13 | | |
| | Toluene - Co-disposal - HAP/VOC | 170 | 92.13 | | |
| | Trichloroethylene (trichloroethene) - HAP/VOC | 2.8 | 131.40 | | |
| | Vinyl chloride - HAP/VOC | 7.3 | 62.50 | | |
| | Xylenes - HAP/VOC | 12 | 106.16 | | |
| | | | | | |
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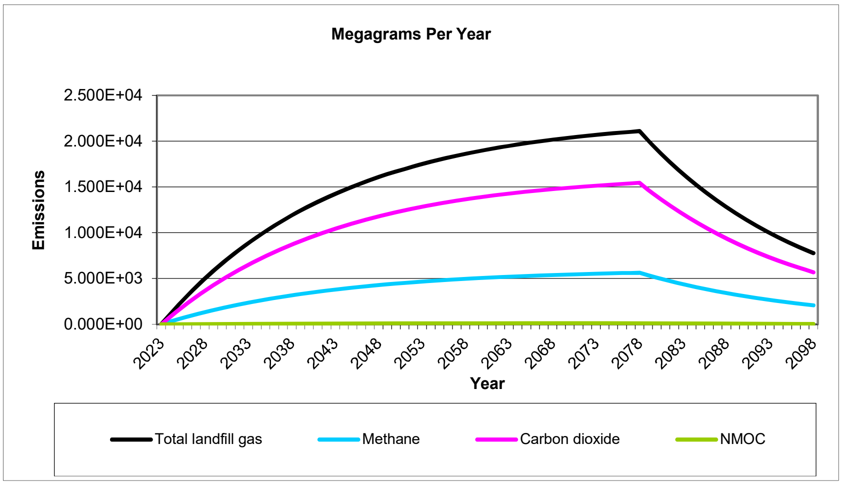
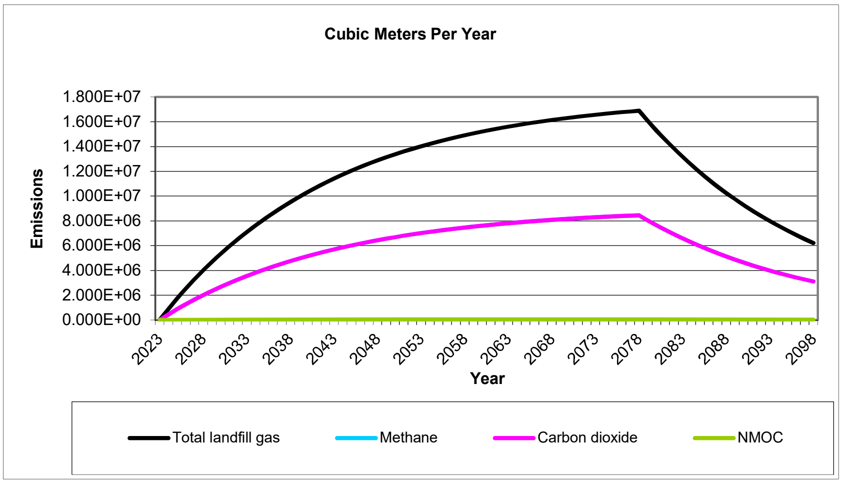
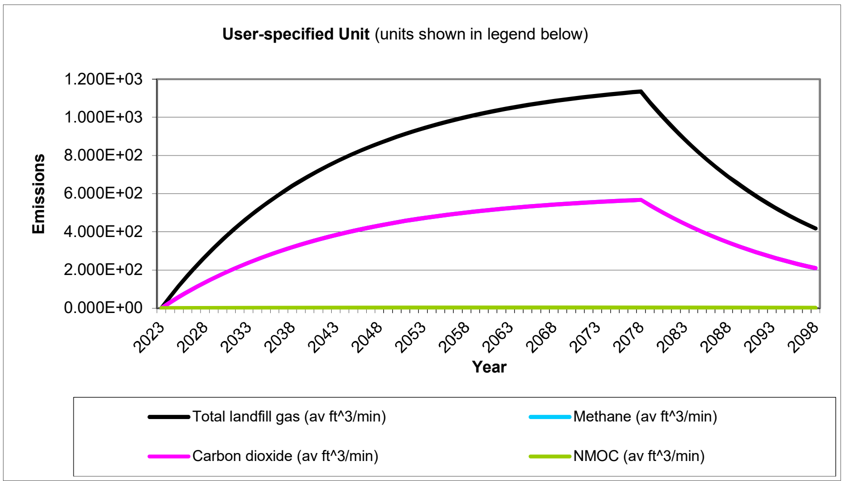
## Graphs


Megagrams Per Year
Emissions
2.500E+04
2.000E+04
1.500E+04
1.000E+04
5.000E+03
0.000E+00
2023
2028
2033
2038
2043
2048
2053
2058
2063
2068
2073
2078
2083
2088
2093
2098
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
Emissions
1.800E+07
1.600E+07
1.400E+07
1.200E+07
1.000E+07
8.000E+06
6.000E+06
4.000E+06
2.000E+06
0.000E+00
2023
2028
2033
2038
2043
2048
2053
2058
2063
2068
2073
2078
2083
2088
2093
2098
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
1.200E+03
1.000E+03
8.000E+02
6.000E+02
4.000E+02
2.000E+02
0.000E+00
2023
2028
2033
2038
2043
2048
2053
2058
2063
2068
2073
2078
2083
2088
2093
2098
Year
Total landfill gas (av ft^3/min)
Methane (av ft^3/min)
Carbon dioxide (av ft^3/min)
NMOC (av ft^3/min)

## Results

| Year | Total landfill gas | | | Methane | | |
|---|---|---|---|---|---|---|
| | (Mg/year) | ($m^3$/year) | (av ft^3/min) | (Mg/year) | ($m^3$/year) | (av ft^3/min) |
| 2023 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024 | 1.099E+03 | 8.801E+05 | 5.913E+01 | 2.936E+02 | 4.400E+05 | 2.957E+01 |
| 2025 | 2.144E+03 | 1.717E+06 | 1.154E+02 | 5.728E+02 | 8.586E+05 | 5.769E+01 |
| 2026 | 3.139E+03 | 2.514E+06 | 1.689E+02 | 8.384E+02 | 1.257E+06 | 8.444E+01 |
| 2027 | 4.085E+03 | 3.271E+06 | 2.198E+02 | 1.091E+03 | 1.636E+06 | 1.099E+02 |
| 2028 | 4.985E+03 | 3.992E+06 | 2.682E+02 | 1.331E+03 | 1.996E+06 | 1.341E+02 |
| 2029 | 5.841E+03 | 4.677E+06 | 3.142E+02 | 1.560E+03 | 2.338E+06 | 1.571E+02 |
| 2030 | 6.655E+03 | 5.329E+06 | 3.580E+02 | 1.778E+03 | 2.664E+06 | 1.790E+02 |
| 2031 | 7.429E+03 | 5.949E+06 | 3.997E+02 | 1.984E+03 | 2.975E+06 | 1.999E+02 |
| 2032 | 8.166E+03 | 6.539E+06 | 4.394E+02 | 2.181E+03 | 3.270E+06 | 2.197E+02 |
| 2033 | 8.867E+03 | 7.100E+06 | 4.771E+02 | 2.368E+03 | 3.550E+06 | 2.385E+02 |
| 2034 | 9.533E+03 | 7.634E+06 | 5.129E+02 | 2.546E+03 | 3.817E+06 | 2.565E+02 |
| 2035 | 1.017E+04 | 8.142E+06 | 5.470E+02 | 2.716E+03 | 4.071E+06 | 2.735E+02 |
| 2036 | 1.077E+04 | 8.625E+06 | 5.795E+02 | 2.877E+03 | 4.312E+06 | 2.897E+02 |
| 2037 | 1.134E+04 | 9.084E+06 | 6.104E+02 | 3.030E+03 | 4.542E+06 | 3.052E+02 |
| 2038 | 1.189E+04 | 9.521E+06 | 6.397E+02 | 3.176E+03 | 4.761E+06 | 3.199E+02 |
| 2039 | 1.241E+04 | 9.937E+06 | 6.677E+02 | 3.315E+03 | 4.968E+06 | 3.338E+02 |
| 2040 | 1.290E+04 | 1.033E+07 | 6.942E+02 | 3.447E+03 | 5.166E+06 | 3.471E+02 |
| 2041 | 1.337E+04 | 1.071E+07 | 7.195E+02 | 3.572E+03 | 5.354E+06 | 3.598E+02 |
| 2042 | 1.382E+04 | 1.107E+07 | 7.435E+02 | 3.691E+03 | 5.533E+06 | 3.718E+02 |
| 2043 | 1.424E+04 | 1.141E+07 | 7.664E+02 | 3.805E+03 | 5.703E+06 | 3.832E+02 |
| 2044 | 1.465E+04 | 1.173E+07 | 7.882E+02 | 3.913E+03 | 5.865E+06 | 3.941E+02 |
| 2045 | 1.503E+04 | 1.204E+07 | 8.089E+02 | 4.016E+03 | 6.019E+06 | 4.044E+02 |
| 2046 | 1.540E+04 | 1.233E+07 | 8.285E+02 | 4.113E+03 | 6.166E+06 | 4.143E+02 |
| 2047 | 1.575E+04 | 1.261E+07 | 8.473E+02 | 4.206E+03 | 6.305E+06 | 4.236E+02 |
| 2048 | 1.608E+04 | 1.288E+07 | 8.651E+02 | 4.295E+03 | 6.438E+06 | 4.325E+02 |
| 2049 | 1.639E+04 | 1.313E+07 | 8.820E+02 | 4.379E+03 | 6.564E+06 | 4.410E+02 |
| 2050 | 1.669E+04 | 1.337E+07 | 8.981E+02 | 4.459E+03 | 6.684E+06 | 4.491E+02 |
| 2051 | 1.698E+04 | 1.360E+07 | 9.135E+02 | 4.535E+03 | 6.798E+06 | 4.567E+02 |
| 2052 | 1.725E+04 | 1.381E+07 | 9.280E+02 | 4.607E+03 | 6.906E+06 | 4.640E+02 |
| 2053 | 1.751E+04 | 1.402E+07 | 9.419E+02 | 4.676E+03 | 7.009E+06 | 4.710E+02 |
| 2054 | 1.775E+04 | 1.422E+07 | 9.551E+02 | 4.742E+03 | 7.108E+06 | 4.776E+02 |
| 2055 | 1.799E+04 | 1.440E+07 | 9.677E+02 | 4.804E+03 | 7.201E+06 | 4.838E+02 |
| 2056 | 1.821E+04 | 1.458E+07 | 9.796E+02 | 4.863E+03 | 7.290E+06 | 4.898E+02 |
| 2057 | 1.842E+04 | 1.475E+07 | 9.910E+02 | 4.920E+03 | 7.374E+06 | 4.955E+02 |
| 2058 | 1.862E+04 | 1.491E+07 | 1.002E+03 | 4.973E+03 | 7.455E+06 | 5.009E+02 |
| 2059 | 1.881E+04 | 1.506E+07 | 1.012E+03 | 5.024E+03 | 7.531E+06 | 5.060E+02 |
| 2060 | 1.899E+04 | 1.521E+07 | 1.022E+03 | 5.073E+03 | 7.604E+06 | 5.109E+02 |
| 2061 | 1.916E+04 | 1.535E+07 | 1.031E+03 | 5.119E+03 | 7.673E+06 | 5.156E+02 |
| 2062 | 1.933E+04 | 1.548E+07 | 1.040E+03 | 5.163E+03 | 7.739E+06 | 5.200E+02 |
| 2063 | 1.949E+04 | 1.560E+07 | 1.048E+03 | 5.205E+03 | 7.801E+06 | 5.242E+02 |
| 2064 | 1.963E+04 | 1.572E+07 | 1.056E+03 | 5.244E+03 | 7.861E+06 | 5.282E+02 |
| 2065 | 1.978E+04 | 1.584E+07 | 1.064E+03 | 5.282E+03 | 7.918E+06 | 5.320E+02 |
| 2066 | 1.991E+04 | 1.594E+07 | 1.071E+03 | 5.318E+03 | 7.972E+06 | 5.356E+02 |
| 2067 | 2.004E+04 | 1.605E+07 | 1.078E+03 | 5.352E+03 | 8.023E+06 | 5.391E+02 |
| 2068 | 2.016E+04 | 1.614E+07 | 1.085E+03 | 5.385E+03 | 8.072E+06 | 5.423E+02 |
| 2069 | 2.028E+04 | 1.624E+07 | 1.091E+03 | 5.416E+03 | 8.118E+06 | 5.454E+02 |
| 2070 | 2.039E+04 | 1.632E+07 | 1.097E+03 | 5.445E+03 | 8.162E+06 | 5.484E+02 |
| 2071 | 2.049E+04 | 1.641E+07 | 1.102E+03 | 5.473E+03 | 8.204E+06 | 5.512E+02 |
| 2072 | 2.059E+04 | 1.649E+07 | 1.108E+03 | 5.500E+03 | 8.244E+06 | 5.539E+02 |

