

Technical Report D

Air Quality and Odour Technical
Assessment



Redvale Landfill Expansion

Air Quality and Odour Technical Assessment

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Background

Tonkin & Taylor Ltd (T+T) has been engaged by WM New Zealand (WMNZ) to provide technical air quality and odour assessments to understand the effects from a proposal to extend the use of Redvale Landfill, north of Auckland (the Project).

Redvale Landfill is currently scheduled to cease accepting waste in December 2028 and due to a delay in the authorisation and establishment of the replacement Auckland Regional Landfill (ARL) a transition plan is required. The proposal (ARL-TP or the Project) is to continue sending the current residual waste (around 600,000 tonnes per year) to Redvale Landfill, beyond the existing consent timeframe of December 2028. This would require new resource consents at Redvale Landfill.

Air Quality Effects

The primary discharges of contaminants to air from the Project result from the combustion of collected landfill gas (LFG) in generators or flares (release of particulate matter and combustion products), and from the leachate evaporator unit (releasing ammonia and volatile organic compounds). Peak LFG collection rates are projected to be in the order of 8,000 Sm³/hr, which is similar to current levels, meaning emissions will continue to be managed by the existing Energy Centre configuration using up to 15 operating LFG generators (or back-up flares where required).

Because LFG and leachate will continue to be generated for many years, the cumulative effects of ongoing emissions from currently authorised activities and the Project have been assessed. Dispersion modelling, informed by stack testing data, demonstrates that ground-level concentrations of all evaluated contaminants will continue to comply with relevant New Zealand ambient air quality standards and guidelines.

While conservative modelling indicates theoretical exceedances of the stringent WHO 2021 guidelines for sulphur dioxide (SO₂) and nitrogen dioxide (NO₂), ambient monitoring at the Site shows that real-world SO₂ concentrations are well below these guidelines (noting the WHO 2021 guidelines do not have any current regulatory status in New Zealand and this modelling has been undertaken for completeness). An ambient NO₂ monitoring programme has been initiated to verify actual effects.

Overall, the effects of discharges of contaminants to air are assessed as minor.

Odour effects

Odour is the key air quality issue for the Project, primarily originating from the active tip face (odour associated with refuse and fugitive LFG emissions) and the LEU. An evaluation of the existing odour baseline using a combination of field observations, daily patrols, third-party audits, and complaints records indicates that intermittent, lower-intensity odours currently have the potential to cause chronic effects up to approximately 1.5 km from the Site along predominant wind corridors.

To substantially reduce the risk of odour beyond the site boundary, WMNZ will implement enhanced at-source controls to be secured through conditions of consent. These include:

- Maintaining a minimum 500 m separation distance between the placement of putrescible (odorous) waste and existing sensitive dwellings. Waste placed closer to the boundary will be restricted to non-putrescible waste and limiting the active tip face for putrescible waste to a maximum of 900 m². Together, these measures are aligned with EPA Victoria's Landfill Buffer Guidelines.

- Increasing the thickness of daily cover to at least 300 mm (from 150 mm) and intermediate cover to 450 mm (from 300 mm) to suppress fugitive emissions. This is expected to effectively eliminate odour from areas under cover.
- Delaying the acceptance of putrescible waste until 7:30 a.m. during the cooler months (May to August) to reduce opening the working face during morning meteorological conditions that are poor for odour dispersion.

Odour dispersion modelling and comparative analyses demonstrate that these operational improvements will effectively contract the spatial footprint of potential odour exposure. While transient odours may occasionally be detectable off-site, the risk of offensive or objectionable odour effects at sensitive locations is assessed as low, and the overall odour effects of the Project are considered minor.

Dust effects

Potential dust emissions associated with the Project are limited to construction earthworks, the stockpiling and removal of cover material, traffic movements on unpaved internal roads, and the placement of waste at the working face. These activities primarily generate larger "settleable" dust particles, which typically deposit within a short distance (100 to 200 m) from the source.

A range of standard dust management and mitigation measures are used at the site. These include the use of water carts and dust suppression units, 30 km/h speed restrictions on haul roads, wheel washing for exiting vehicles, and the progressive grassing of areas under intermediate and final cover. Given the effectiveness of these controls and a minimum separation distance of at least 140 m to the nearest off-site sensitive receptors, it is considered very unlikely that operational dust emissions will result in discernible adverse effects beyond the site boundary. Consequently, the effects of dust emissions are assessed as negligible.

Definitions

Abbreviations and acronyms

Abbreviation	Definition
AAAQT	Auckland Ambient Air Quality Targets
AAQG	New Zealand Ambient Air Quality Guidelines
AEE	Assessment of Environmental Effects
ARL	Auckland Regional Landfill
AP-42	Compilation of Air Pollutant Emissions Factors from Stationary Sources published by the US Environmental Protection Agency
AUP	Auckland Unitary Plan
CALMET	Meteorological model used for dispersion modelling
CALPUFF	Air dispersion model
CASANZ	Clean Air Society of Australia and New Zealand
CLG	Community Liaison Group
DDO	Dynamic dilution olfactometry
DEM	Digital elevation model
EPA	Environmental Protection Authority
ETS	Emissions Trading Scheme
FID	Flame ionisation detector
FIDOL	Frequency, intensity, duration, offensiveness and location
ISM	Instantaneous surface monitoring
LEU	Leachate evaporator unit
LFG	Landfill gas
LMP	Landfill Management Plan
MfE	Ministry for the Environment
NESAQ	National Environmental Standards for Air Quality
NZTA	New Zealand Transport Agency
OEHHA	Office of Environmental Health Hazard Assessment
OU	Odour unit (the units of odour concentration)
RH	Relative humidity
SHRA	Screening Health Risk Assessment
T+T	Tonkin & Taylor Ltd
WAC	Waste acceptance criteria
WHO	World Health Organization
WMNZ	WM New Zealand
WRF	Weather Research and Forecasting model

Chemical symbols

Symbol	Substance
BTEX	Benzene, toluene, ethylbenzene and xylenes
CH ₄	Methane
CO	Carbon monoxide
CO ₂	Carbon dioxide
H ₂ S	Hydrogen sulphide
NMOC	Non-methane organic compound
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
PM ₁₀	Particulate matter with an aerodynamic diameter of 10 micrometres or less
PM _{2.5}	Particulate matter with an aerodynamic diameter of 2.5 micrometres or less
SO ₂	Sulphur dioxide
TSP	Total suspended particulates
VOC	Volatile organic compound

Units

Units	Definition
°C	Degrees Celsius
kPa	kilopascal
MW	Megawatt
Nm ³ /h	Normal cubic metres per hour (at a temperature of 0°C and 101.3 kPa)
ppm	Parts per million
MW	Megawatt
µg/m ³	Micrograms per cubic metre

1 Introduction

1.1 Background

Tonkin & Taylor Ltd (T+T) has been engaged by WM New Zealand (WMNZ) to provide technical assessments to understand the effects from a proposal to extend the use of Redvale Landfill, north of Auckland (the Project). This report forms part of a suite of technical reports prepared for WMNZ for inclusion in a substantive application for resource consent under the Fast-Track Approvals Act 2024.

This report assesses the actual and potential effects of discharges to air of contaminants and odour from the Project and is intended to support the Assessment of Environmental Effects (AEE).

1.2 Site description

The Redvale Landfill is located in Dairy Flat, to the north of Auckland, approximately 9 km northwest of Albany and 1 km west of State Highway 1. Redvale Landfill, including the existing landfilling area and buffer zones, occupies approximately 88 ha in area. The landfill is divided into five main sub-areas for the purpose of describing the work within this application, known as the Northern, Eastern, Western, South-Western and South-Eastern Property.

The Landfill is accessed from the south-east along Landfill Access Road off Dairy Flat Highway, with Horseshoe Bush Road running along part of the northern boundary of the Landfill area. A tributary of the Rangitopuni Stream runs eastwards along the northern and eastern site boundaries towards the Dairy Flat Highway. A full description of the site is provided in the AEE prepared for the project.

1.3 Project description

Redvale Landfill is currently scheduled to cease accepting waste in December 2028 and due to a delay in the authorisation and establishment of the replacement Auckland Regional Landfill (ARL), a transition plan is required. To address this potential gap in critical landfill infrastructure for residual waste disposal in the Auckland region, WMNZ is proposing to extend the operation of Redvale Landfill to the end of 2036 and develop 4.56 Mm³ of additional airspace at the existing facility. This includes 3.13 Mm³ in additional Class 1 Landfill expansion on top of the existing Class 1 refuse placement area and 1.43 Mm³ of Class 2 Landfill extension. The proposed works include the following:

- **Class 1 landfill expansion:** placement of waste within the existing landfill footprint, involving the removal of final cover and steepening of the final cap slope to accommodate additional waste.
- **Class 2 footprint extension:** extension of the landfill to the southwest of the Class 1 area to accommodate disposal of waste meeting Class 2 landfill waste acceptance criteria (WAC).
- **Relocation of ancillary activities:** the relocation of ancillary activities to allow for the placement of waste.
- **Sediment Retention Ponds:** The removal and filling in of Sediment Retention Pond 6 and the Office Pond while enlarging Pond 1 to capture and treat the stormwater from these catchments.

A full description of the proposal is included in the AEE prepared for the Project.

1.4 Air discharges

The actual or potential discharges to air from the Project are the same or similar in nature and scale to the discharges from the existing landfill activities, and principally comprise:

- Odour, which can be related to the active tip face, the waste itself and/or fugitive emissions of landfill gas (LFG).
- Combustion products from the burning of collected LFG in the flare, electricity generators and leachate evaporator. The collected LFG is burnt to destroy methane (a greenhouse gas) and other contaminants (including odorous contaminants).
- Combustion products, ammonia, odour and other contaminants from the Leachate Evaporator Unit (LEU). The LEU is located within the landfill footprint and will be decommissioned prior to additional waste filling occurring in that area.
- Dust emissions from construction activities and landfill operations, including stockpiling of cover material.

Odour is considered to be the key air quality issue associated with the Project. The potential effects of odour have been taken into account in the Project design, in particular:

- Placement of putrescible (odorous) waste will be kept at least 500 m from any existing dwelling (non-putrescible waste will be placed in areas of the landfill footprint within that distance).
- At-source controls will be tightened by limiting the working face to no more than 900 m² (down from about 1,200 m², typically) and by increasing cover depths to at least 300 mm for daily cover (up from 150 mm) and 450 mm for intermediate cover (up from 300 mm) to reduce the risk of fugitive emissions.
- During the colder months (from 1 May to 31 August), acceptance of putrescible waste will commence later than standard hours (i.e. after 7:30 a.m.), reducing the overlap between daily cover removal and putrescible waste placement with unfavourable dispersion conditions.

1.5 Existing resource consents relating to contaminants and odour

The Redvale Landfill opened in 1993 and is subject to a number of resource consents. Conditions relating to control of odour are included in the following consents (the regional consents expire in December 2028 and the land use consent requires WMNZ to cease accepting waste in December 2028):

- An air discharge consent for the landfill and related activities (Permit 37802, granted in 2013).
- An air discharge consent for the LEU (DIS60373665, granted in 2022).
- A land use consent (LAN61338 (NRSI 42575, granted in 2016)).

The conditions proposed in the AEE are more stringent than the conditions included in these consents.

The air discharge consent for the landfill (Permit 37802) recognises a 'notional odour boundary', which is shown in Attachment Two to the consent. The notional odour boundary includes a number of properties that are not owned by WMNZ and do not form part of the Site for the purposes of the consent. Permit 37802 requires that there shall be no odour caused by discharges from the Site which, in the opinion of an enforcement officer, is noxious, dangerous, offensive or objectionable (Condition 9). However, this condition does not apply to land that is within the notional boundary (Condition 57).

For the purposes of this air quality and odour technical assessment, the notional odour boundary in the air discharge consent has been disregarded and effects on these properties have been considered within the assessment. This is because easements and covenants that are registered over these properties were used to create the notional odour boundary. which do not require the land owners and occupiers to provide their written approval to these consent applications, however, effects on these properties cannot be disregarded.

1.6 Relationship with Screening Health Risk Assessment

The purpose of this technical air quality assessment is to estimate changes in air pollutant concentrations from sources at the landfill and to compare those changes, cumulative with background pollutant concentrations, against health-based air quality guidelines and standards.

A Screening Health Risk Assessment (SHRA)¹ has also been prepared to support the application for the Redvale Landfill Expansion. The purpose of the SHRA is to translate changes in air pollutant concentrations, taking into account exposure patterns and toxicity data, into estimated health risks for people. In the context of a landfill, one of the main drivers for a screening level health risk assessment (in addition to an air quality assessment) is to consider if there are multiple pathways for exposure (e.g. ingestion, dermal) for some pollutants.

For conventional pollutants, such as fine particulate matter and combustion products associated with LFG combustion, the ambient air quality guidelines and standards are based on robust epidemiological data. Provided exposures are within these criteria, it can be assumed that the risk of adverse health effects is low and these pollutants are not generally also considered in the health risk assessment.

A wide range of different VOCs are present in LFG and leachate. The SHRA assesses the potential cumulative effects of exposure to VOCs, reduced sulphur compounds, mercury and per- and polyfluoroalkyl substances (PFAS) which can be emitted from several different sources at the landfill (generally at very low concentrations). For this reason, in relation to VOCs (including benzene) and mercury, the scope of this air quality assessment is limited to:

- A screening assessment of VOC and mercury emissions from the LEU; and
- An evaluation of the available air quality monitoring data for key VOC contaminants in comparison with New Zealand air quality standards and guidelines.

1.7 Report structure

This report describes the actual and potential effects of discharges to air of contaminants and odour from the proposed activities at Redvale Landfill.

This report is structured as follows:

- Section 2: The sensitivity of the receiving environment and the environmental setting as it relates to the dispersion of contaminants and background air quality.
- Section 3: Operational and management controls to minimise odour from landfilling activities.
- Section 4: Description of the LFG collection and management system.
- Section 5: Description of the leachate collection and management system, including the leachate evaporator.
- Section 6: Dust sources and dust management.
- Section 7: Assessment of odour effects.
- Section 8: Assessment of contaminant emissions (principally combustion products) from the Energy Centre.
- Section 9: Assessment of contaminant emissions from the LEU.
- Section 10: Overall conclusions.

¹ T+T. 2026. Screening Health Risk Assessment

2 Environmental setting

2.1 Sensitivity of the receiving environment

The land use zoning around the Site and nature of existing and permitted land uses is relevant to the sensitivity of the receiving environment to odour and air quality effects from the landfilling operations.

The Site and immediate surrounds are generally within the 'Rural – Mixed Rural Zone' in the Auckland Unitary Plan (AUP). The purpose of the Rural – Mixed Rural Zone is to provide for rural production (e.g. agriculture, horticulture, etc), generally on smaller rural properties and non-residential activities of a scale compatible with smaller site properties. Properties in this zone provide flexibility to accommodate a range of rural production activities and associated non-residential activities while still ensuring good amenity levels for residents who use their land for rural lifestyle purposes.

Within this mixed rural environment, the most sensitive locations for air quality and odour effects are dwellings. These are the most sensitive locations because people can be present continuously for long periods of time and have a high expectation of amenity. Areas that are less frequently occupied, such as farmland and public roads are considered to have a low sensitivity to odour and air quality impacts, given the reduced potential for exposure.

Effects of air emissions reduce with increasing distance from the source. Separation distance is therefore an important consideration in regard to the likelihood of effects being experienced at an identified dwelling or other sensitive receptor. In the absence of New Zealand guidance on appropriate separation distances from industrial and other activities, reference is often made to Australian State guidance. The most recently published guidance in Australia on appropriate separation distances from landfills for land use planning, is the EPA Victoria Landfill Buffer Guideline (EPA Victoria, 2024) (Landfill Buffer Guideline).

The purpose of the Landfill Buffer Guideline is to support land use and development decisions in relation to landfills and sensitive activities wishing to establish within the buffer of a landfill. They are not intended to be applied retrospectively to existing facilities but are relevant to changes at an existing facility. The recommended buffer distances for landfills accepting municipal (putrescible) waste are:

- 500 m from sensitive land uses for landfills with a working face up to 900 m².
- 1,500 m from sensitive land uses for landfills with a working face greater than 900 m². This may be varied to a minimum of 1,000 m with an appropriate odour risk assessment that demonstrates an alternative buffer is acceptable in accordance with EPA Victoria guidance.

The Project is proposing to maintain a 500 m separation distance between placement of putrescible waste and sensitive receptors. However, for completeness, residences and other sensitive activities within 1,500 m of the Class 1 landfill footprint have been identified and included as receptors in the dispersion modelling.

Non-residential sensitive receptors within 1,500 m of the Class 1 landfill footprint include:

- Dairy Flat School (1220 Dairy Flat Highway).
- Greenpark Preschool (84 Postman Road).
- Dairy Flat Community Hall (4 Postman Road).

The surrounding existing environment also includes the staged development of a surf park at 1350 Dairy Flat Highway, Silverdale, Auckland (Surf Park). Only the first stage of this development has received resource consent which comprises of the construction and operation of a surf lagoon,

restaurant(s), market space, 70 visitor accommodation units and eco cabins, a solar farm, a data centre and associated infrastructure, earthworks and landscaping (together, Stage 1). We understand that, as at the date of this report, the Surf Park has lodged the second version of its Stage 2 application but as it has not yet approved, it has not been considered as part of the existing environment for the purposes of this assessment.

2.2 Topography

The local topography and meteorology determine how odour and dust are dispersed and transported. This is particularly relevant when assessing potential effects on sensitive activities.

The local topography is illustrated in Figure 2.1.

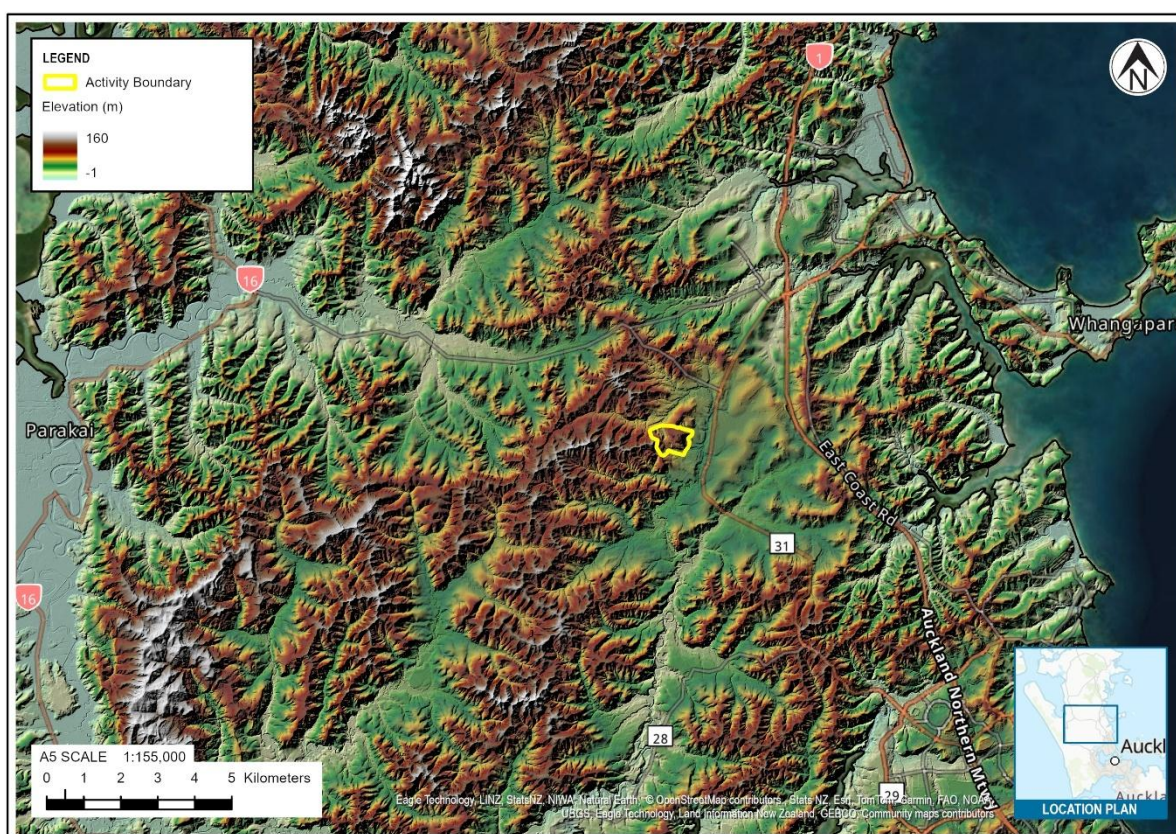


Figure 2.1: Topography surrounding the Site. Class 1 landfill footprint represented by yellow polygon

The Site is on the end of a ridgeline between two localised valleys. A larger valley runs from approximately north to south to the east of the Site. Elevated terrain can cause katabatic drainage winds in cool calm conditions as air flows down from the valley, from higher elevation to lower elevation. Localised drainage air flows down this larger valley are expected in cool calm conditions, however as the valley is wide and shallow with no significant terrain, the drainage flows are not expected to persist for long periods.

Calm and light wind conditions are of particular interest when assessing odour, as odour may accumulate on-site during these conditions. When the wind speed increases the accumulated envelope of odour moves off-site and can cause odours in the downwind receiving environment. This phenomenon is particularly prevalent during inversion conditions, which are experienced at night in cold weather.

2.3 Meteorology

The meteorology in the area is dominated by prevailing winds in the southeast to northwest plane, which is consistent with the predominant wind direction in the wider Auckland region.

Figure 2.2 shows the location of the two weather monitoring stations at or near the Site:

- WMNZ station within the Site. Mast height of 10 m.
- North Shore Airport station, approximately 2 km east of the Site. Mast height of approximately 2.5 m.

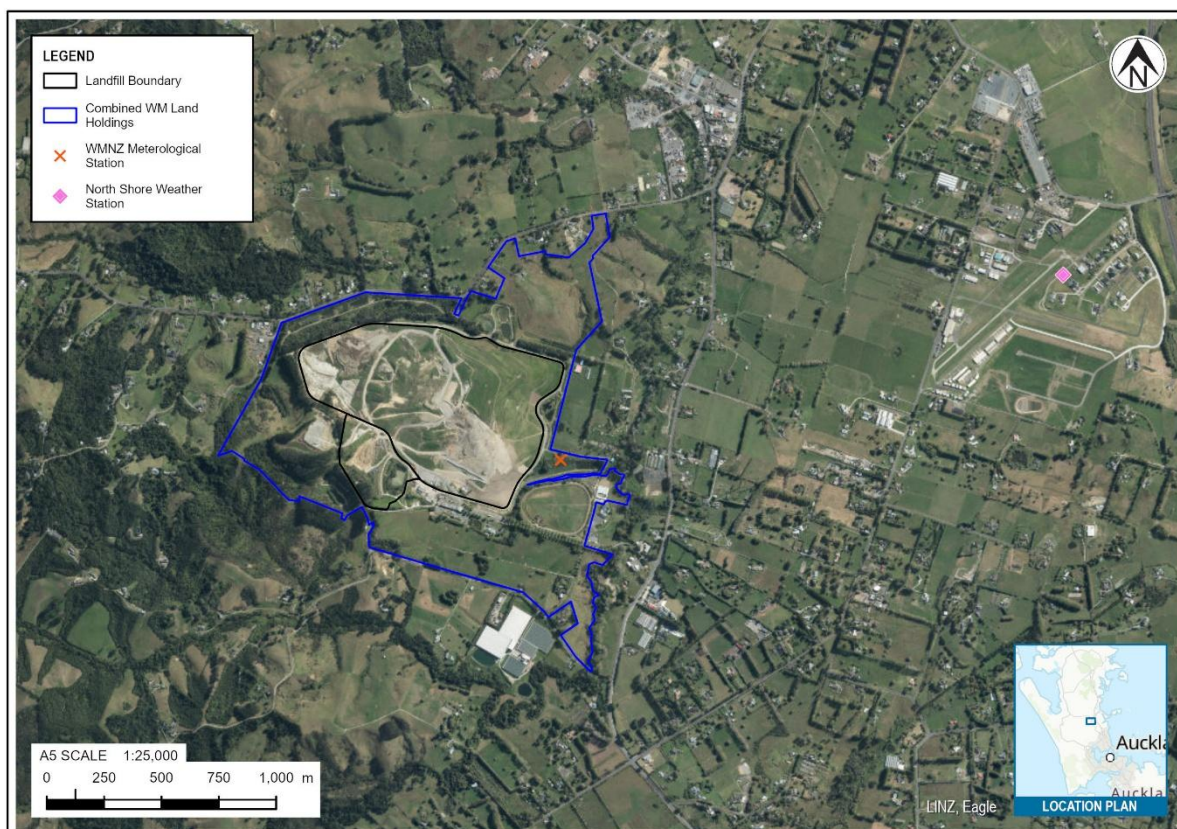


Figure 2.2: Location of WMNZ Redvale and North Shore Airport meteorological stations

Figure 2.3 presents wind roses for both the WMNZ and North Shore Airport meteorological stations for two years combined (2022 and 2023). The petals of the wind rose show the direction that winds come from, and the petal length indicates the frequency of winds from that direction. The different colour bands within each petal indicate the frequency distribution of wind speeds for each direction.

The wind speeds recorded at the North Shore Airport are generally lower than recorded at the Site weather station, which is to be expected because of the lower mast height.

The wind conditions for different periods during the day are presented (as well as the full two-year period), as these are useful to illustrate diurnal wind patterns. The wind roses show the following:

- All hours for years 2022 to 2023.
- Early morning 6:00 a.m. to 12:00 p.m. These times of day are typically associated with sunrise and earth warming, with the break-up of stable meteorological conditions that have developed overnight.

- Day time 12:00 p.m. to 7:00 p.m. These times of day are typically associated with convective wind conditions and more elevated wind speeds compared to other times.
- Sunset to sunrise 7:00 p.m. to 6:00 a.m. These times of day are characterised by no (or reduced) incoming solar radiation and land cooling, with resulting drainage flows and possible inversions.

Wind direction patterns are consistent with general patterns in the Auckland region, with a predominance of southwesterly and northeasterly winds.

Calm or light air conditions (wind speeds less than 1.8 m/s) are of particular interest when assessing odour from sources that are relatively close to ground level (such as from a landfill), as these conditions are typically associated with poor dispersion. Calm and light wind speed conditions predominantly occur overnight, when the landfill is not actively accepting waste and all waste is at least under daily cover, but can persist into the early morning, which can coincide with the daily cover being removed and waste being received.

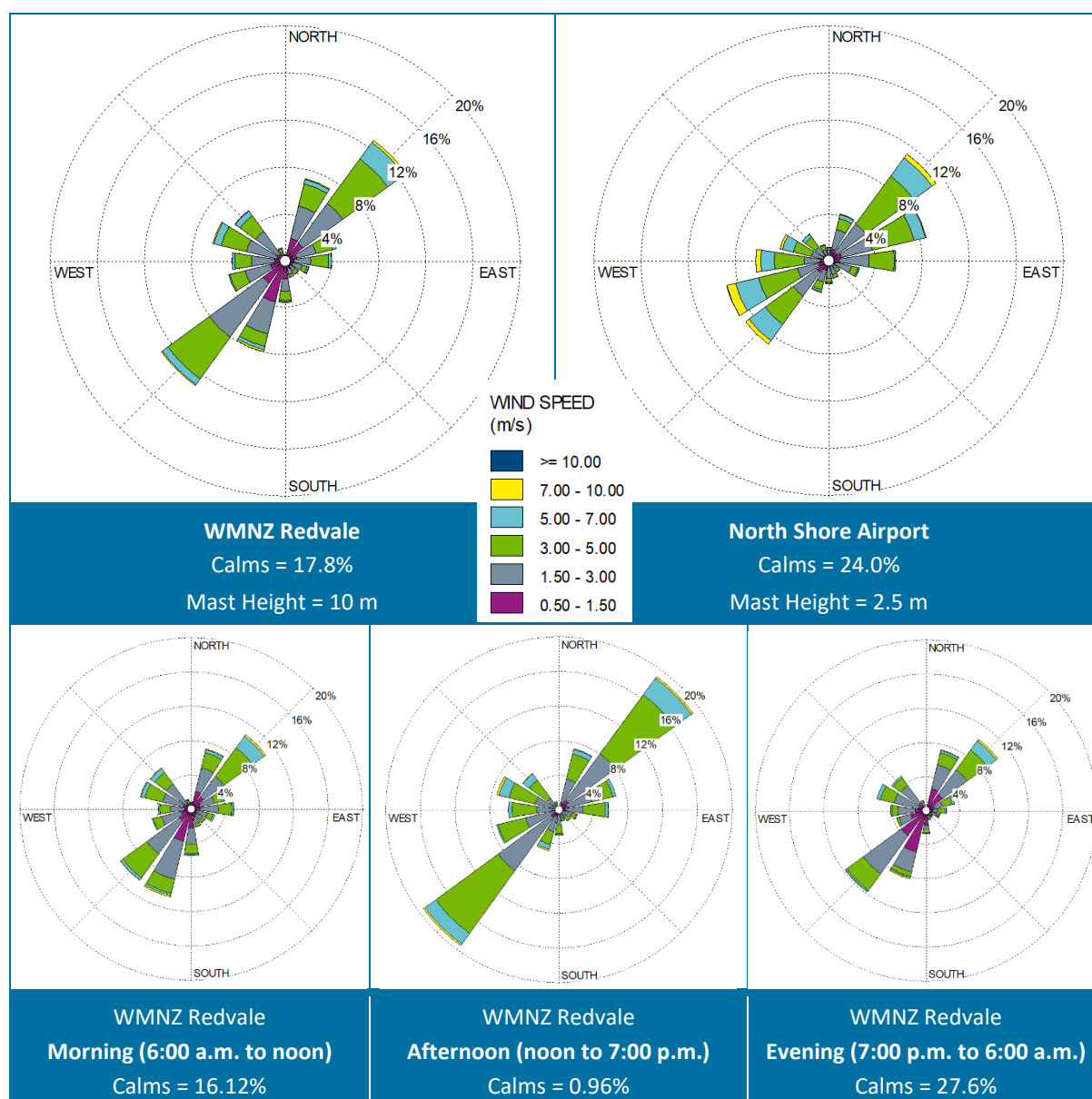


Figure 2.3: Wind roses generated from the WMNZ and North Shore Airport meteorological stations for years 2022 – 2023 (inclusive).

2.4 Background air quality

2.4.1 Combustion products and other contaminants

The contaminants of interest for this assessment include combustion products of LFG, particularly:

- Particulate matter, expressed as particles less than 10 micron (PM₁₀) and particles less than 2.5 micron (PM_{2.5}).
- Oxides of nitrogen (NO_x), particularly nitrogen dioxide (NO₂).
- Sulphur dioxide (SO₂).
- Carbon monoxide (CO).

Background air quality refers to contaminant levels that would exist in the absence of the emissions from the Site. Potential background sources of combustion-related air pollutants in the area include:

- Motor vehicle emissions from Dairy Flat Highway and local roads.
- Coal-fired boilers at the green houses (tomato growing) at 1198b Dairy Flat Highway.
- Domestic heating emissions (mainly in winter).
- Discharges from agricultural activities, which may include burning of vegetation.

There is no ongoing air quality monitoring undertaken in the wider area that is representative of background air quality in the environment around the Site². The nearest active air quality monitoring site is located in Silverdale. Data from Silverdale will be influenced by urban sources such as domestic heating emissions and is unlikely to be directly comparable to the Site. This data has accordingly not been used for the purposes of this report.

Background air quality in the vicinity of the Site is expected to be good. In the absence of local air quality monitoring data, the Ministry for the Environment Good Practice Guide for Assessing Discharges to Air from Industry (GPG Industry) recommends using default background air quality values for rural areas, as follows:

- PM₁₀ – 18.1 µg/m³ (24-hour average) and 6.9 µg/m³ (annual average) (NZTA default values)³
- PM_{2.5} – 8.7 µg/m³ (24-hour average) and 2.7 µg/m³ (annual average) (NZTA default values)
- Nitrogen dioxide – 4.5 µg/m³ (annual average) (NZTA default values)
- Sulphur dioxide (SO₂) – zero
- Carbon monoxide (CO) – 5.0 mg/m³ (1-hour average) and 2.0 mg/m³ (8-hour average)

Background concentrations of other contaminants associated with the leachate evaporator, such as ammonia, have been assumed to be zero.

2.4.2 Odour and dust

The landfill is located in a rural area where there are a variety of rural activities that can give rise to odour. Some of these odours, such as silage, manure or compost-type odours, may be similar in character to refuse odour. However, in many cases, the character of these odours will be able to be readily differentiated from the odour from the landfill.

² WMNZ has undertaken air quality monitoring for some contaminants within, or at the boundary of, the Site. These data are not representative of background air quality as they include the effects of emissions from the Site.

³ Air quality map | NZ Transport Agency. Retrieved from <https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/tools/air-quality-map/>

Other identified sources of odour and/or dust from commercial activities in the area are:

- Portaloo hire yard at 222 Horseshoe Bush Road (odour).
- Green waste mulching at 222 Horseshoe Bush Road (odour and dust).
- Topsoil screening plant operating at the Surf Park construction site (dust).
- WMNZ staff have also observed odour from the Surf Park construction site, which was considered likely to be from uncovering buried peat.

3 Odour management

3.1 Overview of odour sources and controls

Odours from landfills result from the waste itself and from fugitive emissions of LFG, which contains odorous compounds. There is potential for odour whenever waste is exposed to open air. This can occur when daily or intermediate cover is pulled back, when fresh waste is tipped or when excavating into old waste for gas extraction or leachate re-injection points. Leachate is stored at the Site in enclosed tanks and therefore leachate storage is not expected to be a source of odour.

The active tip face is generally the main ongoing source of odour at landfills. Potential unplanned or intermittent odour sources at the landfill also include:

- Inbound odorous loads (still in the truck).
- Excavation into older waste (for burial of odorous loads or installation of LFG collection or other infrastructure).
- Leakage around penetrations through the cap, for example at gas wells, or damage to the LFG collection system.
- Any areas of impaired cap integrity, such as cracking or erosion.

