REPORT

Tonkin+Taylor

Reconsenting of Ravensdown Napier Works

Air Quality Assessment

Prepared for
Ravensdown Limited
Prepared by
Tonkin & Taylor Ltd
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Executive Summary

Ravensdown Limited (Ravensdown) is a leading supplier of fertiliser, lime, agrochemical, animal health products and associated application and advisory services to farmers throughout New Zealand. Ravensdown operates three superphosphate Manufacturing Plants located in Napier, Christchurch, and Dunedin.

The Ravensdown Napier Works is located near the coast at 200 Waitangi Road, Awatoto, approximately 6.5 km from Napier city (see Figure 1.1). It produces up to 440,000 tonnes per annum of superphosphate fertiliser and is the largest superphosphate Manufacturing Plant in New Zealand.

The manufacture of superphosphate at the Napier Works gives rise to the discharge of contaminants into air, which are currently authorised[1] under resource consent AUTH-115256-04 from the Hawke's Bay Regional council (HBRC). This resource consent expires on 21 October 2022. Accordingly, Ravensdown is applying for a replacement resource consent to discharge contaminants into air.

Potential effects covered – discharges to air

The main discharges to air from the site are:

- Fluoride and acid mist from the Manufacturing Plant;
- Sulphur dioxide (SO_2) and acid mist from the Acid Plant;
- PM_{10} and $PM_{2.5}$ from the Bradley Mills;
- Emissions associated with diesel combustion from on-site vehicles, machinery and the diesel burners used during a cold start-up of the Acid Plant;
- Odour (including hydrogen sulphide from the acid melter), and
- Dust from raw material and product handling.

The potential air quality effects of the discharges include those on human health (SO_2, PM_{10} and $PM_{2.5}$), impacts on vegetation (fluoride, SO_2 and acid mist), and amenity impacts (odour and dust). Fluoride emissions also have the potential to result in window etching on properties close to the site.

Assessments undertaken:

Discharges of fluoride, SO_2 PM_{10} and $PM_{2.5}$ have been assessed using air dispersion modelling to predict contaminant ground level concentrations enabling an assessment against relevant air quality assessment criteria for human health and sensitive ecological ecosystems[2]. This has been combined with a review of available ambient monitoring data.

The assessment evaluates the existing site configuration as well as proposed changes to the plant in line with Ravensdown's Air Discharge Strategy, most notably associated with the new Den Scrubber and combined Manufacturing Plant stack, as well as the new Acid Plant converter.

The potential effects of diesel combustion emissions associated with the infrequent cold start-up of the Acid Plant have been assessed qualitatively.

Odour and dust effects have been assessed qualitatively, taking into account the frequency, intensity, duration, offensiveness and location of impacts (the FIDOL factors). This has been informed by a review of separation distances to sensitive locations, meteorology and historic complaint records.

[1] This permit was varied on 5 July 2021 to provide for discharges into air from a new combined Manufacturing Plant stack that replaced the existing two Den Scrubber stacks and the existing Hygiene Scrubber stack. At the time of this report, the Changes to the plant have not been implemented.

[2] Based on the New Zealand ambient air quality guidelines for plants showing the maximum allowable concentration (critical level) of fluoride for selected averaging times (Ministry for the Environment 2002).

Results of assessments:

Regarding effects on vegetation, this assessment provides an evaluation of predicted fluoride and SO_2 concentration against ambient air quality guidelines for sensitive ecosystems and the results are used to further inform a separate assessment by The New Zealand Institute for Plant & Food Research Limited and a Public Health assessment by Environmental Medicine Limited. Notwithstanding this, the predicted concentrations are well within the relevant MfE guidelines for the protection of sensitive ecosystems except for land to the immediate east of the site (former Winstone site and foreshore). Further consideration of vegetation effects is provided by The New Zealand Institute for Plant and Food Research Limited.

Dispersion modelling has shown that the planned new Manufacturing Plant stack and proposed reduction in maximum fluoride emission will lead to a reduction in fluoride ground level concentrations compared with the previous plant configuration (i.e., the Den Scrubber system discharging via two separate stacks and the Hygiene Scrubber via its own stack).

Predicted SO_2 concentrations from the normal operation of the site are well within the relevant assessment criteria for human health and vegetation impacts and the potential effects are considered to be low. Concentrations are expected to reduce further as a result the replacement of the Acid Plant converter.

Isolated events have occurred where high concentrations of SO_2 have been measured off-site at the Winstone monitoring site. These events have historically been associated with start-up of the Acid Plant, although more recently fires associated with the sulphur melter also resulted in high concentrations. Ravensdown has implemented changes to the Acid Plant start-up procedures to reduce SO_2 emissions and has increased the height of the start-up stack from 3 m to 18 m to improve dispersion of those emissions – no monitoring exceedances at the Winstone site have been attributed to start-up conditions since this time. Notwithstanding this, Ravensdown continues to investigate measures to minimise emissions associated with start-up conditions and has implemented measures to minimise the likelihood of a melter fire occurring in future. Regarding the melter, Ravensdown has engaged an independent review of the melter fire suppression system and is progressing plans for its replacement, working with international suppliers regarding industry best practice.

Emissions of oxides of nitrogen, carbon monoxide, PM_{10}/$PM_{2.5}$ and SO_2 from diesel-fired external combustion appliances used during the infrequent cold start-up of the Acid Plant are not expected to give rise to off-site ground level concentrations that approach relevant assessment criteria. The risk of any such exceedance actually occurring is further minimised given the very infrequent nature of cold start-up of the Acid Plant.

Given the above, T+T considers the adverse effects associated with the discharge of SO_2 from the site is low, and effects will reduce further with the proposed convertor replacement. On this basis we consider the potential SO_2 effects to be less than minor.

For PM_{10} and $PM_{2.5}$, relatively high concentrations are predicted for the location immediately east of the Bradley mills (i.e., the Winstone site). The model predictions are broadly consistent with the measured PM_{10} concentrations at the Winstone monitoring site. However, exposure over a 24-hour period is not reasonably expected to occur at this location given the industrial nature of the site. At the most impacted location where human exposure is relevant, predicted cumulative concentrations are low relative to the assessment criteria. On this basis the effects of PM_{10} and $PM_{2.5}$ emissions are considered to be less than minor.

A qualitative FIDOL assessment has been made regarding the potential odour and dust nuisance effects. The findings of these assessments concluded that there is low potential for offensive or objectionable odour effects to occur as a result of discharges from the Ravensdown site, which is consistent with the record of dust and odour complaints (few complaints). Accordingly, it is considered the odour and dust effects are less than minor.

The ongoing potential for fluoride emissions to give rise to widow etching has been assessed as less than minor.

Suggested approach for effects identified:

Overall, the ongoing potential for adverse air quality effects described above is assessed as being less then minor. Notwithstanding this, several improvements to the site are proposed that will reduce air discharges in line with Ravensdown's Air Discharge Strategy (Ravensdown 2021). The most notable upgrades include the Den Scrubber system (which has recently been authorised through a consent variation) and a proposed upgrade to the Acid Plant converter. The Ravensdown Board has approved the funding for the capital expense of the new plant with a committed timeframe for the installation of the plant (2022 for the Manufacturing Plant scrubbers and 2023 for the Acid Plant converter).

1 Introduction

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The Ravensdown Napier Works is located near the coast at 200 Waitangi Road, Awatoto, approximately 6.5 km from Napier city (see Figure 1.1). It produces up to 440,000 tonnes per annum of superphosphate fertiliser and is the largest superphosphate Manufacturing Plant in New Zealand.

The manufacture of superphosphate at the Napier Works gives rise to the discharge of contaminants into air, which are currently authorised[3] under resource consent AUTH-115256-04 from the Hawke's Bay Regional council (HBRC). This resource consent expires on 21 October 2022. A copy of this resource consent is available in Appendix A**.**

Ravensdown is applying to renew its resource consent to discharge contaminants into air. This Assessment of Environmental Effects (AEE) relating to the site's air discharges has been prepared to support Ravensdown's application.

Several improvements to the site are proposed that will reduce air discharges in line with Ravensdown's Air Discharge Strategy (Ravensdown 2021). The most notable upgrades include the Den Scrubber system (which has recently been authorised through a consent variation) and a proposed upgrade to the Acid Plant converter. The Ravensdown Board has approved the funding for the capital expense of the new plant with a committed timeframe the installation of the plant (2022 for the Manufacturing Plant scrubbers and 2023 for the Acid Plant converter).

This report has been prepared in accordance with Tonkin & Taylor Limited's (T+T) letter of engagement dated 1 November 2019. Its purpose is to detail the methods, results, and findings of the assessment of actual and potential effects of discharges to air from the Ravensdown Napier Works to inform the AEE for the consent application.

[3] This permit was varied on 5 July 2021 to provide for discharges into air from a new combined Manufacturing Plant stack that replaced the existing two Den Scrubber stacks and the existing Hygiene Scrubber stack. At the time of this report, the Changes to the plant have not been implemented.

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APPROVED	DATE	

CLIENT **RAVENSDOWN LIMITED**
PROJECT **RAVENSDOWN NAPIER WORKS**
TITLE SITE LOCATION

SCALE (A4) 1:15,000 FIG No. FIGURE 1.1 REV 0

2 Description of site activities

2.1 Overview

The Ravensdown Napier Works is situated at the southern extent of the Awatoto industrial area and adjacent to the foreshore. The Site has been in operation since 1954 and has been owned by Ravensdown since 1987.

Ravensdown produces superphosphate fertiliser, which requires the import of bulk materials and the production of sulphuric acid. As New Zealand's largest superphosphate Manufacturing Plant, production of superphosphate typically ranges between 250,000 and 300,000 tonnes per annum, although the Site has the capacity to produce up to 440,000 tonnes per annum in its current configuration.

Superphosphate is produced by reacting ground phosphate rock with concentrated sulphuric acid, which results in the phosphate being soluble and available for plant uptake as a fertiliser. The manufacturing process initially requires the production of sulphuric acid. The various steps involved in superphosphate manufacture are summarised in the flow diagram given in Figure 2.1 and are described in more detail in the following sections.

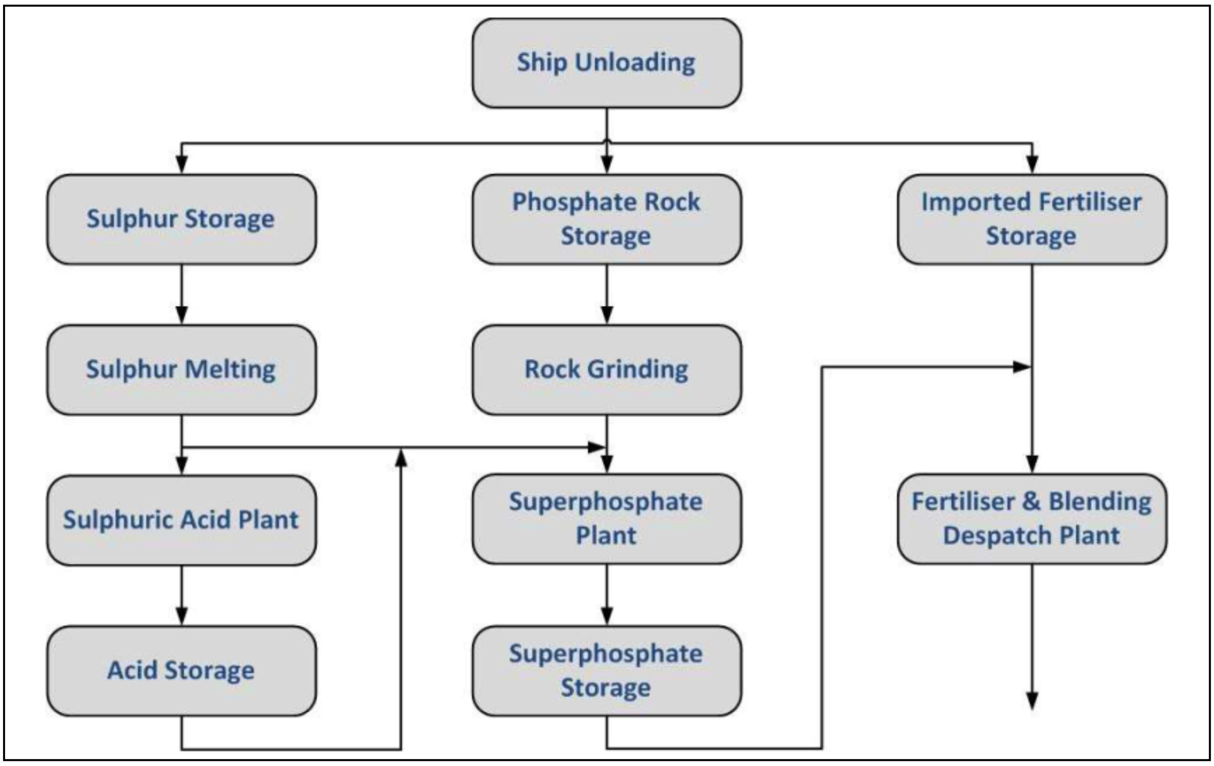

Figure 2.1: Summary of the Site activities that occur at the Ravensdown Napier Works (source: Ravensdown).

2.2 Bulk materials

Ravensdown receives approximately 200,000 tonnes per year of bulk materials for manufacture at Napier Works via the Port of Napier, mostly in the form of sulphur and phosphate rock. These are transferred from the port in covered trucks to the Site.

Up to 27,000 tonnes of prilled[4] sulphur is stored within the sulphur stores, while the phosphate rock is stored within several covered/enclosed 'rock stores' with capacity of approximately 80,000 tonnes. The location of the sulphur and rock stores are indicated in Figure 2.10.

2.3 Sulphuric acid production

2.3.1 Sulphur receipt and storage

Elemental sulphur is currently imported primarily from Canada. It is a by-product of the petrochemical industry. The sulphur is received by ship at the Port of Napier and is transported by truck to the Site. The sulphur is in a granular form (prill) with a specification[5] of less than 5% fines to reduce dust emission during the handling and conveying process. Prior to shipping the elemental sulphur will have SLS (Sodium Lauryl Sulphate) applied to minimise formation of hydrogen sulphide (H_2S).

The prilled sulphur is received at the Site into an intake hopper and then conveyed into one of two bulk sulphur storage sheds. The location of the storage sheds is shown in Figure 2.10.

2.3.2 Sulphur melter

Sulphur prills are loaded from the stores into a melting plant to be melted indirectly via steam, which causes any water contained within the sulphur to be released as well as some H_2S gas. Both the steam and hydrogen sulphide are discharged through vents. The molten sulphur is pumped to the Acid Plant or Manufacture Plant. A schematic of the sulphur melting process is given in Figure 2.2.

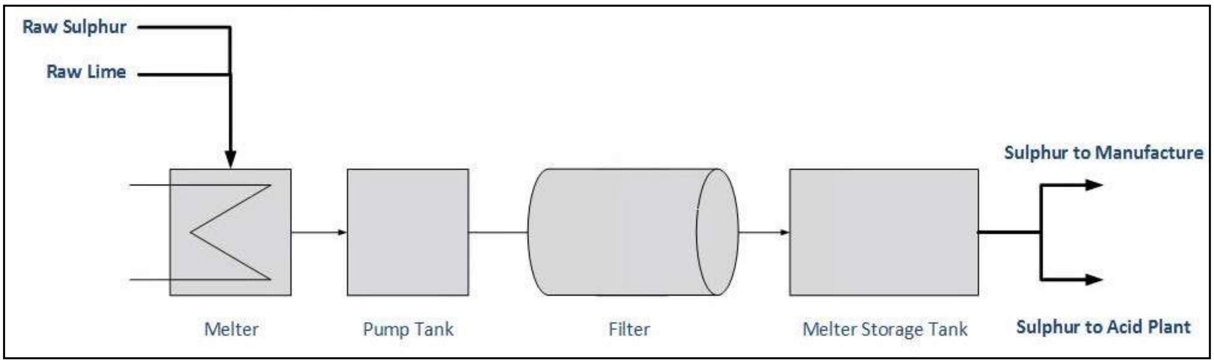

Figure 2.2: Sulphur melter flow diagram (source: Ravensdown).

[4] Prilled refers to the sulphur being in a granulated state that minimises the potential for dust generation from its handling.
[5] The as received fines content is typically less than 3%.

Figure 2.3: View of the sulphur melter and sulphur stores from Waitangi Road, outside of the Site.

2.3.3 Acid Plant

Sulphuric acid is produced through a Sim-Chem (Monsanto) designed plant that uses the ‘Contact Process’, which is a widely known and understood means of sulphuric acid manufacture. This process initially involves burning molten sulphur with dried air to form sulphur dioxide (SO_2). SO_2 is then passed over a catalyst (vanadium pentoxide), which converts it into sulphur trioxide (SO_3) – this is done in the ‘converter’. SO_3 is then scrubbed from the gas stream using strong sulphuric acid (H_2SO_4), further concentrating the acid. Water is added to dilute the concentration and the resulting sulphuric acid is pumped to storage tanks for use in the fertiliser Manufacturing Plant or commercial sales. Figure 2.4 provides a simplified schematic of the acid production process and Figure 2.5 provides a view of the Acid Plant from State Highway 51.

The Napier Works operates a double absorption process. This two-step conversion and adsorption process reduces the amount of SO_2 released to atmosphere for a given production rate when compared to single absorption plants. This is because of the greater rate of removal of SO_3, which allows the reaction equilibrium to move further.

Approximately 100,000 tonnes of sulphuric acid are produced each year, depending on sales the majority of which is used in the manufacturing process and the remainder sold directly to consumers.

Many of the reaction steps involved in the production of sulphuric acid result in the generation of excess heat. The excess heat is used to generate steam. Low-pressure steam is used in the Acid Plant, while high-pressure steam is used to create electricity through a steam turbine.

In times when the Acid Plant is not operating, a diesel-powered boiler is required to continue the supply of low-pressure steam. Further information on the Acid Plant start-up is given in the following section.

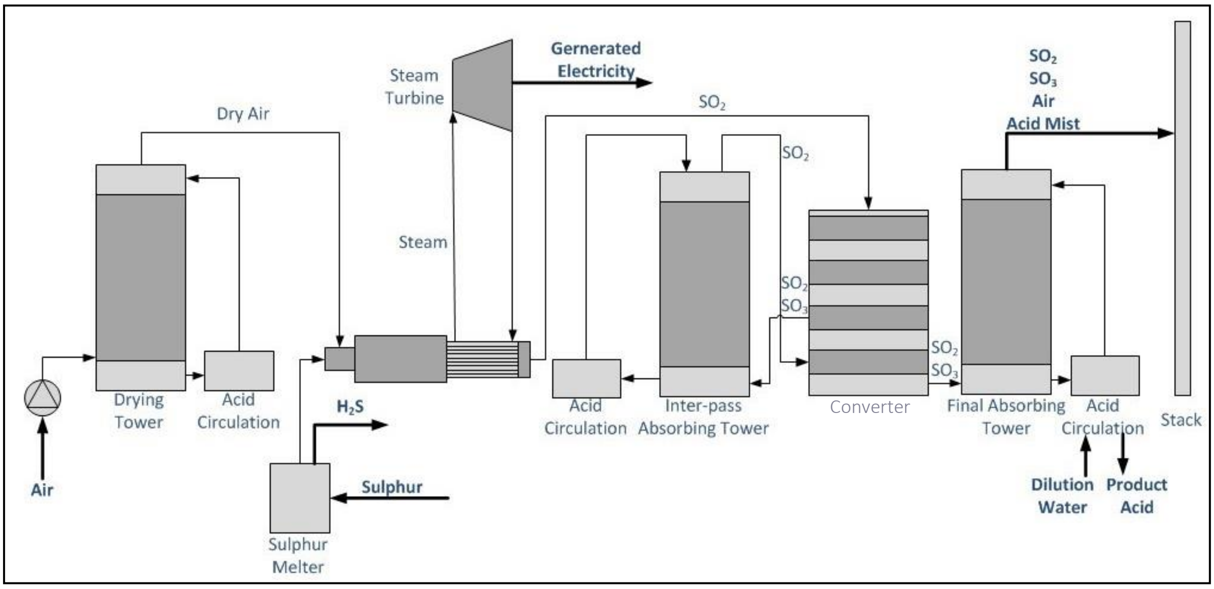

Figure 2.4: Double absorption sulphuric Acid Plant flow diagram (source: Ravensdown).

Figure 2.5: View of Acid Plant from State Highway 51.

2.3.3.1 Acid Plant pre-heating and shut down

The diesel-powered auxiliary boiler is used to generate low pressure steam for short periods when the Acid Plant process is not operating but intended to restart. This boiler discharges products of combustion.

Diesel combustion emissions and SO_2 are also discharged from heating the process vessels during restart of the Acid Plant.

Heating of the furnace refractory, catalyst and other process equipment also occurs before firing the Acid Plant on sulphur and this results in discharge of diesel combustion products.

Since November 2016, the start-up procedure has been refined to minimise SO_2 emissions. A 'start-up stack' was also installed extending the height of the previous temporary stack that was used for pre-heating the furnace. These measures help minimise the ambient concentrations of SO_2 during start-up. Ravensdown is continuing to investigate measures to further reduce the impact of SO_2 emissions during start-up, including the configuration of the start-up stack.

The technique for cooling the Acid Plant down prior to an annual maintenance shutdown has also been refined. The plant is now allowed to cool more gradually, ensuring residual sulphur is largely burnt off and converted to acid prior to completely shutting down. The consequence of this is it also helps to minimise SO_2 emissions during plant start-up.

As discussed in the Ravensdown Air Discharge Strategy' (Ravensdown 2021), it plans to investigate and implement measures to reduce SO_2 emissions during start-up.

2.3.4 Converter replacement

As described in Ravensdown's 'Air Discharge Strategy', a planned replacement of the existing converter tower is programmed for 2023, which will increase the volume of catalyst inside the tower and enable a greater conversion of SO_2 to SO_3. Ravensdown expects the increased catalyst volume will enable them to meet a lower SO_2 emission rate limit, which is discussed further in Section 3.2.2.2.

2.4 Manufacturing Plant

2.4.1 Phosphate rock receipt and grinding

The primary ingredient of superphosphate is phosphate rock. This raw material is purchased internationally and shipped to the Port of Napier. From the port the rock is trucked to the Napier Works and received over an intake system which conveys it into rock storage sheds. The location of the rock stores is shown in Figure 2.10.

In its raw state, the phosphate rock has a range of consistencies, such as sand-like, coarse chip or damp topsoil consistence. In this state the rock is too coarse to react sufficiently with acid and make superphosphate. Prior to processing, the rocks are blended through a weighed silo system to create a mix, which satisfies the chemical characteristics required by the plant. It is then fed to the milling plant where it is ground to the consistency of talcum powder (more than 80% passing a 75 µm sieve) and conveyed to a storage tank. Figure 2.6 provides a schematic of the rock grinding process.

Dust is generated from the grinding of raw phosphate rock and the manufacturing of superphosphate. This dust is collected through bag house systems, which are associated with each mill (collectively referred to as Bradley Mills). The baghouse system uses a fan to draw in air and pass it over a set of filter bags capturing any dust before it is discharged. Dust collected on the filter bags is reused in the feed for the powder plant.

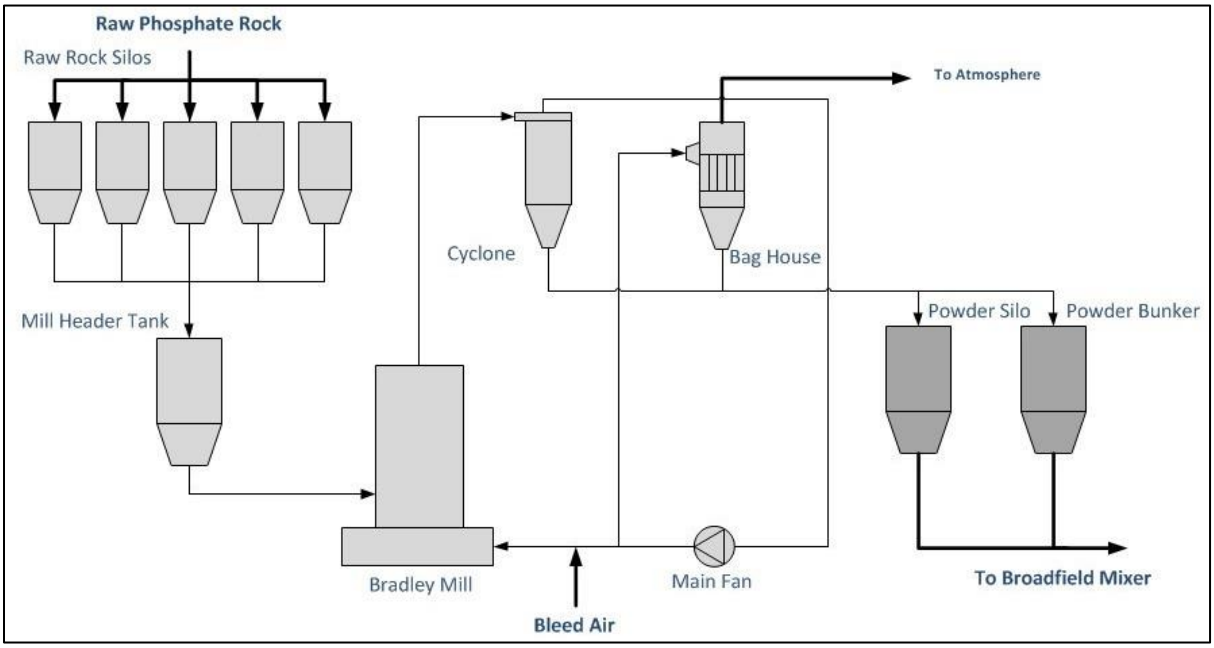

Figure 2.6: Rock grinding plant flow diagram (source: Ravensdown).

Figure 2.7: View of the Manufacturing Plant looking from Waitangi Road across the site office. The stacks to the right are the existing Den Scrubber stacks and the stack in the distance to the left is the existing Hygiene scrubber stack.

2.4.2 Rock acidulation

From the storage tank, the finely ground phosphate rock powder is fed into the Broadfield Mixer and Den. In the mixer sulphuric acid and phosphate rock are reacted, alongside hydrofluorosilicic acid (FSA)[6] and fresh water to form a product with the consistency of wet concrete. Elemental

[6] The FSA is sourced from the Den and Hygiene scrubbers described later in this report.

sulphur may also be added from the sulphur melter on occasions to provide a product containing sulphur.

Two reactions occur. The first occurs quickly between sulphuric acid and phosphate rock to create phosphoric acid and gypsum. The second reaction uses the phosphoric acid and more phosphate rock to produce monocalcium phosphate, which occurs over a couple of weeks depending on rock source and grind consistency.

Figure 2.8: View of the Manufacturing Plant looking from SH51. The stacks in the background are the existing Den Scrubber stacks and the stack in foreground is the existing Hygiene scrubber stack.

The initial manufacturing process occurs for approximately 20 minutes inside a reaction chamber called the 'Den', which allows completion of the first reaction and significant progress through the second. Once cured, the material is crushed and passed through the granulation system to form the final granulated product. This product is conveyed into the storage sheds and allowed to mature until the granules fully harden and the reaction completes.

The process of adding H_2SO_4 to the mixer causes the phosphate to convert to a soluble state. Phosphate is mostly bound within the same mineral (usually fluorapatite) as fluoride, causing fluoride to be released during the mixing process, as well as carbon dioxide, heat, and steam. A wet scrubbing system referred to as the 'Den Scrubber' is used to absorb fluoride gases from the process. The Den Scrubber system is comprised of a series of large towers that contain sprays that wash the steam and absorb the fluoride before the steam is discharged through the Manufacturing Stack(s).

There are also some fluoride gases that are released during the granulation and conveying systems. These are collected through a second scrubber system known as the 'Hygiene Scrubber', allowing fluoride levels to be minimised within the building. Emissions associated with the Hygiene Scrubber are also discharged through the Manufacturing Stack.

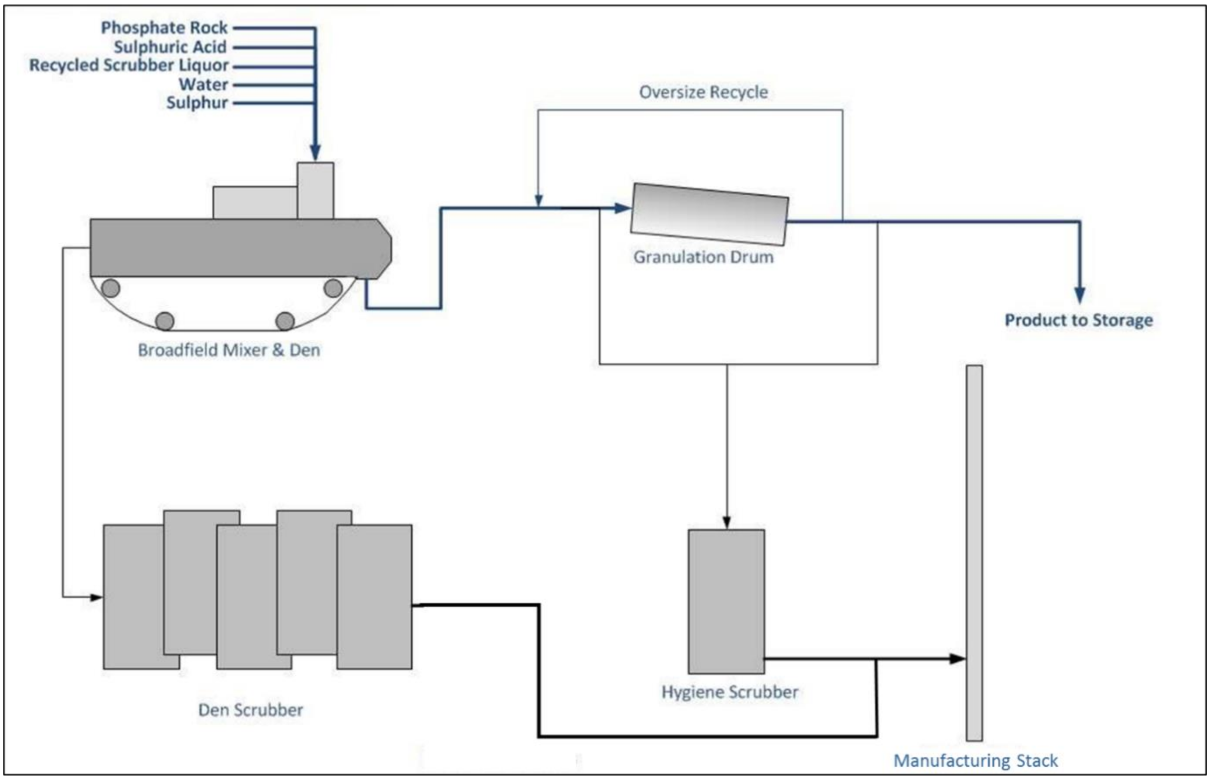

Figure 2.9: Superphosphate plant flow diagram with a combined Manufacturing Stack.

The Hygiene and Den Scrubber systems currently discharge via separate stacks (two for the Den Scrubbers and a single stack for the Hygiene scrubber). Ravensdown was granted a variation to its existing air discharge permit on 5 July 2021 to replace the Den Scrubber system and combine all three stacks into a new, taller 50 m stack. As described in the Discharge Strategy, this new scrubber system will enable Ravensdown to operate in a lower fluoride discharge limit and lower ambient fluoride levels, which is discussed further in Section 3.2.1

2.5 Cooling towers

The Acid Plant operates two cooling towers that are used for cooling the freshly made sulphuric acid and for cooling the turbine/alternator system. The bulk of the heat generated in the acid manufacture process is reclaimed and used to generate steam. Manufacturing steps such as acid dilution release low grade heat which is not hot enough to be used to create steam. This heat must be removed from the plant and is dissipated through cooling towers. The cooling towers consume fresh water and remove heat from the plant through evaporation. The evaporated water may be seen as a vapour plume above the cooling tower fans on occasions and contains no contaminants.

2.6 Dispatch process

A loader is used to collect the cured superphosphate from the storage sheds and feed it into a dressing plant. This dressing plant breaks up any lumps in the product before it is loaded into trucks to be dispatched from the Site. A portion of the superphosphate is also fed into a blending plant which allows other products which are not manufactured on the Site to be blended with it to achieve the nutrient characteristics required by a customer. This is loaded into trucks using conveyors or front-end loaders to be dispatched from Site.

The processes of conveying, dressing, and loading of the fertiliser can all result in some dust becoming airborne.

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CLIENT **RAVENSDOWN LIMITED**
PROJECT **RAVENSDOWN NAPIER WORKS**
TITLE SITE LAYOUT
SCALE (A4) 1:4,000 FIG No. FIG 2.10 REV 0

3 Nature of discharges

3.1 Main sources

3.1.1 Introduction

There are generally two types of emissions that are associated with an industrial site: stack discharges and fugitive emissions. Stack discharges refer to emissions that are intentionally extracted from an industrial process with the air stream undergoing treatment processes to reduce contaminant levels to acceptable levels if required before being discharged to air. Stack discharges at the Napier Works arise from the processes involved in the production of sulphuric acid and superphosphate fertiliser. Fugitive emissions typically occur at ground level or through buildings and generally do not undergo any treatment processes. Dust and odours are well known fugitive emissions due to the nuisance effects that they may cause.

3.1.2 Stack emissions

Most stack emissions from the site will occur from the Acid Plant stack and the Manufacturing stack(s). Emissions from the Acid Plant stack are associated with the production of sulphuric acid and will mainly consist of SO_2 and acidic gases (SO_3) and some acid aerosols (H_2SO_4).

During a cold start-up of the Acid Plant, diesel is used to fire burners used to pre-heat the plant. This includes the direct firing of the sulphur furnace on diesel, the firing of the Auxiliary Boiler which generates steam for heating the sulphur melter, and indirect heating of the remainder of the Acid Plant. The combustion of diesel gives rise to emission of nitrogen oxides (NO_X), particulate matter less than ten microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), carbon monoxide (CO) and SO_2 (although SO_2 emissions from diesel combustion are negligible given the very low sulphur content of diesel – less than 0.001%). Notwithstanding this, SO_2 emissions from the firing of the furnace can also occur from the burning-off of any residual sulphur that has settled on the refractory lining of the furnace during the previous plant shutdown.

The Manufacturing Plant contains two scrubber systems (den and hygiene) which currently discharge via three stacks (two den stacks and the hygiene stack), but which are to be combined and discharged through a single 'Manufacturing' stack. The main contaminant discharged from the manufacturing process is fluoride but some SO_2, acidic gases, and steam are also discharged.

The Manufacturing Plant's four Bradley mills each discharge through a bag-house filter system. Three of these (Mill #2, Mill #3, and Mill #4) discharge to the atmosphere through vents above the roof of the Manufacturing Building, and one (Mill #5) discharges to the atmosphere underneath the 'Rock Canopy' (Figure 2.10). Bradley Mill #1 was decommissioned in 2011. The main discharge from the bag filters is residual particulate matter.

The physical stack parameters used as input to the dispersion modelling assessment are summarised in Table 3.1. Stack emission rates are discussed in Section 3.3 and summarised in Table 3.2.

3.1.3 Fugitive and other emissions

Fugitive emissions come from a variety of sources and can include the contaminants mentioned above as well as dust and odour. A summary of the probable sources of fugitive and other air emissions from the Napier Works is listed below:

- Dust from wind erosion (from either plant surfaces or stockpiles);
- Dust generated by vehicle movements;
- Dust from the handling of materials e.g., loading and unloading;

- Exhaust emissions (e.g., SOX, NOX, and PM) from heavy vehicles;
- Hydrogen sulphide (rotten egg odour) from the melting of sulphur;
- Sulphur dioxide from the manufacturing of sulphuric acid;
- Acidic gases (e.g., SO3, H2SO4, and FSA) that escape the Acid Plant or Manufacturing Plant;
- Volatile gas releases from the superphosphate piles and the Manufacturing Plant stack (superphosphate type odour);
- Fugitive fluoride emission from the manufacturing process;
- Water vapour;
- Emissions associated with diesel combustion from on-site vehicles, machinery and the start-up boiler; and
- "Upset" emissions such as fires involving sulphur.

Due to difficulty in quantifying fugitive emissions, they have not been assessed through dispersion modelling. Instead, they have been assessed qualitatively taking into consideration good practice mitigation measures that are being used and an investigation in the complaint history. This is with the exception of fugitive fluoride emissions, where monitoring data and dispersion modelling have been used to estimate the fugitive fluoride emission rate.

3.2 Contaminants discharged

3.2.1 Fluoride

Fluoride emissions are the main contaminant discharged from the manufacturing process. Fluoride is a highly reactive gas and readily forms as hydrogen fluoride (HF). Exposure to high concentrations of HF can result in irritation of the respiratory tract, burning of the skin, and prolonged visual effects. However, ambient air concentrations required to cause such human health effects are not typically associated with the manufacture of superphosphate – this is further addressed in Section 6.1.3. and in the Environmental Health Effects Assessment (Environmental Medicine Limited 2021).

Fluoride emissions can also result in damage to sensitive crops and the etching/frosting of window glass where the exposure is sufficient, and this is typically the key air quality concern in relation to superphosphate manufacture. Such effects on sensitive vegetation occur at concentrations approximately 1,000 times less than those where human health effects typically occur.

Adverse effects on sensitive vegetation result from an accumulation of fluoride in the leaves, interfering with a plant's metabolic activity and causing effects such as reductions in growth, nutrient uptake, seed germination, photosynthesis, protein synthesis, and enzymatic activities.

The site's current resource consent limits the discharge of fluoride gas to 1.5 kilograms per hour (kg/hr). This discharge limit applies as a combined total from the existing two Den Scrubber stacks and the Hygiene Scrubber stack. However, Ravensdown is in the process of replacing the Den Scrubber system and combining all three stacks into a new single stack (a combined Manufacturing Plant stack) and obtained a variation to its air discharge permit in July 2021 to enable this change. The current discharge limit applying to the combined Manufacturing Plant Stack is also 1.5 kg/hr

Because the new combined Manufacturing Plant stack is not yet in place, the assessment of effects associated with this application presents results for:

- The existing plant configuration (i.e., two Den Scrubber stacks and a Hygiene Scrubber stack) with a combined discharge rate of 1.5 kg/hr; and
- The new Manufacturing Plant Stack with a revised lower discharge rate of 1.0 kg/hr. The revised discharge rate follows a review by Ravensdown, as set out in its Air Discharge Strategy.

For completeness, an analysis of stack testing data has been based on the three-stack configuration and is summarised in Figure 3.1 for the period January 2015 to August 2021. This provides a comprehensive spread of data while being relevant in terms of current site operations. The results largely show Ravensdown has achieved the combined stack emission rate limit of 1.5 kg/hr. Two exceptions to this occurred as follows:

- 29 September 2017: The operator reconfigured the plant away from standard practice because of a break down with the grey water system, which resulted in elevated fluoride concentration from the Hygiene Scrubber. This configuration was for only a short period. This has been addressed through staff training and relocation of freshwater make-up to the hygiene system; and
- 28 August 2019: A transfer line blockage resulted in a reduced makeup flow through part of the scrubber system. This affected the scrubber liquor concentrations, which consequently affected the stack fluoride concentration. To address this Ravensdown now monitor cumulative make up flow as well as instantaneous flow rate.

Figure 3.1 shows that for the majority of time fluoride emissions are well with the consent limit. Accordingly, a lower emission rate that is consistent with the 75th percentile of measured data (0.12 kg/hr) is used in the dispersion model to better represent long term impacts of fluoride (for example 30 day and 70 day average impacts).

The discharge parameters and emission rates used for the dispersion modelling assessment are summarised in Section 3.4.

As discussed in Section 3.1.3, fugitive emissions of fluoride also occur from the following sources. These fugitive sources cannot be readily quantified but are instead evaluated through a review of ambient monitoring provided in Section 5.2.

- Gaseous releases from superphosphate stockpile as curing of the product continues;
- Emissions from the Manufacturing Plant not contained by direct extraction to the Den and Hygiene Scrubber systems; and
- Dust emissions containing fluoride.

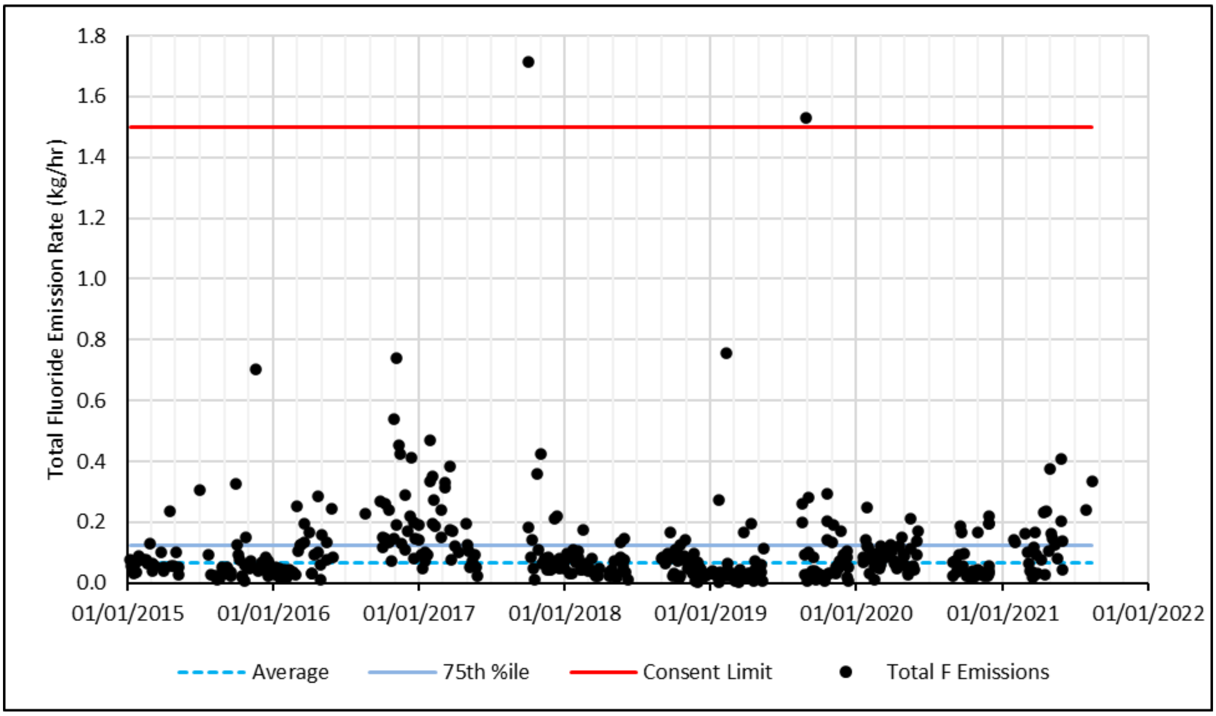

Figure 3.1: Combined fluoride stack emission rates measured from the Manufacturing Stacks (two Den stacks and one hygiene), January 2015 – August 2021.

3.2.2 Sulphur oxides

3.2.2.1 Introduction

In terms of sulphur oxides, the stack emissions from the Acid Plant will contain principally SO_2 but can also contain lesser amounts of SO_3 and acid mist. A smaller quantity of SO_2 emissions can also occur from the Manufacturing Plant.

SO_2 is of interest with respect to potential human health effects because it is a potent respiratory irritant when inhaled and asthmatics are particularly susceptible. SO_2 acts directly on the upper airways (nose, throat, trachea and major bronchi), producing rapid responses within minutes. SO_2 can also impact sensitive ecosystems.

The discharge parameters and emission rates used for the dispersion modelling assessment are summarised in Section 3.4. The following summarises emissions of SO_2 and SO_3.

3.2.2.2 Sulphur dioxide

The Acid Plant is the principal source of sulphur oxides, including SO_2, SO_3 and H_2SO_4. Fugitive emissions of SO_2 may also occur from small pin-hole leaks within ducting.

The site's air discharge permit limits the collective discharge of these gases from the Acid Plant stack to 60 kg/hr (and 1.5 kg/min as a 2-minute average). As set out in its Air Discharge Strategy, Ravensdown seeks to retain this existing consent limit until it upgrades the Acid Plant convertor, after which it proposes a lower SO_2 emission rate of 40 kg/hr

Figure 3.2 presents the 2015 – 2021 total SO_2 (including SO_3 and H_2SO_4 expressed as SO_2) from stack emission testing from the Acid Plant stack. This illustrates emissions have been within the 60 kg/hr consent limit, with the average emission rate being approximately 14 kg/hr. Emissions do on occasions approach the 60 kg/hr limit, depending on the production rate of the Acid Plant However, the plant operations and automatic shutdown system continuously monitor for in-stack SO_2 concentrations to avoid exceeding the existing 60 kg/hr limit.

Given the above, using the consent emission rate limit of 60 kg/hr is appropriate for assessing off-site modelled concentrations against the 1-hour and 24-hour assessment criteria. However, using this maximum emission rate will significantly overstate off-site annual average concentrations. To address this, the 75th percentile emission rate (18.7 kg/hr) derived from stack emission testing measurements between 2015 and 2021 has been used. We consider this provides a more realistic, albeit still conservative, representation of long-term SO_2 impacts associated with the Acid Plant.

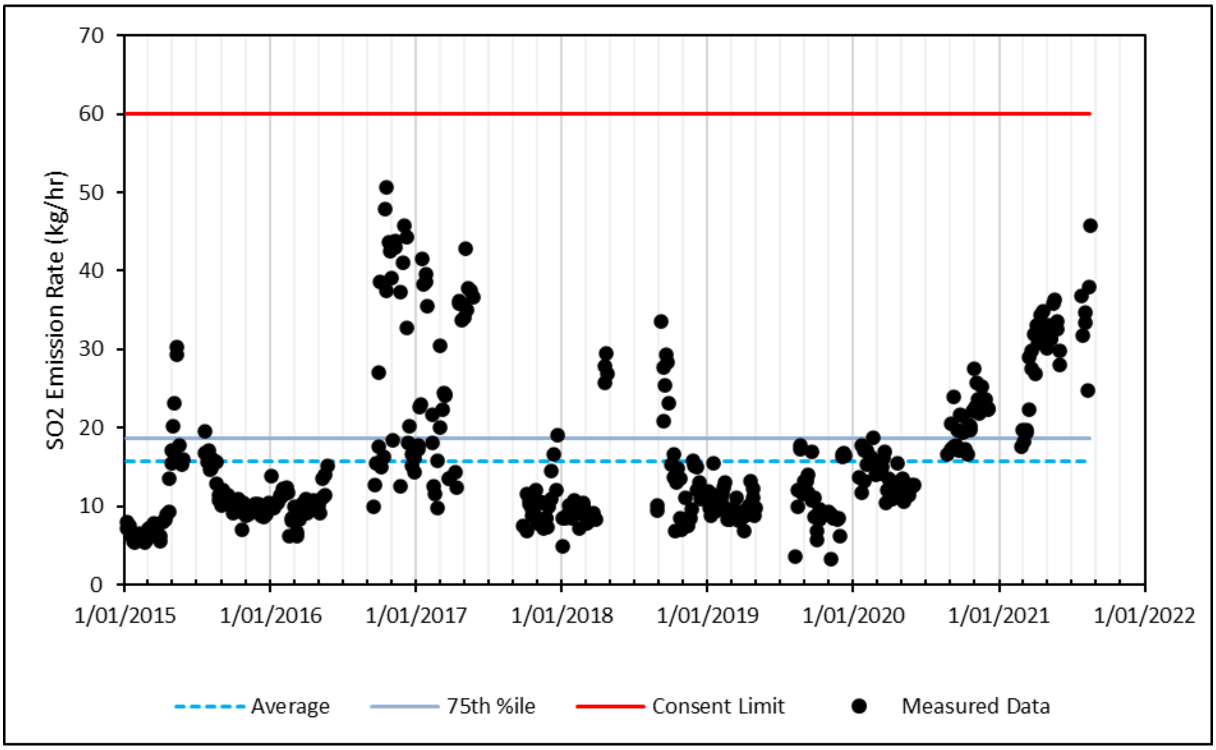

Figure 3.2: Measured SO_2 emission rate (kg/hr) from the Acid Plant Stack, January 2015 – August 2021.

The Manufacturing Plant can also be a source of SO_2. SO_2 from the Manufacturing Plant (principally the Den) has not been measured historically at the site. Ravensdown has undertaken testing of the Den Scrubber stacks, which indicates a combined emission rate of approximately 1 kg/hr. However, due to the limited amount of testing associated with the Manufacturing Plant, Ravensdown (as set out in its Air Discharge Strategy) proposes a discharge limit of 10 kg/hr. An annual average emission rate of 3.1 kg/hr has been adopted for the dispersion modelling assessment based on the ratio of the maximum to the annual rate used for the Acid Plant and applying that ratio to the assumed peak value for the Manufacturing Plant. These modelled emission rates are expected to be conservative given they are both higher than the measured emission rate.

Emissions of SO_2 associated with a cold start-up of the Acid plant occur from the use of diesel for pre-heating the plant.

The main source of SO_2 during a cold start-up is instead from the preheating of the sulphur furnace where any residual sulphur that has settled on or in the refractory lining of the furnace during the previous plant shutdown is burned off. During pre-heating, the discharge from the sulphur furnace is diverted to a 13 m high 'Start-up' stack.

SO_2 emissions associated with the Start-up stack have not been measured to date. This is mainly due to the start-up process being a very infrequent activity (typically occurring once per year over a period of approximately 60 hours – 2.5 days).

Therefore, while it is technically possible to model start-up emissions, we consider this is of limited value in understanding air quality effects given the intermittent nature of start-ups and the absence of reliable emissions data. We consider that evaluation of the ambient SO_2 monitoring data presented in Section 5.3 provides a better means for assessing the impact of start-up emissions compared to dispersion modelling.

3.2.2.3 Acidic gases and aerosols

The acid gas SO_3 and H_2SO_4 aerosols are discharged from the acid stack in small quantities. These gases can result in adverse impacts for sensitive vegetation where the long-term exposure is sufficiently high.

The existing consent (Condition 18) limits the emission rate of these gases (expressed as SO_3) to no more than 2 kg/hr, with 50% of 1-hour average samples over a 3-month period being no more than 0.5 kg/hr.

Figure 3.3 presents a time-series graph of measured SO_3/H_2SO_4 emission rates for the Acid Plant stack, which shows good compliance with the consent limits. In particular, measured emission rates have not approached 2 kg/hr and have remained within 0.5 kg/hr and have been relatively consistent since 2018. Notwithstanding this, it is noted there is a general increase in concentrations in 2021 compared to previous years. The reason for this increase is not clear, with possible causes being a reduced absorption efficiency in the final tower, the mist elimination candles not working ideally or an increased gas velocity through the plant (due to use of the bigger forced draft fan) that reduces the efficiency of the candles.

As set out in its Air Discharge Strategy, Ravensdown proposes to retain the existing discharge limits for acid gases and aerosols.

To model the long term impacts of SO_3 and sulphur deposition impacts, the following emission rates have been used, which are derived from the 75th percentile of measured SO_3 emissions:

- SO_3 emission rate of 0.09 kg/hr.
- SO_4 emission rate of 0.11 kg/hr.

The conclusions reached in Sections 6.2.4 and 6.2.6.1 regarding long term average impacts of SO_3 and SO_4 emissions indicate the above long term emission rates would need to be substantially higher to give rise to levels that approach the relevant assessment criteria.

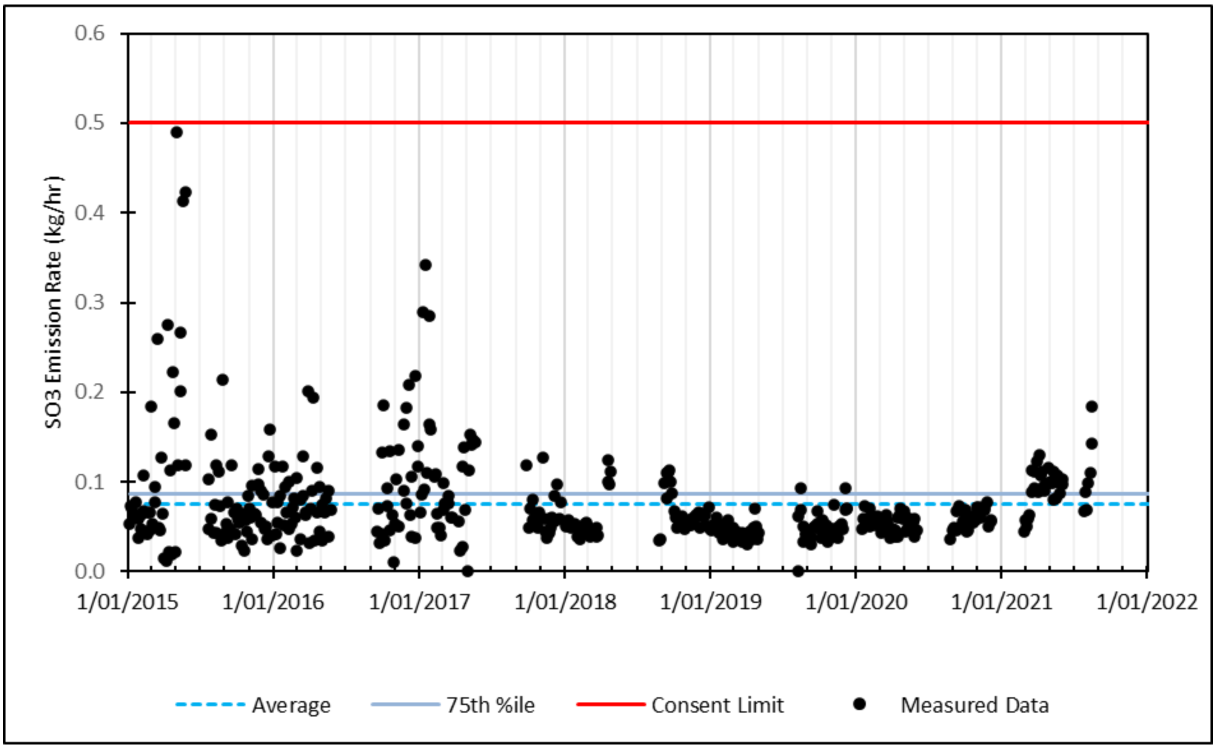

Figure 3.3: Combined SO_3 and H_2SO_4 emission rate (expressed as SO_3 in kg/hr) measured from the Acid Plant Stack at the Ravensdown Napier Works, January 2015 – August 2021.

3.2.3 Particulate matter

Particulate matter emissions of interest are those that are smaller than ten microns in diameter (PM_{10}) and those smaller than 2.5 microns in diameter ($PM_{2.5}$).

The health effects of particulate matter relate to its size. Particles less than 2.5 microns in diameter pose the greatest problems, because they can travel deep into the lungs, and some may even pass into the bloodstream. Ambient air concentrations of particulate matter are typically reported as PM_{10} or $PM_{2.5}$.

The main source of PM_{10} and $PM_{2.5}$ from the Ravensdown site occurs as residual emissions from the bag-filter exhausts associated with the Bradley Mills. The existing air discharge permit limits the total suspended particulate (TSP)[7] emission to the following rates:

- No more than 1 kg/hr per mill; and
- No more than 2 kg/hr if two mills are operating concurrently.

Emission testing of TSP discharges from the Bradley Mills is routinely undertaken by Ravensdown. Figure 3.4 shows the sum of the Bradley Mill stack testing emissions where concurrent testing of mills occurred, from January 2015 to August 2021, with individual results shown in Figure 3.5. This figure illustrates emissions from the mills are well controlled and have been within the combined limit of 2 kg/hr stipulated by the air discharge permit, although the individual emission rate on one occasion has reached 1 kg/hr.