## Results (Continued)

| Year | Total landfill gas | | | Methane | | |
|---|---|---|---|---|---|---|
| | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* |
| 2073 | 2.069E+04 | 1.656E+07 | 1.113E+03 | 5.525E+03 | 8.282E+06 | 5.565E+02 |
| 2074 | 2.078E+04 | 1.664E+07 | 1.118E+03 | 5.549E+03 | 8.318E+06 | 5.589E+02 |
| 2075 | 2.086E+04 | 1.670E+07 | 1.122E+03 | 5.572E+03 | 8.352E+06 | 5.612E+02 |
| 2076 | 2.094E+04 | 1.677E+07 | 1.127E+03 | 5.594E+03 | 8.385E+06 | 5.634E+02 |
| 2077 | 2.102E+04 | 1.683E+07 | 1.131E+03 | 5.615E+03 | 8.416E+06 | 5.655E+02 |
| 2078 | 2.109E+04 | 1.689E+07 | 1.135E+03 | 5.635E+03 | 8.446E+06 | 5.675E+02 |
| 2079 | 2.007E+04 | 1.607E+07 | 1.080E+03 | 5.360E+03 | 8.034E+06 | 5.398E+02 |
| 2080 | 1.909E+04 | 1.528E+07 | 1.027E+03 | 5.098E+03 | 7.642E+06 | 5.135E+02 |
| 2081 | 1.816E+04 | 1.454E+07 | 9.768E+02 | 4.850E+03 | 7.269E+06 | 4.884E+02 |
| 2082 | 1.727E+04 | 1.383E+07 | 9.292E+02 | 4.613E+03 | 6.915E+06 | 4.646E+02 |
| 2083 | 1.643E+04 | 1.316E+07 | 8.839E+02 | 4.388E+03 | 6.578E+06 | 4.419E+02 |
| 2084 | 1.563E+04 | 1.251E+07 | 8.408E+02 | 4.174E+03 | 6.257E+06 | 4.204E+02 |
| 2085 | 1.487E+04 | 1.190E+07 | 7.998E+02 | 3.971E+03 | 5.952E+06 | 3.999E+02 |
| 2086 | 1.414E+04 | 1.132E+07 | 7.608E+02 | 3.777E+03 | 5.661E+06 | 3.804E+02 |
| 2087 | 1.345E+04 | 1.077E+07 | 7.237E+02 | 3.593E+03 | 5.385E+06 | 3.618E+02 |
| 2088 | 1.279E+04 | 1.025E+07 | 6.884E+02 | 3.418E+03 | 5.123E+06 | 3.442E+02 |
| 2089 | 1.217E+04 | 9.746E+06 | 6.548E+02 | 3.251E+03 | 4.873E+06 | 3.274E+02 |
| 2090 | 1.158E+04 | 9.270E+06 | 6.229E+02 | 3.092E+03 | 4.635E+06 | 3.114E+02 |
| 2091 | 1.101E+04 | 8.818E+06 | 5.925E+02 | 2.941E+03 | 4.409E+06 | 2.962E+02 |
| 2092 | 1.048E+04 | 8.388E+06 | 5.636E+02 | 2.798E+03 | 4.194E+06 | 2.818E+02 |
| 2093 | 9.964E+03 | 7.979E+06 | 5.361E+02 | 2.662E+03 | 3.989E+06 | 2.681E+02 |
| 2094 | 9.478E+03 | 7.590E+06 | 5.100E+02 | 2.532E+03 | 3.795E+06 | 2.550E+02 |
| 2095 | 9.016E+03 | 7.220E+06 | 4.851E+02 | 2.408E+03 | 3.610E+06 | 2.425E+02 |
| 2096 | 8.576E+03 | 6.868E+06 | 4.614E+02 | 2.291E+03 | 3.434E+06 | 2.307E+02 |
| 2097 | 8.158E+03 | 6.533E+06 | 4.389E+02 | 2.179E+03 | 3.266E+06 | 2.195E+02 |
| 2098 | 7.760E+03 | 6.214E+06 | 4.175E+02 | 2.073E+03 | 3.107E+06 | 2.088E+02 |
| 2099 | 7.382E+03 | 5.911E+06 | 3.972E+02 | 1.972E+03 | 2.955E+06 | 1.986E+02 |
| 2100 | 7.022E+03 | 5.623E+06 | 3.778E+02 | 1.876E+03 | 2.811E+06 | 1.889E+02 |
| 2101 | 6.679E+03 | 5.348E+06 | 3.594E+02 | 1.784E+03 | 2.674E+06 | 1.797E+02 |
| 2102 | 6.354E+03 | 5.088E+06 | 3.418E+02 | 1.697E+03 | 2.544E+06 | 1.709E+02 |
| 2103 | 6.044E+03 | 4.839E+06 | 3.252E+02 | 1.614E+03 | 2.420E+06 | 1.626E+02 |
| 2104 | 5.749E+03 | 4.603E+06 | 3.093E+02 | 1.536E+03 | 2.302E+06 | 1.547E+02 |
| 2105 | 5.469E+03 | 4.379E+06 | 2.942E+02 | 1.461E+03 | 2.189E+06 | 1.471E+02 |
| 2106 | 5.202E+03 | 4.165E+06 | 2.799E+02 | 1.389E+03 | 2.083E+06 | 1.399E+02 |
| 2107 | 4.948E+03 | 3.962E+06 | 2.662E+02 | 1.322E+03 | 1.981E+06 | 1.331E+02 |
| 2108 | 4.707E+03 | 3.769E+06 | 2.532E+02 | 1.257E+03 | 1.884E+06 | 1.266E+02 |
| 2109 | 4.477E+03 | 3.585E+06 | 2.409E+02 | 1.196E+03 | 1.793E+06 | 1.204E+02 |
| 2110 | 4.259E+03 | 3.410E+06 | 2.291E+02 | 1.138E+03 | 1.705E+06 | 1.146E+02 |
| 2111 | 4.051E+03 | 3.244E+06 | 2.180E+02 | 1.082E+03 | 1.622E+06 | 1.090E+02 |
| 2112 | 3.854E+03 | 3.086E+06 | 2.073E+02 | 1.029E+03 | 1.543E+06 | 1.037E+02 |
| 2113 | 3.666E+03 | 2.935E+06 | 1.972E+02 | 9.791E+02 | 1.468E+06 | 9.861E+01 |
| 2114 | 3.487E+03 | 2.792E+06 | 1.876E+02 | 9.314E+02 | 1.396E+06 | 9.380E+01 |
| 2115 | 3.317E+03 | 2.656E+06 | 1.785E+02 | 8.860E+02 | 1.328E+06 | 8.923E+01 |
| 2116 | 3.155E+03 | 2.526E+06 | 1.698E+02 | 8.428E+02 | 1.263E+06 | 8.488E+01 |
| 2117 | 3.001E+03 | 2.403E+06 | 1.615E+02 | 8.017E+02 | 1.202E+06 | 8.074E+01 |
| 2118 | 2.855E+03 | 2.286E+06 | 1.536E+02 | 7.626E+02 | 1.143E+06 | 7.680E+01 |
| 2119 | 2.716E+03 | 2.175E+06 | 1.461E+02 | 7.254E+02 | 1.087E+06 | 7.305E+01 |
| 2120 | 2.583E+03 | 2.068E+06 | 1.390E+02 | 6.900E+02 | 1.034E+06 | 6.949E+01 |
| 2121 | 2.457E+03 | 1.968E+06 | 1.322E+02 | 6.563E+02 | 9.838E+05 | 6.610E+01 |
| 2122 | 2.337E+03 | 1.872E+06 | 1.258E+02 | 6.243E+02 | 9.358E+05 | 6.288E+01 |
| 2123 | 2.223E+03 | 1.780E+06 | 1.196E+02 | 5.939E+02 | 8.902E+05 | 5.981E+01 |

## Results (Continued)

| Year | Total landfill gas | | | Methane | | |
|---|---|---|---|---|---|---|
| | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* |
| 2124 | 2.115E+03 | 1.694E+06 | 1.138E+02 | 5.649E+02 | 8.468E+05 | 5.689E+01 |
| 2125 | 2.012E+03 | 1.611E+06 | 1.082E+02 | 5.374E+02 | 8.055E+05 | 5.412E+01 |
| 2126 | 1.914E+03 | 1.532E+06 | 1.030E+02 | 5.112E+02 | 7.662E+05 | 5.148E+01 |
| 2127 | 1.820E+03 | 1.458E+06 | 9.794E+01 | 4.862E+02 | 7.288E+05 | 4.897E+01 |
| 2128 | 1.732E+03 | 1.387E+06 | 9.316E+01 | 4.625E+02 | 6.933E+05 | 4.658E+01 |
| 2129 | 1.647E+03 | 1.319E+06 | 8.862E+01 | 4.400E+02 | 6.595E+05 | 4.431E+01 |
| 2130 | 1.567E+03 | 1.255E+06 | 8.430E+01 | 4.185E+02 | 6.273E+05 | 4.215E+01 |
| 2131 | 1.490E+03 | 1.193E+06 | 8.018E+01 | 3.981E+02 | 5.967E+05 | 4.009E+01 |
| 2132 | 1.418E+03 | 1.135E+06 | 7.627E+01 | 3.787E+02 | 5.676E+05 | 3.814E+01 |
| 2133 | 1.349E+03 | 1.080E+06 | 7.255E+01 | 3.602E+02 | 5.399E+05 | 3.628E+01 |
| 2134 | 1.283E+03 | 1.027E+06 | 6.902E+01 | 3.426E+02 | 5.136E+05 | 3.451E+01 |
| 2135 | 1.220E+03 | 9.771E+05 | 6.565E+01 | 3.259E+02 | 4.885E+05 | 3.282E+01 |
| 2136 | 1.161E+03 | 9.294E+05 | 6.245E+01 | 3.100E+02 | 4.647E+05 | 3.122E+01 |
| 2137 | 1.104E+03 | 8.841E+05 | 5.940E+01 | 2.949E+02 | 4.420E+05 | 2.970E+01 |
| 2138 | 1.050E+03 | 8.410E+05 | 5.651E+01 | 2.805E+02 | 4.205E+05 | 2.825E+01 |
| 2139 | 9.990E+02 | 8.000E+05 | 5.375E+01 | 2.668E+02 | 4.000E+05 | 2.687E+01 |
| 2140 | 9.503E+02 | 7.609E+05 | 5.113E+01 | 2.538E+02 | 3.805E+05 | 2.556E+01 |
| 2141 | 9.039E+02 | 7.238E+05 | 4.863E+01 | 2.415E+02 | 3.619E+05 | 2.432E+01 |
| 2142 | 8.599E+02 | 6.885E+05 | 4.626E+01 | 2.297E+02 | 3.443E+05 | 2.313E+01 |
| 2143 | 8.179E+02 | 6.550E+05 | 4.401E+01 | 2.185E+02 | 3.275E+05 | 2.200E+01 |
| 2144 | 7.780E+02 | 6.230E+05 | 4.186E+01 | 2.078E+02 | 3.115E+05 | 2.093E+01 |
| 2145 | 7.401E+02 | 5.926E+05 | 3.982E+01 | 1.977E+02 | 2.963E+05 | 1.991E+01 |
| 2146 | 7.040E+02 | 5.637E+05 | 3.788E+01 | 1.880E+02 | 2.819E+05 | 1.894E+01 |
| 2147 | 6.697E+02 | 5.362E+05 | 3.603E+01 | 1.789E+02 | 2.681E+05 | 1.801E+01 |
| 2148 | 6.370E+02 | 5.101E+05 | 3.427E+01 | 1.701E+02 | 2.550E+05 | 1.714E+01 |
| 2149 | 6.059E+02 | 4.852E+05 | 3.260E+01 | 1.619E+02 | 2.426E+05 | 1.630E+01 |
| 2150 | 5.764E+02 | 4.615E+05 | 3.101E+01 | 1.540E+02 | 2.308E+05 | 1.551E+01 |
| 2151 | 5.483E+02 | 4.390E+05 | 2.950E+01 | 1.464E+02 | 2.195E+05 | 1.475E+01 |
| 2152 | 5.215E+02 | 4.176E+05 | 2.806E+01 | 1.393E+02 | 2.088E+05 | 1.403E+01 |
| 2153 | 4.961E+02 | 3.972E+05 | 2.669E+01 | 1.325E+02 | 1.986E+05 | 1.335E+01 |
| 2154 | 4.719E+02 | 3.779E+05 | 2.539E+01 | 1.260E+02 | 1.889E+05 | 1.269E+01 |
| 2155 | 4.489E+02 | 3.594E+05 | 2.415E+01 | 1.199E+02 | 1.797E+05 | 1.208E+01 |
| 2156 | 4.270E+02 | 3.419E+05 | 2.297E+01 | 1.141E+02 | 1.710E+05 | 1.149E+01 |
| 2157 | 4.062E+02 | 3.252E+05 | 2.185E+01 | 1.085E+02 | 1.626E+05 | 1.093E+01 |
| 2158 | 3.864E+02 | 3.094E+05 | 2.079E+01 | 1.032E+02 | 1.547E+05 | 1.039E+01 |
| 2159 | 3.675E+02 | 2.943E+05 | 1.977E+01 | 9.817E+01 | 1.471E+05 | 9.887E+00 |
| 2160 | 3.496E+02 | 2.799E+05 | 1.881E+01 | 9.338E+01 | 1.400E+05 | 9.404E+00 |
| 2161 | 3.325E+02 | 2.663E+05 | 1.789E+01 | 8.883E+01 | 1.331E+05 | 8.946E+00 |
| 2162 | 3.163E+02 | 2.533E+05 | 1.702E+01 | 8.449E+01 | 1.266E+05 | 8.510E+00 |
| 2163 | 3.009E+02 | 2.409E+05 | 1.619E+01 | 8.037E+01 | 1.205E+05 | 8.094E+00 |