The LEU is a continuous source of odour emissions at the Site, due to the stripping of ammonia and other volatile compounds from the leachate as the water is evaporated off. The odour from the LEU has a different character to, and is readily differentiated from, tip face and LFG odour.

The combustion of LFG in the generators or flares at the Site effectively destroys odorous compounds, such as hydrogen sulphide and reduced sulphur compounds⁴. The residual odour from the generators is described as hydrocarbon-type smell (similar to the exhaust smell from burning fossil fuels).

The Landfill Management Plan (LMP) documents the range of procedural and structural controls to minimise odour from the Site⁵. The current controls used at the site include:

- Waste acceptance criteria that are intended to identify potentially odorous loads in advance, minimise odour from these wastes by requiring pretreatment, and to avoid unacceptably odorous waste being received.
- Waste placement practices, including keeping the working face to a practical minimum and covering the waste at the end of each day with daily cover.
- Use of odour suppressant sprays around the working face to minimise the effects of unavoidable odours.
- Placement of thicker cover over areas that will not be worked for a period of time to minimise fugitive LFG emissions and maximise the efficiency of the LFG collection system.
- Actively collecting LFG and treating it by combustion to destroy odorous compounds.
- Storing collected leachate in enclosed systems (pipes and tanks).

An updated draft LMP has been prepared for the purposes of this application that includes the improved controls proposed to be implemented (as discussed in the following sub-section).

⁴ Stack testing undertaken by Watercare in 2025 shows no detectable H₂S in the generator outlets

⁵ Relevant sections of the LMP include Section 3.1, Section 3.2 Disposal, Waste Control, Section 3.3 Cover, Section 3.6 Odour Management Plan, Section 3.7 Landfill Gas Management Plan, Section 3.13 Dust Management Plan

Even with best practice management measures it is not possible to completely eliminate odour emissions at the landfill, particularly from the tip face during working hours. Therefore, in addition to at-source controls, WMNZ uses a comprehensive system of fogging cannons and sprays to apply odour suppressant on and around the tip face.

3.2 Changes relevant to odour effects

3.2.1 Overview of changes

The Redvale Landfill opened in 1993. Because of its long operating history, there is a good understanding of the nature of discharges to air (contaminants and odour) from the Landfill and the effects of those discharges. The effects of existing activities at the Site provide a baseline for comparison with the effects of the Project.

Waste meeting the Class 1 WAC will continue to be placed within the existing consented landfill footprint. To enable this, the ground profile will be steepened, to a maximum grade of 1V:3H. Bunds, varying between 2 and 6 m high, will be constructed along the eastern and southern boundaries to enable the required additional waste volumes to be placed. This will result in waste being placed at a slightly higher elevation than authorised under the current consents.

Landfilling practices, including key practices to minimise odour emissions, will continue in a similar manner to the existing operation. However, some new operating practices will be introduced that will improve the control of odours compared to current activities. These are discussed in more detail in the following sub-sections, but include:

- Limiting the placement of putrescible waste to maintain a minimum separation distance of 500 m to occupied dwellings, compared to the current minimum distance of approximately 140 m;
- Reducing the size of the working face for putrescible waste, from the current area of approximately 1,200 m² to a maximum area of 900 m²;
- Increasing the thickness of daily and intermediate cover from 150 mm and 300 mm, up to 300 mm and 450 mm respectively; and
- Shifting the earliest time that putrescible waste can be accepted on site by an hour during the winter to minimise overlap with poor dispersive conditions.

3.2.2 Management of putrescible waste

The Project includes the ongoing disposal of waste meeting Class 1 WAC (Class 1 waste) within the existing consented landfill footprint and the creation of a new landfill cell for waste meeting Class 2 (Construction and Demolition) WAC (Class 2 waste).

The Class 2 waste is essentially inert and non-biodegradable and does not generate LFG. Some components of Class 2 waste, such as gypsum board, contain sulphur, which can be broken down over time by sulphur-reducing bacteria and produce hydrogen sulphide (H₂S). Odour from a Class 2 landfill can generally be adequately managed by the use of cover. For the purposes of this assessment, it has been assumed that the Class 2 waste cell is not an ongoing source of odour, on the basis that off-site odours can be avoided with standard controls.

In the context of odour management, the Class 1 waste falls into two broad classes:

- Putrescible waste, which includes biodegradable organic material that breaks down quickly and produces odour, leachate, and LFG – for example, food scraps, garden organics, and biosolids.

- Non-putrescible waste, which comprises inert materials (e.g. bricks, concrete, soil) and slow-degrading organic materials (e.g. timber, paper, or cardboard) that are not odorous when received and will degrade slowly over time.

It is proposed that the Class 1 landfill will be operated with two tip faces; one for putrescible waste and the other for non-putrescible waste. The putrescible waste tipping face will be located no closer than 500 m to existing occupied dwellings. This is expected to significantly reduce the potential for odour effects from the landfill, because the placement of putrescible waste at the tip face is an unavoidable source of odour at any landfill.

Non-putrescible Class 1 waste will be placed on top of previously filled areas within the existing landfill footprint. Therefore, although the placement of non-putrescible waste at the tip face will not be a source of odour, the tip face provides a potential pathway for the escape of fugitive LFG (and associated odour), if not carefully managed. For this reason, key controls for the management of fugitive LFG will be used at both Class 1 tip faces (e.g. keeping the tip face as small as possible, using daily cover, and optimising extraction of LFG around the tip face). With these controls in place, the non-putrescible Class 1 waste tip face is not expected to be an ongoing source of odour.

3.3 Waste acceptance criteria

The Site is not open to the general public and, other than kerbside collected wastes, all loads entering the Site are subject to commercial contracts that include a declaration of the nature of the waste and confirmation that it meets the Site's WAC.

Certain wastes are defined in WAC as "Special Wastes" because they require special handling due to their physical or chemical properties or potential to be a source of odour, such as:

- Contaminated soil not meeting Class 3 WAC.
- Asbestos.
- Abattoir, fish waste, or other wastes which are highly odorous or potentially harmful to human health.

Acceptance of Special Wastes is subject to a specific assessment, as described in the Waste Acceptance Criteria report⁶. The purpose of this process is to identify any special handling or disposal requirements and to manage waste quantities.

Special wastes are required to be accompanied by a manifest which details the description of the waste, handling information and certification of burial. The tip face operator is responsible for confirming the details of the waste. Practices for the management of special wastes at the tip face are detailed in the LMP and generally involve the following steps:

- Advanced notice of the special waste load is given to the Site.
- Odour control systems such as odour sprayers are prepared.
- General waste and cover soil are set aside to immediately bury the load.
- A pit is formed within the active tip face.
- The waste is tipped and buried immediately with general waste or soil.

⁶ Tonkin & Talor td. (2026). Waste Acceptance Criteria. Section 4.4

3.4 Waste handling and tip face management

The current posted hours for acceptance of material at the landfill are⁷:

- 6:15 a.m. to 4:30 p.m. Monday to Friday
- 7:00 a.m. to 2:00 p.m. Saturday

A particular activity that can give rise to odours is the process of pulling back the daily cover in each morning. This has the potential to release both LFG and refuse odours that have accumulated overnight under the cover material. As this activity occurs in the morning, it can often coincide with cold, calm (i.e. no or very low wind) conditions. Under these weather conditions odours will tend to drift “downhill” (or downwind if there is a very light wind) following the terrain closely and with minimal dilution. To reduce the potential for odour effects related to pulling back daily cover, it is proposed that putrescible waste will not be accepted prior to 7:30 a.m. (currently 6:15 a.m.) during autumn and winter (May to August). This will enable pulling back of daily cover to be delayed until around 7:15 a.m. during these months. This will not completely avoid unstable inversion conditions but will reduce the overlap.

Odour from the tipping face is minimised by keeping the working face as small as possible and ensuring daily cover is placed over all refuse at the end of each day. Under the current resource consents, the tip face (open working area) must be kept to a practicable minimum and is restricted to a maximum size of 50 m wide and 4.5 m deep (Condition 61 of LAN61338). The depth refers to the “lift” of waste on that day and is typically much smaller than the 4.5 m limit (typically less than approximately 0.6 m deep).

Since early 2025, WMNZ has been managing the tip face to a target of no more than 1,200 m² (excluding the push ramp). However, the size of the tip face on any given day is determined by the amount of waste being received and other factors, related to the geometry of the working area and the safe movement of equipment and traffic. Under the Project, the size of the working faces at the Class 1 Landfill will be limited to no more than 900 m² (excluding the push ramp).

The procedure for managing the active working face includes practices for the management of Site personnel, delivery contractors, Site machinery and odour control equipment. These practices are essential for ensuring waste is buried in an effective and timely manner to control odour. All operators and leading hands on the landfill are considered to be “Spotters” and required to take immediate action upon identifying any unacceptable (including odorous) waste brought to the Landfill.

Site personnel are trained to quickly recognise odorous loads or activities with high potential for odour and to take action as set out in the LMP. Odour awareness is a part of the staff training programme and personnel are empowered to take the necessary actions to minimise or mitigate odour from all aspects of activities on the Site.

3.5 Landfill cover

3.5.1 Use of cover material

The use of cover material is critical to minimising odour, by minimising physical exposure of waste to the open air, minimising fugitive emissions of LFG and increasing the effectiveness of the LFG collection system (while avoiding drawing air into the system).

⁷ There are various activities that need to be undertaken prior to receipt of the first load of waste, and at the end of the working day, such as placement of daily cover. Therefore, the current hours of landfill operation (as opposed to waste acceptance) are defined as 6:00 a.m. to 6:00 p.m. Monday to Saturday

Daily cover is placed over the entire working face, by the end of each operating day so that no waste remains exposed overnight. Daily cover is generally soil but may also be a non-soil alternative where it can be demonstrated that this would achieve a comparable level of control. The current consents require 150 mm depth of daily cover to be applied at the end of each working day (Condition 35 of Permit 37802 and Condition 62 of LAN61338). It is proposed that this will be increased to require a minimum 300 mm daily cover. As discussed in Appendix E4, the odour emissions measured from areas under 300 mm cover were the same as odour emissions from a background site (a grassed paddock). The thickening of daily cover to a minimum 300 mm is a significant improvement on current practices and should effectively eliminate odour from areas under daily cover.

Intermediate cover is used on landfill areas that are not intended to be filled further for a period of three months or more. The existing consents do not stipulate the depth of intermediate cover, but the LMP describes a minimum 300 mm cover. Exposed areas of cover that are unlikely to be worked for more than 6 months are required to be grassed (Conditions 40-42 of LAN61338) and where practicable this will also be applied to areas that are unlikely to be worked for more than 3 months. Defects in areas of intermediate cover are occasionally identified as a source of fugitive LFG (and associated odour) during weekly odour walkovers and instantaneous surface monitoring (ISM) surveys. It is proposed that the minimum requirement for intermediate cover will be increased to 450 mm and included as a condition of consent.

3.5.2 Management of stripping

To allow further waste to be placed within the landfill, the cover material (whether daily or intermediate) needs to be stripped back to provide direct contact between old and new waste. Leaving cover in place could affect the stability of the landfill by creating slip layers within the waste mass and/or causing perching of leachate (preventing travelling down into the leachate collection system).

The Project will require stripping of some areas of final cover. Waste material under final cover will generally be in an advanced state of decomposition. The odour profile (intensity, character and hedonic tone) of waste under final cover is not expected to be materially greater than waste material that has been under intermediate cover for several years. Stripping of final cover will be carried out as follows:

- At the beginning of the week, the area that will be filled during that week will have the final cap removed to a depth of 300 mm (i.e. similar to the former requirement for intermediate cover), as illustrated on the right-hand side of Figure 3.1.
- Only the area that will be filled on that day will be fully stripped to expose the old refuse, and waste placed on top as illustrated on the left-hand side of Figure 3.1.

Based on the above, the odour emissions associated with stripping and placement of waste in areas currently under final cover are not expected to be materially different to current odour emissions from day-to-day landfill operations.

- Remove the final cap leaving about 300mm as intermediate cover.
- Remove only enough intermediate cover for the day's work and tie new waste to old waste.
- Placing Daily Cover by the close of day.

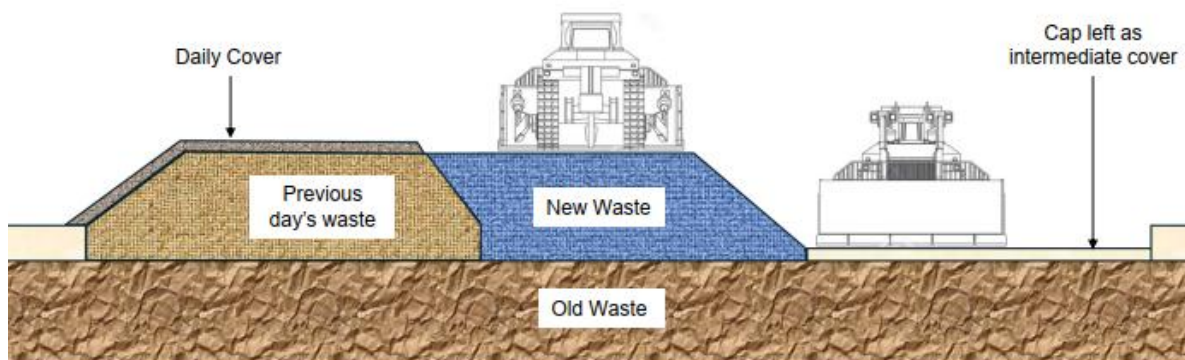


Figure 3.1: Progressive removal of final capping for placement of new waste. (Image provided by WMNZ)

3.5.3 Walkover inspections and surface methane monitoring

To inspect the integrity of the cover material and ensure compliance with the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ) for methane emissions, WMNZ undertakes:

- Weekly walkover inspections of areas of intermediate cap, noting any odours, visible staining or distressed vegetation, leachate breakouts or surface erosion (Condition 16 of the existing air discharge consent).
- Monthly instantaneous surface monitoring (ISM) surveys on areas of intermediate cover, and quarterly surveys on final cover areas (Condition 17 requires quarterly monitoring and the LMP reflects that WMNZ carries out surveys monthly on areas of intermediate cover (additional to consent requirements)).

If areas are identified during the ISM surveys where the surface methane concentration exceeds 5,000 ppm, the cover is repaired/remediated as appropriate and retested.

Since mid-2022, WMNZ has been using drone-mounted methane detection cameras to conduct flyover surveys, in addition to the monthly ISM surveys. The drone-mounted cameras are able to detect “plumes” of methane but do not have the same ability as ISM surveys to detect small areas of elevated concentrations close to the landfill surface. Drones can cover large areas more efficiently than surface walkovers and help identify ‘hotspots’ for further investigation by technicians with surface emissions monitoring equipment.

3.6 Odour suppressant sprays

WMNZ uses mobile odour fog cannons and portable T-bar sprayers to apply odour suppressant chemical solution around the active tip face and push ramp. While less powerful than fog cannons, T-bar sprayers still contribute to odour reduction when deployed and maintained correctly. Odour suppressants are intended to chemically neutralise odours, i.e. they are not masking agents, which disguise an odour with another smell. Odour suppressants complement source control measures and are proven to be an effective secondary measure, particularly at the tip face where odour generation is unavoidable.

The effectiveness of odour suppressant sprays is directly related to the ability to intercept the plume and maximise contact between airborne odours and the spray droplets. For this reason, odour suppressant sprays will be most effective under calm to low wind speed conditions, which are the worst conditions for dispersion of odours.

As noted in Section 3.4, the process of stripping back the daily cover in the morning can release odours and can frequently coincide with calm conditions where odour can be transported greater distances with minimal dilution. Odour suppressant sprayers are started before removing cover to introduce neutraliser into the air before odour is released.

The effectiveness of the odour suppressant sprays has been evaluated by undertaking a series of odour observations downwind of the tip face while the fog cannons were turned off and on, as described in Appendix C. Odours were observed and recorded using a standard odour intensity scale of 0 (no odour) to 6 (extremely strong) at distances of 100, 150 and 180 m from the tip face. The fog cannon trial demonstrated that there was a statistically significant reduction in perceived odour intensity with the cannons on compared to when the cannons were off.

The greatest reduction in perceived odour intensity was at 100 m from the tip face, where odours were also generally strongest (compared to the observations at larger distances). At a distance of 100 m, the fog cannons reduced the perceived odour intensity by an estimated 20%. There is a logarithmic relationship between perceived odour intensity and odour concentration. This means that to reduce the perceived odour intensity from “weak” to “very weak” would require the concentration to be reduced by 90%. Using this logarithmic relationship, it was estimated that the odour suppressant sprays were achieving a 60% reduction in odour concentration at a distance of 100 m from the tip face. This is considered a relatively good removal efficiency given the challenge of providing effective contact between the spray droplets and odour plume in the open air.

While the odour sprays can be effective at mitigating odours, the trial highlights the importance of minimising odours at source because a relatively high odour removal efficiency is required to meaningfully reduce perceived odour intensity.

3.7 Field odour observations

3.7.1 Daily odour patrols and odour observations

Odour patrols, sometimes referred to as “Internal odour surveys” are carried out every weekday, at least twice (usually three times), by the Redvale Landfill Odour Technician. The purpose of these patrols is to identify any odours on- or off-site and provide feedback to the operational team.

It is noted that the land use consent requires odour patrols to be conducted daily (Condition 66A of LAN61338), so WMNZ’s practice of carrying out these patrols up to three times a day exceeds the consent requirements.

The methodology for the patrols is set out in Section 3.6 of the LMP. In summary, the odour patrols involve:

- 1 The technician leaves the Site office with the windows of their vehicle down.
- 2 A slow circuit of the Site using the internal ring road is undertaken to note any locations where odour is noticed near the boundary (Points A in Figure 3.2).
- 3 If odour is detected, the sector(s) are noted and the technician travels off-site.
- 4 The technician investigates odours within the identified sector (or for downwind sectors if no on-site odour was detected) by driving on publicly accessible roads (Points B, C and/or D, depending on the sector, in Figure 3.2).

- 5 The wind speed and direction, as recorded by the on-site weather station, and visual observation of cloud cover is recorded.
- 6 Results are submitted immediately to the Landfill Operations Manager.

In addition to the odour patrols, one formal odour observation is taken each working day at a location most likely to have odour between Point B and D in the relevant sector, based on the results of the odour patrols. The formal odour observation lasts 15-minutes and includes recording the character, intensity and duration of any odours. These once daily formal odour observations started in 2024. These daily formal odour observations are in addition to any requirement of consent conditions.

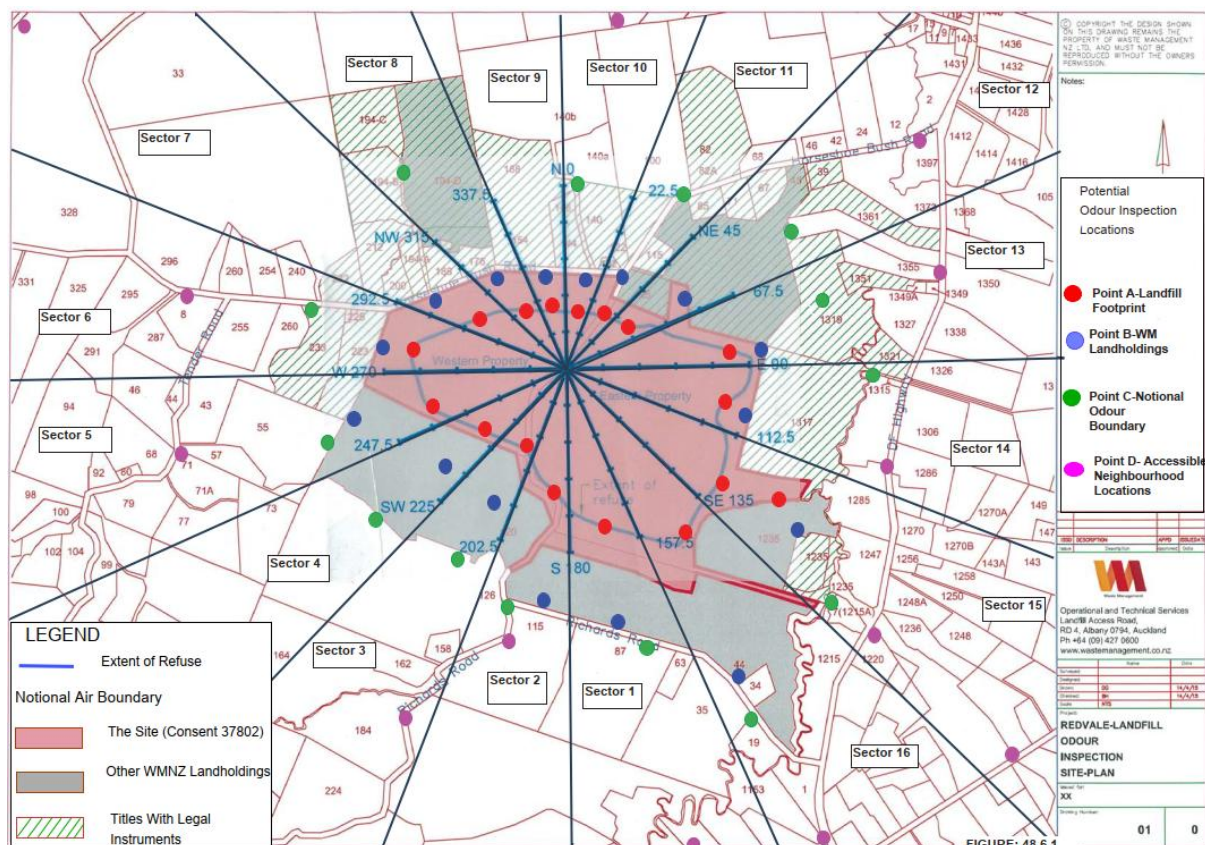


Figure 3.2: Odour patrol sectors (reproduced from Section 3.6 of LMP)

It is noted that during odour observations and complaint investigations, WMNZ staff sometimes score the odour intensity as “1 (very weak)” while also identifying its specific character (e.g., rubbish, tip face, LFG). Standard definitions of the 1 to 6 odour intensity scale used by air quality practitioners (including Watercare and Verum, who have previously conducted the independent odour observations, and Auckland Council staff undertaking compliance inspections) are that an odour with a “very weak” intensity would be at a level where its character is indiscernible. In other words, if an odour is strong enough to be able to identify the source, its intensity would typically be rated as a minimum of “2 (weak)”.

Given this, when reviewing historical records of the intensity of odours assessed by WMNZ staff, either during daily odour patrols or complaint investigations, it is likely that where an odour associated with the landfill is identified as a 1 (very weak) it may more closely correspond with a 2 (weak).

The difference in reporting of the “very weak” and “weak” categories does not affect other odour intensity categories. That is, intensity 3 (distinct) as reported by WMNZ is expected correspond to intensity 3 as defined in the standard definitions used by air quality practitioners.

3.7.2 Independent odour observations

In addition to the daily odour patrols, monthly field odour observations are undertaken by a third party (sometimes referred to as “External odour surveys”). To date these odour surveys have been undertaken by Watercare Services and, more recently, Verum. These surveys have a similar purpose as the odour patrols but are also intended to independently verify the nature of off-site odours.

3.7.3 Complaint investigation and response

Information about how to make a complaint or provide feedback to WMNZ, including about odour, is included on the Redvale community liaison web page. Complaints/feedback can be made by email, phone or text message. WMNZ provides guidance on the type of information that is useful to be included in a complaint to assist them in investigating the cause.

WMNZ aims to respond to odour complaints within 30 minutes of receiving them during working hours (as required by Condition 66A of LAN61338). This quick response is intended to increase the likelihood of verifying the odour while it is still present. Complaints made outside of working hours (e.g., late at night, early in the morning) or on weekends are investigated as soon as is reasonably practicable during the next working hours. These delays often result in “no odour detected” by the time staff arrive.

A trained WMNZ staff member conducts a FIDOL assessment⁸ at the complaint location. This assessment is typically conducted over a 15-minute period, which is longer than the 10-minutes usually adopted by air quality practitioners and increases the likelihood of identifying intermittent odours. If no odour is found, the complaint is logged as “no odour detected”. If an odour is verified, operations staff are immediately notified of its intensity and location so that mitigation measures can be taken.

WMNZ communicates back to the complainant, confirming whether the complaint was validated, explaining the likely cause of the odour, and outlining the operational improvements being made to address it.

All external complaints (i.e. from locations outside the notional odour boundary) are reported to the Auckland Council within 24 hours. All complaints (internal and external) are documented in the complaints register.

When a complaint is verified, WMNZ undertakes the following procedure:

- Reviews daily Site activity to identify any root causes.
- Reviews the effectiveness of odour suppression measures, including equipment operation, suppressant dosing, and the gas network vacuum.
- Takes specific response measures, which can include adjusting the position of odour fog cannons, relocating T-bar spray lines, adding more odour suppressant, and monitoring gas well vacuums.

⁸ The FIDOL factors are described in Section 7.6

3.8 Annual independent odour review

An independent assessment of odour management at the Landfill is carried out each year in accordance with Condition 68 of LAN61338. The primary objective of the annual independent review is to review the odour management controls and complaints during the review period and provide recommendations for further improvement. The results are reported to Auckland Council. The scope of these annual reviews includes:

- A site visit and walkover to interview the Odour Technician, observe current landfill operations, and understand the odour management practices in place.
- Review of actions undertaken by WMNZ in response to the recommendations of the previous year's audit.
- Review of all odour complaints received during the audit year and the response to those complaints.
- Review of the results from daily odour patrols and independent odour observations.
- Review of the landfill odour management practices. This includes examining waste acceptance and placement, the size of the open tipping face, the use of intermediate cover, and the effectiveness of the LFG collection system.
- Preparation of a final report to document the audit findings and provide recommendations for changes to improve odour management practices.

The independent odour audit reports for 2021-22, 2022-23 and 2023-24 have been reviewed and the key findings have been considered as part of the assessment of odour effects.

3.9 Conclusions on odour management

In T+T's experience, the odour management practices and engineering controls currently in use at Redvale Landfill are consistent with good practice in New Zealand for landfills receiving waste from commercial customers and transfer stations. With the proposed operational improvements, in particular increasing the required thickness of daily and intermediate cover, T+T considers the proposed odour management practices and engineering controls represent best industry practice.

4 Landfill gas generation and management

4.1 LFG composition

LFG is generated by the decomposition of organic waste materials by bacteria within a landfill. It consists mainly of methane (typically approximately 50%) and carbon dioxide, with trace amounts of other substances including odorous reduced sulphur compounds (including hydrogen sulphide) and volatile organic compounds (VOCs).

As well as being a greenhouse gas, methane is flammable in air at concentrations between 5 and 15% by volume. Therefore, a primary hazard associated with LFG that needs to be managed at the landfill is its explosive/flammable properties. While methane is non-odorous, LFG can be odorous depending on the concentration of odorous components. Odours are the main potential off-site effect of fugitive LFG emissions. The efficient collection and combustion of LFG effectively destroy methane and odorous compounds.

The concentration of key constituents in the collected LFG at the Energy Centre over the period 2021 to 2025 are summarised in Table 4.1. This data is based on 6-monthly samples collected and sent to an accredited laboratory for analysis (11 samples).

Table 4.1: Landfill gas composition (2020 to 2025)

Compound	Unit	Minimum	Maximum
Methane	(% v/v)	43.4	54.3
Carbon dioxide (CO ₂)	(% v/v)	33.0	37.5
Oxygen (O ₂)	(% v/v)	1.4	4.2
Non-methane organic compounds (NMOCs) as hexane	(mg/m ³ at 0°C)	480	3472
Hydrogen sulphide	(mg/m ³ at 0°C)	53	606

The composition (methane, carbon dioxide and oxygen content) of the collected LFG is also recorded at the Energy Centre on an approximately daily basis. The long-term trends in composition are shown in Figure 4.1. This illustrates that composition of the collected LFG has been relatively consistent over time, as would be expected.

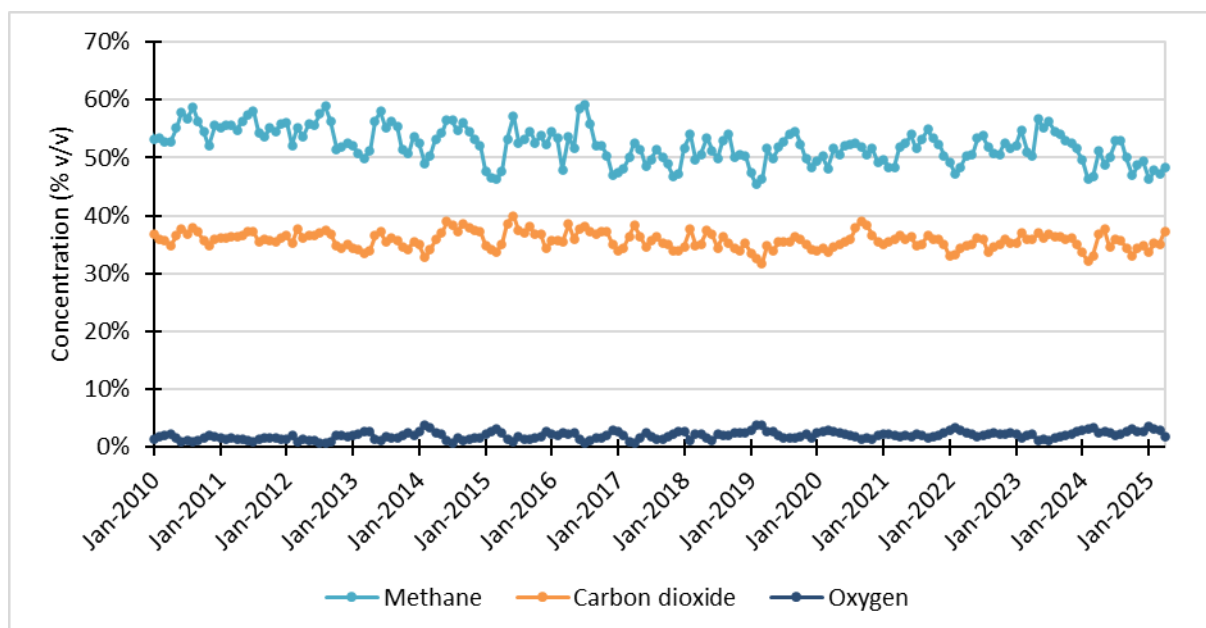


Figure 4.1: LFG composition

4.2 Rate of landfill gas generation and collection

LFG begins to be generated once anaerobic (oxygen-deprived) conditions and associated methanogenic bacteria have been established in the waste. During the initial stages of waste placement, the waste will be under aerobic conditions. The time that it will take for anaerobic conditions to develop is dependent on several factors, including the nature of the waste, the rate of filling and the waste depth, but would typically be within the first six months after waste placement.

The rate at which LFG is generated at a landfill is related to a number of factors, including:

- Waste acceptance rates.
- Waste composition, particularly the organic fraction of the waste.
- The density and age of the waste.
- Landfill construction and site operation procedures, particularly cover practices.
- Physical and chemical conditions within the landfill, particularly moisture content, temperature and pH.
- Climate, particularly temperature and precipitation.

Under optimal conditions, the putrescible content of a modern landfill may be largely biodegraded within 10 years or less (subject to moisture, temperature, etc. within the waste mass). However, paper and less anaerobically degradable material may continue to break down for 30 years or more. This means that LFG continues to be generated, at a diminishing rate, for years after the closure of the landfill cells.

The ultimate LFG collection efficiency, once the final cap has been placed, is estimated to be of the order of 95%. However, modelling of LFG generation and collection rates typically assumes 85% efficiency⁹. The balance of the LFG generally permeates through the landfill cap and is bioremediated by bacteria and natural processes within the cap layer. Surface methane emission measurements at a well-run landfill facility show that there is typically no detectable methane at the surface of the final cap (in the absence of cracks or defects in the capping layer).

The amount of LFG collected at the Redvale Landfill increased rapidly from the late 1990s to around 2010. Since 2010, LFG flows to the Energy Centre have flattened off. This is illustrated in Figure 4.2, which shows the monthly average LFG flow rate at the Energy Centre between 2010 and 2024 (the total LFG flow rate is approximately double the methane flow rate).

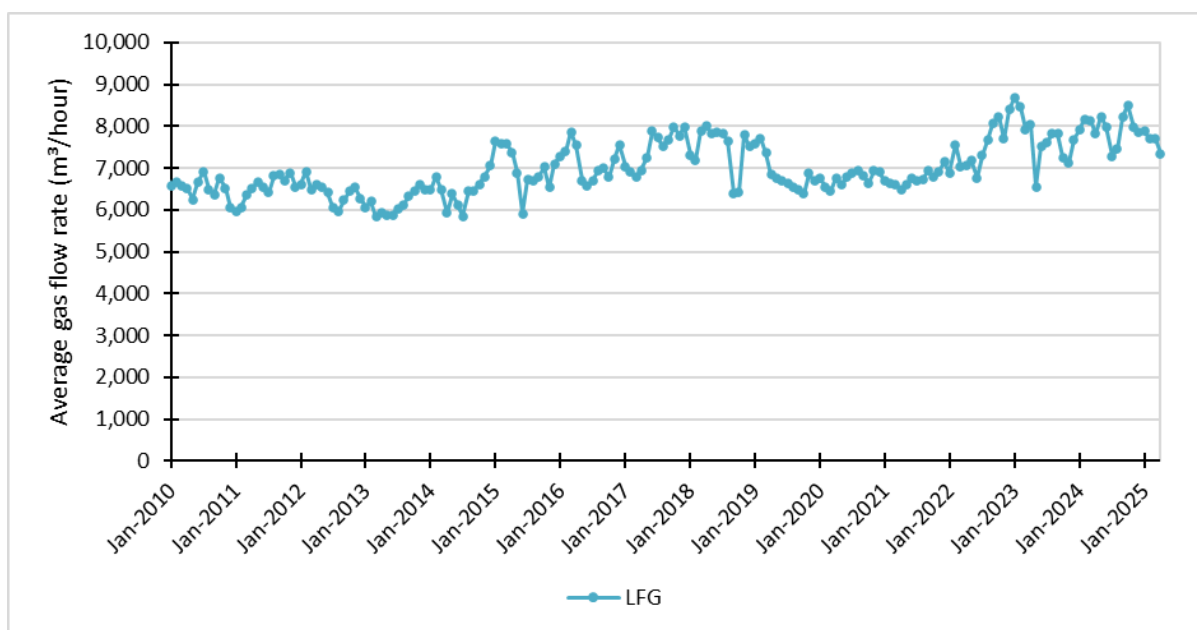


Figure 4.2: Flow rate of total LFG at the Energy Centre (2009 – 2024)

Projected LFG collection rates have been estimated and are shown in Figure 4.3. The projected collection rates are based on a first order decay model that has been calibrated to site conditions based on the historical gas collection rates (see Appendix A for more information).