In practice, one or more mills will operate whenever the Manufacturing Plant is in operation. However, the number of mills operating concurrently depends on the rock blend being used and the

[7] TSP refers to particles smaller than 30 microns in diameter and includes particles in the PM_{10} and $PM_{2.5}$ size range.

product being manufactured. Most commonly three mills are operated at the same time, very occasionally four mills and on occasions just two mills.

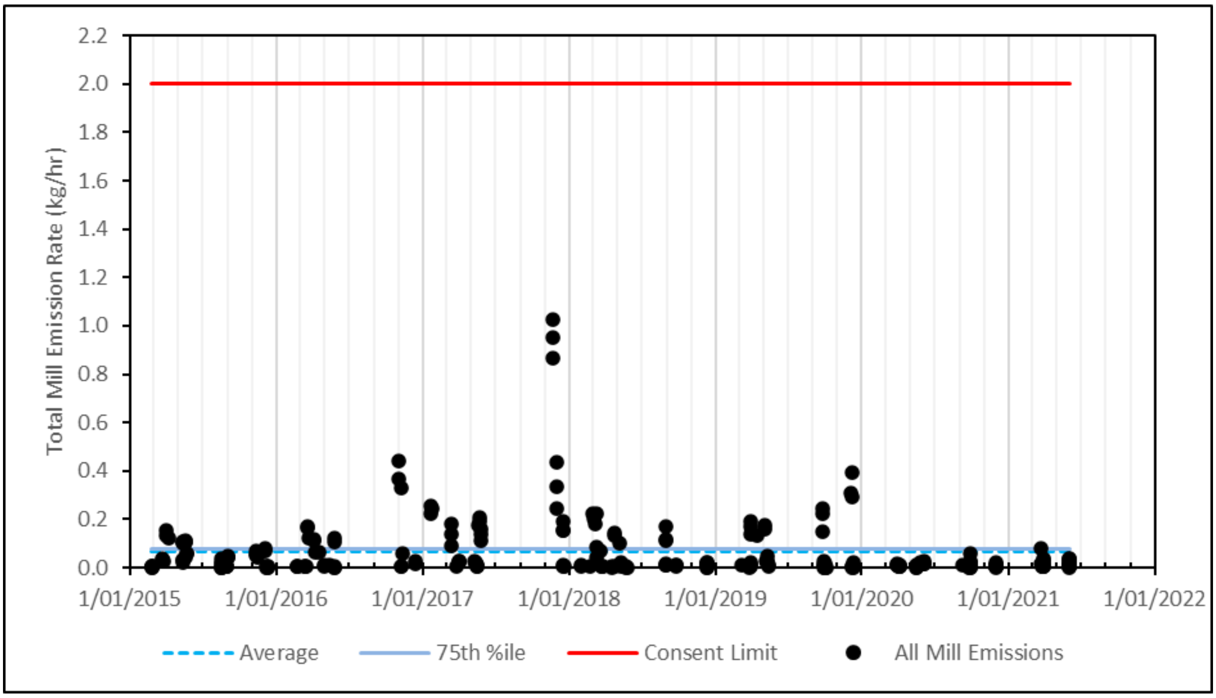

Figure 3.4: Combined TSP emission rates, measured from the Bradley Mills, at the Ravensdown Napier Works, January 2015-August 2021.

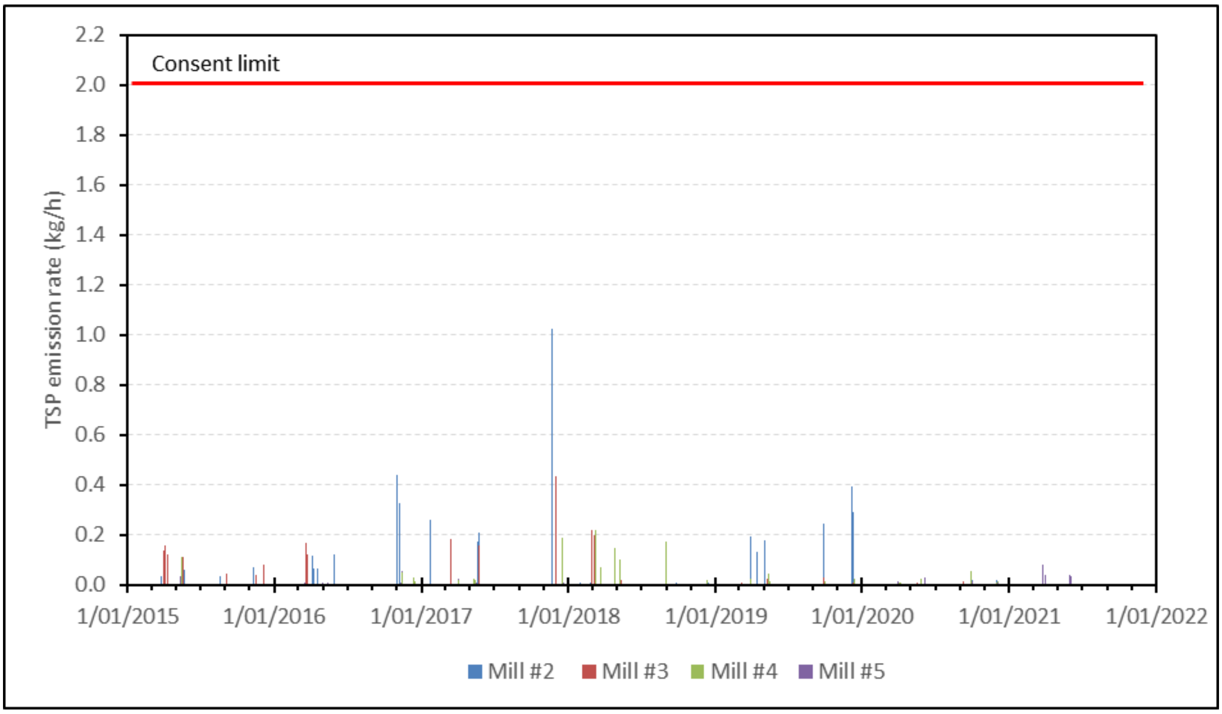

Figure 3.5: Individual TSP emission rates measured for each of the Bradley Mills, January 2015-August 2022.

Bradley Mill #1 was decommissioned in 2011 and consequently the site currently operates four of the original five Bradley Mills. It is not practicable to select any two mills that might operate concurrently for the purpose of dispersion modelling. Accordingly, the dispersion modelling assessment assumes all mills operate concurrently, but collectively discharging at a combined rate pro-rated to be equivalent of the five original mills discharging at 2 kg/hr. For the four current mills this equates to each mill discharging at a rate of 0.4 kg/hr (or a combined rate of 1.6 kg/hr). This maximum consented emission rate has been used to evaluate effects against short term assessment criteria for PM_{10} and $PM_{2.5}$ (i.e., 24-hour average concentrations).

Using the above emission rate values for the Bradley Mills as input to the dispersion model to assess against the long term annual average assessment criteria would result in a gross over-prediction of off-site concentrations. Accordingly, a lower emission rate for each of the Bradley Mills that more reasonably reflects emissions has been used. For this purpose, the 75^{th} percentile of all TSP measurements made collectively of all four mills from 2015 to 2021 has been used, giving a value of 0.12 kg/hr per mill.

The proportion of the TSP discharge from the Bradley Mills that is comprised of particles in the PM_{10} or $PM_{2.5}$ size fraction is currently unknown. Accordingly, for the purpose of this assessment we have conservatively assumed 100% of the TSP discharge is PM_{10}, and 90% of TSP is $PM_{2.5}$.

Emissions of PM_{10} and $PM_{2.5}$ will also occur from engine exhausts of trucks and machinery (loaders etc) operating within the site. However, these emissions are expected to be very low relative to process emission and are not considered further.

Particles greater than 10 microns are typically referred to as ‘dust’, with the potential to cause nuisance effects rather than human health effects. Dust emissions can be associated with the handling of raw materials and products on site (i.e., phosphate rock and manufactured superphosphate). Dust emissions are largely minimised by having those activities carried out within the various storage sheds. However, some dust emissions may occur from openings to those storage buildings. Potential dust effects are considered further in Section 7.

PM_{10} and $PM_{2.5}$ emissions will also occur from the very infrequent combustion of diesel used for the cold start-up of the Acid Plant. This is discussed further in Section 3.2.6.

3.2.4 Odour

Odour emissions can occur from the site as a result of the handling and melting of sulphur as well as there being an intrinsic ‘fertiliser’ odour associated with the manufactured superphosphate fertiliser.

The formation of sulphides can occur during the melting of sulphur. The process of melting sulphur causes water to evaporate which can result in small quantities of H_2S gas being released. H_2S has a characteristic ‘rotten egg’ odour and its emission depends on microbial activity within the sulphur as well as the state of the sulphur upon its arrival.

Condition 29 of the current air discharge permit limits the ambient concentrations of H_2S to 7 µg/m³ (1-hour average) at or beyond the site boundary. This concentration limit is same as the Ambient Air Quality Guideline (AAQG, MfE 2002), and is for the protection of nuisance and unpleasant odour, rather than human health. Condition 50 requires the measurement of H_2S over a 7 day period and on at least two occasions per year.

A review of recent H_2S ambient monitoring is provided in Section 5.4.3. Of note is that the melting of sulphur does give rise to a ‘signature’ of elevated H_2S when the monitoring site is downwind. However, significantly elevated levels of H_2S that have been measured are associated with winds from the direction of the neighbouring Bio-Rich composting facility.

3.2.5 Pathogens

The site operates several cooling towers, particularly with regard to the Acid Plant. Poorly operated cooling towers have the potential to result in pathogen emissions, such as Legionella bacteria that may form in the recirculating water in a cooling tower and be discharged as an aerosol. A management regime involving testing and dosing the cooling water with disinfectant is used to minimise the risk of exposure and potential health effects of pathogens.

3.2.6 Other discharges

Other discharges to air occur from the site but are considered negligible in the context of the main site emissions. By way of example, this can include combustion related emissions such as NO_X and CO, that will be discharged from the use of the diesel-fired boiler used during start-up of the Acid Plant and from the operation of machinery and vehicles on site.

Emissions of NO_X and CO associated with diesel combustion during a cold start-up of the Acid Plant occurs very infrequently (typically once per year) over a period of approximately 60 hours to 2.5 days. Based on typical diesel fuel consumption during a start-up sequence, it is calculated that the combined combustion rate is equivalent to a 7 megawatt (MW) diesel fired boiler. To provide context for the scale of these short-term emissions, emission rates for NO_X, CO, PM_{10}/$PM_{2.5}$ and SO_2 from the combined burning of diesel fuel have been calculated using USEPA AP42 emission factors for a small diesel fired boiler and are provided in Appendix B and summarised in Table 3.1.

Notwithstanding the above, it is T+T's experience that emissions of NO_X, CO, PM_{10}/$PM_{2.5}$ and SO_2 from diesel fired external combustion appliances of this scale (i.e., 7 MW) do not typically give rise to off-site ground level concentrations that approach relevant assessment criteria (summarised in Section 6.1.3). The risk of any such exceedance is further minimised given the very infrequent nature of cold start-up of the Acid Plant. Given this, no further assessment of the effect of emissions from diesel combustion for the cold start-up of the Acid Plant is provided.

The expectation that assessment criteria will not be exceeded is further reflected in the findings of work undertaken to inform the activity status of diesel-fired boilers in several regional plans. These studies (NIWA 2013, Golder 2012) used generalised dispersion modelling for a range of scenarios and show that ground level effects of emissions from a 7MW diesel-fired boiler with a stack in excess of 10 m are small in comparison with assessment criteria.

Table 3.1: Summary of emission rates associated with diesel firing for the cold start-up of the Acid Plant

Contaminant	Emission rate (kg/hr)
NO_X	2.1
$PM_{10}/PM_{2.5}$ *	0.2
CO	0.6
SO_2	0.02

* PM_{10} emissions are assumed to be entirely comprised particles in the $PM_{2.5}$ fraction.

3.3 Manufacturing Plant upset emissions

There are two main types of upset conditions during superphosphate manufacture that can result in abnormally high fluoride emissions:

- A sudden failure of the Den emissions extraction system, resulting in emission venting into the manufacturing building without treatment. Den extraction failure can result from a failure of the extraction fan, but historically was more commonly due to blockages within the Den that closed off the extraction system. Notwithstanding the above, Ravensdown advises that it has not experienced a Den extraction failure since 2007. The effect of, and occurrence of, Den extraction failures is minimised by the following measures:
  - The installation of the Hygiene extraction and scrubbing system in early 2004 has helped minimise the impacts of Den extraction failure events, both in terms of worker health and acid vapour impacts on sensitive vegetation;
  - An opacity sensor above the mixer shuts the plant down should an excess of fume be detected above the mixer (the primary point of gas escape during a Den extraction failure);
  - An automated water deluge system; and
  - A vacuum pressure-sensor in the ducting between the mixer and the scrubber, which detects a change in vacuum pressure which might indicate a blockage and shuts the mixer plant down.
- The second upset condition results from the re-circulating scrubber liquor becoming too laden with dissolved fluoride (> 20 wt.%) such that the water scrubbing system becomes inefficient. The new Den Scrubber system will inherently be more stable and have improved process monitoring, further minimising the likelihood of this.

3.4 Summary of discharge and emission parameters

3.4.1 Stack parameters

The stack discharge parameters used in dispersion modelling assessment for each discharge stack are provided in Table 3.1.

The temperature and velocity parameters adopted for the Acid Stack are conservatively derived from a review of stack emission testing data for when the plant is operating at, or near to, its consented SO_2 mass emission limit of 60 kg/hr. Based on this an efflux velocity of 10 m/s and efflux temperature of 69 °C have been selected. Graphs illustrating the relationship between temperature and SO_2 mass rate and velocity and SO_2 mass rate are provided in Figure 3.2.

The discharge parameters for the existing two Den Scrubbers stack and the Hygiene Scrubber stack are derived from a review of monitoring data. Discharge parameters for the combined

Manufacturing Stack, which will replace the existing two Den Scrubber stacks and the Hygiene Scrubber stack, have been provided by Armatec.

The discharge values used for each of the Bradley Mills has been derived from a review of stack testing data. Notable considerations relating to configuration of the Bradley Mill sources are:

- Bradley Mill #2, #3, and #4 all discharge horizontally or near to horizontally. This reduces the dispersion characteristics of a stack emission compared with a stack that discharges vertically. Consequently, these sources were configured to use the 'vertical momentum flux factor'[8] setting in CALPUFF to simulate such sources;
- The efflux temperature and velocity used for Bradley Mill #2, #3, and #4 were derived from values provided by Ravensdown; and
- Bradley Mill #5 discharges under the 'Rock Canopy' which is open at either end. As such this source cannot be realistically modelled as a 'stack source' within the dispersion model and has instead been simulated as a volume source at either end of the Rock Canopy. The measured emission rate from Bradley Mill #5 has been split evenly between the two volume sources.

As described earlier, Bradley Mill #1 was decommissioned in 2011. Consequently, it has not been included in the dispersion modelling.

Table 3.2: Stack physical discharge parameters used in dispersion modelling assessment

Source	Height (m)	Diameter (m)	Temperature (°C)	Efflux velocity (m/s)
Acid Stack	55	1.2	69	10
Combined Manufacturing Stack†	50	2.35	44	10
Den Scrubber stack 1	38	0.85	57	9
Den Scrubber stack 2	38	0.85	57	9
Hygiene Scrubber stack	36	1.0	24	26
Bradley Mill #2*	17.5	0.6	40	9
Bradley Mill #3*	17.5	0.7	30	9
Bradley Mill #4*	17.5	0.7	40	11.5
Bradley Mill #5**	N/A	0.3	40	21

* Bradley Mills #2, #3, and #4 all discharge horizontally or near horizontally. Accordingly, these sources have all been modelled using the 'vertical momentum flux factor' setting in CALPUFF to simulate such sources.

** Bradley Mill #5 discharges under the 'Rock Canopy' and so has been modelled as two separate volume sources at either end of the Rock Canopy within CALPUFF to best represent this source. The values given in the table are the physical discharge parameters of the Mill within the Rock Canopy.

† The combined Manufacturing Stack will replace the two existing Den Scrubber stacks and the Hygiene Scrubber stack.

[8] The vertical momentum flux setting was set to simulate a discharge source that does not discharge vertically.

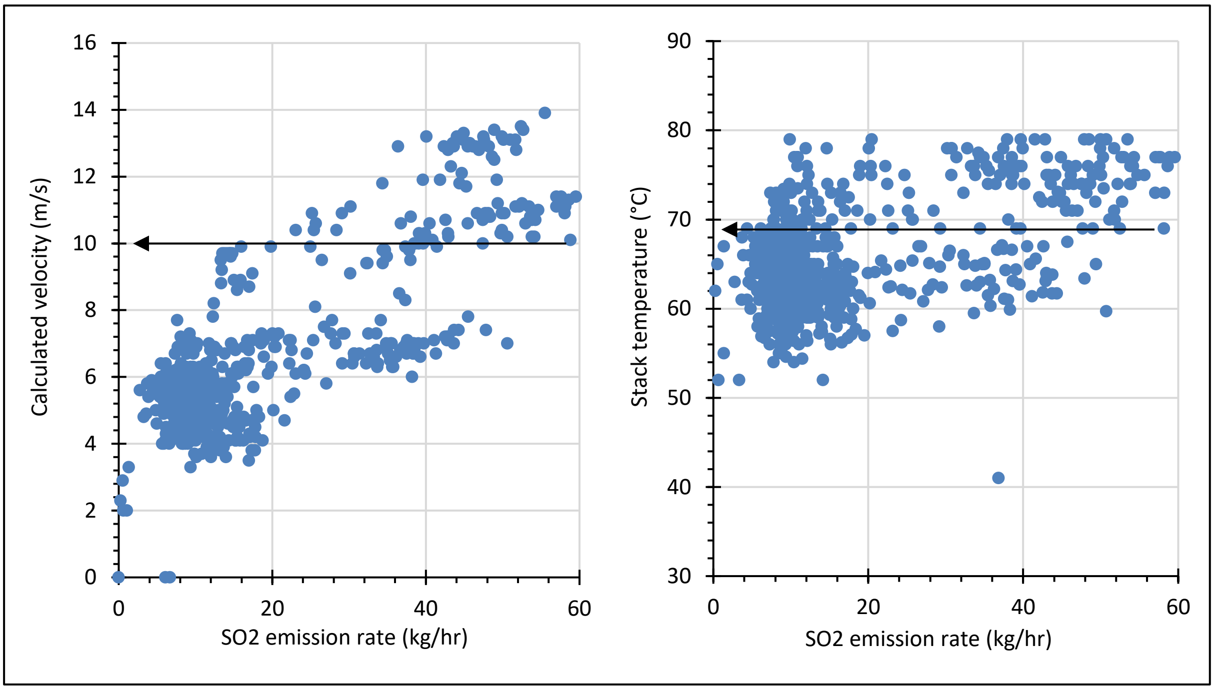

Figure 3.6: Relationship between velocity and SO_2 mass emission rate (left graph) and temperature and SO_2 mass emission rate (right graph) for the Acid Stack. Derived from stack testing data between 2010 and 2021.

3.4.2 Emission Rates

Two emission scenarios are assessed as part of this application: (1) the existing site; and (2) that associated with planned site improvements (i.e., the new combined Manufacturing Plant stack and the upgraded Acid Plant converter). The emission rates used for each scenario for the dispersion modelling assessment are summarised in Table 3.2.

Table 3.3: Summary of contaminant emission rates used in dispersion modelling

Source	Contaminant	Modelled averaging period	Emission rate (kg/hr)
Existing site scenario			
Acid Stack	SO_2	1-hour 24-hour	60
		Annual	18.7
	SO_4*	Annual	0.11
	SO_3	1-hour	2
		Annual	0.09
Den Scrubber stack 1 Den Scrubber stack 2 Hygiene Scrubber stack (emissions split evenly across the three stacks)	Fluoride	12-hour 24-hour 7-day	1.5
		30-day 90-day	0.12
	SO_2	1-hour 24-hour	10
		Annual	3.1
Bradley Mills	PM_{10}	24-hour	0.4
		Annual	0.12
	$PM_{2.5}$	24-hour	0.36
		Annual	0.11
Site improvements scenario			
Acid Stack	SO_2	1-hour 24-hour	40
		Annual	18.7
Manufacturing Stack	Fluoride	12-hour 24-hour 7-day	1.0
		30-day 90-day	0.11

* SO_4 has been modelled for the purposes of sulphur deposition. It has been assumed that 100% of SO_3 is converted to SO_4.

4 Environmental Setting

4.1 Site and receiving environment

The site is located approximately 6.5 km south of Napier City centre and 11.5 km northeast of the Hastings central business area.

The closest residential area is located to the north, approximately 1.8 km from the site's manufacturing stacks. Residential zones are also present to the south and west of the site, located approximately 2.75 km and 5.5 km, respectively, from the stacks. However, the closest residential home is located within the industrial zone, approximately 400 m north-northeast of the Manufacturing Plant.

Waitangi Road borders the manufacturing site along the western boundary, while State Highway 51 and the railway line border the site along the eastern boundary. A cycle way also runs on the coastal side of State Highway 51. The site is located within a 'Main Industrial' zone in the Napier District Plan (NCC 2011). The 'Main Industrial' zone continues to the north of the site, and in some areas to the east. Other activities undertaken within the Main Industrial zone include wool-scouring, fisheries, recycling, rendering, and transport services. The main potential effects associated with fluoride emissions are ecological effects on sensitive vegetation particularly horticultural crops (discussed further in Section 6), and the etching/frosting of windows (discussed further in Section 8). Activities within the industrial zone (with the exception of residential activities) are not expected to be sensitive to discharges from the site.

The beach is located approximately 150 m to the east and is classified as 'foreshore reserve'. Between the site and the beach is a discontinued gravel pit formerly operated by Winstone Aggregates. As with the industrial area, the beach and gravel pit are generally not expected to be sensitive to discharges from the site.

Land to the west of the site is predominately zoned 'Main Rural' under the Napier District Plan, featuring a mix of pastoral and horticultural activities (predominately apple orchards and to a lesser extent vineyards). These horticultural activities can be sensitive to fluoride gas and acid aerosol discharges due to the effect on sensitive vegetation and this is reflected in the dispersion modelling assessment and choice of assessment criteria (discussed in Section 6.1.3).

Land to the northwest of the site is zoned 'Wastewater Treatment' and includes the Napier Wastewater Treatment Plant (WWTP), which is located approximately 700 m north-northwest of the site. The WWTP is not expected to be sensitive to fluoride emissions from the site, although we note that much of this zone remains in horticultural use which is considered sensitive.

Land to the immediate south of the site is zoned 'River Conservation' under the Napier District Plan, and includes the Tūtaekurī River, Waitangi Regional Park, and Ngaruroro River comprising the Waitangi Estuary (Figure 4.1). T+T understands that Ravensdown has confirmed with Dr David Doley[9] that the general land use category of the Ambient Air Quality Guidelines (AAQG) provides sufficient protection for the native plants in the Waitangi Estuary (refer to Appendix B).

[9] Dr Doley (Honorary Associate Professor, University of Queensland) provided expert evidence on the air pollution effects on vegetation at the consent hearing in 2007 for the current air discharge permit and was involved in the development of the fluoride vegetation guidelines.

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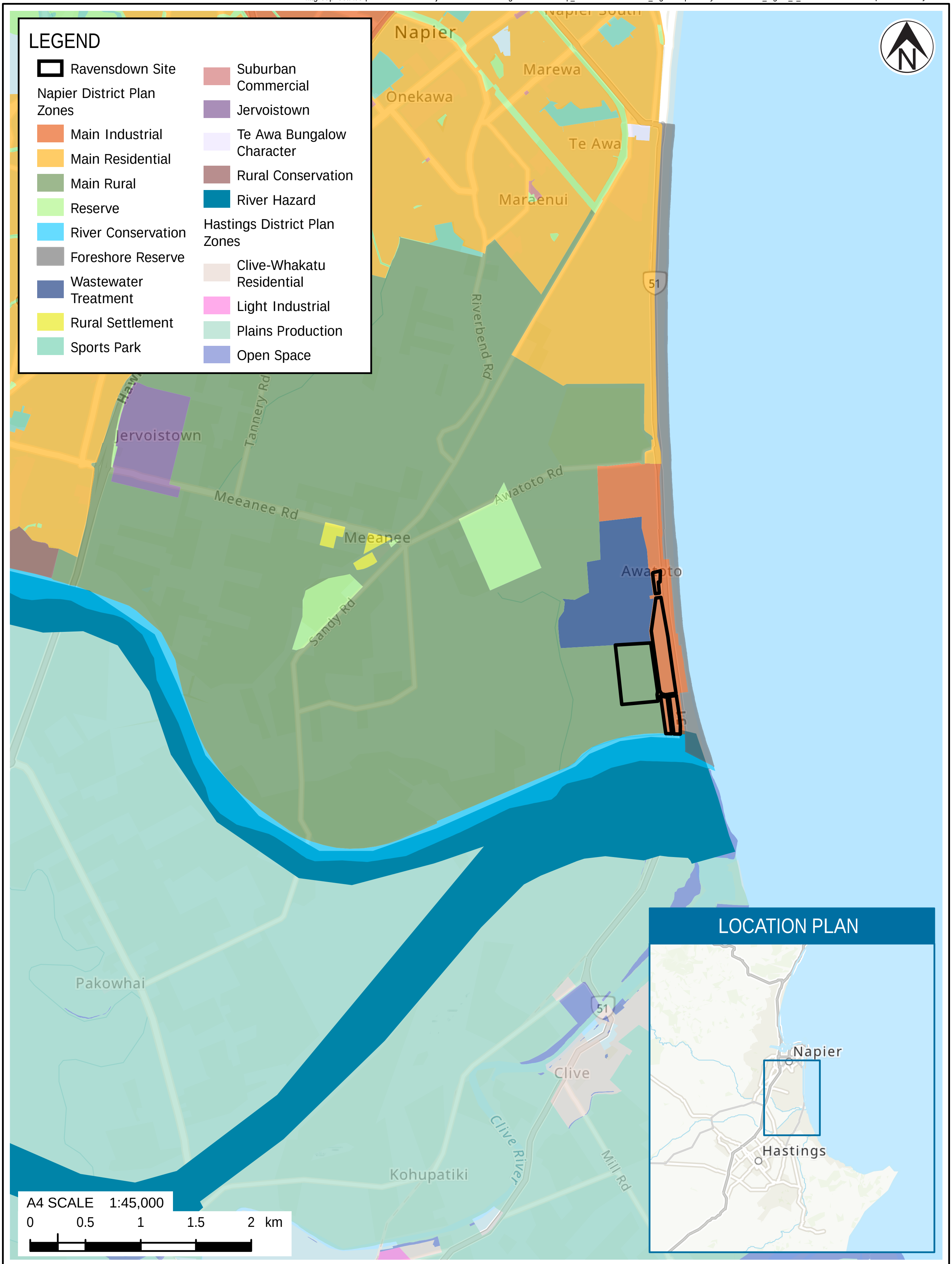

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4.2 Sensitive receptors

Discharges of particulate matter and SO_2 are mainly of concern in terms of human health effects, although elevated long-term levels of SO_2 can also affect vegetation. Conversely, the discharge of fluoride is mainly a concern regarding the potential impacts on sensitive areas of vegetation, particularly horticultural and viticultural crops.

Given the above, sensitive receptors have been identified and categorised as either 'community' or 'agricultural/vegetation' receptors. These locations are described in Table 4.1 and are specifically included as discrete receptors within the dispersion modelling assessment presented later in this report. Notwithstanding this, the modelling assessment also predicts concentrations for nested grids of receptors over a wide area surrounding the site.

Sensitive receptor locations also include the locations where ambient fluoride monitoring is undertaken by Ravensdown. A total of 43 sensitive receptors have been identified, with 24 of these being classified as community receptors and the remaining 20 being agricultural related. The community locations have been selected in consultation with Dr Kelly, while the agricultural receptor locations include locations that have been previously assessed as part of the assessment associated with the current air discharge permit with the addition of several other locations of interest. This list is not intended to be exhaustive but is intended to reflect representative locations in the receiving environment.

Table 4.1: Summary of sensitive receptors identified

Receptor Type	Receptor ID	Description
Agricultural	A1	Apollo Orchard
	A2	Bayleaf Organics Orchard
	A3	Brookfield Orchard (Ravensdown Monitoring Station)
	A4	Brookfields Winery
	A5	Dewer Orchard
	A6	Enzafruit
	A7	Gibson Orchard
	A8	Golden Del Orchards
	A9	Hohepa Farm
	A10	McKelvie Orchard
	A11	Jonny Appleseed (Meeanee) Orchard
	A12	Mr Apple Orchard North
	A13	Mr Apple Orchard South
	A14	Plumpton Park (Ravensdown Monitoring Station)
	A15	Rivergold Orchard
	A16	Ruby Glen Orchard
	A17	The Vege Barn
	A18	Vege Land
	A19	Waitangi Regional Park
	A20	Wells Orchard
Community	C1	Samoan Assembly of God
	C2	Beach
	C3	Bette Christie Kindergarten
	C4	Clive School
	C5	Flowers by Chilton
	C6	Maraenui Golf Club
	C7	Hopeha Homes
	C8	Learning Adventures Maraenui
	C9	Meeanee School
	C10	Model Flying Hawke’s Bay
	C11	Napier Boys High School
	C12	Pukemokimoki Marae
	C13	Revival Centres Church
	C14	Richmond School
	C15	Summerset Te Awa
	C16	Tiny Footsteps
	C17	Voguehaven Rest Home
	C18	Winstone Aggregates (Ravensdown Monitoring Station)
	C19	House North
	C20	House Northwest
	C21	House West
	C22	House Southwest
	C23	House South
	C24	House (cluster) Northeast

Figure 4.2: Location of discrete receptors (yellow triangles) and nested receptors (blue crosses). Ravensdown site shaded orange.

4.3 Meteorology and topography

The dispersion of site emissions in the receiving environment, and therefore the concentrations of contaminants experienced by sensitive receptors, is influenced by wind flows. Wind roses graphically summarise wind speed and wind direction data, over a period. The petals of the wind rose show the direction that winds come from – their length indicating the frequency of winds from that direction. The different coloured bands within each petal indicates the frequency distribution of wind speeds for each direction.

A windrose plot has been generated for the Ravensdown Napier Works (Figure 4.3). The data are derived from on-site measurements of wind speed and directions for the years 2015 and 2016 – these data are used in the CALMET meteorological dataset developed for the dispersion modelling assessment presented later in this report. Discussion regarding the selection of the years 2015 and 2016 is provided in Section 6.1.2. The windrose shows that:

- The prevailing winds come from the west-southwest;
- Winds also prevail from the northeast;
- Strong winds (>7 m/s) prevail from the northeast; and
- That there are a low percentage of calm conditions.

Both wind speed and wind direction are influenced by the surrounding topography. The topography immediately surrounding the site is relatively flat and begins to rise approximately 7 km away from the site. This rise in elevation will cause drainage winds as air flows down from the valley (higher elevation) towards the sea (lower elevation), giving rise to winds prevailing from the southwest. The significant change in surface temperature, from land to ocean, will also cause a prevalence of onshore breezes during the day. Breakdown of the windrose shows that onshore breezes become prevalent between 10 am and 11 am.

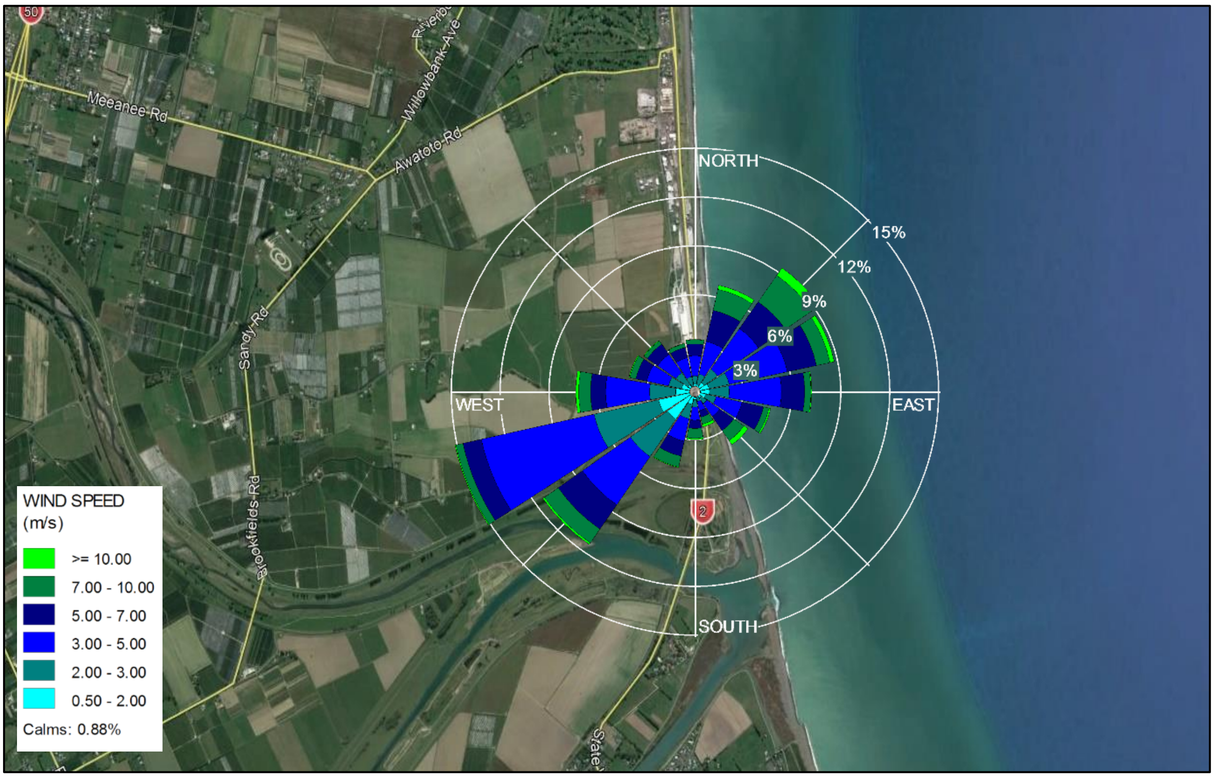

Figure 4.3: Wind rose for the Ravensdown Napier site generated from the measured site data used in the CALMET data set.

Figure 4.4 presents two wind roses enabling a comparison of the prevailing winds that occur at night (17:00 – 07:00) with those during the day (07:00 – 17:00). This illustrates typical night-time conditions whereby winds are generally lighter than those during the daytime and flow from elevated areas to the coast (i.e., from the southwest). By contrast, wind conditions during daytime hours are generally stronger and are typically the result of onshore conditions (i.e., from the northeast to east).

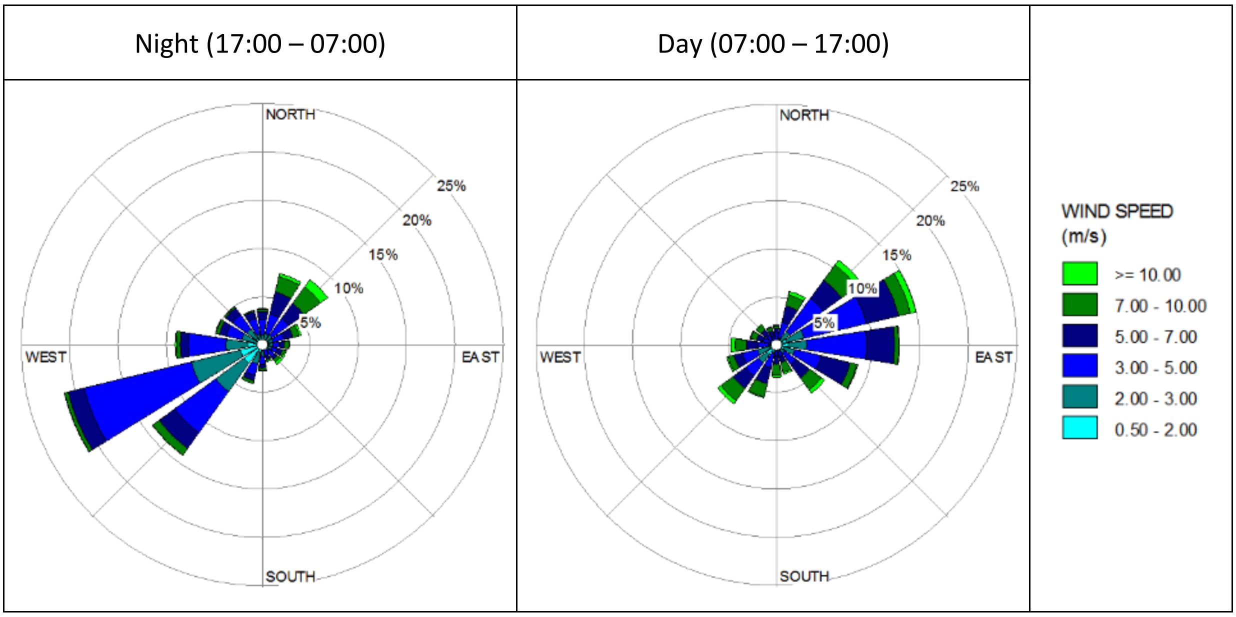

Figure 4.4: Diurnal wind roses for the Ravensdown Napier Works, generated from measured site data used in the CALMET data set.

Seasonal variation in wind patterns is also apparent as illustrated in Figure 4.5. This shows onshore breezes are most prevalent in summer months (winds from the northeast to east), whereas winds from the southwest are most prevalent during winter months.

4.4 Other industrial activities

Given the site's location within the Awatoto Industrial area there are a number of other industrial activities that give rise to discharges to air. Examples of these are listed below (location given in Figure 4.6) along with the type of discharge to air that may occur from each:

- Bio-Rich Limited compost facility (odour and dust);
- Former Winstone Aggregates gravel yard (dust);
- Napier City Council – Napier Wastewater Treatment Plant (odour);
- Hawke's Bay Protein Limited – rendering plant (odour);
- Higgins Contractors – asphalt plant (PM_{10}, odour, dust);
- Advanced Media Supplies Limited – bark storage (odour and dust); and
- New Zealand Woolscouring Limited – wool scour (odour)

None of the above sites are expected to be appreciable sources of SO_2 or fluoride. Except for the former Winstone Aggregates and Bio-Rich sites, the remaining industrial locations are located a significant distance from the Ravensdown site. Consequently, any cumulative contribution the above industrial activities may make to ambient concentrations of SO_2 and fluoride are expected to be negligible.

With regard to odour, the sources listed above tend to have odours that are distinctly different in their character to those odours that may be generated at the Ravensdown site or they are sufficiently far away to not be additive. The exception is the Bio-Rich site immediately adjacent to the Ravensdown Site which can be a source of hydrogen sulphide.

The former Winstone Aggregate site may have contributed significantly on occasions to levels of PM_{10} that are measured within that site as a result of significant dust generating events that occurred on site. With the site now disused, dust emissions will only occur as a result of wind erosion from unpaved or unvegetated surfaces.

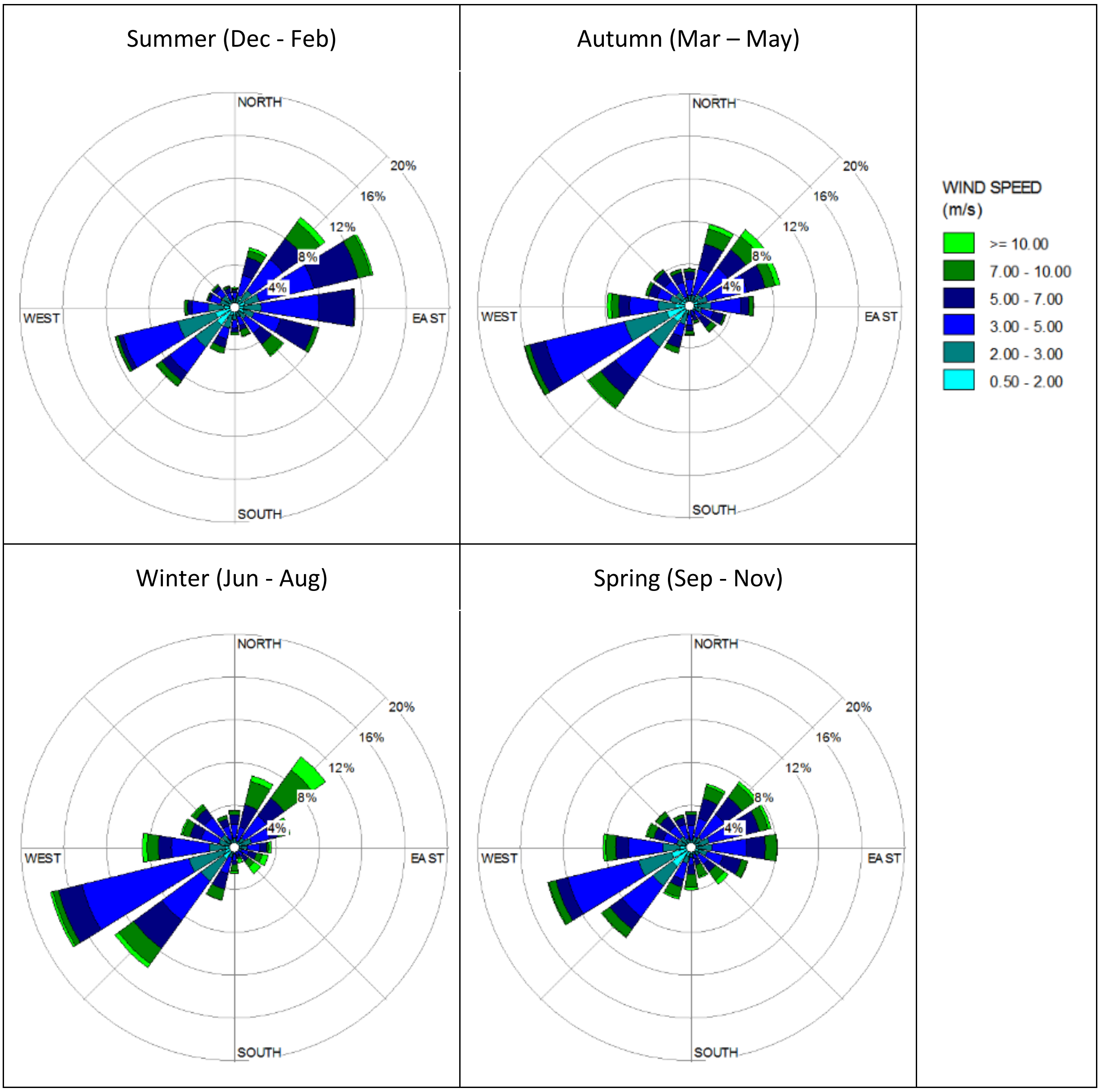

Figure 4.5: Seasonal wind roses for the Ravensdown Napier Works, generated from measured site data used in the CALMET the 2015 – 2016 CALMET data set.

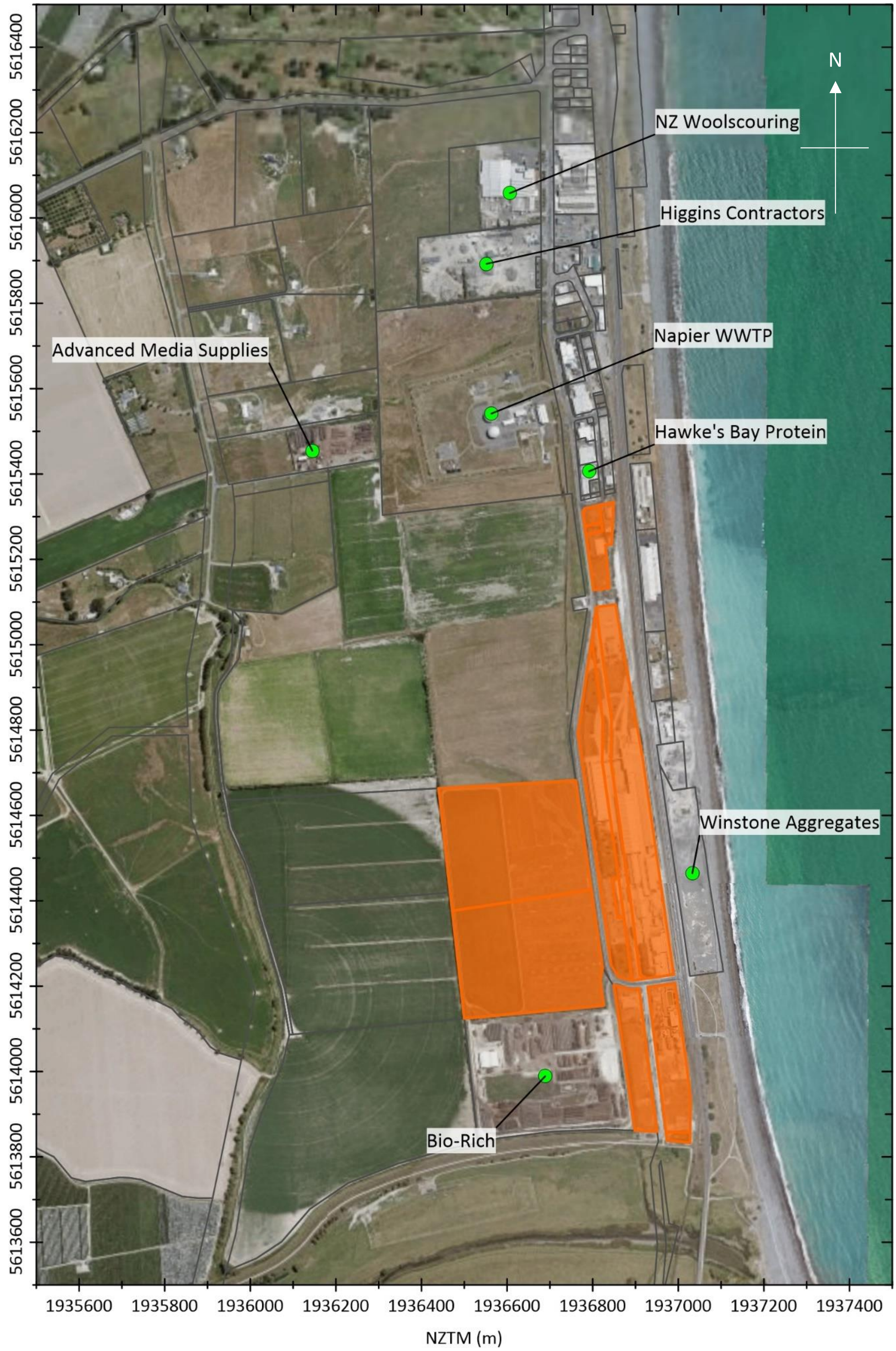

Figure 4.6: Location of other notable industrial air discharge activities. Ravensdown site shaded in orange.

5 Review of ambient monitoring

5.1 Overview

Ambient monitoring of several contaminants has been undertaken either by Ravensdown as an ongoing requirement of its air discharge permit or by the HBRC in relation to its regulatory functions relating to the Awatoto Airshed. This section provides a review of the various data for the following purposes:

- Evaluating measured ambient concentrations against relevant criteria; and
- Confirming typical background contaminant levels in the absence of discharges from the Ravensdown site.

Measured ambient concentrations of SO_2 are also used in evaluating the performance of the dispersion modelling assessment. That evaluation is provided in Section 6.3.4.

HBRC measures both PM_{10} and $PM_{2.5}$ in relation to the Awatoto Airshed. The HBRC monitoring site is located approximately 780 m north of the existing Hygiene Scrubber stack (although located on land owned by Ravensdown).

Ambient monitoring undertaken by Ravensdown is extensive and includes the following:

- PM_{10} and SO_2 concentrations, measured immediately east of the site on what is described as the 'Winstone site' (Conditions 57 and 58 of the current air discharge permit); and
- Fluoride concentrations measured at five locations (Condition 54 of the current air discharge permit).

Ravensdown also measures SO_2, H_2S[10] and wind speed and direction at its Archimedes pump station immediately adjacent to the Acid Plant and within the site boundary. This location is not subject to the requirements of the NES_{AQ} (as it is within the site where resource consent provides for the discharge of SO_2). Given this, data from this site are not useful for examining off-site impacts of SO_2 emissions and are not considered further.

The location of the various monitoring sites is shown in Figure 5.1. The following sections provide a review of the relevant data for each contaminant and location.

[10] H_2S is measured in March and September each year for at least 7-days on each occasion.

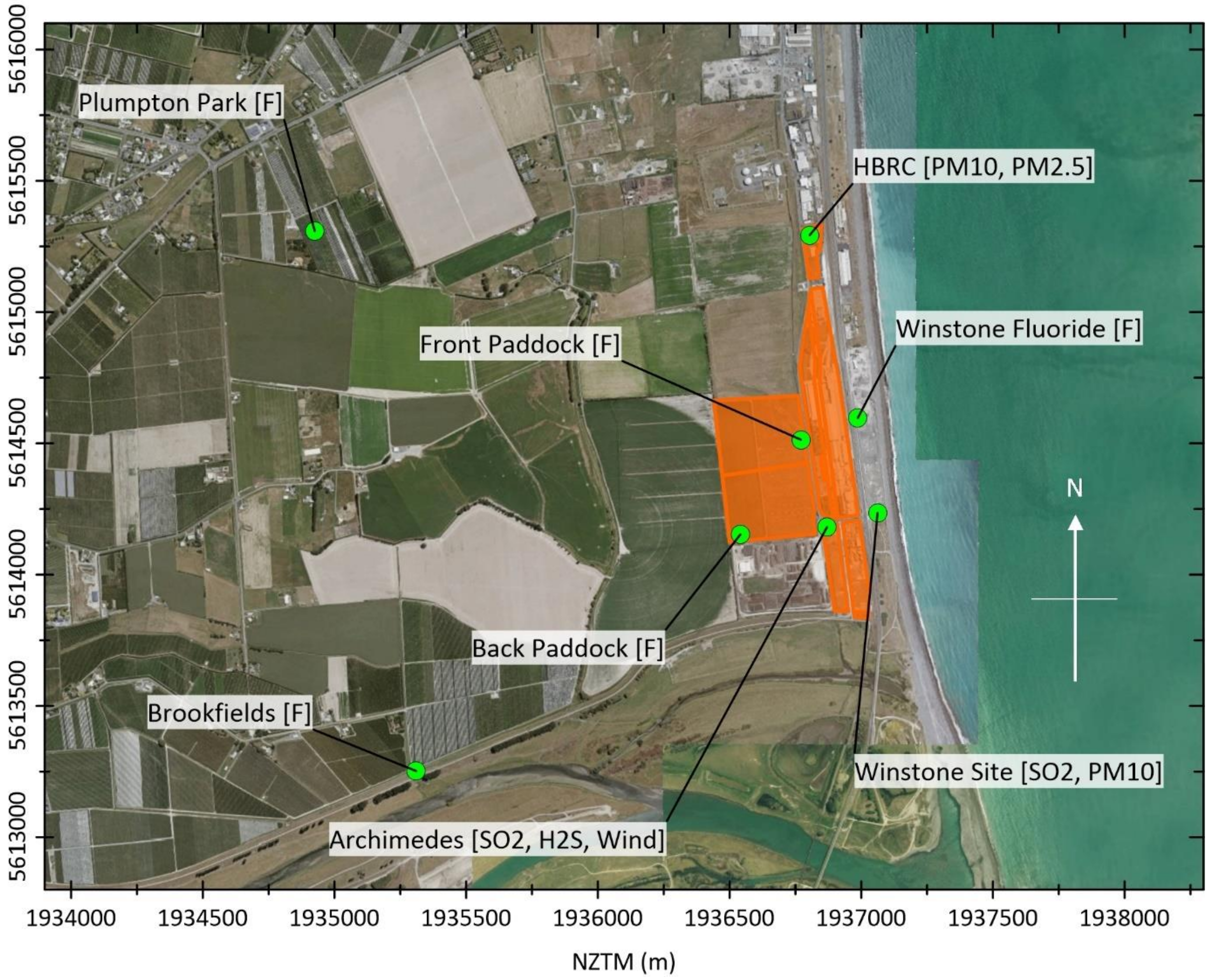

Figure 5.1: Location of various ambient monitoring sites and parameters measured. Ravensdown site depicted in orange.

5.2 Fluoride

Fluoride concentrations from the five monitoring stations are reported as a 7-day average. As shown in Table 6.2, the Ministry of the Environment uses different critical levels to protect ecosystems from fluoride, depending on whether the land use is considered ‘special’ or ‘general’.

Two of the five monitoring stations are located on land owned by Ravensdown (Front Paddock and Back Paddock), and the remaining three stations are located off-site (Figure 5.1).

Section 4.1 describes the land uses and activities surrounding the site. Of note is that the land uses to the west of the site, notably the horticultural activities, are categorised as ‘special land use’ in the context of the AAQG for fluoride with the remaining industrial area and coast categorised as ‘general land use’.

Fluoride monitoring stations Brookfields, Plumpton Park, Front Paddock and Back Paddock, are situated on land used for agricultural purposes and so concentrations are assessed against the ‘special land use’ criteria of 0.8 µg/m³ (7-day average). However, because the Front and Back Paddock are within Ravensdown-owned land the consent limits for these two locations are higher. In addition, Ravensdown had a consent limit relating to the former Winstone site, which is also a higher concentration than the ‘general land use’ criteria.

The consent limit for each monitoring station from discharge stacks are summarised in Table 5.1.

Table 5.1: Ravensdown fluoride monitoring stations and their respective consent limits

Station Name	Total fluoride consent limit (µg/m) – 7-day average
Brookfields Orchard	0.8
Plumpton Park	0.8
Back Paddock	1.7
Front Paddock	5.5
Former Winstone Aggregates site	5.5

Figure 5.2 presents time-series plots of 7-day average fluoride concentrations for the five ambient monitoring sites. These plots show good compliance with the corresponding consent limits for each of the sites, with the exception of the Front Paddock and Winstone site where concentrations have been recorded above the limits on one and two occasions respectively. However, these two monitoring sites are locations that are not sensitive to fluoride impacts on vegetation (one being on Ravensdown land and the latter being a former and currently disused aggregate yard site).

Figure 5.3 presents seasonal plots of 7-day average fluoride concentrations for the five ambient monitoring stations. These plots show some seasonal variation in concentrations, but generally show the lowest concentrations occur during June and July each year, which coincides with the period when the site shuts down for maintenance. Similarly, the highest concentrations typically occur from late spring through to early autumn when manufacturing rates are high, coinciding with peak seasonal demand for the supply of fertiliser and a greater frequency of on-shore winds.