## Results (Continued)

| Year | Carbon dioxide | | | NMOC | | |
|---|---|---|---|---|---|---|
| | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* |
| 2023 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024 | 8.055E+02 | 4.400E+05 | 2.957E+01 | 7.571E+00 | 2.112E+03 | 1.419E-01 |
| 2025 | 1.572E+03 | 8.586E+05 | 5.769E+01 | 1.477E+01 | 4.121E+03 | 2.769E-01 |
| 2026 | 2.301E+03 | 1.257E+06 | 8.444E+01 | 2.162E+01 | 6.032E+03 | 4.053E-01 |
| 2027 | 2.994E+03 | 1.636E+06 | 1.099E+02 | 2.814E+01 | 7.850E+03 | 5.275E-01 |
| 2028 | 3.653E+03 | 1.996E+06 | 1.341E+02 | 3.434E+01 | 9.580E+03 | 6.437E-01 |
| 2029 | 4.281E+03 | 2.338E+06 | 1.571E+02 | 4.023E+01 | 1.122E+04 | 7.542E-01 |
| 2030 | 4.877E+03 | 2.664E+06 | 1.790E+02 | 4.584E+01 | 1.279E+04 | 8.593E-01 |
| 2031 | 5.445E+03 | 2.975E+06 | 1.999E+02 | 5.118E+01 | 1.428E+04 | 9.593E-01 |
| 2032 | 5.985E+03 | 3.270E+06 | 2.197E+02 | 5.625E+01 | 1.569E+04 | 1.054E+00 |
| 2033 | 6.498E+03 | 3.550E+06 | 2.385E+02 | 6.108E+01 | 1.704E+04 | 1.145E+00 |
| 2034 | 6.987E+03 | 3.817E+06 | 2.565E+02 | 6.567E+01 | 1.832E+04 | 1.231E+00 |
| 2035 | 7.452E+03 | 4.071E+06 | 2.735E+02 | 7.004E+01 | 1.954E+04 | 1.313E+00 |
| 2036 | 7.894E+03 | 4.312E+06 | 2.897E+02 | 7.420E+01 | 2.070E+04 | 1.391E+00 |
| 2037 | 8.314E+03 | 4.542E+06 | 3.052E+02 | 7.815E+01 | 2.180E+04 | 1.465E+00 |
| 2038 | 8.714E+03 | 4.761E+06 | 3.199E+02 | 8.191E+01 | 2.285E+04 | 1.535E+00 |
| 2039 | 9.095E+03 | 4.968E+06 | 3.338E+02 | 8.548E+01 | 2.385E+04 | 1.602E+00 |
| 2040 | 9.457E+03 | 5.166E+06 | 3.471E+02 | 8.889E+01 | 2.480E+04 | 1.666E+00 |
| 2041 | 9.801E+03 | 5.354E+06 | 3.598E+02 | 9.212E+01 | 2.570E+04 | 1.727E+00 |
| 2042 | 1.013E+04 | 5.533E+06 | 3.718E+02 | 9.520E+01 | 2.656E+04 | 1.785E+00 |
| 2043 | 1.044E+04 | 5.703E+06 | 3.832E+02 | 9.813E+01 | 2.738E+04 | 1.839E+00 |
| 2044 | 1.074E+04 | 5.865E+06 | 3.941E+02 | 1.009E+02 | 2.815E+04 | 1.892E+00 |
| 2045 | 1.102E+04 | 6.019E+06 | 4.044E+02 | 1.036E+02 | 2.889E+04 | 1.941E+00 |
| 2046 | 1.129E+04 | 6.166E+06 | 4.143E+02 | 1.061E+02 | 2.960E+04 | 1.988E+00 |
| 2047 | 1.154E+04 | 6.305E+06 | 4.236E+02 | 1.085E+02 | 3.026E+04 | 2.033E+00 |
| 2048 | 1.178E+04 | 6.438E+06 | 4.325E+02 | 1.108E+02 | 3.090E+04 | 2.076E+00 |
| 2049 | 1.201E+04 | 6.564E+06 | 4.410E+02 | 1.129E+02 | 3.151E+04 | 2.117E+00 |
| 2050 | 1.223E+04 | 6.684E+06 | 4.491E+02 | 1.150E+02 | 3.208E+04 | 2.156E+00 |
| 2051 | 1.244E+04 | 6.798E+06 | 4.567E+02 | 1.170E+02 | 3.263E+04 | 2.192E+00 |
| 2052 | 1.264E+04 | 6.906E+06 | 4.640E+02 | 1.188E+02 | 3.315E+04 | 2.227E+00 |
| 2053 | 1.283E+04 | 7.009E+06 | 4.710E+02 | 1.206E+02 | 3.364E+04 | 2.261E+00 |
| 2054 | 1.301E+04 | 7.108E+06 | 4.776E+02 | 1.223E+02 | 3.412E+04 | 2.292E+00 |
| 2055 | 1.318E+04 | 7.201E+06 | 4.838E+02 | 1.239E+02 | 3.456E+04 | 2.322E+00 |
| 2056 | 1.334E+04 | 7.290E+06 | 4.898E+02 | 1.254E+02 | 3.499E+04 | 2.351E+00 |
| 2057 | 1.350E+04 | 7.374E+06 | 4.955E+02 | 1.269E+02 | 3.540E+04 | 2.378E+00 |
| 2058 | 1.365E+04 | 7.455E+06 | 5.009E+02 | 1.283E+02 | 3.578E+04 | 2.404E+00 |
| 2059 | 1.379E+04 | 7.531E+06 | 5.060E+02 | 1.296E+02 | 3.615E+04 | 2.429E+00 |
| 2060 | 1.392E+04 | 7.604E+06 | 5.109E+02 | 1.308E+02 | 3.650E+04 | 2.452E+00 |
| 2061 | 1.405E+04 | 7.673E+06 | 5.156E+02 | 1.320E+02 | 3.683E+04 | 2.475E+00 |
| 2062 | 1.417E+04 | 7.739E+06 | 5.200E+02 | 1.332E+02 | 3.715E+04 | 2.496E+00 |
| 2063 | 1.428E+04 | 7.801E+06 | 5.242E+02 | 1.342E+02 | 3.745E+04 | 2.516E+00 |
| 2064 | 1.439E+04 | 7.861E+06 | 5.282E+02 | 1.353E+02 | 3.773E+04 | 2.535E+00 |
| 2065 | 1.449E+04 | 7.918E+06 | 5.320E+02 | 1.362E+02 | 3.800E+04 | 2.554E+00 |
| 2066 | 1.459E+04 | 7.972E+06 | 5.356E+02 | 1.372E+02 | 3.826E+04 | 2.571E+00 |
| 2067 | 1.469E+04 | 8.023E+06 | 5.391E+02 | 1.380E+02 | 3.851E+04 | 2.587E+00 |
| 2068 | 1.477E+04 | 8.072E+06 | 5.423E+02 | 1.389E+02 | 3.874E+04 | 2.603E+00 |
| 2069 | 1.486E+04 | 8.118E+06 | 5.454E+02 | 1.397E+02 | 3.897E+04 | 2.618E+00 |
| 2070 | 1.494E+04 | 8.162E+06 | 5.484E+02 | 1.404E+02 | 3.918E+04 | 2.632E+00 |
| 2071 | 1.502E+04 | 8.204E+06 | 5.512E+02 | 1.412E+02 | 3.938E+04 | 2.646E+00 |
| 2072 | 1.509E+04 | 8.244E+06 | 5.539E+02 | 1.418E+02 | 3.957E+04 | 2.659E+00 |

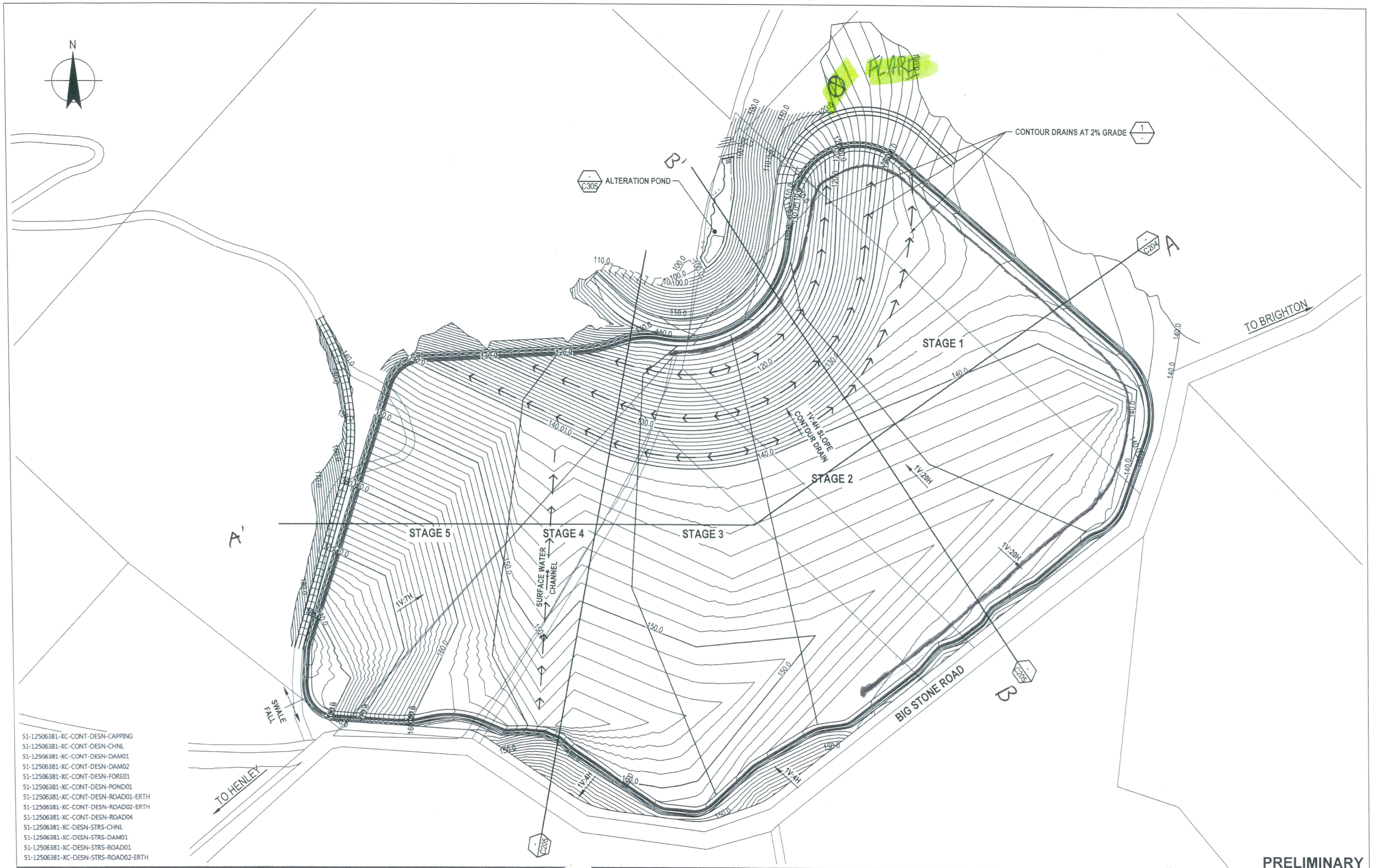
## Results (Continued)

| Year | Carbon dioxide | | | NMOC | | |
|---|---|---|---|---|---|---|
| | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* |
| 2073 | 1.516E+04 | 8.282E+06 | 5.565E+02 | 1.425E+02 | 3.975E+04 | 2.671E+00 |
| 2074 | 1.523E+04 | 8.318E+06 | 5.589E+02 | 1.431E+02 | 3.993E+04 | 2.683E+00 |
| 2075 | 1.529E+04 | 8.352E+06 | 5.612E+02 | 1.437E+02 | 4.009E+04 | 2.694E+00 |
| 2076 | 1.535E+04 | 8.385E+06 | 5.634E+02 | 1.443E+02 | 4.025E+04 | 2.704E+00 |
| 2077 | 1.541E+04 | 8.416E+06 | 5.655E+02 | 1.448E+02 | 4.040E+04 | 2.714E+00 |
| 2078 | 1.546E+04 | 8.446E+06 | 5.675E+02 | 1.453E+02 | 4.054E+04 | 2.724E+00 |
| 2079 | 1.471E+04 | 8.034E+06 | 5.398E+02 | 1.382E+02 | 3.856E+04 | 2.591E+00 |
| 2080 | 1.399E+04 | 7.642E+06 | 5.135E+02 | 1.315E+02 | 3.668E+04 | 2.465E+00 |
| 2081 | 1.331E+04 | 7.269E+06 | 4.884E+02 | 1.251E+02 | 3.489E+04 | 2.344E+00 |
| 2082 | 1.266E+04 | 6.915E+06 | 4.646E+02 | 1.190E+02 | 3.319E+04 | 2.230E+00 |
| 2083 | 1.204E+04 | 6.578E+06 | 4.419E+02 | 1.132E+02 | 3.157E+04 | 2.121E+00 |
| 2084 | 1.145E+04 | 6.257E+06 | 4.204E+02 | 1.077E+02 | 3.003E+04 | 2.018E+00 |
| 2085 | 1.089E+04 | 5.952E+06 | 3.999E+02 | 1.024E+02 | 2.857E+04 | 1.919E+00 |
| 2086 | 1.036E+04 | 5.661E+06 | 3.804E+02 | 9.741E+01 | 2.717E+04 | 1.826E+00 |
| 2087 | 9.858E+03 | 5.385E+06 | 3.618E+02 | 9.266E+01 | 2.585E+04 | 1.737E+00 |
| 2088 | 9.377E+03 | 5.123E+06 | 3.442E+02 | 8.814E+01 | 2.459E+04 | 1.652E+00 |
| 2089 | 8.920E+03 | 4.873E+06 | 3.274E+02 | 8.384E+01 | 2.339E+04 | 1.572E+00 |
| 2090 | 8.485E+03 | 4.635E+06 | 3.114E+02 | 7.975E+01 | 2.225E+04 | 1.495E+00 |
| 2091 | 8.071E+03 | 4.409E+06 | 2.962E+02 | 7.586E+01 | 2.116E+04 | 1.422E+00 |
| 2092 | 7.677E+03 | 4.194E+06 | 2.818E+02 | 7.216E+01 | 2.013E+04 | 1.353E+00 |
| 2093 | 7.303E+03 | 3.989E+06 | 2.681E+02 | 6.864E+01 | 1.915E+04 | 1.287E+00 |
| 2094 | 6.947E+03 | 3.795E+06 | 2.550E+02 | 6.529E+01 | 1.822E+04 | 1.224E+00 |
| 2095 | 6.608E+03 | 3.610E+06 | 2.425E+02 | 6.211E+01 | 1.733E+04 | 1.164E+00 |
| 2096 | 6.286E+03 | 3.434E+06 | 2.307E+02 | 5.908E+01 | 1.648E+04 | 1.107E+00 |
| 2097 | 5.979E+03 | 3.266E+06 | 2.195E+02 | 5.620E+01 | 1.568E+04 | 1.053E+00 |
| 2098 | 5.687E+03 | 3.107E+06 | 2.088E+02 | 5.346E+01 | 1.491E+04 | 1.002E+00 |
| 2099 | 5.410E+03 | 2.955E+06 | 1.986E+02 | 5.085E+01 | 1.419E+04 | 9.532E-01 |
| 2100 | 5.146E+03 | 2.811E+06 | 1.889E+02 | 4.837E+01 | 1.349E+04 | 9.067E-01 |
| 2101 | 4.895E+03 | 2.674E+06 | 1.797E+02 | 4.601E+01 | 1.284E+04 | 8.625E-01 |
| 2102 | 4.656E+03 | 2.544E+06 | 1.709E+02 | 4.377E+01 | 1.221E+04 | 8.204E-01 |
| 2103 | 4.429E+03 | 2.420E+06 | 1.626E+02 | 4.163E+01 | 1.161E+04 | 7.804E-01 |
| 2104 | 4.213E+03 | 2.302E+06 | 1.547E+02 | 3.960E+01 | 1.105E+04 | 7.423E-01 |
| 2105 | 4.008E+03 | 2.189E+06 | 1.471E+02 | 3.767E+01 | 1.051E+04 | 7.061E-01 |
| 2106 | 3.812E+03 | 2.083E+06 | 1.399E+02 | 3.583E+01 | 9.997E+03 | 6.717E-01 |
| 2107 | 3.626E+03 | 1.981E+06 | 1.331E+02 | 3.409E+01 | 9.509E+03 | 6.389E-01 |
| 2108 | 3.450E+03 | 1.884E+06 | 1.266E+02 | 3.242E+01 | 9.046E+03 | 6.078E-01 |
| 2109 | 3.281E+03 | 1.793E+06 | 1.204E+02 | 3.084E+01 | 8.604E+03 | 5.781E-01 |
| 2110 | 3.121E+03 | 1.705E+06 | 1.146E+02 | 2.934E+01 | 8.185E+03 | 5.499E-01 |
| 2111 | 2.969E+03 | 1.622E+06 | 1.090E+02 | 2.791E+01 | 7.786E+03 | 5.231E-01 |
| 2112 | 2.824E+03 | 1.543E+06 | 1.037E+02 | 2.655E+01 | 7.406E+03 | 4.976E-01 |
| 2113 | 2.687E+03 | 1.468E+06 | 9.861E+01 | 2.525E+01 | 7.045E+03 | 4.733E-01 |
| 2114 | 2.556E+03 | 1.396E+06 | 9.380E+01 | 2.402E+01 | 6.701E+03 | 4.502E-01 |
| 2115 | 2.431E+03 | 1.328E+06 | 8.923E+01 | 2.285E+01 | 6.374E+03 | 4.283E-01 |
| 2116 | 2.312E+03 | 1.263E+06 | 8.488E+01 | 2.173E+01 | 6.063E+03 | 4.074E-01 |
| 2117 | 2.200E+03 | 1.202E+06 | 8.074E+01 | 2.067E+01 | 5.768E+03 | 3.875E-01 |
| 2118 | 2.092E+03 | 1.143E+06 | 7.680E+01 | 1.967E+01 | 5.486E+03 | 3.686E-01 |
| 2119 | 1.990E+03 | 1.087E+06 | 7.305E+01 | 1.871E+01 | 5.219E+03 | 3.507E-01 |
| 2120 | 1.893E+03 | 1.034E+06 | 6.949E+01 | 1.779E+01 | 4.964E+03 | 3.336E-01 |
| 2121 | 1.801E+03 | 9.838E+05 | 6.610E+01 | 1.693E+01 | 4.722E+03 | 3.173E-01 |
| 2122 | 1.713E+03 | 9.358E+05 | 6.288E+01 | 1.610E+01 | 4.492E+03 | 3.018E-01 |
| 2123 | 1.629E+03 | 8.902E+05 | 5.981E+01 | 1.532E+01 | 4.273E+03 | 2.871E-01 |