The estimated maximum LFG collection rate is in the order of 8,000 Sm³/hr, which is similar to the rate currently being managed on the Site and similar to the projections being used by WMNZ to plan future gas infrastructure requirements. The implications for the Energy Centre (e.g. maximum number of generators likely to be operated) are discussed in Section 4.3.4.

⁹ The NZ ETS recommends a default collection efficiency of 90%. A collection efficiency of 85% has been used for the purposes of this modelling of LFG collection, combined with site-specific information about rainfall and organic content of the waste rather than the generic ETS values. This combination of site-specific parameters correlates well with the actual LFG collection rates at the landfill. Notwithstanding this, the overall LFG destruction efficiency at Redvale Landfill (combustion of collected LFG and oxidation through the cap) is expected to be in excess of 90%.

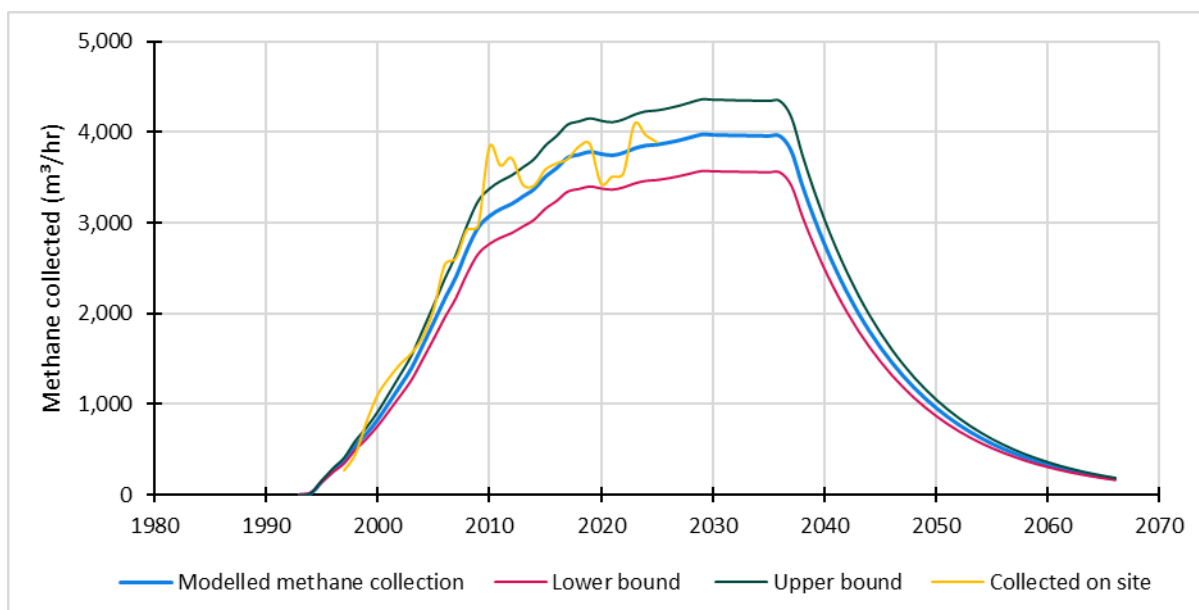


Figure 4.3: Methane collection rate projections

4.3 Landfill gas management system

4.3.1 Introduction

If not actively managed, LFG within a landfill will migrate from higher pressure zones within the landfill to lower pressure zones (typically the atmosphere). LFG management systems are designed to actively extract LFG from the waste mass, thus avoiding or minimising the migration and fugitive escape of LFG. Generation of LFG creates positive pressure within the landfill mass. Creating a uniformly distributed negative pressure (slightly below atmospheric pressure) within the landfill has been shown to be the best way to minimise fugitive LFG escaping from landfills, thereby minimising LFG hazard and adverse effects of odour.

Regulation 26 of the NESAQ requires the Landfill to have a system for the collection of LFG, that is designed and operated to ensure that the concentration of gas at the surface of the landfill does not exceed 5,000 ppm methane and for the collected gas to be flared (in accordance with Regulation 27) or used as a fuel or for generating electricity. The requirements for flares under Regulation 27 of the NESAQ are discussed in Section 4.3.4.

An LFG collection system generally incorporates the following elements:

- A system to retain LFG within the landfill cells and prevent off-site migration, including liner and capping systems.
- A network of collection wells and pipework maintained under a negative pressure.
- Condensate drainage, knockout pots and traps.
- Monitoring to confirm the effectiveness of the system, including LFG monitoring at extraction wellheads and regular surface methane emission monitoring on capped areas.

The following subsections describe the LFG collection system and the management of collected LFG.

4.3.2 Landfill lining and capping systems

The lining and capping systems at a landfill are integral to effective capture of LFG. At a landfill with a well-constructed cap and an effective LFG extraction system, emissions of fugitive LFG through the capping system are usually negligible. However, LFG can escape through defects in the capping or areas of poor cover and from the working face. The integrity of areas of intermediate and final cap will continue to be regularly monitored through a combination of visual inspections and surface monitoring. Weekly visual inspections will continue to be made to identify any distressed vegetation, visible cracking or drying out of the cap and discernible LFG odours. Instantaneous surface emissions monitoring will continue to be carried out on a monthly basis for areas with intermediate cover and quarterly basis for areas of final cover to detect any fugitive LFG emissions so that they can be remedied as soon as practicable.

4.3.3 LFG collection system

The extraction and destruction of LFG is achieved through the use of a comprehensive network of LFG extraction wells that are constructed progressively during placement of the landfilling material. The system incorporates features such as horizontal feeders to vertical wells ("Norfolk Pine" design), carefully graded header network and control systems that provide early warning of any damage to the extraction system. A plan showing the collection system layout is shown in Drawing 092369.3000-C40.

The wells are installed from the bottom up in each cell and feature a slipform riser that enables the wells to be extracted from an early stage and progressively raised as each cell is filled. As additional waste placement related to this application will be in areas where there is already an established network of gas collection wells, progressive extension to the vertical wells and horizontal collectors will continue as normal.

Optimum LFG extraction is achieved by the adjustment of the vacuum at individual wells, promptly repairing any damage to the extraction system or landfill cap and the installation of supplementary LFG extraction wells as required. Additional care is required to maximise LFG extraction around the tip face and areas of daily cover, to avoid ingress of air. In practice, this means watching out for any sudden increases in CO, oxygen or temperature in the wells and more frequent gas well balancing to ensure conditions are optimised.

4.3.4 Energy Centre

The majority of LFG collected at Redvale Landfill is used to generate electricity, with flares available to destroy the gas if the generators are not available. The flares and generators are located at the Energy Centre, as shown in Figure 4.4.

A relatively small amount of LFG (equivalent to about half the gas used by a single generator) is burnt to provide heat for leachate evaporation in the LEU, located as shown in Figure 4.4. The LEU is discussed further in Section 5.

Some of the collected LFG is also piped to a nearby greenhouse where it is burnt in a boiler to produce heat. In 2025, the average quantity of LFG sent to the greenhouse was approximately 2,200 m³/day. This is around 1% of the LFG burnt at the Energy Centre daily and has therefore not been considered further in this assessment.

The nature of discharges to air from LFG-fired generators and flares are very similar and comprise the combustion products of LFG (NO_x, CO, SO₂ and particulate matter). Minor amounts of volatile organic compounds and methane from incomplete combustion will also be discharged.

The current air discharge consent (Permit 37802) does not explicitly limit the number of generators or flares that can be installed at the Site. However, the Assessment of Environmental Effects report

that supported the application assessed the potential need to manage up to 12,250 m³_{LFG}/hour, based on model projections at the time¹⁰. As discussed in Section 4.2, the rate of LFG collection at the Site, allowing for additional waste placement, is not expected to exceed approximately 8,000 m³_{LFG}/hour (of the order of 4,000 m³_{methane}/hour).

There are currently 15 generators and three flares installed at the Site. Typically, only 14 generators are operated at any one time. The generators and flares have been progressively installed since 2000. The generators have an operational life of the order of 20 years. As such, the first five generators (G1 to G5, installed between 2000 and 2005) have been replaced (these new generators are now referred to as G1b to G5b). There are small differences in the generator configuration depending on when they were installed, however they each generate a nominal 1 MW electricity from approximately 670 m³_{LFG}/hour (assuming 50% methane).

For the purposes of this assessment, it has been assumed that no more than 15 generators would be required to operate at any one time (noting that one or more additional generators may need to be installed to provide redundancy). Consequently, the combustion emissions and associated effects sought to be authorised by these applications are lower than authorised by the current consents.

The generator units are each housed in a standard shipping container and exhaust via individual stacks at a height of 6.4 m (G4 to G7) or 10 m (all other generators). Details of the generator emissions and stack configurations are in Appendix E5. The generators are maintained and tuned in accordance with supplier recommendations, and stack testing has been carried out on a rotating basis under the terms of the existing consent.

There are three fully enclosed ground flares at the Site that are used to destroy LFG that is not utilised in the generators, for example during planned maintenance or power grid outages when the generators are not available. The flares range in size from approximately 2,500 to 3,500 m³_{LFG}/hour (assuming 50% methane). There is sufficient capacity to enable all of the LFG collected at the Site to be destroyed by flaring if the generators are not available or in the event of a power failure. A standby diesel generator is available to power-up systems to operate the flares, if needed.

The flares are fully compliant with the NESAQ requirements for a 'principal flare' as set out in Regulation 27 of the NESAQ. These requirements are:

- A flame arrestor.
- An automatic backflow prevention device, or an equivalent device, between the principal flare and the landfill.
- An automatic isolation system that ensures that, if the flame is lost, no significant discharge of unburnt gas from the flare occurs.
- A continuous automatic ignition system.
- A design that achieves a minimum flue gas retention time of 0.5 seconds.
- Designed and operated so that gas is burned at a temperature of at least 750°C.
- A permanent temperature indicator.
- Adequate sampling ports to enable emission testing to be undertaken.
- Provision for safe access to sampling ports while any emission tests are being undertaken.

¹⁰ The assessment evaluated the effects of discharges to air from up to 20 generators operating at the same time (assuming up to 24 generators could be installed), up to four enclosed ground flares (each with a capacity of 2,500 Nm³_{LFG}/hour) and a low temperature leachate evaporator (no longer used).



Figure 4.4: Location of discharge stacks associated with the generators, flares, and LEU

5 Leachate management

Leachate is the liquid produced when rainwater percolates through the waste, collecting dissolved and/or suspended matter from the waste as it passes through. The landfill is managed to minimise the volume of leachate that is produced by:

- Minimising the size of the active tip 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 the stormwater collection system and minimising percolation of water through these layers into the underlying waste.
- Providing well managed stormwater systems to divert stormwater away from areas where waste is placed.

The leachate collection system is described within the Engineering Report. In simple terms, leachate generated within the waste will flow to the leachate collection system in the base of the landfill cell (above the liner). Leachate is collected in the drains along the floor of the landfill into leachate pipes and into sumps. The leachate is pumped to the leachate holding tanks and:

- Treated by evaporation to reduce its volume, with the resulting sludge placed back in the landfill; and/or
- Recirculated back into the landfill; and/or
- Transported by road tanker for off-site disposal.

Historically, the Redvale Landfill used a low temperature leachate evaporator unit (LTLEU) to reduce the volume of leachate that needs to be managed. The LTLEU discharged steam and volatile compounds into one of the flares. The LTLEU had a relatively small capacity and a low efficiency, meaning that there was a significant reduction in the beneficial use of LFG to generate electricity.

A BeneVap™ BV300 LEU has been operated at the Site since early 2021. As part of this application, WMNZ is seeking to authorise the ongoing discharges from this unit. The LEU is located within the landfill footprint and therefore, at some point over the life of the Project, the LEU will need to be decommissioned to allow additional waste placement and any excess leachate will be trucked off site for treatment and disposal.

The LEU is a direct-fired submerged combustion leachate evaporator, which use combustion gases from the burning of LFG to directly heat and evaporate the liquid leachate, reducing the volume and concentrating the remaining solids. The LEU incorporates a treatment vessel with an operating volume of approximately 2.6 m³. It has a design evaporation capacity of 50 m³/day and uses approximately 270 m³_{LFG}/hr for the combustion burner (i.e. about half the gas used by an LFG generator at the Energy Centre). The leachate within the BV300 does not exceed 90°C, i.e. the bulk volume of leachate does not reach boiling point.

The discharges to air from the LEU comprise mainly water vapour and a mixture of combustion gases (oxides of nitrogen, carbon monoxide, sulphur dioxide) from the evaporator burner, as well as ammonia and small amounts of VOCs that evaporate from the leachate.

The concentrated leachate residue and sludge, which has been reduced to approximately 10% of its original volume, is stored in an enclosed tank prior to disposal in the landfill. As with the raw leachate, because this material is fully contained, it is not expected to be a source of odour.

6 Assessment of dust effects

Operational activities that have the potential to generate dust at the landfill include stockpiling and handling of soil/clay for cover, vehicle movements on unpaved internal roads, placement of dusty waste at the working face (particularly in windy conditions), and placement of cover. Most dust generated from these activities comprise larger, “settleable” particles (typically >50 µm). These particles usually settle to the ground quickly, typically depositing within about 100 to 200 m from where they are generated. This means that their effects are usually limited to localised amenity impacts (e.g. surface soiling and minor eye/nose irritation) rather than longer-range impacts.

A range of management measures are currently used at the Site to minimise emissions of dust. These controls include the use of water carts on unsealed roads (under dry conditions), 30 km/h speed limits on haul roads, and vegetation establishment on intermediate/final cover areas. Measures to prevent tracking of material onto sealed surfaces (including public roads) are also in place, including cattle grids/rumble strips, an on-site wheel wash, and wash-down of sealed roads if mud is tracked during or after rainfall. These controls are considered good practice and appropriate for the activities undertaken on Site. No changes are therefore proposed to these dust controls.

Given the implementation of existing dust suppression and track-out controls that minimise dust emissions at source, and the separation distance to the nearest sensitive receivers (approximately 140 m from the closest operational landfill areas), the risk of operational dust emissions causing discernible effects at the nearest sensitive receivers is considered very low, and discernible adverse effects beyond the site boundary are unlikely.

7 Assessment of odour effects

7.1 Assessment methodology

7.1.1 Assessment approach

The Ministry for the Environment's Good Practice Guide for Assessing and Managing Odour (GPG Odour) sets out the various techniques for assessing odour effects of an existing activity (or change to an existing activity) (Tables A2.1 and A2.2 in Appendix A of the GPG Odour). These tools are used in combination to inform an overall assessment using the FIDOL factors (frequency, intensity, duration, offensiveness/character and location).

Offensive and objectionable odour effects can occur from acute exposure, (i.e. a single occurrence of a very high intensity odour), or chronic exposure (i.e. where lower intensity odour events occur on multiple occasions and/or for longer durations). The FIDOL factors can take account of both acute and chronic effects. In T+T's experience, odour effects from landfills are more likely to arise from chronic exposure than acute exposure.

As the Redvale Landfill has been operating since 1993 there is a good understanding of effects of the current landfilling activities. An assessment of the odour effects of these current landfilling activities has been used as a baseline to evaluate effects of the Project, taking into account differences (relevant to odour effects) between the Project and current activities, as discussed in Section 3.2.

The odour from the LEU has a different character (described as a burnt, chemical smell) compared to the refuse/LFG odours associated with landfilling activities. For this reason, the odour effects of the LEU have been considered separately to understand the extent to which they contribute to overall odours from the Site.

7.1.2 Assessment tools

A description of the assessment tools recommended in the GPG Odour and how they have been used to inform this assessment are set out in Table 7.1.

The GPG Odour discusses the use of odour annoyance surveys and odour diaries as assessment tools. These are both recommended in urban areas where there is sufficient density of population for the results to be analysed statistically. Odour annoyance surveys are generally telephone-based surveys and, given the reducing number of properties with landlines, are rarely used these days. As an alternative to odour surveys and odour diaries, the sources of community feedback on odour used in this assessment are complaints records (including investigations) and feedback from the Community Liaison Committee.

The GPG Odour does not discuss the use of field odour observation programmes as a tool for assessing odour effects. The use of structured field observations is increasingly common as a method for providing both qualitative and quantitative data about odours over time. As described in Section 3.7, field odour observations ("odour patrols" and formal odour observations) are regularly undertaken by the WMNZ Odour Technician, and by a third party on a quarterly basis (previously eight times per year). The records of these field odour observations have been evaluated to inform the odour assessment.

Table 7.1: Evaluation of Odour GPG assessment tools for this assessment

Assessment tool	Commentary
Community consultation	WMNZ facilitates a Community Liaison Committee, which meets quarterly. This is a two-way forum that provides an opportunity for the community to provide ongoing feedback to WMNZ about the performance of the landfill.
Complaint records	The community is actively encouraged to provide feedback, including about odour, by telephone, text or through the online feedback form. There is a history of odour complaints relating to the operation of the Redvale Landfill. These have been evaluated (Appendix D) to inform the assessment of effects for this proposal. When evaluating odour complaints, it is important to note that there is a range of factors that can influence whether people choose to complain or not. Odour complaints are not an objective measure of odour but provide an indication of community satisfaction or dissatisfaction.
Industry/Council experience	WMNZ has extensive experience with the operation of landfills throughout New Zealand, including large regional landfills such as the existing Redvale Landfill, the Whitford Landfill in Auckland and the Kate Valley Landfill in Canterbury. This experience has informed the management and operational practices at the landfill. The Redvale Landfill has been operating for over 30 years. As well as regular compliance reporting from WMNZ, Auckland Council has extensive experience with odour effects of the Site, including through: • Periodic compliance inspections. • Regular reporting by the Independent Peer Review Panel. • Annual independent odour audits.
Meteorology and terrain assessment	Dispersion modelling and comparison with numeric guideline values is not recommended as an assessment tool for existing activities, particularly where odour emission rates are highly variable (such as at a landfill). However, dispersion modelling can assist in understanding dispersion patterns, which are influenced by meteorology and terrain.
Dynamic dilution olfactometry (DDO) measurements and odour dispersion modelling.	Odour emissions from the landfill surface have been measured using flux hoods and DDO analysis in different areas at Redvale Landfill. These odour emission measurements do not include acute emissions (such as a particularly malodorous load) or abnormal conditions that can occur from time-to-time. Given the highly variable nature of odour emissions at a landfill, dispersion modelling has mainly been used to understand dispersion patterns. For example, the modelling has been used to characterise the relative likelihood of different locations being impacted by odours due to the combined influences of meteorology, terrain and separation distance. Odour emissions from the LEU are from a stack source and are therefore more suited to be characterised using stack emission testing and DDO and assessed using dispersion modelling.
Site management and contingency plans, and whether the best practicable option is being applied.	The operational and management controls for odour are described in Section 3 and in the LMP. These controls are informed by those used at WMNZ's other landfills and are considered to represent best practice for the management of landfills in New Zealand and our experience with landfills internationally, particularly in Australia.

Assessment tool	Commentary
Process controls and design, including details of emission controls and engineering risk assessment for system failures.	Experience at other landfills has shown that acute off-site odour events are generally related to specific incidents, such as a particularly malodorous load of waste or issues affecting the integrity of the cap resulting in fugitive LFG emissions. There is a variety of specific controls directed at identifying and remedying these non-routine events. There is also a range of controls used to minimise ongoing emissions of odour from routine operations, in particular the active placement of waste at the working face.

7.2 Community feedback

7.2.1 Community Liaison Committee

The Community Liaison Committee (CLC) is independently chaired and includes representatives of neighbours, as well as the Dairy Flat School, Community Board and Auckland Council. The CLC provides a regular (3-monthly) forum for WMNZ to provide operational updates to the community and to receive feedback on a range of matters, including odour performance. The CLC meeting minutes for the last 5 years have been reviewed as they relate to odour and landfill management¹¹.

CLC members regularly raise concerns about LFG, rubbish smells, and emissions from the LEU. Concerns relating to dust, noise, health effects, pests and the management of hazardous wastes have also been raised at different times.

Based on the information contained in the meeting minutes, the following factors appear to be correlated with odour complaints:

- Humid weather conditions.
- Weather changes or certain weather patterns.
- Operational factors such as changing between cells, removing cover, or during equipment failures.

WMNZ provides updates at these meetings on operational performance, consent compliance and improvements, and is responsive to requests made by the CLC for further information. Following feedback received at these meetings, the complaints register is sent out with the meeting agenda, and WMNZ provides the committee with reports on pest control, water quality, and a list of complaints made directly to Auckland Council. All complaints are now recorded in a combined register with Auckland Council.

7.2.2 Odour complaints and investigations

The odour complaint records (supplied by WMNZ) for the period January 2018 to December 2025 have been summarised in Appendix D).

¹¹ <https://www.wm.nz/my-region/auckland/redvale-energy-park-community-liaison/>

The analysis shows clear temporal patterns in the complaints. Most complaints are during landfill operational hours (and a large proportion are early in the morning), with relatively few complaints received on Sundays. This is consistent with WMNZ's findings in regard to potential odour sources, i.e. there do not appear to be significant odour emissions outside landfill operating hours. The period with the highest number of complaints is the early morning, from 7:00 a.m. to 10:30 a.m. This peak corresponds with a combination of factors, including cool, calm morning weather conditions that are less conducive to odour dispersion, a higher likelihood of residents being at home, and the commencement of site operations such as the removal of daily cover and the arrival of waste.

The most frequently identified landfill-related odours identified by WMNZ staff when investigating complaints was tip face/rubbish odour. BeneVap and landfill gas (LFG) odours were detected only rarely (9 of 1,031 observations).

In October and November 2021, there was a significantly higher number of odour complaints compared to the previous 3 years. This has been attributed to flooding at the landfill during a period when nickel slag was being placed. WMNZ identified that the waterlogged nickel slag became anaerobic and produced hydrogen sulphide. The subsequent dewatering process on site took approximately 2.5 months, during which time odour complaints remained elevated.

In addition to the specific issue identified with nickel slag in late 2021, the 2020-2021 annual independent odour review identified that earlier in 2021 there were some delays in remediation of areas of intermediate cover that were picked up by the ISM surveys. Fugitive LFG emissions from these areas potentially contributed to a period of higher numbers of odour complaints.

As shown in Figure Appendix D.7, the number of complaints increased markedly in April 2025, and have continued at an elevated level since this time. This corresponds with the timing of WM commencing consultation on the proposed expansion of the landfill.

There is no clear pattern in the spatial distribution of complaints, other than a reduction in complaints with increasing distance. The landfill is in a rural area, with varying density of housing (i.e. a mix of small and large land parcels), which will influence the spatial patterns in complaints.

The majority of complaints originate from within approximately 1,000 m of the landfill area, although complaints do occur out to approximately 1,500 m (and very rarely beyond that distance). Historically, the bulk of complaints originated from a small number of complainants.

7.3 Summary of field odour observations

7.3.1 Daily odour patrols

The methodology for the daily odour patrols is detailed in Section 3.7. The odour patrols (which are carried out at least twice each working day) are used by WMNZ to proactively identify odour and make operational adjustments if needed. If odour is identified off-site during the odour patrol, an investigation is undertaken to identify the likely source and implement appropriate mitigation measures.

The odour patrol data can assist in understanding:

- The frequency at which odours are identified off-site.
- The sectors where odours are detected compared to the dispersion patterns discussed in Section 7.3.

A large amount of manually recorded data is generated from these odour patrols. The records between January 2024 and December 2025 have been digitised by WMNZ and reviewed to inform this assessment.

The frequency at which odour was detected during the off-site odour patrols is presented in Figure 7.1. This illustrates that most of the time, odour is not detected at off-site locations during the odour patrols.

Findings ● No Odour detected ● Detected



Figure 7.1: Odour detections during off-site odour patrols. “No odour detected” includes non-landfill related odour as classified by WMNZ staff. (January 2024 – December 2025)

The annual independent odour review reports discuss the independent odour walkovers conducted by Watercare in 2022-23 (eight) and in 2023-24 (four). The findings of these independent odour walkovers were that:

- In the 2022-23 period, mostly no odours were detectable, and any detected rubbish odours from the landfill were typically brief and at “very slight” to “slight” intensity levels.
- In the 2023-24 period, while occasional rubbish-type odours were detected by Watercare, they were brief, of low intensity (“slight” or “very slight”), and not considered offensive. One survey (April 2024) detected no odour at any of the five locations assessed.

7.3.2 Daily odour observations

As discussed in Section 3.7.1, at least one formal off-site 15-minute odour observation is made on each working day at the address considered most likely to experience odour, based on the results of the odour patrols. These daily observations have been recorded since January 2024 and include the character, odour intensity and duration of any odours. A fixed odour observation address has been identified for each sector, which is intended to represent the closest off-site sensitive receptor in that sector (noting that there are practical access constraints in some sectors). As these observations are consistently made at the same locations, they can provide useful information about the frequency of off-site odours (noting the assumption that the address visited was assessed as the most likely to experience odour on that day).

There is a low frequency of positive odour detections during the daily odour observations. Figure 7.2 shows the locations of the odour observations completed in 2024 and 2025 and the incidence of odour being detected during the observation. These data include all odours detected, not just landfill-related odour. The size of the dot represents the relative number of observations at each location (the smallest dots represent a single observation).

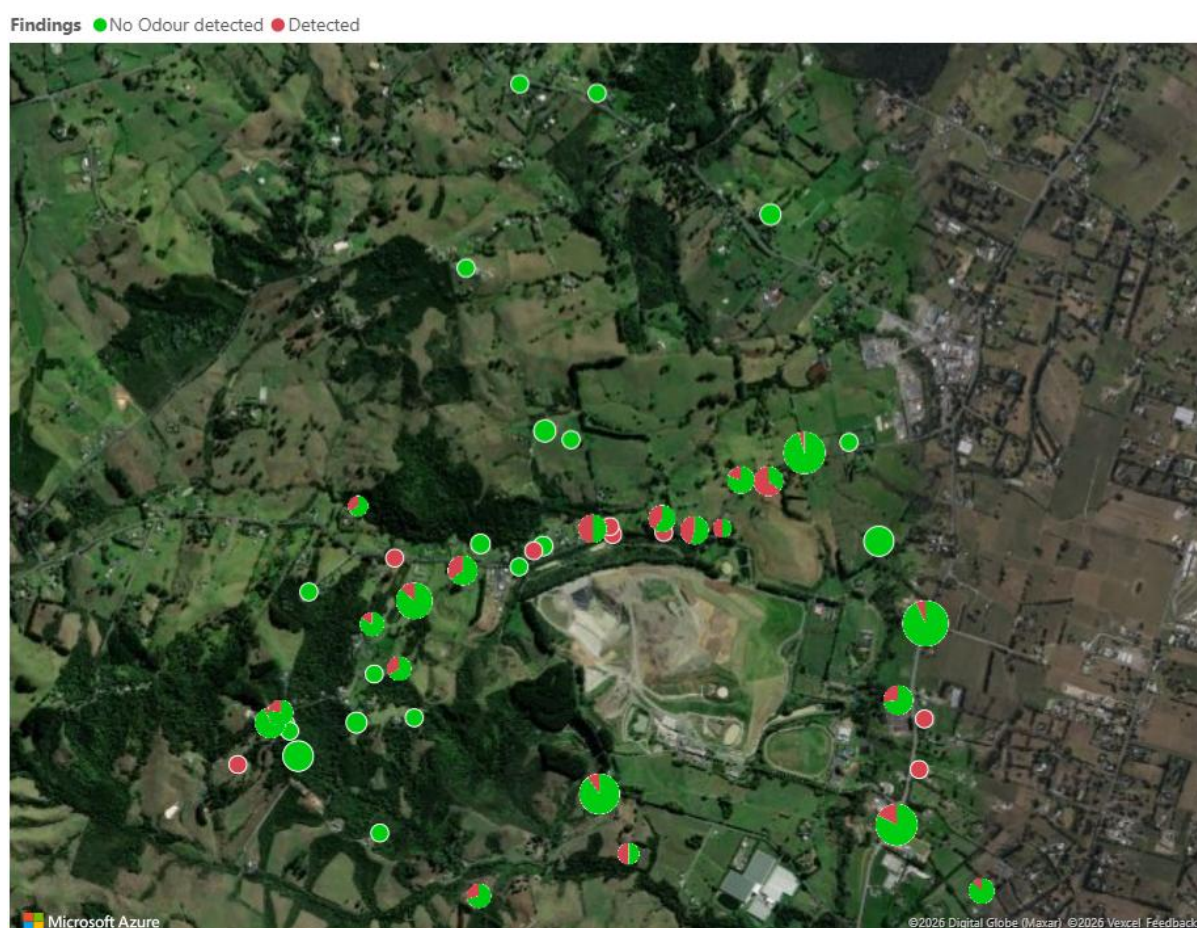


Figure 7.2: WMNZ daily odour observations results (2024 and 2025)

7.3.3 Discussion

Overall, the field odour observations indicate that off-site landfill-related odours are not persistent, but they do occur intermittently under certain conditions. The daily odour patrols and formal odour observations show that most off-site checks record no odour. Where odour is detected, it is generally brief and of low intensity, which is consistent with the findings of the independent odour walkovers (see Section 3.7.2).

7.4 Dispersion modelling of landfill odours

7.4.1 Purpose and modelling approach

When assessing odour effects, it is important to distinguish between acute and chronic impacts. Acute effects can result from a single occurrence of very high intensity odour, such as from an unusually odorous load or a temporary failure of odour controls. These events may be infrequent but sufficiently intense to constitute an offensive or objectionable effect.

Chronic effects occur when lower intensity odour events happen frequently and/or for longer durations. Even if individual odour episodes are of moderate intensity, their cumulative impact over time can result in adverse effects on amenity and wellbeing.

The modelling approach used in this assessment is primarily focused on understanding the risk of chronic odour effects from routine landfill operations, rather than predicting acute events from intermittent sources.

The Odour GPG does not recommend the use of dispersion modelling and comparison with numeric modelling guideline values as an assessment technique for existing activities, particularly where odour emission rates are highly variable. Therefore, dispersion modelling has been used to support this assessment in two main ways:

- To understand how the combined effects of terrain and meteorology influence dispersion patterns. While the modelling cannot be used to accurately quantify odour concentrations, the model findings can be compared with other sources of information, such as odour complaints, to provide a more complete picture of the risk of odours being present at levels that could cause adverse effects; and
- To understand how odour effects of the Project are likely to differ from the odour effects from current consented landfilling activities, i.e. the relative change in odour effects.

The details of the odour modelling study are set out in Appendix D and the following sub-sections describe the scenarios that have been considered and the overall findings.

The outputs of the odour dispersion modelling have been presented in two different ways:

Odour concentration contours

Odour concentration contours are graphical plots used to map the peak strength (intensity) of modelled odours (typically at a specific percentile, such as the 99.5th percentile) across the surrounding environment. Because actual odour emission rates from a landfill are highly variable depending on daily operations, waste types and volumes, etc, these concentration plots are not highly accurate at predicting the absolute odour levels that a person might experience on any given day. Instead, their primary value lies in demonstrating relative changes in odour effects between different operational setups. For example, they are used to compare existing landfill activities against proposed scenarios to visually illustrate how reduced emission rates and increased separation distances lower the modelled peak odour concentrations reaching sensitive receptors.

Odour frequency contours

Odour frequency contours map the percentage of time that a modelled odour is predicted to exceed a specific, nominal concentration threshold at various locations. Rather than predicting how strong an odour will be, these contours illustrate the relative likelihood or risk of an odour pathway existing between the source and a receptor, taking into account the influences of terrain and meteorology (such as predominant wind directions). For instance, a location situated on a 10% frequency contour is twice as likely to be exposed to odour conditions compared to a location on a 5% contour. Because landfill emissions fluctuate, frequency contours are considered a more useful for mapping the general dispersion patterns and understanding the spatial risk of chronic odour effects over time.

When combined with other information (like complaint records and field observations), they help build a complete picture of odour risk.

7.4.2 Odour emission rates

The landfill odour modelling uses surface odour emission rates measured from different areas at Redvale Landfill using flux hood sampling and analysis, as described in Appendix E4. It has been assumed that these emission rates are constant over the relevant time period (e.g. constant emissions from the tip face during landfill working hours).

Odour concentrations are expressed as Odour Units (OU). One OU is defined as the volume of 'odour free air' required to dilute a unit volume of a sample of odorous air until the detection threshold of the odour is reached. For example, if an odour sample needs to be diluted 100-fold to reach the point where the odour is just detectable, then it is described as having an odour concentration of 100 OU.

7.4.3 Modelled scenarios

Existing scenarios

As discussed in Section 3.4, WMNZ currently manages the tip face area to a target of no more than 1,200 m² (excluding the push ramp). The size of the tip face on any given day is determined by the amount of waste being received and other factors, related to the geometry of the working area and the safe movement of equipment and traffic. For the purposes of dispersion modelling, a tip face area of 2,000 m² has been used and the maximum area under daily cover has been set at 7,500 m² (i.e. five of the six active faces to be used during the week are under daily cover at any given time). This represents the largest tip face area that is likely to have occurred in recent years.