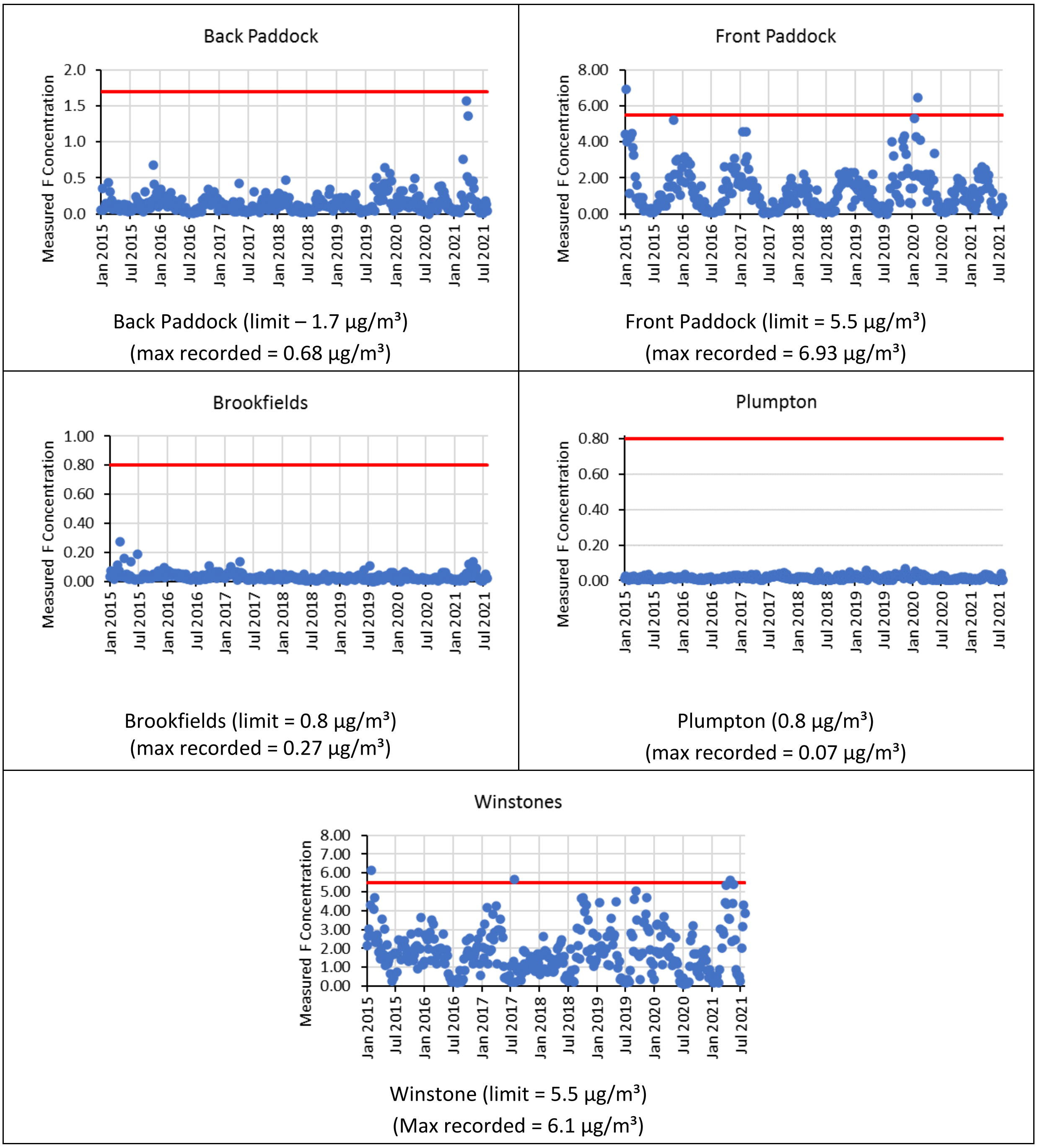

Figure 5.2: Timeseries plots of 7-day average fluoride concentrations (µg/m³). 1 January 2015 to 11 August 2021. Red lines on each plot indicates the current consent limit relating to the corresponding monitoring site.

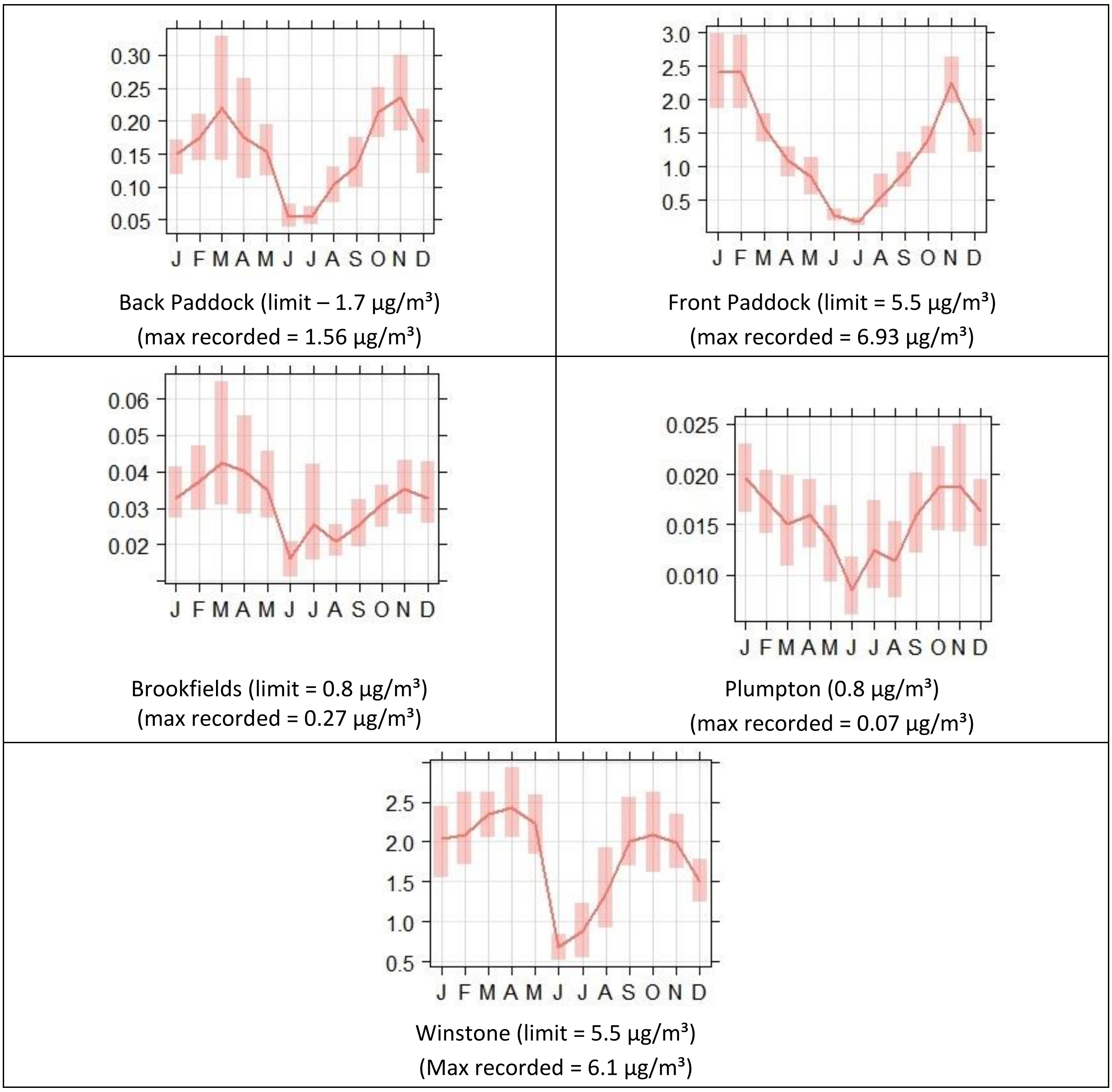

Figure 5.3: Monthly variation in measured 7-day average fluoride concentrations (µg/m³) – mean and 95% confidence interval in mean. 1 January 2015 to 4 August 2021.

A suitable background fluoride concentration for the dispersion modelling assessment provided in Section 6 can be established by reviewing the relatively low concentrations[11] of fluoride measured at each of the monitoring sites in June each year. This is because these lower concentrations coincide with the annual winter shutdown of the site. Accordingly, the ensemble average for June for each monitoring location relative to the distance from the coast is presented in Figure 5.4. This shows a clear relationship of significantly decreasing concentrations with increasing distance from the coast (although arguably the same could be concluded regarding distance from the site). This is most likely the result of fluoride associated with marine aerosols. Putting aside the values for the Winstone and Front Paddock sites which are closest to the coast, concentrations at the Back Paddock site and those sites beyond are within 10 to 45 ng/m³ (equivalent to 0.01 to 0.045 µg/m³), which is consistent with the findings of Lewandowska et al (2013). Therefore, for the purposes of

[11] These lower levels are well within the criteria set out in Section 6.1.3 and the effects of the proposed change are assessed further in Section 6.2.2.

the dispersion modelling assessment, a naturally occurring background concentration of 45 ng/m³ has been used.

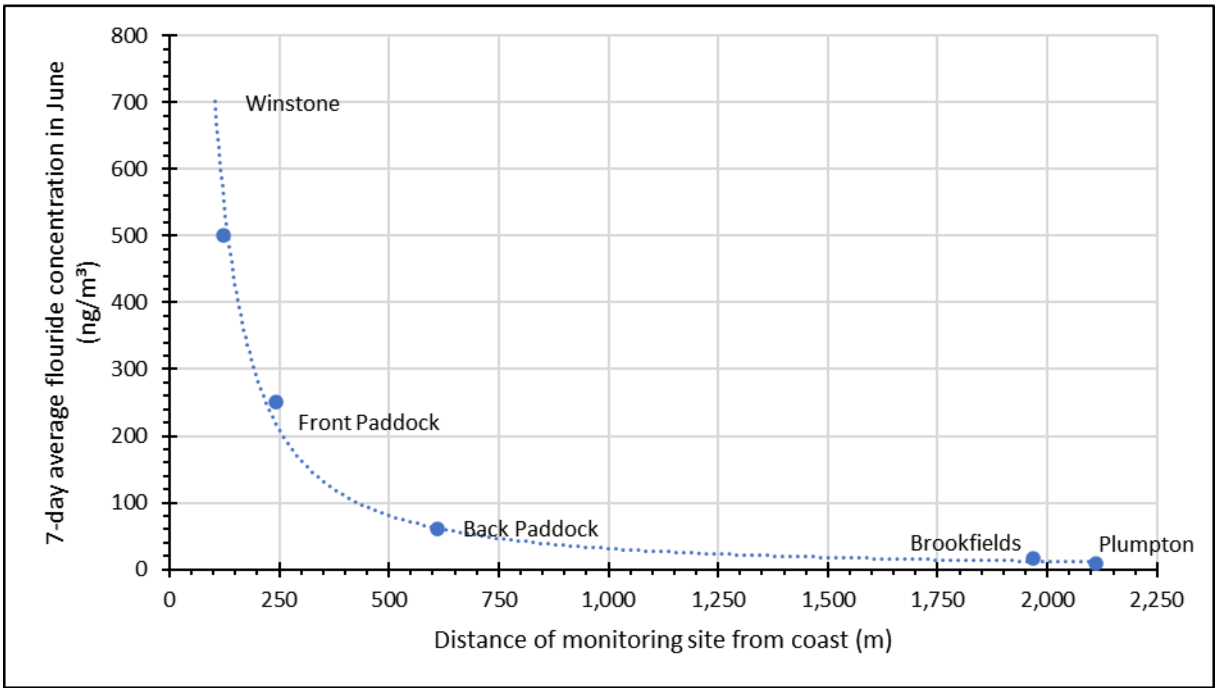

Figure 5.4: Ensemble average of 7-day average fluoride concentrations for June from January 2015-August 2021 for each of the five ambient fluoride monitoring sites.

5.3 Sulphur dioxide

Sulphur dioxide is not routinely monitored by HBRC. It has been historically monitored for in Hastings but only for 3 months (September, October, and November) in both 1994 and 1998. Within these monitoring periods there were no exceedances of either the 1-hour or 24-hour averaging periods, with the maximum recorded values being 12 µg/m³ and 5 µg/m³, respectively.

Ravensdown undertakes ambient monitoring of SO_2 at two locations:

- The Winstone site (located off-site); and
- The Archimedes site (located within the site boundary and adjacent to the Acid Plant).

As the Archimedes site is located with the Ravensdown site, the NES_{AQ} for SO_2 do not apply[12]. For this reason, our analysis focuses on the measured SO_2 concentrations made at the Winstone monitoring site and no further discussion is made regarding the Archimedes site.

Figure 5.5 and Figure 5.6 present time-series plots of the 1-hour and 24-hour average SO_2 concentrations measured at the Winstone site respectively. For the 1-hour average there are two occasions where the NES_{AQ} of 570 µg/m³ was exceeded, with the latter of these two occasions also resulting in the MfE 24-hour average guideline value of 120 µg/m³ also being exceeded. Site activities occurring at the time of these exceedances and measures taken to prevent these activities causing future exceedances are described as follows:

[12] Regulation 14(2) of the NES_{AQ} notes states that *"… if the discharge of contaminant is expressly allowed by a resource consent, the ambient air quality standards for the contaminant does not apply to the site on which the resource consent is exercised."*

- 18 November 2016: The sulphur coil was repaired and heat was used to remove sulphur from the coil. The cleaning methodology has since been updated to prevent future exceedances arising from cleaning;
- 11 April 2018: The Acid Plant required pre-heating and the associated emissions were discharged through a temporary stack that was situated at the back of the furnace. A 13 m high permanent stack was installed over the 2018 winter shut-down period (prior to this a temporary 3 m high stack was used) to avoid future exceedance of this nature during the heating up phase along with updated protocols around the shut-down of the Acid Plant that minimise SO_2 emissions on start-up;
- 13 December 2021: This event was caused by a car crashing through to the Melter and starting a fire while the plant was shut down and no staff were on site. The resulting concentrations were very high with four 1-hour averages exceeded, ranging from 1,383 to 196,537 µg/m³. The 24 hour average exceeded recorded as 9,775 µg/m³; and
- 3 & 4 March 2021: This event was due to a fire in the Melter Storage Tank. The steam suppression system was modified as a result of this fire.

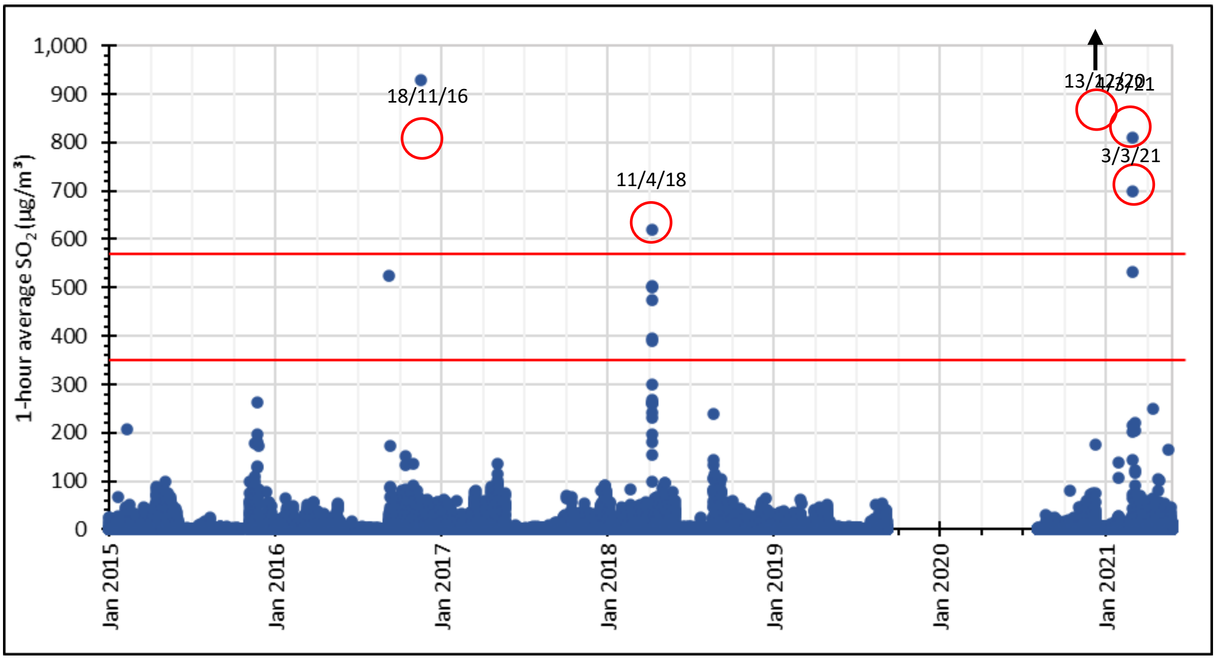

Figure 5.5: Timeseries plot of 1-hour average SO_2 concentrations (µg/m³) measured at the Winstone site between January 2015 and May 2021. Red lines indicate the NES_{AQ} 1-hour average SO_2 concentration of 570 µg/m³ and 350 µg/m³. Scale of graph does not show the exceedances associated with the sulphur melter fire on 13 December 2020.

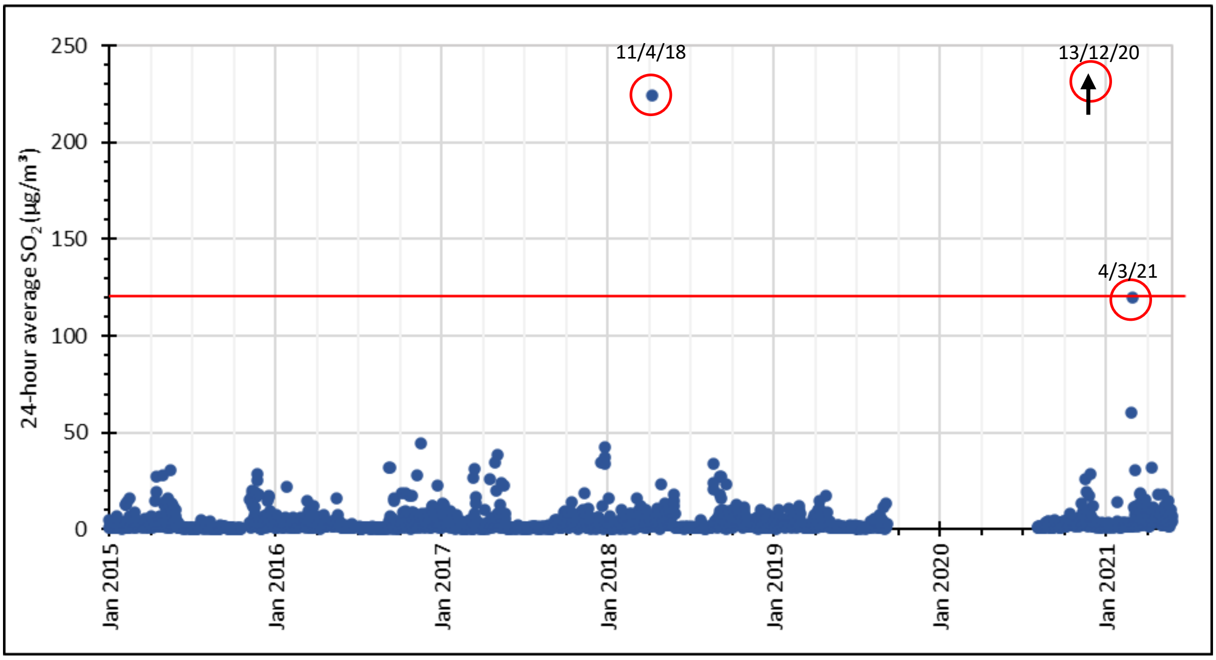

Figure 5.6: Timeseries plot of 24-hour average SO_2 concentrations (µg/m³) measured at the Winstone site between January 2015 and May 2021. Red lines indicate the 24-hour average MfE guideline SO_2 concentration of 120 µg/m³. Scale of graph does not show the exceedances associated with the sulphur melter fire on 13 December 2020.

Figure 5.7 and Figure 5.8 provide two polar plots of measured 1-hour average SO_2 measured at the Winstone site. The first of these is for all data points in the monitoring period, with the second excluding the peak concentrations from 18 November 16, 13 December 2020, 3 March 2021 and 4 March 2021. A polar plot provides a useful graphical indication of the direction from which elevated concentrations originate and the corresponding wind speed conditions. In this instance the top-most plot clearly illustrates peak concentrations originating from the general direction of Melter. The highest concentrations appear to come from the west under moderate wind conditions (about 5 m/s) and are expected to be associated with the historic event on 13 December 2020described above. The lower plot which excludes the peak concentrations described above shows more clearly that concentrations are typically associated with the Acid Plant stack.

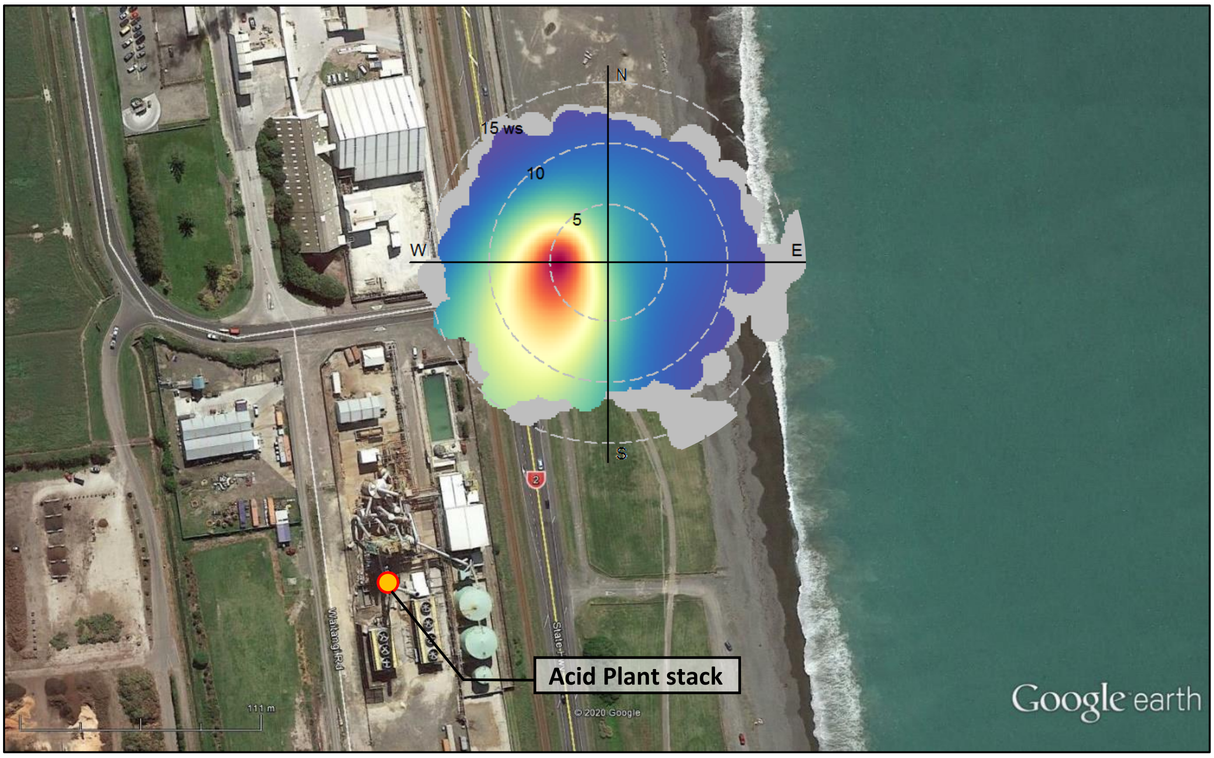

Figure 5.7: Polar plot of maximum 1-hour average SO_2 measured at the Winstone site from January 2015 to May 2021 inclusive overlaid on top of an aerial image of the location of the monitoring site. This plot represents all data for the monitoring period. Aerial image from Google, 27 March 2018.

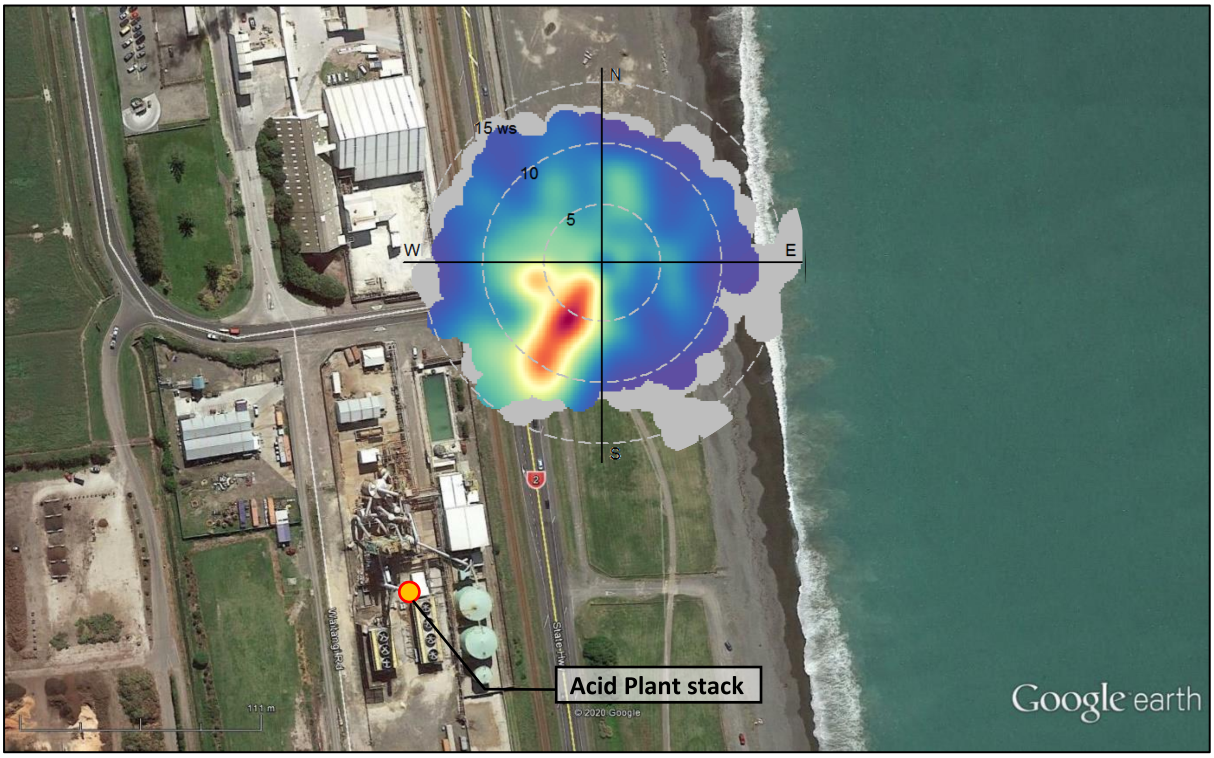

Figure 5.8: Polar plots of maximum 1-hour average SO2 measured at the Winstone site from January 2015 to May 2021 inclusive overlaid on top of an aerial image of the location of the monitoring site. This plot represents all data for the monitoring period, excluding the peak concentrations measured on 18 November 16, 11 April 18, 13December 2020, 3 March 2021 and 4 March 2021. Aerial image from Google, 27 March 2018.

A suitable background SO_2 concentration for the dispersion modelling assessment provided in Section 6 can be established by reviewing the measured SO_2 concentrations against wind direction. Examining mean SO_2 concentrations on a diurnal and seasonal basis provides a useful means of identifying typical lower SO_2 concentrations that are likely to be representative of background concentrations (i.e., excluding the impact of the site). Figure 5.9 provides plots of mean SO_2 concentrations by hour of day, month and weekday. From this there is a clear diurnal trend, where concentrations between approximately midnight and 2 am are typically less than 3 µg/m³. This is consistent with the monthly plot, which indicates concentrations as low as 1 µg/m³ for June when the site is typically shut-down for maintenance. Given these observations, as well as noting the absence of other appreciable sources in the wider receiving environment, it is considered a background concentration of 3 µg/m³ is an appropriate background concentration for the dispersion modelling assessment.

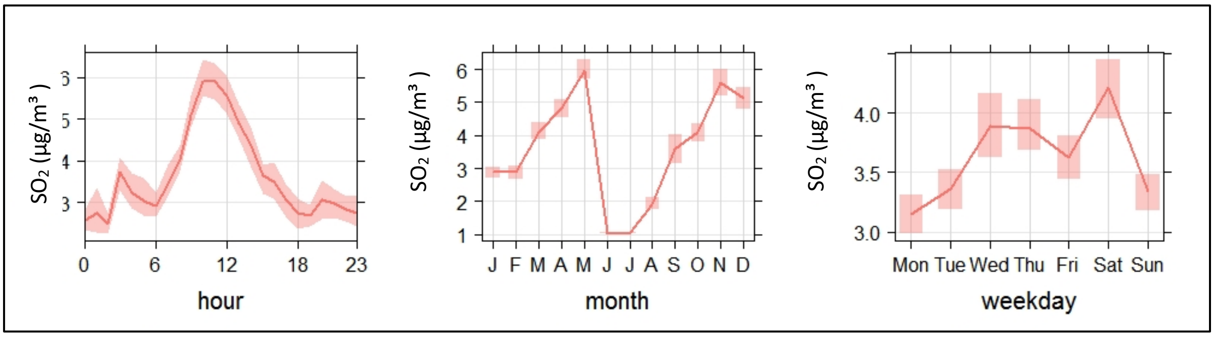

Figure 5.9: Plots of mean and 95th confidence interval in mean of diurnal (hourly), monthly and weekday measured SO2 concentrations for the Winstone monitoring site for the period January 2015 to May 2021 inclusive. Data excludes peak concentrations events discussed in Section 5.3.

5.4 Particulate matter

5.4.1 HBRC site

The HBRC Awatoto site is situated on Waitangi Road and is used for evaluating PM_{10} and $PM_{2.5}$ concentrations within the Awatoto Airshed. Its proximity to coast means that the airshed is susceptible to sea breezes and therefore sea spray and wind-blown dust can cause particulate matter concentrations to be high (LAWA, 2013). LAWA (2013) describes the emission into the Awatoto airshed as being dominated by industrial activities, with anthropogenic emissions from industry accounting for 90% of the airshed's PM_{10} concentrations. Emissions from traffic (9%) and residential (1%) make up the remaining 10%. Naturally occurring particulate sources are not described by LAWA, but will include marine aerosols and soil. Given the coastal location of the HBRC Awatoto site, the contribution from marine aerosols is likely to be significant during strong onshore wind conditions. HBRC[13] notes that source apportionment studies have been undertaken at its Awatoto monitoring site in May 2010 and then in April 2016 to May 2017. These studies identified marine aerosols (sea salt) and soil were predominant sources. With the latter monitoring period, $PM_{2.5}$ and PM_{10} samples collected were found to comprise 36% and 56% on average respectively. For peak concentration days this increased to 80% for PM_{10}. The study notes that other sources of $PM_{2.5}$ includes secondary sulphates (25%), biomass combustion (20%) and fertiliser (10%). While 'fertiliser' may contribute a small proportion of measured samples and could be associated with discharges from the Napier Works, the following analysis indicates that the discharges from the site are very unlikely to have been the cause of measured exceedances.

[13] https://www.hbrc.govt.nz/environment/air-quality/research/.

Monitoring of PM_{10} has been carried out since 2012, and $PM_{2.5}$ has been monitored from late 2016. Available data have been analysed and compared to the NES_{AQ} and World Health Organisation (WHO) guidelines (see Section 6.1.3).

Table 5.2 summarises the results of monitoring for PM_{10} and $PM_{2.5}$ that are available for the LAWA website[14] - this is augmented with data through to May 2021 obtained from the HBRC. Analysis of the data shows the following:

- There have been 14 exceedances of the 24-hour standard for PM_{10} since 2012, with 5 exceedances occurring in 2020, and 5 in 2021 for the period to the end of May. Given this, the Awatoto Airshed is considered 'polluted' in accordance with Regulation 17 of the NES_{AQ};
- The annual average PM_{10} concentration in 2013 and 2020 exceeded the AAQG of 20 µg/m³;
- There has been one exceedance of the 24-hour WHO guideline for $PM_{2.5}$ (25 µg/m³) in 2017; and
- No exceedances of the annual average $PM_{2.5}$ guideline (10 µg/m³) have occurred.

Table 5.2: Summary of PM_{10} and $PM_{2.5}$ data recorded in the Awatoto Airshed

Statistic	Year									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	PM_{10}									
Number of Exceedances*	1	1	**3**	**3**	0	1	**4**	1	**5**	**5**
Maximum 24-hour average concentration (µg/m³)	**51.3**	**59.1**	**63.6**	**80.1**	46.9	**74.7**	**65.6**	**81.0**	**135.1**	**82.4**
Annual average concentration (µg/m³)	18.1	**20.7**	18.4	19.5	18.4	18.0	19.7	17.8	**20.9**	N/A
	$PM_{2.5}$									
Number of Exceedances					0	1	0	0	0	0
Maximum 24-hour average concentration (µg/m³)					15.1	**40.0**	18.2	21.2	16.5	19.7
Annual average concentration (µg/m³)					5.2	6.2	6.1	6.5	6.2	N/A

*Number of records that exceed the 24-hour guideline (50 µg/m³).

Figure 5.10 presents a time-series plot of the 24-hour average PM_{10} concentrations measured at the HBRC Awatoto site and highlights the occasions when exceedances of the NES_{AQ} have occurred. The dates that these exceedances occurred have been evaluated further to understand if the Ravensdown site was a likely significant contributor based on comparing the hourly PM_{10} concentrations and corresponding wind directions for the day in question. Time-series plots of each of the selected days are provided in Figure 5.11 and Figure 5.12. From these plots, it is evident that the monitoring site is not downwind of the Ravensdown site during periods of elevated hourly

[14] https://www.lawa.org.nz/explore-data/hawkes-bay-region/air-quality/.

average PM_{10} concentrations resulting in the measured 24-hour average exceedance, except for the exceedance that occurred on 22 February 2019.

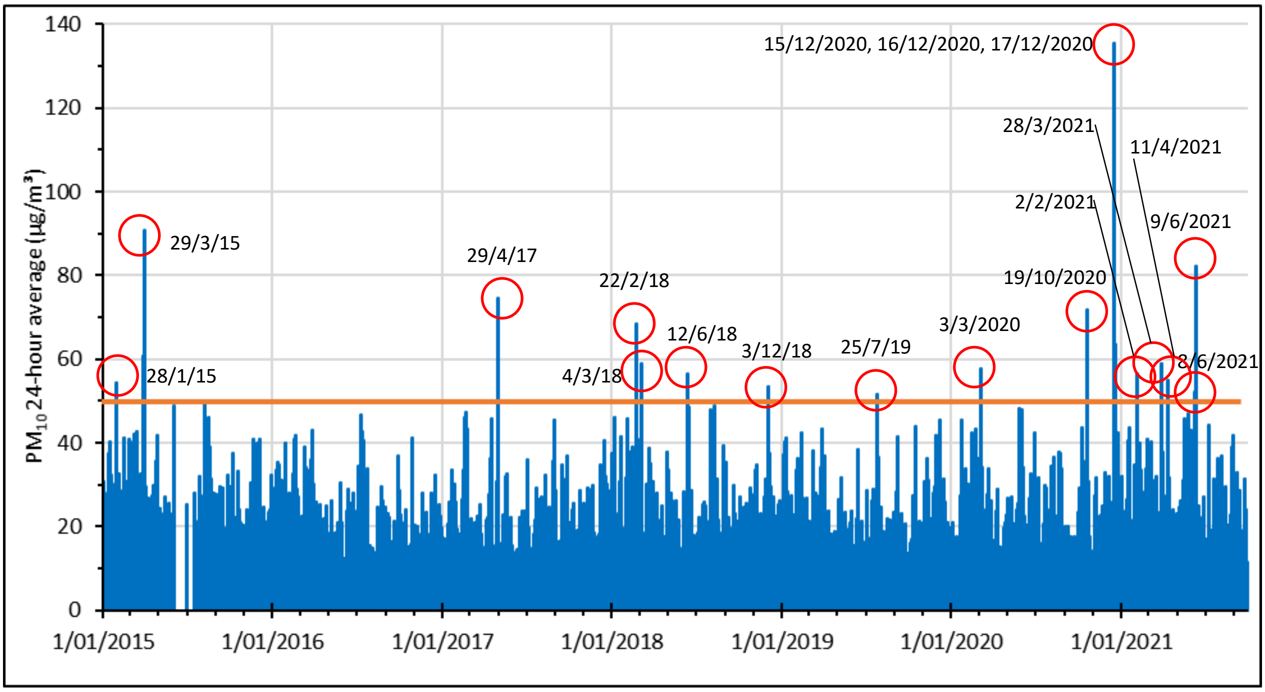

Figure 5.10: Measured 24-hour average PM_{10} concentration (µg/m³) for the HBRC site from January 2015 to May 2021 inclusive. The NES_{AQ} for PM_{10} (50 µg/m³) is indicated as a solid orange line.

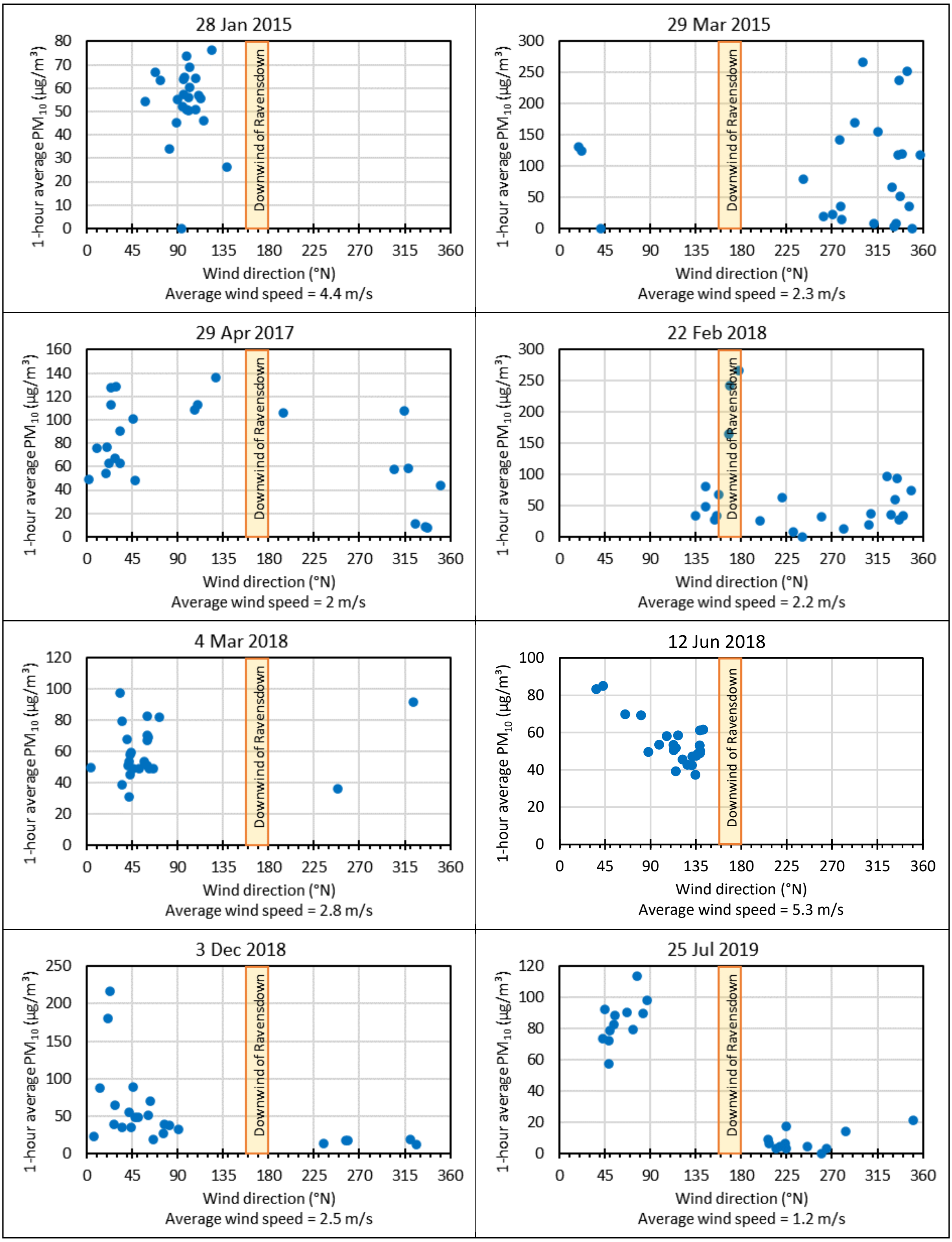

Figure 5.11: Hourly PM_{10} concentrations and wind directions on days when the 24-hour average PM_{10} concentration exceeded 50 µg/m³ - 2015-2019.

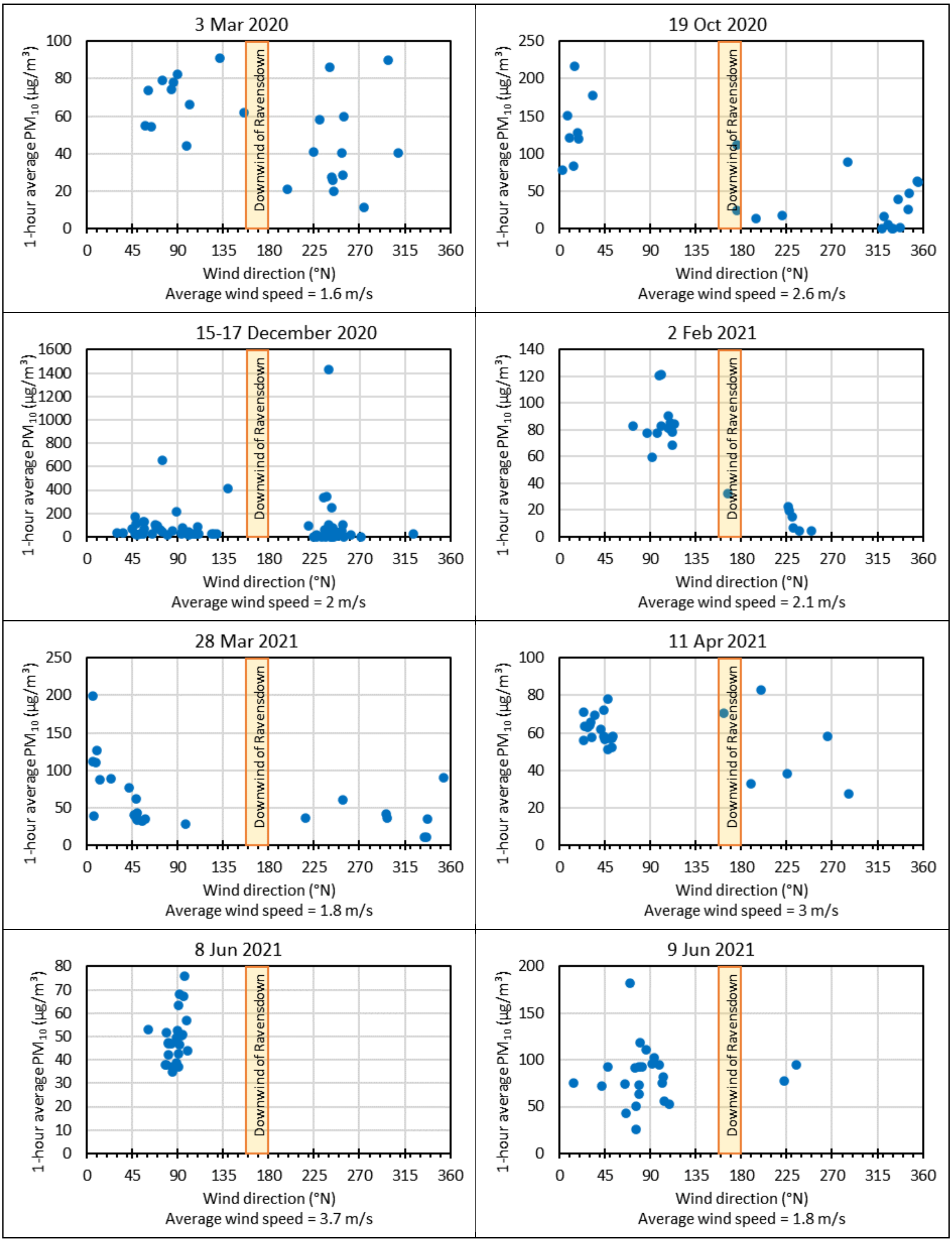

Figure 5.12: Hourly PM_{10} concentrations and wind directions on days when the 24-hour average PM_{10} concentration exceeded 50 µg/m³ - 2020-2021.

A polar plot has been produced using the hourly average PM_{10} concentrations and wind data for the period 2015 to 2019 and is presented in Figure 5.12. This plot illustrates the direction and wind speed that coincides with the maximum pollutant concentration. From this plot, it is clearly evident that the peak 1-hourly average PM_{10} concentrations are not typically associated with winds blowing from the direction of the Ravensdown site (south-southeast to south). Instead, the peak concentrations are typically associated with relatively light winds (typically less than 2.5 m/s) and when the wind is from the north to north-northeast. Despite this, a signature of slightly elevated concentrations from the direction of Ravensdown site under moderate winds (approximately 4 m/s) is evident.

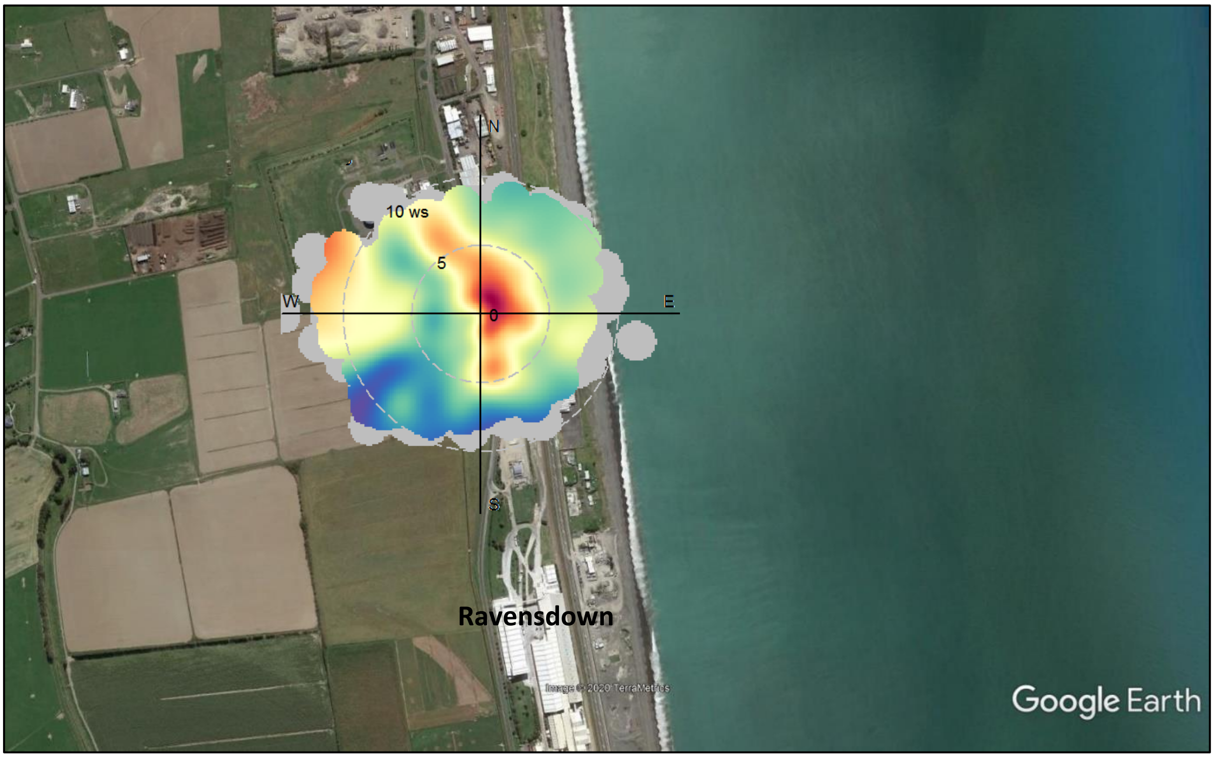

Figure 5.13: Polar plot of maximum 1-hour average PM_{10} measured at the HBRC site from January 2015 to May 2021 inclusive overlaid on top of an aerial image of the location of the monitoring site. Aerial image from Google, 27/3/2018.

A timeseries plot of the 24-hour average $PM_{2.5}$ concentrations is provided in Figure 5.14. The data generally show 24-hour average concentrations that fall well below the existing MfE monitoring guideline of 25 µg/m³, except for the event that occurred on 1 August 2017. As shown in the inset plot in Figure 5.13, the exceedance that occurred on this date coincides with winds from the south through to the west, including one hour when the wind was from the direction of Ravensdown site. This event is further evident in the polar plot given in Figure 5.15, which again shows the peak concentrations occurring from the south through west, but under relatively calm wind speeds (< 2 m/s). We consider it is unlikely that emissions from the Ravensdown site were responsible for the 24--hour average exceedance on this date because elevated hourly concentrations occur under a wide range of wind directions (south to west). Notwithstanding this, we note there is a slight signature evident in the polar plot from the direction of the Ravensdown site during moderate winds (4-5 m/s).

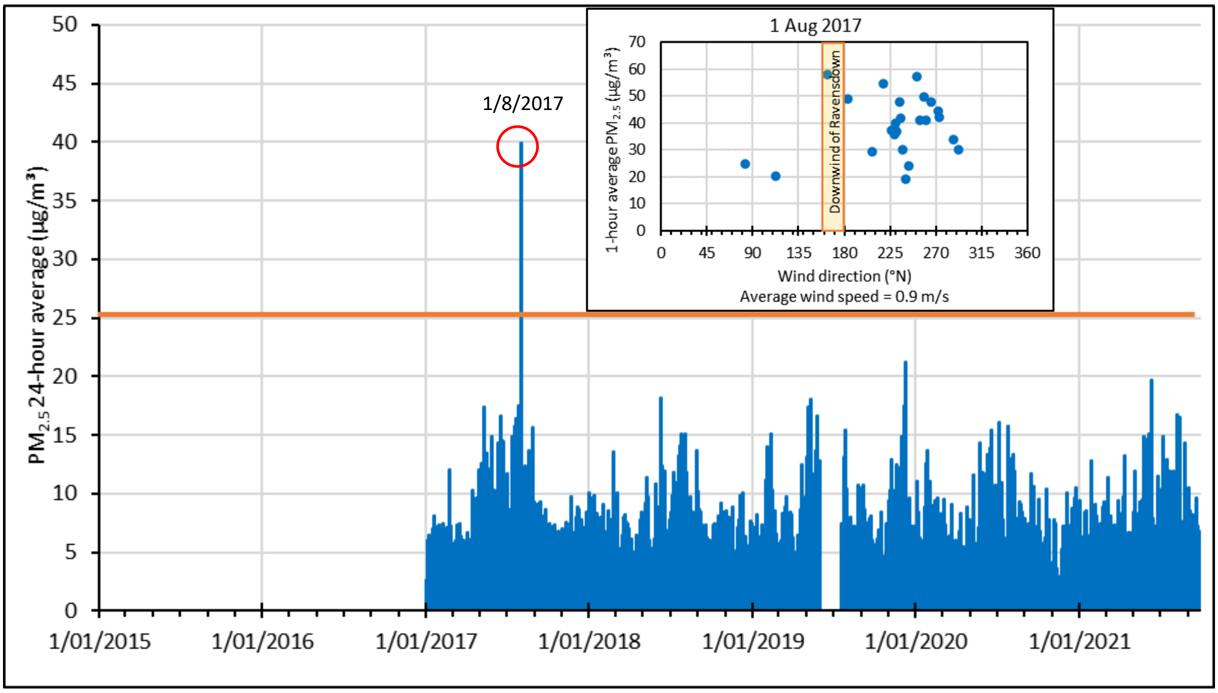

Figure 5.14: Measured 24-hour average $PM_{2.5}$ concentration (µg/m³) for the HBRC site from January 2015 to May 2021 inclusive. The MfE monitoring guideline for $PM_{2.5}$ (25 µg/m³) is indicated as a solid orange line. Inset plot shows 1-hour average $PM_{2.5}$ concentrations by wind direction for the 1 August 2017 event.

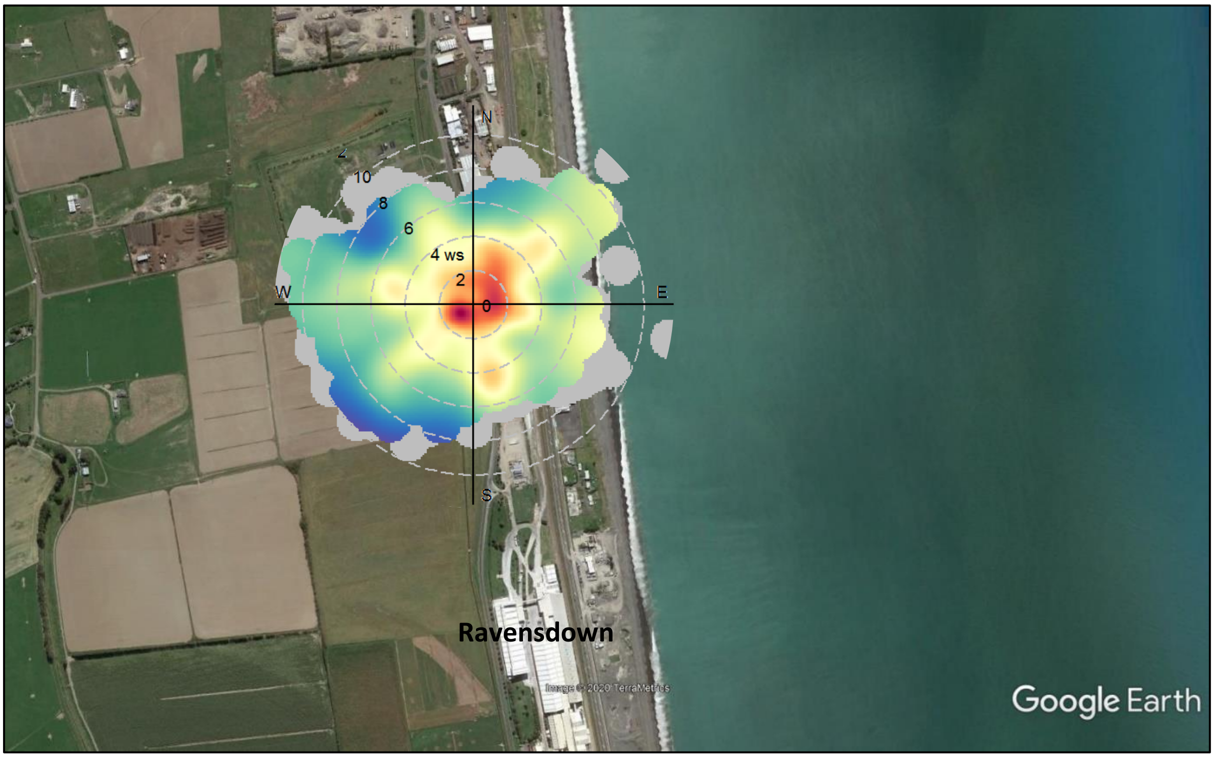

Figure 5.15: Polar plot of maximum 1-hour average $PM_{2.5}$ measured at the HBRC site from 2017 to May 2021 inclusive overlaid on top of an aerial image of the location of the monitoring site. Aerial image from Google, 27/3/2018.

5.4.2 Former Winstone site

Monitoring of PM_{10} is undertaken at the Winstone site immediately southeast of the Manufacturing Plant. Historically the site has been operated as an aggregate yard by Winstone Aggregates, although it has recently ceased being used for this purpose.

Figure 5.15 presents a timeseries plot of 24-hour average PM_{10} concentrations. From this plot it is evident that PM_{10} concentrations measured at this location have been very high, frequently exceeding the NES_{AQ} of 50 µg/m³ with some concentrations as high as 700 µg/m³. However, there are a few important considerations when evaluating this data:

- The Winstone site is not a location where persons would reasonably be present for a 24-hour period (the relevant exposure period of the NES_{AQ} for PM_{10}). Similarly, persons occupying nearby locations, such as the foreshore reserve, would not be continuously exposed for a 24-hour period;
- The site is situated within an unpaved aggregate yard and at the coast. The gravel yard ich can also be a source of PM_{10} during periods of elevated dust from yard operations, particularly during strong wind events when wind erosion would be higher. Coastal locations area also exposed to marine aerosols (sea salt) that can give rise to elevated particulate matter measured concentrations; and
- Concentrations since 2018 have been notably lower than previous years, but still are above the NES_{AQ} on frequent occasions.