## Results (Continued)

| Year | Carbon dioxide | | | NMOC | | |
|---|---|---|---|---|---|---|
| | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* | *(Mg/year)* | *($m^3$/year)* | *(av ft^3/min)* |
| 2124 | 1.550E+03 | 8.468E+05 | 5.689E+01 | 1.457E+01 | 4.064E+03 | 2.731E-01 |
| 2125 | 1.474E+03 | 8.055E+05 | 5.412E+01 | 1.386E+01 | 3.866E+03 | 2.598E-01 |
| 2126 | 1.402E+03 | 7.662E+05 | 5.148E+01 | 1.318E+01 | 3.678E+03 | 2.471E-01 |
| 2127 | 1.334E+03 | 7.288E+05 | 4.897E+01 | 1.254E+01 | 3.498E+03 | 2.351E-01 |
| 2128 | 1.269E+03 | 6.933E+05 | 4.658E+01 | 1.193E+01 | 3.328E+03 | 2.236E-01 |
| 2129 | 1.207E+03 | 6.595E+05 | 4.431E+01 | 1.135E+01 | 3.165E+03 | 2.127E-01 |
| 2130 | 1.148E+03 | 6.273E+05 | 4.215E+01 | 1.079E+01 | 3.011E+03 | 2.023E-01 |
| 2131 | 1.092E+03 | 5.967E+05 | 4.009E+01 | 1.027E+01 | 2.864E+03 | 1.924E-01 |
| 2132 | 1.039E+03 | 5.676E+05 | 3.814E+01 | 9.766E+00 | 2.724E+03 | 1.831E-01 |
| 2133 | 9.883E+02 | 5.399E+05 | 3.628E+01 | 9.290E+00 | 2.592E+03 | 1.741E-01 |
| 2134 | 9.401E+02 | 5.136E+05 | 3.451E+01 | 8.836E+00 | 2.465E+03 | 1.656E-01 |
| 2135 | 8.943E+02 | 4.885E+05 | 3.282E+01 | 8.406E+00 | 2.345E+03 | 1.576E-01 |
| 2136 | 8.507E+02 | 4.647E+05 | 3.122E+01 | 7.996E+00 | 2.231E+03 | 1.499E-01 |
| 2137 | 8.092E+02 | 4.420E+05 | 2.970E+01 | 7.606E+00 | 2.122E+03 | 1.426E-01 |
| 2138 | 7.697E+02 | 4.205E+05 | 2.825E+01 | 7.235E+00 | 2.018E+03 | 1.356E-01 |
| 2139 | 7.322E+02 | 4.000E+05 | 2.687E+01 | 6.882E+00 | 1.920E+03 | 1.290E-01 |
| 2140 | 6.965E+02 | 3.805E+05 | 2.556E+01 | 6.546E+00 | 1.826E+03 | 1.227E-01 |
| 2141 | 6.625E+02 | 3.619E+05 | 2.432E+01 | 6.227E+00 | 1.737E+03 | 1.167E-01 |
| 2142 | 6.302E+02 | 3.443E+05 | 2.313E+01 | 5.923E+00 | 1.652E+03 | 1.110E-01 |
| 2143 | 5.994E+02 | 3.275E+05 | 2.200E+01 | 5.634E+00 | 1.572E+03 | 1.056E-01 |
| 2144 | 5.702E+02 | 3.115E+05 | 2.093E+01 | 5.360E+00 | 1.495E+03 | 1.005E-01 |
| 2145 | 5.424E+02 | 2.963E+05 | 1.991E+01 | 5.098E+00 | 1.422E+03 | 9.556E-02 |
| 2146 | 5.159E+02 | 2.819E+05 | 1.894E+01 | 4.850E+00 | 1.353E+03 | 9.090E-02 |
| 2147 | 4.908E+02 | 2.681E+05 | 1.801E+01 | 4.613E+00 | 1.287E+03 | 8.647E-02 |
| 2148 | 4.668E+02 | 2.550E+05 | 1.714E+01 | 4.388E+00 | 1.224E+03 | 8.225E-02 |
| 2149 | 4.441E+02 | 2.426E+05 | 1.630E+01 | 4.174E+00 | 1.164E+03 | 7.824E-02 |
| 2150 | 4.224E+02 | 2.308E+05 | 1.551E+01 | 3.970E+00 | 1.108E+03 | 7.443E-02 |
| 2151 | 4.018E+02 | 2.195E+05 | 1.475E+01 | 3.777E+00 | 1.054E+03 | 7.080E-02 |
| 2152 | 3.822E+02 | 2.088E+05 | 1.403E+01 | 3.593E+00 | 1.002E+03 | 6.734E-02 |
| 2153 | 3.636E+02 | 1.986E+05 | 1.335E+01 | 3.417E+00 | 9.534E+02 | 6.406E-02 |
| 2154 | 3.458E+02 | 1.889E+05 | 1.269E+01 | 3.251E+00 | 9.069E+02 | 6.093E-02 |
| 2155 | 3.290E+02 | 1.797E+05 | 1.208E+01 | 3.092E+00 | 8.627E+02 | 5.796E-02 |
| 2156 | 3.129E+02 | 1.710E+05 | 1.149E+01 | 2.941E+00 | 8.206E+02 | 5.514E-02 |
| 2157 | 2.977E+02 | 1.626E+05 | 1.093E+01 | 2.798E+00 | 7.806E+02 | 5.245E-02 |
| 2158 | 2.832E+02 | 1.547E+05 | 1.039E+01 | 2.661E+00 | 7.425E+02 | 4.989E-02 |
| 2159 | 2.693E+02 | 1.471E+05 | 9.887E+00 | 2.532E+00 | 7.063E+02 | 4.746E-02 |
| 2160 | 2.562E+02 | 1.400E+05 | 9.404E+00 | 2.408E+00 | 6.718E+02 | 4.514E-02 |
| 2161 | 2.437E+02 | 1.331E+05 | 8.946E+00 | 2.291E+00 | 6.391E+02 | 4.294E-02 |
| 2162 | 2.318E+02 | 1.266E+05 | 8.510E+00 | 2.179E+00 | 6.079E+02 | 4.085E-02 |
| 2163 | 2.205E+02 | 1.205E+05 | 8.094E+00 | 2.073E+00 | 5.783E+02 | 3.885E-02 |

# **Appendix C** – Conceptual Site Models




PRELIMINARY

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | ISSUED FOR CONCEPT DESIGN | * | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 20 40 60 80 100m
SCALE 1:2000 AT ORIGINAL SIZE

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GHD

Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com

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09/09/2019

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Drawn | Designer
Drafting Check | Design Check
Approved (Project Director)
Date
Scale AS SHOWN

This Drawing must not be used for Construction unless signed as Approved

Client: DUNEDIN CITY COUNCIL
Project: SMOOTH HILL LANDFILL
Title: LANDFILL CAPPING PLAN

Original Size: A1
Drawing No: 51-12506381-C202
Rev: A

Plot Date: 9 September 2019 - 10:53 AM Plotted by: Gretzen Gurrea Cad File No: \\ghdnet\ghd\PH\Manila\Projects\51\12506381\CADD\Drawings\51-12506381-C202_capping.dwg

NOTE
1. FOR GENERAL ARRANGEMENT PLAN, REFER TO DRAWING 51-12506381-C110.


DATUM RL 95.00

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESIGN CAPPING SURFACE LEVEL | | | | 164.38 | 161.71 | 155.80 | 148.81 | 144.99 | 145.96 | 144.90 | 143.79 | 143.08 | 143.26 | 143.11 | 142.24 | 141.25 | 140.4[illegible] | 139.20 | 138.07 | 137.52 | 136.71 | | | | |
| LINER SURFACE CUT - / FILL + | | | -5.38 | 1.73 | 2.60 | 4.92 | 16.26 | 7.50 | 1.61 | -1.81 | -10.84 | -7.21 | -5.48 | -7.17 | -6.42 | -0.44 | -1.46 | 1.86 | -6.84 | -5.50 | -10.78 | -5.85 | | | |
| DESIGN LINER SURFACE LEVEL | | | 165.356 | 158.725 | 149.104 | 140.078 | 130.358 | 120.652 | 110.938 | 107.394 | 106.859 | 113.818 | 121.808 | 119.226 | 111.064 | 106.560 | 106.291 | 106.524 | 108.116 | 118.445 | 128.422 | 135.153 | | | |
| EXISTING SURFACE LEVEL | 159.09 | 166.66 | 172.01<br>170.74 | 157.00 | 146.50 | 135.16 | 114.08 | 113.15 | 109.33 | 109.20 | 117.70 | 121.02 | 127.29 | 126.40 | 117.48 | 107.00 | 107.75 | 104.66 | 114.95 | 123.94 | 139.20 | 141.00<br>141.00 | 138.35 | 123.95 | 117.16<br>116.67 |
| CHAINAGE | 0.00 | 50.00 | 138.98<br>150.00 | 150.00 | 200.00 | 250.00 | 300.00 | 350.00 | 400.00 | 450.00 | 500.00 | 550.00 | 600.00 | 650.00 | 700.00 | 750.00 | 800.00 | 850.00 | 900.00 | 950.00 | 1000.00 | 1050.00<br>1050.00 | 1100.00 | 1150.00 | 1200.00<br>1205.76 |

LONGITUDINAL SECTION - SECTA
HORZ 1:2000 VERT 1:500

A' — A

PRELIMINARY

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| | ISSUED FOR CONCEPT DESIGN | JC | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

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GHD
Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com

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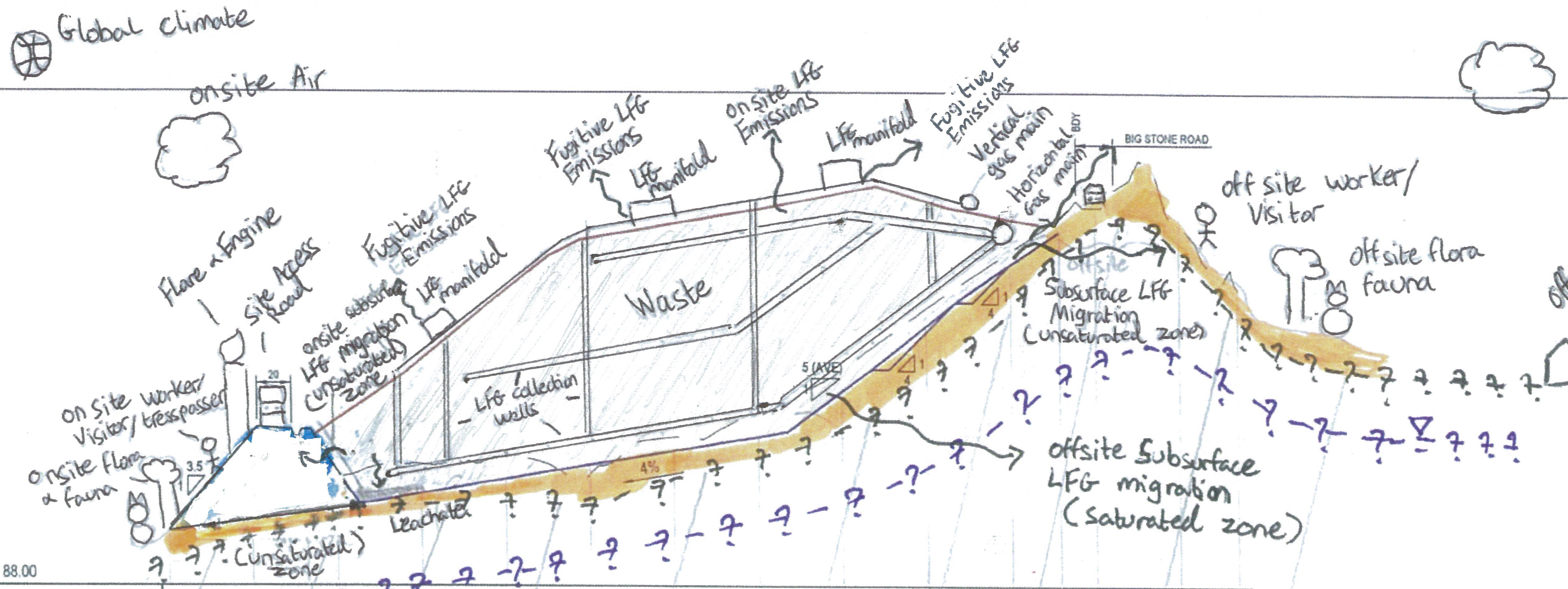
Drafting Check | Design Check
Approved (Project Director)
Date
Scale AS SHOWN
This Drawing must not be used for Construction unless signed as Approved

Client DUNEDIN CITY COUNCIL
Project SMOOTH HILL LANDFILL
Title LANDFILL LONG SECTION

Original Size A1 Drawing No: 51-12506381-C204 Rev: A

Plot Date 9 September 2019 - 10:23 AM Plotted by Gretzen Gurrea Cad File No: \\ghdnet\ghd\PH\Manila Projects\51\12506381\CADD\Drawings\51-12506381-C204-C206_long_sec.dwg




NOTE

1. FOR GENERAL ARRANGEMENT PLAN, REFER TO DRAWING 51-12506381-C110.

LEGEND

- FINAL CAPPING
- LANDFILL LINER
- EXISTING SURFACE LEVEL
- Intermediate Cover
- = Alluvium, colluvium or Loess
- = LFG Pathway
- = Groundwater
- = Henley Breccia