The model has been configured so that emission rates representative of the tip face only occur during Site operating hours (i.e., 6:00 a.m. to 6:00 p.m.). Outside of operating hours the entire 9,500 m² active area is assumed to be under daily cover (see Appendix E).

Over the last few years, the closest filling to sensitive receptors has been occurring in the northwest corner of the landfill. Consequently, an existing modelling scenario with the working face/area under daily cover in the northwest corner of the landfill has been used (ES_N). This scenario has been used as a baseline model for comparison with odour complaints (see Section 7.4.4).

A second existing consented scenario has been modelled that represents the area of future waste filling under the current consents that is closest to receptors to the east of the landfill (ES_E). Filling would occur in this area to bring the landfill up to its final consented contour under the current consents.

The locations of the modelled sources (tip face and area under 150 mm daily cover) for each of the existing scenarios discussed above are illustrated in Figure 7.3.

Proposed scenarios

Four future scenarios have been modelled with the tip face positioned at different locations representative of where putrescible waste filling would occur (while maintaining 500 m separation distance from sensitive receptors). These scenarios are:

- Proposed Scenario – West (PS_W)
- Proposed Scenario – North (PS_N)
- Proposed Scenario – East (PS_E)
- Proposed Scenario – South (PS_S)

The model settings reflect the improved odour controls that have been incorporated into the Project:

- Reducing the size of the tip face to 900 m².
- Delaying the time that putrescible can be accepted for the cooler months of 1 May to 31 August, so that the start of waste placement starts at 7:30 a.m. instead of at 6:15 a.m.

Odour emissions from areas under 300 mm daily cover are expected to be negligible, based on the odour flux emission monitoring outlined in Appendix E4 and therefore the only odour source modelled in the proposed scenarios is the tip face.

The locations of the modelled tip face for each of the proposed scenarios identified above are illustrated in Figure 7.3.

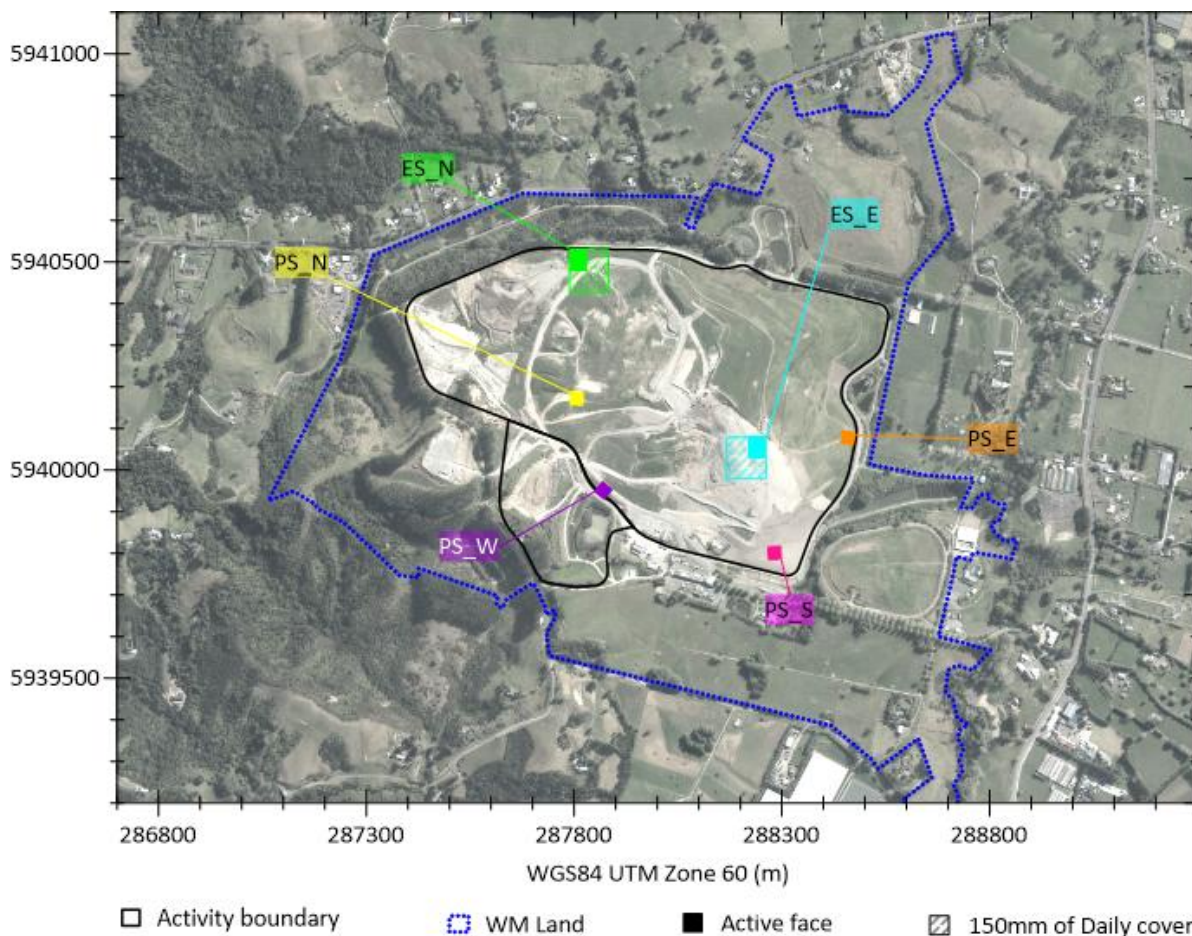


Figure 7.3: Location of tip face and areas under 150 mm daily cover for each of the modelled scenario - Existing Scenarios (ES) and Proposed Scenarios (PS)

7.4.4 Odour dispersion patterns and complaints

As discussed in Section 7.4.1, odour frequency contours show the percentage of the time that the hourly modelled odour exceeds a nominated odour concentration. These contours illustrate the relative likelihood or risk of an odour pathway existing between the source and a receptor.

To understand how the modelled dispersion patterns reflect community feedback about odour effects (in the form of complaints), the frequency contour plots have been overlaid on a map showing the location and number of odour complaints in 2022 (see Figure 7.4). For this modelled “existing scenario”, the working face has been positioned at its northernmost location (ES_N). The position of the tip face will have moved throughout the 2022 year but was broadly on the northern and central parts of the landfill.

A nominal concentration threshold of 0.0005 OU has been used in the frequency contour plot shown in Figure 7.4. It is important to note that this odour concentration is not a threshold for odour effects and is only used to illustrate the dispersion pattern. As an example of how the frequency contours can be interpreted, the risk of odour occurring at a location with a modelled frequency of 10% (i.e. 10% of modelled hours exceeding the concentration threshold) is twice as high as the risk at a location with a modelled frequency of 5%. However, although the risk of odour may be twice as high, effects may never occur if the odour emissions at source are low.

Buffer distances of 500 m, 1,000 m, 1,500 m and 2,000 m from the tip face are also shown for context. The blue dots on Figure 7.4 show location of the odour complainant and the size of the dot represents the number of complaints received. All complaints are shown in Figure 7.4 regardless of the WMNZ investigation outcome of the complaint.

When interpreting this figure, it is important to note that:

- Odour complaints are not an objective measure of odour effects, and the pattern of complaints is influenced by factors such as the number of receptors in particular areas and the tendency of the people in those locations to complain if they experience an odour that they attribute to the Site (or the level of odour that would cause them to complain).
- Prior to 2025, a relatively small number of complaints were received from properties along Horseshoe Bush Road, north of the landfill. This may be because many of these properties are within the notional odour boundary under the current air discharge consent (Permit 37802) and people living within the notional odour boundary may have had a lower tendency to complain. As such, the complaints records may not reflect the frequency of odours at these locations.

Broadly, Figure 7.4 shows that odour effects from existing landfill activities may be occurring at distances of the order of 1 km from the landfill tip face in any direction and up to 1.5 km from the landfill in the northeast/southwest plane. This bias towards the northeast/southwest reflects the predominant wind directions at the site (i.e. receptors in this plane are more frequently downwind of the landfill compared to receptors in other directions).

For the nominated odour concentration threshold, the 15% contour is a reasonable indicator for the maximum extent of odours complaints. The next sub-section uses this information to help understand how the risk of odour effects will change (reduce) with the Project.

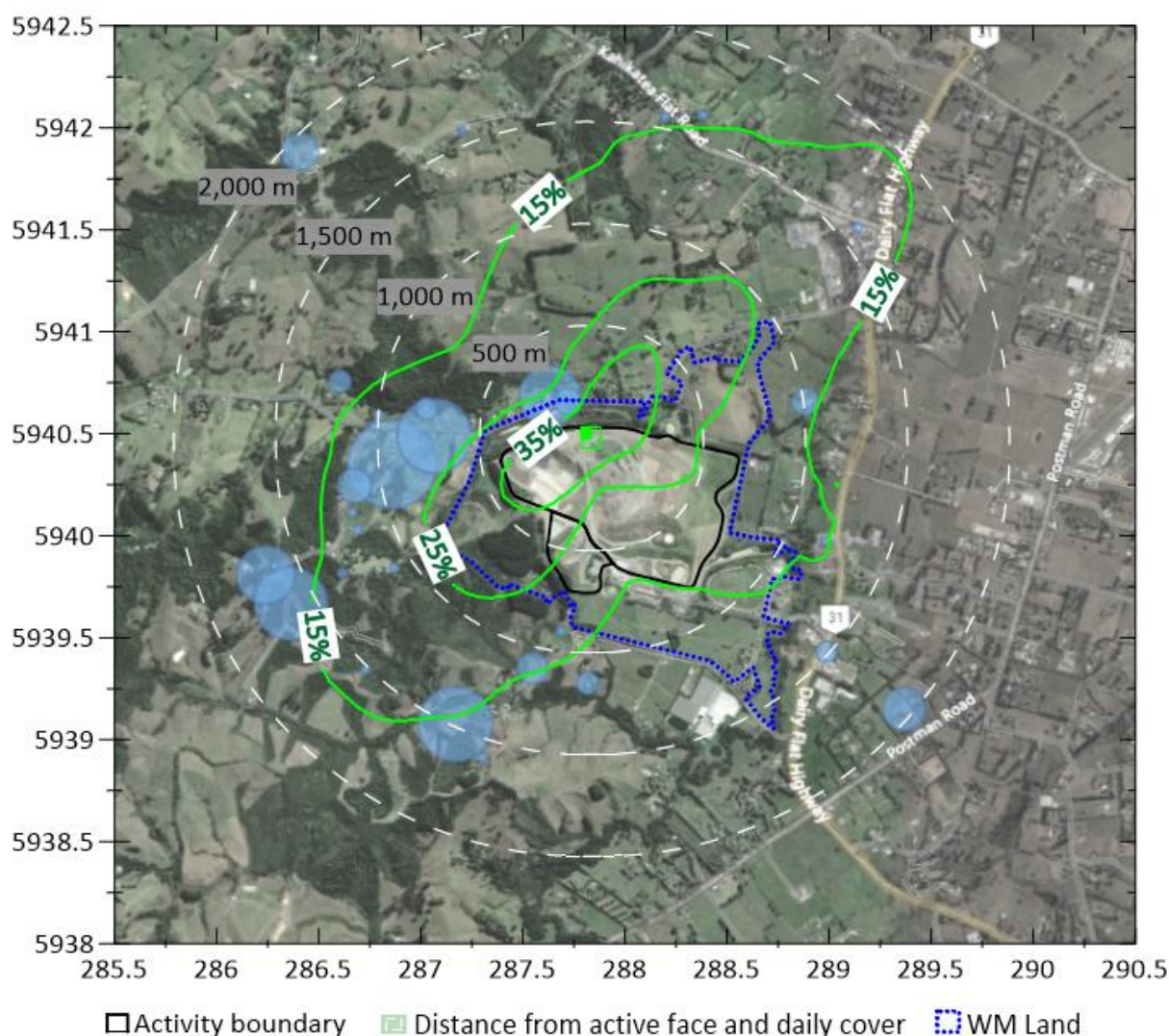


Figure 7.4: Odour frequency contour plots (frequency exceeding 0.005 OU) (ES_N) and odour complaints for 2022

7.4.5 Odour dispersion patterns and separation distance guidance

The analysis described in the previous sub-section identified that the 15% odour frequency contour for exceedance of a nominal concentration of 0.0005 OU generally captured the maximum extent of odour complaints in 2022. To understand how the risk of odour effects will change with the enhanced odour controls described in Section 3.2, odour frequency contour plots for the same current scenario (ES_N) have been compared with the proposed scenario with the northernmost tip face (PS_N) (see Figure 7.5).

These plots demonstrate that the 15% odour contour “contracts” under the proposed scenario and remains largely within the 500 m separation distance contour. This is broadly consistent with the separation distance recommendation in the EPA Victoria Landfill Buffer Guideline (see Section 2.1), for a 500 m buffer from sensitive land uses for landfills with a working face up to 900 m².

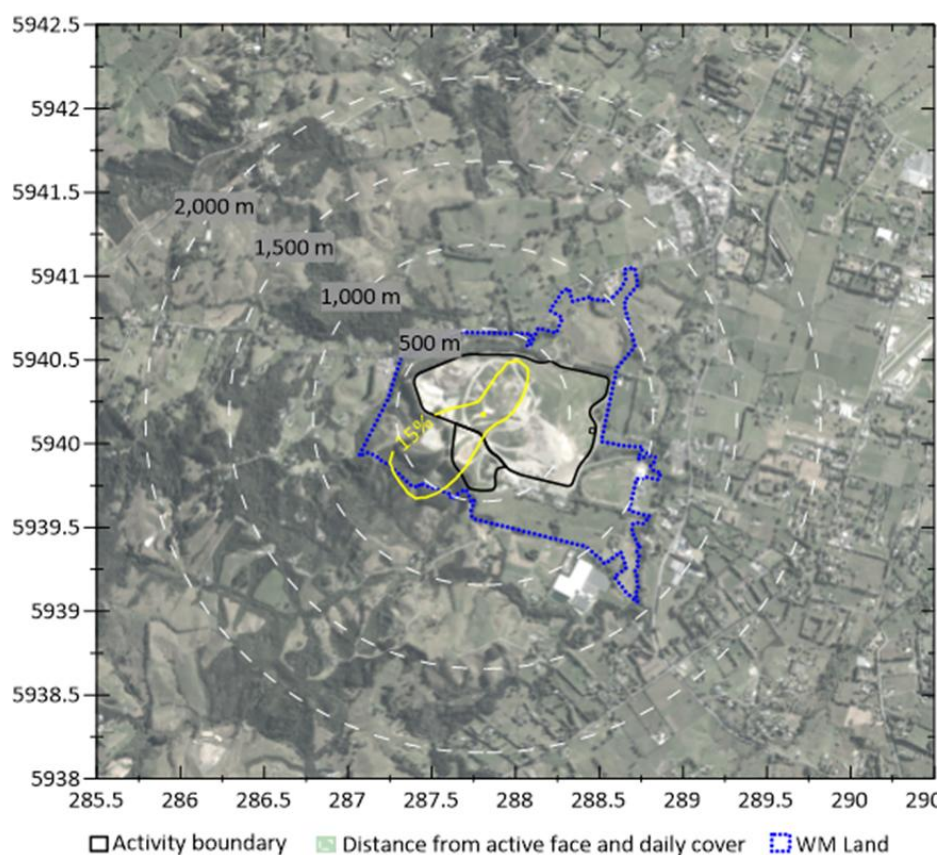
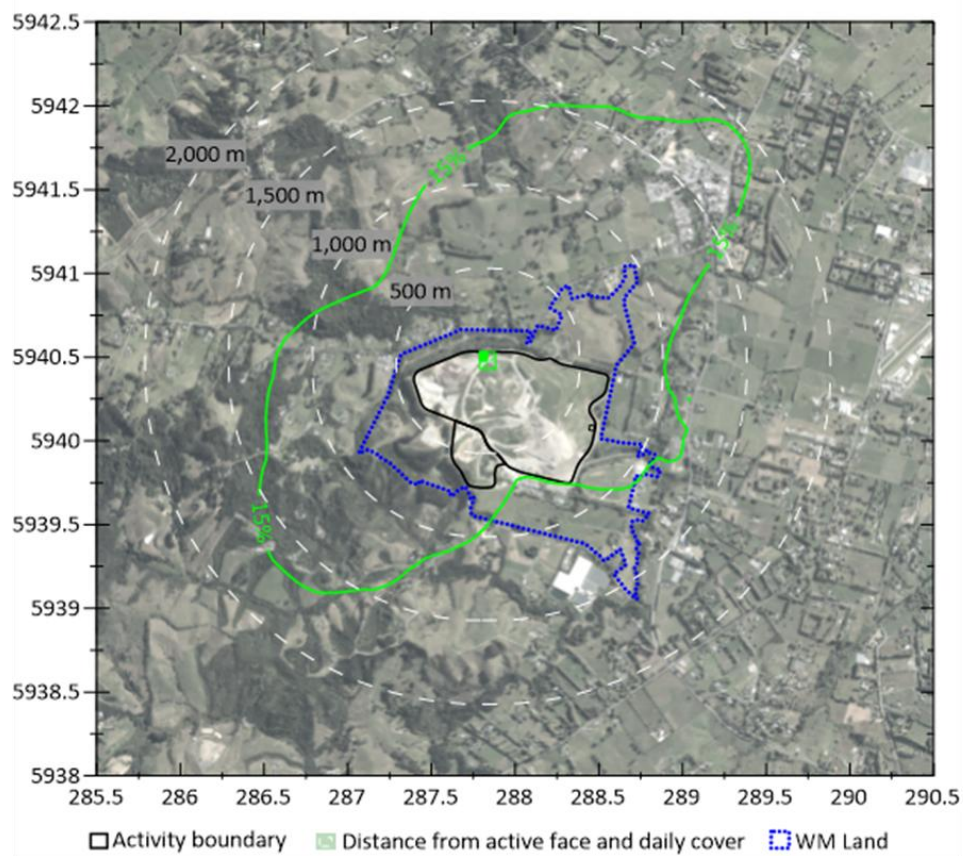


Figure 7.5: Comparison 15% odour frequency contour (exceeding 0.0005 OU) for existing (ES_N) (top) and proposed (PS_N) (bottom) scenarios

7.4.6 Comparison of existing and proposed scenarios

Another way of illustrating the difference between the impacts of the current landfilling activities and the Project is to compare concentration contour plots. As discussed in Section 7.4.1, the absolute odour concentrations predicted by the modelling are unlikely to be accurate, but odour concentration contours can be useful to illustrate the relative change in odour intensity.

North tip face comparison

Figure 7.6 compares the predicted 0.05 OU (99.5th percentile) concentration contour for the northernmost point of filling authorised under the current consents (scenario ES_N) and the northernmost point of filling of putrescible waste for the Project (PS_N). This illustrates how the combination of reduced odour emission rates (from a smaller working face and increased thickness of daily cover) and increasing the separation distance to sensitive receptors reduces the 99.5th modelled odour concentration at any given location.

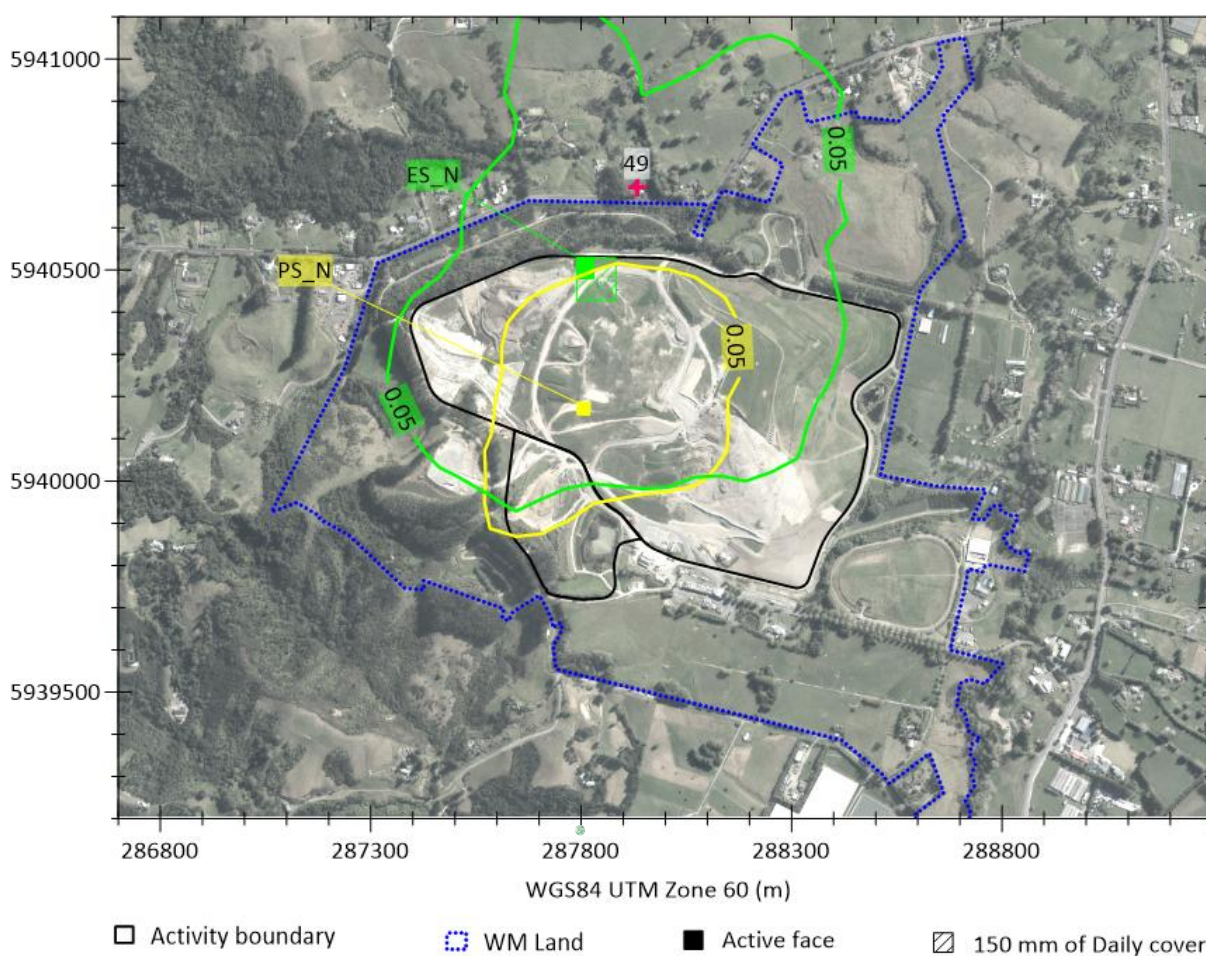


Figure 7.6: Comparison of the 0.05 OU (99.5th percentile) concentration contour for (existing (ES_N) and proposed (PS_N) northside tip face scenarios, 2022 meteorological year.

This analysis can be taken further using cumulative frequency distributions to show how the predicted distribution of hourly modelled odour concentrations at a particular receptor differs between the two scenarios. Looking at the entire distribution of hourly modelled concentrations can provide a more complete picture of the difference in effects compared to simply looking at the peak (99.5th) modelled concentrations.

The most impacted receptor under the modelled existing scenario (ES_N) is Receptor 49. The modelled concentrations at Receptor 49 under the modelled existing scenario (ES_N) and proposed northernmost putrescible tip face scenario (PS_N) are shown in Figure 7.7.

The green dashed lines have been added to show how the graph can be interpreted. These show that, for example, 90% of the time, the modelled odour concentrations are:

- Less than approximately 0.03 OU for the existing scenario; and
- Less than approximately 0.001 OU for the proposed scenario.

This confirms that there is a much lower risk of odour effects at this receptor under the proposed model scenario, which incorporates the larger setbacks and other controls, compared to the existing scenario.

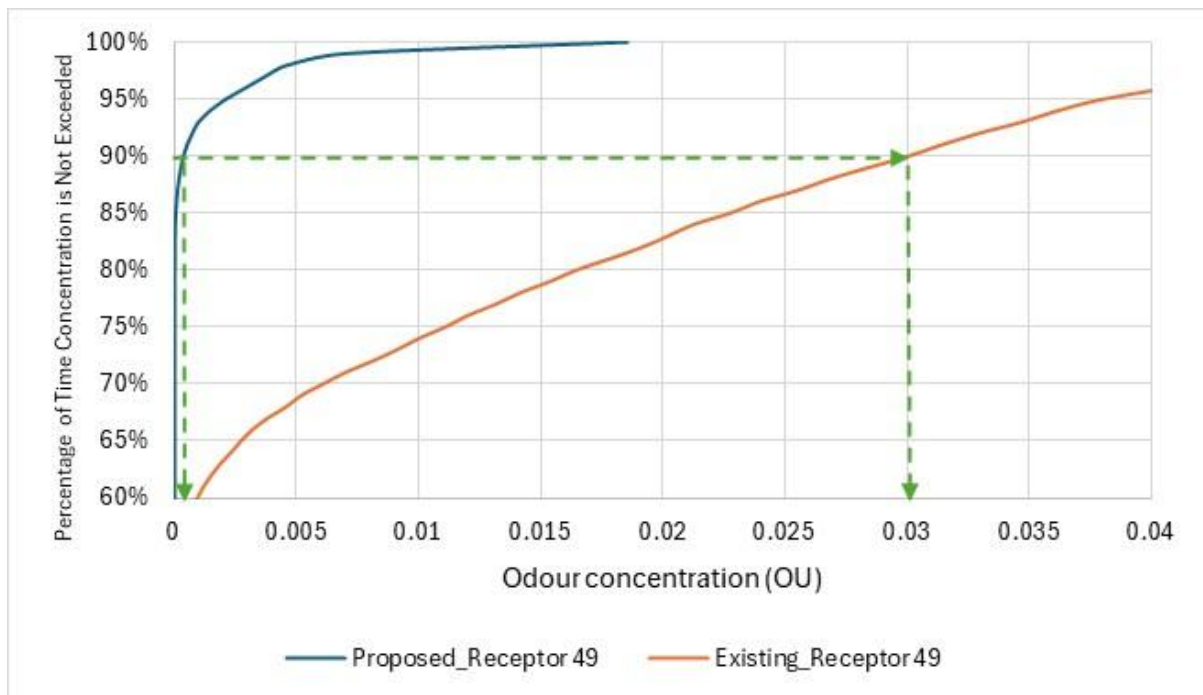


Figure 7.7: Cumulative frequency plot of modelled odour concentrations at Receptor 49 under existing (ES_N) and proposed (PS_N) scenarios

East tip face comparison

Figure 7.8 compares the 0.05 OU (99.5th percentile) concentration contour for the easternmost point of filling authorised under the current consents (ES_E) and the easternmost point of filling of putrescible waste under the proposed consents (PS_E). This scenario differs to the previous one in that filling on the eastern side of the landfill under the currently consented footprint is largely complete.

The location of the tip face under the “existing” scenario represents the closest location where filling will occur on top of previously placed waste to bring the landfill up to final consented contours. Therefore, under the proposed scenario, waste placement could occur closer to sensitive receptors on the eastern side of the landfill than would occur in the future under the current consents (noting that filling has historically occurred in this location).

The closest location of the proposed tip face (PS_E) to any sensitive receptor is shown in Figure 7.8 (note that it is more than 500 m from the closest sensitive receptor). This is a conservative model scenario as the depth of waste in this location would be relatively shallow (so filling would only occur for a relatively short period of time) and will occur behind a bund wall. The effect of the bund at mitigating odours has not been considered in the modelling.

The most impacted receptor under the existing scenario is R77 and under the proposed scenario is R140. Hourly modelled concentrations over a full year at both receptors, for the proposed and existing scenarios, are graphed in Figure 7.9 and Figure 7.10, respectively.

Receptor 77 shows a similar pattern as in the previous sub-section, with substantially lower concentrations under the proposed scenario compared to the existing scenario even though the tip faces are at a similar distance (this will be partly because Receptor 77 is less frequently downwind of the tip face for the proposed scenario compared to the existing scenario).

Receptor 140 is substantially closer to the proposed easternmost tip face compared to the existing scenario. The graph on Figure 7.10 shows that the worst-case concentrations (above the 98th percentile) are higher for the proposed scenario. However, for most of the hours in the year the modelled odour concentrations of odour are lower under the proposed scenario compared to the existing scenario. Importantly, even though the worst-case concentrations are slightly higher under the proposed scenario, they remain low compared to the modelled concentrations predicted at other receptors in the vicinity of the landfill.

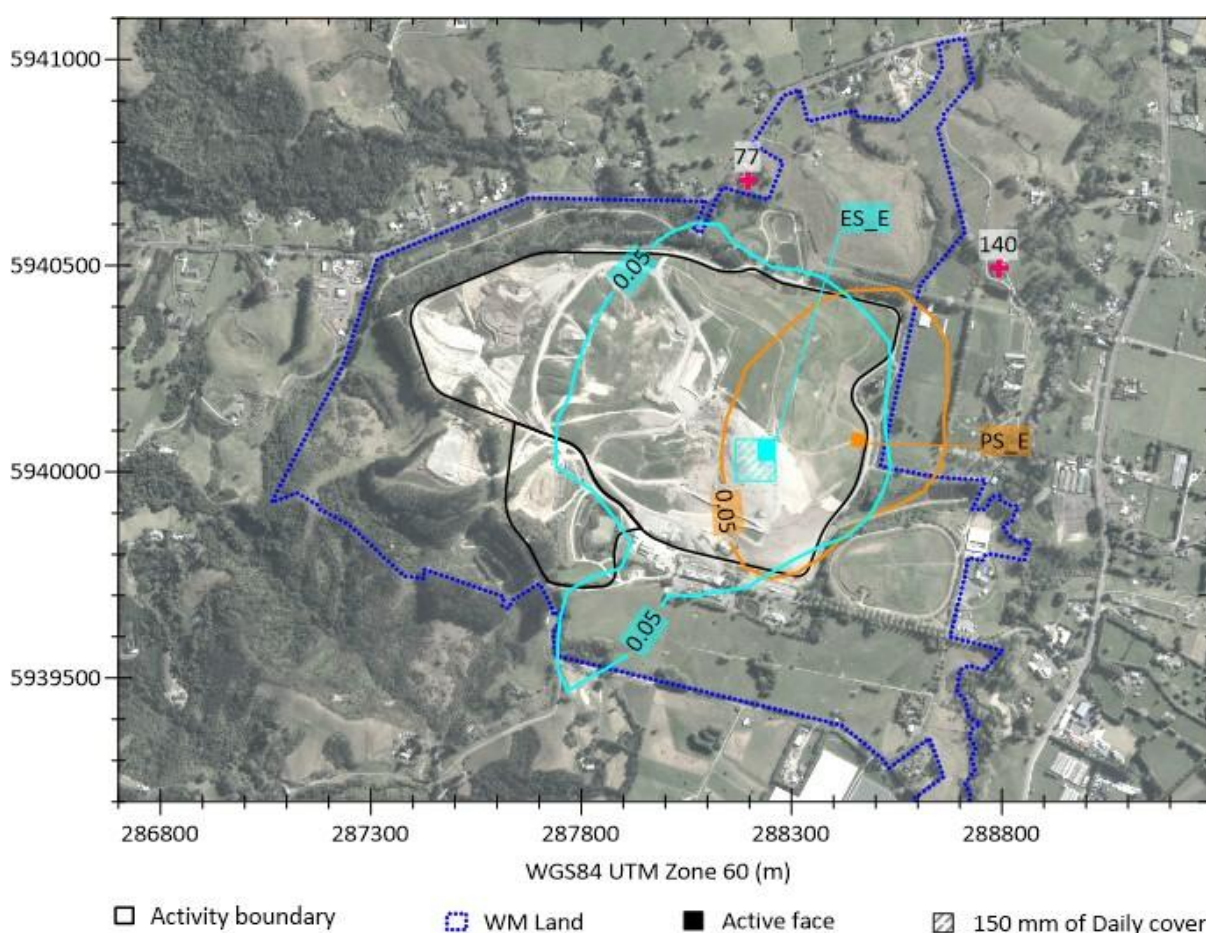


Figure 7.8: Comparison of 0.05 OU (99.5th percentile) concentration contour for (existing (ES_E) and proposed (PS_E) east-side model scenarios, 2022 meteorological year

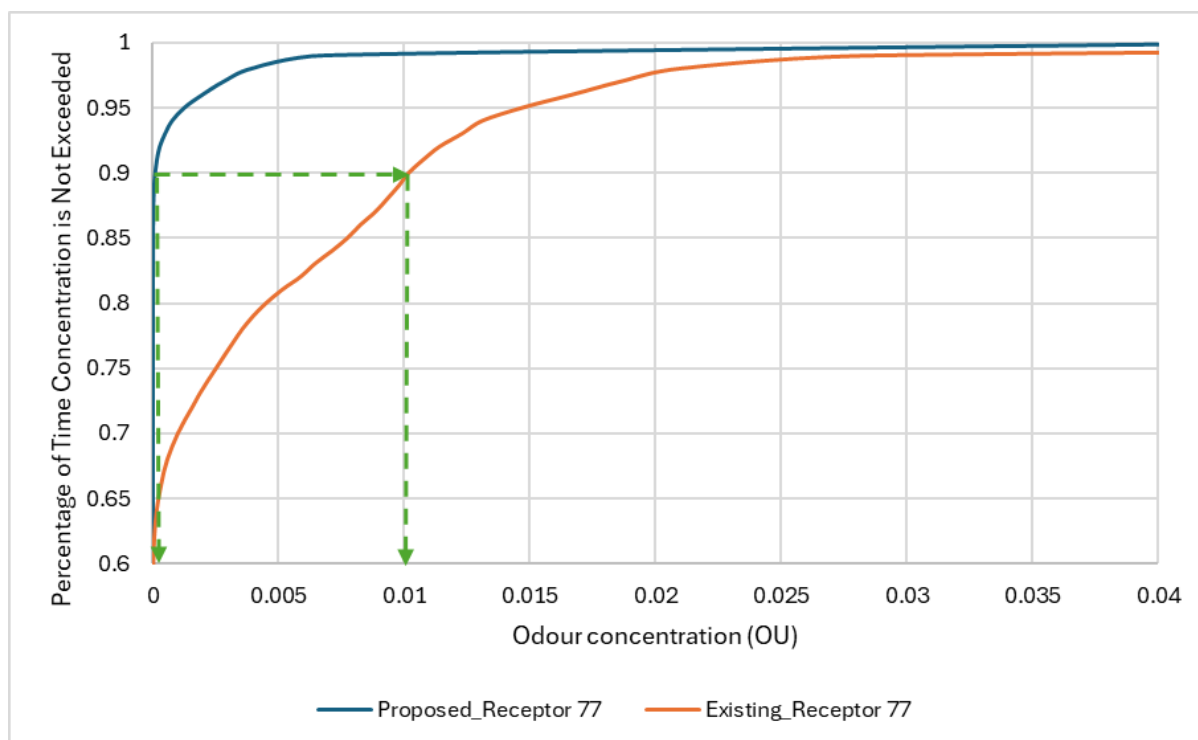


Figure 7.9: Cumulative frequency plot of modelled odour concentrations at Receptor 77 under existing (ES_E) and proposed (PS_E) model scenarios

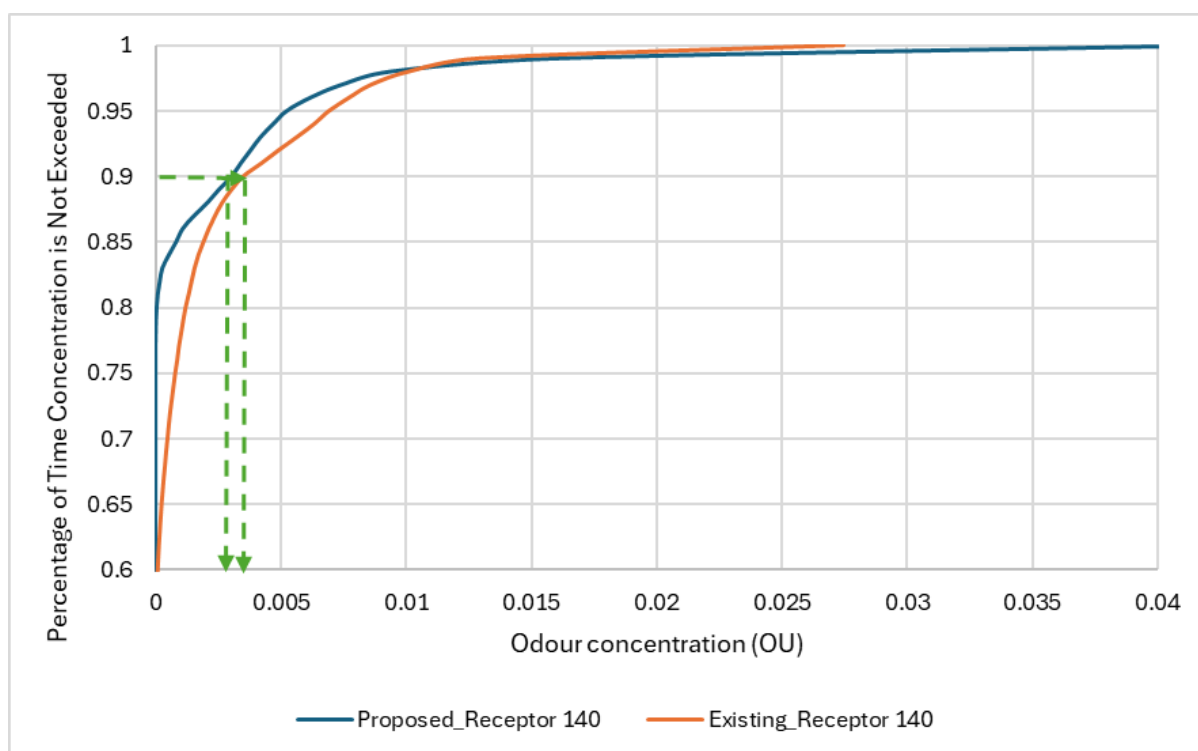


Figure 7.10: Cumulative frequency plot of modelled odour concentrations at Receptor 140 under existing (ES_E) and proposed (PS_E) model scenarios

7.4.7 Discussion of landfill odour dispersion modelling

Odour dispersion modelling has been used to evaluate the relative change in odour effects between landfilling activities authorised by the existing consent and the Project, taking into account the combined influences of meteorology, terrain, separation distance and at-source odour controls.