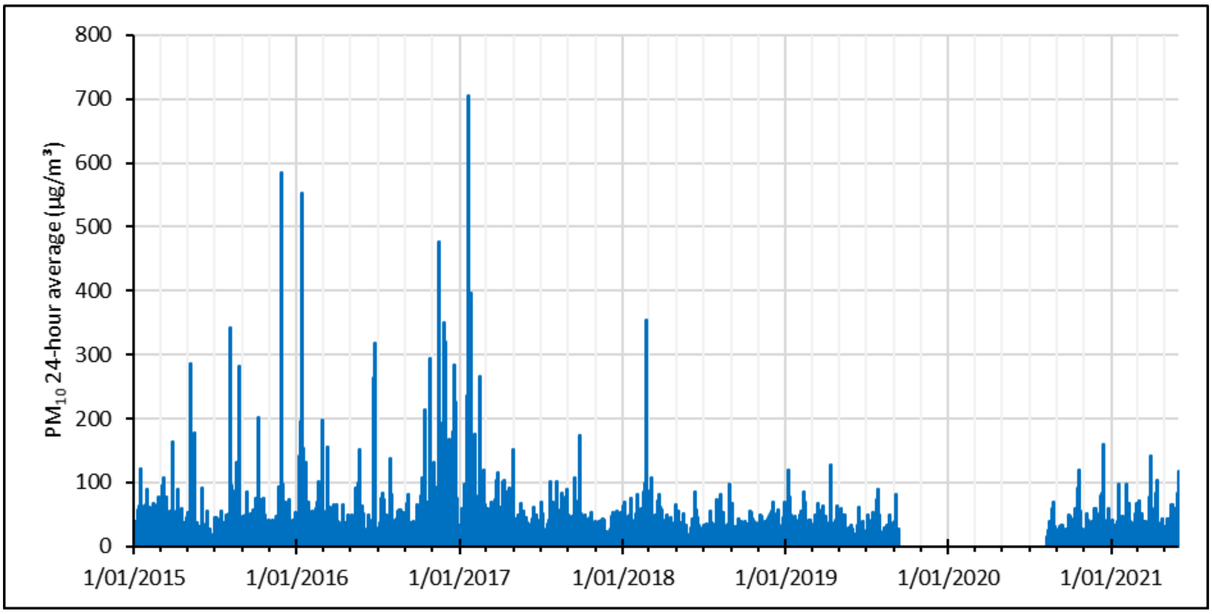

Figure 5.16: Measured 24-hour average PM_{10} concentration (µg/m³) for the Winstone site from January 2015-May 2021 inclusive.

Further analysis of the hourly PM_{10} concentrations has been carried out with measured wind data and presented as a polar plot (Figure 5.16) overlaid on an aerial photograph of the location of the Winstone Monitoring site. This shows a very distinctive signature of peak PM_{10} concentrations occurring under strong northwest winds. This direction closely aligns with direction of the Manufacturing Plant. However, there is also a portion of the gravel yard that is exposed in this direction. This result contrasts with the peak concentrations that are measured at the HBRC site which occur under near calm wind conditions.

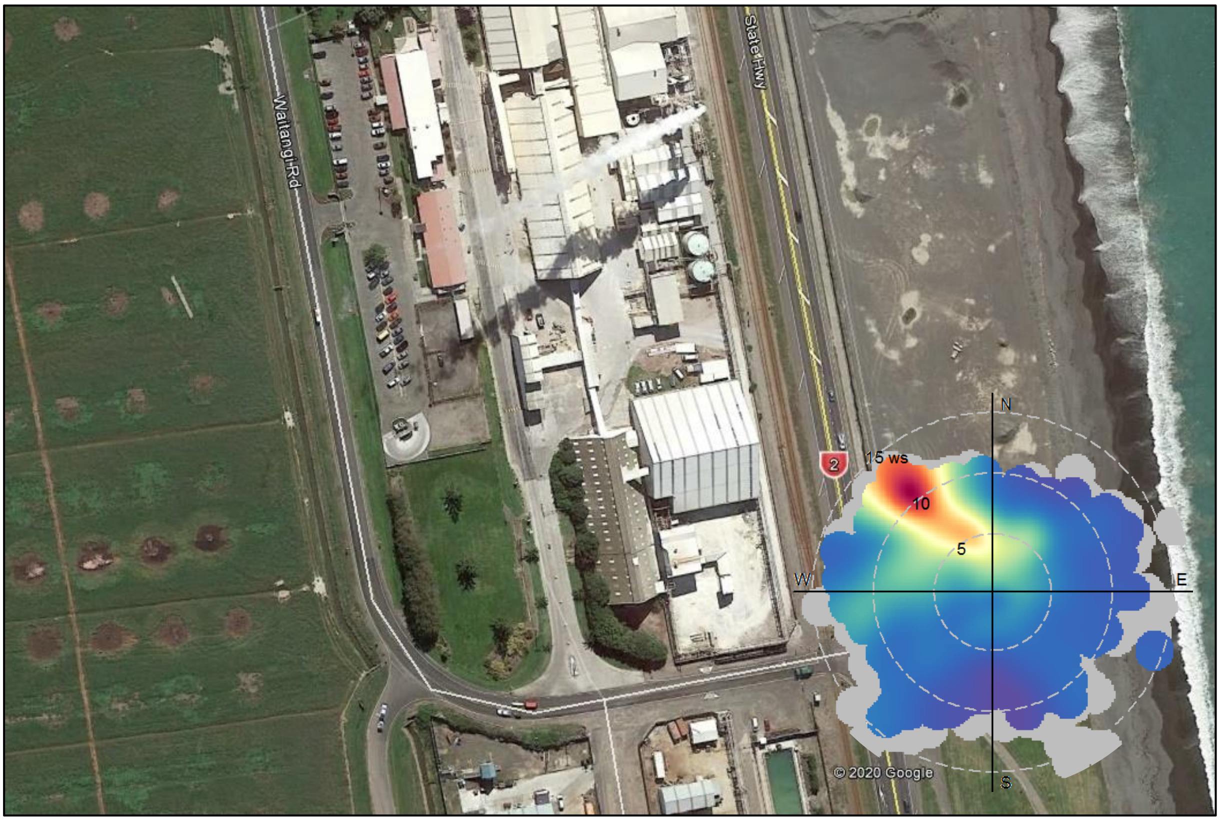

Figure 5.17. Polar plot of maximum 1-hour average PM_{10} measured at the Winstone site from January 2015 to May 2021 inclusive overlaid on top of an aerial image of the location of the monitoring site. Aerial image from Google, 27/3/2018.

5.4.3 Estimate of background PM_{10} and $PM_{2.5}$

The HBRC site could be used to calculate background concentration for the purpose of this assessment, on the basis of our analysis which indicated that the Ravensdown site is not contributing appreciably to measured concentrations. However, the HBRC site is strongly affected by local sources, particularly marine aerosols and would therefore experience higher concentrations than the wider area further from the coast where sensitive receptors are located.

Notwithstanding the above, simply adding model predictions of the site's contribution to the maximum measured PM_{10} or $PM_{2.5}$ at the HBRC site will grossly overstate the impact. This is because the analysis of maximum concentrations measured at the HBRC site (discussed in Section 5.4.1) demonstrates that those events:

- Do not occur when winds are by in large from the direction of the Ravensdown site; and
- Occur under relatively calm conditions, whereas peak impacts from Ravensdown are expected to occur under relatively strong wind conditions (see Section 5.4.2).

Waka Kotahi New Zealand Transport Agency (Waka Kotahi) produces an interactive air quality map 11F that estimates background concentrations of PM_{10} across New Zealand (by Census Area Unit). These maps have recently been updated, although the data and supporting documentation have not yet been made publicly available. They have, however, been made available by Waka Kotahi to some air quality consultants to assist in the preparation or air quality assessments.

The background PM_{10} and $PM_{2.5}$ values for the Awatoto area are based on the HBRC monitoring site at Awatoto. The updated Waka Kotahi background $PM_{2.5}$ concentrations for Awatoto are 15.2 µg/m³ (24-hour average) and 6.3 µg/m³ (annual average). The representative 24-hour average concentration of 15.2 µg/m³ is the average of the fourth highest $PM_{2.5}$ concentration measured in each of the three monitoring years considered (2017, 2018 and 2019).

The annual average PM_{10} concentration in the background map is 18.5 µg/m³. The updated maps do not include a representative 24-hour average PM_{10} concentration, however using the same methodology as for $PM_{2.5}$, a value of 48 µg/m³ (24-hour average) is obtained. This is an increase from the value in the currently published Waka Kotahi interactive map for Awatoto of 22 µg/m³. However, the existing value of 22 µg/m³ is likely to have been estimated prior to the HBRC's Awatoto monitoring station being established. Accordingly, a value of 48 µg/m³ is considered a more realistic and reasonable value to use for the purpose of this assessment.

In adopting these values as representative of background air quality (i.e., air quality in the absence of impacts from the site) it is important to note that this will introduce an element of "double counting". This is because the monitoring data used as the basis for the Waka Kotahi background maps includes the effects of the site's emissions. However, given that the incremental impact of the site's emissions is relatively small, the updated background map values have been adopted to provide a conservative assessment.

5.5 Hydrogen sulphide

The main on-site source of H_2S is the storage and melting of sulphur.

H_2S is monitored as a requirement of the site's air discharge permit. The consent requires the results of the monitoring be compared against an ambient concentration of 7 µg/m³ (1-hour average). This concentration limit is the same as the MfE ambient air quality guideline of H_2S, which is for managing odour effects rather than human health effects.

Since 2019, Ravensdown has contracted Watercare to measure H_2S concentrations at the Archimedes site. Prior to this time, HBRC carried out the monitoring of H_2S.

An analysis of hourly average H_2S concentrations with wind direction measured at the Archimedes site during March to May, June to July and September 2019, March and September 2020 and March 2021 is provided in Figure 5.17. Annotated on this figure are the wind directions under which the monitoring site was down wind of the sulphur melter and the nearby Bio-Rich compost facility[15]. From this it is evident that the high concentrations of H_2S occur when the monitoring site is downwind of the compost facility. Notwithstanding this, there is a 'signature' of slightly elevated hourly average H_2S concentrations when the monitoring site is downwind of the sulphur melter.

5.6 Summary of background concentrations

Table 5.3 summarises contaminant background concentrations that have been determined in the above sections in relation to the contaminants that have been modelled.

[15] The production of compost can give rise to odours, including those associated with reduced sulphides such as H_2S, especially where the compost becomes anaerobic.

Table 5.3: Summary of background concentrations for modelling assessment

Contaminant	Background concentrations (µg/m³)
SO_2	3 µg/m³ (all averaging periods)
PM_{10}	48 µg/m³ (24-hour average) 18.8 µg/m³ (Annual average)
$PM_{2.5}$	15.2 µg/m³ (24-hour average) 6.3 µg/m³ (Annual average)
Fluoride	0.045 µg/m³ (all averaging periods)

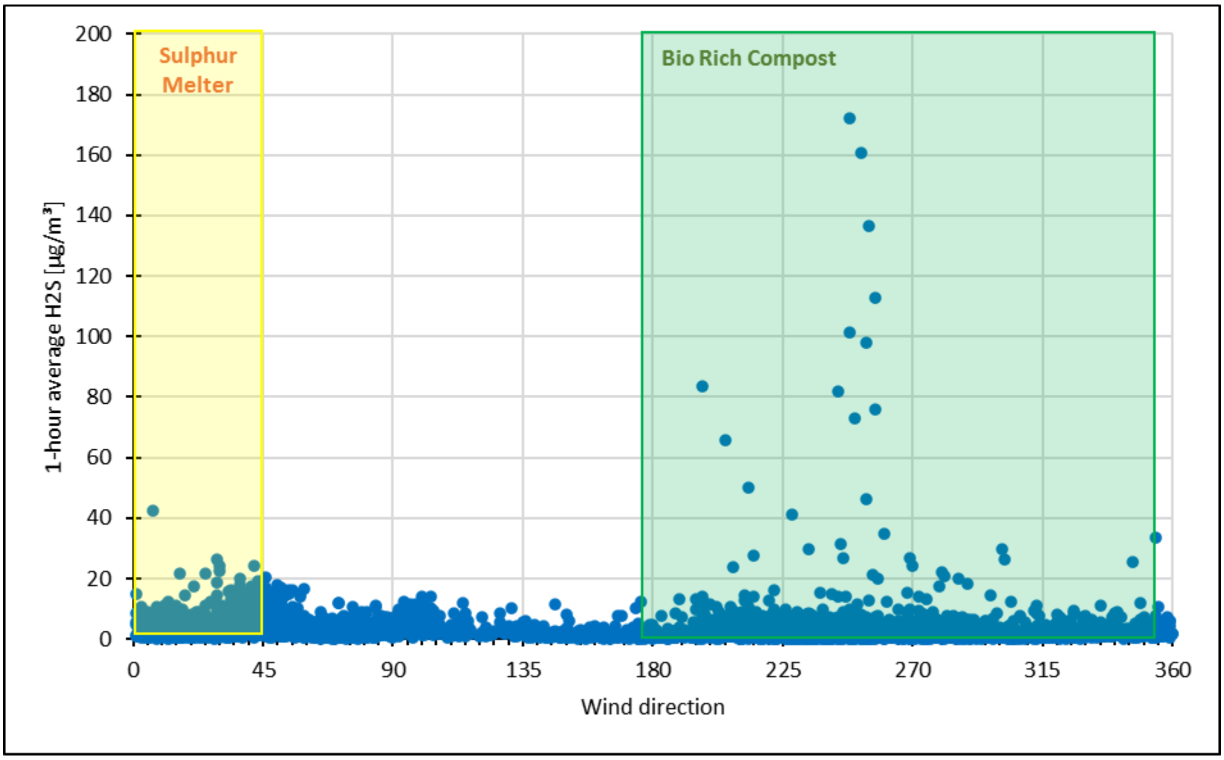

Figure 5.18: Measured hourly average H_2S concentrations during March 2019, March 2020, September 2020 and March 2021 by wind direction. The shaded areas indicate measured concentrations occurring when downwind of the sulphur melter (yellow) and the Bio-Rich Compost site (green).

A polar plot of the maximum hourly average H_2S data is provided in Figure 5.18 further illustrating the direction from which elevated concentrations occur. Of note is that highest concentrations occur from the direction of the compost facility occur under relatively calm conditions (< 2 m/s), with a clear signature coming from the direction of the sulphur melter under a much greater range of wind speeds.

The above data suggests that strong H_2S odours in and around the Acid Plant are more likely the results of emissions from the adjoining Bio-Rich compost facility. This matter is considered further in the assessment of potential odour effects in Section 7.

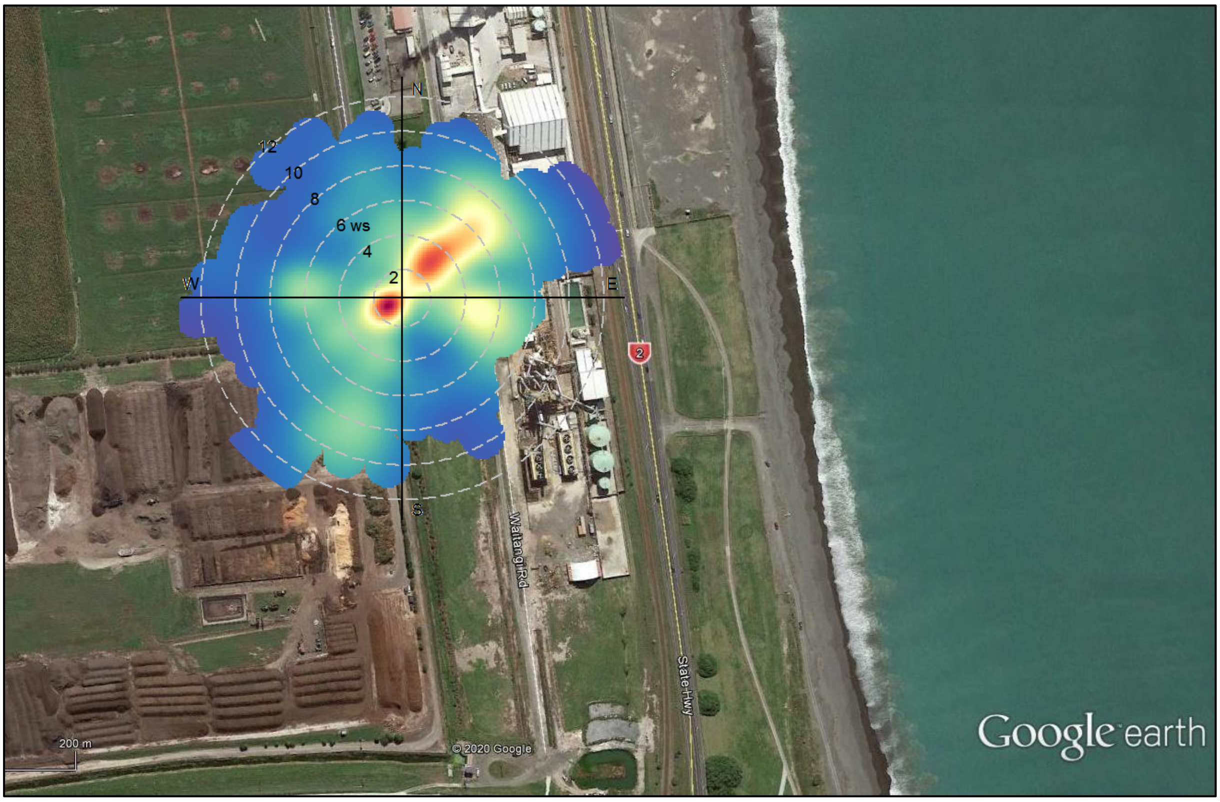

Figure 5.19: Polar plot of measured hourly average H_2S concentrations overlaid on an aerial photograph of the site.

6 Assessment of effects – stack discharges

6.1 Assessment method

The air quality effects of the site's stack discharges have been assessed using both dispersion modelling and a review of ambient air quality monitoring data (the latter which has been provided in Section 5).

The following sections summarise the dispersion modelling approach, meteorological inputs to the model and the relevant assessment criteria.

6.1.1 Dispersion modelling

The CALPUFF dispersion model has been used to model stack emissions from the Ravensdown site and predict ambient concentrations beyond the site boundary, enabling an assessment of those impacts against relevant assessment criteria (Section 6.1.3). The CALPUFF model (version 7) was chosen due to the site's coastal location, making it the most appropriate model in this instance. An earlier version of the CALPUFF model was used for past assessments to assess impacts of site emissions.

CALPUFF was configured to model discharges from the stack sources described in Section 3.4 and their cumulative impacts on the receiving environment surrounding the site.

Separate model runs were used to assess the peak and long-term impacts of fluoride, SO_2, and PM_{10}/$PM_{2.5}$ impacts. These separate runs consider the peak short-term emission rates versus the upper quartile emission rates and how they relate to assessment criteria that are expressed in terms of short-term (acute) and long-term (chronic) assessment criteria for each contaminant.

In accordance with recommended good practice (MfE 2004), the maximum predicted one-hour average results are the 99.9th percentile of the yearly model predictions.

The CALPUFF model was configured to predict GLCs for a number of discrete receptor locations representing locations of particular interest for the assessment, as well as three grids of evenly-spaced receptors at increasing resolution. The 'nested receptor' grid approach provides a high level of detail close to the site where the magnitude and spatial variation in impacts is typically greatest, with decreasing resolution in grid spacing further afield. This allows for a significant reduction in model computation time. Figure 6.1 shows the location of three receptor grids and discrete receptors relative to the Ravensdown site. The extents and resolution of the three nested receptors are as follows:

- 1,000 m by 1,000 m at a 50 m resolution;
- 2,000 m by 2,000 m at a 100 m resolution; and
- 6,400 m by 9,000 m at a 200 m resolution.

Buildings and structures can affect the dispersion of a plume from a stack, causing it to be brought to the ground rapidly – this is known as 'building downwash'. To account for this, the PRIME building downwash algorithm with the CALPUFF model is used to simulate this effect. The PRIME building downwash algorithm is the recommended option for dispersion modelling (MfE 2004)[16].

Building downwash ordinarily needs to be considered where a building or structure located near to a stack is greater than 40% of the height of the stack. Figure 6.2 shows a representation of the

[16] MfE 2004. Good Practice Guide for Atmospheric Dispersion Modelling. Publication number ME 522. Ministry for the Environment. June 2004.

buildings/structures relating to the Manufacturing and Acid Plants as a three-dimensional view of the site as configured in the CALPUFF model.

Previous studies undertaken for Ravensdown have identified that modelled building downwash effects are an important factor influencing near-field contaminant concentrations associated with the Manufacturing Plant. Historically, the representation of building/structures in the CALPUFF model setup for the Napier Works have conservatively simulated buildings as being flat roofed structures. However, a more refined representation within the model of the buildings has been made that better represents the sloped roofs of many of the bulk storage buildings at the site.

Further details of the CALPUFF configuration are provided in Appendix C.

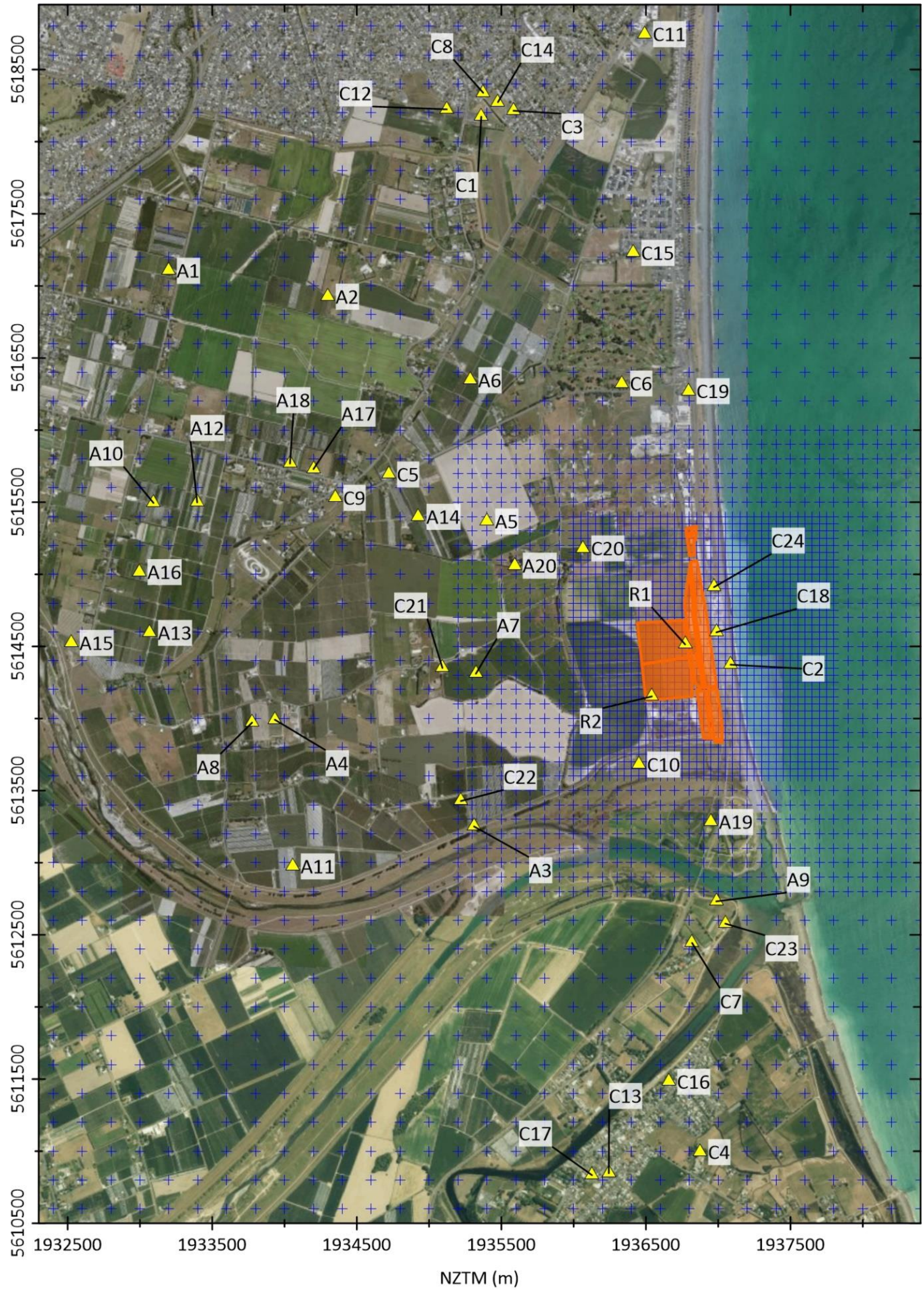

Figure 6.1: Location of nested receptors (blue crosses) and discrete receptors (yellow triangles). Ravensdown site shaded orange.

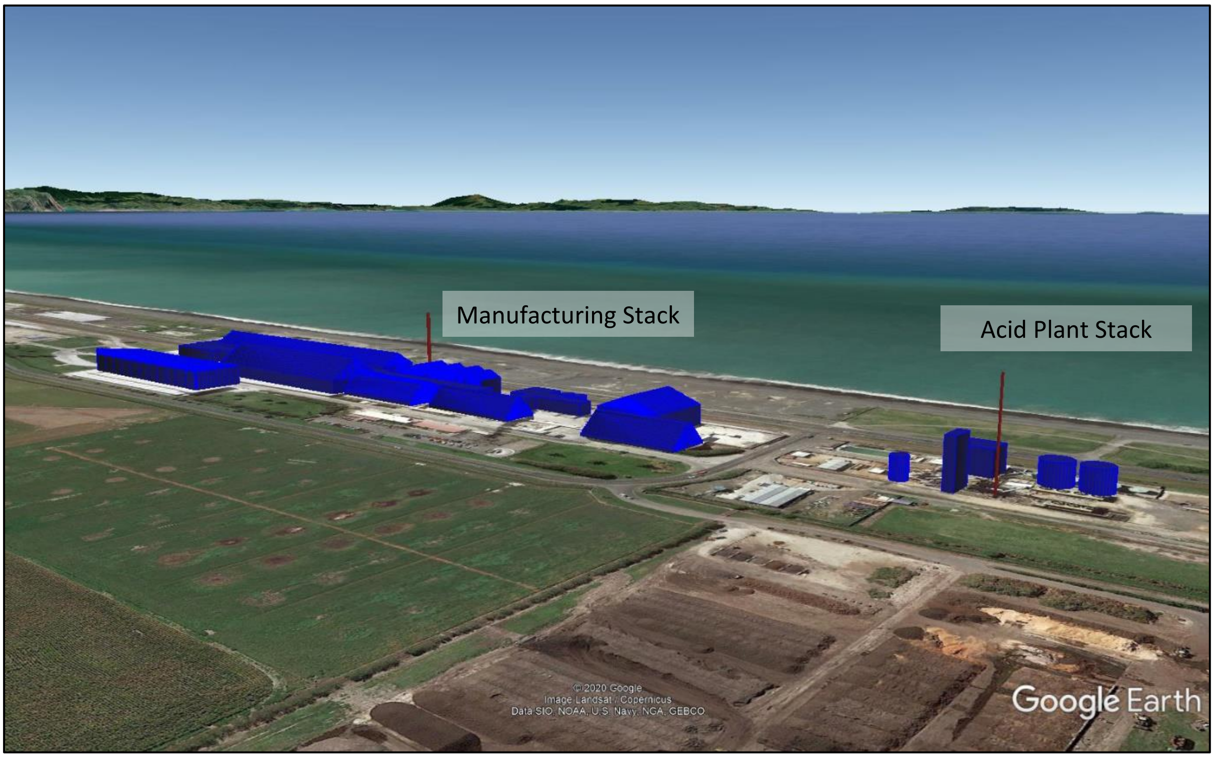

Figure 6.2: Three-dimensional view of the existing buildings (blue) and stacks (red) at the Ravensdown site as represented in the CALPUFF model.

6.1.2 Meteorological modelling

The HBRC has developed CALMET datasets for years 2006 and 2010 covering the Hastings/Awatoto area (including the Ravensdown site) for the purpose of dispersion modelling assessments. However, following an analysis of the wind output from the HBRC dataset for the location of the site, T+T determined that the CALMET dataset needed to be updated for the following reasons:

- The wind fields in the HBRC dataset did not closely match the winds measured at the Ravensdown site;
- The HBRC dataset did not include observational monitoring data from sites near to the coast in the Awatoto area, which are likely to be important in representing the coastal wind conditions experienced at the site; and
- The terrain data (GEO.DAT) file for the HBRC used terrain heights over the Ravensdown site and much of the surrounding land that were too low (i.e., at 0 m above sea level).

Given the above considerations, T+T has developed a new CALMET dataset covering the same geographical area as the original HBRC dataset. The following describes the development of the new dataset.

A key consideration for the development of the new dataset has been to incorporate measured wind data from Ravensdown's on-site meteorological stations. A two-year dataset was developed in line with current good practice. The choice of the two years followed a review of Ravensdown's wind and ambient sulphur dioxide monitoring data to confirm data availability while selecting relatively recent consecutive years. The analysis identified some significant gaps in both datasets for some recent years, but that data for the years 2015 and 2016 were sufficiently complete. This period, particularly 2015, includes El Niño climatic conditions, with the latter half of 2016 trending more towards La Niña conditions. Given this, it is expected the choice of 2015 and 2016 will provide a suitably wide range of meteorological conditions appropriate for the dispersion modelling assessment.

The revised CALMET dataset for this project was developed in a similar manner to that used by HBRC. However, it uses meteorological outputs from the WRF[17] model and on-site meteorological measurements. The WRF model was used in preference to the TAPM model (used in the HBRC dataset) for several reasons, but mainly because it is significantly more sophisticated and is consistent with current industry practice.

The CALMET dataset also uses measured meteorological parameters from three climate stations from those used in the HBRC dataset, but most importantly Ravensdown's own weather station so as to better reflect conditions of the site and its coastal location. The climate stations used for the new dataset are listed in Table 6.1.

Further details of the CALMET configuration are provided in Appendix D.

Table 6.1: Climate stations used in CALMET dataset

ID	Station name	Operating authority	Parameters measured	Mast height
S1	Ravensdown Napier Works Archimedes site	Ravensdown	WS, WD	10 m
S3	Awatoto *	HBRC	T, RH	10 m
S2	Whakatu	NIWA	WS, WD, T, RH, rainfall	10 m

Notes: WS = wind speed, WD = wind direction, T = temp, RH = relative humidity.

* With regard to the HBRC Awatoto meteorological monitoring station, although data for wind speed and direction are available, these parameters were excluded from input to the model due to the very close proximity to the Ravensdown met station.

[17] Weather Research and Forecasting (WRF) model is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications.

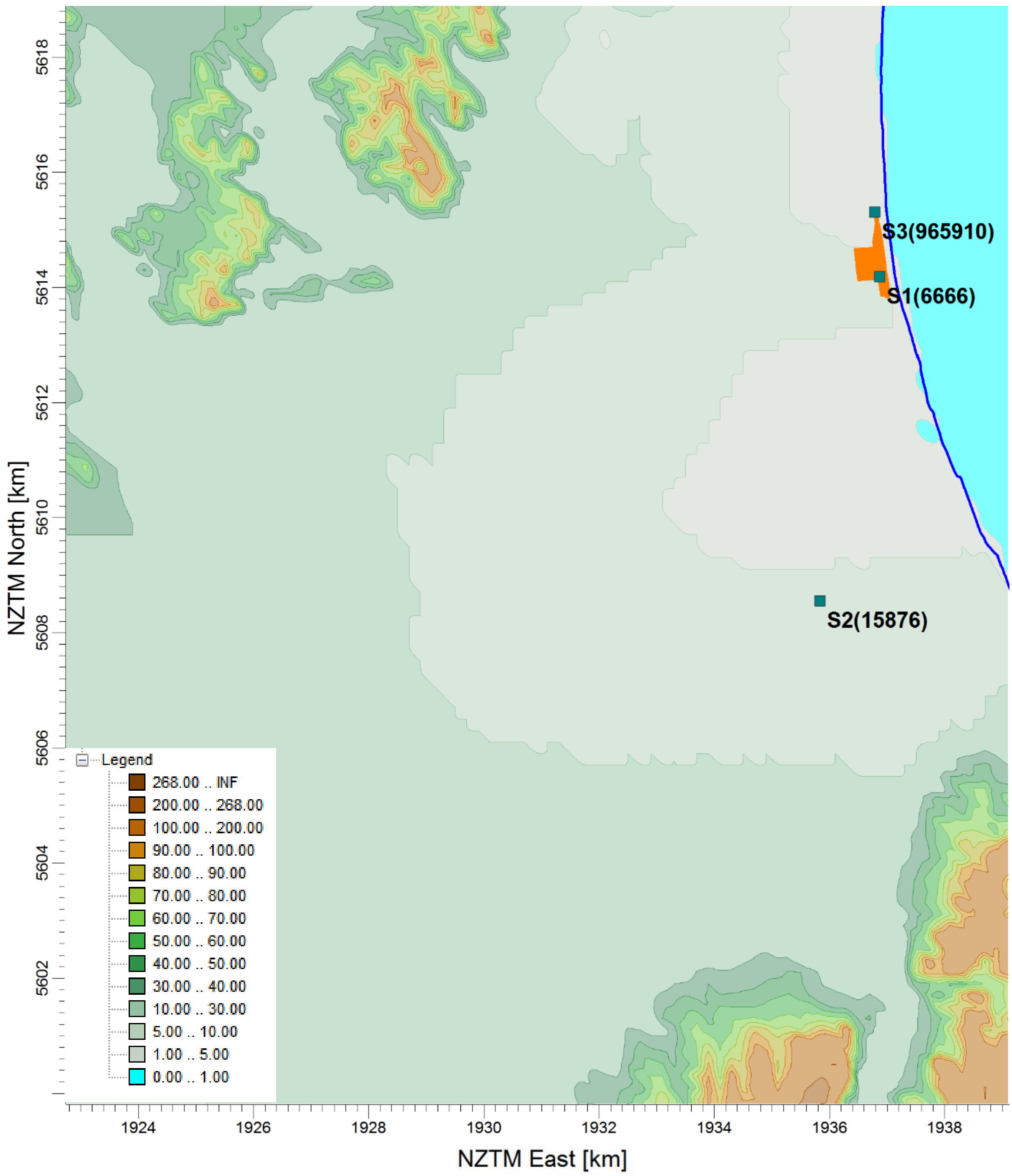

Figure 6.3: Location of meteorological stations used in the meteorological model. Figure also shows topography in the surrounding environment. Ravensdown site is solid orange.

6.1.3 Assessment criteria

6.1.3.1 Criteria adopted for this assessment

The choice of ambient air quality assessment criteria used to evaluate the results of dispersion modelling is based on MfE (2016a) guidance, which sets out the following criteria to be used in order of priority:

- Ambient air quality standards set in the National Environmental Standards for Air Quality (NES_{AQ});
- The National Ambient Air Quality Guidelines (AAQG – MfE 2002);
- Regional objectives (unless more stringent than above criteria – note HBRC does not have any specific air quality guidelines or standards that are more stringent than the NES_{AQ} or AAQG in its operative or proposed plans);
- World Health Organisation (WHO) air quality guidelines (WHO 2005). We note that the MfE (2016a) specifically references the WHO 2005 guidelines;
- California reference exposure levels (acute and chronic) and US EPA inhalation reference concentrations and unit risk factors (chronic) (OEHHA 2016); and
- Texas effects screening levels (if these have been derived from toxicological data in a transparent manner) (TCEQ 2016)

As discussed in Section 3, there are three contaminants of interest associated with the production of fertiliser at the Ravensdown site: particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide, and fluoride. Based on the above references, the relevant ambient air quality assessment criteria for the three contaminants considered in the modelling assessment are set out in Table 6.2, below, along with the corresponding averaging period and the reference for each criterion. For completeness, the additional criteria for NO_2 and CO (associated with diesel combustion during the Acid Plant start-up) are also included in Table 6.2.

Table 6.2: Dispersion modelling assessment criteria for the protection of human health

Contaminant	Concentration (µg/m³)	Averaging period	Reference
PM_{10}	50	24-hour	NES_{AQ}
	20	Annual	AAQG
$PM_{2.5}$ **	25	24-hour	WHO (2005) / MfE (2020)
	10	Annual	WHO (2005) / MfE (2020)
SO_2	570 (not to be exceeded)	1-hour	NES_{AQ}
	350 (9 exceedances per year)	1-hour	NES_{AQ}
	120	24-hour	AAQG
SO_3	120	1-hour	OEHHA
	1	Annual	
H_2S*	7	1-hour	AAQG

Contaminant	Concentration (µg/m³)	Averaging period	Reference
NO_2	200 100 40	1-hour 24-hour Annual	NES_{AQ} AAGL WHO (2005)
CO	30,000 10,000	1-hour 8-hour running mean	AAQG NES_{AQ}

* H_2S guideline is described as being for managing odour in the AAQGs.

** The WHO (2005) guidelines are the same as set out by the MfE (2020) in its consultation document regarding amendments to the NES_{AQ}.

The Californian Environmental Protection Agency - Office of Environmental Health Hazard Assessment (OEHHA) publishes Reference Exposure Levels (RELs) that are intended for the protection of human health. Table 6.3 lists the relevant acute (1-hour average) and chronic (annual average) REL values for fluoride and hydrogen fluoride. These values are significantly higher than those described in Table 6.4 for the protection of ecosystems. Consequently, it is considered that meeting the guidelines set out in Table 6.4 will be protective in terms of human health effects.

Table 6.3: OEHHA Reference Exposure Levels relating to fluoride

Contaminant	Acute (1-hour average – µg/m³)	Chronic (annual average - µg/m³)
Fluorides	-	13
Hydrogen fluoride	240	14

Table 6.4: AAQGs for the protection of ecosystems

Time averaging period	Ecosystem Type	SO_2	F
12-hour	Special Land Use General Land Use	-	1.8 3.7
24-hour	Special Land Use General Land Use	-	1.5 2.9
7-day	Special Land Use General Land Use	-	0.8 1.7
30-day	Special Land Use General Land Use	-	0.4 0.84
90-day	Conservation Areas Special Land Use General Land Use	-	0.1 0.25 0.5
Annual	Agricultural Crops Forest and Vegetation Lichen	30 20 10[4]	-

6.1.3.2 Updated WHO global air quality guidelines (2021)

In September 2021, WHO (2021) published and update of its ‘global air quality guidelines’, which includes updated values from the previous 2005 guidelines. The WHO guidelines for 2005 and 2021 (including interim targets) applicable to the contaminants considered in this assessment are listed in Table 6.5.

Of particulate note is that the 24-hour average guideline for SO_2 has increased from 20 µg/m³ to 40 µg/m³, with the latter also including provision for 3 to 4 exceedance days to occur per year. The former 2005 guideline (20 µg/m³) was not formally adopted in New Zealand as a guideline or standard. The matter was examined extensively through a number of reginal plan hearings (notably for the Auckland Unitary Plan and the Canterbury Air Regional Plan) with there being concerns regarding the underlying science and applicability of the guideline to impacts from isolated industrial sources of SO_2 versus regularly high airshed-wide levels of SO_2 experienced in cities overseas.

The WHO guidelines for both PM_{10} and $PM_{2.5}$ have reduced as indicated in Table 6.5. We have not yet undertaken a detailed review of the underlying science and justification for these new guidelines. However, we note that the guideline concentrations for $PM_{2.5}$ are similar to concentrations experienced at background monitoring sites. We would expect that many coastal locations would exceed these concentrations due to the influence of marine aerosols.

It is also noted that the MfE (2020) has proposed amendments to the NES_{AQ} that seek to adopt the WHO 2005 guidelines and that these are consistent with the WHO 2021 Level 4 Interim Target.

Table 6.5: Comparison of the 2006 and 2021 WHO guidelines

Pollutant	Averaging time	Guideline concentration (µg/m³)					
		WHO 2005	WHO 2021 – interim target and AQG Level				
			1	2	3	4	AQL
SO_2	24-hour	20	125	50	-	-	40 *
PM_{10}	24-hour	50	150	100	75	50	45
	Annual	25	70	50	30	20	15
$PM_{2.5}$	24-hour	25	75	50	37.5	25	15
	Annual	10	35	25	15	10	5

* 99^{th} percentile (i.e., 3-4 exceedance days per year).

6.1.4 Fugitive discharges

To assess the cumulative effects of all gaseous fluoride discharges from the site using dispersion modelling, it is important to consider the contribution from fugitive fluoride discharges. As described in Section 3.1.3, fugitive emissions of gaseous fluoride will occur primarily from the manufacturing building and to a lesser degree from the superstore building. Unlike stack emissions of fluoride, fugitive fluoride emissions are expected to impact very close to the site and have a relatively minor impact further afield.

A key challenge in modelling fugitive emissions is quantifying the rate of discharge. This is because fugitive emissions cannot be readily measured in the same way that stack emissions are. To address this, T+T has back-modelled the "unknown" fugitive emissions by including these sources along with the existing stack discharges and using the results of the results of 7-day average ambient monitoring data. Fugitive emission from the Manufacturing Building and Superstore were modelled as volume sources. From this, the following fugitive fluoride emission rate for peak short term and longer term averaging periods have been determined:

- **Peak emission rate** (used for the modelling of 1-hour, 12-hour, 24-hour and 7-day averages) **of 0.10 kg/hr** , which closely matches peak measured ambient concentrations; and
- **Average emission rate (**used for the modelling of 30-day and 90-day averages) of **0.03 kg/hr**, which closely matches average measured ambient concentrations)

The fugitive emissions estimated in this manner have then been incorporated into all modelling of fluoride emission presented in the subsequent sections of this report.

Figure 6.4 provides a box and whisker plot summarising the results for each of the five ambient fluoride monitor sites. Overlaid on this plot are the results from the maximum model predicted 7-day average fluoride concentrations from stack emissions only (green dotted line) as well the model results of fugitive and stack emissions at peak levels (orange dotted line) and average levels (blue dotted line). A comparison of the model results with the measured ambient fluoride concentrations shows the following:

- Modelling of stack emissions only significantly underpredicts ambient fluoride concentrations at locations close to the site but provides a reasonable prediction of concentrations and locations further away from the site; and
- The model results for fugitive and stack emissions shows a good match with the ambient monitoring data, especially the three closest monitoring sites (the Winstone, Front Paddock and Back Paddock sites). This indicates fugitive emissions from the plant are likely to drive near-field impacts, but will have a very small contribution for locations further afield.

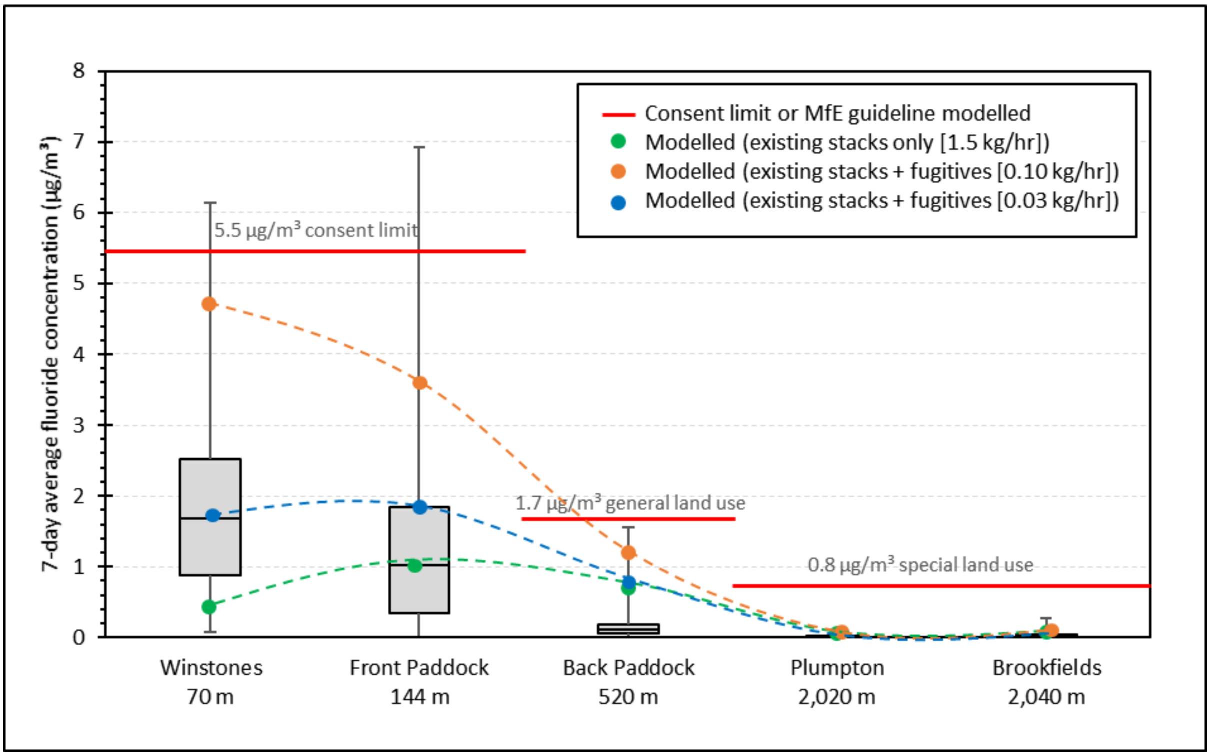

Figure 6.4: Model predicted 7-day average concentrations for the existing site configuration (green for stack discharges only and orange for stack and fugitive discharges) overlaid on a box and whisker plot of measured 7-day average fluoride measurements – 1 January 2015 to August 2021. Redlines indicate existing consent limits for monitoring data.

6.2 Model results – Existing site configuration

6.2.1 Overview

The following sections present the model results and assessment for stack discharges associated with fluoride, SO_2, PM_{10}, $PM_{2.5}$ emissions from the Site as it is currently configured. It also presents the results of fluoride and sulphur deposition modelling. Appendix E presents the predicted concentrations for all averaging periods for the various sensitive receptor locations described in Section 4.1. Contour plots for the wider model domain are provided in Appendix F.

6.2.2 Fluoride

The model-predicted maximum 1-hour, 12-hour, 24-hour, 7-day, 30-day and 90-day average GLCs due to fluoride emissions from existing site configuration are summarised in Table 6.5. Corresponding contour plots for each time averaging period are provided in Figure 6.6 to Figure 6.10 and include an overlay to indicate the location of the Foreshore Reserve and Waitangi Regional Park (in green hatching).

Predicted 1-hour average GLCs are low relative to the OEHHA criterion of 240 µg/m³. This reinforces the expectation that human health effects are not a concern in relation to fluoride emission.

The contour plots show concentrations reducing rapidly with increasing distance from the site. For all averaging periods, the greatest impact is predicted to occur to the immediate east of the Manufacturing Plant over the former Winstone site. The predicted concentrations at this location above the relevant assessment criteria for 'general land use'. However, it is noted that the location where these elevated concentrations occur is localised to the former Winstone Site and the foreshore immediately beyond that.

For locations to the west of the site predicted concentrations are within the 'general land use' criteria and concentrations reduce further to be within the 'special land use' criteria at distances where sensitive horticultural crops and vineyards are understood to be located.

Land to the immediate south of the site is zoned 'River Conservation' under the Napier District Plan, and includes the Tūtaekurī River, Waitangi Regional Park, and Ngaruroro River comprising the Waitangi Estuary (Figure 4.1). As noted earlier, Ravensdown has confirmed with Dr David Doley[18] that the general land use category of the Ambient Air Quality Guidelines (AAQG) provides sufficient protection for the native plants in the Waitangi Estuary (refer to Appendix B). In this regard, 90-day average concentrations are predicted to be below the general land use criteria (0.25 µg/m³), and fall within 0.1 µg/m³ within approximately 500 m.

In summary, the cumulative fluoride concentrations due to discharges from the Site as currently configured are predicted to be within the relevant assessment criteria for the protection of ecosystems, taking into account the sensitivity of locations in the receiving environment with regard to 'general land use' and 'special land use'. The only exception is a small area of land immediately east of the site over the former Winstone site and the adjoining foreshore reserve where concentrations are predicted to be above the 'general land use' criteria. To the east of Ravensdown's land, model-predicted concentrations are above the general land use criteria for only a few tens of metres.

[18] Dr Doley (Honorary Associate Professor, University of Queensland) provided expert evidence on the air pollution effects on vegetation at the consent hearing in 2006 for the current air discharge permit and was involved in the development of the fluoride vegetation guidelines.

Table 6.6: Summary of predicted fluoride GLC (due to stack and fugitive emissions) compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)**	Assessment Criteria (µg/m³)
Most impacted off site location	1-hour*	East of site	77	77	240
Most impacted general land use location	12-hour	East of Site	36	36	3.7
	24-hour	East of Site	23	23	2.9
	7-day	East of Site	16	16	1.7
	30-day	East of Site	4.1	4.1	0.84
	90-day	East of Site	3.9	3.9	0.5
Most impacted sensitive land use location	12-hour	Wells Orchard (A20)	1.4	1.5	1.8
	24-hour	Wells Orchard (A20)	0.76	0.80	1.5
	7-day	Gibson Orchard (A7)	0.29	0.34	0.8
	30-day	Gibson Orchard (A7)	0.03	0.07	0.4
	90-day	Gibson Orchard (A7)	0.02	0.06	0.25
Most impacted residence where exposure is relevant	Annual	Northeast House (C24)	0.054	0.10	13

Notes:

1-hour, 12-hour, 24-hour and 7-day average model predictions are based on the maximum consent emission rate.

30-day and 90 day average model predictions are based on the 75th percentile of measured emission rates.

* Relates to the assessment criteria for human health related to HF.

** Background concentrations in all cases are 0.045 µg/m³ based on analysis provided in Section 5.2

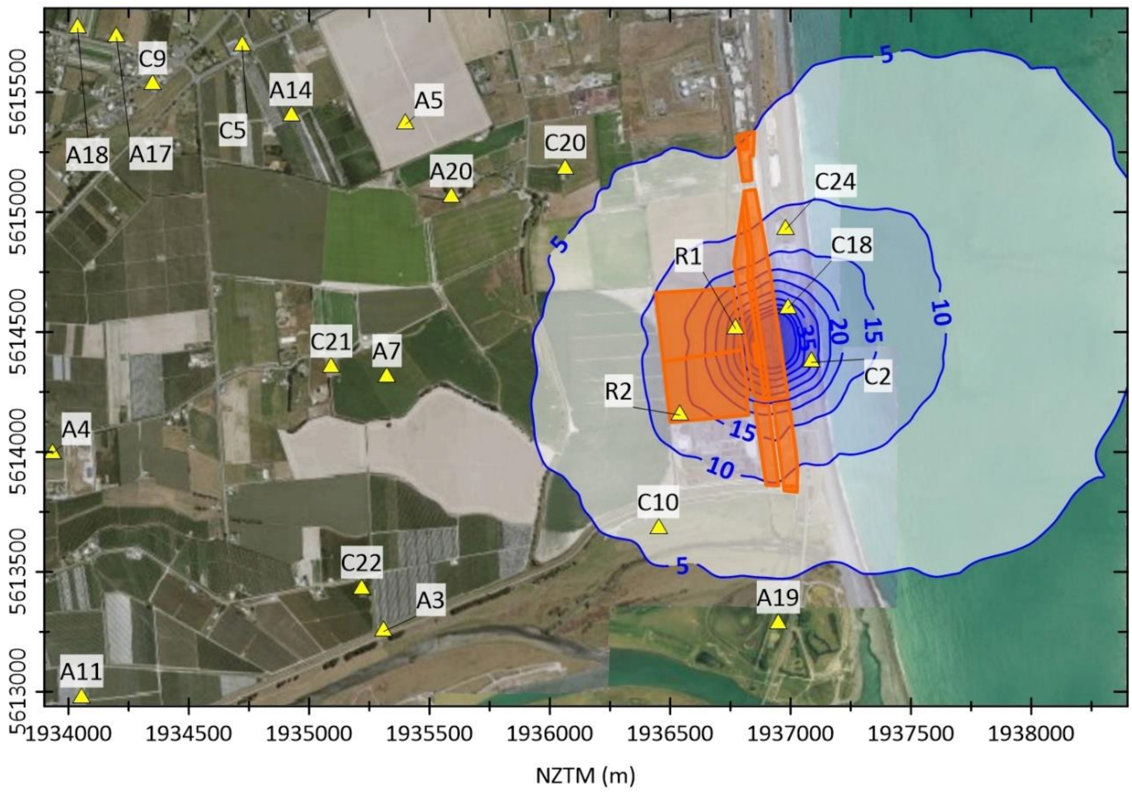

Figure 6.5: Predicted maximum 1-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon.