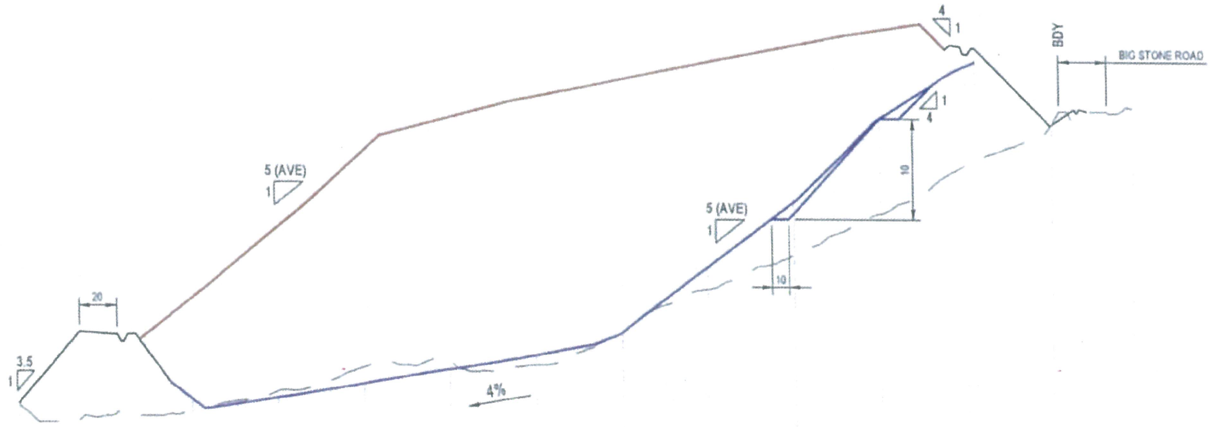
DATUM RL. 88.00

| CHAINAGE | 0.00 | 50.00 | 82.16 | 100.00 | 150.00 | 200.00 | 250.00 | 300.00 | 350.00 | 400.00 | 450.00 | 500.00 | 528.53 | 550.00 | 600.00 | 634.38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESIGN CAPPING SURFACE LEVEL | | | | 113.63 | 122.53 | 132.69 | 140.27 | 142.44 | 144.63 | 147.02 | 145.86 | 143.14 | | | | |
| LINER SURFACE CUT - / FILL + | | | -6.00 | -0.13 | -4.34 | -3.35 | 1.43 | -2.05 | -4.65 | -3.20 | -2.60 | -1.93 | -1.95 | | | |
| DESIGN LINER SURFACE LEVEL | | | 108.770 | 103.896 | 101.571 | 103.709 | 105.828 | 107.937 | 110.039 | 116.787 | 126.454 | 135.574 | 140.335 | | | |
| EXISTING SURFACE LEVEL | 96.00 | 99.96 | 102.77 | 103.77 | 105.91 | 107.06 | 104.40 | 109.99 | 114.69 | 119.99 | 129.05 | 137.50 | 142.28 | 144.00 | 141.46 | 131.80 |

LONGITUDINAL SECTION - SECTB

HORZ 1:2000 VERT 1:500

B' - B




DATUM RL. 90.00

| CHAINAGE | 0.00 | 50.00 | 64.82 | 100.00 | 150.00 | 200.00 | 250.00 | 300.00 | 350.00 | 400.00 | 450.00 | 500.00 | 550.00 555.54 | 600.00 | 646.70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESIGN CAPPING SURFACE LEVEL | | | | 116.97 | 127.10 | 138.01 | 142.70 | 145.73 | 148.21 | 150.69 | 153.17 | 155.41 | | | |
| LINER SURFACE CUT - / FILL + | | | 9.05 | 1.67 | -0.93 | -2.39 | -1.30 | 1.35 | -0.15 | 3.14 | 7.44 | 13.98 | 14.07 13.87 | | |
| DESIGN LINER SURFACE LEVEL | | | 108.770 | 101.381 | 101.586 | 103.625 | 105.712 | 107.756 | 111.106 | 120.451 | 129.795 | 142.187 | 149.357 149.952 | | |
| EXISTING SURFACE LEVEL | 100.59 | 98.98 | 99.72 | 99.72 | 102.52 | 106.01 | 107.02 | 106.40 | 111.26 | 117.31 | 122.35 | 128.20 | 135.32 136.08 | 141.24 | 143.47 |

LONGITUDINAL SECTION - SECTC

HORZ 1:2000 VERT 1:500

PRELIMINARY

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| | ISSUED FOR CONCEPT DESIGN | JC | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

SCALE 1:1000 AT ORIGINAL SIZE

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Client: DUNEDIN CITY COUNCIL

Project: SMOOTH HILL LANDFILL

Title: LANDFILL CROSS SECTION

Original Size A1 Drawing No: 51-12506381-C205 Rev: A

Plot Date: 9 September 2019 - 10:23 AM Plotted by: Gretzen Ocmes Cad File No: \\ghdnet\ghd\PH\Manila\Projects\51\12506381\CADD\Drawings\51-12506381-C204-C206_long_sec.dwg

# **Appendix D** – Concept design drawings of LFG collection and treatment/destruction system


| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | CONCEPT DESIGN | LP | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 20 40 60 80 100m
SCALE 1:2000 AT ORIGINAL SIZE

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27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com

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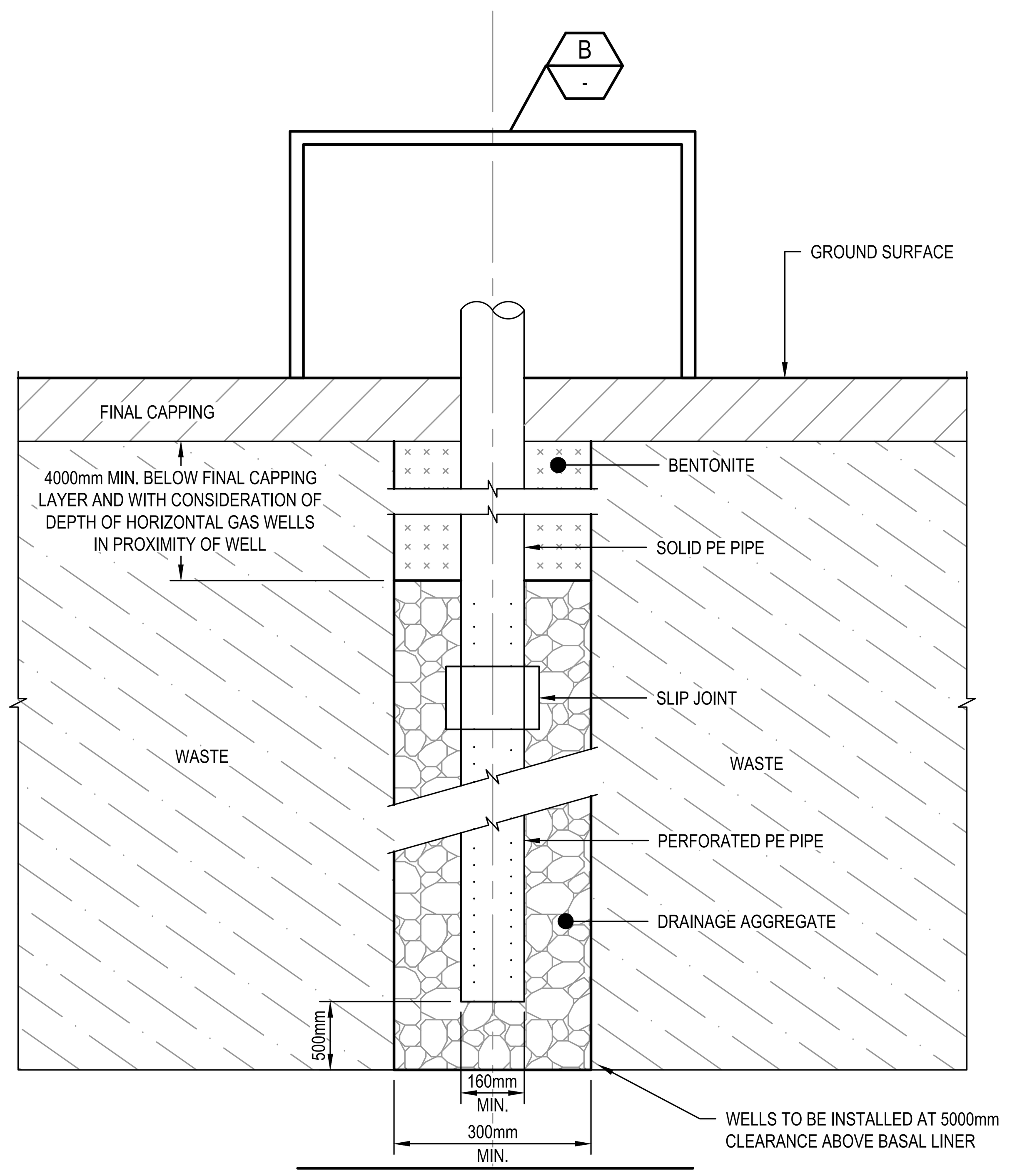
Drawn LP
Designer FC
Drafting Check
Design Check
Approved (Project Director)
Date
Scale 1 : 2000
This Drawing must not be used for Construction unless signed as Approved

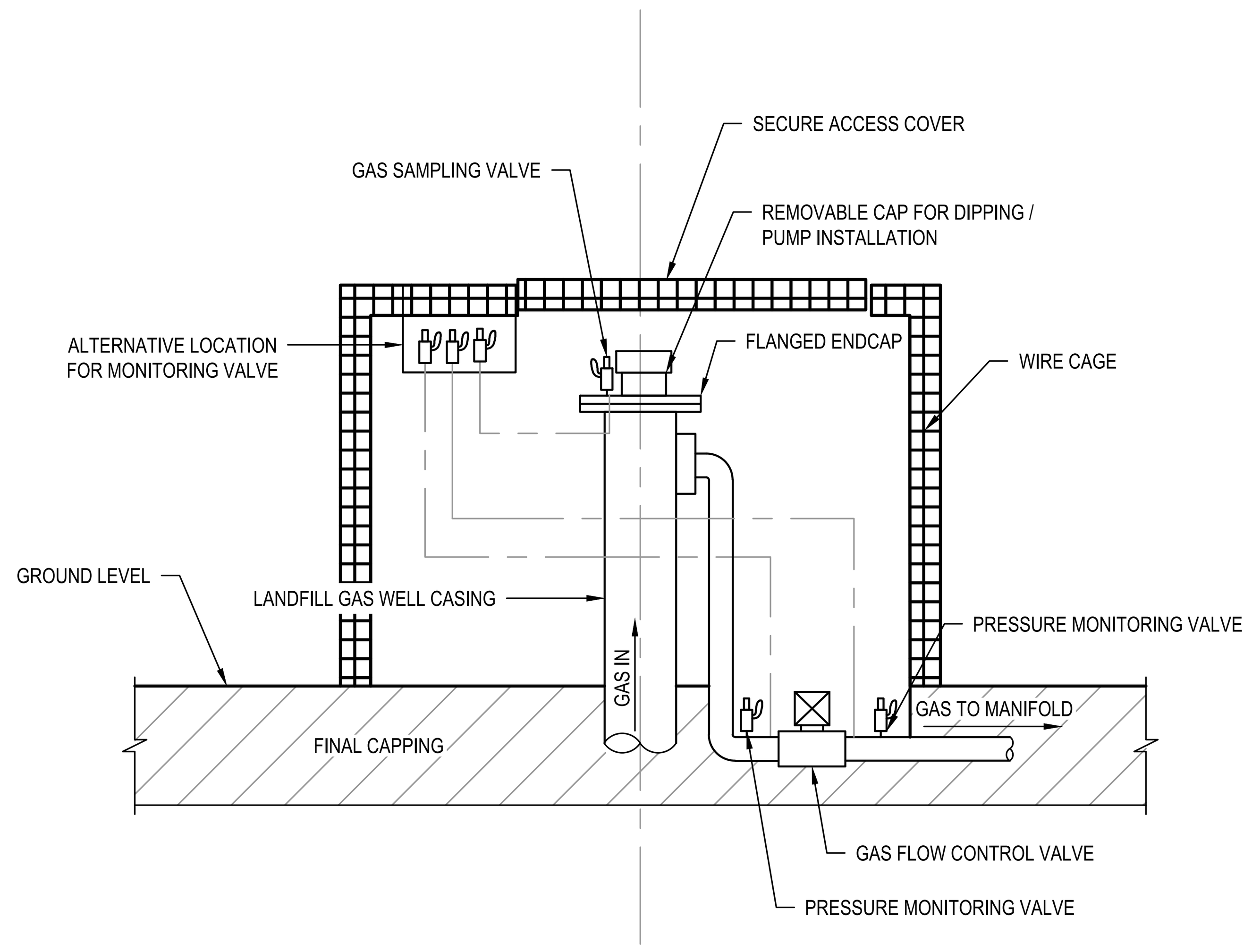
Client **DUNEDIN CITY COUNCIL**
Project **SMOOTH HILL LANDFILL**
Title **LANDFILL GAS MANAGEMENT CONCEPTUAL FINAL SYSTEM LAYOUT**
Original Size A1
Drawing No: **12506381-01-C501**
Rev: A

Plot Date: 1 October 2019 - 9:14 AM Plotted by: Fabrice Cheong Cad File No: \\ghdnet\ghd\NZ\Christchurch\Projects\51\12506381\CADD\Drawings\12506381-01-C501.dwg



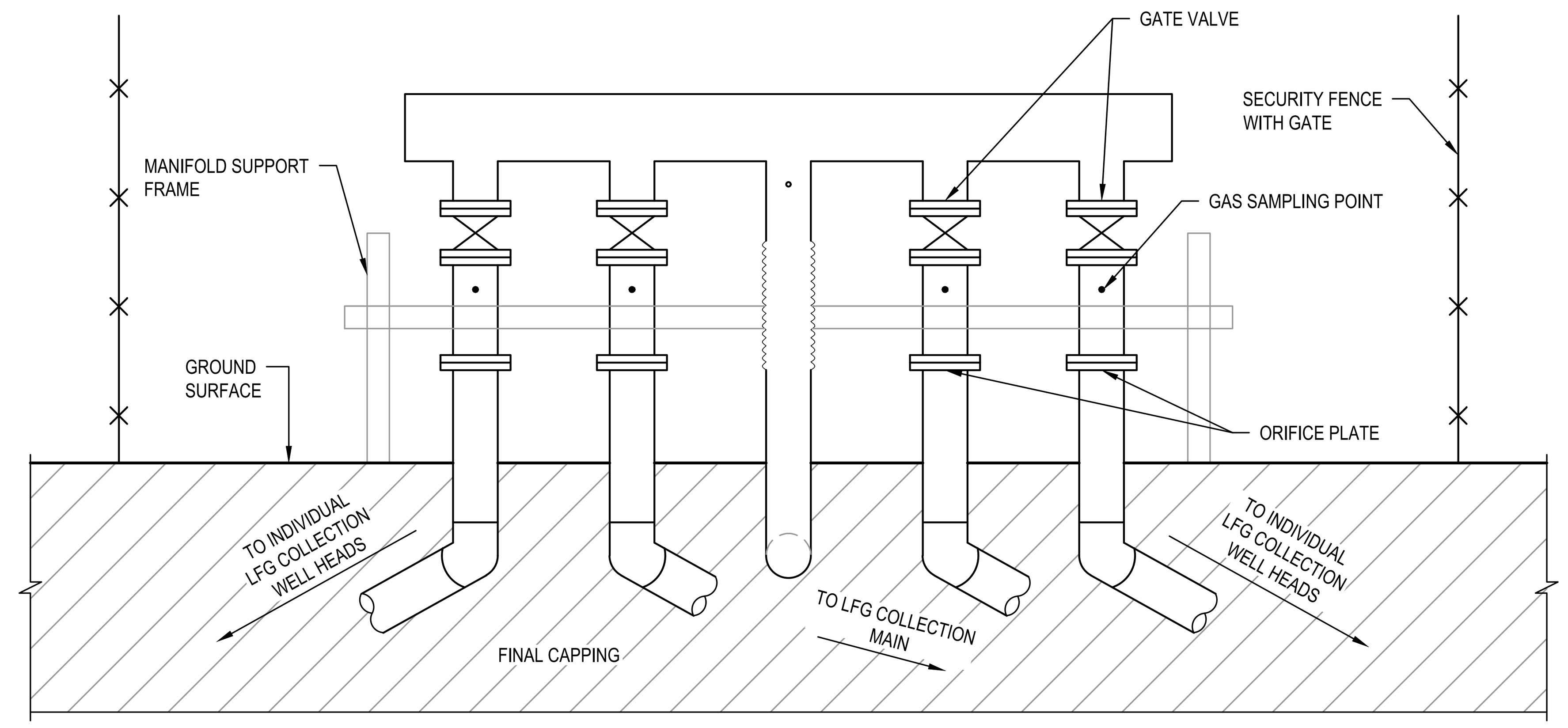

A DETAIL
C501 N.T.S

LANDFILL GAS COLLECTION WELL (VERTICAL) (TYP.)