It is important to note that the absolute odour concentrations predicted by the model should be interpreted with caution given the highly variable nature of landfill odour emissions. The model cannot accurately predict actual odour levels that people might experience on any given day.

Instead, the modelling has been used to:

- Understand how weather patterns and terrain affect where odours are most likely to travel, and
- Compare the proposed operation with currently consented activities to show the relative change in odour risk.

The modelling demonstrates that the proposed odour management controls will result in a significant reduction in the risk of off-site odour effects compared to current activities (and currently authorised activities). The key improvements contributing to this reduction that have been incorporated into the model are:

- Reducing the working face area from up to 2,000 m² (recent practice) to a maximum of 900 m²;
- Increasing daily cover thickness from 150 mm to 300 mm, which effectively eliminates odour emissions from covered areas;
- Delaying acceptance of putrescible waste until 7:30 a.m. during autumn and winter months to avoid overlap with poor dispersive conditions; and
- Maintaining a 500 m separation distance between the tip face for putrescible waste and sensitive receptors

The comparison of existing and proposed scenarios at both the northernmost and easternmost tip face locations shows that modelled odour concentrations are substantially lower under the proposed scenarios for approximately 90% of modelled hours. For example, at Receptor 49 (the most impacted receptor under the proposed northern scenario), the modelled odour concentration that is exceeded 10% of the time reduces from 0.03 OU under the existing scenario to 0.001 OU under the proposed scenario.

While the modelling indicates worst-case modelled odour concentrations may be slightly higher compared to the existing scenario (for the eastern tip face location), the overall frequency and magnitude of potential odour exposure is significantly reduced under the proposed controls.

7.5 Evaluation of LEU odours

7.5.1 Assessment approach

The odour from the LEU has a distinctly different character (described as a burnt, chemical smell) compared to the refuse/LFG odours associated with landfilling activities. This difference in odour character means that the extent to which the LEU contributes to overall odours from the Site can be evaluated separately. The assessment techniques used to evaluate the effects of odour emissions from the LEU are:

- Review of odour patrols and field odour observations that record LEU odours.
- Review of complaints data in relation to LEU odour.
- Odour stack emission testing and dispersion modelling.

As the LEU has a characteristic odour, it has been modelled as a separate odour source and has not been modelled cumulatively with odours from the landfill working face.

It is noted that there are some limitations in modelling plumes that are saturated with water vapour (like the LEU exhaust). As a moist plume rises and cools, water vapour can condense (releasing latent heat) or liquid droplets can evaporate (consuming heat). There is often a net gain in heat and associated plume rise (higher initial buoyancy) from this heating/cooling process, particularly when there is high ambient humidity.

The algorithms in the dispersion model are based on a dry plume. This means that the model will not account for the initial plume rise of a saturated plume and may over-estimate near-field concentrations. As the worst-case impacts of the LEU plume occur relatively close to the source, the modelled concentrations are likely to be slightly over-estimated (i.e. the predicted concentrations should be conservative, rather the under-estimated).

7.5.2 Odour patrols and field odour observations

The daily field odour observations undertaken by WMNZ are described in Section 3.7.1. The nature and strength of any odours detected during these odour patrols is recorded. A summary of LEU-related odour detected during the daily odour patrols is shown in Table 7.2.

Odour from the LEU is not commonly detected. Where odour presence has been detected, it is mostly of very weak intensity with occasional weak intensity and was almost always detected in Sector 1 and/or 2 which are to the south of the Site (see Figure 2.1). Sectors 1 and 2 are downwind of the LEU under northerly and north northeasterly winds and monitoring Points B and C are located relatively close to each other in these sectors along Richards Road close to the WMNZ site boundary.

Table 7.2: Detection of LEU odour in daily odour patrols

Year	LEU-related odour detected at Points B (just inside boundary of WMNZ landholding in Sectors 1 and 2)		LEU-related odour detected at Points C (just outside boundary of WMNZ landholding in Sectors 1 and 2)		LEU-related odour detected at Points D (community monitoring locations)	
	Very weak	Weak	Very weak	Weak	Very weak	Weak
2020	-	-	5	-	-	-
2021	-	-	2	8	-	-
2022	2	-	12	-	12	-
2023	-	-	-	-	-	-
2024	-	-	-	-	-	-
2025	-	-	-	2	-	3

7.5.3 Odour complaints

A summary of the number of odour complaints received by WMNZ that refer to the LEU is set out in Table 7.3. Only three of these complaints were confirmed by WMNZ as being attributable to the LEU, based on consideration of wind conditions, operating status of the LEU, and the presence of odour when a WMNZ staff member attended the complaint¹². The number of complaints from the community about odour from the LEU is low.

¹² Note: the absence of odour when a WMNZ staff member investigate is not taken as meaning there was no odour at the time of the complaint, but is considered alongside other factors such as wind direction and operational information.

Table 7.3: Summary of odour complaints referencing the LEU

Year	Number of odour complaints from community reported as being related to the LEU
2020	3, recorded for the following locations: • 184 Richards Road • 115 Richards Road
2021	7, recorded for the following locations: • 184 Richards Road • 55 Postman Road • 102 Tender Road
2022	4, recorded for the following locations: • 184 Richards Road • 115 Richards Road
2023	5, recorded for the following location: • 184 Richards Road
2024	4, recorded for the following locations: • 184 Richards Road • 126 Richards Road
2025	0

7.5.4 Dispersion modelling of LEU odour emissions

7.5.4.1 Stack parameters

The BeneVap 300 leachate evaporator has two stacks, each with the discharge parameters shown in Table 7.4.

Table 7.4: LEU stack parameters

Parameter (units)	Value
Stack height (m)	6.3
Stack diameter at exit (m)	0.58
Exit velocity (m/s)	2.7
Exit temp (°C)	72

7.5.4.2 Odour emission rates

Odour stack emission testing has been carried out on the LEU on two occasions, with markedly different results (see Table 7.5). Following receipt of the first round of testing (June 2025), discussions were held with Watercare about whether the saturated nature of the LEU emissions could have affected the results; for example, if there had been condensation within the sample bags that may have impacted the odour of the samples.

The standard test method used by Watercare (AS/NZS 4323.3:2001) recommends pre-dilution of the odour sample where there is a risk of condensation of the sample when stored at ambient conditions¹³. The maximum pre-dilution allowed under that standard is 9 (i.e. 8 volumes of neutral gas to 1 volume of sample). Watercare indicated that there was no visible condensation in the sample bags during the June 2025 testing. Notwithstanding this, for the subsequent round of testing (September 2025), two different sample collection methods were used: normal sample collection and samples collected into a partly filled bag (nitrogen) to achieve a nine-fold dilution. Watercare also took photographs of the sample bags to confirm no visible condensation.

As shown in Table 7.5, the odour emission rates measured during the September 2025 testing were similar with and without dilution and were approximately half the odour emission rates measured in the June 2025 testing.

Table 7.5: LEU odour stack emission testing

Date	Odour concentration (OU)			Average odour concentration (OU)	Average odour emission rate (OU/s)
	Run 1	Run 2	Run 3		
June 2025	27,316	31,292	32,604	30,318	19,323
September 2025 (without dilution)	12,498	17,088	17,976	15,658	9,583
September 2025 (with dilution)	11,950	16,444	17,093	14,796	9,165

T+T has also reviewed odour emissions testing from BeneVap LEUs installed at Shoal Bay Landfill, Darwin. The testing was also undertaken in accordance with AS/NZS 4323.3:2001. The testing reports note that due to the high levels of moisture in the emission the odour samples bags were diluted beyond the suggested limit in AS4323.3. The testing company indicated they considered this was required to avoid condensation forming in the sample bags.¹⁴ The dilution rate used is not stated but it is likely that it was calculated to ensure the diluted sample was maintained above the dew point at ambient temperature, similar to the method set out in Ontario (Canada) stack testing guidance.¹⁵

The odour concentrations recorded at Shoal Bay Landfill are shown in Table 7.6. The average odour concentration recorded at Shoal Bay Landfill was much lower (around half) the odour concentration recorded at Redvale Landfill in the September 2025 testing.

Table 7.6: Shoal Bay Landfill BeneVap odour concentrations

Date	Average odour concentration (OU)
17/12/2020	7,523
5/03/2021	5,687
9/02/2022	8,996
9/02/2022	10,039

¹³ AS/NZS 4323.3:2001 'Stationary Source Emissions Part 3: Determination of odour concentration by dynamic olfactometry.

¹⁴ AS4323.3

¹⁵ <https://www.ontario.ca/document/ontario-source-testing-code/part-g-method-6-determination-odour-emissions-stationary-sources>

Date	Average odour concentration (OU)
9/02/2022	9,856
10/08/2022	8,450
10/08/2022	9,190
10/08/2022	7,759
19/10/2022	8,215
19/10/2022	8,501
19/10/2022	8,151
5/02/2023	7,172
5/02/2023	7,293
5/06/2023	8,472
Average	8,236

For the purposes of dispersion modelling, an odour emission rate of 10,730 OU/s was adopted. This was based on the median odour emission rate (rounded up) from the September 2025 testing. This is considered a reasonable (but likely conservative) estimate, based on a comparison with the monitoring data from Shoal Bay Landfill.

7.5.4.3 Results

The odour dispersion modelling results for odour are summarised in Table 7.7 (for the 2022 model year¹⁶) and compared to the GPG Odour, odour dispersion modelling guidelines. An odour concentration contour plot is shown in Figure 7.11.

Table 7.7: Predicted ground level odour concentrations

Receptor Location	Odour Concentration (OU, 99.5 th percentile)	Odour modelling guideline (OU)
Sensitive receptor (R80)	1.3	2 (High sensitivity ¹)
Off-site (south boundary)	2.5	5 (Low sensitivity ²)

Notes:

1. Worst-case impacts during neutral to stable conditions.
2. A guideline of 5-10 OU/m³ is recommended for low sensitivity environments.

¹⁶ The 2022 model year gives rise to higher concentrations than the 2023 model year.

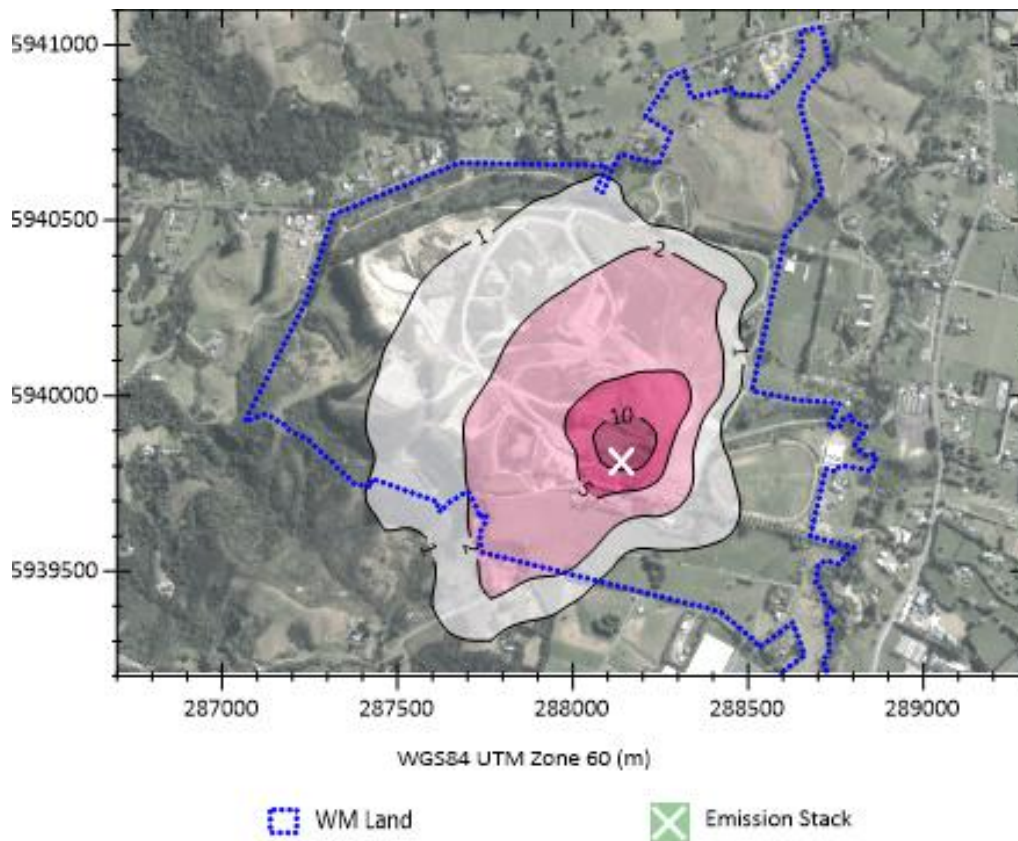


Figure 7.11: Modelled predicted 1-hour average (99.5th percentile) odour concentrations (OU) from the LEU (2022 model year)

7.5.5 Discussion of LEU odours

The LEU is located within the landfill footprint and therefore, at some point over the life of the Project, the LEU will need to be decommissioned to allow additional waste placement. The odour from the LEU has a distinctly different character (described as a burnt, chemical smell) compared to the refuse/LFG odours associated with landfilling activities and therefore the effects of odour from the LEU are not assessed cumulatively with landfill (tip face) odour.

Dispersion modelling (using the median odour emission value from the most recent testing of 10,730 OU/s) demonstrates that odour concentrations from the LEU are predicted to be below the relevant odour modelling assessment criteria at both the most impacted sensitive receptor (1.3 OU/m³ compared to a guideline of 2 OU/m³) and at the off-site boundary (2.5 OU/m³ compared to a guideline of 5 OU/m³).

There appears to be variability in the odour stack emission testing, with measured rates ranging from approximately 9,500 to 19,300 OU/s across the two testing rounds. While applying the highest recorded emission rates in the model would result in exceedance of the odour modelling guidelines it is important to note that the dispersion model is inherently conservative for the LEU emissions. As discussed in Section 7.5.1, the model algorithms assume a dry plume and do not account for the additional plume rise generated by the latent heat dynamics of a saturated, wet plume, which likely results in the over-estimation of near-field concentrations.

Given the limitations and conservatism of the near-field modelling for saturated plumes, empirical evidence should also be considered as it provides a more realistic representation of actual off-site effects. The daily odour patrols indicate that LEU odour is not commonly detected off-site. When it is detected, it is predominantly of very weak to weak intensity in Sectors 1 and 2 (south of the Site), which is consistent with modelled dispersion patterns under northerly winds. Furthermore, odour complaints specifically attributed to the LEU have been consistently low, ranging from 1 to 7 complaints per year over the period from 2020 to 2024. These complaints are almost all from one location south of the Site, which is consistent with the dispersion modelling pattern.

Overall, while there is some uncertainty arising from the variability in the odour emission testing data, the empirical evidence (odour complaints, daily odour patrols, etc) demonstrates that the odours from the LEU do not result in offensive and objectionable odours off-site. Consequently, the odour effects of the LEU are assessed as being minor.

7.6 FIDOL assessment

7.6.1 FIDOL assessment methodology

The Odour GPG sets out an objective framework for evaluating odour effects based on the FIDOL factors, which are described as follows:

Frequency:	The frequency of exposure to odour/dust impacts experienced at a given location. This depends on both the frequency of discharges and the frequency of weather conditions that could transport a discharge towards a sensitive location.
Intensity:	The intensity of odour/dust impacts refers to the strength of the odour or quantity of dust and depends on the degree to which odour sources are controlled but also the separation distance between a source and the receptor.
Duration:	The duration of odour impacts depends on both the duration of the discharge and how long a sensitive location is continuously downwind of the odour source.
Offensiveness:	The offensiveness of the odour relates to both the character of odour and the degree of how pleasant or unpleasant the odour is (i.e. the hedonic tone). For dust, the offensiveness relates to the character of the dust, for example, some dust types such as coal dust have a greater potential for soiling.
Location:	The location factor relates to the sensitivity of the location being assessed, and is typically expressed as low, medium or high. Residential dwellings are considered to have a high sensitivity, whereas rural/pastoral land is considered to have a low sensitivity.

FIDOL factors can take account of both acute and chronic exposure. For example, a single occurrence of a very high intensity odour may constitute an offensive or objectionable effect. This is known as an 'acute' effect. However, 'chronic' effects can also occur if lower intensity odour events occur frequently and/or for longer durations.

The FIDOL assessment is informed by a review of exposure of sensitive receptors to certain wind conditions and terrain features to inform the likely frequency and duration of potential impacts. For odour effects, this focuses on the occurrence of calm conditions and light winds, as these provide the poorest conditions for the dispersion and dilution of odours. For dust, strong winds during dry weather are the focus as these conditions can result in rapid drying of surfaces and wind erosion of material.

7.6.2 FIDOL assessment for odour

The overall assessment of odour effects using the FIDOL factors is presented in Table 7.8. This assessment draws upon multiple lines of evidence discussed in the preceding sections, including historical complaint data, field odour observations, and comparative dispersion modelling.

Table 7.8: FIDOL assessment

Parameter	Discussion	Assessment
Frequency	Provided the LFG collection system is well maintained and operated and the integrity of the cap is maintained, the frequency of odour exposure is mostly influenced by continuous emissions from the active tip face and the occurrence of poor dispersion conditions. The Project incorporates controls to manage this, including delaying the acceptance of putrescible waste until 7:30 a.m. during autumn and winter (May to August). This measure aims to reduce the overlap of the working face being open during periods of higher-risk meteorological conditions.	Based on the expected lower odour emissions from the smaller tip face and areas under daily cover, the frequency of conditions that might give rise to adverse odour events at sensitive receptors is expected to be significantly reduced compared to the current baseline. As indicated by the dispersion modelling and comparative assessment with odour complaints, the risk of sensitive receptors experiencing odour at an intensity that could lead to either acute or chronic effects is assessed as low. Therefore, the frequency of odour effects at sensitive receptors is expected to be low.
Intensity	Odour intensity at sensitive locations is determined by the emission strength at the source and the available separation distance for dilution. The Project includes at-source controls designed to lower emission strength, such as limiting the putrescible working face to a maximum of 900 m², and increasing daily and intermediate cover depths to 300 mm and 450 mm, respectively. Additionally, the Project incorporates a 500 m separation distance between putrescible waste placement and sensitive dwellings. This is broadly consistent with EPA Victoria Landfill Buffer Guidelines for a landfill with a less than 900 m² working face.	Comparative dispersion modelling indicates that under the proposed parameters, modelled 90th percentile odour concentrations at the most impacted receptors are generally much lower than those associated with the current landfill. The combination of the reduced working face area and the 500 m separation distance is expected to adequately manage the intensity of residual odour reaching sensitive receptors, reducing the likelihood of offensive or objectionable effects. Although it is not possible to conclude that odours will never be detectable off-site, the intensity of off-site odour at sensitive locations is anticipated to be weak to very weak, at most.
Duration	The duration of an odour event relies on the persistence of the emission and the prevailing weather conditions transporting it. Investigations of historical complaints indicate that off-site odours from the Site typically dissipate rapidly and are often not detectable by the time the odour is investigated by WM (usually within 30 minutes). The Project's operational controls, including delayed winter opening times, the rapid burial of special wastes, and the use of odour suppressant sprays, are designed to further manage the duration of any transient odour plumes.	Extended exposure to noticeable landfill odour at sensitive receptors is not expected to be a frequent occurrence. Any off-site odour detections are likely to be brief and transient.

Parameter	Discussion	Assessment
Offensiveness / Character	By their nature, landfill odours (including refuse and LFG) have an unpleasant character and are generally classified as moderately to very unpleasant.	While the intrinsic character of the odour from the landfill remains unpleasant, the potential effect is mitigated by reducing its intensity (generally to below detectable levels) at sensitive locations. With the intensity and frequency managed by the 500 m setback and 900 m ² tip face limit, the risk of exposure to this offensive character at sensitive receptors is assessed to be low.
Location	The receiving environment includes rural lifestyle dwellings, which are considered to have a high sensitivity to odour due to continuous occupancy and high amenity expectations. The Project incorporates this sensitivity into its design by restricting putrescible waste placement to areas at least 500 m away from these dwellings, while utilising areas closer to the boundaries for non-putrescible waste.	By maintaining a minimum 500 m separation distance between the primary odour source (the tip face for putrescible waste) and sensitive receptors, the amenity expectations of these locations are accounted for. Based on this framework, the overall odour effects on these sensitive locations are assessed as minor.

7.7 Conclusions about effects of odour

The assessment of odour effects for the Project concludes that the overall risk of offensive or objectionable odour effects at sensitive locations is low, and the project's odour effects are considered minor. The evaluation considered two distinct odour sources: general landfill operations (specifically the active tip face and fugitive landfill gas emissions) and the LEU,

Landfill Odour

Subject to implementation of best practice controls on the LFG collection system and landfill cap, the active tip face is expected to remain the most significant source of odour at the landfill. The assessment demonstrates that proposed operational improvements will effectively reduce the spatial footprint and risk of off-site odour exposure compared to the current situation (based on currently consented activities). This conclusion is based on enhanced at-source odour controls and management strategies, including:

- Limiting the active working face for putrescible waste to a maximum of 900 m², down from the recent practice of 1,200 m² (up to 2,000 m² at times).
- Maintaining a minimum separation distance of 500 m between the placement of putrescible waste and sensitive receptors (dwellings). This aligns with the recommended separation distances in the EPA Victoria Landfill Buffer Guidelines.
- Increasing the thickness of daily cover from 150 mm to 300 mm and intermediate cover from 300 mm to 450 mm. Flux hood sampling indicates this effectively eliminates odour emissions from covered areas.
- Delaying the acceptance of putrescible waste until 7:30 a.m. during the cooler months of autumn and winter (May to August). This prevents the removal of daily cover during cold, calm meteorological conditions that are least conducive to odour dispersion.

Odour dispersion modelling, calibrated against historical field observations and complaints records, indicates that these measures will substantially contract the area of potential odour exposure. A FIDOL (Frequency, Intensity, Duration, Offensiveness, and Location) assessment concludes that while the intrinsic character of landfill odour remains unpleasant, the controls will heavily manage the intensity and frequency of odours reaching sensitive locations. As a result, off-site odour detections are expected to be brief, transient, and of weak to very weak intensity at most.

LEU Odour

Odour from the LEU was assessed separately because it has a distinct "burnt, chemical smell" that is readily distinguishable from typical refuse and landfill gas odours. The assessment found the odour effects from the LEU to be minor, based on the following reasoning:

Modelling (which assumes a dry plume and ignores the beneficial thermal rise of the saturated LEU exhaust) predicts an odour concentration of 1.3 OU/m³ at the most impacted sensitive receptor, which is well below the stringent high-sensitivity guideline of 2 OU/m³. Odour emission testing suggests the odour emissions from the LEU are variable and may be higher than the modelled emission rate at times. However, LEU-related complaints are consistently low, ranging from only 1 to 7 complaints per year between 2020 and 2024, and are mostly isolated to a single location. Furthermore, LEU odours were rarely detected during daily off-site odour patrols, with zero detections recorded in 2023 and the first three quarters of 2024.

Overall, through the implementation of at-source odour controls and increased separation distances, the odour effects generated by the Project will be adequately managed and are assessed as minor.

8 Effects of contaminant emissions from the Energy Centre

8.1 Assessment approach

Most of the time, the LFG collected at the Site will be managed through combustion in the generators. However, there may be times when a mix of generation and flaring is required and, for example in the event of a prolonged power cut, when it may be necessary to flare all the gas for a period of time.

The impact of emissions of products of combustion from burning LFG in the generators and/or flares on local air quality has been assessed using atmospheric dispersion modelling and comparison with assessment criteria. As described in Section 4.2, the maximum rate of LFG collection is expected to be approximately 8,000 m³/hour (which is similar to current levels). For the purpose of dispersion modelling, the following two scenarios have been considered:

- Operation of 15 generators, each burning approximately 670 m³_{LFG}/hour (assuming 50% methane), representing emissions in the worst-case year¹⁷; and
- Operation of three flares, representing conditions that may occur in the event of a power failure or other outage affecting all of the generators.

The generator emissions scenario gives higher ground level pollutant concentrations than the flare scenario (so, flaring does not introduce different air quality effects compared to the generators). This is due to the increased thermal buoyancy of plume emissions from the flare stacks compared to 15 individual generator stacks.

The details of the atmospheric dispersion modelling study are set out in Appendix E.

8.2 Ambient air quality monitoring for SO₂

The previous air discharge consenting process for Redvale Landfill identified uncertainty with the stack emission measurements of SO₂ emissions from the generators. Given this, the dispersion modelling used a worst-case SO₂ emission rate based on a mass balance of the maximum amount of H₂S likely to be present in the incoming LFG. To address the uncertainty about SO₂ emission rates, the current air discharge consent includes a requirement for SO₂ air quality monitoring to be conducted.¹⁸

WMNZ commissioned Watercare Services Limited to undertake monitoring of SO₂ in the air around Redvale Landfill from July 2019 to July 2021. Over the monitoring period there were 14 generators installed at the Site (currently there are 15 however typically only 14 are operating at any one time). Therefore, current levels of ambient SO₂ are likely to be similar to the concentrations measured during the 2019 to 2021 period. Similarly, the monitoring period is likely to be representative of the worst case (as discussed in Section 4.3.4, there are not expected to be more than 15 generators operating any one time).

A continuous SO₂ monitor was operated at a location on the southern side of the WMNZ landholding, approximately 230 m west southwest of the generators. This location is specified in the consent and was based on dispersion modelling of the Energy Centre emissions carried out for the previous resource consent application.

¹⁷ This is a conservative scenario as it is equivalent to approximately 10,000 m³/hour LFG being combusted

¹⁸ Condition 54 of the air discharge consent for the landfill (Permit 37802), required SO₂ monitoring to be carried out before the installation of a 16th generator (note the 16th generator has not yet been installed).

The measured SO₂ levels over the two-year monitoring period were low compared to relevant New Zealand air quality standards and guidelines (NESAQ and AAQG) and the WHO 2021 guidelines (see Table 8.3).

The same conservative modelling approach used previously, has been used in the dispersion modelling assessment described later in this report (see Section 8.6). The measured concentrations (with 14 generators operating) were much lower than the values predicted at the monitoring location (with 15 generators operating), as shown in Table 8.1. As such, the monitoring results are considered to provide a more realistic assessment of likely effects of SO₂ compared to the dispersion modelling.

Table 8.1: Comparison of highest measured SO₂ concentration and maximum modelled SO₂ concentration at monitoring location (15 generators)

Averaging period	Highest measured concentration (July 2019 – July 2021) (µg/m ³)	Modelled concentration (µg/m ³)	Assessment criteria
1-hour ¹	45.2	195	350 ²
24-hour	26.3	87	120 (40 ³)

Notes:

1. 99.9th percentile modelled concentration.
2. Nine allowable exceedances in a 12-month period.
3. 3 to 4 allowable exceedances in a 12-month period.

8.3 Emission rates

Stack exhaust emissions from the generators are routinely monitored under the conditions of the air discharge consent (Permit 37802). Stack testing is carried out every three years on three of the generators, on a rotating basis. Five rounds of stack testing data (from 2013 to 2025) have been reviewed to develop representative emission rates of PM₁₀ and CO. The NO_x emission rate is based on the supplier's specified maximum concentration of 500 mg/Nm³, which is higher than the stack testing results.

Stack emission testing of SO₂ emissions from the generators using a combustion gas analyser typically gives very low concentrations. These concentrations are much lower than would be expected from the amount of sulphur (mostly in the form of H₂S) present in the LFG, if it is assumed that all of the sulphur is oxidised and converted to SO₂. For the purposes of a conservative assessment, the modelled emission rate of SO₂ is based on a mass balance calculation assuming the concentration of H₂S in the LFG is 600 mg/Nm³. This is at the upper end of the range of H₂S concentrations measured in the LFG over the period 2020 to March 2025 (228 to 606 mg/Nm³).

8.4 Atmospheric conversion of NO_x to NO₂

NO_x refers to the sum of the most common oxides of nitrogen; nitric oxide (NO) and nitrogen dioxide (NO₂). The component of NO_x with a potential to affect human health is NO₂. The relative proportions of NO and NO₂ in a plume vary with distance from the source as NO is oxidised in the atmosphere to NO₂. The MfE Good Practice Guide for Assessing Discharges to Air from Industry (GPG Industry) provides guidance on evaluating the atmospheric conversion of NO to NO₂, based on the modelled total NO_x emissions from a source. The approach is referred to as the 'proxy method' and is described in the following equation.

$$[NO_2] = [NO_x]_{mod} \times F(NO_2) + [Proxy NO_2]$$

Where:

$[NO_x]_{mod}$ = the modelled NO_x concentration

$F(NO_2)$ = the mass fraction of nitrogen dioxide in the NO_x emission

$[Proxy NO_2]$ = Background combined nitrogen dioxide and ozone

The first terms in the equation represent the primary NO_2 emissions from the stack (i.e. the proportion of NO_x emitted as NO_2). Typically, NO_x emissions from combustion processes comprise about 5 to 10 % NO_2 . However, the lean emission technology used in the LFG generator burners to minimise total NO_x emissions can produce a higher percentage of primary NO_2 . Emission testing of the generators at Redvale Landfill has produced variable results in regard to the NO_2/NO_x ratio in the generator emissions. A value of 20% has been used in this assessment. The flare emissions have been assumed to comprise 10% primary NO_2 , which is likely to be conservatively high.