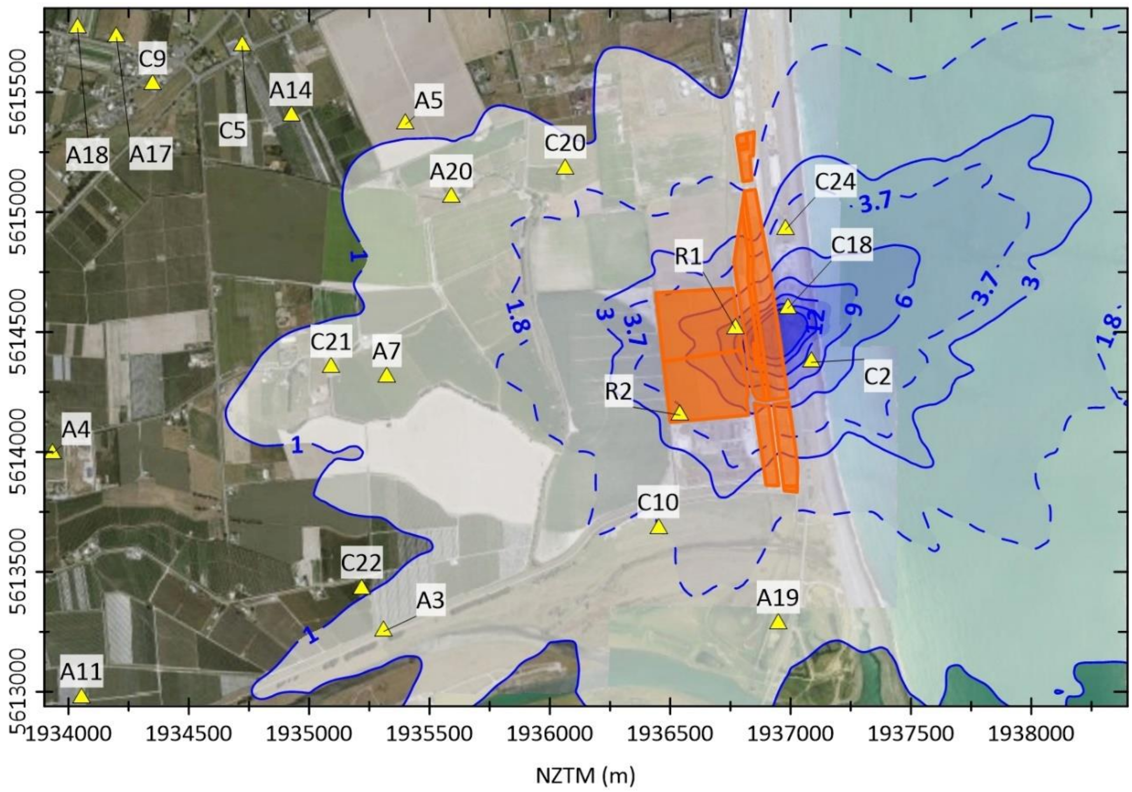

Figure 6.6: Predicted maximum 12-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

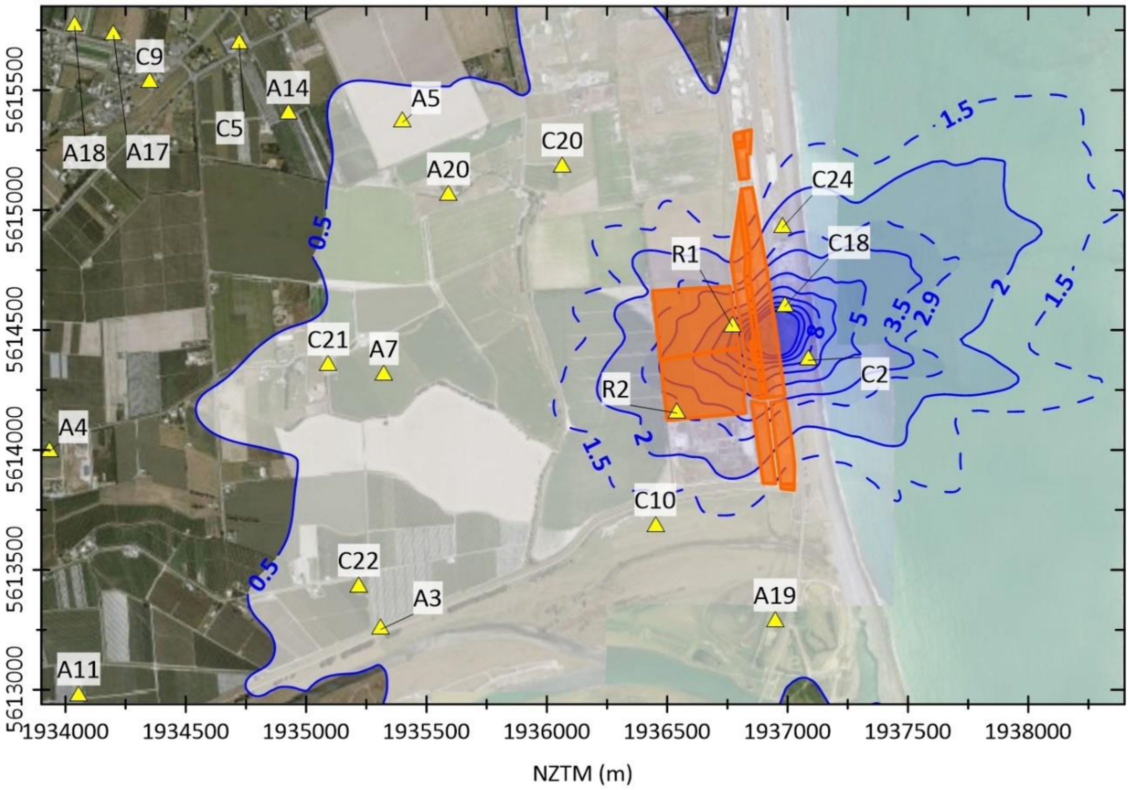

Figure 6.7: Predicted maximum 24-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

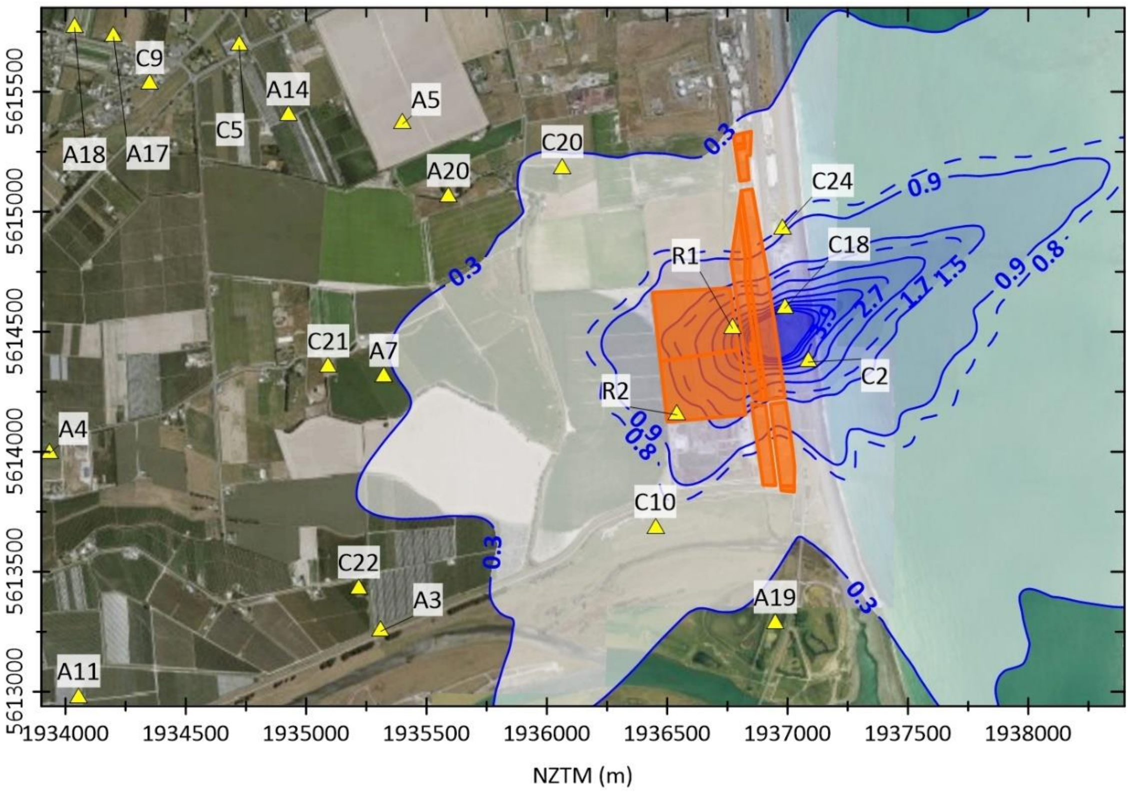

Figure 6.8: Predicted maximum 7-day average fluoride GLC (µg/m³)– based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

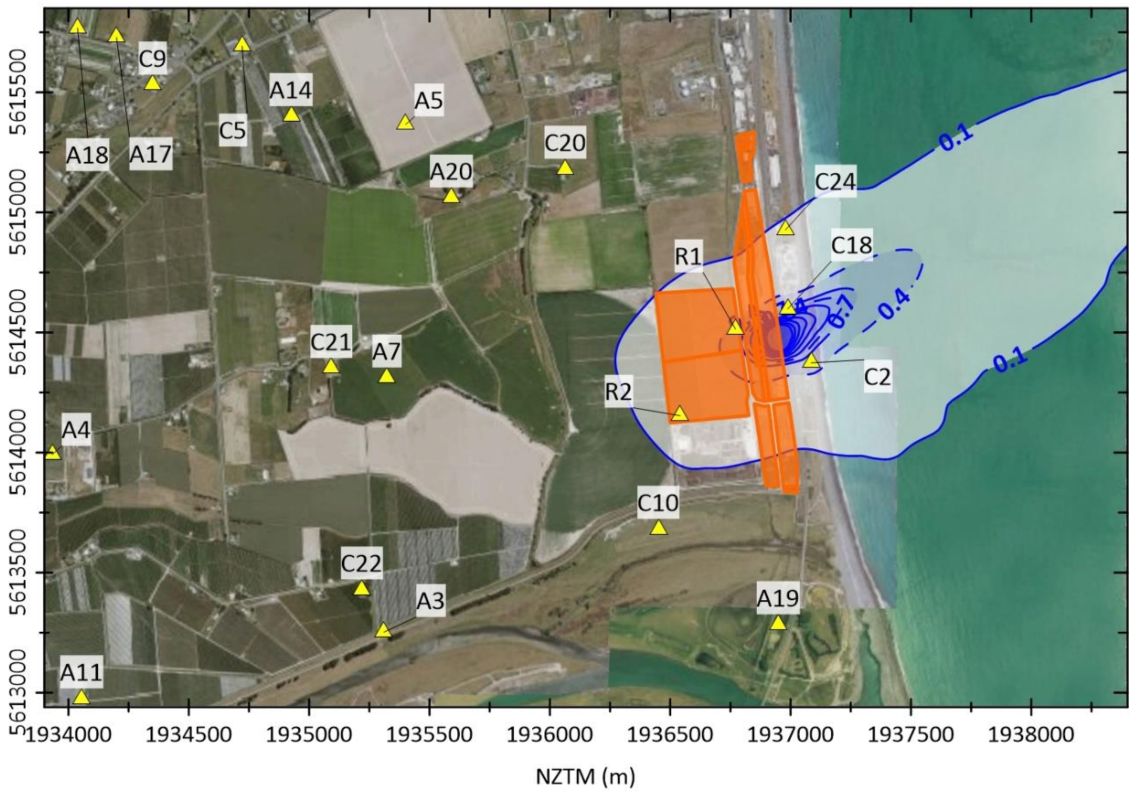

Figure 6.9: Predicted maximum 30-day average fluoride GLC (µg/m³) – based on 75th%ile of measured emission rates. Existing site configuration - site stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

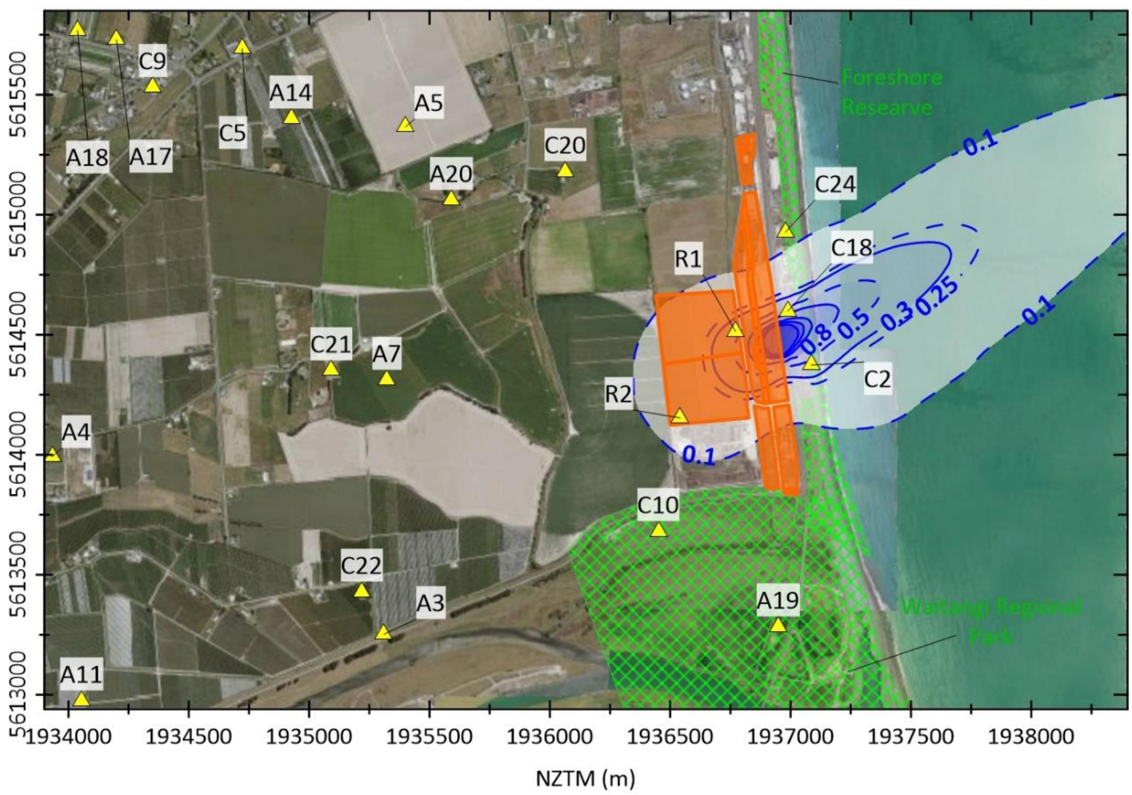

Figure 6.10: Predicted maximum 90-day average fluoride GLC (µg/m³)– based on 75th%ile of measured emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

6.2.3 Sulphur dioxide

The model-predicted maximum 1-hour, 24-hour and annual average ground level concentrations (GLCs) due to SO_2 emissions from the Ravensdown site (both the Acid Plant and to a lesser extent the Manufacturing Plant) are summarised in Table 6.6. Corresponding contour plots for each time averaging period are provided in Figure 6.11 to Figure 6.12. Contour plots showing the wider model domain are provided in Appendix F.

Figure 6.11 shows the maximum off-site 1-hour average SO_2 GLC is expected to occur immediately west of the Ravensdown boundary, over the Bio-Rich compost site. However, the predicted cumulative concentration of 343 µg/m³ is below the NES_{AQ} criteria (350 µg/m³ no more than 9 occasions per year, and 570 µg/m³ upper limit).

The maximum predicted off-site cumulative 24-hour average SO_2 GLC for a residential location where 24-hour exposure is relevant is 27 µg/m³ (Receptor C24). This is well within the AAQG value of 120 µg/m³.

The maximum predicted off-site cumulative annual average SO_2 GLC at a sensitive location in terms of vegetation impacts occurs over the Waitangi Regional Park – Receptor C10. The cumulative concentration at this location is 1.7 µg/m³, which is well within the AAQG of 10 µg/m³ for the protection of lichens (the most stringent of the vegetation guidelines).

In summary, the predicted impacts of SO_2 are well within the relevant assessment criteria for human health and vegetation impacts. The assumptions made in the assessment are conservative, reflecting maximum emission rates (based on proposed consent limits) for short term impacts, and the 75th percentile of measured rates for the annual average impacts. An evaluation of the model performance (provided in Section 6.3.4) against measured concentrations of SO_2 at the Winstone monitoring site shows good performance for the model predictions. Given this, it is concluded that SO_2 effects from normal operation of the site are low.

Table 6.7: Summary of predicted SO_2 GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location where exposure for the averaging period is relevant	1-hour	West of Acid Plant	340	343 [3]	570 / 350
	24-hour	Residence [C24]	24	27 [3]	120
	Annual**	Waitangi Regional Park	0.66	1.7 [1]	10

* Site discharges plus background. Background concentrations are in square brackets.

** Annual average results relate to vegetation impacts.

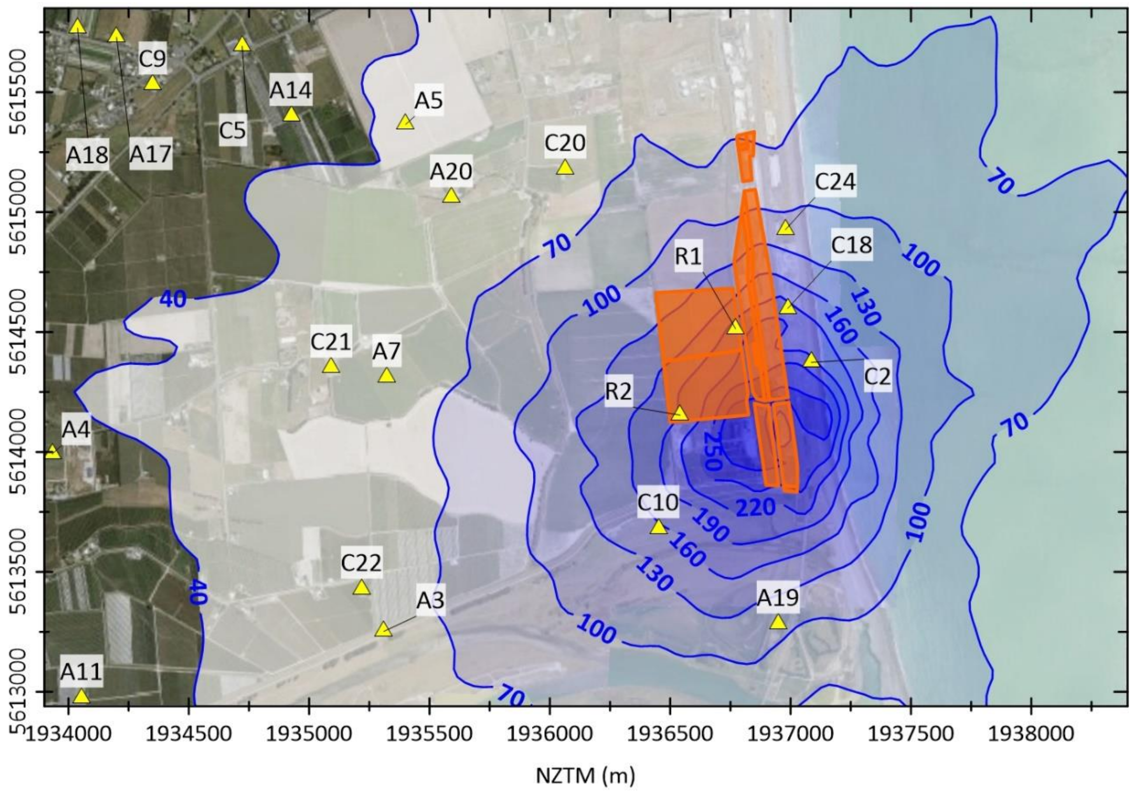

Figure 6.11: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC (µg/m³) – based on peak emission rates. Existing site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon.

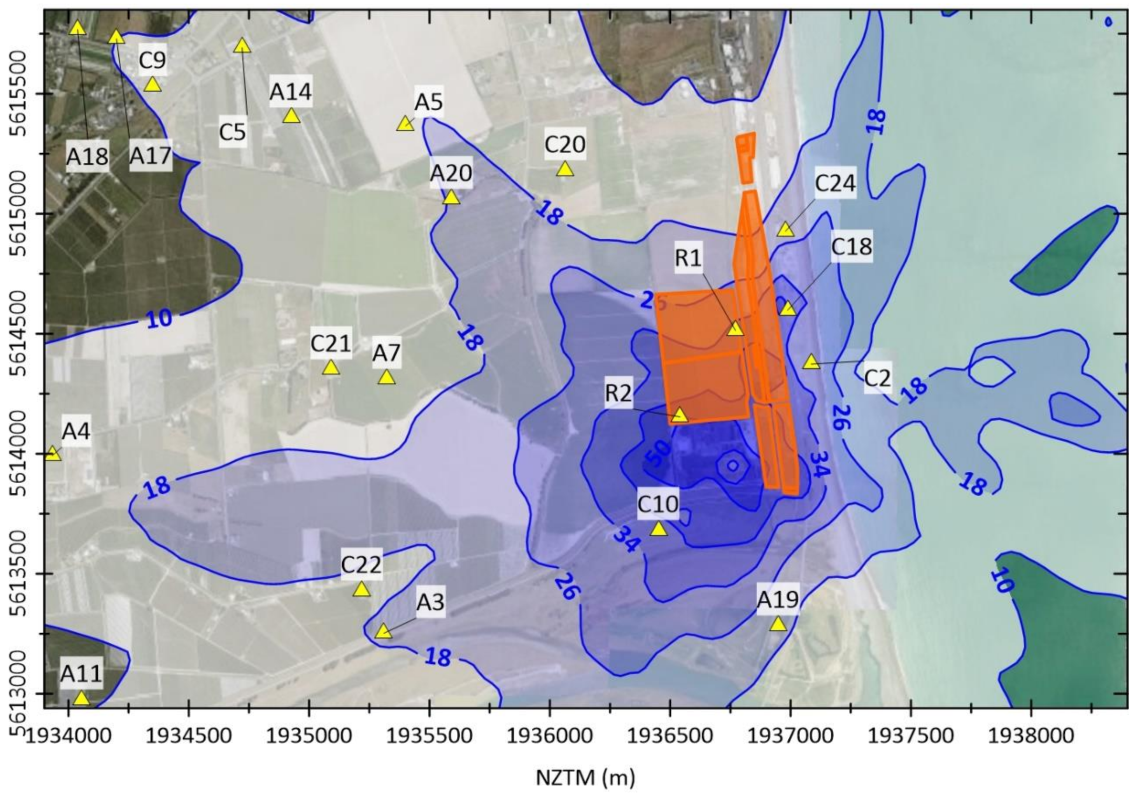

Figure 6.12: Predicted maximum 24-hour average SO_2 GLC (µg/m³)– based on peak emission rates. Existing site configuration - site emissions only.

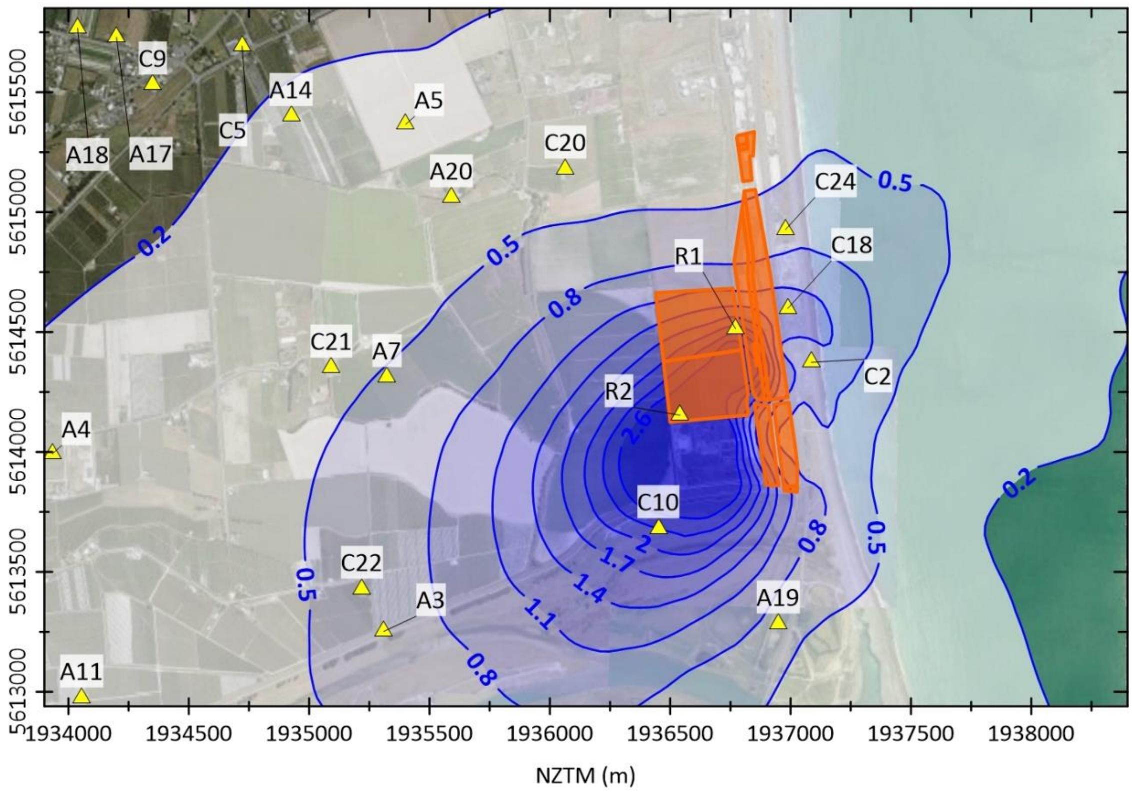

Figure 6.13: Predicted annual average SO_2 GLCs (µg/m³)– based on the 75th percentile of stack testing data. Existing site configuration - site emissions only.

As shown in Figure 3.2, the discharge velocity and temperature for the Acid Plant stack varies with SO_2 emission rate. To account for the potential change in predicted off-site SO_2 concentrations arising from lower velocity and temperature (less ideal dispersion conditions) a further model scenario has been undertaken. The scenario considered the impacts arising from a reduced velocity of 3 m/s, a temperature of 50 °C and a SO_2 emission rate of 20 kg/hr (this represents the 77th percentile of measured SO_2 emission rates for the Acid Plant). The combination of these factors is considered to provide a reasonable 'alternative' scenario whereby lower velocity and temperature conditions occur.

The results of the alternative scenario are presented as a contour plot for the predicted 1-hour average SO_2 concentrations in Appendix G. This plot presents two sets of contours for SO_2 emissions associated with the Acid Plant at peak emission conditions as presented above and for the alternative scenario. It clearly indicates substantially lower predicted SO_2 concentrations for the alternative scenario. Accordingly, the modelling scenario representing the Acid Plant discharging at its maximum SO_2 emission rate of 60 kg/hr (with corresponding exhaust temperature and velocity conditions) provides the most conservative (i.e., highest) off-site predictions of SO_2.

6.2.4 Sulphur trioxide

Predicted 1-hour and annual average SO_3 concentrations are summarised in Table 6.7 with corresponding contour plots provided in Figure 6.14 and Figure 6.15. The results are significantly below the corresponding human health criteria published by the OEHHA. Accordingly, the potential air quality effects of SO_3 are considered less than minor.

Table 6.8: Summary of predicted SO_3 GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location where exposure for the averaging period is relevant	1-hour	West of Acid Plant	11	11 [0]	120
	Annual	C22	0.002	0.002 [0]	1

* Site discharges plus background. Background concentrations are in square brackets.

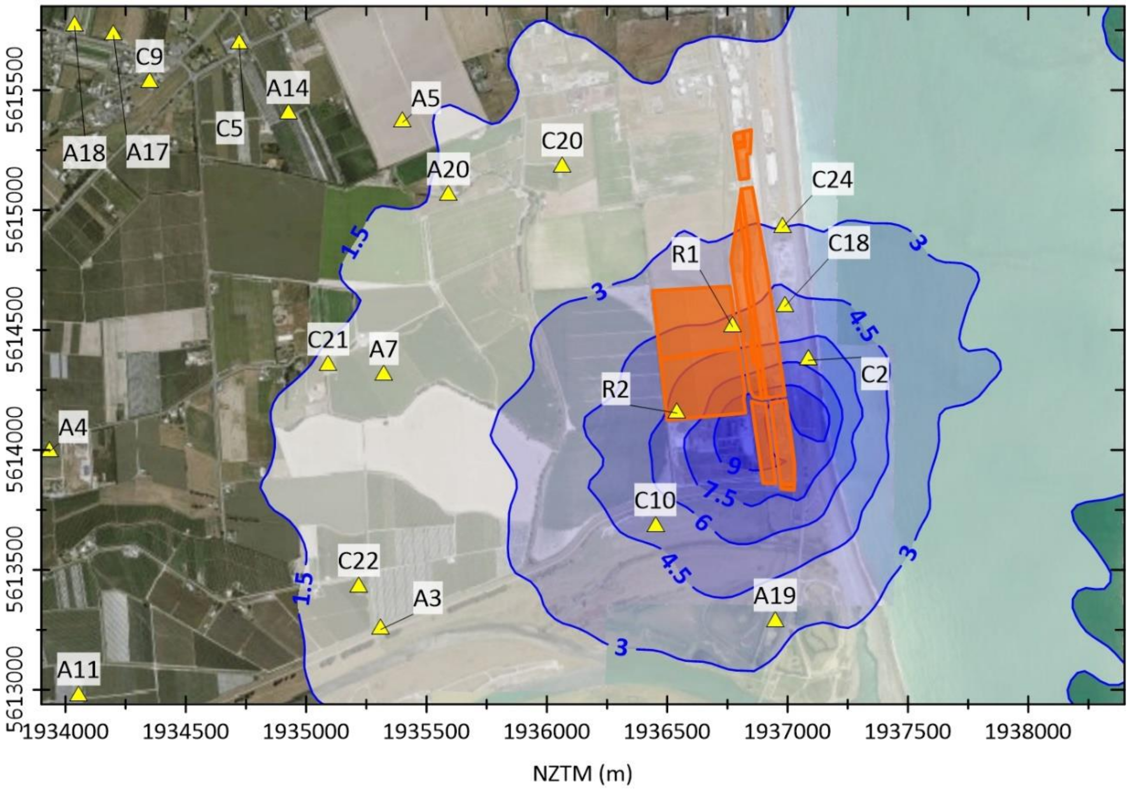

Figure 6.14: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_3 GLC (µg/m³) – based on peak emission rates. Existing site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon.

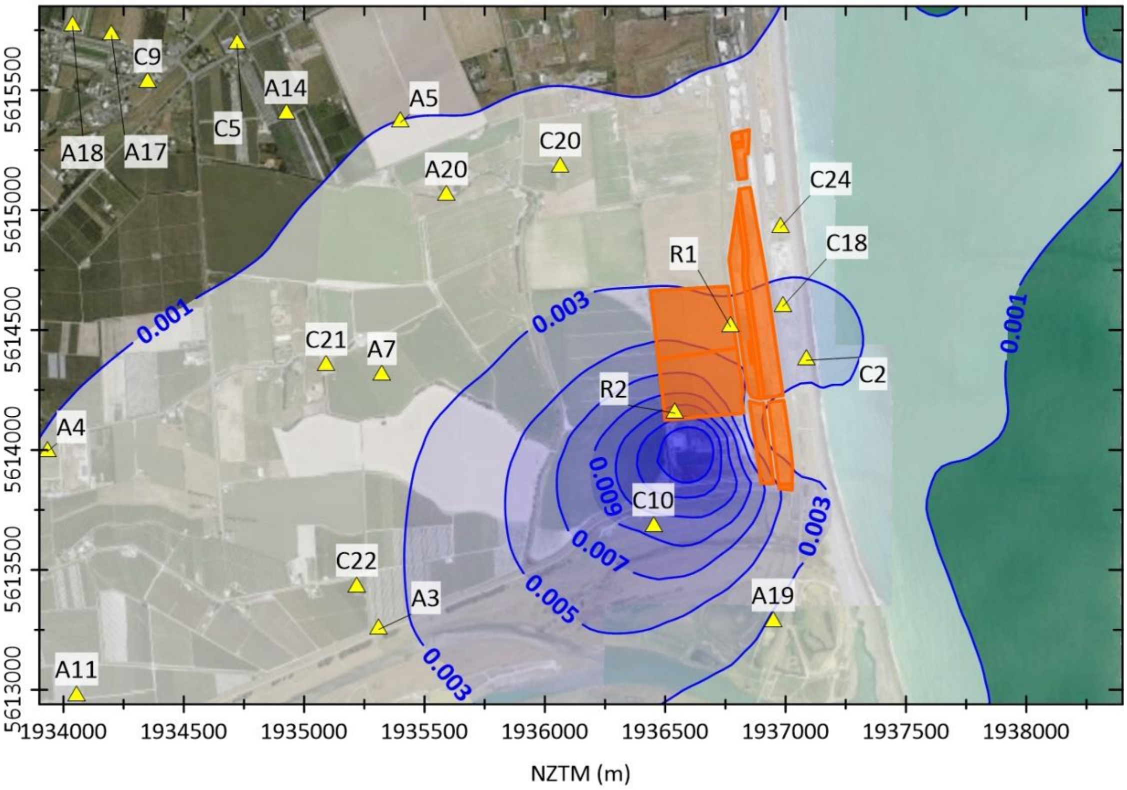

Figure 6.15: Predicted annual average SO_3 GLCs (µg/m³)– based on the 75th percentile of stack testing data. Existing site configuration - site emissions only.

6.2.5 Particulate matter

6.2.5.1 PM_{10}

The predicted maximum PM_{10} concentration at the most impacted off-site location and community receptor due to emissions from the Bradley Mills are summarised in Table 6.8. Contour plots for each averaging period are provided in Figure 6.16 and Figure 6.17.

The predicted contours for PM_{10} are distinctly different from those presented for fluoride and SO_2, in that the contours extend to the east in an off-shore direction whereas those for fluoride and SO_2 extend westward (inland). This is due to emissions of fluoride and SO_2 emissions occurring from relatively tall stacks compared to the PM_{10} discharges from the relatively short Bradley Mill vents.

The maximum off-site 24-hour average PM_{10} GLC for a location where exposure for the relevant averaging period is relevant is for the residences at Receptor C24. At this location, the predicted contribution from the site is 2 µg/m³, which is a low concentration and is within the limit of detection of standard ambient monitoring instruments (i.e., it would not be a measurable concentration). However, assuming a background concentration of 48 µg/m³ (24-hour average), this gives a cumulative worst case 24-hour average concentration of the NES_{AQ} of 50 µg/m.

The cumulative annual average concentration at this location is predicted to be 18.8 µg/m³, which is just below the AAQG of 20 µg/m³. However, the contribution from the site at this location is very small (0.03 µg/m³) and, similar to the 24-hour average prediction, the cumulative concentration is predominantly driven by the assumed background concentration.

The maximum predicted off-site 24-hour average PM_{10} concentration occurs over the former Winstone site with a cumulative concentration of 75 µg/m³. While this predicted concentration exceeds the NES_{AQ}, being a dis-used industrial site people are not realistically expected to be exposed for a 24-hour period. It is noteworthy that the model predictions, including background concentrations, are broadly consistent with the results of ambient PM_{10} monitoring at the Winstone site presented in Section 5.4.2.

In summary, the predicted impacts of PM_{10} at locations where human exposure is relevant (i.e., the nearest residential locations) are well within the relevant assessment criteria. Given this, it is concluded that PM_{10} effects are low and therefore are expected to be no more than minor.

Table 6.9: Summary of predicted PM_{10} GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location where exposure for the averaging period is relevant	24-hour	C24	2.0	50 [48]	50
	Annual	C24	0.03	18.8 [18.8]	20

* Site discharges plus background. Background concentrations are in square brackets.

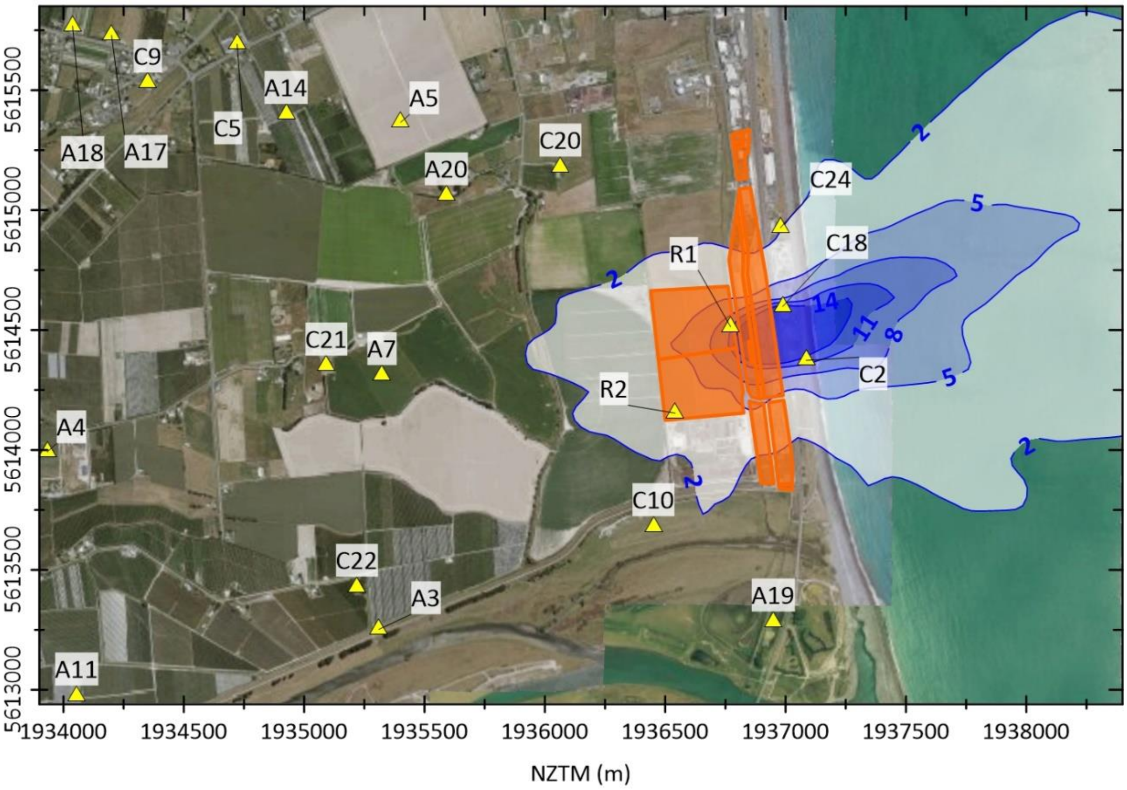

Figure 6.16: Predicted maximum 24-hour average PM_{10} GLC (µg/m³) in the immediate surroundings – based on peak emission rates. Site emissions only.

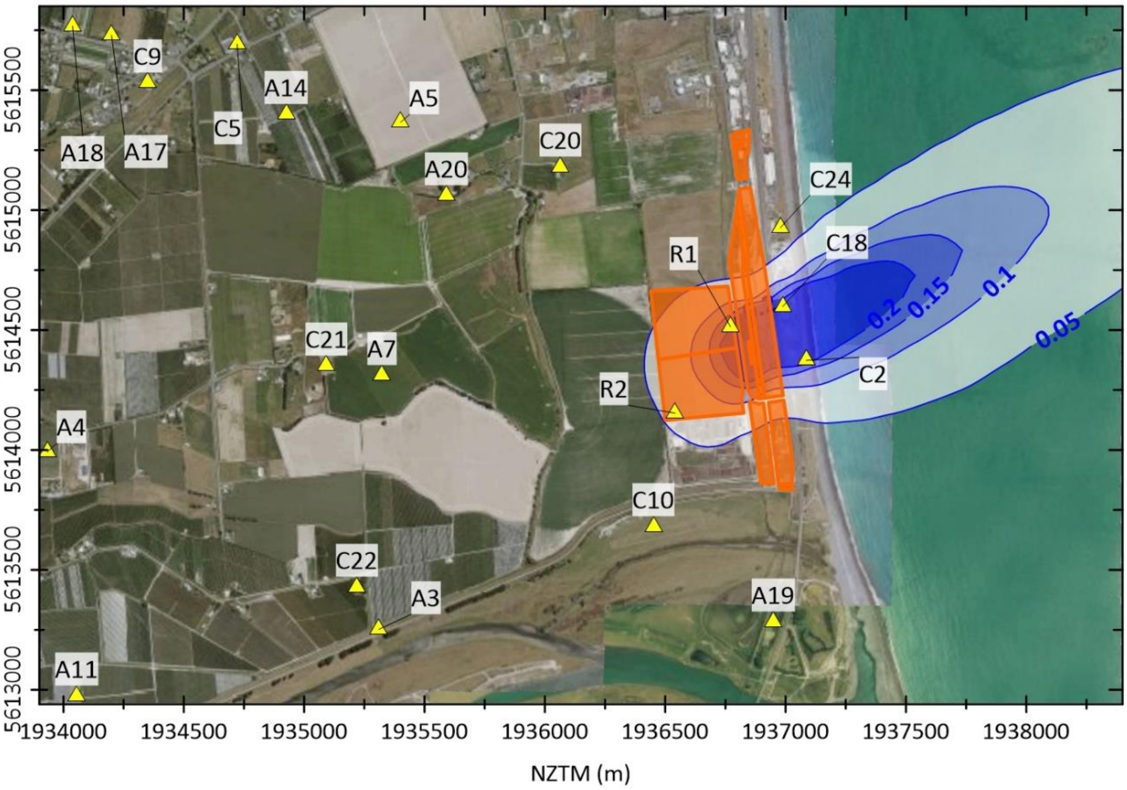

Figure 6.17: Predicted maximum annual average PM_{10} GLC (µg/m³) in the immediate surroundings – based on the 75th percentile of stack testing data. Site emissions only.

6.2.5.2 $PM_{2.5}$

The predicted maximum $PM_{2.5}$ concentration due to emissions from the Bradley Mills are summarised in Table 6.9. Contour plots for each averaging period are provided in Figure 6.18 and Figure 6.19.

The maximum off-site 24-hour average $PM_{2.5}$ GLC for a location where exposure for the relevant averaging period is relevant is for the residences at Receptor C24. At this location, the cumulative 24-hour average concentration is predicted to be 17.1 µg/m³, which is well below the WHO guideline of 25 µg/m³. The cumulative annual average concentration is predicted to be negligible and is not expected to increase measurably above the estimated background concentration of 6 µg/m, resulting in a predicted cumulative concentration that is below the WHO guideline of 10 µg/m³.

In summary, the predicted impacts of $PM_{2.5}$ at locations where human exposure is relevant (i.e., the nearest residential locations) are well within the relevant assessment criteria. Given this, it is concluded that $PM_{2.5}$ effects are low and therefore are expected to be less then minor.

Table 6.10: Summary of predicted $PM_{2.5}$ GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location where exposure for the averaging period is relevant	24-hour	C4	1.8	17.1 [15.3]	25
	Annual	C4	0.027	6.0 [6]	10

* Site discharges plus background. Background concentrations are in square brackets.

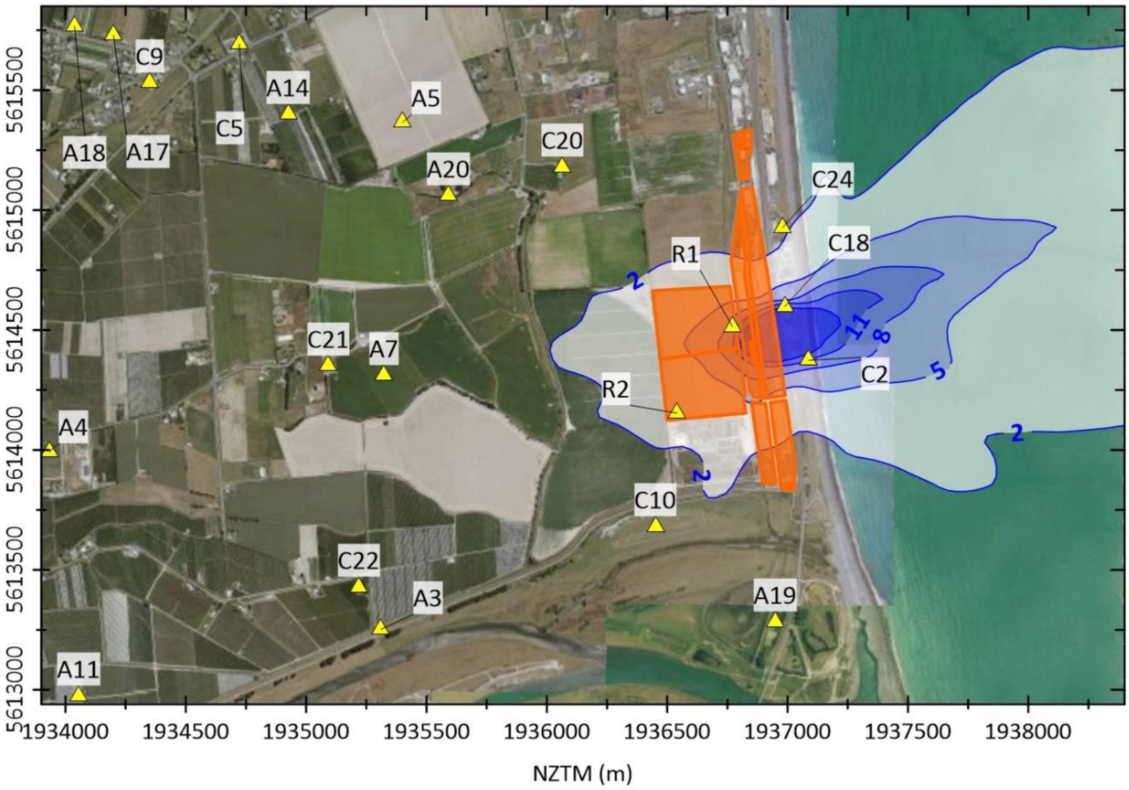

Figure 6.18: Predicted maximum 24-hour average $PM_{2.5}$ GLC (µg/m³) in the immediate surroundings – based on peak emission rates. Site emissions only.

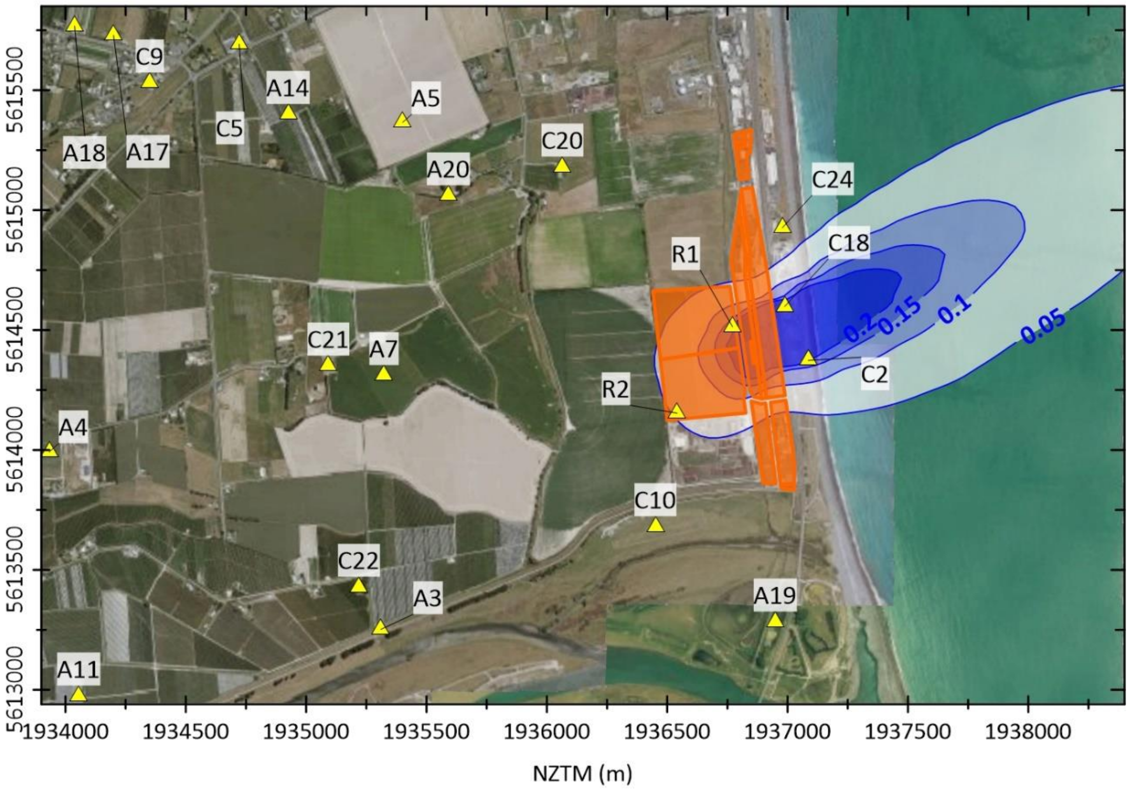

Figure 6.19: Predicted maximum annual average $PM_{2.5}$ GLC (µg/m³) in the immediate surroundings – based on the 75th percentile of stack testing data. Site emissions only.

6.2.6 Fluoride and sulphur deposition

Fluoride and sulphur deposition have been modelled to inform the vegetation impact assessment. For each contaminant, dry and wet deposition were modelled to determine the total deposition rate. Default wet and dry deposition parameters were assumed within the model for SO_2 and SO_4. Our literature review did not identify deposition parameters for hydrogen fluoride, although it is known that hydrogen fluoride is readily dissolved in water. Given this, dry deposition parameters for SO_2 and wet deposition parameters for SO_4 have been used to approximate likely conditions for deposition associated with fluoride.

6.2.6.1 Sulphur deposition

The model-predicted maximum annual off-site total sulphur deposition has been used to assess vegetation impacts. The peak off-site deposition rate is predicted to occur at the same location as the maximum off-site annual SO_2 GLC, i.e., to the southwest of the site over the Bio-Rich compost site. The maximum total sulphur deposition rate is predicted to be 2.5 kg/ha/yr at this location. Further afield, deposition rates reduce rapidly with the predicted rate at the most impacted agricultural receptor is 0.39 kg/ha/yr.

Table 6.11: Summary of predicted sulphur deposition rates

Receptor Type	Averaging period	Location	Model predicted deposition rate (kg/ha/yr)
Most impacted off-site location	Annual	West of Acid Plant	3.1
Most impacted area of sensitive vegetation receptor	Annual	Brookfield Orchard	0.39

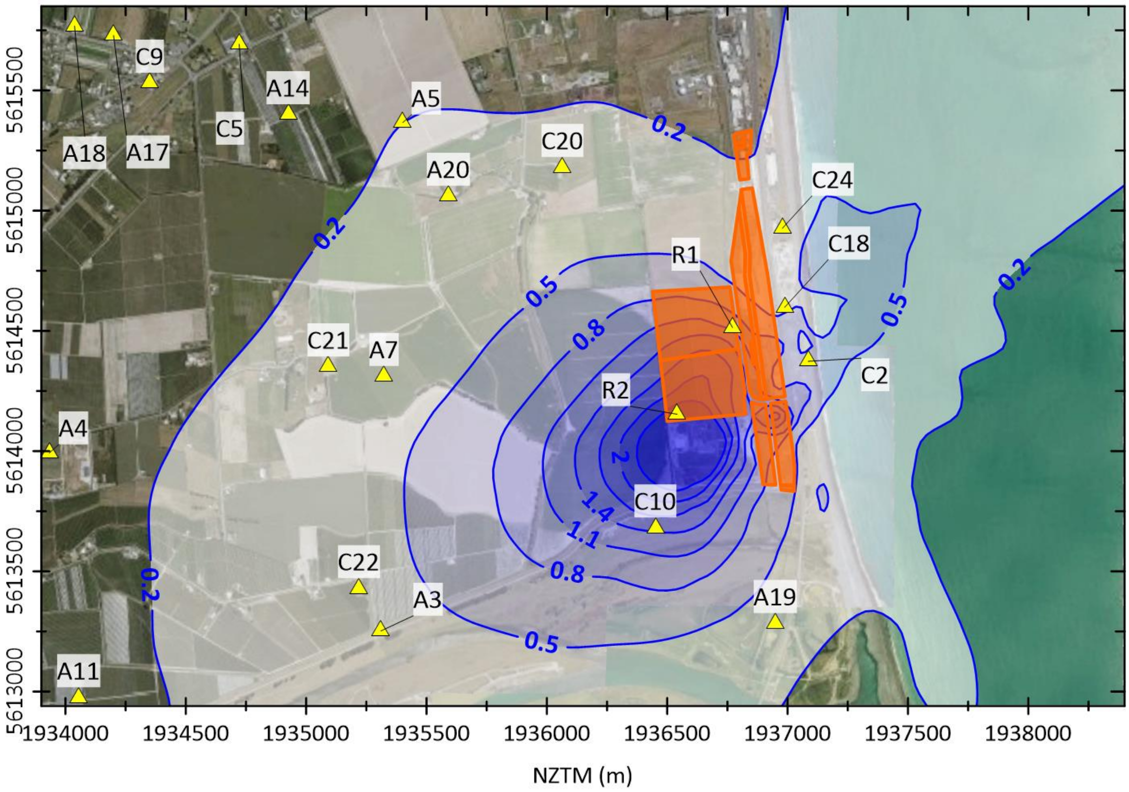

Figure 6.20: Predicted annual total sulphur deposition rate (kg/ha/yr) – based on the 75th percentile of stack testing data. Existing site configuration - site emissions only.

6.2.6.2 Fluoride deposition

The Kingett Mitchell Limited (KML 2007) report that was prepared for the previous application to reconsent the air discharges from the site noted the potential impacts of fluoride deposition impacts over short time-averaging periods as a result of rainfall or high humidity and the potential this has for vegetation impacts. Accordingly, maximum off-site 1-hour and annual average fluoride deposition rates have been modelled for to inform the assessment of vegetation impacts. The results of this are summarised in Table 6.11.

Figure 6.21 provides a contour plot of the predicted deposition rates. This illustrates that elevated levels of deposition occur to the immediate east of the Manufacturing Plant stack, with deposition rates reducing rapidly with increasing distance from the site.

Table 6.12: Summary of predicted fluoride deposition rates

Receptor Type	Averaging period	Location	Model predicted deposition rate
Most impacted off-site location	1-hour (kg/ha/hr)	East of Site	0.006
	Annual (kg/ha/yr)	East of Site	1.0
Most impacted sensitive agricultural receptor*	1-hour (kg/ha/hr)	Wells Orchard (A20)	0.00029
	Annual (kg/ha/yr)	Gibson Orchard (A7)	0.013

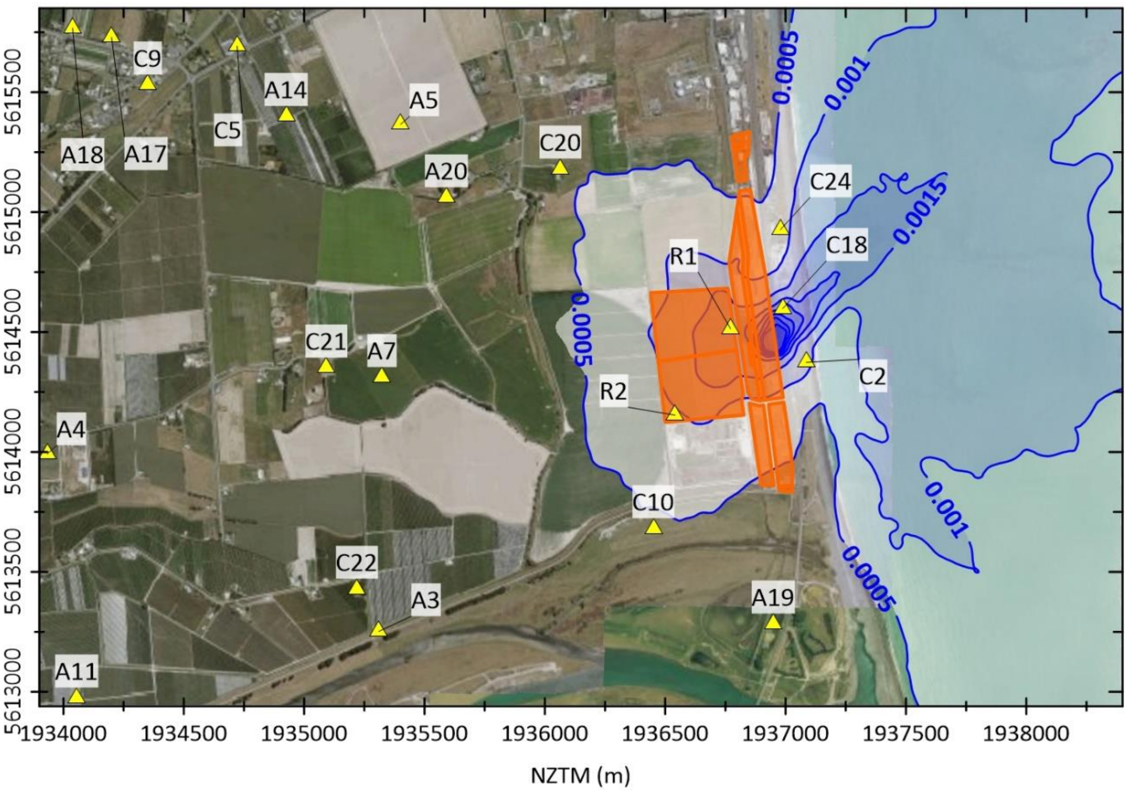

Figure 6.21: Predicted maximum 1-hour fluoride deposition (kg/ha/hr). Existing site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon.