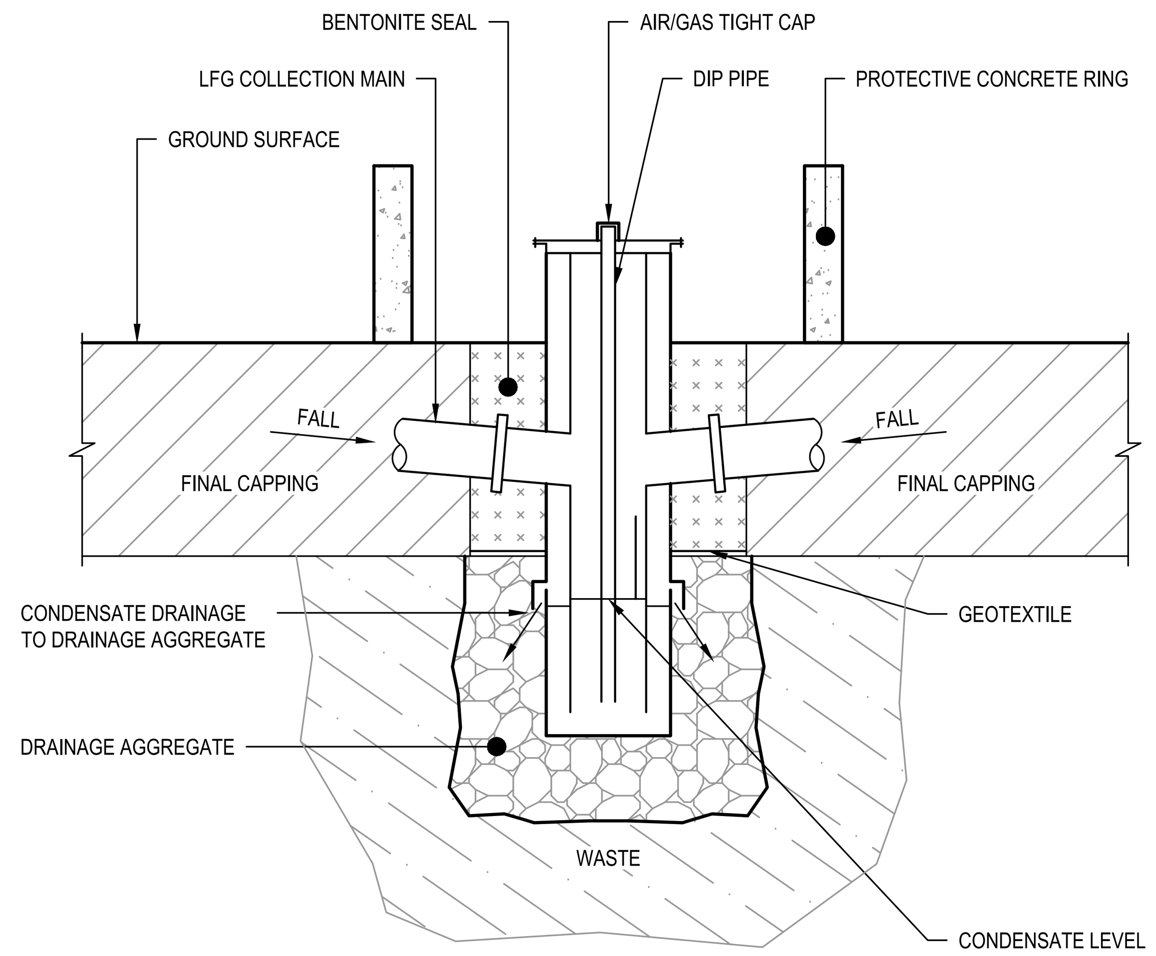

B DETAIL
- N.T.S

LANDFILL GAS COLLECTION WELL HEAD (TYP.)



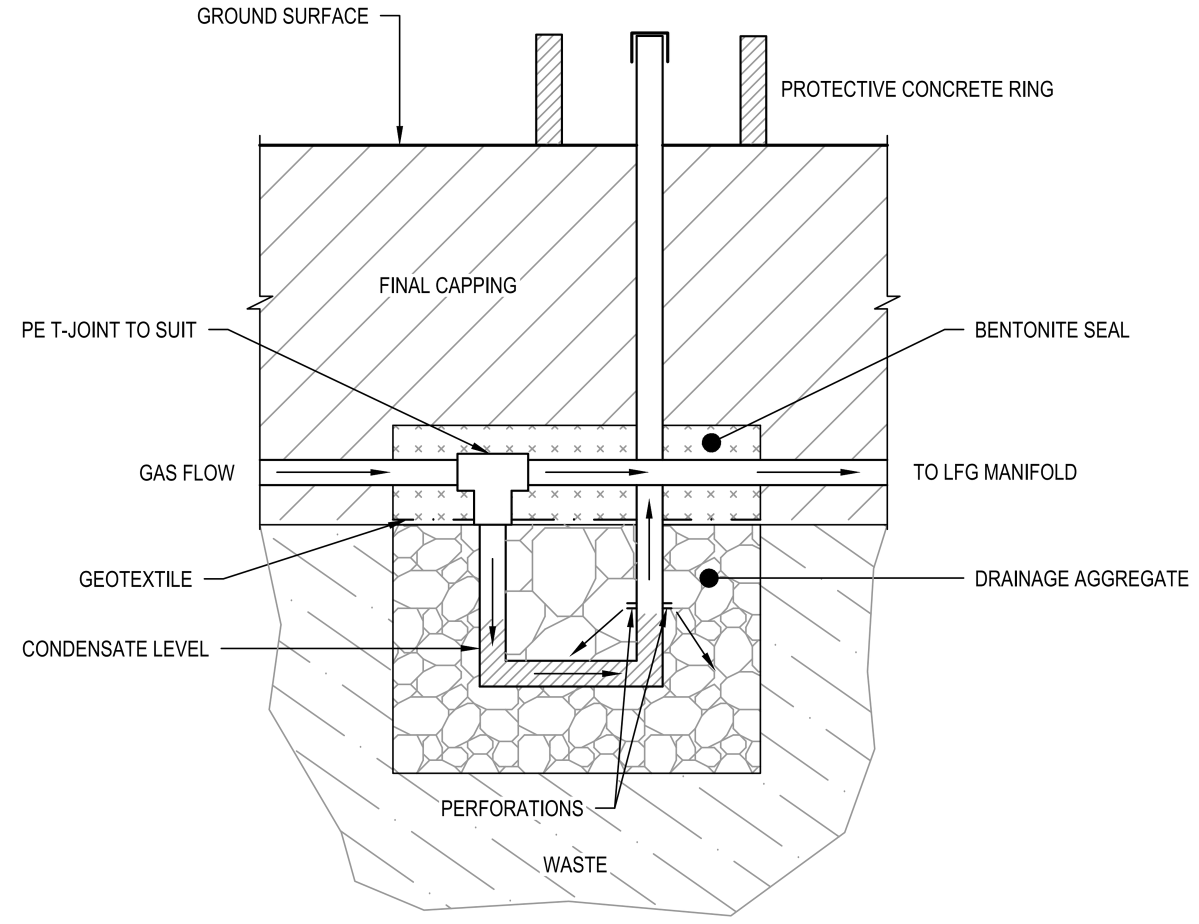

C DETAIL
C501 N.T.S

LANDFILL GAS MANIFOLD (TYP.)



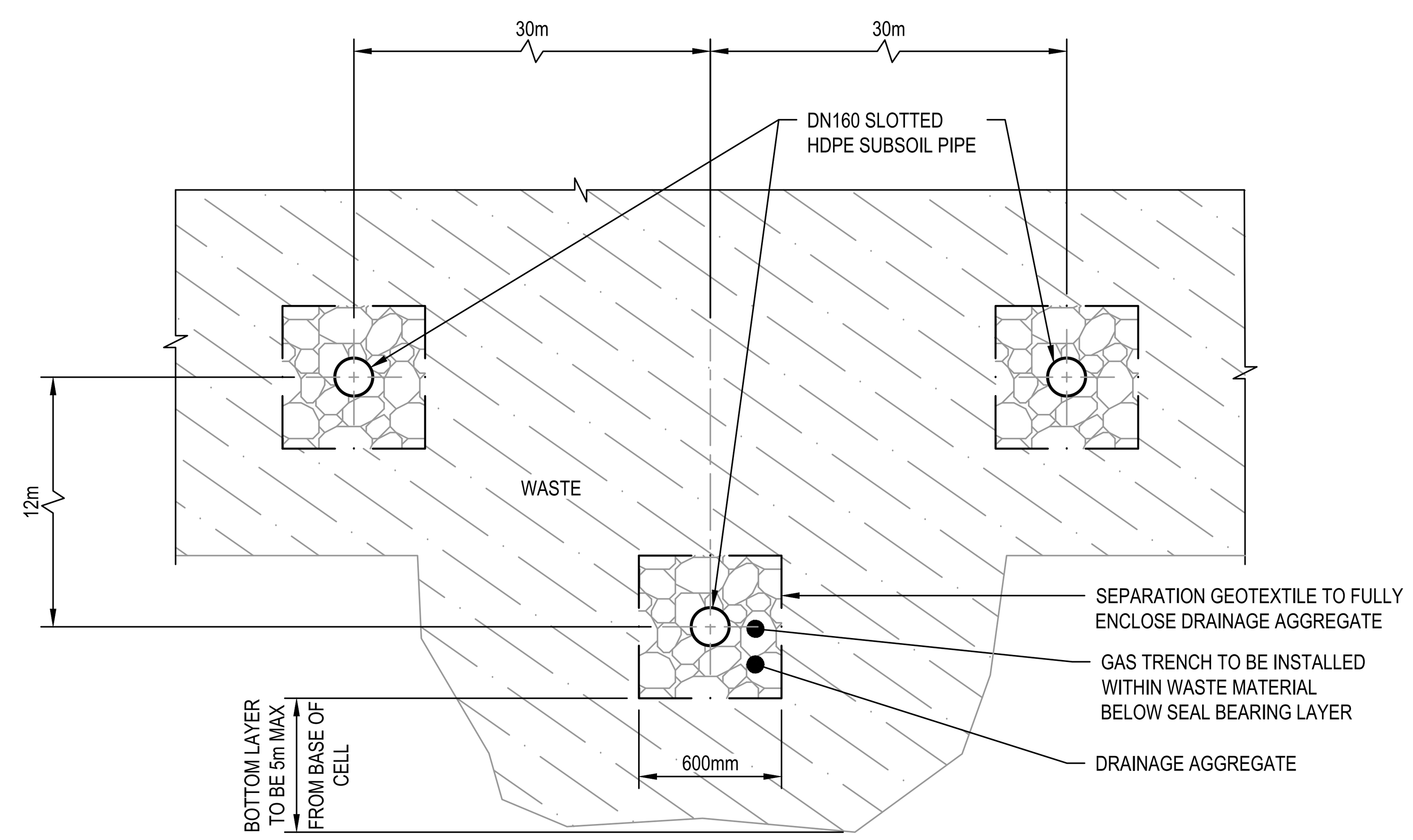

D DETAIL
C501 N.T.S

CONDENSATE DRAINAGE POT (TYP.)




E DETAIL
C501 N.T.S

J-TRAP (TYP.)




F DETAIL
- N.T.S

HORIZONTAL LFG WELL
(SEE NOTE 1)

NOTE:

1. LAYOUT OF HORIZONTAL LFG WELLS NOT SHOWN ON PLAN C501 DUE TO 3D NATURE.

**PRELIMINARY**

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | CONCEPT DESIGN | LP | | | |

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**DRAFT**
**01/10/2019**

Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com

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Client **DUNEDIN CITY COUNCIL**
Project **SMOOTH HILL LANDFILL**
Title **LANDFILL GAS MANAGEMENT DETAILS SHEET**

Original Size **A1** Drawing No: **12506381-01-C502** Rev: **A**

Plot Date: 1 October 2019 - 8:30 AM Plotted by: Fabrice Cheong Cad File No: \\ghdnet\ghd\NZ\Christchurch\Projects\51\12506381\CADD\Drawings\12506381-01-C502.dwg


## LEGEND:

LFG MONITORING BORE

WASTE FOOTPRINT BOUNDARY

## NOTES:

1. LFG MONITORING BORE NETWORK BASED ON GUIDANCE FROM APPENDIX B OF EPA VICTORIA (AUSTRALIA) (2015) BEST PRACTICE ENVIRONMENTAL MANAGEMENT (BPEM)

**PRELIMINARY**

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | CONCEPT DESIGN | LP | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 20 40 60 80 100m
SCALE 1:2000 AT ORIGINAL SIZE

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**DRAFT**
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Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com

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Client **DUNEDIN CITY COUNCIL**
Project **SMOOTH HILL LANDFILL**
Title **LANDFILL GAS MANAGEMENT LFG BORE MONITORING NETWORK (COMPLIANT)**

Original Size **A1**
Drawing No: **12506381-01-C503**
Rev: **A**

Plot Date: 9 October 2019 - 1:34 PM Plotted by: Fabrice Cheong Cad File No: \\ghdnet\ghd\NZ\Christchurch\Projects\51\12506381\CADD\Drawings\12506381-01-C503.dwg