Default 'Proxy NO_2 ' concentrations are recommended in the GPG Industry. However, the default concentrations have been derived from measurements in central Auckland where there are much higher levels of traffic emissions and background NO_x concentrations. Use of default Proxy NO_2 concentrations are likely to significantly overstate background NO_2 concentrations around the Site.

The Proxy NO_2 method was evaluated in a research paper presented at the Clean Air Society of Australia and New Zealand (CASANZ) conference in 2022 (Turnwald, R, Simpson, J. 2022). This paper recommended alternative proxy NO_2 concentration values for rural settings based on NO_x concentration measurements near the NZ Steel Mill at Glenbrook. The alternative proxy NO_2 concentration values are compared with the MfE recommended values in Table 8.2. Given the similarity of the rural receiving environment, these alternative Proxy NO_2 concentration values have been used in this assessment.

The 'Proxy Method' is only applicable to 1-hour and 24-hour averaging periods. Consequently, for the purposes of assessing annual average NO_2 , a conservative screening approach has been used: The predicted NO_x concentration has been assumed to be entirely NO_2 and has been added to the NZTA default background NO_2 concentration (i.e., 4.5 $\mu\text{g}/\text{m}^3$).

Table 8.2: Comparison of proxy NO_2 concentration values

Location	Averaging period	Proxy NO_2 value ($\mu\text{g}/\text{m}^3$)
MfE (2016c) recommendations for non-roadside locations	1-hour	95
	24-hour	75
Recommendations for rural locations from (Turnwald & Simpson, 2022)	1-hour	42
	24-hour	23

8.5 Assessment criteria

The dispersion modelling predictions have been compared to the relevant New Zealand ambient air quality standards and guidelines (Table 8.3). These standards/guidelines are sourced from:

- Ambient air quality standards set in the National Environmental Standards for Air Quality (NESAQ)¹⁹.
- The National Ambient Air Quality Guidelines (AAQG)²⁰.

¹⁹ Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (updated 2011)

²⁰ Ministry for the Environment (2002). Ambient Air Quality Guidelines. Wellington

- The Auckland Ambient Air Quality Targets (AAAQT) from (Table E14.3.1 in the Auckland Unitary Plan.

The ambient air quality standards and guidelines set out in Table 8.3 and Table 8.4 apply at locations where people are likely to be exposed over the relevant averaging period. Exposure can be categorised as short-term (e.g., 1-hour) or longer-term exposure (e.g., 24-hours or longer). Accordingly, for short-term exposure (i.e., 1-hour), it is reasonable to assume a person could be exposed at any location beyond the WMNZ site boundary including rural land. By contrast, longer term exposure periods (24-hours and longer) are most applicable at locations such as residences where people may reasonably be present for 24-hours or longer.

Table 8.3: New Zealand ambient air quality standards, guidelines and Auckland regional targets

Pollutant	Averaging period	Standard/guideline value ($\mu\text{g}/\text{m}^3$)	Allowable annual exceedances	Source
Fine particulate (PM_{10})	24-hour	50	1	NESAQ
	Annual	20	N/A	AAQG/AAAQT
Fine particulate ($\text{PM}_{2.5}$)	24-hour	25	N/A	Proposed NESAQ / AAAQT
	Annual	10	N/A	Proposed NESAQ / AAAQT
Nitrogen dioxide (NO_2)	1-hour	200	9	NESAQ
	24-hour	100	N/A	AAQG/AAAQT
Sulphur dioxide (SO_2)	1-hour	570	0	NESAQ
	1-hour	350	9	NESAQ
	24-hour	120	N/A	AAQG
Carbon monoxide (CO)	1-hour	30,000	N/A	AAQG/AAAQT
	8-hour	10,000	N/A	AAQG

The GPG Industry specifically references the World Health Organization (WHO) 2005 air quality guidelines that were published in 2006. However, in September 2021, the WHO published an updated suite of ambient air quality guidelines (WHO 2021 guidelines)²¹. These guidelines are defined as a level where “it is assumed that adverse health effects do not occur or are minimal below this concentration level”²².

The WHO 2021 guidelines are intended to be used as science-based recommendations to policymakers at a national or local level for consideration in setting their own standards and frameworks for managing air pollution. They have not yet been formally evaluated in New Zealand for adoption as New Zealand air quality guidelines or standards. In a recent decision, the Environment Court²³ agreed with the position that it would be premature to adopt the WHO 2021 guidelines as assessment criteria, but that they should be considered to provide a complete assessment. For this reason, the WHO 2021 guidelines have also been considered in this assessment for completeness.

²¹ World Health Organization. (2021). WHO global air quality guidelines: Particulate matter ($\text{PM}_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide.

²² Ibid., ix

²³ *Allied Asphalt Ltd v Bay of Plenty Regional Council* [2024] NZEnvC 247 at [254]-[255].

Table 8.4: WHO 2021 air quality guidelines

Pollutant	Averaging period	Guideline value ($\mu\text{g}/\text{m}^3$)	Allowable annual exceedances
Fine particulate (PM_{10})	24-hour	45	3–4
	Annual	15	N/A
Fine particulate ($\text{PM}_{2.5}$)	24-hour	15	3–4
	Annual	5	N/A
Nitrogen dioxide (NO_2)	24-hour	25	3–4
	Annual	10	N/A
Sulphur dioxide (SO_2)	24-hour	40	3–4
Carbon monoxide (CO)	24-hour	4,000	3–4

8.6 Dispersion modelling results

8.6.1 Evaluation against New Zealand ambient air quality standards and guidelines

The dispersion modelling results for all combustion scenarios are presented in Appendix E, for both model years. The highest predicted concentrations of contaminants, which are from the generator emissions modelling, are summarised in Table 8.5.

The predicted concentrations of all pollutants are below (and in most cases well below) the New Zealand ambient air quality standards and guidelines at sensitive receptors (or anywhere beyond the boundary in the case of pollutants with 1-hour averaging criteria).

Table 8.5: Assessment of dispersion modelling results against New Zealand ambient air quality standards and guidelines (generator emissions, 2022 model year)

Contaminant	Averaging Period	Maximum predicted ground level concentration at sensitive receptor ($\mu\text{g}/\text{m}^3$)	Background concentration ($\mu\text{g}/\text{m}^3$)	Worst case predicted cumulative concentration at sensitive receptor ($\mu\text{g}/\text{m}^3$)	Air quality guideline/standard concentration ($\mu\text{g}/\text{m}^3$)	Source	Percentage of standard/guideline
Fine particulate (PM_{10})	24-hour	3.4	18.1	21.5	50	NESAQ	43%
	Annual	0.2	6.9	7.1	20	AAQG	35%
Fine particulate ($\text{PM}_{2.5}$)	24-hour	3.4	8.7	12.1	25	Proposed NESAQ	48%
	Annual	0.2	2.7	2.9	10	Proposed NESAQ	29%
Nitrogen dioxide (NO_2)	1-hour	100	42 ^a	142	200	NESAQ	71%
	24-hour	35	23 ^a	58	100	AAQG	58%
Sulphur dioxide (SO_2)	1-hour	201	0	201	350	NESAQ	57%
	24-hour	71	0	71	120	AAQG	59%
Carbon monoxide (CO)	1-hour	2,384	5,000	7,384	30,000	AAQG	25%
	8-hour	1,828	2,000	3,828	10,000	NESAQ	38%

Notes:

a Proxy NO_2 values as discussed in Section 8.4

8.6.2 Comparison with WHO 2021 guidelines

The maximum model result for 24-hour average SO₂ exceeds the WHO 2021 guideline. This model result is much higher than measurements of ambient SO₂ concentrations discussed in Section 8.2. The highest measured 24-hour concentration, at a location within the Site that will be more impacted than the nearest dwelling, was 26.3 µg/m³, which is well below the WHO 2021 guideline value of 40 µg/m³. This suggests that the modelling is highly conservative, likely due to the emission rates being over-stated.

Cumulative concentrations of 24-hour and annual average NO₂ are predicted to exceed the WHO 2021 guideline. The annual average model prediction is likely to over-state actual effects as it uses the highly conservative assumption that all emitted NO_x is converted to NO₂. There is some uncertainty about NO₂ impacts because of the variability in the Primary NO₂ emissions and the need to account for atmospheric chemistry. To address this uncertainty, WMNZ has recently commenced ambient air quality monitoring for NO₂ at the same location where the ambient SO₂ monitoring was previously undertaken.

Table 8.6: Comparison of dispersion modelling results with WHO 2021 guidelines (generator emissions, 2022 model year)

Contaminant	Averaging Period	Maximum predicted ground level concentration at sensitive receptor ($\mu\text{g}/\text{m}^3$)	Background concentration ($\mu\text{g}/\text{m}^3$)	Worst case predicted cumulative concentration at sensitive receptor ($\mu\text{g}/\text{m}^3$)	WHO 2021 air quality guideline ($\mu\text{g}/\text{m}^3$)	Percentage of guideline
Fine particulate (PM_{10})	24-hour	3.4	18.1	21.5	45	48%
	Annual	0.2	6.9	7.1	15	47%
Fine particulate ($\text{PM}_{2.5}$)	24-hour	3.4	8.7	12.1	15	81%
	Annual	0.2	2.7	2.9	5	58%
Nitrogen dioxide (NO_2)	24-hour	35	23	58	25	232%
	Annual	10	4.5	14.5	10	145%
Sulphur dioxide (SO_2)	24-hour	71	0	71	40	178%
Carbon monoxide (CO)	24-hour	842	0	842	4,000	21%

8.7 Conclusions about effects of emissions from the Energy Centre

All modelled concentrations of contaminants, cumulative with expected background concentrations, are below, and in most cases well below, the relevant New Zealand air quality standards and guidelines.

The modelled concentrations of SO₂ (24-hour) and NO₂ (24-hour and annual) are higher than the WHO 2021 guidelines. These guidelines do not have any formal status in New Zealand but have been considered for completeness.

In regard to SO₂, a 2-year ambient SO₂ monitoring programme conducted by WMNZ demonstrates that these model predictions are highly conservative and unlikely to occur in reality.

In regard to NO₂, the ability to assess effects against the much lower WHO 2021 guidelines is limited by the available techniques to reliably predict the atmospheric conversion of emitted NO to NO₂. To address potential uncertainties in the assessment of NO₂ effects against the WHO 2021 guidelines, WMNZ has commenced an NO₂ monitoring programme at the same location the previous SO₂ monitoring was carried out.

9 Effects of contaminant emissions from the LEU

9.1 Assessment approach

The discharges to air from the LEU comprise mainly water vapour and a mixture of combustion gases (NO_x , CO, SO_2 , ammonia and trace quantities of VOC).

The LEU will divert a small proportion ($370 \text{ m}^3/\text{hr}$ per unit) of the collected LFG from being destroyed in the generators. As such, the emissions of combustion products from the LEU are less than (around half) the emissions from a single generator. The LEU is located slightly north of the Energy Centre. The dispersion modelling of combustion emissions from the Energy Centre has considered the air quality impact of burning all of the collected LFG in generators (or in flares in the event the generators are not available). For this reason, the emissions of combustion products from the LEU have not been evaluated separately as they are considered to already be adequately addressed.

Other than combustion products and odour, ammonia is the main contaminant emitted from the LEU. Ammonia will contribute to odour emissions from the LEU. Odour effects have been assessed in Section 7.5.

Model predictions of ammonia have also been compared to the AAQG critical level of $8 \mu\text{g}/\text{m}^3$ (annual average) for the protection of ecosystems.

In terms of potential human health effects, ammonia is a respiratory and eye irritant. There are no New Zealand health-based air quality guidelines for ammonia. The California Office of Environmental Health Hazard Assessment (OEHHA) acute and chronic Reference Exposure Levels (REL) for ammonia are $3,200 \mu\text{g}/\text{m}^3$ (1-hour average) and $200 \mu\text{g}/\text{m}^3$ (annual average). The OEHHA REL is two orders of magnitude higher than the ecological effects-based critical level. For this reason, the assessment has focussed on ecological effects. If ecological effects are acceptable then it follows that there will also be no unacceptable human health effects from ammonia.

There will also be some emissions of low boiling point VOCs from the LEU. The effects of VOC emissions from the LEU have been assessed at a screening level using benzene as an indicator contaminant because of its relatively low boiling point and assessment criterion. The cumulative effects of benzene and other VOCs is assessed more comprehensively in the Health Risk Assessment report (HRA).

The details of the atmospheric dispersion modelling study are set out in Appendix E.

9.2 Emission rates

Stack emission testing for ammonia, BTEX²⁴, VOCs, mercury and H_2S was undertaken on the LEU stack by Watercare in June 2025 and the results are presented in Table 9.1. As discussed above, benzene has been selected as a representative VOC for this assessment and a more comprehensive assessment of VOC emissions from the LEU is included in the HRA.

The stack concentration of H_2S was less than the AAQG of $7 \mu\text{g}/\text{m}^3$ (without any dispersion) and all results for mercury were below the limits of detection ($8.25 \mu\text{g}/\text{m}^3$), therefore emissions of mercury and H_2S have not been modelled as the effects will be well below the AAQG.

²⁴ Benzene, toluene, ethylbenzene and xylenes

Table 9.1: Stack emission testing for LEU stack

Contaminant (unit)	Measured concentration (mg/Nm ³)			Average concentration	Representative stack emission rate (g/s)
	Run 1	Run 2	Run 3		
Ammonia	532.1	749.3	126.6	469.3	0.14
Benzene	0.16	0.11	0.16	0.14	4.1 x 10 ⁻⁵
Hydrogen sulphide (H ₂ S)	0.007	0.005	0.002	0.004	1.1 x 10 ⁻⁶

9.3 Dispersion modelling results

9.3.1 Ammonia

The dispersion modelling results for ammonia are shown in Table 9.2 and a concentration contour plot is shown in Figure 9.1. Maximum predicted concentrations of ammonia are well below the critical level of 8 µg/m³ (annual average) at the Site boundary. For this reason, the effects of ammonia emissions from the LEU are assessed as negligible and there have been no further investigations to identify whether there are any sensitive ecological receptors in the area.

Table 9.2: Ammonia dispersion modelling results

Averaging period	Receptor location	Maximum predicted ground level concentration at sensitive receptor (µg/m ³)		Air quality guideline/standard concentration (µg/m ³)	Source	Percentage of guideline
		2022	2023			
Annual	Off-site	1.67	1.22	8 (ecosystems)	AAQG	21%

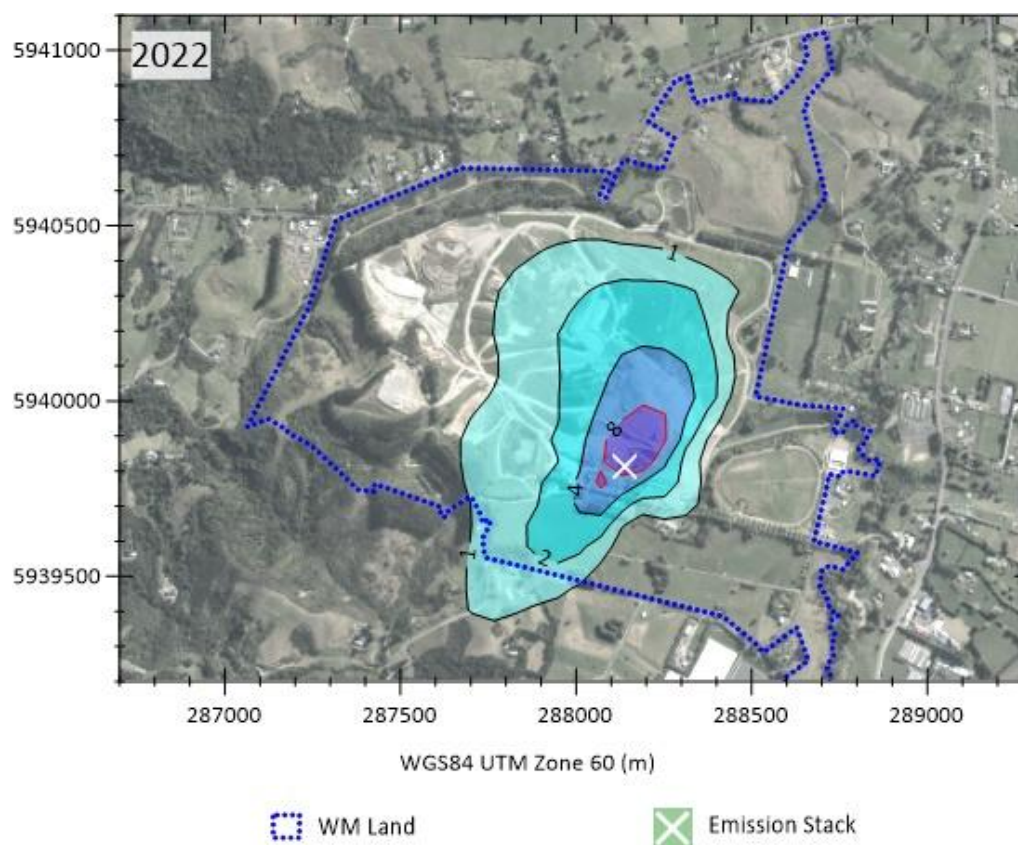


Figure 9.1: Modelled predicted annual average ammonia concentrations ($\mu\text{g}/\text{m}^3$) from the LEU

9.3.2 Benzene

The dispersion modelling results for ammonia are shown in Table 9.3. The maximum predicted concentration of benzene at the most impacted receptor is $0.00023 \mu\text{g}/\text{m}^3$ (annual average), which is less than 0.01% of the AAQG of $3.6 \mu\text{g}/\text{m}^3$ (annual average).

Table 9.3: Benzene dispersion modelling results

Averaging period	Receptor location	Maximum predicted ground level concentration at sensitive receptor ($\mu\text{g}/\text{m}^3$)		Air quality guideline/standard concentration ($\mu\text{g}/\text{m}^3$)	Source	Percentage of guideline
		2022	2023			
Annual	R80	0.00023	0.00016	3.6	AAQG	<0.01%

9.4 Conclusions about effects of emissions from the LEU

The assessment of contaminant emissions from the LEU has focused on ammonia and VOCs (using benzene as an indicator contaminant). Emissions of combustion products from the LEU burner are comparable to emissions from a single generator and are encompassed within the Energy Centre assessment presented in Section 8.

The dispersion modelling demonstrates that predicted concentrations of both ammonia and benzene are well below the relevant New Zealand ambient air quality guidelines:

- Ammonia: Maximum predicted annual average concentration at the Site boundary is well below the critical level of $8 \mu\text{g}/\text{m}^3$ recommended for the protection of ecosystems.
- Benzene: Maximum predicted annual average concentration at the most impacted receptor is $0.00023 \mu\text{g}/\text{m}^3$, which is less than 0.01% of the AAQG of $3.6 \mu\text{g}/\text{m}^3$.

Given these very low predicted concentrations, the effects of ammonia and VOC emissions from the LEU are assessed as negligible. The cumulative effects of VOC emissions are assessed more comprehensively in the Health Risk Assessment report.

The effects of odour emissions from the LEU are addressed separately in Section 7.5.

It is noted that the LEU is located within the landfill footprint and will be decommissioned at some point over the life of the Project to allow for additional waste placement. Therefore, emissions from the LEU will not occur over the whole life of the Project.

10 Conclusions

The sources of actual or potential discharges to air from the Project are the same as from the existing landfill activities, and principally comprise:

- Odour, which can be related to the active tip face, the waste itself and/or fugitive emissions of LFG.
- Combustion products from the burning of collected LFG in the electricity generators or flares at the Energy Centre. The collected LFG is burnt to destroy methane (a greenhouse gas) and other contaminants (including odorous contaminants).
- Combustion products, ammonia, odour and other contaminants from the LEU.
- Dust emissions from construction activities and landfill operations, including stockpiling of cover material.

Odour

Provided the LFG collection system cap is well maintained and operated and the integrity of the cap is maintained, the tip face is the most significant source of odour from landfilling activities. By limiting the working face for putrescible waste to a maximum of 900 m² and maintaining a minimum separation distance of 500 m from existing occupied dwellings, the Project aligns with the recommended separation distances in the EPA Victoria Landfill Buffer Guidelines. These Guidelines were developed based on EPA Victoria's experience with odour complaints at a range of landfills in Victoria, Australia.

Further improvements in odour control are proposed as part of the Project. In particular:

- Restricting the acceptance of putrescible waste until after 7:30 a.m. (currently 6:15 a.m.) during autumn and winter (May to August) to minimise odour emissions from opening up the working face coinciding with poor dispersive conditions.
- Increasing the required thickness of daily and intermediate cover.

With these improvements, the odour controls proposed for the Project are considered to reflect best practice in Australasia.

The effects of emissions of odour from landfilling activities have been assessed using a variety of assessment tools, in accordance with recommended good practice. These various assessment tools have been used together to inform an overall evaluation using the FIDOL factors. As the landfill has been operating since 1993, the effects of current landfill activities are well understood and have been used as a baseline to evaluate the potential effects of the Project, taking into account differences between the existing and proposed activities.

Dispersion modelling shows that the overall frequency, duration and spatial extent of exposure to odour from landfilling (principally odour from the tip face) is reduced under the Project compared to the existing consented activities. While waste placement on the eastern side will occur closer to some residents than future stages of the currently consented footprint, historical filling has already occurred in these locations). The dispersion modelling, calibrated against historical field observations and complaints records, demonstrates that the spatial footprint of potential odour exposure is heavily contracted under the Project compared to the existing landfill activities. By adopting the 900 m² limit on the active working face and maintaining a 500 m separation distance between sensitive receptors and the placement of putrescible waste (along with the other proposed controls to reduce odour), the risk of offensive or objectionable odour effects at sensitive locations is assessed as low.

The LEU is another source of odour at the Site. The LEU has a distinctive odour that is readily differentiated from landfill odours. While there is some uncertainty arising from the variability in the odour emission testing data, the empirical evidence (odour complaints, daily odour patrols, etc) demonstrates that the odours from the LEU do not result in offensive and objectionable effects. Consequently, the odour effects of the LEU are assessed as being minor.

Combustion products and other contaminants

The combustion of LFG is a key control to minimise the discharge of contaminants to air. However, the combustion process generates contaminants (such as NO_x and SO₂). Contaminants are also discharged from the evaporation of leachate in the LEU. The effects of these contaminants have been assessed using dispersion modelling and comparison with relevant New Zealand ambient air quality standards and guidelines. All modelled concentrations, cumulative with expected background concentrations, are below the relevant New Zealand air quality guidelines and standards.

The more stringent WHO 2021 air quality guidelines have also been considered for completeness, although these do not have any formal status in New Zealand. The modelled concentrations of SO₂ (24-hour) and NO₂ (24-hour and annual) at sensitive receptors are higher than the WHO 2021 guidelines.

In regard to SO₂, a 2-year ambient SO₂ monitoring programme conducted by WMNZ demonstrates that these model predictions are highly conservative. Measured SO₂ concentrations were less than one third of the model predictions at the same location (approximately 230 m west southwest of the Energy Centre) and well below the WHO 2021 guidelines. Concentrations beyond the Site boundary will be even lower.

While modelling indicates theoretical exceedances of the WHO 2021 guidelines for NO₂, these results are considered conservative. The model results are being ground-truthed by ambient air quality monitoring, which will confirm the actual level of effects.

Dust

Potential dust emissions associated with the Project are limited to activities such as construction earthworks, stockpiling and removal of cover material, traffic movements on unpaved internal roads, and placement of waste and cover at the working face. The majority of dust generated by these activities comprises relatively coarse, settleable particles, which typically deposit within a short distance of the source.

A range of standard dust management and mitigation measures will be implemented at the Site, including the use of water carts and dust suppression units, vehicle speed restrictions, wheel washing, road maintenance, and progressive grassing of areas under intermediate and final cover. These measures are consistent with good practice for landfill operations and are expected to be effective in minimising dust generation.

Taking into account the nature of the activities, the effectiveness of the proposed dust control measures, and the separation distances between potential dust sources and the nearest sensitive receptors (at least 140 m), it is considered very unlikely that operational dust emissions would result in any discernible adverse effects beyond the Site boundary.

11 References

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- Ministry for the Environment (2002). Ambient Air Quality Guidelines. Wellington: Ministry for the Environment
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12 Applicability

This report has been prepared for the exclusive use of our client WMNZ, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application under the Fast-track Approvals Act 2024 and that an Expert Panel as the consenting authority will use this report for the purpose of assessing that application. We understand and agree that this report will be used by the Expert Panel in undertaking its regulatory functions.

Tonkin & Taylor Ltd
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Appendix A Code of Conduct

Compliance with the Environment Court Practice Note 2023

I confirm that, in my capacity as lead author of this report, I have read and abided by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses contained in the Practice Note 2023.

I am a Technical Director at Tonkin & Taylor Ltd (T+T), where I specialise in air quality and hazardous substances management. I have been employed at T+T for over 25 years. Prior to joining T+T, I worked in the fertiliser and speciality chemicals industry.

I have over 25 years' experience in the assessment and management of air quality, including the evaluation of risks to human health. I am a Fellow of the Clean Air Society of Australia and New Zealand. I hold the following qualifications – Bachelor of Engineering (Chemical and Materials) and a Diploma in Environmental Management, both from the University of Auckland.

Recent relevant projects and services that I have been involved with include:

- Proposed Auckland Regional Landfill - preparation of the air quality and odour assessment and screening health risk assessment for a proposed new landfill.
- Tirohia Landfill - preparation of the air quality and odour assessment for a proposed new phase of development.
- New Zealand Steel, Glenbrook – preparation of technical air quality assessment and Screening Health Risk Assessment for potential exposure to contaminants via water and air to support applications for replacement consents for discharges to air and water from the Steel Mill.
- Redvale Landfill – preparation of various technical assessments to support applications for changes to consent conditions, new (replacement) air discharge consent and land use consent



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Jennifer Simpson

Technical Director – Environmental Engineering

Appendix B LFG collection modelling

B1 Overview

Landfill gas (LFG) is a byproduct of the anaerobic decomposition of organic waste, such as food, paper, and green waste, in a landfill. As microorganisms break down this material in the absence of oxygen, they generate a mixture of gases, primarily methane (CH₄) and carbon dioxide (CO₂), along with trace amounts of other compounds like nitrogen, oxygen, ammonia, sulphides, and volatile organic compounds (VOCs). Methane, which typically makes up 45 to 60% of LFG, is a potent greenhouse gas and poses safety risks due to its flammability, while the trace gases can contribute to odours and air pollution.

The rate and volume of LFG generation depend on factors such as organic waste composition and type, availability of nutrients, moisture content, temperature, pH and landfill design. The most widely used LFG prediction model is the first order model. The simplest approach is the single stage first order decay such as the Scholl Canyon Model, which assumes that waste degradation parameters are constant over the analysis period.

The model assumes that the gas generation rate is at its peak upon initial waste placement, after a lag time during which anaerobic conditions are established in the landfill. The gas generation rate is then assumed to decrease exponentially (i.e. first order decay) as the organic fraction of the landfill waste decreases. The total methane generation from the entire landfill is generally assumed to be at its peak upon the landfill closure if a constant annual acceptance rate is assumed.

The model calculates methane generation rates, and these are converted to total LFG using the average methane concentration of 50%.

The Scholl Canyon equation is as follows:

$$Q_{\text{Methane}} = k \cdot L_0 \cdot R(e^{-k(t)})$$

Where:

Q_{Methane}	=	Methane generation rate at time “t” (cubic metres per year)
L_0	=	Methane generation potential (cubic metres per tonne of waste)
R	=	Average annual waste acceptance rate during the active life (tonnes per year)
k	=	Methane generation rate constant (1/year)
t	=	Time since initial waste placement (years)

The annual waste acceptance rate (R) is as per historical data available for the Site. The projected annual tonnage until closure is assumed to be 600,000 tonnes. The selection of values used of the key parameters of L_0 and k are discussed in more detail below.

B2 Methane generation potential (L_0)

The theoretical maximum yield of LFG from a tonne of municipal solid waste is dependent upon its composition. However, an estimate based upon balanced stoichiometric equations for a mixture of paper waste and food waste probably provides an upper limit of the potential yield. In practice, the gas yield is considerably less than this.

Some researchers have reported “obtainable L_0 ” which accounts for the nutrient availability, pH, and moisture content within the landfill. The researchers point out that “obtainable L_0 ” is less than the theoretical L_0 . Even though waste may have a high cellulose content, if the landfill conditions are not hospitable to the methanogens, the potential methane generation capacity of the waste may never be reached. The “obtainable L_0 ” is approximated from overall biodegradability of “typical” composite waste or individual waste components, assuming a conversion efficiency based on landfill conditions.

The maximum “obtainable L_0 ” for typical waste streams is 170 m³/tonne for a 100% organic waste stream. WMNZ has provided historical annual tonnage data with organic content for each year. Therefore, the appropriate L_0 value has been calculated on the basis of the assumed percentage of organic material in the incoming waste. The range of values used for L_0 in the methane generation model is between 54.4 m³/tonnes and 83.3 m³/tonnes, equivalent to a range of organic fraction between 32% and 49%.

B3 Methane generation rate constant (k)

The methane generation rate constant, k, describes how quickly the methane generation rate decreases, once it reaches the peak rate after waste has been placed. The higher the value of k, the faster the methane generation rate from each sub-mass decreases over time.

The value of k is a function of:

- Waste moisture content
- Availability of nutrients
- pH
- Temperature
- Nature of the waste (whether it degrades rapidly or slowly).

The higher the value of k, the greater the predicted peak LFG generation rate and the more quickly the LFG production will decrease once the landfill is closed.

An empirical relationship of a line of best curve between rainfall and k has been developed by SWANA²⁵ based on literature, laboratory simulator results, and measured gas generation rates. The value for k adopted in the methane generation model is 0.106 year⁻¹, based on the average rainfall encountered at the Site in the order of 1,200 mm/year.

B4 Landfill gas collection predictions

The methane generation model has been developed and calibrated against the historical methane collection data available at the Site from 1997 to 2025. The collection efficiency that has been applied to the model assumes a collection rate of 85%. The upper bound and lower bound methane collection estimates have been developed with $\pm 10\%$. All of this data is shown in Figure Appendix B.1. The peak rate of methane collection, which is assumed to occur around the year of landfill closure, is estimated to be between 3,600 m³/hr and 4,400 m³/hr.

²⁵ Solid Waste Association of North America

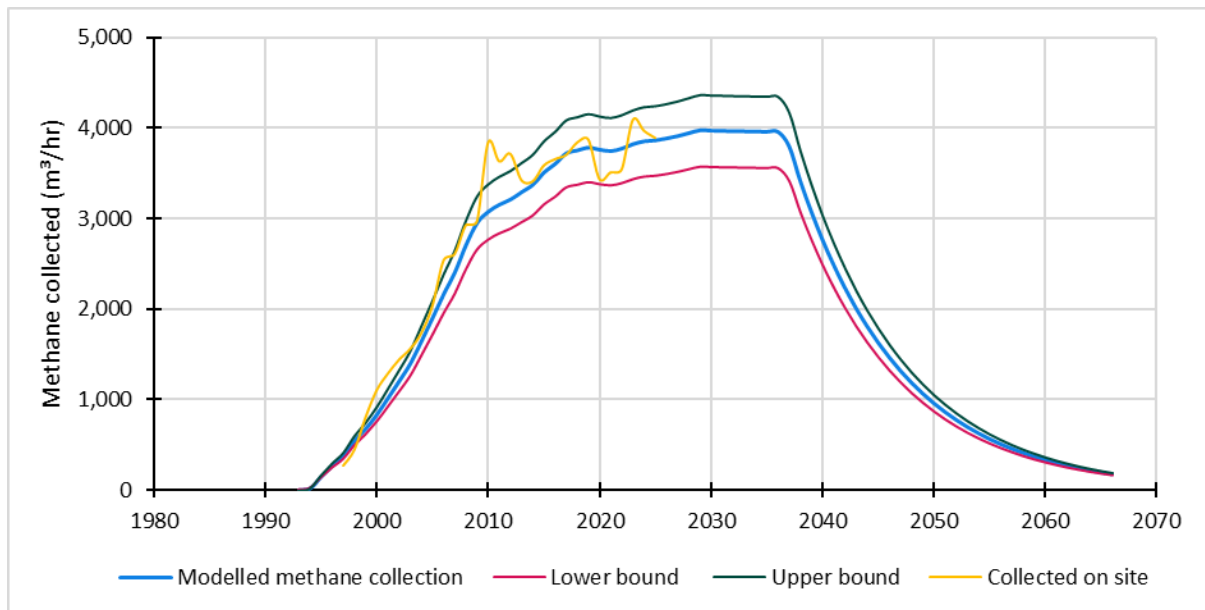


Figure Appendix B.1: Predicted rates of methane collection

Appendix C Evaluation of odour suppressant fog cannons

C1 Overview

Odour fog cannons are currently used at the Site as a mitigation measure for odour emissions from the push ramp and tip face. To investigate the efficacy of the odour fog cannons, T+T completed a series of odour observations at the Site on 13 May 2025.

The on-site odour field observations were undertaken in a manner consistent with standard methods and five of the six observers had a current “nose calibration” by Watercare Services to ensure they were in the normal range of population sensitivity to odour. Each odour observation involved recording the intensity and character of odour per every ten seconds for ten minutes.

The week before the observations there had been heavy rain at the Site that had flooded some of the LFG collection network. As a result, work was underway on the day of the observation to remove some of the pipework and five gas wells to reroute them to an alternative vacuum source. Consequently, there was some LFG odour noted during the observations. A team calibration observation (Observation 1) was conducted to ensure all members could discern the LFG from the fresh refuse (tip face) odour. Odour observations characterised as LFG were excluded from the analysis.

The observers recorded an average odour intensity for the ‘calibration’ survey of 1.3 to 1.9. The purpose of using multiple observers is to account for any differences in sensitivity and allow the results to be averaged.

Hydrogen sulphide monitoring was conducted by WMNZ during the observations. There were some detections at low levels, however given the potentially confounding influence of the LFG leak these results have not been included in this report.