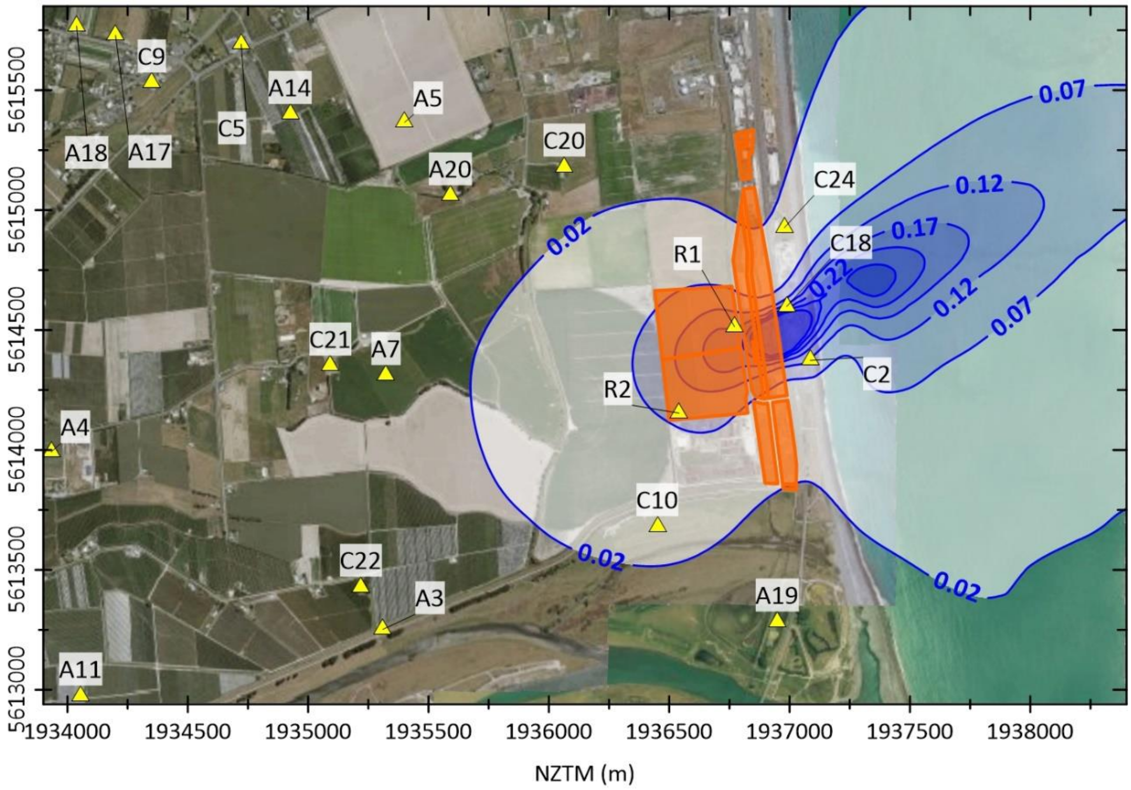

Figure 6.22: Predicted maximum annual fluoride deposition (kg/ha/yr). Existing site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon.

6.3 Model results – site improvements

6.3.1 Overview

This section presents the model results after the following planned site improvements have been implemented:

- The consented upgraded Den/Hygiene scrubber system with discharges through a taller (50 m) combined Manufacturing Plant stack. This assumes a lower fluoride emission rate of 1 kg/hr in line with Ravensdown's Air Discharge Strategy. SO_2 emissions from the combined Manufacturing Plant stack will also undergo greater dispersion than the existing site configuration; and
- The planned upgrade of the Acid Plant converter to increase the volume of catalyst. This upgrade will reduce SO_2 emissions during normal operation of the Acid Plant. Accordingly, a reduced SO_2 emission rate of 40 kg/hr is assumed, in line with Ravensdown's Air Discharge Strategy,

Given the above, revised results for ambient fluoride, SO_2, fluoride deposition and sulphur deposition are presented in this section. Discharges of $PM_{10}/PM_{2.5}$ and SO_3 are not affected by these changes.

6.3.2 Fluoride

Table 6.12 summarises the model results for the revised modelling of fluoride emissions associated with the new combined Manufacturing stack and lower stack discharge rate, with corresponding contour plots for each averaging period provided in Figure 6.23 to Figure 6.28. In each case the contour plots present the existing and proposed scenario model results. The results show concentrations at the eastern Site boundary are unchanged, which is due to fugitive emissions dominating concentrations at this location. However, to the west of the Site concentrations reduce significantly, especially for locations further afield where application of the 'sensitive land use' criteria is relevant (such as at orchards and vineyards). This reduction is due to the improved dispersion from the combined Manufacturing Plant stack, as well as the lower emission rate (T+T 2020b). For the most impacted sensitive land use location to the east of the site, the reduction in predicted fluoride concentrations varies between 38% and 39% for the 12-hour, 24-hour and 7-day average model predictions. The predicted reduction in 30-day and 90-day average concentrations is smaller at 6.6% and 5.7% respectively, which is expected to reflect model assumptions regarding fugitive emission rates.

The model predictions for the 30-day and 90-day average fluoride concentrations (Figure 6.28) close to the site are largely unchanged from those predicted for the existing site configuration (Figure 6.10). This is a function of the model assumption regarding fugitive emissions, which are the dominant contributing sources close to the site.

Overall, the cumulative model predictions show concentrations below MfE guidelines for fluoride taking into account the relevant land uses. The only exception is a small area over the former Winstone Site and adjoining foreshore to the immediate west of the site.

The technical air quality assessment that accompanied the application for the new combined Manufacturing Plant stack (T+T 2020b) assessed the impacts of the change in stack emissions only (i.e., without taking into account the contribution from fugitive sources) and clearly demonstrates the significant reduction in ambient concentrations from stack emission sources due to enhanced dispersion of combined Manufacturing Plant stack.

Table 6.13: Summary of predicted fluoride GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (μg/m³)	Cumulative off-site GLC (μg/m³)**	Assessment Criteria (μg/m³)
Most impacted off site location	1-hour*	East of site	77	77	240
Most impacted general land use location	12-hour	East of Site	36	36	3.7
	24-hour	East of Site	23	23	2.9
	7-day	East of Site	16	16	1.7
	30-day	West of Site	4.0	4.0	0.84
	90-day	West of Site	3.8	3.8	0.5
Most impacted sensitive land use location	12-hour	Gibson Orchard (A7)	0.85	0.90	1.8
	24-hour	Gibson Orchard (A7)	0.46	0.51	1.5
	7-day	Gibson Orchard (A7)	0.18	0.23	0.8
	30-day	Gibson Orchard (A7)	0.03	0.07	0.4
	90-day	Gibson Orchard (A7)	0.02	0.06	0.25

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)**	Assessment Criteria (µg/m³)
Most impacted residence where exposure is relevant	Annual	Northeast House (C24)	0.05	0.09	13

Notes:

1-hour, 12-hour, 24-hour and 7-day average model predictions are based on the maximum consent emission rate.

30-day and 90 day average model predictions are based on the 75th percentile of measured emission rates.

* Relates to the assessment criteria for human health related to HF.

** Background concentrations in all cases are 0.045 µg/m³ based on analysis provided in Section 5.2.

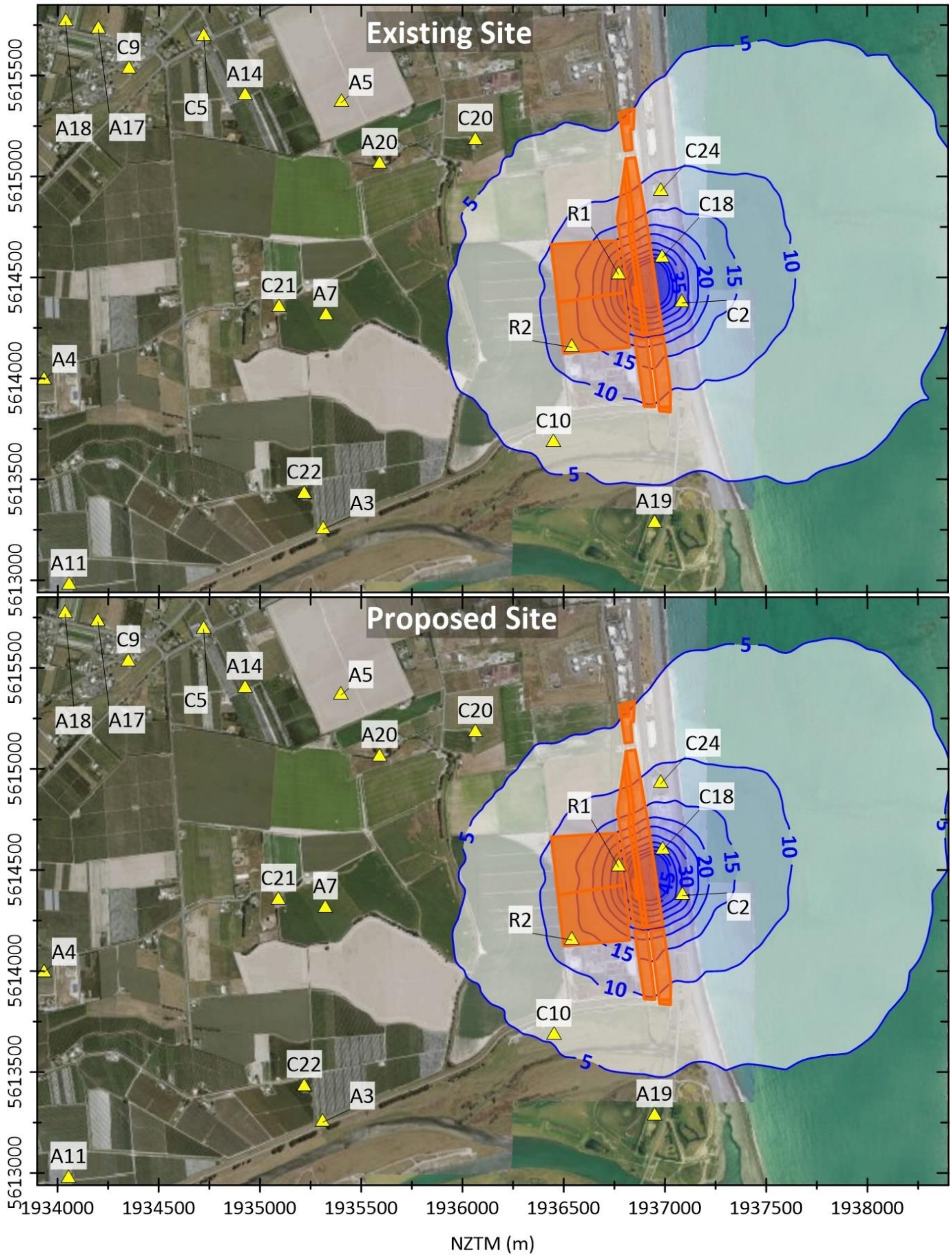

Figure 6.23: Predicted maximum 1-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon.

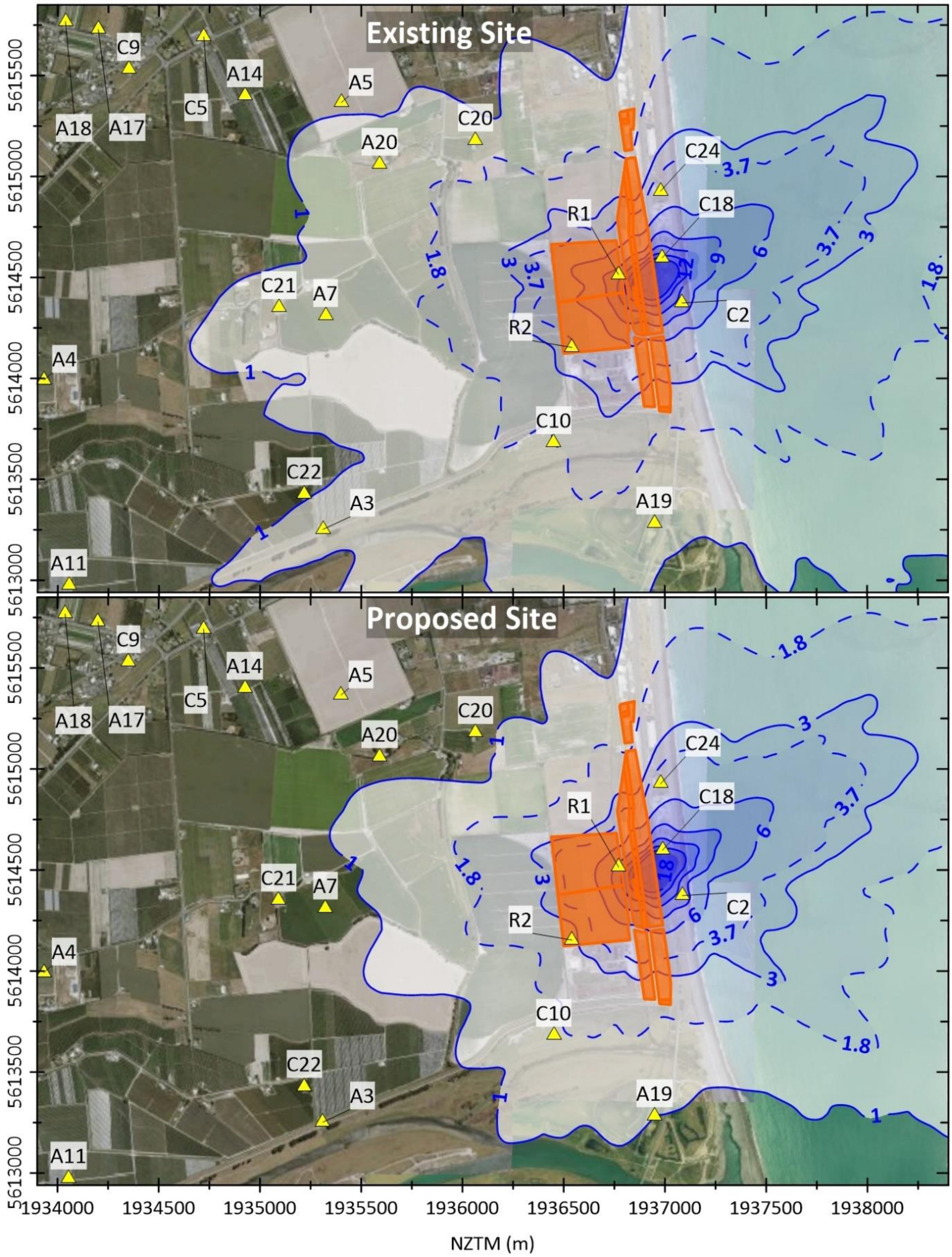

Figure 6.24: Predicted maximum 12-hour average fluoride GLC (µg/m³)– based on peak emission rates. Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

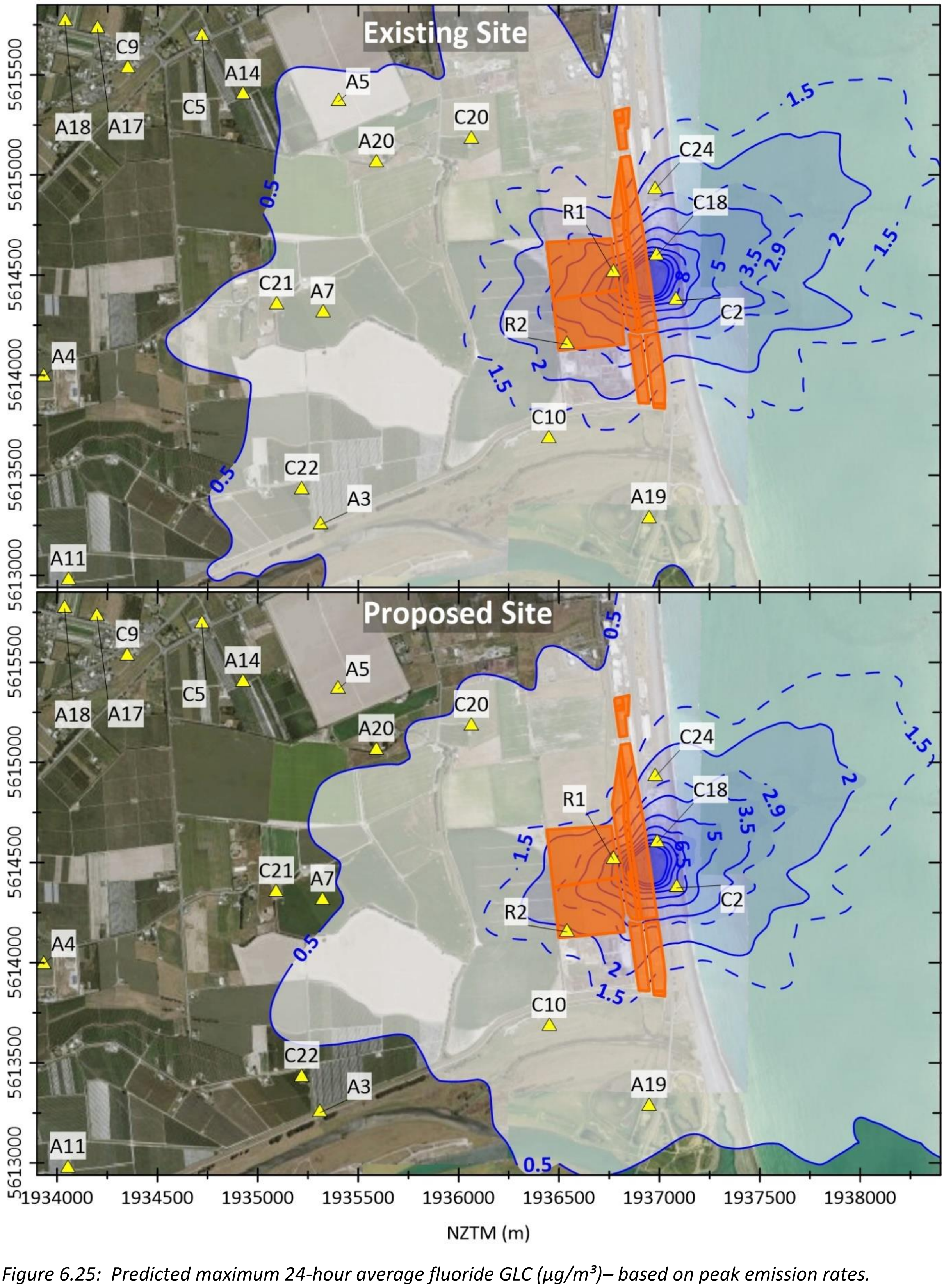

Figure 6.25: Predicted maximum 24-hour average fluoride GLC (µg/m³)– based on peak emission rates. Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

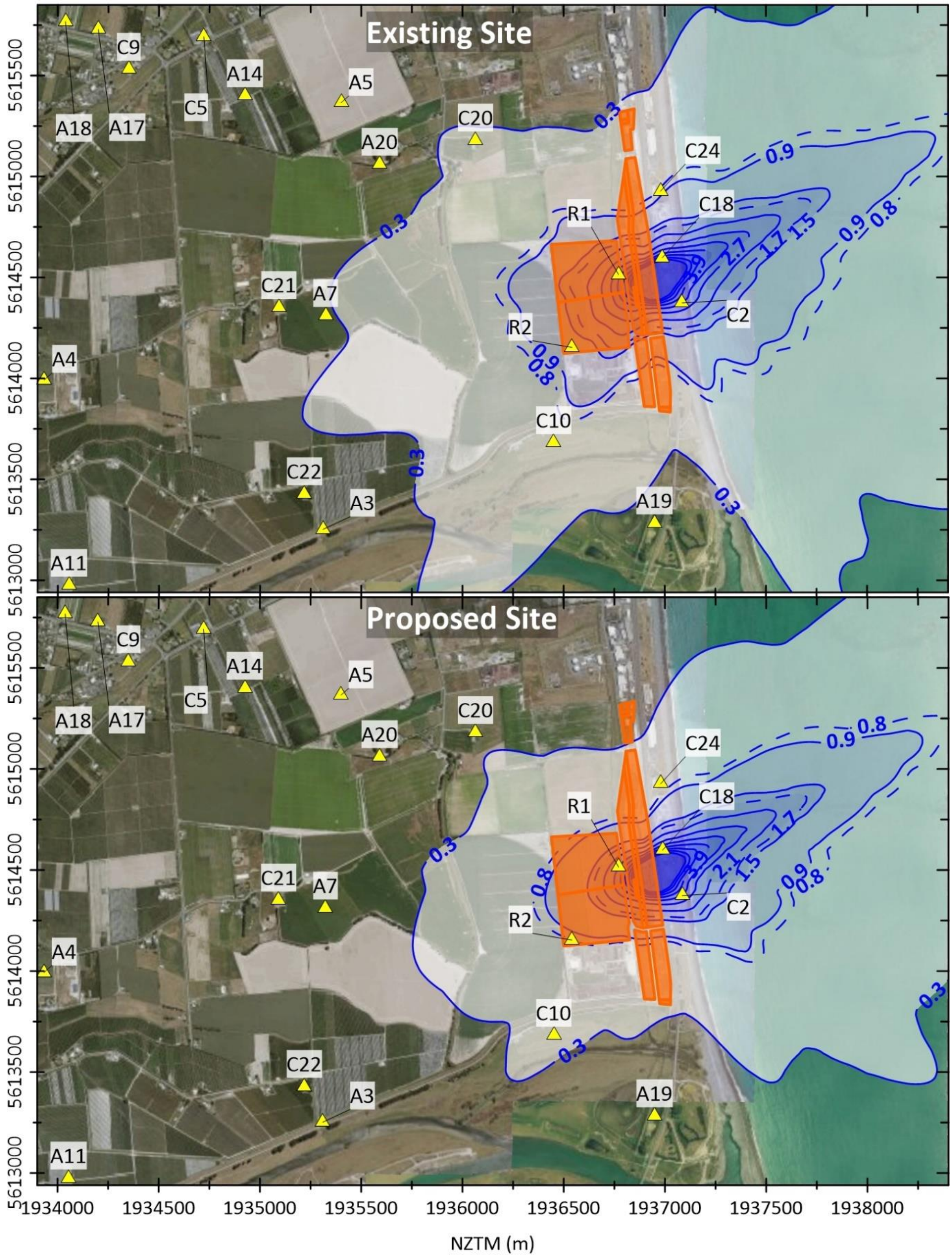

Figure 6.26: Predicted maximum 7-day average fluoride GLC (µg/m³) – based on peak emission rates. Existing (top) and proposed (bottom) site configuration - fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

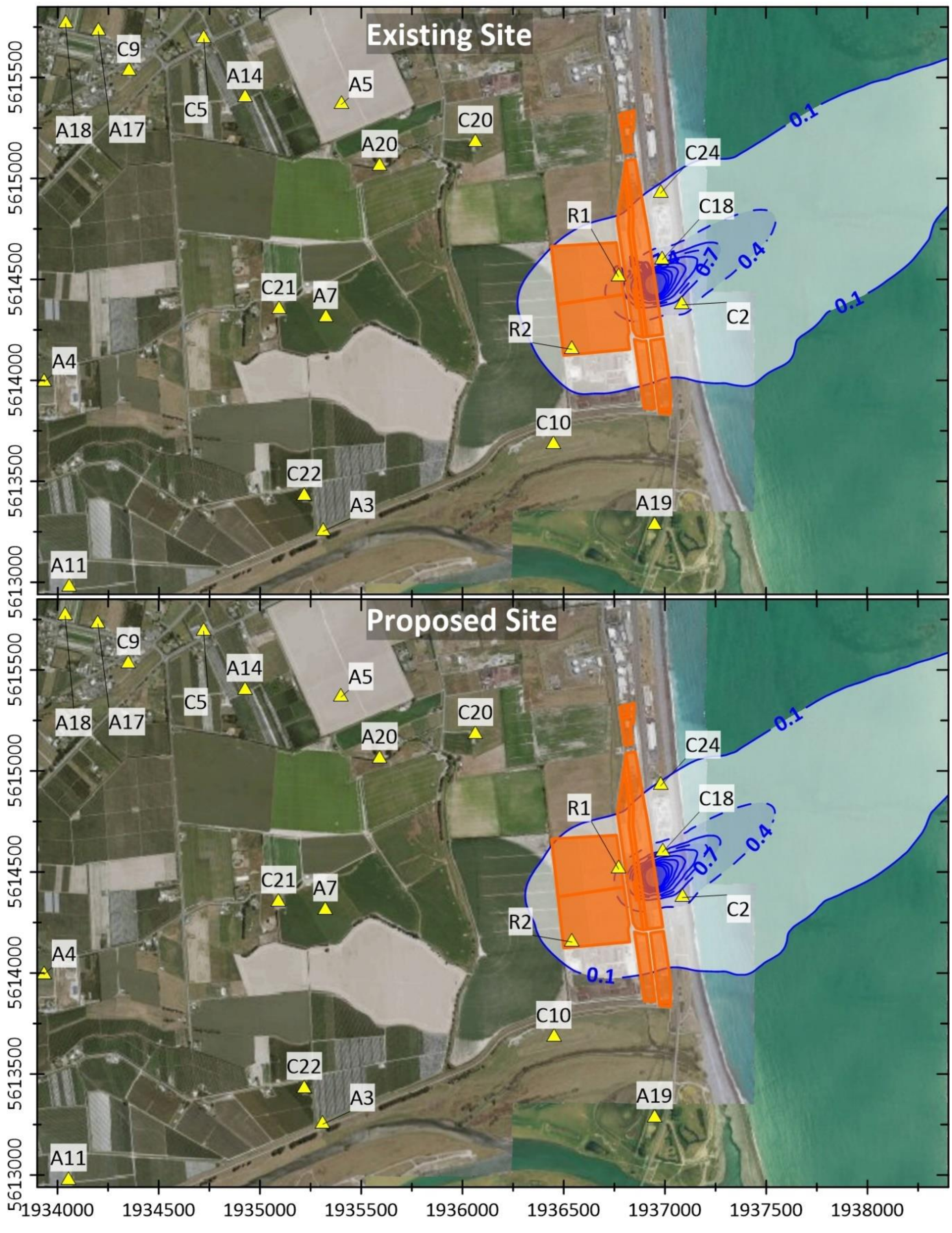

Figure 6.27: Predicted maximum 30-day average fluoride GLC (µg/m³)– based on 75th%ile of measured emission rates. Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

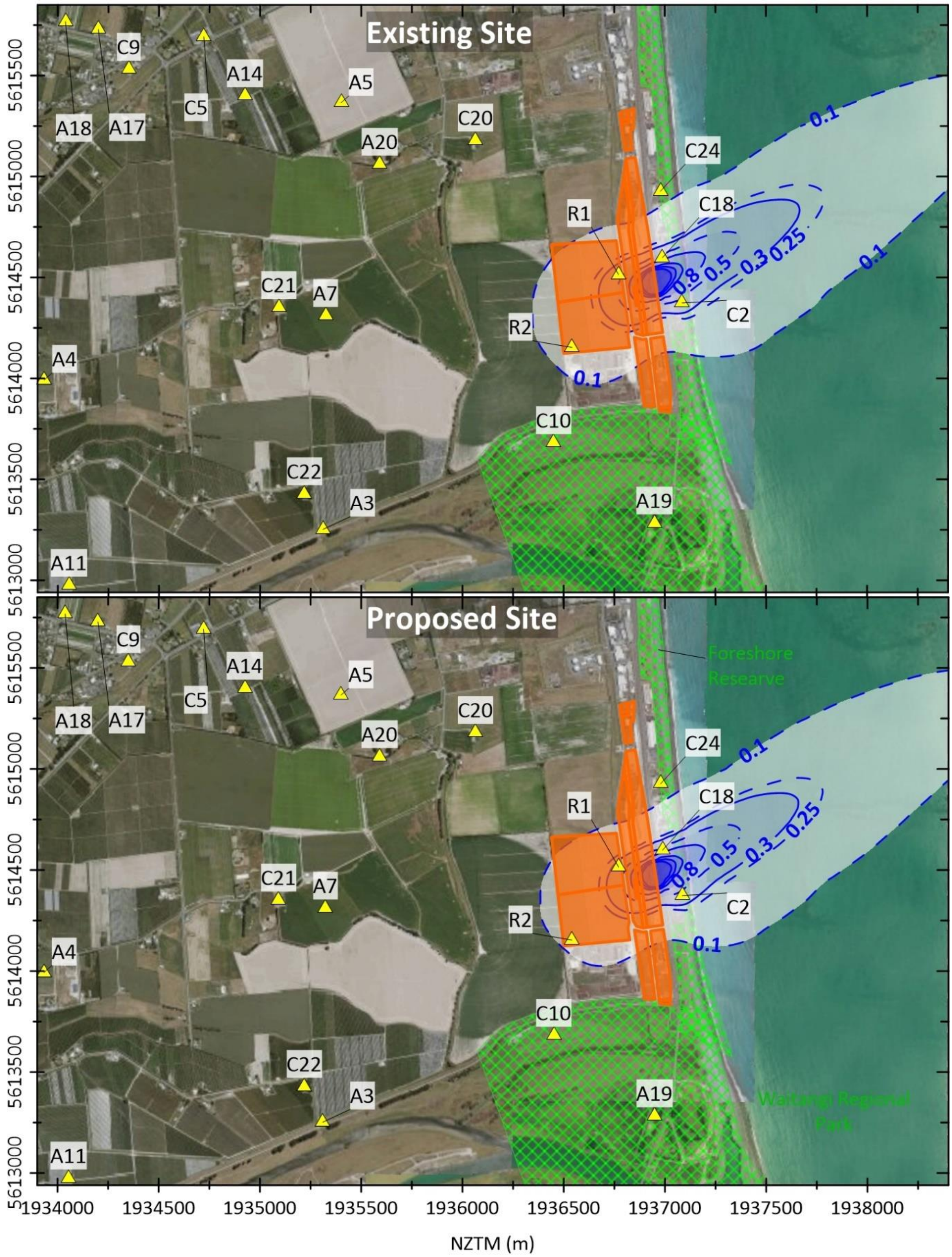

Figure 6.28: Predicted maximum 90-day average fluoride GLC (µg/m³)– based on 75th%ile of measured emission rates. Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values.

6.3.3 Sulphur dioxide

The model-predicted maximum 1-hour, 24-hour and annual average ground level concentrations (GLCs) due to SO_2 emissions from the Ravensdown site (both the Acid Plant with the proposed new converter and to a lesser extent the combined Manufacturing Plant stack) are summarised in Table 6.13. Corresponding contour plots for each time averaging period are provided in Figure 6.29 to Figure 6.31. Contour plots showing the wider model domain are provided in Appendix F. The results show a significant reduction in predicted 1-hour and 24-hour average concentrations due to the lower proposed maximum emission rate of 40 kg/hr for the Acid Plant following the proposed upgrade of the convertor. The predicted reduction in concentration varies with location and averaging period but for the most impacted receptor location (C24), the reduction is 32% for the 1-hour average and 38% for the 24-hour average .

The long-term average emission rate for the Acid Plant was kept the same for this scenario, which is expected by T+T to be conservative. Accordingly, annual average emission rates are only slightly lower, with the small reduction being associated with the improved dispersion associated with the combined Manufacturing Plant stack.

Overall, the predicted concentrations are well within the assessment criteria and therefore the effects from the normal operation of the Acid Plant are assessed as being low, and therefore less than minor.

Table 6.14: Summary of predicted SO_2 GLC compared with assessment criteria

Receptor Type	Averaging period	Location	Model predicted GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location where exposure for the averaging period is relevant	1-hour	West of Acid Plant	230	233 [3]	570 / 350
	24-hour	Residence [C24]	15	18 [3]	120
	Annual**	Waitangi Regional Park	0.64	1.6 [1]	10

* Site discharges plus background. Background concentrations are in square brackets.

** Annual average results relate to vegetation impacts.

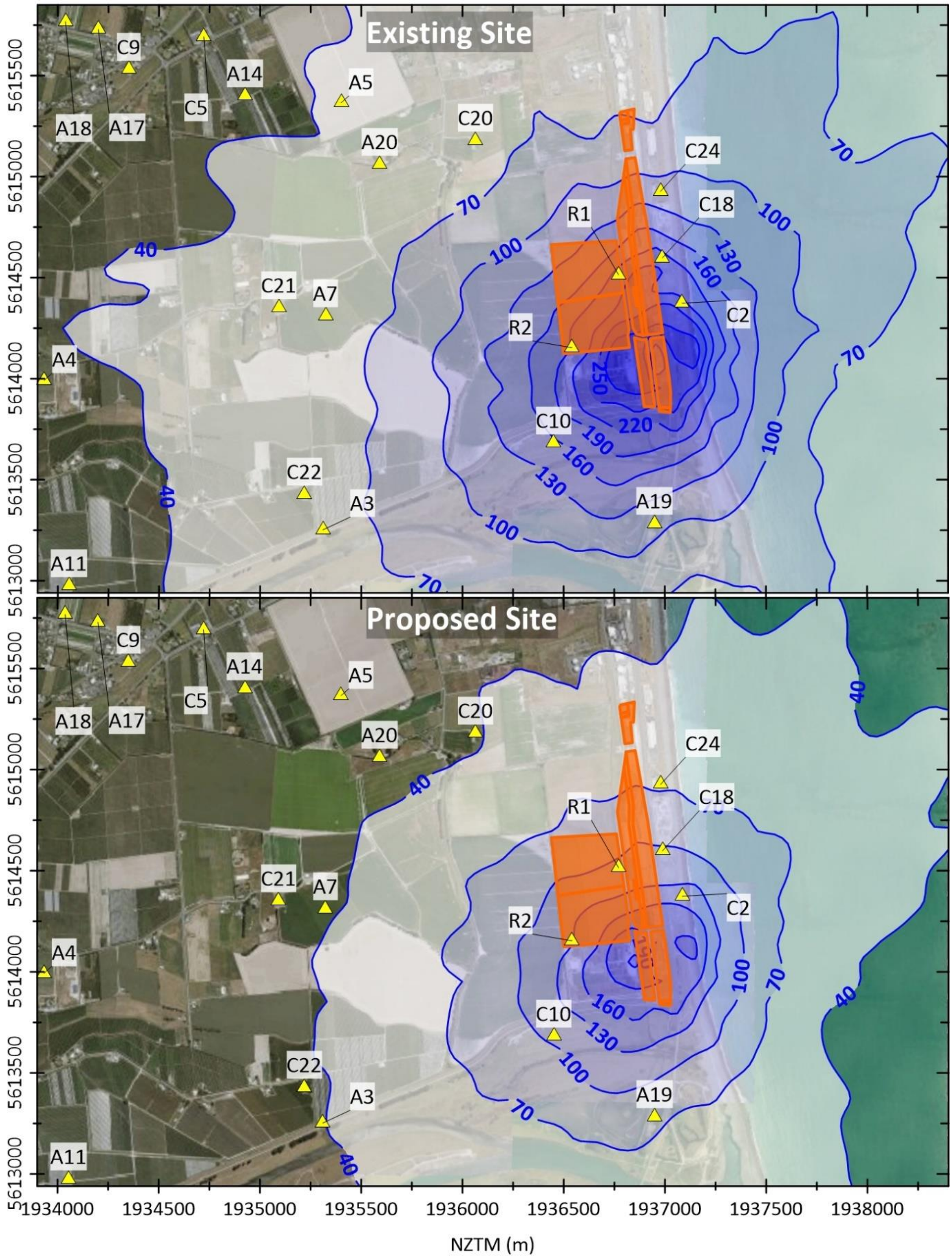

Figure 6.29: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC (µg/m³) – based on peak emission rates. Existing (top) and proposed (bottom) site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon.

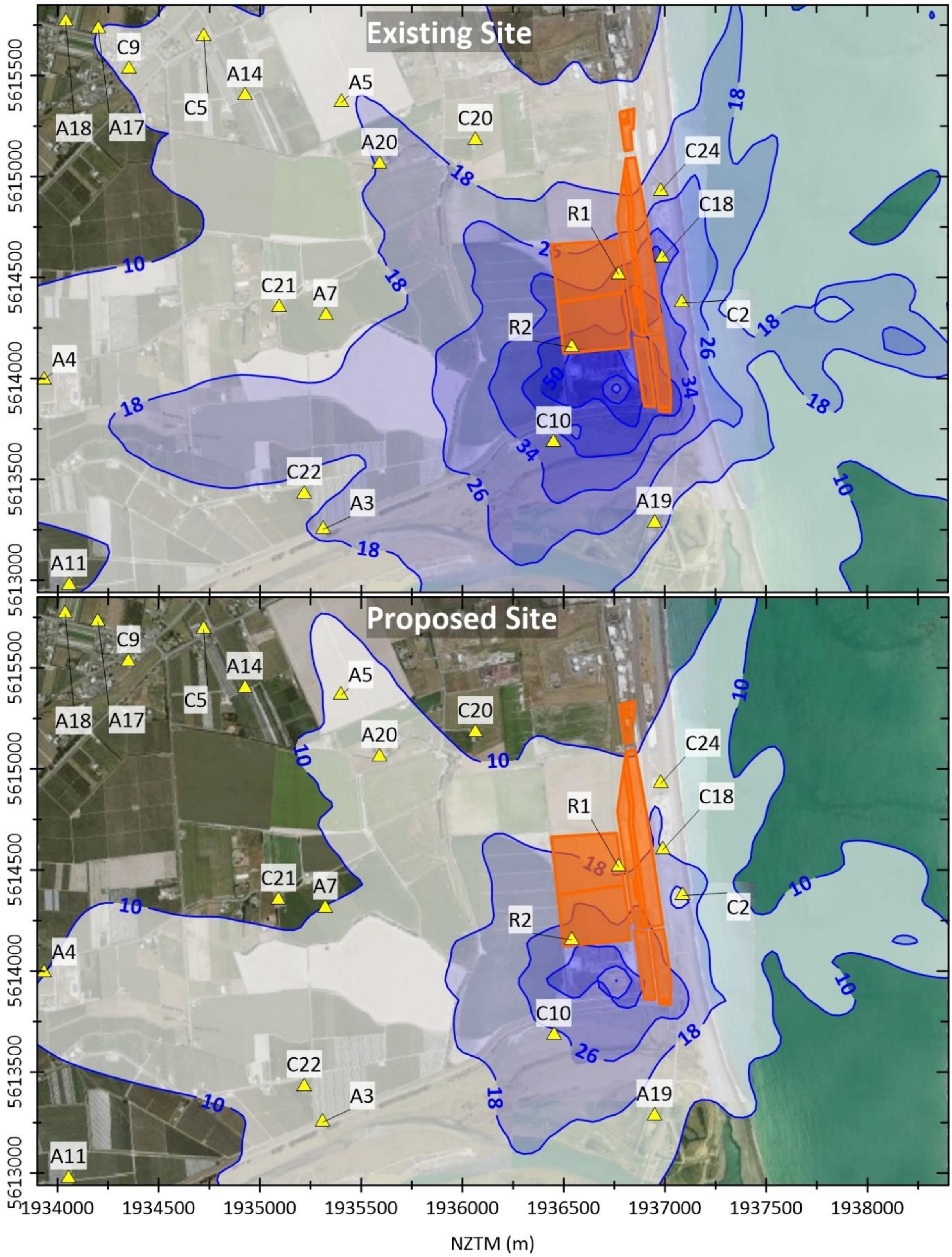

Figure 6.30: Predicted maximum 24-hour average SO_2 GLC (µg/m³) in the immediate surroundings – based on peak emission rates. Existing (top) and proposed (bottom) site configuration - site emissions only.

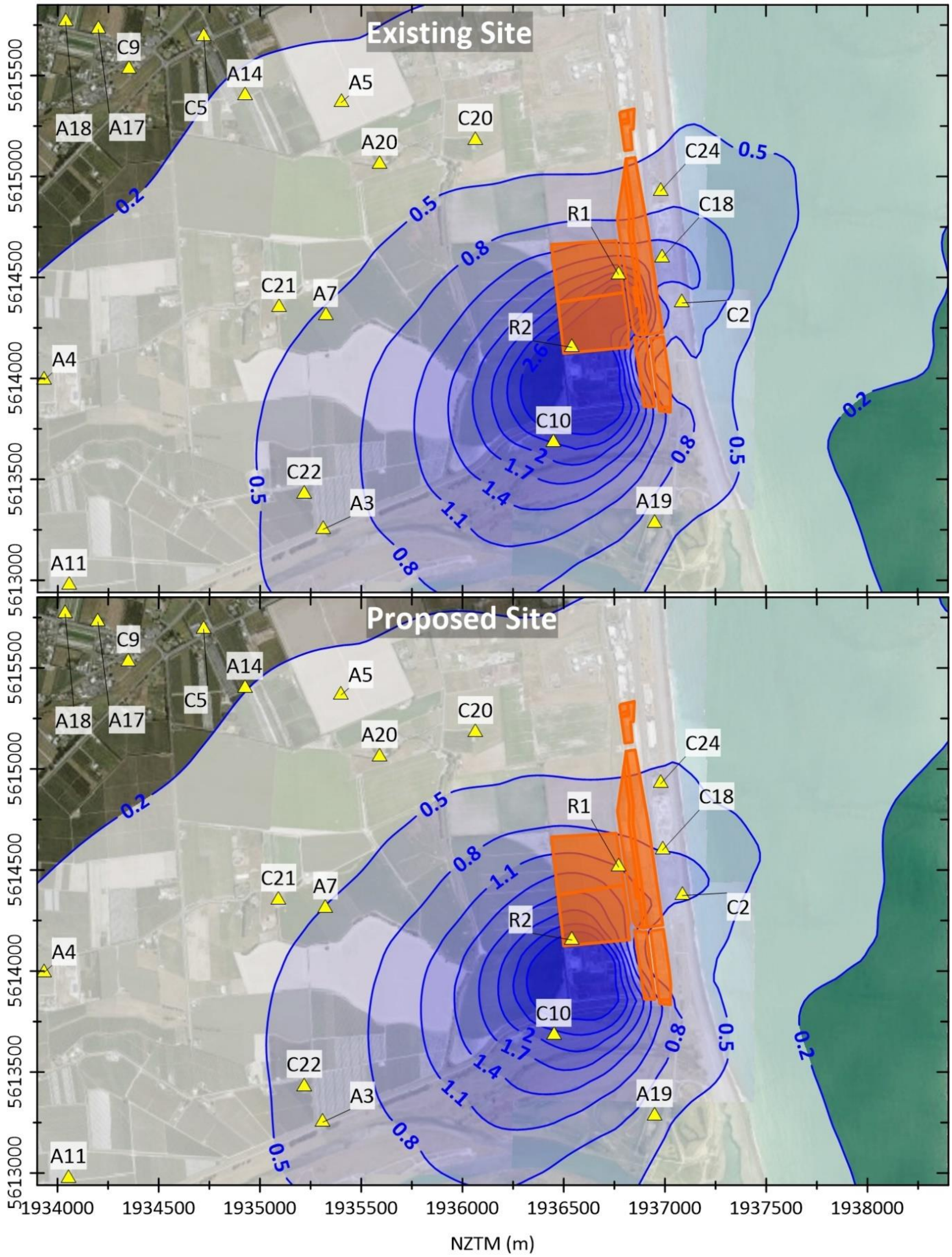

Figure 6.31: Predicted annual average SO_2 GLCs (µg/m³) in immediate surroundings – based on the 75th percentile of stack testing data. Existing (top) and proposed (bottom) site configuration - site emissions only.

6.3.4 Fluoride and sulphur deposition

6.3.4.1 Sulphur deposition

The model-predicted maximum annual off-site total sulphur deposition due to discharges from planned upgrades (Acid Plant converter and combined Manufacturing Plant Stack) are summarised in Table 6.14, with Figure 6.32 providing a contour plot of the results.

The results presented in Table 6.14 are only slightly lower than those presented in Section 6.2.6.1. The relatively small reduction in predicted concentrations is due to the assumption regarding the long term SO_2 emission rate from the Acid Plant, which is unchanged from that assumed for the existing plant. However, in practice, the reduction is expected to be significantly greater than suggested by these model results with the proposed converter replacement.

Table 6.15: Summary of predicted sulphur deposition rates

Receptor Type	Averaging period	Location	Model predicted deposition rate (kg/ha/yr)
Most impacted off-site location	Annual	West of Acid Plant	3.0
Most impacted area of sensitive vegetation receptor	Annual	Waitangi Regional Park	0.37

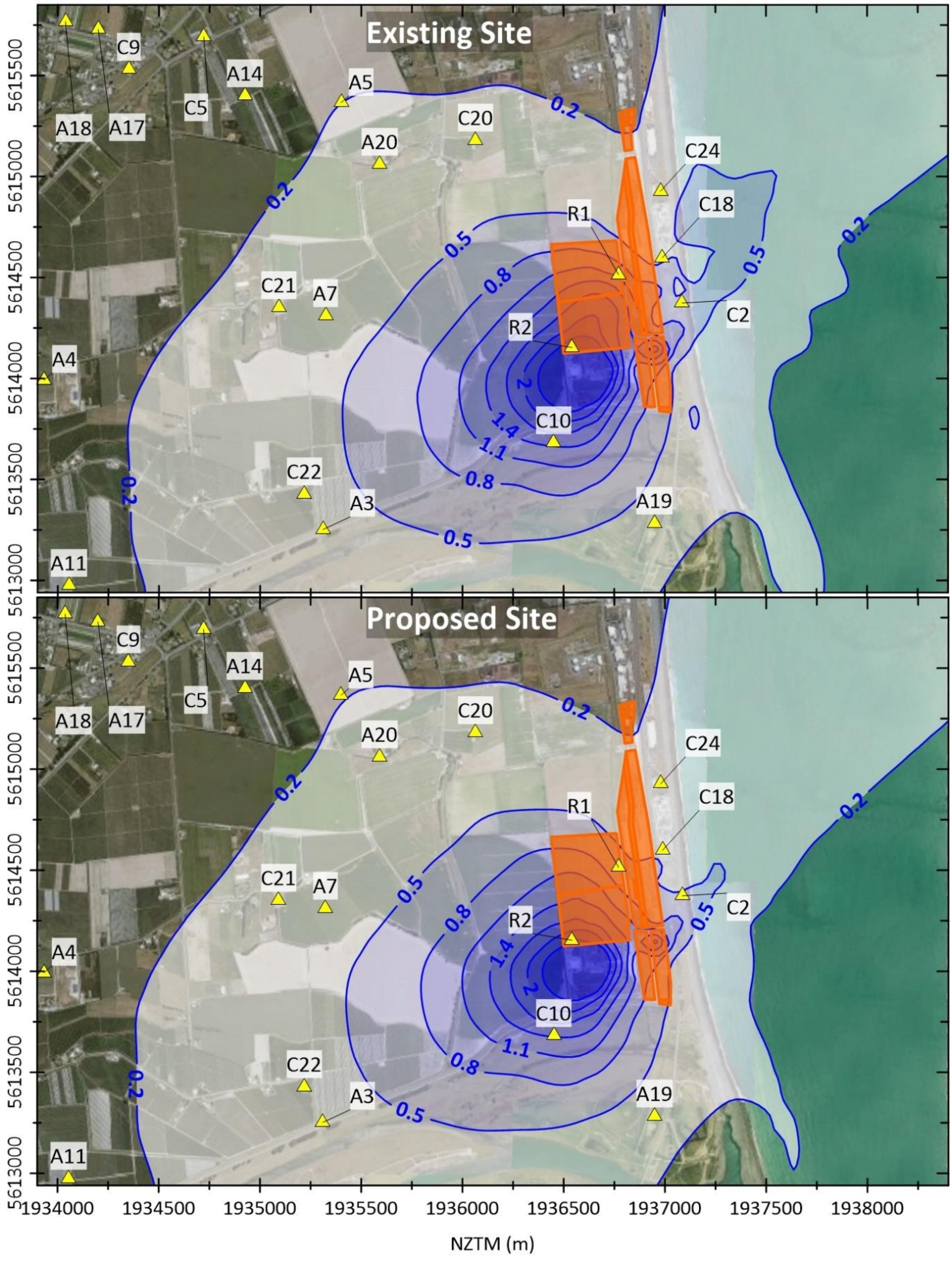

Figure 6.32: Predicted annual total sulphur deposition rate (kg/ha/yr) – based on the 75th percentile of stack testing data. Existing (top) and proposed (bottom) site configuration - site emissions only.

6.3.4.2 Fluoride deposition

Table 6.15 summarises the predicted fluoride deposition rates from the combined Manufacturing Plant stack. Contour plots for the 1-hour and 24-hour are presented as Figure 6.33 and Figure 6.34.

The results for the most impacted location (immediate east of the site) are largely unchanged due to impacts at this location being driven by fugitive emissions. However, the deposition rates at the most impacted sensitive agricultural receptors are significantly reduced as a result of the better dispersion and reduced emission rate associated with the upgraded plant and stack.

Table 6.16: Summary of predicted fluoride deposition rates

Receptor Type	Averaging period	Location	Model predicted deposition rate
Most impacted off-site location	1-hour* (kg/ha/hr)	East of Site	0.004
	Annual (kg/ha/yr)	East of Site	1.0
Most impacted sensitive agricultural receptor*	1-hour * (kg/ha/hr)	Wells Orchard (A20)	0.0002
	Annual (kg/ha/yr)	Gibson Orchard (A7)	0.013

* Maximum predicted 1-hour averaged values are derived from the 99.9th percentile model predictions as discussed in Section 6.1.1.

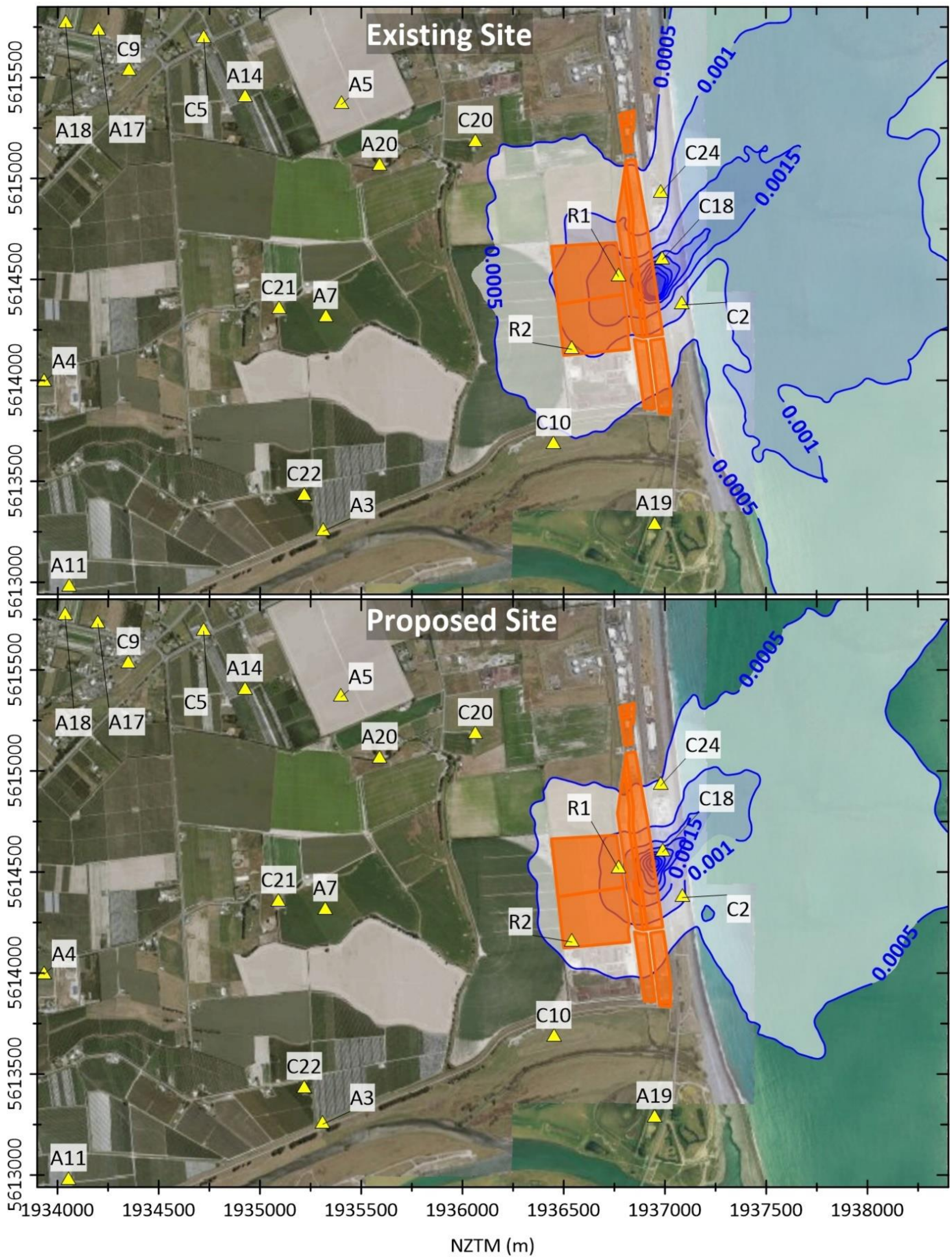

Figure 6.33: Predicted maximum 1-hour fluoride deposition (kg/ha/hr). Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon.

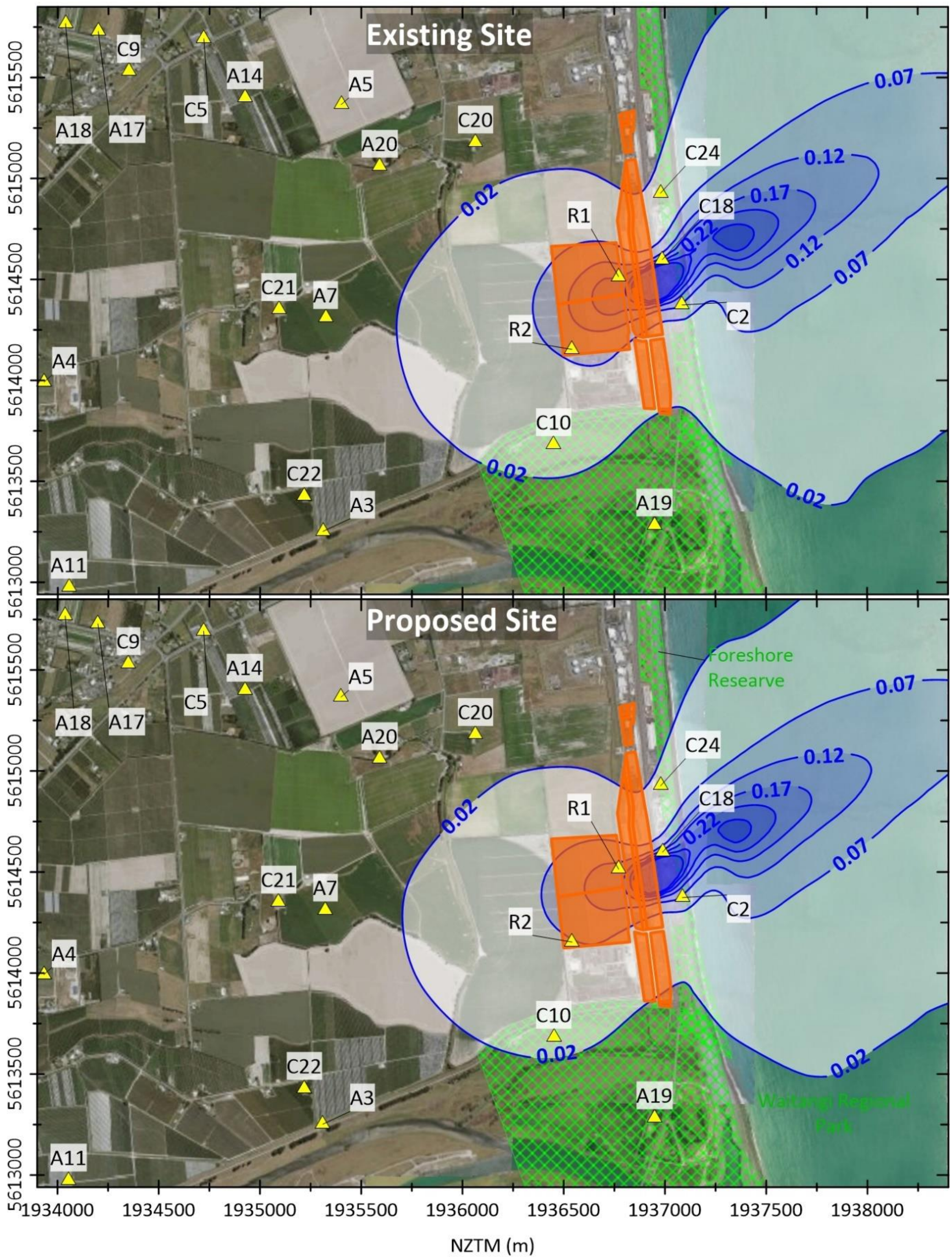

Figure 6.34: Predicted maximum annual fluoride deposition (kg/ha/yr). Existing (top) and proposed (bottom) site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon.