## LEGEND:

LFG MONITORING BORE

WASTE FOOTPRINT BOUNDARY

## NOTES:

1. LFG MONITORING BORE NETWORK BASED ON GUIDANCE FROM APPENDIX B OF EPA VICTORIA (AUSTRALIA) (2015) BEST PRACTICE ENVIRONMENTAL MANAGEMENT (BPEM)
2. BORE SPACING >50m DUE TO NO IDENTIFIED RECEPTORS LOCATED WEST/NORTH-WEST/SOUTH-EAST OF THE WASTE FOOTPRINT BOUNDARY
3. BORE SPACING OF 50m DUE TO OFF-SITE RECEPTOR IDENTIFIED APPROXIMATELY 300m SOUTH OF THE WASTE FOOTPRINT BOUNDARY
4. BORE SPACING OF 20m DUE TO ON-SITE RECEPTORS (BUILDINGS) LOCATED NORTH/NORTH-EAST OF THE WASTE FOOTPRINT BOUNDARY

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | CONCEPT DESIGN | LP | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 20 40 60 80 100m
SCALE 1:2000 AT ORIGINAL SIZE

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Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com


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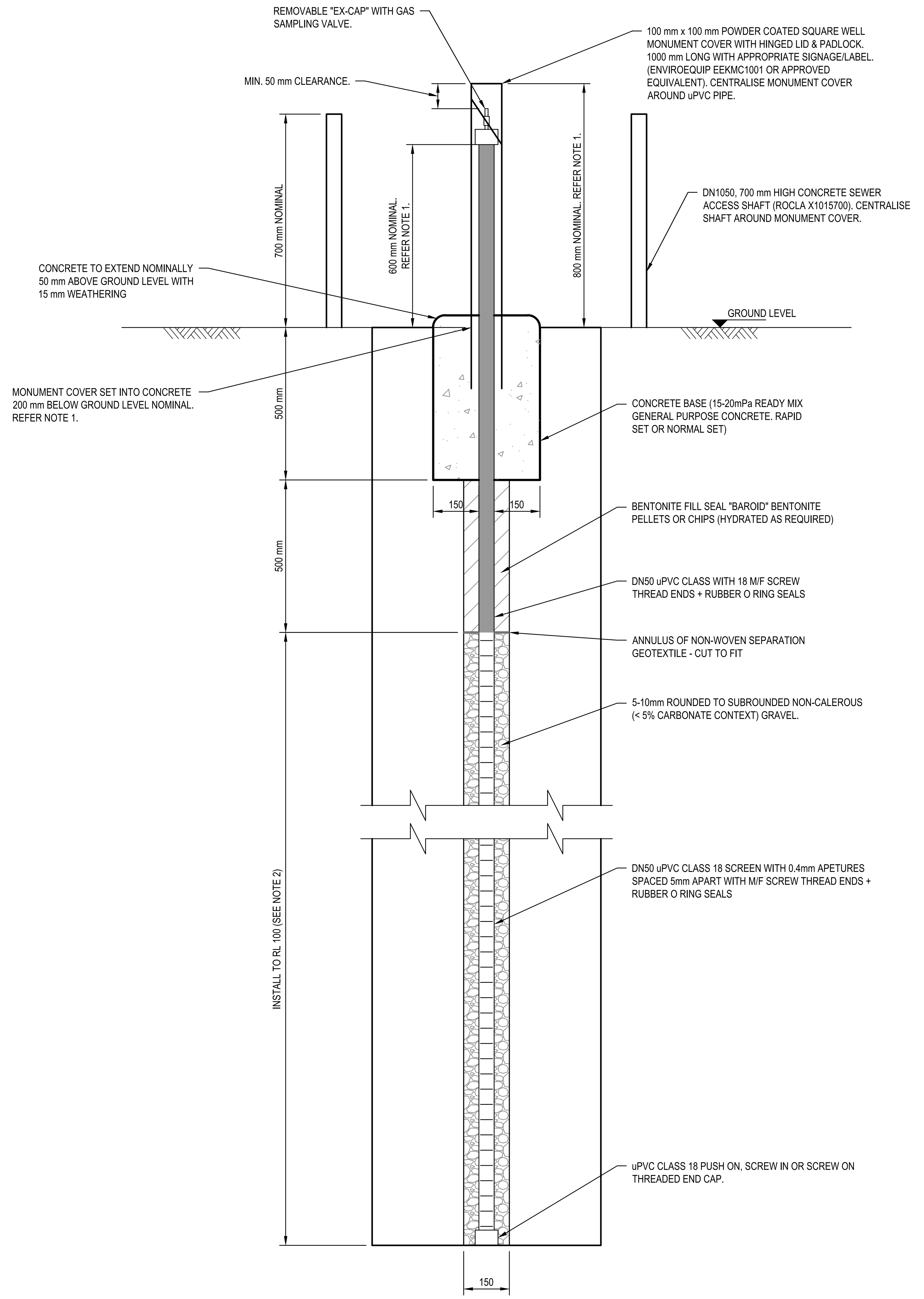
Client **DUNEDIN CITY COUNCIL**
Project **SMOOTH HILL LANDFILL**
Title **LANDFILL GAS MANAGEMENT LFG BORE MONITORING NETWORK (REVISED)**

Original Size **A1** Drawing No: **12506381-01-C504** Rev: **A**

Plot Date: 9 October 2019 - 1:29 PM Plotted by: Fabrice Cheong Cad File No: \\ghdnet\ghd\NZ\Christchurch\Projects\51\12506381\CADD\Drawings\12506381-01-C504.dwg




## NOTES:

1. ADJUST MONUMENT COVER AS REQUIRED TO ALLOW READY REMOVAL OF "EX-CAP" DURING FUTURE MONITORING EVENTS AND TO ALLOW MONUMENT COVER TO FULLY CLOSE.
2. RL 100 IS THE LOWEST DESIGN LINER SURFACE LEVEL.

G DETAIL
C501 SCALE 1 : 10

LANDFILL GAS MONITORING BORE (TYP.)

THE ORIGINAL OF THIS DRAWING WAS PRODUCED USING COLOUR SEPARATION FOR GREATER CLARITY. WORKING WITH A BLACK AND WHITE COPY MAY CAUSE ERRORS. IF THIS DRAWING IS NOT IN COLOUR THEN YOU DO NOT HAVE THE CORRECT PRESENTATION.

PRELIMINARY

| No | Revision | Drawn | Job Manager | Project Director | Date |
|---|---|---|---|---|---|
| A | CONCEPT DESIGN | LP | | | |

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 100 200 300 400 500mm
SCALE 1:10 AT ORIGINAL SIZE

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Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E aklmail@ghd.com W www.ghd.com


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Client **DUNEDIN CITY COUNCIL**
Project **SMOOTH HILL LANDFILL**
Title **LANDFILL GAS MANAGEMENT TYPICAL DETAIL**

Original Size A1
Drawing No: **12506381-01-C505**
Rev: **A**

Plot Date: 26 September 2019 - 1:53 PM Plotted by: Laurence Gae Posadas Cad File No: \\ghdnet\ghd\PH\Cebu\Projects\51\12506381\CADD\Drawings\12506381-01-C505.dwg

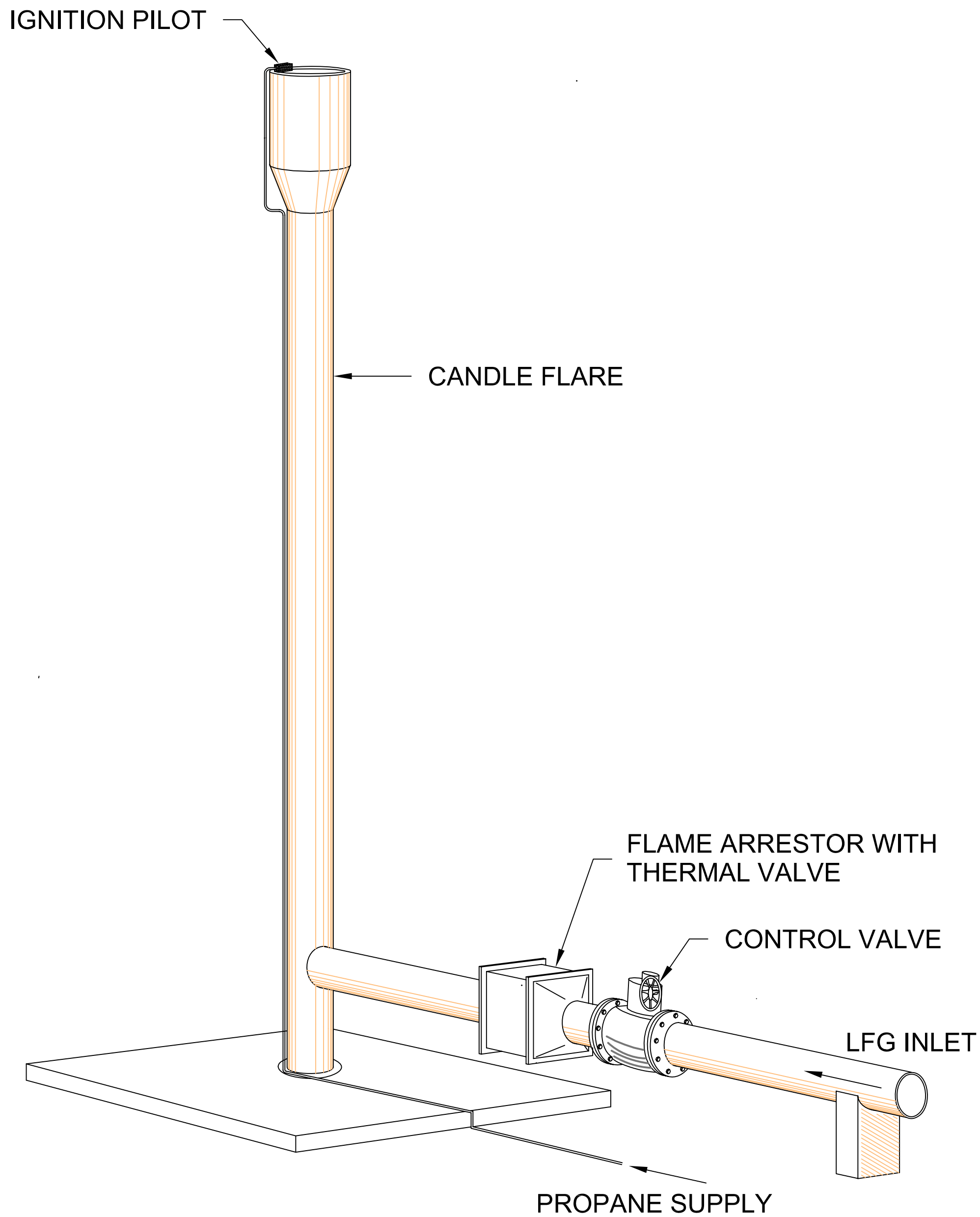


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figure 5.14

LANDFILL GAS CANDLESTICK FLARE

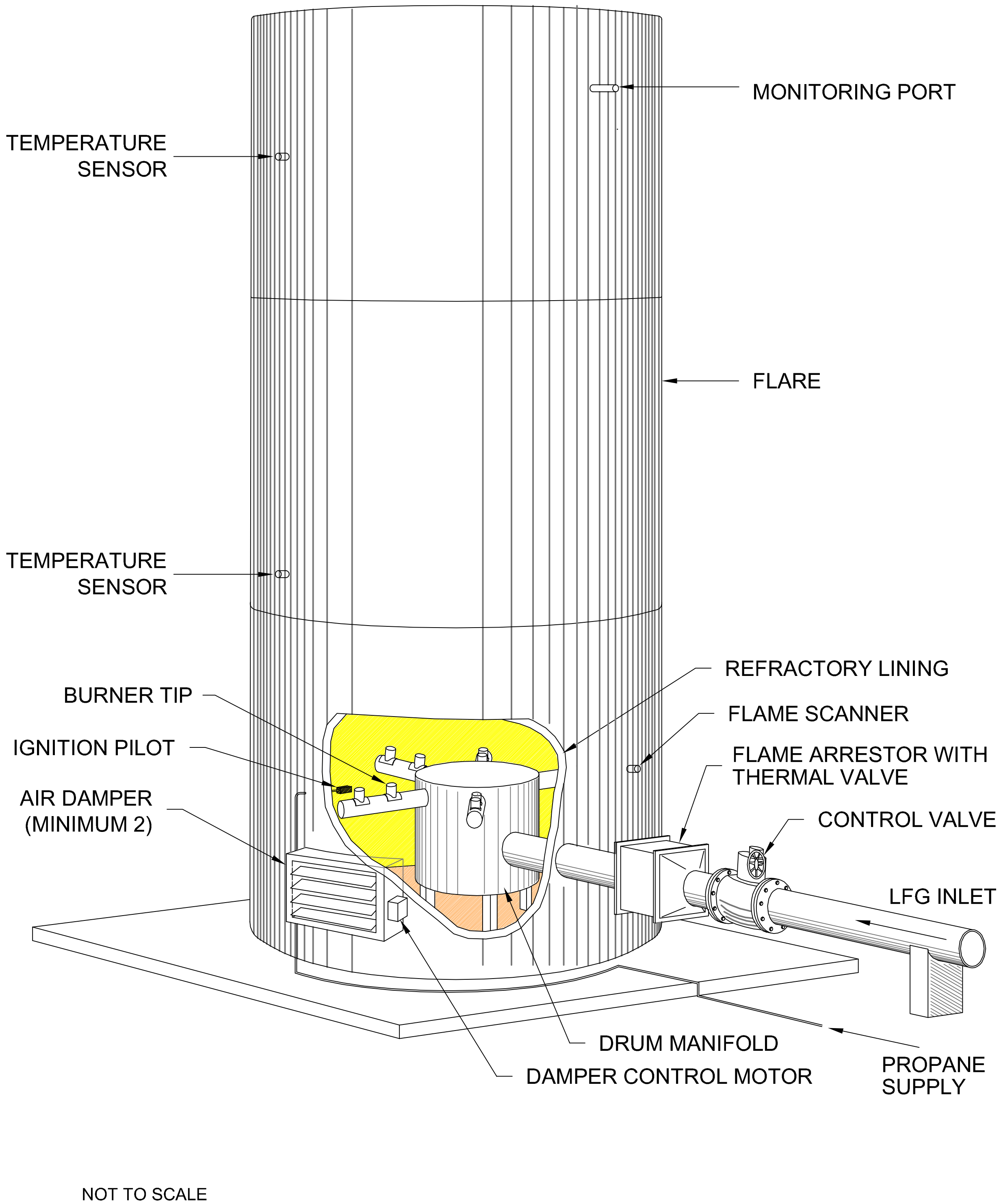
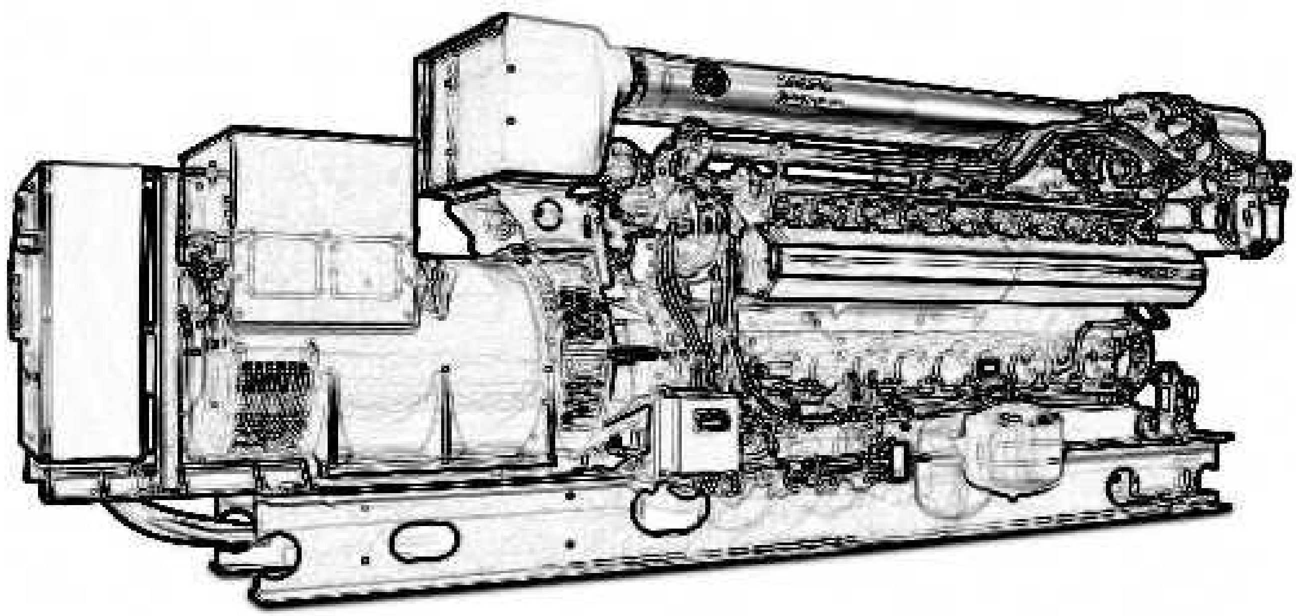