C2 Methodology

The methodology of the observation study is detailed in Table Appendix C.1

Table Appendix C.1: Odour fog cannon observation study methodology

Parameter	Description
Staff	Odour monitoring was undertaken with the following staff: • Six T+T staff members undertook observations • Three WMNZ staff (one operated H₂S monitor downwind, two switched cannons on and off)
Wind conditions	The forecast wind conditions were monitored to allow for the study to be undertaken with as close to ideal wind conditions as possible. The preferred wind conditions were as follows: • Wind strength: Light to moderate winds to drive odour toward observers (light air to fresh breeze on the Beaufort scale). Strong breeze and higher classifications were scheduled to be avoided, likewise, complete calms may not be suitable if the odour is not dispersed toward the observers. • Wind direction: Winds blowing from the southwest through to the west (toward the northeast or east of the working cell). Observations were taken downwind of push ramp and tip face. On 13 May 2025, wind conditions ranged from a Beaufort 1 - 3 (light air to gentle breeze) from the southwest, as shown in Figure Appendix C.2
Locations	Observers were positioned far enough away from the working cell so that odour was not overwhelming while the odour fog cannons were operational. This was done so that the 'on' and 'off' odour conditions were not both characterised as 'strong'. Conversely, observers were not positioned so far away that odour was undetectable under either condition. Based on the initial scouting Site visit, staff were located 100-180 m downwind of the nearest odour cannon. Observers were arranged in two main tiers in an arc to accommodate minor shifts in wind direction with a further single observer located further downwind. Two observers were positioned at the closer tier, three at the intermediate arc, and one as far downwind as possible within the Site. The monitoring locations are shown in Figure Appendix C.3.
Method	An initial observation, where all observers were positioned together, was undertaken to determine variations in odour sensitivity between the staff. Following this, observers were positioned at the arc locations as described above. An alternating sequence of field observations was undertaken as follows: 1 One 10-minute field odour observation downwind while cannons were operating. 2 Instruction given to switch cannons off. 3 One 10-minute field odour observation downwind while cannons were off. 4 Cannons switched back on. 5 Repeated alternating cannon-on and off observations (steps 1 – 4) twice more. 6 Final 10-minute field odour survey downwind while cannons were on. Observations were recorded using T+T's GIS-integrated field odour observation survey form. In one instance, where a staff member's phone battery ran out, a printed version of the 10-second interval record was used. Paper forms were later entered into the GIS-integrated system for analysis. Staff remained at the same location for each observation. It is noted that while the odour fog cannons were switched off, the network of T-bar odour suppressant sprays continued to operate throughout.

The observation timings and cannon status are summarised in Table Appendix C.2.

Table Appendix C.2: Observation sequence

Start time	Observation number	Note
11:15	1	Cannons on – test run, all participants located on the second tier of the observation locations
11:36	2	Cannons on
11:54	3	Cannons off
12:15	4	Cannons on
12:32	5	Cannons off
12:55	6	Cannons on
13:13	7	Cannons off
13:38	8	Cannons on

The locations of the odour observations conducted during the study are shown in Figure Appendix C.3, and a wind rose representing wind conditions measured at the Redvale weather monitoring station during the study period is shown in Figure Appendix C.2.

Observers were positioned based on the actual wind direction experienced on the ground at the time of the survey. The weather station data is supplementary to these on-ground observations and, because the readings are taken from a 10 m mast and may differ slightly from conditions at ground level (i.e. winds tend to be stronger with increasing height above ground level).

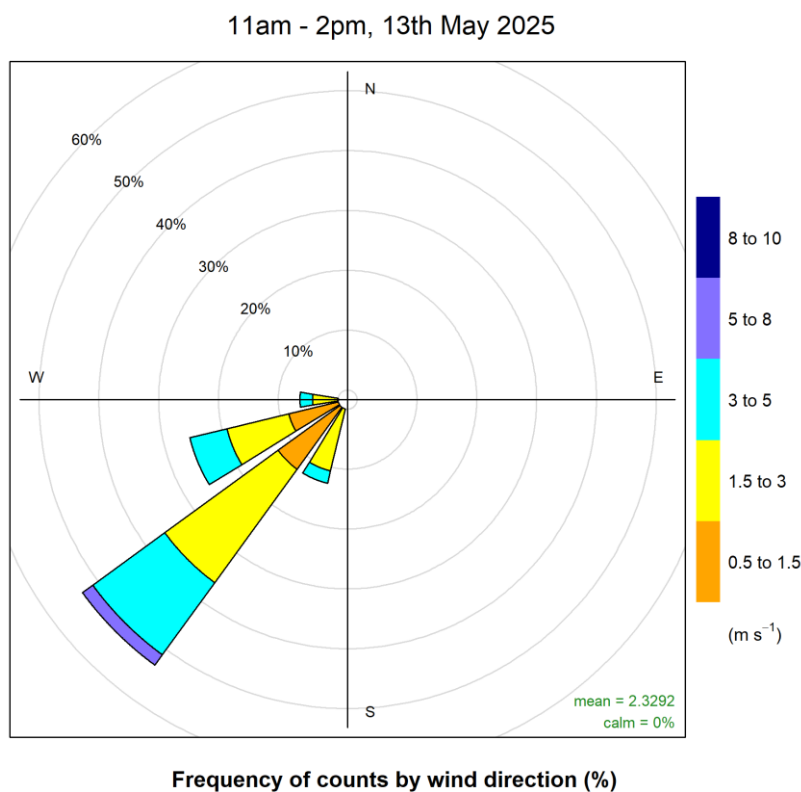


Figure Appendix C.2: Windrose representing conditions during observations on 13 May 2025, meteorological data from Redvale Site weather station

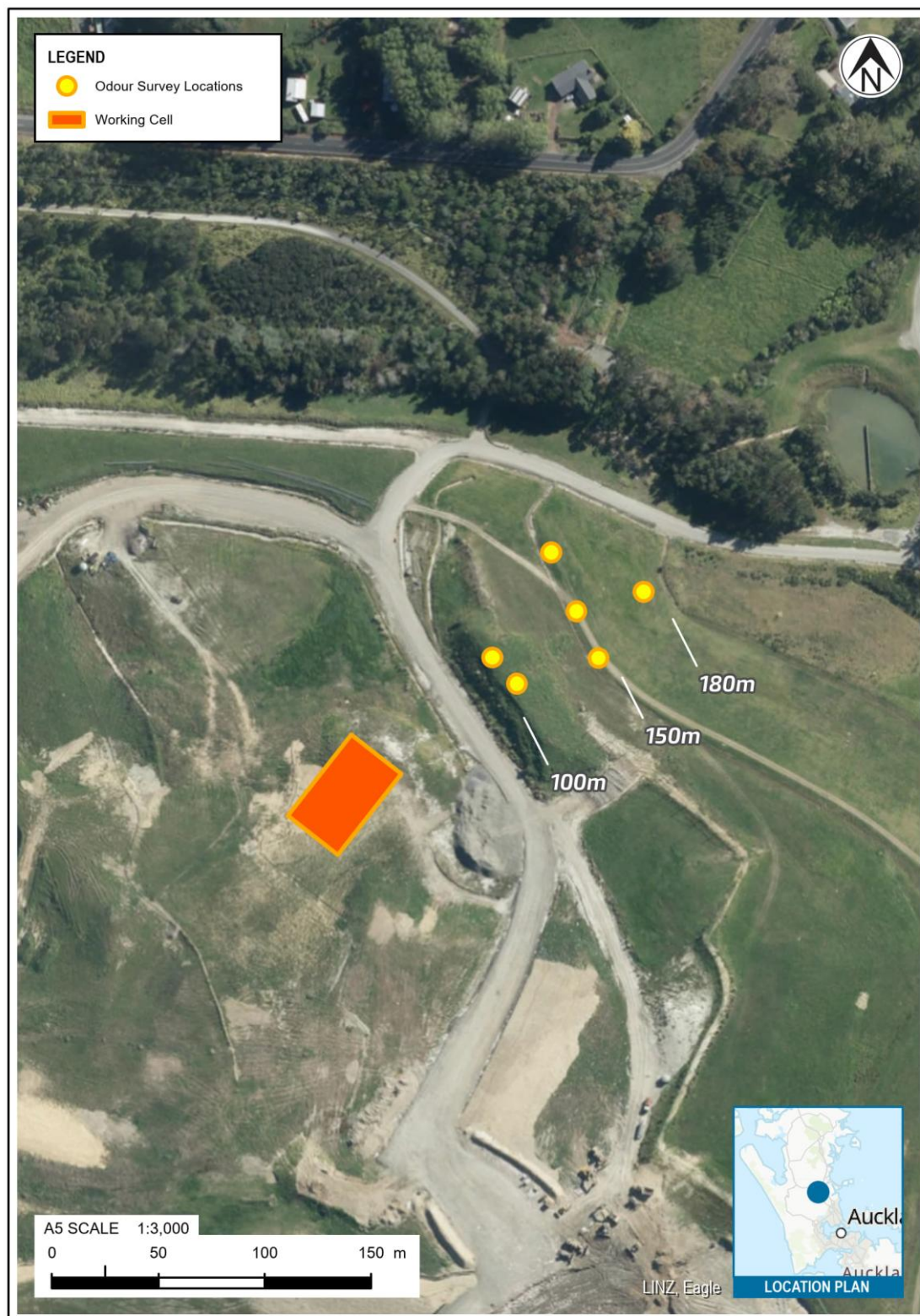


Figure Appendix C.3: Observation locations for odour cannon study

C3 Results

The intensity of observed odour is recorded on a scale of 0 (no odour) to 6 (extremely strong). The odour cannon observation survey results are summarised graphically in Figure Appendix C.4. This illustrates that the odour intensity was more frequently classed as zero when the odour cannons were operating, compared to when they were not, and that overall there was a reduction in observations of stronger odour (intensity 2 or 3).

The average odour intensities (overall and at each distance) are summarised in Table Appendix C.1. As there was only one observer at a distance of 180 m, there is a higher degree of uncertainty in these observations compared to the distances of 100 m (two observers) and 150 m (three observers). The closest location to the working cell (100 m) had the highest odour intensity and also had the greatest reduction in observed odour intensity.

Table Appendix C.3: Average recorded odour intensity during odour cannon trial

Cannon status	Average recorded intensity (Intensity scale)			
	All surveys	100 m	150 m	180 m
Cannons off	1.53	2.04	1.14	1.55
Cannons on	1.31	1.64	1.05	1.46
Difference in intensity	0.22	0.40	0.09	0.09
Percent reduction in intensity	14%	20%	8%	
Statistical significance ($p < 0.05$)	Yes	Yes	Yes	Inconclusive

A Wilcoxon-Mann-Whitney (WMW) statistical test was performed to investigate whether the difference over all the surveys is statistically significant. The WMW test is a non-parametric method and is appropriate as the datasets are not normally distributed. The WMW test indicates that there is a statistically significant difference in the odour intensity for the two datasets (with $p < 0.05^{26}$).

Some of the observers noted a change in character of the odour between when the cannons were on and off. Primarily the odour was described as “rubbish”. However, there was a greater frequency of the descriptor “sweet rubbish” when the cannons were on, and a greater frequency of “sharp or pungent rubbish” when the cannons were off.

²⁶ A p value of <0.05 means that there is only a 5% chance that the two datasets have the same underlying distribution, i.e. there is a moderate degree of confidence that the datasets have a different distribution.

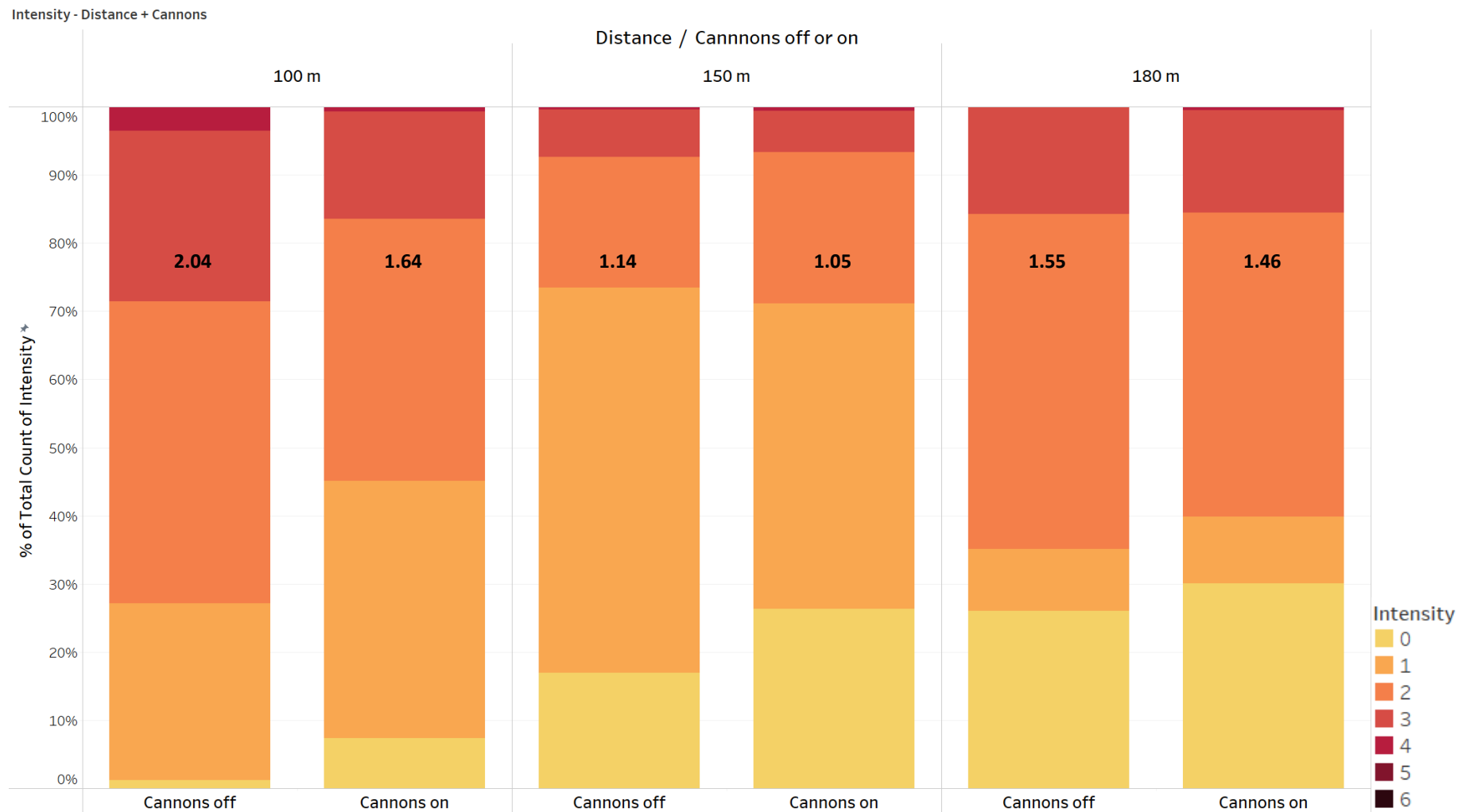


Figure Appendix C.4: Comparison of intensity of 'rubbish' odours when cannons off compared to cannons on by distance to the working cell. The average concentration is included for each bar

C4 Evaluation of change in odour concentration

The perception of the intensity of an odour follows a logarithmic relationship in relation to the odour concentration. Therefore, there is a 10-fold difference in odour concentration between an odour of “1” and an odour of “2”, i.e. reducing the odour from 2 to 1 would require a 90% reduction in odour concentration.

The greatest reduction in odour intensity was observed at 100 m from the tip face, where the perceived odour intensity was reduced from an average of 2.04 to 1.64 (based on a 0 to 6 scale). This represents an approximately 20% reduction in perceived odour intensity.

Based on the logarithmic relationship between perceived odour intensity and odour concentration, the reduction in odour concentration (unitless) at 100 m can be estimated as follows:

$$\text{Log}(A) = 2.04; A = 10^{2.04} = 109.65$$

$$\text{Log}(B) = 1.64; B = 10^{1.64} = 43.65$$

Where:

A is the concentration with the odour cannons off.

B is the concentration with the odour cannons on.

The percentage reduction in odour concentration = $(109.65 - 43.65) / 109.65 \times 100\% = 60\%$.

Table Appendix C.4: Estimated change in average odour concentration

Cannon status	Average concentration (unitless) ($10^{\text{observed Intensity}}$)		
	All surveys	100 m	150 m
Cannons off	33.9	109.6	13.8
Cannons on	20.4	43.7	11.2
Difference in concentration	13.5	66.0	2.6
Percent reduction in concentration	40%	60%	19%

C5 Conclusions

The odour fog cannon trial demonstrated that there was a statistically significant reduction in perceived odour intensity with the cannons on compared to when the cannons were off. The greatest reduction in perceived odour intensity was at 100 m from the tip face. The odour fog cannons were reasonably effective and reduced the odour concentration by approximately 60% at approximately 100 m. However, because of the logarithmic relationship between perceived odour intensity and odour concentration, the associated reduction in perceived odour intensity was only 20%. This highlights the difficulty in managing odour effects and the importance of minimising odours at source.

Appendix D Odour complaints analysis

D1 Introduction

The complaints record (as recorded by WMNZ) for the period January 2018 to December 2025 is summarised in the following sub-sections.

WMNZ records as accurately as possible the time and location that the odour was experienced (in addition to the time of the complaint and the address of the complainant), based on the information provided with the complaint. Therefore, while the figures below refer to the time of the complaint, to the extent possible this reflects the time of the odour incident (not the time the complaint was received).

D2 Temporal distribution of complaints

D2.1 Complaints by hour of day

The distribution of odour complaints by hour is shown in Figure Appendix D.5. The majority of complaints are received in the morning (between approximately 7:00 a.m. until 10:30 a.m.). This is broadly consistent with the time the landfill opens to receive waste and when weather conditions are likely to be least conducive to dispersion of odours. The timing of complaints will also be influenced by the times that people are at home (i.e. in the morning before school/work).

Waste is not received at the Site after 4:30 p.m., and the relatively small number of complaints relating to odour after that time and overnight suggests that activities associated with the active receipt and placement of waste at the tip face is a significant factor in odour complaints.

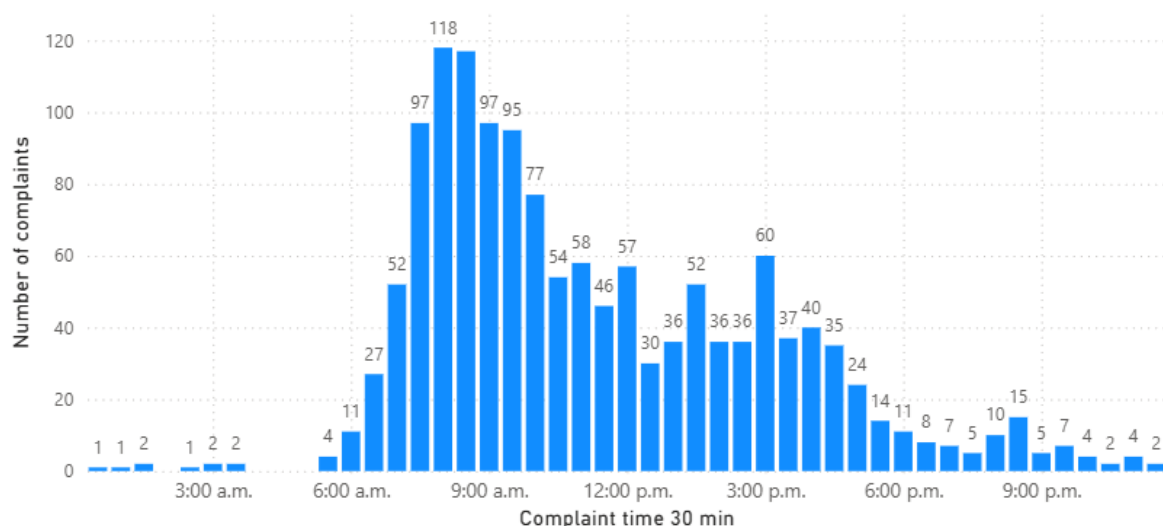


Figure Appendix D.5: Odour complaints by time of day (2018-2025)

D2.2 Complaints by day of the week

The distribution of odour complaints by day of the week is shown in Figure Appendix D.6. Relatively fewer complaints are received about odours occurring on Sunday, when no waste is accepted onto the Site, compared to other days of the week.

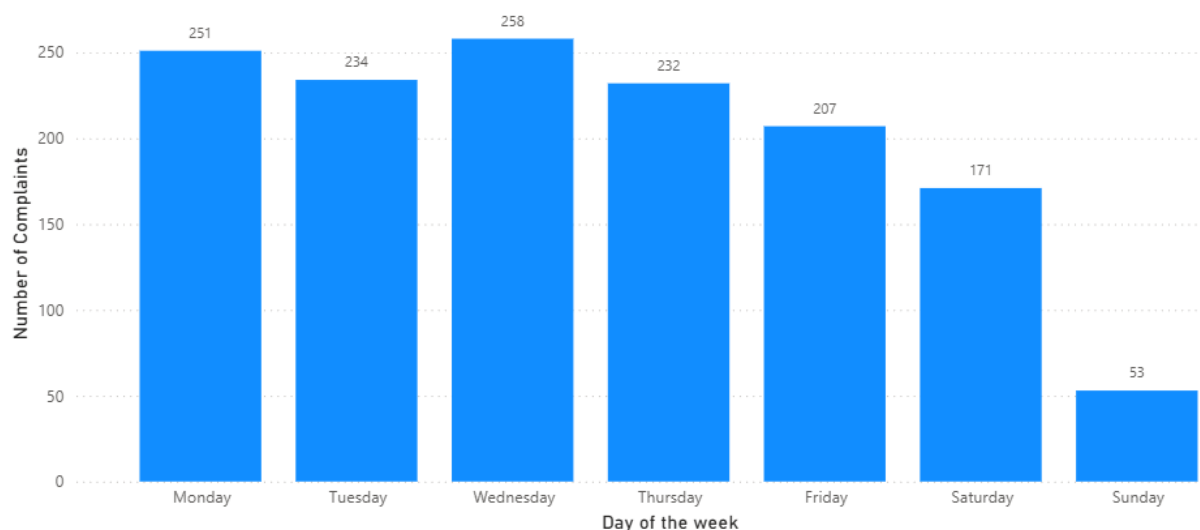


Figure Appendix D.6: Odour complaints by day of the week (January 2018 – December 2025)

D2.3 Complaints by month

The distribution of odour complaints by month shows a high degree of variability year-to-year and no obvious seasonal pattern (Figure Appendix D.7).

There was an increase in the number of complaints received in October and November 2021, compared to previous months, that has been attributed by WMNZ to hydrogen sulphide odours being generated from nickel slag that became saturated due to flooding at the landfill (see Section 7.2.2). The increase in complaints from April 2025 coincides with WM commencing consultation on the Project.

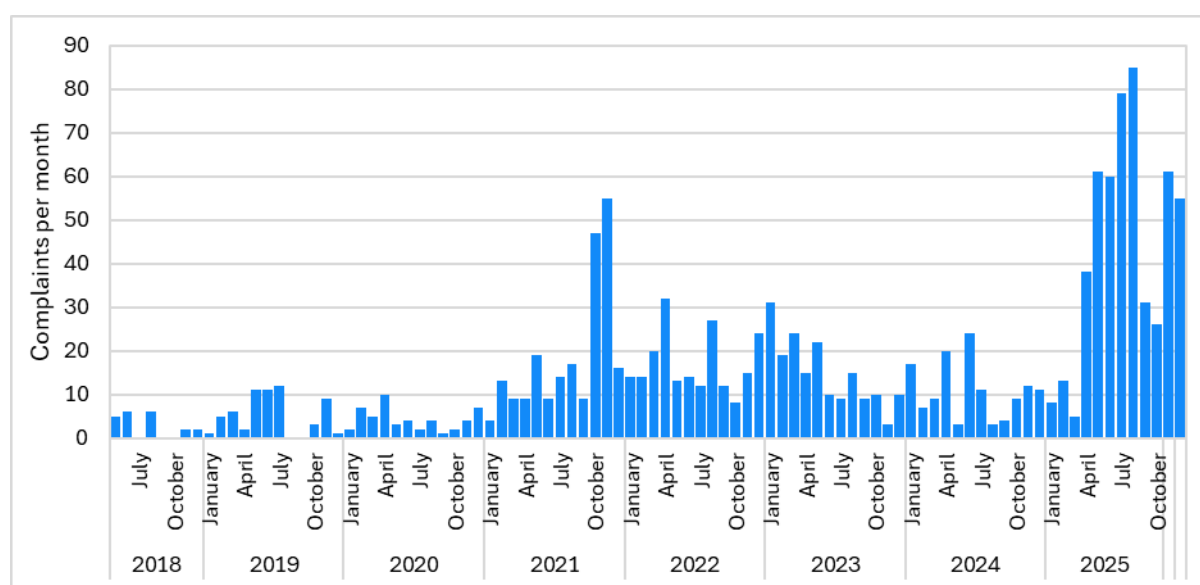


Figure Appendix D.7: Odour complaints by month (May 2018 – December 2025)

D2.4 Complaints by year

The distribution of odour complaints on a yearly basis is shown in Figure Appendix D.8. This illustrates that historically there was a significant increase in complaints in 2021, compared to the two prior years, followed by a gradual decline and a jump in complaints in 2025.

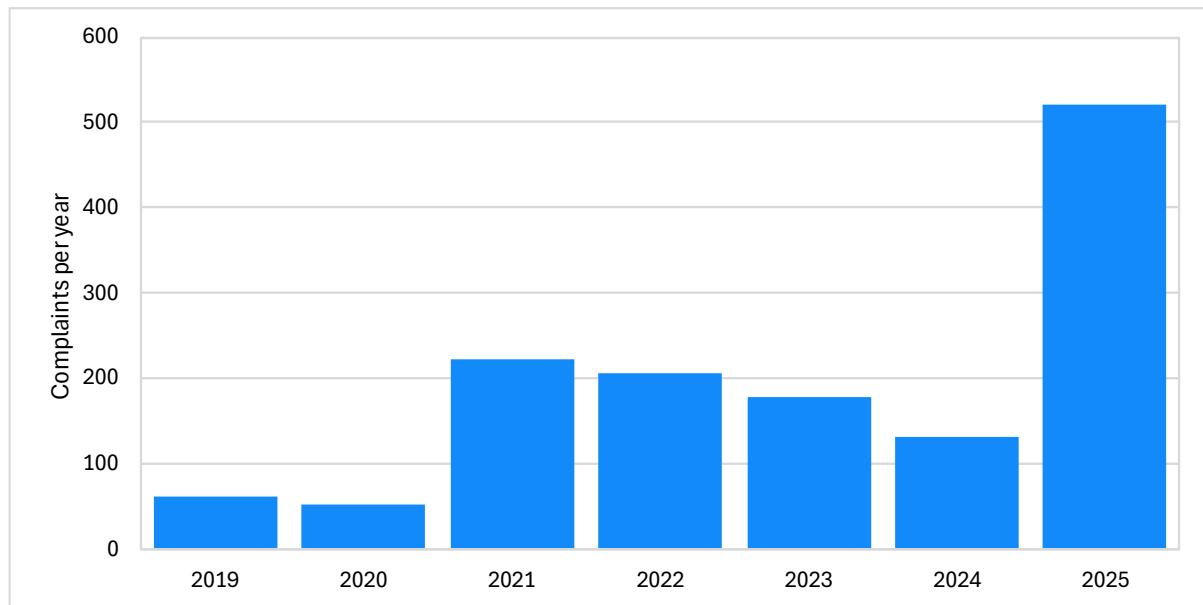


Figure Appendix D.8: Odour complaints by year (January 2018 – December 2025)

D3 Spatial distribution of complaints

The maps on the following page (provided by WMNZ) illustrate the spatial distribution of complaints over two time periods: 2018 to 2021 and 2021 to 2025. The size and colour of the dots indicate the number of complaints from each location.

The spatial distribution will be influenced by a range of factors, including the density of dwellings in different areas around the landfill (which is related to lot size).

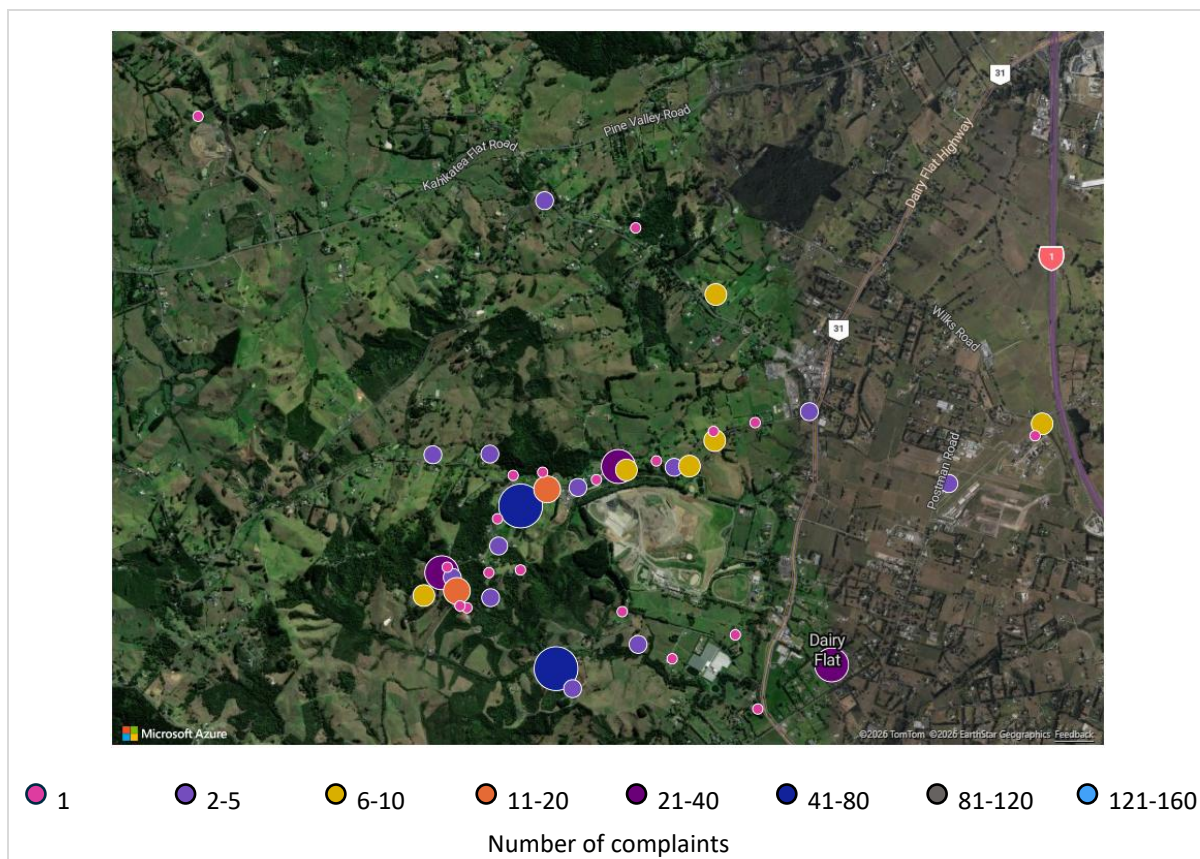


Figure Appendix D.9: Odour complaints between 2018 and 2021.

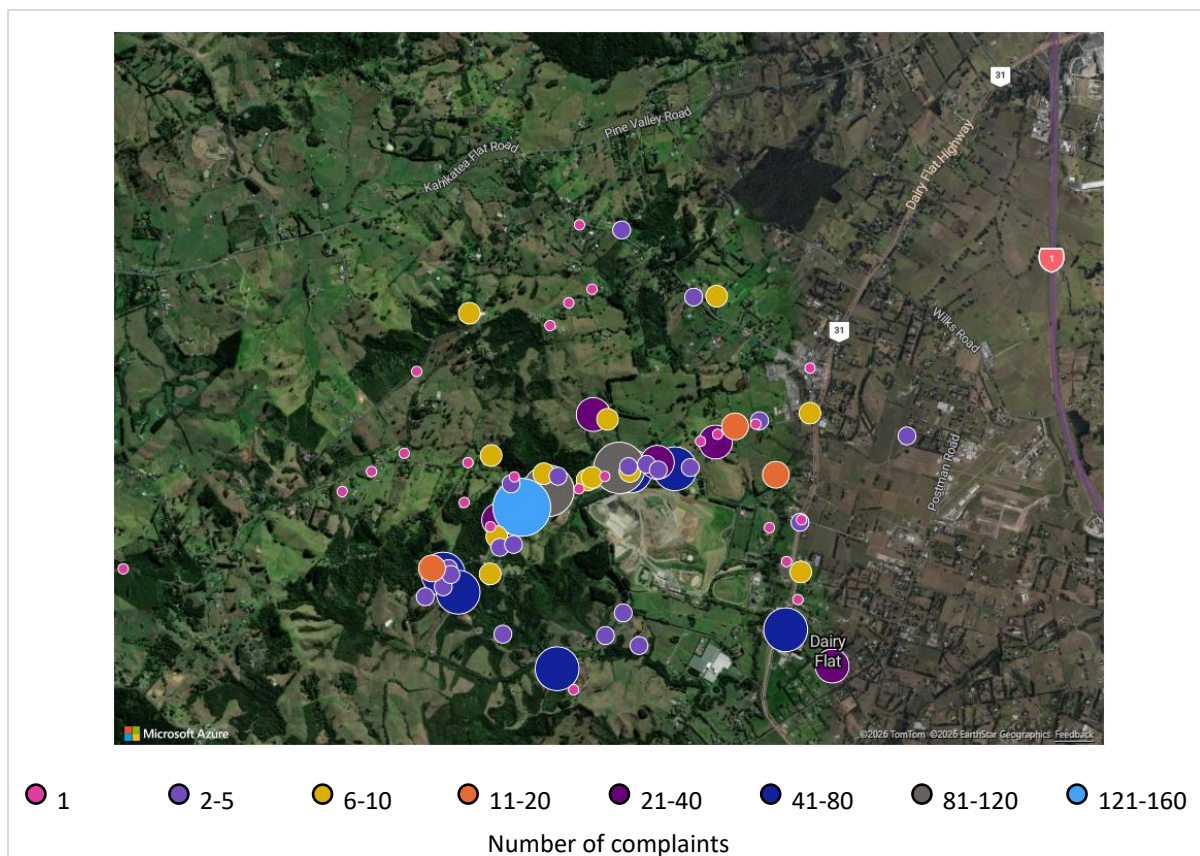


Figure Appendix D.10: Odour complaints between 2022 and 2025.