6.4 Model performance

The performance of the dispersion model has been evaluated against SO_2 measurements made at the Winstone monitoring site to the east of the site. SO_2 was used for model performance verification as Ravensdown is the dominant emission source in the area.

Dispersion models seldom replicate observed concentrations on an hour-by-hour basis. However, a useful means of evaluating model performance is to compare concentrations on a percentile basis for each dataset and to plot those against each other. This has been done for both the time-period that covers the modelled meteorological dataset (2015 and 2016) and with the wider monitoring dataset from 2015 to 2021.

In undertaking the analysis for the Winstone site we have excluded data for the peak monitoring events that have been attributed by Ravensdown to abnormal or start-up conditions associated with the Acid Plant as such events are not accounted for in the dispersion modelling assessment. These events are discussed in Section 5.2.

The percentile plot comparison of modelled versus observed hourly average SO_2 concentrations is presented in Figure 6.35. Model results include the assumed background concentration of 10 $\mu g/m^3$. This plot shows that the model robustly predicts maximum 1-hour average concentration. However, as expected, the dispersion model over-predicts the concentrations most of the time, due to the model being configured to discharge continuously at the maximum emission rate.

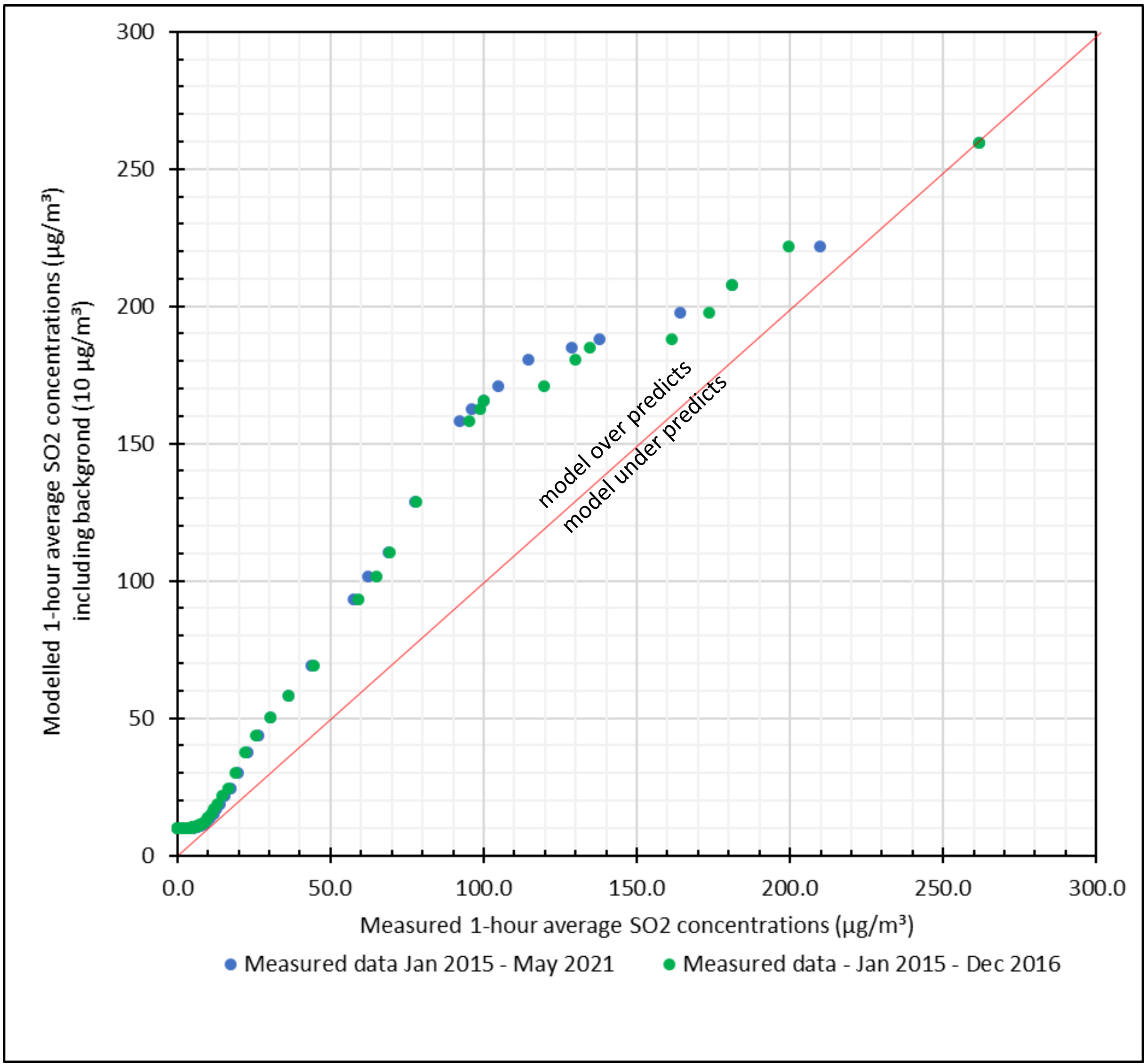

Figure 6.35: Relationship between monitored concentrations and measured concentrations of 1-hour SO_2.

7 Assessment of effects – odour and dust

7.1 Methodology

Odour and dust effects associated with the Ravensdown Napier Works have been assessed using qualitative assessment tools in a manner consistent with the MfE's 'Good Practice Guide for Assessment and Managing Odour' (MfE 2016b) and the 'Good Practice Guide for Assessing and Managing Dust (MfE 2016c). The assessment approach in both instances recognises the generally low level of historic complaints relating to odour and dust effects, as well as the site's industrial/rural location that help to maximise the separation to locations that are sensitive to odour and/or dust impacts.

The assessment of both dust and odour involves a review of historic complaint records, followed by an initial screening evaluation using separation distance guidelines and an evaluation based on the FIDOL factors, which are set out 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 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/dust 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 /dust relates to both the character of odour and the degree of how pleasant or unpleasant the odour is (i.e., the hedonic tone); and
- 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.

The FIDOL assessment is informed by a review of exposure of sensitive locations to certain wind conditions 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.

7.2 Summary of incidents/complaints

A total of 17 complaints relating to air quality have been made since the current consent was granted in 2007.[19] These complaints are summarised in Figure 7.1. Of these complaints:

- 8 related to odour;
- 4 related to dust;
- 2 related to crop damage; and
- 4 related to steam/fume/visible emissions

In T+T's experience this is a low level of complaint for an industrial facility of the scale of the Ravensdown Napier Works and reflects its appropriate location in an industrial/rural environment located away from sensitive receptors.

[19] The record of complaints is consolidated from those recorded by both Ravensdown and by HBRC.

Further consideration of odour and dust effects are provided in the following sections. Analysis of the complaint relating to crop damage is addressed in the report by Plant & Food Research.

The 'other' complaints relate to the following and are considered isolated incidents:

- An incident reported by Ravensdown relating to a fluorosilicic acid leak (May 2018);
- An incident reported by Ravensdown relating to a fire in sulphur store (December 2016);
- A report of visible scrubber fumes from the Winstone site (September 2010); and
- An unspecified complaint relating to steam and vapour across road from the site (May 2010)

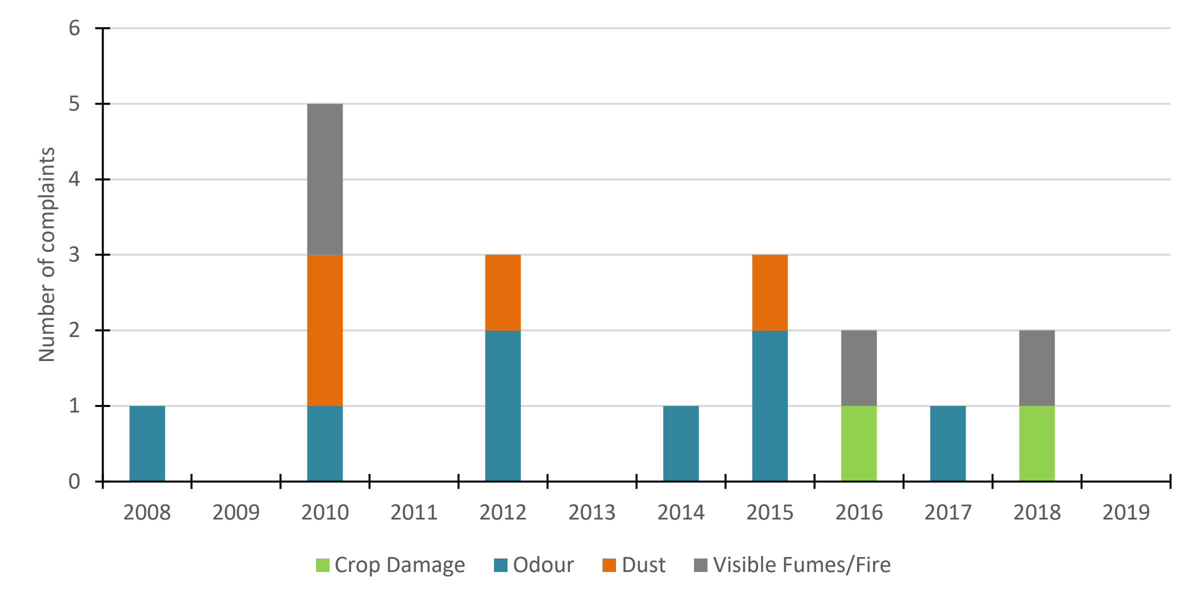

Figure 7.1: Summary of air quality related complaints by type since 2008.

7.3 Separation distances

Separation distance guidelines are published by the Environmental Protection Authority (EPA) West Australia, South Australia, and Victoria, and are routinely used in New Zealand in the absence of similar local guidance. Together, the three guidance documents provide a variety of recommended separation distances that may be applicable to the Ravensdown site activities (Table 7.1).

The principal of using separation distances is derived from the fact that air contaminants decrease in concentration with increasing distance from a source. In this regard, the MfE (2016b) states that:

> *"…the EPA Victoria guidelines (and other similar guidance) are generic. Most of the separation distance guidelines are based on the protection of amenity values at sensitive locations. They do not generally consider risk, or potential health effects. It is also important to note that they do not take into account site specific factors which may influence discharge rates and how they are dispersed (e.g., the specific processes and emission controls used on site). They are also applied in all directions and so do not take into account the effects of local topography and meteorology."*
>
> *"Separation distance guidelines are not intended to be used as a pass/fail test, rather as a trigger for more detailed assessment to determine the appropriate separation distance for a particular site".*

Given the above context, the separation distance criteria are applied as a screening tool to help identify locations where a more detailed FIDOL assessment can assist with assessing odour and dust effects.

Table 7.1: Relevant separation distance guidelines for odour and dust associated with Ravensdown Napier Works

Source	Description of activity	Recommended separation distance
EPA West Australia (2005)	Production of sulphuric acid	2,000 – 3,000 m
EPA South Australia (2016)	Crushing, grinding, or milling of rock, ores, or minerals	500
EPA Victoria (2013)	Production of inorganic fertiliser, >2,000 tonnes per annum	1,000 m

The WA EPA (2005) separation distance for sulphuric acid production is considered by T+T to be excessive for potential dust and odour impacts. However, we note that it is intended to apply to gaseous emissions (SO_2 and SO_3) in addition to odour and dust emissions. Given this context, we have not used the WA EPA values and have instead used the EPA South Australia and EPA Victoria guidelines which are only focused on odour and dust amenity impacts.

The closest residential home (locations with a high sensitivity to odour and dust impacts) in each of the cardinal (north, south, east, and west) and intercardinal (north-east, south-east, north-west, and south-west) directions are identified in Figure 7.2. Of note is that there are no residential homes in the north-east, east, and south-east direction (ocean). In most directions, the distance from the residences to the centre of the site is at least 1,000 m. In the context of the EPA Victoria (2013) separation distance guideline of 1,000 m, this suggest that the site is suitably located to minimise potential impacts of odour and dust effects. This is with the exception of a cluster of five houses located in the Industrial Zone approximately 400 m to the north-northeast of the Manufacturing Plant.

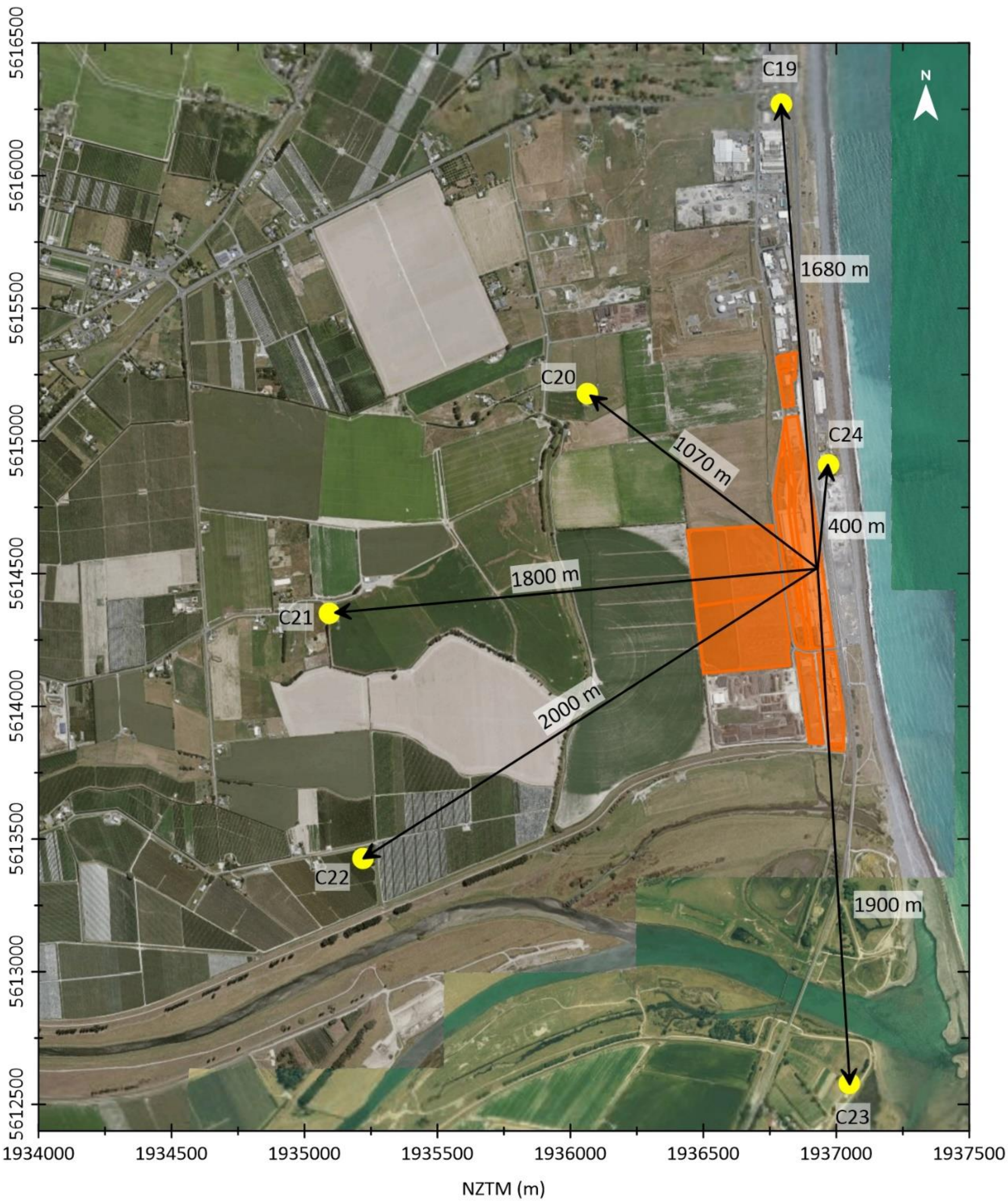

Figure 7.2: Separation distances from the nearest sensitive receptors to the Ravensdown site.

7.4 Dust

7.4.1 FIDOL assessment

Dust emissions are associated with several activities at the Ravensdown site. These are principally associated with the handling of raw materials (phosphate rock and to a lesser extent sulphur) and the manufactured superphosphate. Emissions are largely minimised through the receipt, storage and dispatch of these materials from within covered storage buildings (see Figure 2.10). Dust emissions may occur during periods of strong winds when dusty material within the storage buildings is entrained and transported outside the building through openings. Consequently, it is the occurrence of strong winds, particularly during dry weather, that is the key focus for dust emissions and subsequent impacts.

Table 7.2 provides a discussion of the FIDOL factors in relation to potential dust effects.

Table 7.2: FIDOL evaluation for dust effects

Frequency	The frequency of dust effects depends on (a) the frequency that emissions occur and (b) the frequency of wind conditions that can cause and/or transport material towards a sensitive location. Outside periods of strong winds, dust emissions due to the receipt, handling and dispatch of materials and product are expected to be localised within the storage building housing the materials. Given this, any significant dust generation is likely to be associated with strong winds (> 7 m/s as an hourly average) when wind erosion and any significant draft conditions through buildings may occur. Figure 7.3 provides a wind rose depicting the frequency of strong winds (> 7 m/s) generated from measurements made on site. This indicates that the most prevalent strong winds are those from the northeast (onshore winds). The nearest sensitive locations downwind under these winds (i.e., to the southwest of the site) are located at a significant distance from the site as shown in Figure 7.2. By contrast, strong winds from the southeast that blow towards the nearest sensitive location to the northwest are relatively infrequent (less than 1% of the time).
Intensity	The intensity of dust impacts depends on the amount of dust generated at source and the separation distance between a source and a sensitive location. Typically, coarse aggregate dust drops out of suspension within approximately 100 m of a source, and separation distances typically associated with aggregate handling activities are in the order of 250 m of a source. The nearest receptor with a high sensitivity to dust impacts (rural residence) is located approximately 1,000 m away from the main sources of dust (e.g., rock stores, super stores, and Manufacturing Plant). At this distance, the intensity of dust effects is expected to be negligible.
Duration	The duration of dust discharges will largely be linked to the frequency and duration of wind conditions that give rise to dust emissions (i.e., strong dry winds). It will also be linked to the period when rock shipments are received at the site.
Offensiveness / character	The offensiveness of the dust generated from Ravensdown site activities relates to its characteristics in relation to visibly soiled surfaces. The raw phosphate rock is inert and has a grey/brown appearance not dissimilar to local aggregate and soil in the wider receiving environment. By contrast, sulphur used in the manufacture of sulphuric acid is bright yellow. However, the sulphur is pelletised and therefore not expected to be an appreciable source of dust. The finished superphosphate product is a light grey colour. The material is produced in a granular form, but may still generate some dust through its handling. Overall, the dust that may be generated onsite is considered to have a neutral to slightly unpleasant character.
Location	Land use surrounding the site is a mix of industrial, rural, and rural residential. Unoccupied rural land (excluding rural residences) is considered to have a low sensitivity to potential dust impacts as rural land can be a significant source of dust on occasions and there is a generally low amenity expectation accordingly. The immediate surrounding industrial zone includes the Winstone gravel yard and the Bio-Rich composting facilities. Both facilities are potentially significant

	sources of dust in their own right and are considered to have a low sensitivity to dust impacts. While the foreshore reserve (located beyond the Winstone site) is potentially sensitive, persons will be present for short periods of time. Furthermore, the foreshore reserve runs parallel to the industrial area of the Awatoto and is therefore likely to have a lower amenity expectation. In contrast to the above, rural residences have a high amenity expectation and are considered to have a high sensitivity to potential dust impacts.

On balance given the above FIDOL factors, it is considered that there is a low potential for offensive or objectionable dust effects to occur as a result of discharges from the Ravensdown site. This largely reflects:

- The large separation to the nearest receptors with a high sensitivity to dust impacts;
- That immediate surrounding activities have a low sensitivity or are an appreciable source of dust in their own right;
- That dust discharges are minimised by materials being handled and stored under cover within buildings and storage sheds; and
- That any significant dust discharges are only likely to occur under strong wind conditions that are relatively infrequent.

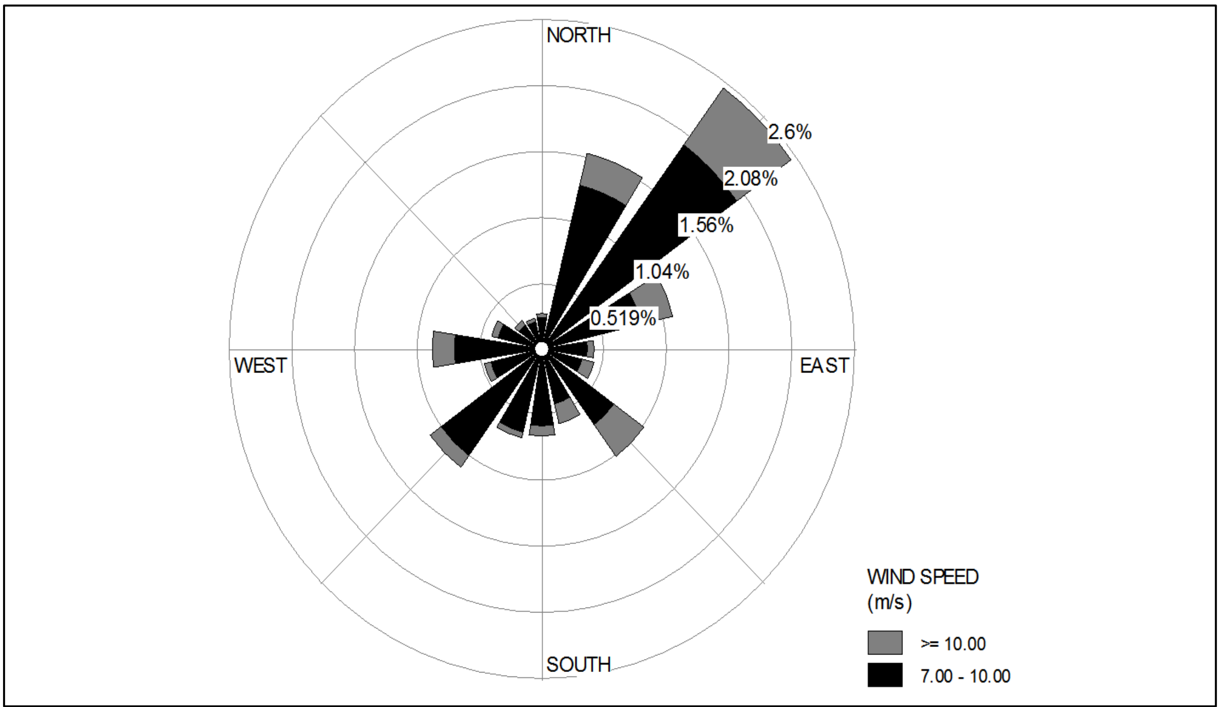

Figure 7.3: Wind rose showing strong winds (> 7 m/s) for the Ravensdown Napier Works, generated from site data for the years 2015 – 2016 (same as the CALMET data set).

7.4.2 Dust related complaints history

The low potential for offensive or objectionable dust effects assessed using the FIDOL approach aligns well with the small number of complaints that have been received in relation to the Ravensdown site: four complaints since 2005, which are described in Table 7.2.

Table 7.2 sets out the nature of each of the four complaints and circumstances associated with each. Notably, none of the four complaints relate to locations considered to have a high sensitivity to dust impacts.

The most recent complaint was received in 2015 from a member of the public walking along Marine Parade. Public roads are generally considered to have low sensitivity to dust impacts. This is on the basis of roads having a low amenity expectation given the industrial/rural nature of the surrounding environment and that persons are unlikely to be present at a given location for any significant duration.

Notwithstanding the above, the four complaints all related to isolated incidents, with actions or measures implemented that minimise the likelihood of future events of a similar nature.

Table 7.3: Detail on complaints relating to dust.

Year	Number of complaints	Detail
2010	2	The first complaint was received in May, regarding visible dust emissions coming from the site. Traced back to the intake of phosphate rock and the intake baghouse (rock shed 1-4) was reactivated following this complaint. The second complaint was received in December, regarding the deposition of white flakes on cars. Lab testing confirmed that the flakes were mostly silica based and was traced back to the start-up of the Manufacturing Plant after a shut-down period. Procedures are now in place regarding cleaning protocols associated with the stack prior to the plant starting up.
2012	1	Complaint was regarding the deposition of dust on vehicles. A sample was collected, and lab testing confirmed the dust deposits were Boucraa rock, which was being loaded into the unroofed rock store #3. Rock store #3 has since been roofed.
2015	1	A member of the public was walking down Marine Parade and noted trucks driving with no cover on. Airborne dust caused irritation of eyes. Trucks transporting material are now required to have covers fitted. This complaint does not strictly relate to discharges from the Site.

7.5 Odour

7.5.1 FIDOL assessment

As described in Section 3.2.4 odour emissions are primarily derived from:

- The handling and melting of sulphur, which can give rise to H_2S with a ‘rotten egg’ odour; and
- An intrinsic low level ‘fertiliser’ odour associated with the manufactured superphosphate fertiliser.

H_2S is also an odour that can be associated with a number of other activities close to the Ravensdown site, include the Hawke’s Bay Protein (rendering) plant to the north and the Bio-Rich Compost facility located immediately west of the Acid Plant. Section 5.5 provides a summary of H_2S ambient monitoring undertaken by Ravensdown and this analysis indicated that the compost facility has been a key source of high concentrations of H_2S.

Table 7.4 provides a discussion of the FIDOL factors in relation to potential odour effects.

Table 7.4: FIDOL evaluation of odour effects

Frequency	The frequency of odour impacts depends on the frequency of emissions from a source and the frequency of time a receptor is downwind of that source. In terms of odour, light wind or near to calm conditions give rise to poor dispersion conditions and the highest potential for off-site odour impacts. Emission sources are likely to be continuous or semi-continuous. Figure 7.4 presents a wind rose highlighting relatively light winds (those being less than 5 m/s). This shows the following: • Light winds are predominantly from the southwest, which would carry odours across the State Highway, over Winstone site and out to sea; • Light onshore winds (i.e., from the northeast) are relatively infrequent, but would have the potential to transport odours across the Bio-Rich site and inland towards the surrounding rural land. In this direction the nearest sensitive residence is approximately 2 km from the site; • Light winds from the north and south are very infrequent, thereby minimising the frequency of exposure for sensitive activities downwind in those directions; and • Light winds blowing towards the nearest sensitive residences (C24) are infrequent (about 3% per year).
Intensity	The intensity of odour impacts depends on the strength of an odour source but also the separation distance between the source and a receptor. Observations made by T+T staff around the site are that the intensity of odour sources is generally weak to distinct. When combined with the significant distance to the vast majority of sensitive receptor (greater than 1 km), odour intensity will be negligible. However, for the nearest residences at receptor location C24, distances are much shorter (in the order of 400 m from the Manufacturing Plant). At this distance odour associated with the site may be apparent on occasions.
Duration	The duration of odour discharges will largely be linked to the frequency and duration of wind conditions that give rise to odour emissions (i.e., low winds and calm conditions).
Offensiveness/character	Odour associated with superphosphate has a characteristic acid/chemical smell that is considered to be slightly unpleasant. Odours associated with H_2S have a very unpleasant ‘rotten egg’ character. However, sources of H_2S (i.e., the sulphur melter) are a significant distance from the nearest residences at receptor C24.
Location	As described for dust, land use surrounding the site is a mix of industrial, rural, and rural residential. Unoccupied rural land (excluding rural residences) is considered to have a low sensitivity to potential odour impacts as rural land can be a source of odour on occasions and there is a generally low amenity expectation accordingly. The immediate surrounding industrial zone includes the Winstone gravel yard and the Bio-Rich composting facilities. The Bio-Rich composting facility is a source of odour and H_2S. While the foreshore reserve (located beyond the Winstone site) and the Waitangi Reserve are potentially sensitive, persons will be present for short periods of time. Furthermore, the foreshore reserve runs parallel to the industrial area of the Awatoto and is therefore likely to have a lower amenity expectation. By contrast to the above, rural residences have a high amenity expectation and are considered to have a high sensitivity to potential odour impacts. The

	residences at the location of receptor C24 are also assessed as having a high sensitivity.

On balance given the above FIDOL factors, it is considered that there is a low potential for offensive or objectionable odour effects to occur as a result of discharges from the Ravensdown site. This largely reflects:

- The large separation to the nearest receptors with a high sensitivity to odour impacts, with the exception of the residence at receptor location C24;
- That immediate surrounding activities have a low sensitivity or are an appreciable source of odour in their own right;
- Light wind conditions with the greatest potential worst-case odour impacts due to poor dispersion are typically from the southwest and would transport odours out to sea away from sensitive locations (including receptor C24); and
- Onshore light winds (from the northeast) are much less frequent and in this direction the separation distance to nearest sensitive location inland from the site is significant (about 2 km).

The findings of the above FIDOL assessment are consistent with the low level of complaints that have historically been received (discussed below in Section 7.5.2).

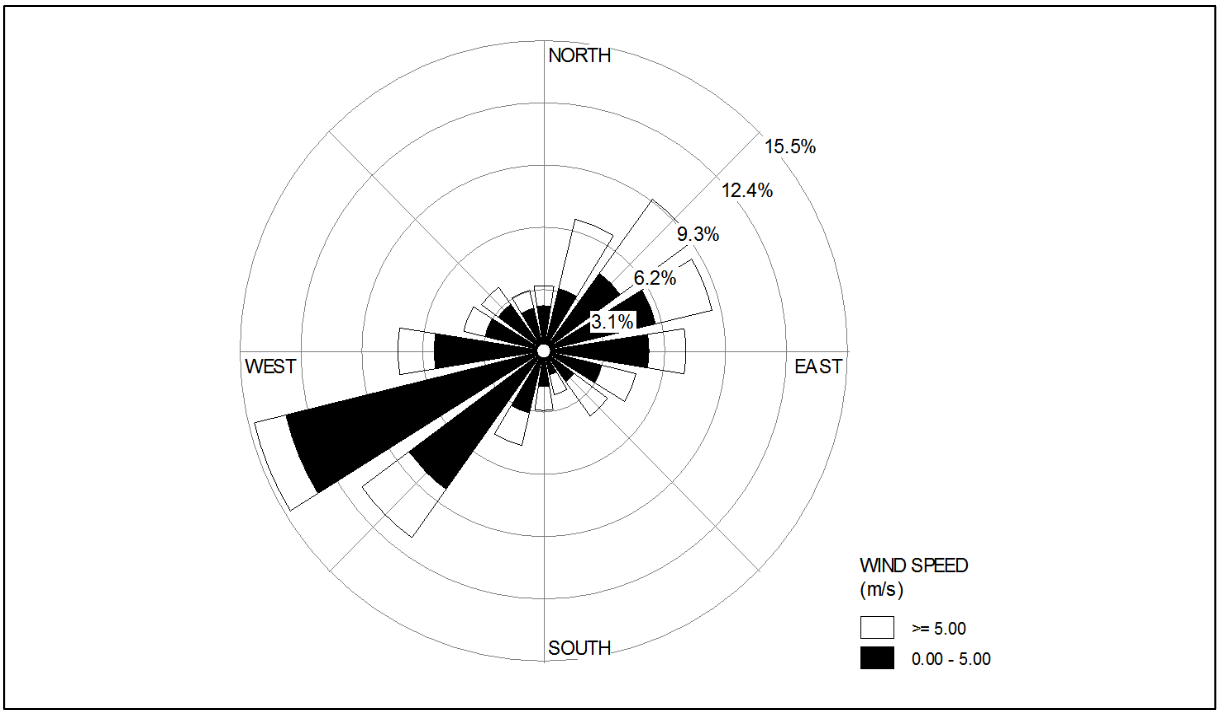

Figure 7.4: Wind rose showing light winds (< 5 m/s) for the Ravensdown Napier Works, generated from site data for the years 2015 – 2016 (same as the CALMET data set).

7.5.2 Odour related complaint history

Table 7.5 summarises the complaints relating to the site that concern odour. As with those for dust, the number of historic complaints is small, and is considered to reflect the appropriate location of the site.

A number of the complaints relate to odour detected when driving past the site. As with dust, it is considered that the low sensitivity of the location (being immediately adjacent to the site), combined with the very short duration of impact means that the complaint ordinarily would not be deemed as offensive (given the FIDOL factors). A number of other complaints were unable to be attributed to the site due to the wind being from the wrong direction or the plant not operating.

The incident in 2014 was related to a cold start of the Acid Plant. Changes to both the shut-down and start-up procedures for the plant have now meant that odour emissions are more appropriately minimised and the likelihood of such events in the future will be minimised.

Table 7.5: Detail on complaints relating to odour

Year	Number of complaints	Detail
2008	1	Complaint was made in April from a resident about a 'strong smell of fertiliser'. On-site weather data was reviewed and did not line up with complaint, wind was going in the opposite direction to the complaint location.
2010	1	A complaint was made in February regarding the detection of a 'strong acid smell' when driving past the Site. HBRC visited Ravensdown and noted that the Acid Plant was not operating and had been shut down since December. However, a reasonably strong smell of superphosphate was detected from the batching plant, wind was a light northwesterly.
2012	2	Two complaints received in March regarding a 'strong odour/strong acidic odour'. Manufacturing and Acid Plant operating without issues. In both cases, the wind was blowing in the right direction. However, when HBRC investigated no odour was detected at the complaint location.
2014	1	A strong chemical/fertiliser odour was detected when driving past the works, with arm and face burning 2-3 mins later and development of a rash on arm. HBRC followed up with Ravensdown which determined that the Ravensdown had done a cold start of the Acid Plant that day and some sulphur was leaching from brick work. Wind was strong in the northern quadrant.
2015	2	Two complaints made from public regarding odour from site when going past the works. First complaint was received in March and referred to a 'offensive chemical odour' which could also be detected from Hohepa Homes. Winds were northerly at the time, investigation by HBRC suggested that odours were coming from Bio-Rich Compost.
2017	1	Complaint made to HBRC regarding strong sulphur smell at residence property. No incidents were reported on site.

8 Assessment of effects - window etching

Etching of windows can occur where there is prolonged and frequent exposure of glass surfaces to sufficiently high concentrations of fluoride. T+T is not aware of any published thresholds or guideline values relating to ambient concentrations of fluoride that are associated with this effect.

Notwithstanding the above, a report prepared for Ravensdown by BRANZ Pty Ltd (BRANZ 2004) in relation to its Ravensbourne manufacturing site in Dunedin investigated the 'clouding' of window glass at a number of houses near to that site. A 'marker pen' test was derived that used chisel point marker or spirit pens to investigate the effect of drawing the pen across the glass. Clouding of the glass was typically associated with a "2" rating – the glass giving 'moderate resistance to the marker pen, with some noise or screeching of the pen'. The study generally concluded that clouding of the windows was apparent for properties out to a distance of about 1 km from the Manufacturing Plant stacks. This is illustrated in Figure 8.1, which provides an analysis by T+T of the BRANZ data for 'marker pen ratings', indicating levels were below Marker Pen Rating 2 beyond 1.2 km.

The Ravensbourne data relates to the historic impacts of the operation of that site at time when fluoride emissions were less controlled. The BRANZ report includes a figure from dispersion modelling undertaken by Aurora Pacific indicating predicted fluoride concentrations over the residential area where clouding of glass was observed to be in the order of 0.2 to 0.4 $\mu g/m^3$ (annual average). However, the BRANZ report explains that the contour plot of predicted annual average fluoride predictions provided by Aurora Pacific were based on *"projected emissions once the scrubber was installed and the cooling ponds were controlled or decommissioned".* This relates to the installation of a Hygiene Scrubber, which was installed in 2003. As such, it likely that historic conditions that gave rise to the etching/cloudiness of windows in the residential area were the result of much higher concentrations than described above.

In the context of Ravensdown's Napier Works, there are only five houses within 1 km of the Manufacturing Plant (the cluster of houses at Receptor location C24 as shown in Figure 4.2).

Notwithstanding the above, fluoride emissions from the Awatoto site are comparatively well controlled. This is evident in the predicted fluoride concentrations associated with the existing site operation presented in Section 5.2, as well as the predicted concentrations presented in Section 6.2.2. Most notably, the predicted 90-day average concentrations for the existing site (Section 6.2.2) are lower than the annual average concentrations predicted by Aurora Pacific for the Ravensbourne site.

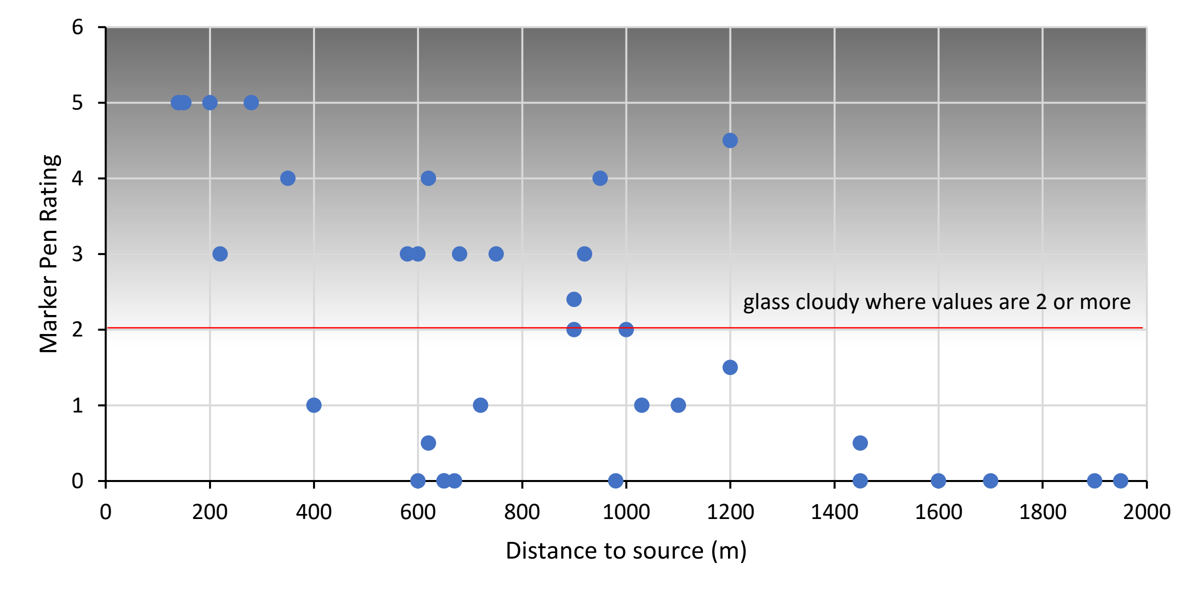

Figure 8.1: Marker Pen Rating for cloudiness relative to distance from the source, Ravensbourne. (Source: BRANZ).

Condition 61 of Ravensdown's existing air discharge permit for the Napier site requires:

> *"… a survey of the effects of fluoride etching on all properties (where the owner accepts the offer of a survey) within 1 km of the site using the methodology outlined in the BRANZ report DCZ059 (25 June 2004). Any windows found to be affected to 'pen test level 3' of where Light Gloss Units (LGU) are equal or less than 115 as described in BRANZ report DCZ059, shall be replaced by the consent holder if the property owner wishes the glass to be replaced."*

The monitoring required by this condition has been undertaken by WSP (formerly Opus). Recent results indicate that etching of window glass has occurred but has not been extensive:

- November 2015: No requests were received by those invited to take part in glass monitoring;
- December 2017: Glass monitoring was requested by one party (residence), located at 88 McLeods Road, which is located approximately 1.2 km west-northwest of the Den Scrubber stacks. This identified the need for replacement of certain windows associated with this property; and
- December 2019: Glass monitoring was requested by one party (industrial site), located at 70 Waitangi Road, which is located approximately 900 m north of the Den Scrubber stacks. The survey found that no glass replacement was required.

Regarding the cluster of houses at Receptor location C24, Ravensdown commissioned BRANZ to undertake a survey of these properties in 2013 (BRANZ 2014). The conclusions reached by BRANZ were that deposits on the glass of the main house and Flat 3 at this occasion were considered predominantly from other sources. This was based on the chemistry of the deposits and that the deposits were *"less adherent than those that can be more readily linked to Ravensdown Awatoto Works emissions"*. This finding is consistent with the dispersion modelling results presented in this report that show Receptor location C24 is not significantly impacted by fluoride emissions due to prevailing wind conditions.

In conclusion, the potential ongoing effects of window etching are expected to be less than minor given the following considerations:

- The BRANZ report suggests that window etching is unlikely to occur at locations greater than approximately 1 km from the Manufacturing Plant. There are only three residences and several industrial sites located within this distance. Regarding the three closest residences, prevailing winds and modelling indicate they are only impacted to a small degree. This is supported by the inspections carried out by BRANZ, which suggested that accumulated material on the windows was unlikely to be related to the site discharges;
- There is a single residence located approximately 1.2 km from the Awatoto site's Den scrubbers where it has previously been recommended that window glass be replaced for that residence; and
- The new Manufacturing Plant stack is expected to reduce off-site fluoride concentrations, particularly at locations not immediately adjacent to the site.

9 Mitigation and monitoring

9.1 Mitigation

As described in Section 2, fluoride emissions are primarily controlled using water scrubbing technology that recovers fluoride and allows this to be recycled to the manufacturing process. Accordingly, maintaining the effectiveness of the existing scrubber systems is of key importance to minimising adverse effects and this is achieved with the following:

- Continuing to control the fluoride emission rate from the existing stacks to be no more than 1.5 kg/hr . This emission rate will reduce to 1.0 kg/hr following the installation of the Den Scrubber, with discharges via a new combined Manufacturing stack;
- Maintaining system maintenance programme for the Hygiene and Den Scrubbers. In this regard Ravensdown is installing a new scrubber system to replace the Den Scrubber, with updated controls, monitoring and improved effectiveness. The new system will also replace open sump void towers with enclosed units, assisting with minimising fugitive emissions;
- Controlling recycled/spent scrubbing liquors to a maximum dissolved fluoride content of 22 wt% via monitoring and process control. The purpose of this is to avoid occurrences of high scrubber liquor fluoride which reduces the effectiveness of the scrubber systems; and
- Maintaining the monitoring frequency at twice a week with tests being separated by 3 to 4 days and with changing week-days for testing.

Additionally, Ravensdown undertakes the following monitoring in relation to the Den Scrubber system to minimise the likelihood of Den extraction failure events:

- An opacity sensor above the mixer shuts the plant down should an excess of fume be detected above the mixer (the primary point of gas escape during a Den extraction failure); and
- Vacuum pressure-sensors in the ducting between the mixer and the scrubber detect a change in vacuum pressure which might indicate a blockage and shut the mixer plant down.

SO_2 emissions during normal operation are minimised through the double absorption system of the Acid Plant, which achieves a very high recovery of SO_2 for the production of H_2SO_4 and is considered current 'best practice'. The impacts of residual SO_2 emissions are further minimised by discharging through a tall stack (i.e., 55 m).

Peak ambient concentrations resulting from the Acid Plant are principally associated with short, and infrequent, periods when the plant starts-up and shuts-down.

Adverse effects are minimised through the following measures, which mainly relate to the start-up and shut-down procedures for the plant, which can give rise to high ambient concentrations of SO_2. Measures used to minimise emissions currently include the following:

- Since November 2016, a significantly slower and longer start-up procedure has been adopted. Ravensdown advises that this reduced the SO_2 concentration and temperatures during start-up;
- The procedure for shutting down the Acid Plant has also been updated, whereby the plant is allowed to cool more gradually, allowing for residual sulphur in the burner to be burnt off and converted to H_2SO_4. This in turn minimises SO_2 emissions during start-up as there is less residual sulphur in the burner; and
- In August 2018 an 18 m 'start-up' stack was installed on the Acid Plant. This extended the height of the previous 3 m 'temporary stack' to improve the dispersion of emissions for ambient SO_2 during the heating up phase.

Ravensdown advises that the recent changes to the start-up and shut-down procedures (described above) have resulted in a significant reduction in measured SO_2 concentrations during start-up, with continuous in-stack measurements reducing from 2,000 ppm to 20 ppm during start-up in 2020. The replacement of the furnace in 2015 used Steuler brick that enables a faster heat-up rate, allowing a short duration of potential SO_2 emissions associated with the start-up process.

With regard to the sulphur melter, Ravensdown has engaged an independent review of the melter fire suppression system. It is also progressing with plans for the replacement of the melter, working with international suppliers regarding industry best practice.

Dust emissions are minimised through the following measures:

- Storing of raw materials and manufactured product within bulk storage buildings . The existing consent (Conditions 6 to 13) provide for the storage of phosphate rock outdoors under certain circumstances, but these provisions have not been used to date;
- The use of dust suppression measures during the outside handling of bulk materials (e.g., phosphate rock);
- Not undertaking the handling of bulk materials outside when the wind speed is greater than 5 m/s; and
- Regular sweeping of the site to minimise the build-up of dust material outside of bulk storage buildings.

The main sources of odour emissions and the controls to minimise them are:

- The main source of odour associated with the Manufacturing Plant is an acidic/rotten cabbage type odour originating from the scrubbers. The effects of this will be minimised with the increased height of the new Manufacturing Plant stack (50 m) that replaces the three previous stacks associated with the plant – i.e., the previous two Den Scrubber stacks and the Hygiene Scrubber stack. The increased height provides better overall dispersion of emissions (including odour); and
- The second source of odour is that associated with the acid manufacturing and the melting of sulphur. At other sites around the country, emissions from the melting of sulphur are often extracted and controlled using a biofilter or scrubber system. However, this has not been adopted at the Napier site given the historic low level of complaints and significant separation distances to neighbours, which results in their being a low potential for objectionable or offensive odour effects. It is also noted that while the sulphur melter is an appreciable source of H_2S odours, the neighbouring Bio-Rich compost facility results in measured concentrations of H_2S that are much greater. Notwithstanding this, chemical inhibitors are used to treat the raw sulphur that minimises the formation of H_2S on-board ships during the transport of sulphur to the site.

9.2 Monitoring

Ravensdown currently undertakes a range of in-stack and ambient monitoring. These are summarised as follows.

Routine stack emission measurements currently undertaken are listed below. The suite of contaminants and frequency of testing is considered by T+T to be appropriate, except where a change is recommended in the following list.

- TSP emissions from the Bradley Mills. It is recommended that future testing be for PM_{10} and $PM_{2.5}$ emissions;
- Fluoride emissions and the pH of the discharge from the Manufacturing Plant stack; and

- SO_2, SO_3 and acid mist emissions from the Acid Plant Stack.

Ambient monitoring in relation to discharges from the Ravensdown site is listed below. Ravensdown is currently in the process of reviewing these requirements, particularly the ongoing suitability of particular monitoring locations:

- Ambient fluoride (7-day average) at five sites;
- Continuous measurement of PM_{10} at the Winstone site. The ongoing suitability of this site is currently being reviewed;
- Continuous measurement of SO_2 at the Winstone site (off-site) and Archimedes site (on-site). The ongoing suitability of these sites is currently being reviewed; and
- Routine measurement of H_2S at the Archimedes site. The suitability of this location is being reviewed, especially given the impact it experiences from the Bio-Rich composting facility.

Additionally, the site measures meteorological parameters, including wind speed and direction at two on site locations (Acid Plant and Archimedes site). The two are located very close to one another and provide for a degree of redundancy should one site cease operating. The monitoring data from these sites assist with various on-site decisions regarding activities, including loading and unloading of bulk materials and operation of the Acid Plant and Manufacturing Plant.

10 Conclusions

This air quality assessment has been prepared on behalf of Ravensdown Limited to accompany a resource consent application to the Hawke's Bay Regional Council (HBRC) for a resource consent authorising the continued discharges of contaminants into air from the Ravensdown's Napier Works.

The discharges to air from the site include fluoride and acid mist from the Manufacturing Plant, sulphur dioxide (SO_2) and acid mist from the Acid Plant, PM_{10} and $PM_{2.5}$ from the Bradley Mills, odour (including hydrogen sulphide from the acid melter), and dust from raw material and product handling.

The potential air quality effects of the discharges include those on human health (SO_2, PM_{10} and $PM_{2.5}$), impacts on vegetation (fluoride, SO_2 and acid mist), and amenity impacts (odour and dust).

With regard to effects on vegetation, this assessment provides an evaluation of predicted fluoride and SO_2 concentration against ambient air quality guidelines for sensitive ecosystems and the results are used to further inform a separate assessment by The New Zealand Institute for Plant & Food Research Limited. Notwithstanding this, the predicted concentrations are well within the relevant MfE guidelines for the protection of sensitive ecosystems with the exception of land to the immediate east of the site (former Winstone site and foreshore). Further consideration of vegetation effects is provided by Plant and The New Zealand Institute for Plant and Food Research Limited.

Dispersion modelling has shown that the planned new Manufacturing Plant stack and proposed reduction in fluoride emission will lead to a reduction in fluoride ground level concentrations compared with the previous plant configuration (i.e., the Den Scrubber system discharging via two separate stacks and the Hygiene Scrubber via its own stack). A detailed comparison of the effect of this change in stack configuration is provided in Appendix C.

Predicted SO_2 concentrations from the normal operation of the site are well within the relevant assessment criteria for human health and vegetation impacts and the potential effects are considered to be low. Concentrations are expected to reduce further as a result the replacement of the Acid Plant converter.

Isolated events have occurred where high concentrations of SO_2 have been measured off-site at the Winstone monitoring site. These events have historically been associated with start-up of the Acid Plant, although more recently fires associated with the sulphur melter also resulted in high concentrations. Ravensdown has implemented changes to the Acid Plant start-up procedures to reduce SO_2 emissions and has increased the height of the start-up stack from 3 m to 18 m to improve dispersion of those emissions – no monitoring exceedences at the Winstone site have been attributed to start-up conditions since this time. Notwithstanding this, Ravensdown continues to investigate measures to minimise emissions associated with start-up conditions and has implemented measures to minimise the likelihood of a melter fire occurring in future.

Given the above, T+T considers the adverse effects associated with the discharge of SO_2 from the site is low, and effects will reduce further with the proposed convertor replacement. On this basis we consider the potential SO_2 effects to be less than minor.

For PM_{10} and $PM_{2.5}$, relatively high concentrations are predicted for the location immediately east of the Bradley mills (i.e., the Winstone site). The model predictions are broadly consistent with the measured PM_{10} concentrations at the Winstone monitoring site. However, exposure over a 24-hour period is not reasonably expected to occur at this location given the industrial nature of the site. At the most impacted location where human exposure is relevant, the sites contribution to predicted cumulative concentrations is very low (2 $\mu g/m^3$). However, the cumulative concentration is predicted to reach the NES_{AQ} for PM_{10} of 50 µg/m³. On this basis the effects of PM_{10} and $PM_{2.5}$ emissions are considered to be no more than minor.

A qualitative FIDOL assessment has been made regarding the potential odour and dust nuisance effects. The findings of these assessments concluded that there is low potential for offensive or objectionable odour effects to occur as a result of discharges from the Ravensdown site, which is consistent with the record of dust and odour complaints (few complaints). Accordingly, it is considered the odour and dust effects are less than minor.

The ongoing potential for fluoride emissions to give rise to widow etching has been assessed as less than minor.

11 Applicability

This report has been prepared for the exclusive use of our client Ravensdown Limited, 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 for resource consent and that Hawke's Bay Regional Council 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 Hawke's Bay Regional Council in undertaking its regulatory functions in connection with the Ravensdown Napier Works site.

Tonkin & Taylor Ltd

Report prepared by:

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Richard Chilton

Principal Air Quality Scientist

Authorised for Tonkin & Taylor Ltd by:

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Jenny Simpson

Project Director

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Appendix A: Resource Consent (AUTH-115256-04)

HAWKE'S BAY REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

RESOURCE CONSENT

Discharge Permit

In accordance with the provisions of the Resource Management Act 1991 (RMA), and subject to the attached conditions, the Hawke's Bay Regional Council (the Council) grants a resource consent for a discretionary activity to:

Ravensdown Limited
Private Bag 6012
Napier 4142

To discharge contaminants into the air from the operation of the company's fertiliser manufacturing plant at Awatoto, including the following processes:

- The manufacture of sulphuric acid,
- The manufacture of superphosphate fertiliser,
- The storage, blending and dispatch of bulk and bagged fertilisers and sulphuric acid,
- The receipt and storage (inside and outside) of raw materials and imported fertiliser,
- General site operations**.**

LOCATION

Address of site:	200 Waitangi Road, Awatoto, Napier
Legal description (site of discharge):	Secs 26,44, Pt Section 32, 43, Lot 4, DP 8546 & Closed Road Blk I Clive SD
Map reference (NZTM):	1936936 E – 5614522 N

CONSENT DURATION

This consent is granted for a period expiring on 21st October 2022.

Malcolm Miller
Manager Consents
POLICY AND REGULATION GROUP
Under authority delegated by Hawke's Bay Regional Council
5th July 2021

This consent was originally granted on 21 October 2008 and subsequently changed under s127 of the RMA, see consent history, page 13.

CONDITIONS All works and structures relating to this resource consent shall be designed and constructed to conform to the best engineering practices and at all times maintained to a safe and serviceable standard.

2. The consent holder shall undertake all operations in accordance with any drawings, specifications, statements of intent and other information supplied as part of the application for this resource consent, and any updated relevant information included in the application for the change of consent conditions dated 31 March 2021. If a conflict arises between any conditions of this consent and the application, the conditions of this consent will prevail.

3. There shall be no discharge of particulate matter (including dust) that causes an offensive or objectionable effect beyond the boundary of the site. Compliance with Conditions 6 to 13 does not automatically result in compliance with this condition.

4. There shall be no discharge of odour that causes an offensive or objectionable effect beyond the boundary of the site.

5. Notwithstanding any other condition of this consent, there shall be no noxious or dangerous levels of gases, airborne liquid or other airborne contaminants beyond the legal boundary of the site, that are likely to cause adverse effects on human health, ecosystems or property. [*Note: for the purpose of this condition the term 'property' shall mean 'land and all assets on it'*].

Product Storage

6. All bulk raw materials stored on site shall be kept in enclosed buildings, with the exception of phosphate rock which must otherwise be securely contained to minimise particulate being discharged into air.

7. The consent holder shall use its best endeavours to avoid outside storage of phosphate rock. Any outside storage shall be undertaken in accordance with the Investigation and Management Plan, as required by Condition 67 of this consent. Outside storage, excluding the management of spills, shall only be undertaken in the area to the south of the Acid Plant.

8. At least 10 working days prior to the use of outside product storage the Consent Holder shall notify the Council that product shipments will be arriving which cannot be stored inside. Notification shall include the following:

   a) A summary of why alternative covered storage is not possible; and

   b) The product type to be stored outside; and

   c) The likely volume of product to be stored outside; and

   d) The estimated date of arrival and the time it will take to place product at the outside location; and

   e) Estimated duration that the product will be stored outside.

9. No outside unloading, pile forming or loading shall occur when average hourly wind speed exceeds 5 metres per second (m/s). The wind speed shall be determined by an onsite meteorological station in accordance with Condition 42 of this consent.