figure 5.15

ENCLOSED LANDFILL GAS FLARE

056417-10(003)GN-VA019 MAR 26/2010

Jenbacher gas engines



# JMS 320 GS-B.L

**Biogas 1.063kW el.**

GE Jenbacher GmbH & Co OG
A-6200 Jenbach, Austria

Tel. +43 5244 600-0
Fax +43 5244 63255

http://information.jenbacher.com
jenbacher.info@ge.com

**JMS 320 GS-B.L**
**Biogas 1.063kW el.**

## CO-GEN Module data:

| | | |
|---|---|---|
| Electrical output | kW el. | 1.063 |
| Recoverable thermal output (180 °C) | kW | 1.103 |
| Energy input | kW | 2.606 |
| Fuel Consumption based on a LHV of | | |
| 4,5 kWh/Nm³ | Nm³/h | 579 |
| Electrical efficiency | % | 40,8% |
| Thermal efficiency | % | 42,3% |
| Total efficiency | % | 83,1% |
| Heat to be dissipated (LT-Circuit) | kW | 67 |
| Emission values: | | |
| NOx < 500 mg/Nm³ (5% O2) | | |

## Additional information:

| | | |
|---|---|---|
| Sound pressure level (engine, average value 1m) | dB(A) | 96 |
| Sound pressure level exhaust gas (1m, 30° off engine | dB(A) | 122 |
| Exhaust gas mass flow rate, wet | kg/h | 5.642 |
| Exhaust gas volume, wet | Nm³/h | 4.387 |
| Max.admissible exhaust back pressure after engine | mbar | 60 |
| Exhaust gas temperature at full load | °C [8] | 450 |
| Combustion air mass flow rate | kg/h | 5.176 |
| Combustion air volume | Nm³/h | 4.004 |
| Max. inlet cooling water temp. (intercooler) | °C | 50 |
| Max. pressure drop in front of intake-air filter | mbar | 10 |
| Return temperature | °C | 70 |
| Forward temperature | °C | 90 |
| Hot water flow rate | m³/h | 47,4 |

## Engine data:

| | | |
|---|---|---|
| Engine type | | J 320 GS-C25 |
| Configuration | | V 70° |
| No. of cylinders | | 20 |
| Bore | mm | 135 |
| Stroke | mm | 170 |
| Piston displacement | lit | 48,67 |
| Nominal speed | rpm | 1.500 |
| Mean piston speed | m/s | 8,5 |
| Mean effe. press. at stand. power and nom. spe | bar | 18,00 |
| Compression ratio | Epsilon | 12,5 |
| ISO standard fuel stop power ICFN | kW | 1095 |
| Spec. fuel consumption of engine | kWh/kWh | 2,38 |
| Specific lube oil consumption | g/kWh | 0,30 |
| Weight dry | kg | 5.200 |
| Filling capacity lube oil | lit | 370 |
| Based on methane number\|Min. methane numb | MZ(*) | 135\|100 |

(*)based on methane number calculation software AVL 3.1

## Alternator:

| | | |
|---|---|---|
| Manufacturer | | Leroy-Somer e) |
| Type | | LSAC 50.2 VL10 e) |
| Type rating | kVA | 1.475 |
| | | |
| | | |
| Efficiency at p.f. = 1,0 | % | 97,1% |
| Efficiency at p.f. = 0,8 | % | 96,1% |
| Ratings at p.f. = 1,0 | kW | 1.063 |
| Ratings at p.f. = 0,8 | kW | 1.052 |
| Frequency | Hz | 50 |
| Voltage | V | 400 |
| Protection Class | | IP 23 |
| Insulation class | | H |
| Speed | rpm | 1.500 |
| Mass | kg | 3.300 |

## Technical parameters:

| | | |
|---|---|---|
| Applicable standards: | Based on DIN-ISO 3046 | |
| | Based on VDE 0530 REM with specified tolerance | |
| | reference value --> 65%CH4 / 35%CO2 | |
| Standard conditions: | Air pressure: | 1000 mbar or 100 m above sea level |
| | Air temperature: | 25°C or 298 K |
| | Relative Humidity: | 30% |
| Engine output derating: | for plants installed at > 500m above see level and/or intake temperature > 30°C, the reduction of engine power is determined for each project. | |
| Gas quality: | according to TA 1000-0300 | |
| | Gas flow pressure: | 80 - 200 mbar |
| | | (Lower gas pressures upon inquiry) |
| | Max. variation in gas pressure: ±10% | |

All data are based on engine full load at specified media temperatures and are subject to change.
The technical Instruction TA 1100-0110 "PARAMETER FOR GE Jenbacher GAS ENGINES" must be strictly observed.

## >>> Scope of supply genset - JGS 320 GS-B.L

### Basic engine equipment:
*Exhaust gas turbocharger, Intercooler
*Motorized carburator for LEANOX control
*Electronic contactless high performance ignition system
*Lubricating oil pump (gear driven)
*Lubricating oil filters in main circuit
*Lubricating oil sump; Lubricating oil heat exchanger
*Jacket water pump
*Fuel-, lubricating oil and jacket water pipe work on engine
*Flywheel for alternator operation; Exhaust gas manifold
*Viscous damper
*Knock sensors

### Engine accessories:
*Electric starter motor
*Electronic speed governor
*Electronic speed monitoring device including starting and overspeed control
*Transducers and switches for oil pressure, jacket water temp., jacket water pressure, charge pressure and mixture temperature
*One thermocouple per cylinder

### Supplied loose:
Gas train according to DIN-DVGW consisting of:
*Manual stop valve, fuel gas filter, two solenoid valves, Leakage control device, gas pressure regulator

### Documentation:
*Operating  and maintenance manual
*Spare parts manual
*Drawings

**Assembly, painting, testing   in Jenbach/Austria**

### Module equipment:
*Base frame for gas engine, alternator and heat exchangers
*Internal pole alternator with excitation alternator and with automatic voltage regulator; p.f. 0,8 lagging to 1,0
*Flexible coupling, bell housing
*Anti-vibration mounts
*Air filter
*Automatic lube oil replenishing with level control
*Wiring of components to module interface panel
*Crankcase breather
*Jacket water electric preheating

### Module control panel:
*Totally enclosed , single door cubicle, wired to terminals and ready to operate, protection IP 40 outside, IP 10 inside, according to VDE-standards

Control equipment:
*Engine-Management-System dia.ne (Dialog Network)
**Visualisation (industry PC-10,4" color graphics display): Operation data, controller display,Exh. gas temp.,Generator electr. connection,etc.
**Central engine- and module control: Speed-, Power output-, LEANOX-Control and knock control, etc.
*Multi-transducer
*Lockable operation mode selector switch
Positions: "OFF", "MANUAL", "AUTOMATIC"
*Demand switch

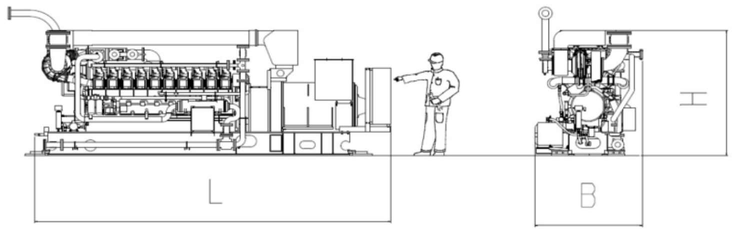
## >>> Scope of supply module - JMS 320 GS-B.L

Identical to Genset except that heat recovery is included.
*jacket water heat exchanger mounted on module frame
*exhaust gas heat exchanger delivered loose
*all heat exchangers with complete pipework
*Heat exchangers and all inherent auxiliaries

## >>> Scope of supply container - JG(M)C 320 GS-B.L

*Identical to module/genset but installed in 40' ISO container (65 dB(A) @ 10m); complete with all pipework and fittings
*Twin circuit radation cooler for dissipation of intercooler jacket water and lube oil thermal output; ventilation equipment
*Gas & smoke detectors; exhaust silencer; lube oil equipment; starting system; flexible connections
*Seperate control room complete with generator switchgear and all internal power and monitoring cables

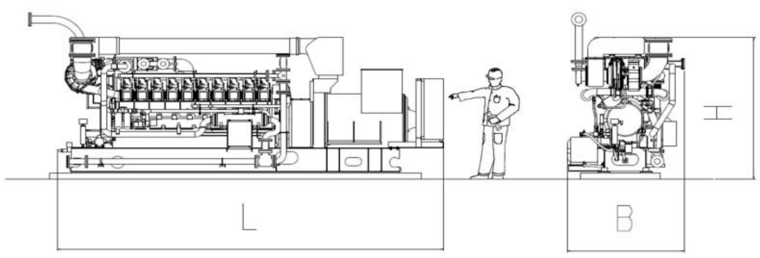
## Genset




| Main dimensions and weights (approximate value) | | |
|---|---|---|
| Length L | mm | 5.700 |
| Width B | mm | 1.700 |
| Height H | mm | 2.300 |
| Weight empty | kg | 13.600 |
| Weight filled | kg | 14.100 |

| Connections (at genset) | | |
|---|---|---|
| Jacket water inlet and outlet | DN/PN | 80/10 |
| Exhaust gas outlet | DN/PN | 250/10 |
| Fuel gas (at gas train) | DN/PN | 100/16 |
| Intercooler water connection: | | |
| Low Temperature Circuit | DN/PN | 65/10 |

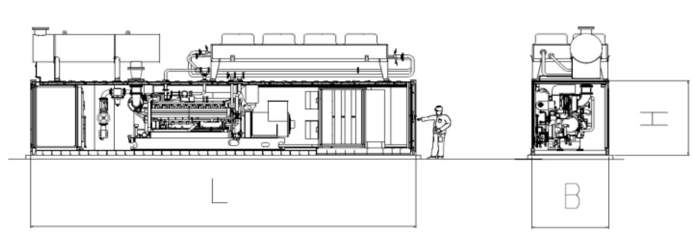
## Module




| Main dimensions and weights (approximate value) | | |
|---|---|---|
| Length L | mm | 5.700 |
| Width B | mm | 1.900 |
| Height H | mm | 2.300 |
| Weight empty | kg | 14.100 |
| Weight filled | kg | 14.600 |

| Connections (at module) | | |
|---|---|---|
| Hot water inlet and outlet | DN/PN | 80/10 |
| Exhaust gas outlet | DN/PN | 250/10 |
| Fuel gas (at gas train) | DN/PN | 100/16 |
| Intercooler water connection: | | |
| Intercooler water-Inlet/Outlet 2nd stage | DN/PN | 65/10 |

## Container




| Main dimensions and weights (approximate value) | | |
|---|---|---|
| Length L | mm | 12.200 |
| Width B | mm | 2.500 |
| Height H | mm | 2.600 |
| Container weight (dry) | kg | 29.600 |
| Container weight (filled) | kg | 31.100 |

| Connections (container) | | |
|---|---|---|
| | | |
| Jacket water inlet and outlet | DN/PN | 80/10 |
| Exhaust gas outlet | DN/PN | 250/10 |
| Fuel gas connection (container) | mm | 150/16 |
| Fresh oil connection | G | 28x2" |

GE Jenbacher GmbH & Co OG
A-6200 Jenbach, Austria
Tel. +43 5244 600-0
Fax +43 5244 63255
http://information.jenbacher.com
jenbacher.info@ge.com

This report was technically directed and reviewed by Matt Welsh, a Senior Environmental Scientist at GHD. Matt has over 20 years experience in the area of landfill gas assessment and management. He has the following qualifications and institutional memberships: BSc. (Hons) 1st Class Environmental Science – University of Sussex, 1998, member of Australian Contaminated Land Consultants Association (ACLCA). The lead author for this report was Fabrice Cheong, a mid-level Civil and Environmental at GHD. Fabrice has 5 years' experience in waste management, including landfill gas assessment and management. He has a B.Eng Civil Engineering and M.Eng Environmental Engineering. He is a member of Waste Management & Resource Recovery Association Australia.

GHD

Level 3, GHD Centre
27 Napier Street
T: 64 9 370 8000 F: 64 9 370 8001 E: aklmail@ghd.com



https://projects.ghd.com/oc/NewZealand1/dccsmoothhillconsent/Delivery/Documents/Smooth Hill Landfill Gas Design Report.docx

Document Status

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|---|---|---|---|---|---|---|
| | | Name | Signature | Name | Signature | Date |
| E | F. Cheong | M. Welsh / R Coombe | | Stephen Douglass | | 17-08-20 |
| | | | | | | |

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This report has been prepared in part by Richard Coombe, an associate and civil engineer at GHD Ltd. Richard has over 20 years experience as a landfill engineer and has the following qualifications and institutional memberships: NZCE (Civil), NZCLS, CPEng and a member of Engineering New Zealand and member of Australasian Land and Groundwater Association and member of the Society of Construction Law. The author would also like to acknowledge the assistance of Nick Eldred (Authoring Sections 1, 2 and 9) and Mathew Welch (Authoring Section 4) in the preparation of this report.

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Level 4 Security Building
115 Stuart Street
T: 64 3 378 0991



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