D4 Odour character identified during complaint investigations

When a complaint is lodged, WMNZ aim to complete an investigation at the location where the odour was identified within 30 mins of receiving the complaint. Where odour is observed by WMNZ staff, the character of the odour at the complaint location is described as part of the investigation (otherwise the character is recorded as 'no odour'). The records kept through 2025 providing more detailed descriptions of the odour character compared to previous years. The recorded odour character(s) have been summarised into the following categories:

- No odour detected
- Indefinable – this is where the odour cannot be characterised
- BeneVap (LEU)
- Gas (LFG)
- Tip face / rubbish
- Possible landfill (odours were detected that could be any of the following: burning; earthy; musty; damp; floral; sweet; sour; sulphur; coffee grinds; putrid; stale)
- Various landfill (odours were classified as “various landfill” when rubbish odours and any combination of “possible landfill” characters were detected)
- Non landfill odours included: animal manure; diesel smoke; dust; soap; woody; exhaust; grassy; animal; manure; agapanthus; rubbish trucks operating outside of the landfill boundary; herbal; minty; native bush; pine

Figure Appendix D.11 summarises the odour categories as described by WMNZ during complaint investigations. The most frequently identified landfill-related odour at the complainant's location was tip face/rubbish odour. BeneVap and landfill gas (LFG) odours were detected only rarely (9 of 1,031 observations). Across 2022–2025, no odour was detected in 42% to 70% of WMNZ observations, while landfill odours were detected in 25% to 34% of observations. The remaining observations were classified as non-landfill, possible landfill, or indefinable odours (32% in 2025).

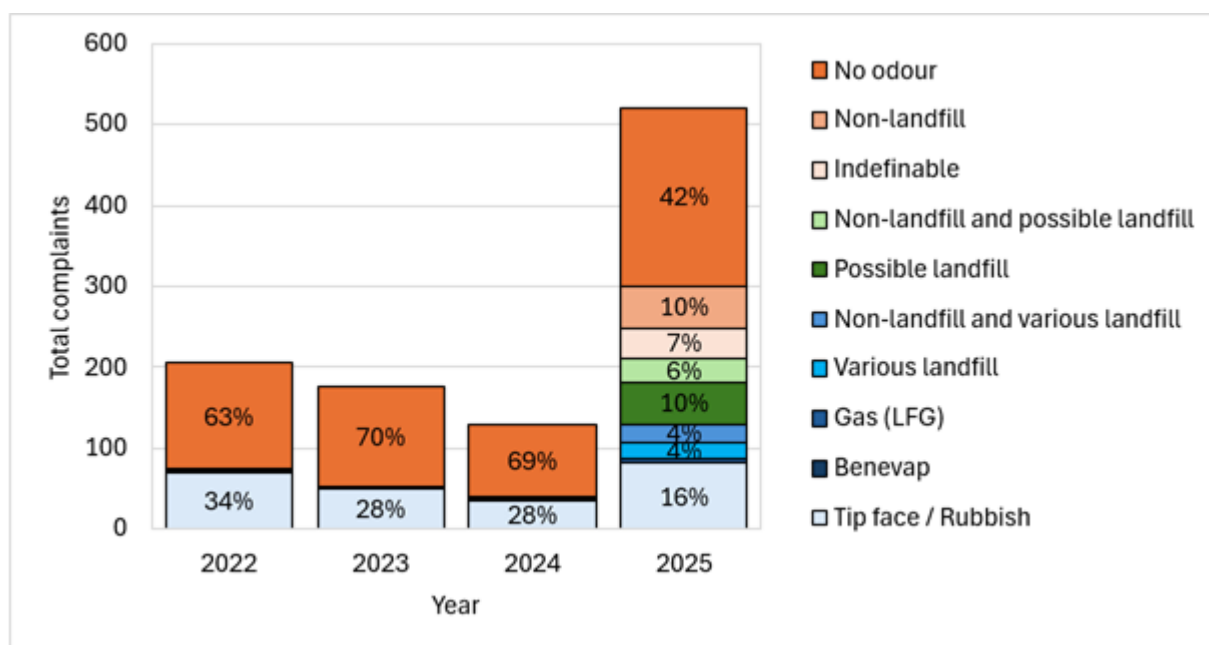


Figure Appendix D.11: Summary of odour character from complaints investigations

D5 Investigations of complaints by WMNZ

As discussed in Section 3.7.3, all odour complaints are investigated as soon as practicable, with a target of within 30 minutes. As shown in Figure Appendix D.12, most of the time the odour has dissipated by the time WMNZ staff visit the location of the complaint. There may be a variety of reasons for this, but it suggests that in many cases odours are of a relatively short duration (over the order of minutes to an hour, rather than hours).

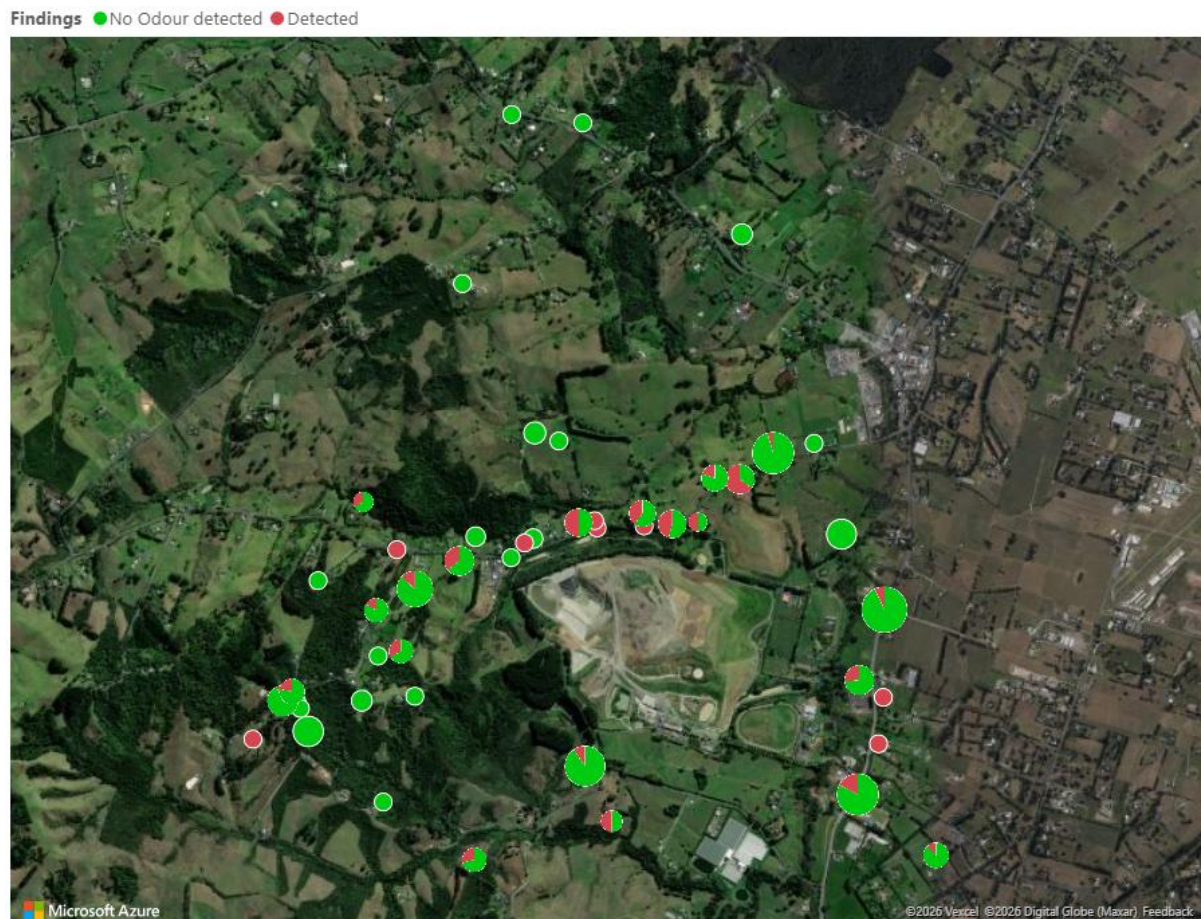


Figure Appendix D.12: Complaint investigation results for January 2022 to December 2025

Appendix E Air dispersion modelling

E1 Introduction

This appendix sets out the methodology, inputs and results of an air dispersion modelling study for emissions of odour and products of combustion of LFG from the Site. The scope of the modelling study is:

- Emissions of odour from the current and proposed landfill operation; and
- Emissions of the products of combustion of LFG in generators, leachate evaporator and flares from the Site taking into account the maximum LFG generation scenario.

This report forms an appendix to the Air Quality Technical Assessment and should be read in conjunction with that document.

E2 Meteorological modelling dataset

E2.1 Introduction

A 3-dimensional meteorological dataset for two modelling years (2022 and 2023) has been prepared using CALMET software (v. 6.5), with upper air inputs derived from the Weather Research and Forecasting (WRF) (v. 4.1) prognostic meteorological model.

The CALMET model domain consists of a 12 x 10 km grid, centred on the Site, with a grid resolution of 100 m.

CALMET configuration details are provided in Appendix E3.

E2.2 Selection of model period

The MfE *'Good Practice Guide for Dispersion Modelling'* (2004) recommends that at least one year of meteorological data is used in dispersion modelling. In accordance with good practice, two separate calendar years (2022 and 2023) have been selected to encompass a wider array of meteorological conditions that are likely to be encountered on-site and in the surrounding area.

The selection of 2022 and 2023 was made based on a consideration of the following:

- Availability of recent prognostic monitoring data.
- Availability of recent and valid meteorological data from the on-site meteorological station and other nearby stations (North Shore Airport, Auckland Airport).
- Consideration of phase of the Southern Oscillation Index. Very strong La Niña conditions, indicated by positive Southern Oscillation Index values, were experienced in early 2022 and neutral to weak El Niño conditions, indicated by negative Southern Oscillation Index values, were experienced in 2023.

E2.3 Upper air meteorological input data

The upper air meteorological dataset was produced using best practice prognostic modelling using the WRF model. The WRF model (v 4.1) was run by T+T for this purpose to a resolution of 1 km covering the model domain area and using up-to-date land use information from the Land Cover Database, version 5.0²⁷, Mainland, New Zealand.

²⁷ Sourced from the Land and Resource Information Systems Portal. Last updated 29 January 2020.

E2.4 Meteorological surface observation input data

Table Appendix E.1 summarises the surface meteorological data used in the CALMET model.

Table Appendix E.1: Climate stations used in CALMET dataset

ID	Station name	Operating authority	Parameters used	Mast height
S1	WMNZ Redvale	National Institute of Water and Atmospheric Research	T, RH, WD, WS	10 m
S2	North Shore Airport	North Shore Airport	T, RH, WD, WS, P	2.5 m
S3	Auckland Airport	MetService	P	10 m

Abbreviations: T = temperature, RH = relative humidity, WD = wind direction, WS = wind speed, P = pressure.

Note: Pressure data from Auckland Airport was used to fill gaps in the data from North Shore Airport

E2.5 Terrain and land cover

Two terrain files were created to enable a comparison between the existing and proposed landform (slope). Terrain data used in the CALMET/CALPUFF model has been derived from 1 m digital elevation model (DEM) files constructed for the Site. The existing slope was based on survey data taken between 29 January 2025 and 27 February 2025 and the proposed slope was based off the design for the final post settlement cap. There is expected to be a 2 m difference in height between the max fill height (pre-settlement and final cover) and the post settlement height. These files incorporate the Site survey data and landfill design elevations covering the immediate area. To cover the wider computational area, Site elevation data was blended with the Auckland 2016 DEM (derived from 1 m grid resolution LiDAR) sourced from Land Information New Zealand (LINZ).

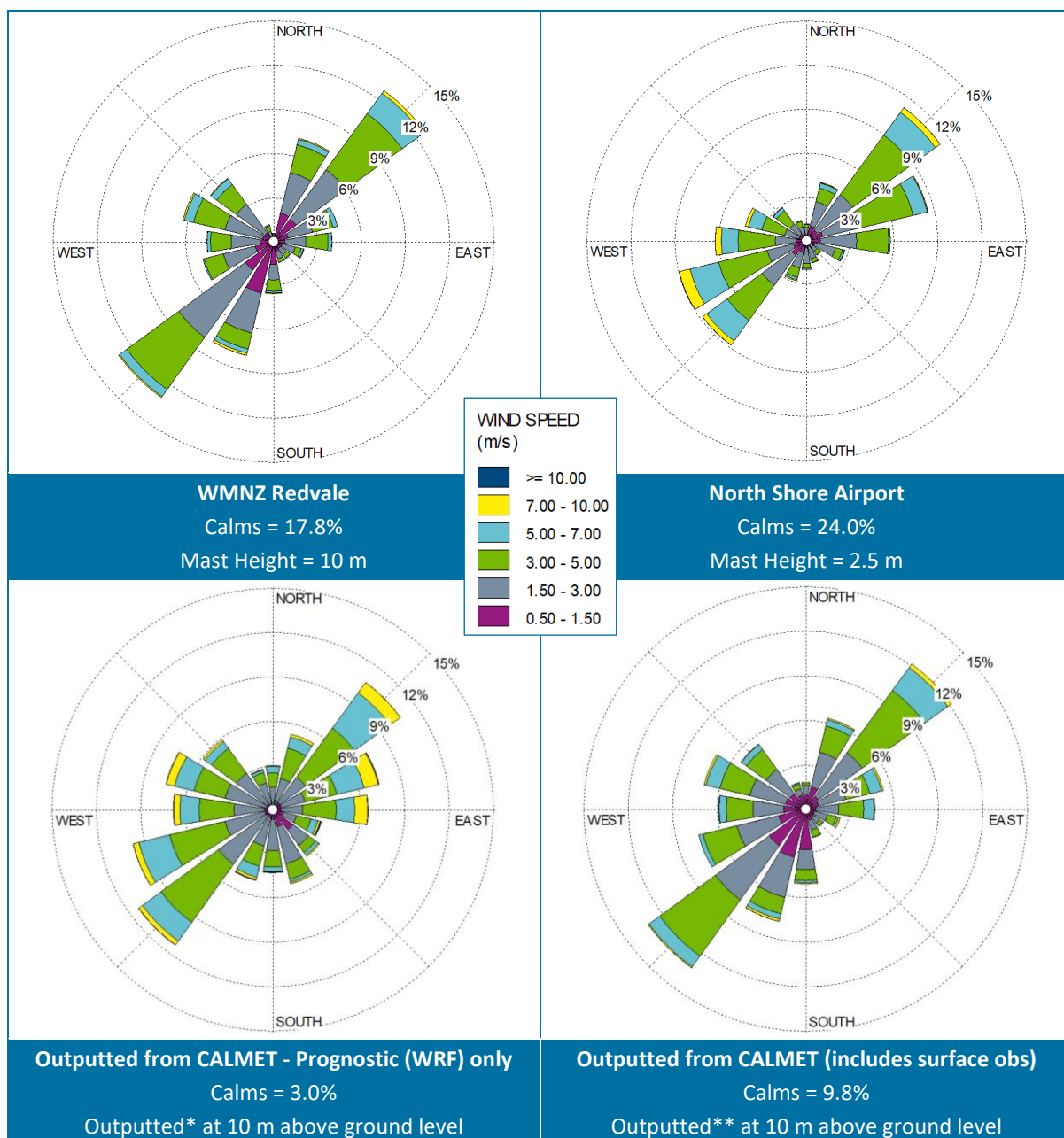
Land cover over the CALMET grid was sourced from the land use information from the Land Cover Database (v 5.0), Mainland, New Zealand and modified based on information from aerial photographs.

E2.6 Evaluation of CALMET generated meteorological dataset

CALMET wind predictions at 10 m elevation at the Site have been compared with the wind roses for the Site and North Shore Airport in Figure Appendix E.13. Data from the WMNZ Redvale station (top left) and the North Shore Airport weather station (top right) reflect the broader wind patterns typical of the Auckland region with a predominance of northeasterly and south-westerly winds.

The North Shore station has a greater frequency of calm conditions, which is expected given that measurements are recorded closer to ground level.

Overall, the predicted winds outputted from CALMET for the Site (bottom right) largely reflect the wind rose for the WMNZ Redvale station but with a lower frequency of calm and light wind conditions (which are the worst-case for odour propagation).



*Outputted at the property of 60 Karahiwi Lane.

**Outputted at the approximate centre of landfill extent.

Figure Appendix E.13: Comparison of wind roses from modelled and observational data

E3 Gridded and discrete receptors

Dispersion modelling of odour and contaminant emissions has been conducted using CALPUFF (v. 7.2.1).

The 6 x 6 km gridded receptor network is shown in Figure Appendix E.14 and comprises nested grids centred on the landfill at 50, 100 and 200 m spacing.

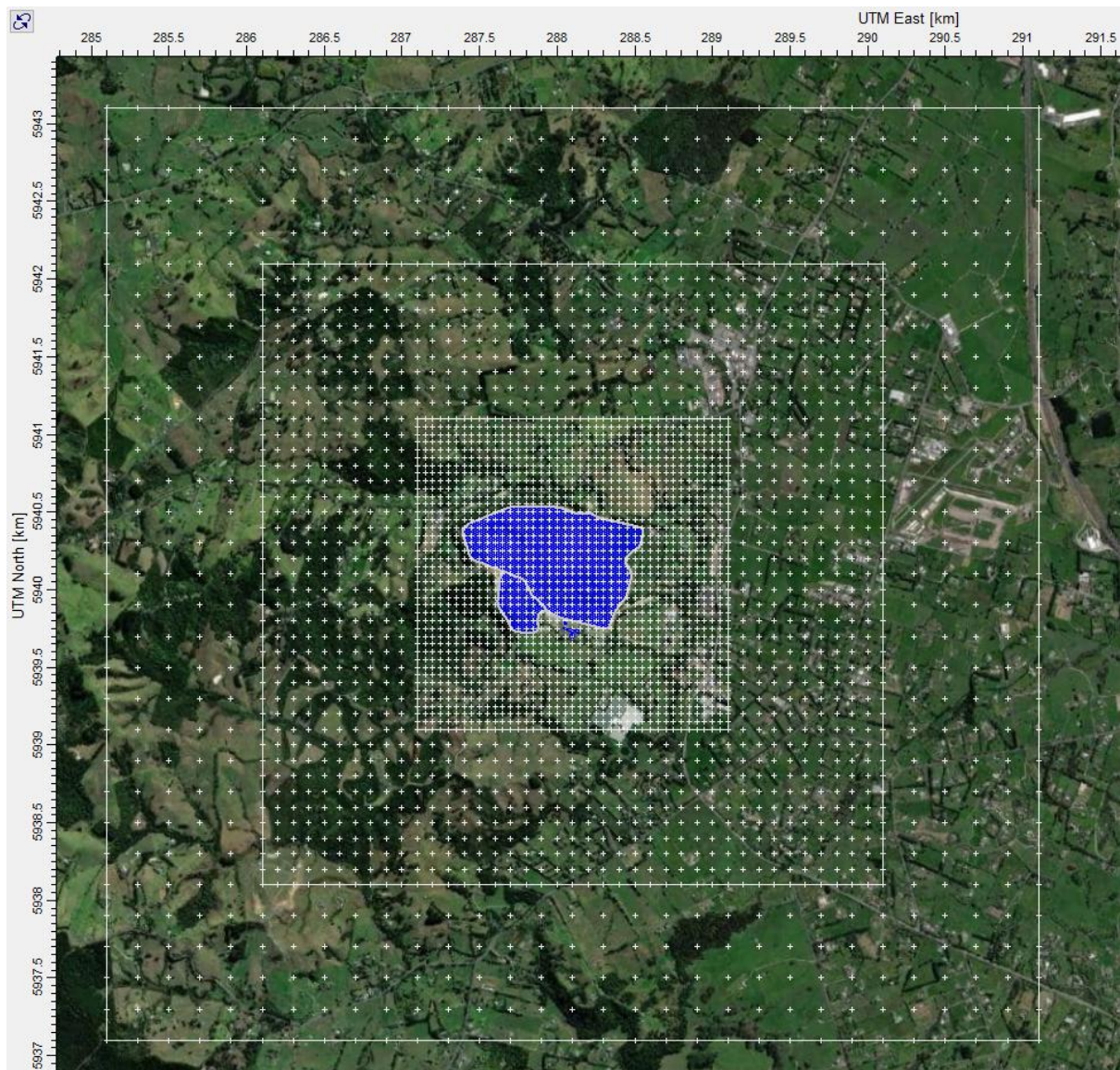


Figure Appendix E.14: Nested receptor grids used in dispersion modelling. Receptors points shown by white crosses and Activity Boundary shown by the blue shaded polygon

In addition to the gridded receptors, discrete receptor points have been placed at the nearest sensitive receptors (dwellings), as shown in Figure Appendix E.15.

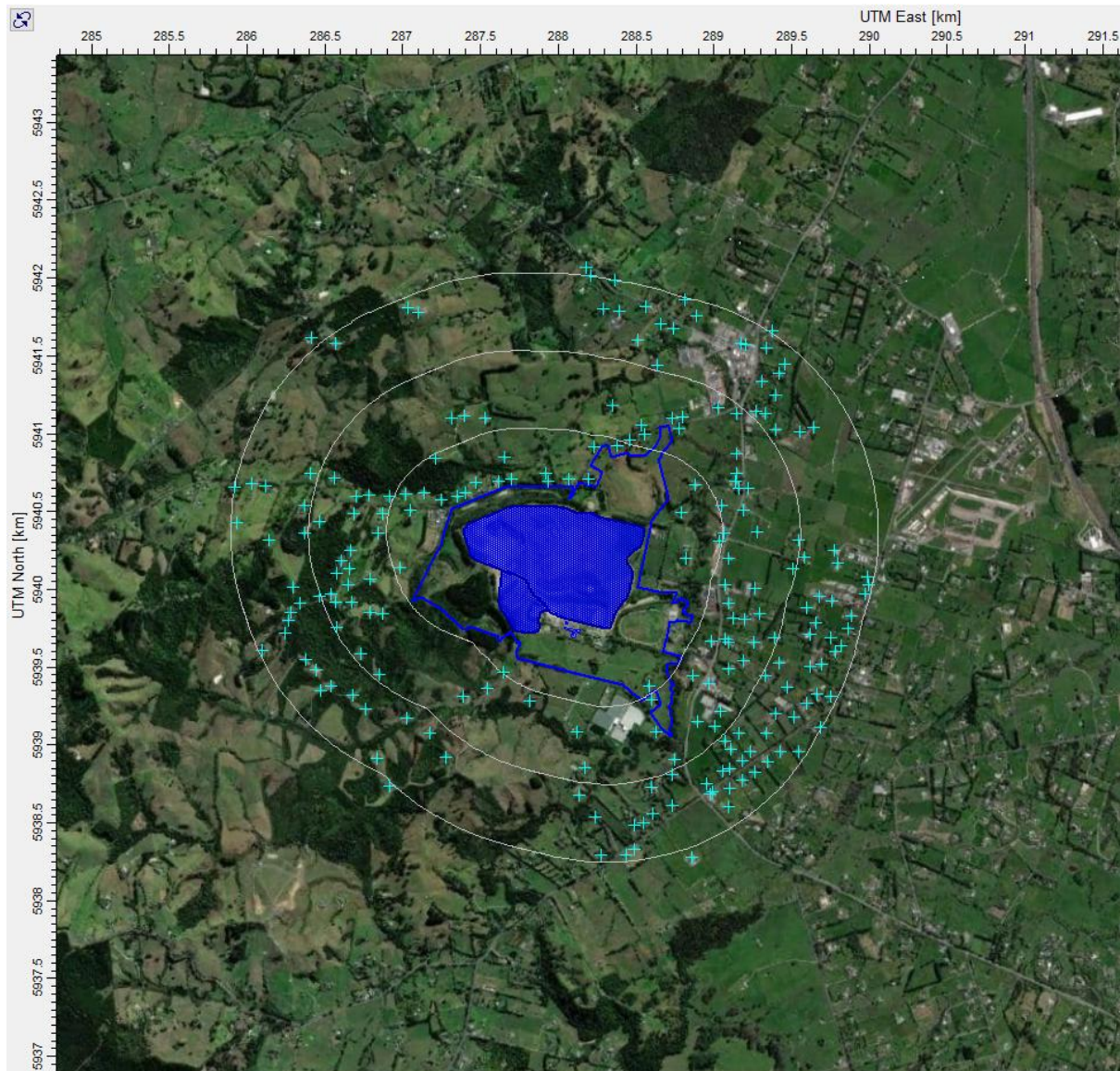


Figure Appendix E.15: Discrete receptor locations (shown by light blue crosses) included in dispersion modelling. Activity Boundary shown by the shaded dark blue polygon, WMNZ land holdings (the Site) shown by dark blue outline, and grey lines indicate 500 m buffers from the Class1 part of the landfill..

E4 Odour emission rates from landfill areas

Odour emissions from areas of the Redvale Landfill were measured on 13 and 14 June 2016 and 25 July 2016. Emissions were measured at the following locations:

- Tip face
- Daily cover
- Intermediate cover
- Final cover
- Hard stand

Three odour samples were collected at each location using a static flux chamber method at locations representative of each of these source types and analysed using dynamic dilution olfactometry.

The resulting odour concentrations are shown in Table Appendix E.2 expressed in “Odour Units” (OU).

Measured odour emission rates from areas under daily, intermediate and final cover at Redvale Landfill were similar and it is noted that the odour emission rates were similar to reported measurements from grass paddock areas in Australia. Experience at landfills suggests that there is a low, but discernible, odour from areas under 150 mm daily cover, whereas no odour is typically observed from areas under intermediate cover. The odour concentrations in the samples were close to the limits of detection of the olfactometry method, which is a possible explanation for why the odour emissions from areas under 150 mm daily cover were not measurably different from intermediate/final cover. It is also possible that a slightly thicker layer of daily cover was in place (daily cover thickness will be variable in practice).

An odour emission rate of 0.022 OU/m²/s has been adopted as representative of areas under 150 mm daily cover, while odour emission rates from areas under 300 mm intermediate cover and final cover are assumed to be zero (effectively “background” earth/grass type odour). An odour emission rate of 0.36 OU/m²/s has been adopted for the tip face.

Given that the daily cover thickness is increasing from 150 mm to 300 mm in the proposed scenarios, no odour has been modelled from the daily cover area in the proposed scenarios. This is because the increased thickness of daily cover is the same as intermediate cover at the time these odour measurements were taken.

Table Appendix E.2: Redvale Landfill odour emission measurements June/July 2016

	Odour emission rate (OU/m ² /s)			
	Tip face	Daily cover (150 mm)	Intermediate cover (300 mm)	Final cap
Sample 1	0.37	0.027	0.017 ^a	0.017 ^a
Sample 2	0.22	0.018 ^a	0.013	0.030
Sample 3	0.495	0.020	0.017 ^a	0.021
Average	0.36	0.022	0.016	0.022
Odour descriptor	Rotten organic matter Moderate chemical	Light earth/vegetation	Light musty/earth Light vegetation	Light musty/earth Light fresh greenery

E5 Dispersion modelling of combustion emissions

E5.1 Generator stack parameters and emission rates

The existing generators are all nominal 1 MW Jenbacher generators, and it has been assumed that any new or replacement generators will be similar. The only difference between the generators currently installed is in the stack height. Generators G1 to G3 and G8 to G15 have 10 m high stacks and Generators G4 to G7 have 6 m high stacks.

Stack testing for PM₁₀, NO_x, CO and SO₂ is carried out every three years on three of the generators on a rotating basis. The stack testing results for PM₁₀ and CO have been used to determine representative emission rates for these contaminants.

The Jenbacher GE generators are specified to achieve a NO_x emission concentration below 500 mg/m³. This value, which is higher than the typically measured NO_x emission rates, has been used to represent worst-case emissions.

Stack emission testing of SO₂ emissions from the generators using a combustion gas analyser typically gives very low concentrations. These concentrations are much lower than would be expected from the amount of sulphur (mostly in the form of H₂S) present in the LFG, if it is assumed that all of the sulphur is oxidised and converted to SO₂. For the purposes of a conservative assessment, the modelled emission rate of SO₂ is based on a mass balance calculation assuming the concentration of H₂S in the LFG is 600 mg/Nm³. This is at the upper end of the range of H₂S concentrations measured in the LFG over the period 2020 to March 2025 (228 to 606 mg/Nm³).

The discharge parameters and contaminant emission rates associated with the generators are summarised in Table Appendix E.3.

Table Appendix E.3: Generator stack parameters and emission rates used in modelling

Parameter	Value	Source of data
Stack height (m)	10 6 (G4 – G7)	From drawings provided by WMNZ
Stack diameter at exit (m)	0.35	From drawings provided by WMNZ
Exit velocity (m/s)	29	Lower range from stack testing data (allowing for difference in stack diameter at testing point)
Exit temp (°C)	450	Upper range of stack testing data
PM ₁₀ (g/s)	0.01	Based on TSP measurements assuming that TSP comprises 100% PM ₁₀
PM _{2.5} (g/s)	0.01	Based on TSP measurements assuming that TSP comprises 100% PM _{2.5}
NO _x (g/s)	0.52	Calculated from supplier NO _x concentration specification of no more than 500 mg/Nm ³
SO ₂ (g/s)	0.21	Calculated from H ₂ S content of LFG using mass balance
CO (g/s)	2.49	AP-42 emission factors

The emission rates have been compared to the results from the most recent round of stack testing in Table Appendix E.4, which confirms the modelled emission rates are conservative.

Table Appendix E.4: Comparison of modelled generator emission rates and stack testing

Parameter	Emission rates used in modelling (g/s)	Measured emission rates (g/s) from stack testing (June 2025)		
		G1B	G2B	G3B
TSP	0.01	0.01	0.01	0.01
NO _x	0.52	0.39	0.29	0.32
SO ₂	0.21	0.02	0.00	0.00
CO	2.49	1.29	1.13	1.33

E5.2 Flare parameters and emission rates

It is difficult to measure emissions from a flare due to the very high temperature of the exhaust gases. T+T is not aware of any emission testing of LFG flares having been undertaken in New Zealand. As with all previous assessments of effects for the flares at the Site, the emissions have been based on emission factors published by the United States Environmental Protection Agency

(AP-42) for flares burning LFG²⁸. The emission factors for PM₁₀, NO₂ and CO species been assigned with an A rating (“Excellent”) indicating a high level of reliability. The AP-42 emission factors are expressed based on emissions (in the combusted gas) per m³ methane (in the unburnt raw form). The AP-42 emission factors are listed in Table Appendix E.5.

The calculated emission rates are shown in Table Appendix E.5 and other discharge parameters that have been used to model emissions from the flares are provided in Table Appendix E.6

Table Appendix E.5: AP-42 emission rates for LFG flares

Parameter	Emission rate (mg per m ³ methane burnt)
PM ₁₀	238
NO _x	631
CO	737

Table Appendix E.6: Flare stack parameters and emission rates

Parameter	Flare 1 (Northern Flare)	Flare 2 (Central Flare)	Flare 3 (Southern Flare)	Source of data
Nominal capacity (m ³ methane/hour)	1,250	1,500	2,100	WMNZ
Height (m)	12	9.1	9.1	WMNZ
Diameter (m)	2	2.59	2.59	WMNZ
Exit velocity (m/s)	4.5	3.2	4.5	Calculated assuming 4% excess oxygen
Exit temp (°C)	750	750	750	Based on minimum flare temperature of 750 °C
PM ₁₀ (g/s)	0.08	0.10	0.14	AP-42 emission factors
PM _{2.5} (g/s)	0.08	0.10	0.14	Assuming that PM ₁₀ comprises 100% PM _{2.5}
NO _x (g/s)	0.22	0.26	0.37	AP-42 emission factors
SO ₂ (g/s)	0.78	0.94	1.32	Calculated from H ₂ S content of LFG using mass balance
CO (g/s)	0.26	0.31	0.43	AP-42 emission factors

E5.3 Comparison of model results for flares and generators

The model outputs from the generator and flare scenarios (i.e. all LFG combusted through the generators or all through the flares) are shown in Table Appendix E.7. These values are the incremental model contributions and do not include background. This illustrates that the generator scenario produces the higher modelled concentrations.

²⁸ United States Environmental Protection Agency AP-42 Compilation of Air Pollutant Emissions Factors from Stationary Sources, Section 2.4, Municipal Solids Waste Landfills

Table Appendix E.7: Modelled contaminant concentrations for 15 generators.

Contaminant	Averaging Period	Model results ($\mu\text{g}/\text{m}^3$)			
		Generator scenario		Flare scenario	
		2022	2023	2022	2023
PM ₁₀	24-hour	3.4	2.7	1.4	1.4
	Annual	0.2	0.2	0.1	0.1
PM _{2.5}	24-hour	3.4	2.7	1.4	1.4
	Annual	0.2	0.2	0.1	0.1
NO _x	1-hour	450	498	14	13
	24-hour	176	141	4	4
	Annual	10	9	0.3	0.2
SO ₂	1-hour	182	201	50	47
	24-hour	71	57	13	13
CO	1-hour	2,154	2,384	16	15
	8-hour	1,657	1,828	14	13
	24-hour	842	675	4	4