10. The consent holder shall carry out the suppression of dust with use of water through various methods that include, but are not limited to, spraying with water cart or sprinkler system to minimise the discharge of all visible dust beyond the site boundary, particularly during the loading, transfer and stockpiling of product. The control of dust discharges from stockpile areas shall include night-time and weekend hours.

11. Notwithstanding Condition 10 the consent holder shall establish and maintain an automated dust suppression sprinkler system that covers all outside storage piles, except for the working face while being worked, which will activate and remain operational for the duration of outside product pile

storage, including unloading and loading. The sprinkler system shall have a capacity in terms of volume and layout that will ensure adequate dampening down of the stockpile in all possible wind conditions.

12. The consent holder shall ensure regular sweeping of yard and road areas using mechanical cleaning to minimise dust emissions.

13. The consent holder shall ensure that the product storage pile does not exceed 4 metres in height.

Acid Plant

14. Except for discharges from the auxiliary boiler, furnace stack, economiser stacks and other minor vents, all discharges from the acid plant shall be via an emission stack with a height no less than 55 metres above ground level.

15. The emission rate of Sulphur Dioxide (SO_2) measured by continuous monitoring in the acid plant stack shall not exceed 1.5 kilograms (kg) per minute (two minute average) and 60 kg/hour (one-hour average) at any time.

16. Notwithstanding Condition 15, the combined discharge rate of SO_2, Sulphur Trioxide (SO_3) and Sulphuric Acid (H_2SO_4) from the sulphuric acid production process shall not exceed 60 kg/hr, expressed as SO_2.

17. An Acid Plant cold start up sulphur ignition shall not occur:

    a) between the hours of 1:00 am and 10:00 am on clear still mornings when the wind speed is less than 2 m/s and there is no cloud; and

    b) when the wind direction is between 030 and 155 degrees (onshore winds).

    Note: For the purposes of this consent, an acid plant ***cold*** start refers to starting the acid plant from cold, this occurs following a complete shutdown when the acid plant is starting from ambient temperatures and diesel is used to pre-heat the plant. An acid plant ***warm*** start refers to starting the acid plant when the plant is already warm, this occurs following a short plant stop, usually less than 8 hours, when the temperature in the acid plant has been maintained above a critical limit.

18. Subject to condition 21, the combined discharge rate of SO_3 and H_2SO_4 (expressed as SO_3) from the sulphuric acid production process shall not exceed:

    a) 2 kg/hr as a 1-hour average at any time;

    b) 0.5 kg/hr for at least 50% of fixed 1-hour averages in any 3 month period.

19. The existing final acid plant absorbing tower shall be replaced with a new tower containing a high efficiency distribution system, high efficiency packing and high efficiency mist eliminators that reduces the acidity of emissions from the acid plant to ensure compliance with the conditions of this consent at all times. The new tower shall be installed and commissioned by 30th October 2012. A suitably qualified independent person approved by Council shall certify in writing that the new absorbing tower, as installed and operated, is capable of meeting the conditions of this consent. This certification shall be provided to the Council by 30th November 2012.

20. The discharge from the acid plant stack shall be clear at all times, except that a visible white plume may occur within four hours of igniting sulphur in the case of a cold start up and within one hour in the case of a warm start up.

21. The discharge from the acid plant may contain up to 150 milligrams per cubic metre (mg/m^3) at NTP SO_3 / H_2SO_4 expressed as SO_3 for not more than 4 hours after igniting sulphur in the case of a cold start and not more than 1 hour in the case of a warm start up. This shall be measured in accordance with USEPA method 8 or another method as approved by Council.

22. The discharge from the acid plant shall not occur during wind directions between 030° and 155° (onshore winds) between the months of September to May inclusive, when either of the following meteorological conditions occur

    a) The relative humidity measured on-site at 10 metres above ground level is 92% or greater, wind speed at 10 metres above ground level is 3 m/s or less and it is not raining; or

    b) The relative humidity measured on-site at 10 metres above ground level is 95% or greater, wind speed at 10 metres above ground is greater than 3 m/s and it is not raining.

    Acid plant discharge shall cease within 30 minutes of the above meteorological conditions being detected and shall not recommence until these conditions have not occurred for a period of at least 30 minutes. Plant operators shall be alerted when the measured relative humidity at 10 metres above ground during onshore winds (030-155 degrees) exceeds 90%, and careful observation of meteorological conditions and the visible plume discharge shall occur during such conditions. A record shall be kept of the dates, time periods and meteorological conditions when the acid plant operation ceases according to this condition. This record shall be provided to the Council on request and otherwise annually.

23. A system shall be installed that automatically shuts off the sulphur feed to the burner so that the discharge to air rate of SO_2, SO_3 and H_2SO_4 from the sulphuric acid production process does not exceed Conditions 15 and 16.

24. a) The consent holder shall install and operate at least two ambient SO_2 monitors around the acid plant in order to detect fugitive SO_2 emissions. The monitoring sites shall be located at or about the southern boundary of the "Winstones" site, as described in Condition 57, and at or about the engineering store compound, to the western side of the acid plant. The concentration of SO_2 in ambient air shall be monitored continuously (at least every minute) by UV fluorescence analysis or an alternative method agreed to in writing by the Council; and

    b) In the event that ambient concentrations of SO_2 measured at either the monitoring sites described by Condition 24(a) or the monitoring site described by Condition 57 exceed 350 $\mu g/m^3$ as a 10-minute average, immediate action shall be taken to ensure that measured SO_2 concentrations are reduced to less than 350 $\mu g/m^3$ as a 10 minute average. A record shall be kept of all occurrences when measured SO_2 concentrations exceed this limit and the corrective action taken. This record shall be provided to the Council on request and otherwise annually.

25. Discharge from the Auxiliary Boiler shall be via an emission stack of 15.8 metres above ground level.

26. The diesel oil burning rate in the auxiliary boiler shall not exceed 580 litres per hour.

27. The auxiliary boiler and the pre-heater shall only burn diesel oil having a maximum sulphur content of 0.005% by weight. Documents showing fuel analysis shall be provided to the Council on request.

28. The opacity of emissions from the auxiliary boiler and pre-heater stacks shall not be darker than Ringelmann Shade 1 as determined in accordance with the New Zealand Standard 5201:1973, except for a period not exceeding 2 minutes in each hour of operation.

29. The concentration of hydrogen sulphide (H_2S) shall be measured in accordance with Condition 50 and shall not exceed 7 $\mu g/m^3$ (with a 1 hour averaging time) in the ambient air at or beyond the boundary of the premises as a result of emissions from the consent holder's property.

Manufacturing Plant

30. Discharges from each den scrubber shall be via stacks with a height of no less than 38 metres above ground level, until the Manufacturing stack is commissioned.

31. Discharges from the hygiene scrubber shall be via a stack with a height of no less than 36 metres above ground level, until the Manufacturing stack is commissioned.

31A The Manufacturing stack shall have a discharge height, including cowling, of no less than 50 metres above ground level as measured from the base of the stack.

32. All emissions from the superphosphate manufacturing process shall be discharged through either the den stacks or the hygiene stack, or the Manufacturing stack following its commissioning. Within 12 months of the commencement of this consent a report shall be provided by an independent suitably qualified person (approved by the Council) that certifies that all necessary remedial work to the ventilation and extraction system has been undertaken such that fugitive contaminant emissions from the manufacturing plant building have been eliminated as far as practicably possible. This ventilation and extraction system shall be maintained and operated at all times during the manufacturing of superphosphate.

33. The 7-day average concentration of fluoride measured at the RFC SW monitoring site (location as detailed in Condition 54), shall not exceed 1.7 $\mu g/m^3$.

34. The 7-day average concentration of fluoride measured at the RFC NW monitoring site (location as detailed in Condition 54), shall not exceed 5.5 $\mu g/m^3$.

35. The rate of particulate matter discharged from any Bradley mill shall not exceed 1 kg/hr per mill, and 2 kg/hr in total when two or more mills are in operation.

36. The sum of the fluoride compounds discharged from the den stacks and the hygiene stack, or from the Manufacturing stack measured in the samples taken in accordance with Condition 49 expressed as fluoride on a one hour average basis, shall not exceed:

    a) a maximum discharge rate of 1.5 kg/hr; and

    b) 1 kg/hr in more than 50% of samples taken in any 12-month period

37. A treatment system that reduces the acidity of emissions from the manufacturing plant shall be installed such that the pH of the condensate from the den and hygiene stacks, or the Manufacturing stack, shall be no lower than 2.7. The method by which the condensate is to measured shall be approved in writing by the Council.

38. An automated water deluge system for the manufacturing den mixer shall be installed and maintained such that contaminant discharges are prevented in the event of failure of the mixing process.

39. Cancelled.

40. The concentration of fluoride in ambient air measured in accordance with Condition 54 shall not exceed 0.8 $\mu g/m^3$ (7 day average) at areas used for horticultural production (including Brookfields Orchard and Plumpton Park (locations as detailed in Condition 54)).

Monitoring (General)

41. The evaporative cooling towers shall be regularly dosed with micro-biocides to maintain the concentration of the micro-biocide in the cooling water at the level recommended by the supplier that prevents the establishment of Legionella bacteria. Records shall be kept to demonstrate compliance with this condition and shall be provided to the Council on request.

Onsite Monitoring

42. The consent holder shall operate a meteorological data collection station in a location that reasonably represents meteorological conditions on the site. The station shall continuously record, wind speed, wind direction, temperature and relative humidity, and display them in real time in the manufacturing

control room and the acid plant control room. The site location and the resolution, accuracy and averaging time of monitoring equipment shall be agreed in writing by the Council. All processed data shall be archived and made available to the Council on request.

43. All sampling and surveys shall be carried out by an independent suitably qualified person, or by the consent holder or its representative where the Council has agreed to this in writing. Where the consent holder or its representative carries out testing or monitoring, an independent suitably qualified person shall audit the monitoring and testing methodology at least once per year, unless otherwise agreed in writing by the Council, and shall provide a written report describing the extent of compliance with the required protocol. A copy of this report shall be provided to the Council.

44. All analyses in accordance with conditions on the consent shall be carried out by an independently accredited laboratory to ISO/IEC Guide 25, or to the satisfaction of the Council.

45. The consent holder shall continuously (i.e. at intervals not exceeding 1 minute) measure the rate of SO_2 discharge in the emissions from the acid plant stack. The method of measurement shall be in accordance with ISO7935:1992 (E) (*Stationary source emissions – Determination of the mass concentration of sulphur dioxide – performance characteristics of automated measuring methods*) or an alternative method, approved in writing by the Council. Testing results shall be reported as a mass emission rate in units of kg/hr as both 1-minute and 1-hour averages.

46. All options for a continuous in-stack SO_3/H_2SO4 monitoring system shall be reviewed and analysed every 18 months by a suitably qualified independent person. The independent reviewer shall prepare a written report detailing the viability and estimated cost of all monitoring options internationally available. This information shall be provided to the Council no later than one month after the time of review.

46a. From 1st November 2012 continuous opacity measurements shall be undertaken in the acid plant stack at all times to provide an indication of acid mist emissions for operational purposes. Records of these measurements shall be kept and made available to Council on request.

47. The consent holder shall measure the rate of discharge of the SO_2, SO_3 and H_2SO_4 in the emissions from the acid plant stack, at least twice per week. This monitoring shall be undertaken in accordance with USEPA Method 8 ("Determination of sulphuric acid mist and sulphur dioxide emissions from stationary sources") or an alternative method that is approved, in writing, by the Council.

48. The discharge rate of the total sulphur compounds obtained in accordance with Condition 47 shall be used in conjunction with the continuous record of sulphur dioxide obtained in accordance with Condition 45 to determine a continuous record of the rate of sulphur compounds discharged, expressed as SO_2.

49. Until the Manufacturing stack is commissioned, the ~~The~~ consent holder shall measure the discharge rate of fluoride in the emissions from each of the den stacks and the hygiene stack, at least twice per week using wet chemistry methods. Following commissioning of the Manufacturing stack, sampling shall occur on it at least twice per week using wet chemistry methods. The measurement is to be carried out during superphosphate manufacture and no test may commence within one hour of starting acidulation. The method of measurements shall be in accordance with USEPA Method 13B ("Total fluoride specific ion electrode") or an alternative method approved, in writing, by the Council.

50. Concentrations of hydrogen sulphide in ambient air shall be monitored in accordance with the method of measurement (AS 3580.8.1 1990). The methods for sampling and analysis shall be automatic intermittent sampling - gas chromotographic method, or an alternate method approved in writing by the Council. The monitoring shall be carried out for a period of at least seven complete days at least twice per year. The location of the monitoring shall be agreed upon with the Council at the time of installation of the monitoring equipment. Results shall be reported as 1-hour averages.

51. The rate of particulate matter discharged from each mill shall be measured at least once every 3 months. The method of sampling and analysis shall comply with USEPA Method 5 or Method 17, ISO 9096:2003 or ASTM D3685-98, or a similar iso-kinetic method to the satisfaction of the Council. The testing time for each sample shall be 2-hours continuous, and at least three samples shall be collected. Results shall be adjusted to 0°C, 101.3 kilopascals, on a dry gas basis, and as a mass emission from each stack expressed as kg/hr.

52. Pressure and particulate in the baghouses serving the Bradley mills shall be continuously monitored and recorded to detect broken bags in the Bradley mills. A central alarm system shall be operated to warn the plant operator of a bag breakage or any change in pressure that may indicate a broken filter bag. The bag filters serving the Bradley mills shall also be manually inspected on a regular basis and shall be replaced where the inspection reveals excessive wear. Records shall be kept of bag filter pressure, Bradley mill shutdowns, manual inspections and filter bag replacements. These records shall be provided to the Council on request.

53. The pH of the condensate from the den scrubbers and the hygiene scrubber stacks, or from the Manufacturing stack following its commissioning shall be measured at least twice each week. The method by which the condensate is to be measured shall be approved in writing by the Council.

Offsite Monitoring

54. The consent holder shall continuously measure ambient fluoride, in accordance with the monitoring plan required by Condition 68 and based on 7-day filter exposures and results reported as average concentration (µg/m^3) over that 7-day sample period. Measurements shall be taken at no less than five sites, within 4 kilometres (km) of the plant, including those listed in Table 1 and 1a below;

1. ***Table 1: Ambient fluoride monitoring sample sites (until the Manufacturing stack is commissioned)***

Site Easting/Northing (NZMS:V21)	Direction from den stack (NZMS:V21)	Distance from den stacks (m)
Brookfields Orchard 2845270 6174882	WSW	2520
Plumpton Park 2844886 6177027	WNW	2010
RFC SW monitoring site 2846500 6175782	WSW	300
RFC NW monitoring site 2846730 6176142	WNW	187
Winstone Aggregates 2846946 6176226	NNE	280

Table 1a: Ambient fluoride monitoring sample sites – Once Manufacturing Plant is commissioned

Site Easting/Northing (NZMS:V21)	Direction from ~~den stack~~ Manufacturing Plant (NZMS:V21)	Distance from ~~den stacks (m)~~ Manufacturing Plant (m)
Brookfields Orchard 2845270 6174882	WSW	~~2520~~ 2060
Plumpton Park 2844886 6177027	WNW	~~2010~~ 2200
RFC SW monitoring site 2846500 6175782	WSW	~~300~~ 540
RFC NW monitoring site 2846730 6176142	WNW	~~187~~ 170

Winstone Aggregates 2846946 6176226	NNE	~~280~~ 90

The location of the sites may be modified with the written approval of the Council.

[*Note: Approval from property owners/occupiers for the placement and operation of monitors is required.*]

55. Ambient fluoride measurement undertaken in accordance with Condition 54 shall occur at a height of 2.4 metres above ground level with no obstruction above 2 metres high in the direction of the RFC plant for 50 metres, unless otherwise approved in writing by the Council.

56. The consent holder shall ensure ambient fluoride measurement is undertaken in accordance with AS3580.13.2 – 1991 ("Method 13.2: Determination of fluorides – Gaseous and acid soluble particulate fluorides – Manual, double filter paper sampling") or an alternative method approved, in writing, by the Council.

57. Concentrations of SO_2 in ambient air shall be monitored continuously according to the method of measurement AS3580.4.1 – 1990 ("Method 4.1: Determination of sulphur dioxide – direct reading instrumental method"), or an alternative method agreed to in writing by the Council. The monitoring shall begin within 3 months of commencement of this consent. The monitoring site shall be located at or about the southern boundary of the "Winstones" site, to the southeast of the ~~den stacks~~ Manufacturing Plant, and in an area agreed to in writing by the Council prior to establishment. Results shall be provided as 1-hour and 24-hour averages. Any exceedance of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NES) for SO_2 shall be reported as soon as it is known.

58. Concentrations of PM_{10} in ambient air shall be monitored continuously according to a method of measurement that complies with the monitoring requirements in the NES, or an alternative method agreed to in writing by the Council. The monitoring shall begin within 3 months of commencement of this consent. The monitoring site shall be located at or about the southern boundary of the "Winstones" site, to the southeast of the ~~den stacks~~ Manufacturing Plant, and shall be agreed in writing by the Council prior to establishment. Results shall be provided as a 24-hour average. Any exceedance of the NES for PM_{10} shall be reported as soon as it is known.

59. Continuous monitoring of total suspended particulate matter shall be undertaken at two locations at all times that bulk material is stored outside. The monitoring sites shall be at the eastern boundary at a location most affected by bulk material dust discharges and at a reference location at the northern end of the site. The monitoring shall have an averaging period of 24-hours or less and the method of monitoring shall be approved in writing by the Council. Monitoring results shall be provided to the Council within two months of the cessation of bulk material storage and otherwise at least annually.

60. Every 24 months, from the commencement of this consent, the consent holder shall review the available methodology for measuring acid deposition at no less than two sites in horticultural areas within 4 km of the plant and this information shall be provided to the Council. Any new methodologies will be reviewed against the current vegetation monitoring programme, as per Condition 66. The deposition monitoring protocol shall be determined in conjunction with and agreed to in writing by the Council prior to the commencement of monitoring.

61. The consent holder shall undertake a survey every two years of the effects of fluoride etching on all properties (where the owner accepts the offer of a survey) within 1 km of the site using the methodology outlined in the BRANZ report DCZ059 (25 June 2004). Any windows found to be affected to 'pen test level 3' or where Light Gloss Units (LGU) are equal or less than 115 as described in BRANZ report DCZ059, shall be replaced by the consent holder if the property owner wishes the glass to be replaced.

Reporting

62. The consent holder shall advise the Council at least 24 hours in advance of a planned warm or cold start up of the acid plant. The Council shall be advised of the time when sulphur will be ignited and the person in charge of the procedure.

63. At monthly intervals the consent holder shall provide the Council with copies of all information (including test results, reports and records) required to be collected in accordance with the conditions of this consent during the previous month, unless the condition specifically allows the information to be provided at a different interval. This information shall be provided in a report format, and shall comment on site performance and compliance with consent conditions.

64. The consent holder shall produce a report every year (the 'annual report') that presents and summarises all information on the monitoring required by this consent. The report shall include, but not necessarily be limited to:

    a) quantification of and assessment of the impact of discharges of dust, PM_{10}, SO_2, fluoride and acidic compounds; and

    b) the fluoride and foliar monitoring report; and

    c) the impact of odour and H_2S discharges from the site; and

    d) a description of any potential and actual effects that have been identified; and

    e) identification of trends of monitoring information; and

    f) a summary of system modifications; and

    g) recommendations for system improvements; and

    h) the monthly fluoride content of phosphate rock blends.

    The annual report shall be prepared for the period beginning July and ending June of the following year and provided to the Council before 31 October each year.

65. The consent holder shall maintain a log of all complaints received directly from the public. The log shall include;

    a) the date, time, and nature of the complaint; and

    b) the telephone number, and address of the complainant (as provided); and

    c) weather information (including an estimate of wind speed and direction); and

    d) details of key operating parameters at the time of the complaint; and

    e) the remedial action taken, as appropriate, to prevent further incidents.

    Complaints shall be reported to the Council within 12 hours of receipt and the log of complaints shall be made available to the Council on request.

66. The consent holder shall undertake a vegetation monitoring programme that has been approved by the Council in accordance with Condition 68 of this consent. The programme shall provide for the following matters:

    a) A visual assessment of vegetation; and

    b) A determination of foliar fluoride concentrations; and

    c) The timing of the vegetation monitoring programme (which shall occur during the months of September to May inclusive for the duration of the consent, unless otherwise agreed in writing by the Council); and

    d) The monitoring methodology which shall be agreed in writing by the Council; and

e) The location of any monitoring, including but not limited to the following sites (Table 2):

Table 2: Fluoride monitoring sample sites.

Site Location	Site Easting/Northing (NZMS:V21)
Brookfields Orchard, Kings Road	2845407 6175251
Plumpton Park Orchard, Awatoto Road	2844864 6177075
Simkin Orchard, Awatoto Road	2844899 6177531
Steiner Apollo Orchard, Willowbank Road	2845130 6177681
Apollo Orchard, Tannery Road	2843161 6178732
Mr Apple Orchard, Meeanee Road	2843358 6177127
Johnny Appleseed Orchard, Meeanee	2844016 6174605
Wells Orchard, McLeod Road	2845551 6176688
Dewer Orchard, Awatoto Road	2845361 6176994

Provided that the location of the monitoring sites may be modified as appropriate with the written agreement of the Council.

f) The requirement for the initial crop assessment to be completed within 12 months of the commencement of this consent; and

g) The requirement for the consent holder to provide a report to the Council upon the completion of the first two years of vegetation monitoring, to determine whether the monitoring programme may be amended or modified as necessary;

Provided that any amendments to the monitoring programme shall only occur with the written agreement of the Council.

Management Plan

67. The consent holder shall prepare and submit to the Council for approval within two months of the date of commencement of this consent and within two months from the commissioning Manufacturing stack, a Management Plan that details how all discharges to air from the site and their effects shall be measured, assessed and managed. The Management Plan shall be complied with at all times during the exercise of this consent, and shall include but not be limited to the management of the following matters:

a) Dust including particulate; and

b) Outside phosphate rock storage; and

c) Sulphur dioxide; and

d) Acidic discharges; and

e) Fluoride; and

f) Odour.

The Management Plan shall specify all actions necessary to ensure ongoing compliance with all conditions of this consent. The consent holder shall update the Management Plan at least once every two years, and otherwise where necessary, with the written agreement of the Council.

Monitoring Plan

68. The consent holder shall prepare and submit to the Council for approval within two months of the date of commencement of this consent and within two months from the commissioning Manufacturing stack, a Monitoring Plan that monitors the impact of discharges to air from the site. The Monitoring Plan must be complied with at all times during the exercise of this permit, and shall include but not be limited to the following monitoring matters:

a) Manufacturing stack monitoring requirements; and

b) Acid plan stack monitoring requirements; and

c) Dust monitoring requirements; and

d) Ambient SO_2, particulate matter and H_2S monitoring; and

e) Off site ambient fluoride monitoring requirements; and

f) Off site crop fluoride monitoring requirements; and

g) Sampling methods; and

h) Analytical methods; and

i) Reporting requirements; and

j) Sampling locations; and

k) Sampling frequencies; and

l) Auditing and peer review.

The consent holder shall update the Monitoring Plan at least once every two years, and otherwise where necessary, with the written agreement of the Council.

Review

69. The Council may review conditions of this consent pursuant to sections 128, 129, 130, 131 and 132 of the Resource Management Act 1991. The actual and reasonable costs of any review undertaken will be charged to the consent holder, in accordance with section 136(1) of the Resource management Act 1991. Notice of any review may be served during the month of May in any year, or within 3 months of any monitoring data being submitted.

a) To deal with any adverse effect on the environment that may arise from the exercise of this consent, which it is appropriate to deal with at that time or which became evident after the date of issue; and

b) To require the adoption of the best practicable option to remove or reduce any effects on the environment; and

c) To modify any monitoring programme, or to require additional monitoring if there is evidence that current monitoring requirements are inappropriate or inadequate; and

d) To review and/or implement measures that prevent acid plant discharge during onshore winds when the discharge plume mixes with mist or low cloud, taking into account relevant monitoring information concerning the emission rates and potential effects on vegetation of SO_3 and H_2SO_4 discharged from the acid plant; and

e) To address adverse effects of outside storage of bulk materials, taking onto account suspended particulate monitoring, complaints and other relevant information; and

f) To require continuous monitoring of SO_3/H_2SO_4 in the acid plant stack, taking into account current monitoring techniques or information provided in the 18-monthly reviews of monitoring options under Condition 46.

Reasons for Decision

The effects of the activity on the environment will not be more than minor. Granting the consent is consistent with the purpose and principles of the RMA, the National Policy Statement for Freshwater, the Resource

Management (National Environmental Standards for Sources of Human Drinking Water) Regulations 2007 and with all relevant plans and policies.

Advice Notes

1. Where conditions of consent require correspondence or interaction with Council, this should be directed to or with the Manager Compliance.

2. All information required by the conditions of this consents can be emailed to ComplianceReturns@hbrc.govt.nz

Monitoring by the Council

Routine monitoring

Routine monitoring inspections will be undertaken by Council officers at least twice a year , or more if necessary to confirm compliance with timelines as required by conditions of the consent. The costs of **any** routine monitoring will be charged to the consent holder in accordance with council's Annual Plan of the time.

Non-routine monitoring

"Non routine" monitoring will be undertaken if there is cause to consider (e.g. following a complaint from the public, or routine monitoring) that the consent holder is in breach of the conditions of this consent. The cost of non-routine monitoring will be charged to the consent holder in the event that non-compliance with conditions is determined, or if the consent holder is deemed not to be fulfilling the obligations specified in section 17(1) of the RMA shown below.

Section 17(1) of the RMA states:

> *Every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity carried on by or on behalf of the person, whether or not the activity is carried on in accordance with*
>
> *a) any of sections 10, 10A, 10B, and 20A; or*
>
> *b) a national environmental standard, a rule, a resource consent, or a designation.*

Consent Impact Monitoring

In accordance with section 36 of the RMA (which includes the requirement to consult with the consent holder) the Council may levy additional charges for the cost of monitoring the environmental effects of this consent, either in isolation or in combination with other nearby consents. Any such charge would generally be set through the Annual Plan process.

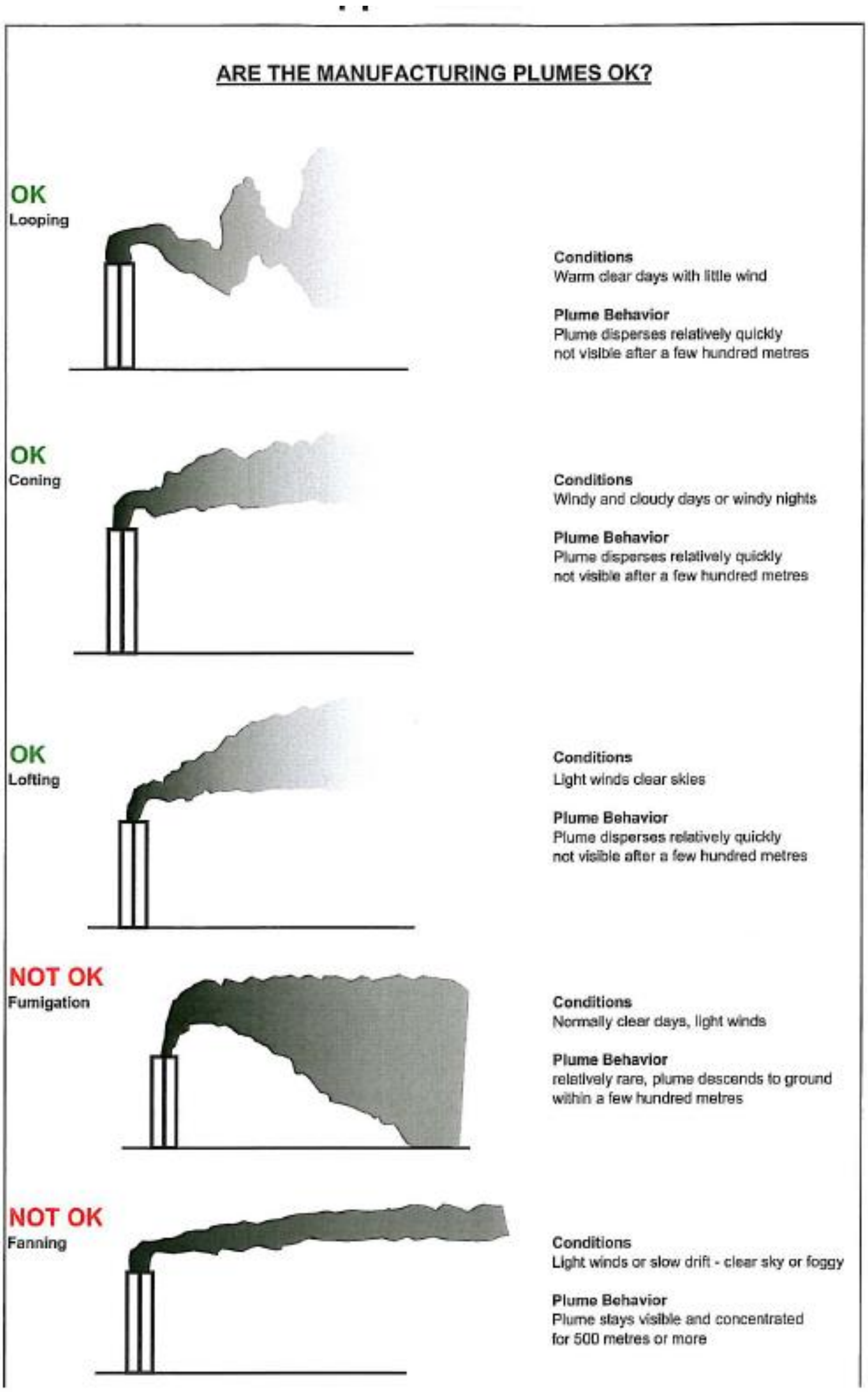
Debt Recovery

It is agreed by the consent holder that it is a term of the granting of this resource consent that all costs incurred by the Council for, and incidental to, the collection of any debt relating to this resource consent, whether as an individual or as a member of a group, and charged under section 36 of the RMA, shall be borne by the consent holder as a debt due to the Council, and for that purpose the Council reserves the right to produce this document in support of any claim for recovery.

CONSENT HISTORY

Consent No./ Authorisation No.	Date	Event	Relevant Rule	Relevant Plan
DP050561A	03/05/2007	Consent initially granted	28	Regional Resource Management Plan
DP050561A	13/10/2008	Consent order signed by the Environment Court	-	-
DP0501561A	21/10/2008	Consent granted	28	Regional Resource Management Plan
DP050561Aa	16/03/2011	Changes to Conditions 17, 19, 21, 24a, 46, 50 and 60.	127	Resource Management Act 1991
DP050561Ab	07/08/2012	Changes to Conditions 19 and 46a to allow extension of installation, commissioning and certification dates; Minor administrative and formatting changes initiated by Council	127	Resource Management Act 1991
AUTH-115256-04	05/07/2021	Changes to conditions 2, 30, 31, 32, 36, 37, 39, 49, 53, 54, 57, 58, 67 and 68 with new proposed condition 31A and discharge point address updated – to reflect the new combined stack	127	Resource Management Act 1991

APPENDIX "A"- MANUFACTURING PLUME ACCEPTANCE CRITERIA "CHART



Appendix B: Combustion and emission calculations for diesel firing of the Acid Plant during a cold start-up

COMBUSTION CALCULATIONS

Ravensdown Awatoto

Diesel combustion for acid plant start up

100% MCR

Assumed actual operating conditions

Parameter	Value	Unit	Comment / source of data
FUEL ULTIMATE ANALYSIS			
Carbon:	88.56	%wt (DAF basis)	Diesel fuel
Hydrogen:	11.44	%wt (DAF basis)	
Oxygen:	0.00	%wt (DAF basis)	
Nitrogen:	0.00	%wt (DAF basis)	
Sulphur:	0.00	%wt (DAF basis)	
Fuel moisture:	0.00	%wt (AR basis)	
Ash content:	0.00	%wt (AR basis)	
DAF portion:	1.000	kg/kg fuel (AR basis)	
AIR REQUIREMENTS			
Theoretical O_2 required:	102.40	moles/kg (DAF basis)	
Excess air:	31	%	
Flue gas CO_2 content:	12.00	%vol dry	Tuned to 12%
Flue gas O_2 content:	5.22	%vol dry	
APPLIANCE DETAILS			
Power Output:	7,160	kW	Solved for fuel consumption rate
Percentage of MCR:	100	%	
As rcvd fuel CV:	43,000	kJ/kg	Diesel
Thermal efficiency:	75.00	%	Assumed typical thermal efficiency (boiler)
Equivalent Stack diameter:	0.81	m	Assumed to meet 10 m/s at 6% O2
Effective power output:	7,160	kW	
Heat produced by combustion:	9,547	kW	
Heat loss:	2,387	kW	
FUEL CONSUMPTION			
Maximum fuel burning rate:	0.2220	kg/s (AR basis)	
	0.80	t/h (AR basis)	
Specific gravity:	0.83	kg/L	
	963.00	L/hr	Site consumes 57,764 L over approx. 60 hrs (= 962 L/hr)
STACK AND FLUE GAS PROPERTIES			
Temperature:	453.15	K	Assumed to be 180 C
Actual volumetric flow rate:	5.55	m³/s	
Efflux velocity:	10.7	m/s	
DRY flow rate:	3.06	m³/s dry STP	
	11,016	m³/hr dry STP	
WET flow rate :	3.34	m³/s STP	
	12,041	m³/hr STP	
EMISSION CALCULATIONS			
SO_2:	0.02	kg/hr	Based on fuel sulphur content (as received)
PM_{10}:	2.0	lb/10^3 gal	USEPA AP42 Table 1.3-1 Distillate oil
	0.2	kg/10^L	
	0.2	kg/hr	
	21.0	mg/m³ dry STP (12% CO2)	Back calculated
NOX:	18.0	lb/10^3 gal	USEPA AP42 Table 1.3-1 Distillate oil
	2.2	kg/10^L	
	2.1	kg/hr	
	188.8	mg/m³ dry STP (12% CO2)	Back calculated
CO:	5.0	lb/10^3 gal	USEPA AP42 Table 1.3-1 Distillate oil
	0.6	kg/10^L	
	0.6	kg/hr	
	52.5	mg/m³ dry STP (12% CO2)	Back calculated

N:	Standard atmospheric conditions (0 °C, 1 atmosphere) and zero humidity
DAF:	Dry, ash free
STP:	Standard temperature (0 °C) and pressure (1 atmosphere)
MCR:	Maximum combustion rate

Appendix C: Advice from Dr Doley

David Doley

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Australia

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Email david.doley@live.com

To Whom It May Concern,

Statement of Competence

As a member of staff of The University of Queensland, between 1973 and 2009, I conducted experimental research and field surveys of the effects of gaseous fluoride on crop and native plant species in Australia and New Zealand. This work resulted in one book, three book chapters, 10 refereed journal articles, 17 refereed conference contributions, and over 150 reports on research, environmental surveys and environmental impact statements. I participated in technical discussions concerning fluoride leading to the Ministry for Environment *Ambient Air Quality Guidelines 2002 Update*.

During the development of the Air Quality Guidelines (2002), the designation of a Conservation Area guideline value of 0.1 $\mu g/m^3$, averaged over 90 days, was made in order to protect threatened species for which there was no information on their sensitivity to fluoride. Such conservation areas were considered to be located at a substantial distance from any site of industrial activity. Discussion at the time accepted that air quality meeting the conservation area guideline would not be achieved close to industrial areas, but would be required for more remote locations such as national parks. This line of thinking was consistent with the regulations implemented by the European Union, although the EU did not set the same numerical limits.

Statement on Environmental Conditions in the Vicinity of Ravensdown Awatoto Works

On 12 occasions between January 2004 and March 2006, I examined field or reported evidence of injury to crop species in the vicinity of the Ravensdown Awatoto works.

One of the injury events, which occurred between 24 and 26 January 2006, was the subject of evidence to a resource consent hearing in 2006 and a court action in 2008 for damages to the Plumpton Park orchard, Awatoto Road, Meeanee. Evidence relating to that event follows this statement.

I visited the Dewar and Plumpton Park orchards in March 2006, but I was not able to inspect other locations, so what follows is supposition. At the time of the court action in 2008, no evidence was produced that damage similar to that reported from the Dewar and Plumpton Park orchards in January 2006 was recorded farther south (specifically, at Brookfields vineyard and orchard).

It was concluded in the evidence that sea spray occurred between 23 and 26 January 2006, during a period of sustained high wind speed over a relatively narrow range of directions. I related the distribution of injury to the fact that, upwind from the area of impact on the orchards, there was limited physical obstruction to wind flow from the ocean, over the Awatoto Pubic Golf Course, the Maraenui Golf Course and adjacent houses, and the cleared land east of these orchards. Farther to the south, there were relatively tall buildings (e.g. Hawkes Bay Woolscourers, Ravensdown sheds, etc.) that may have disrupted near-surface air flow that would be the major zone of transport of entrained sea spray.

At the time, witnesses for Plumpton Park claimed that vineyards and orchards in the Haumoana area that were closer to the coast that the Plumpton park orchard were not adversely affected during the storm event of 24-25 January 2006. The lack of injury in the Haumoana orchards may be associated with the occurrence of closely spaced and probably tall windbreaks that would be expected to have intercepted near-surface sea spray. I was not able to establish this by personal inspection, so it remains a point of conjecture.

The principal complaint in 2006 was that emissions from the Ravensdown works caused the injury at Plumpton Park on 23-25 January 2006. This is not possible, because production at the Ravensdown works was suspended when wind speeds reached 10 m/s, and the wind direction would have meant that any emissions would have travelled to the Brookfields orchards, and not to Plumpton Park.

I concluded, from repeated inspections of vegetation in coastal locations in New Zealand (Awatoto, Dunedin, Bluff) and in Australia that, in general, plant species that are tolerant of sea salt (mostly sodium chloride) also tend to be tolerant of fluoride. Perennial species that grow in coastal locations commonly have surface features that reduce the rate of uptake of salts deposited on leaf surfaces, and these features would also reduce the impact of fluoride deposited from sea spray. However, deposition of greatly increased quantities of salt during storm events are very likely to result in injury, even to species that are adapted to relatively exposed coastal conditions.

It is my opinion that plant species growing naturally in the estuary to the south of the Ravensdown works are likely to be relatively tolerant of salinity, and therefore would be expected to be relatively tolerant to fluoride, whether in the gaseous form or as aerosol droplets in sea spray. I would expect these species to be not adversely affected by ambient fluoride concentrations that meet the Ministry for Environment Air Quality Guidelines for general land use, or even exceed them by a moderate fraction.

D.Doley

David Doley
3 July 2020

Analysis of an injury event on 23-26 January 2006

January 2006 was relatively sunny with three rain periods, the major one occurring between 24 and 26 January.

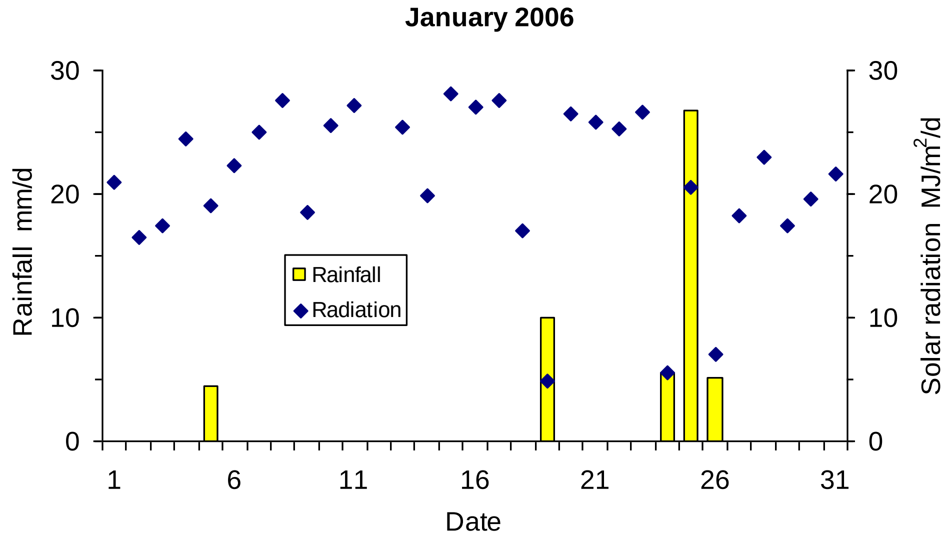

Fig 26. Courses of daily rainfall and total short-wave radiation at Ravensdown Awatoto works during January 2006.

The only period in January when fertiliser production occurred at the Ravensdown works was the 23rd-24th. Winds were consistently from the north-east. The 24th was cloudy (20% clear sky radiation), very windy, with persistent light precipitation totalling about 5 mm. This precipitation is considered to have contained a large proportion of sea spray.

The 25th was a bright day (80% of possible radiation) with a rain event in evening that delivered about 25 mm of rain.

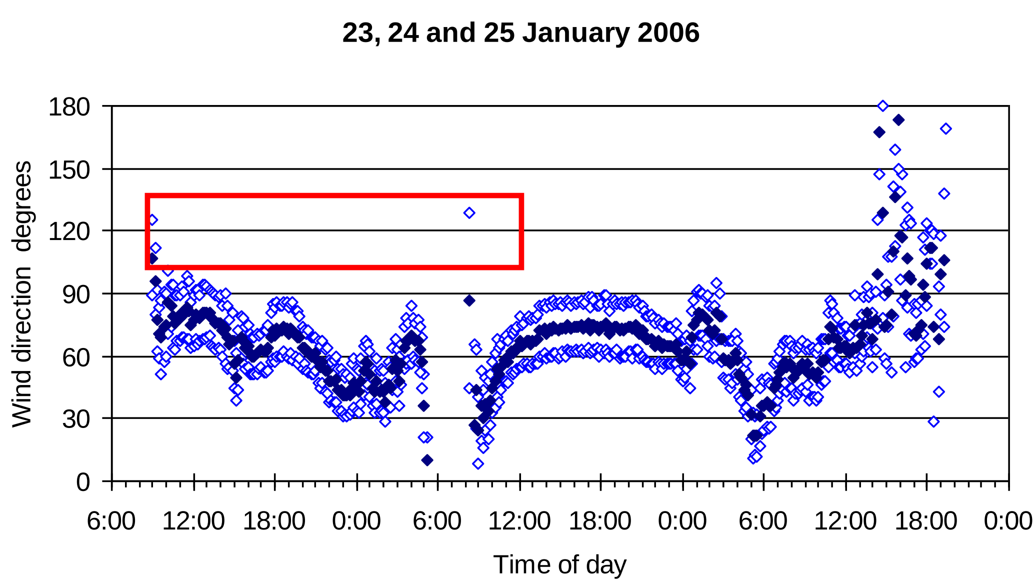

Fig 27. Ten-minute mean (solid diamonds) and standard deviation (open diamonds) of wind direction at Ravensdown Awatoto works during a potential vegetation injury event between 23 and 25 January 2006. The red rectangle indicates the duration of fertiliser production and the wind sector within which emissions might have been carried from Ravensdown towards Plumpton Park.

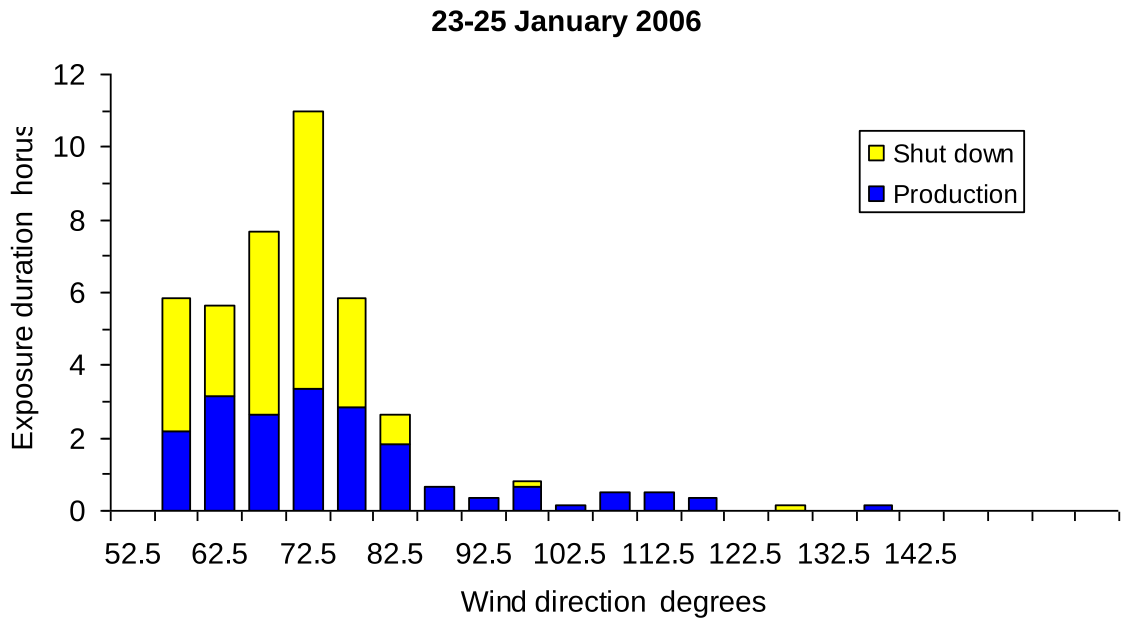

Fig 28. Total duration of winds in five-degree sectors between 50 and 150 degrees during the period 23-25 January 2006. Plumpton Park was not exposed to Ravensdown emissions in the period 23-25 January 2006.

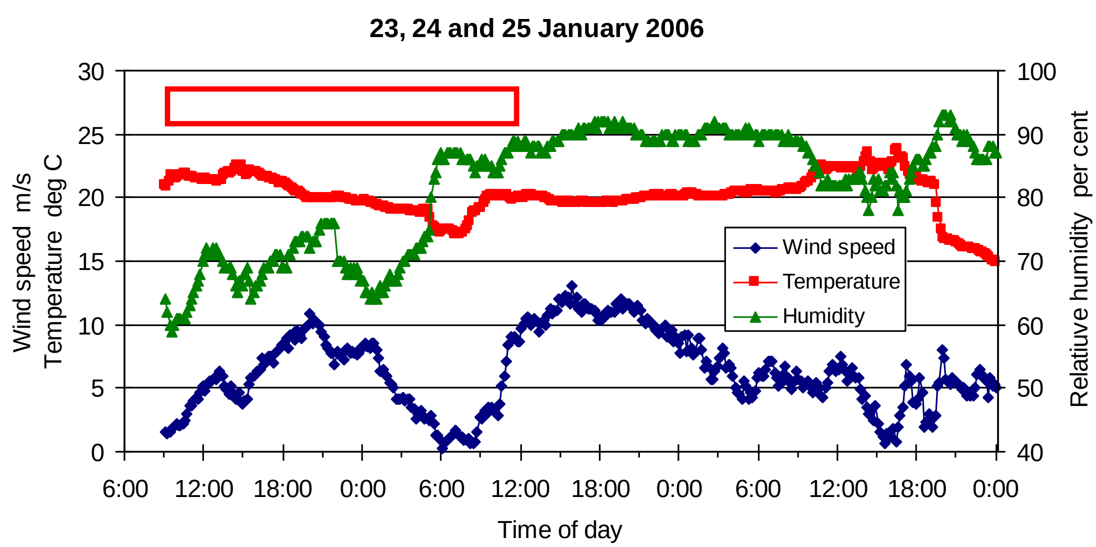

Fig 29. Ten-minute mean wind speed, air temperature and relative humidity at Ravensdown Awatoto works during 23, 24 and 25 January 2006. The red rectangle indicates the period of fertiliser production.

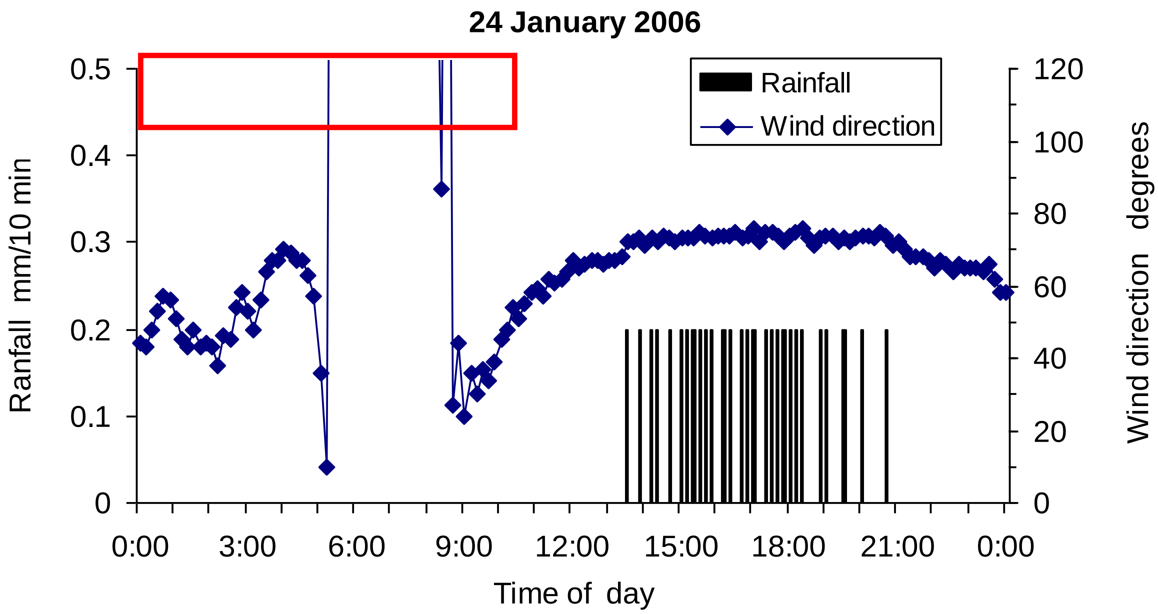

Fig 30. Meteorological conditions at Awatoto for 24 January 2006, showing 10-minute maximum wind speed (diamonds), 10-minute rainfall totals (columns) and the period of fertiliser production (red rectangle). Note the persistent light precipitation between 13:30 and 21:00 hrs that resulted in a total of 5.6 mm.

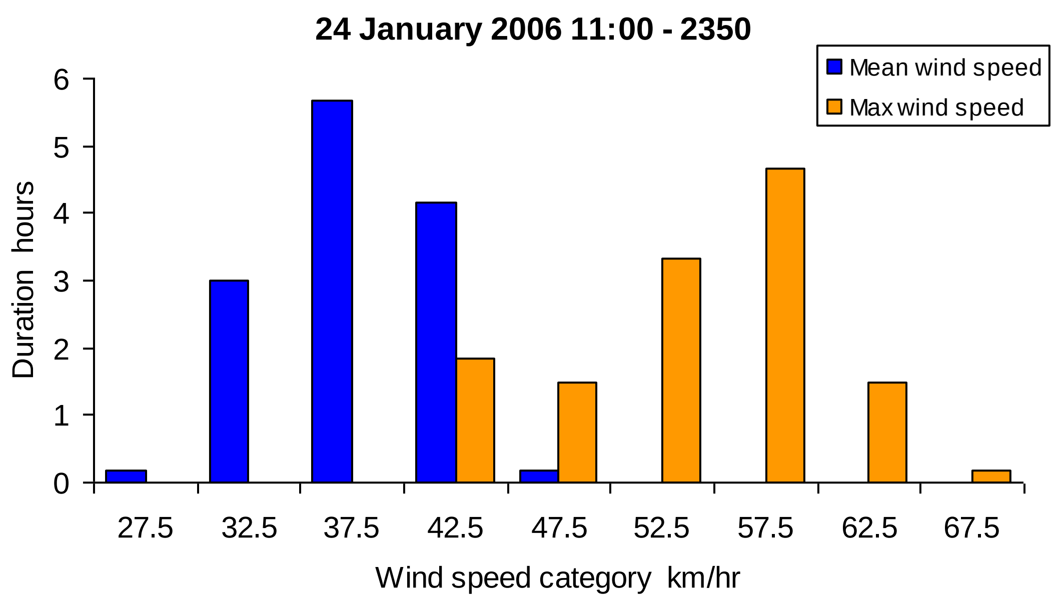

Fig 31. Frequency distribution of mean and maximum wind speeds at Awatoto between 11:00 and 23:50 hrs on 24 January 2006. Note that maximum wind speed exceeded 50 km/h during more than 9 hours.

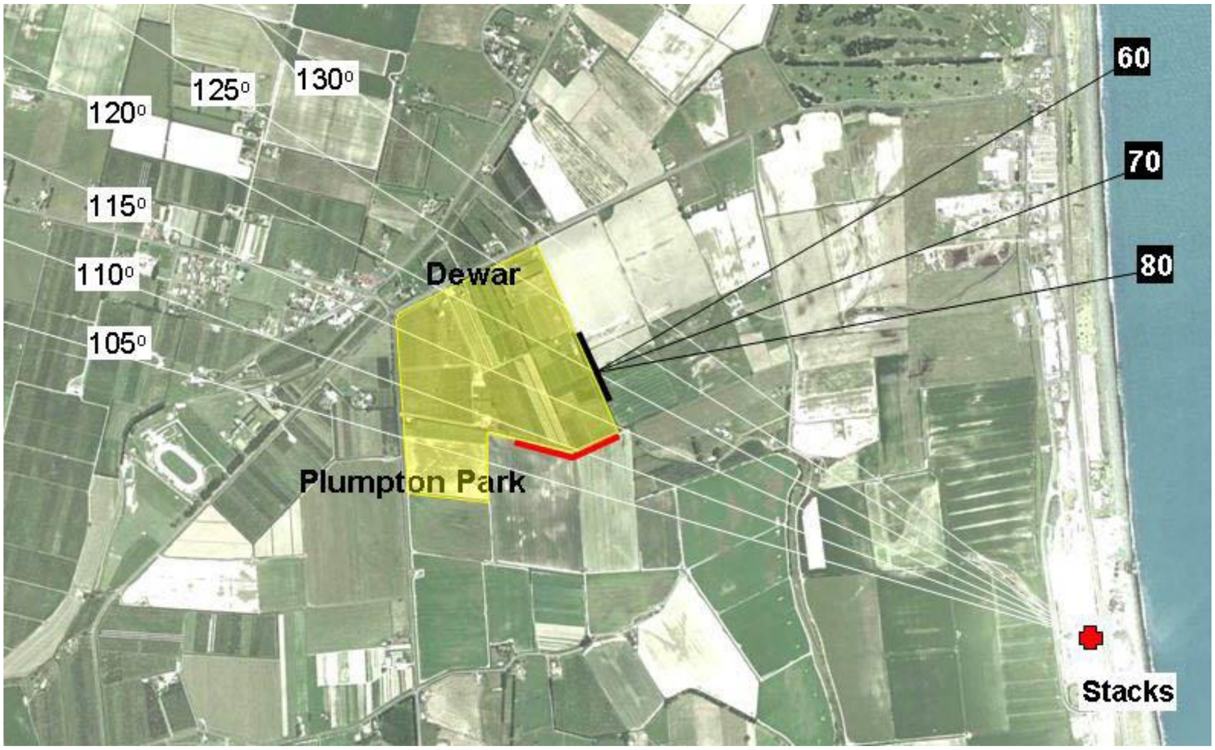

Fig 32. Wind directions during December 2005 that may carry emissions from Ravensdown fertiliser works to Plumpton Park and Dewar orchards (white lines) and wind directions on 24 January 2006 (black lines). The red lines indicate the locations of injury at an inspection on 18 January 2006. The heavy black line indicates the location of injury in an inspection on 9 March 2006.

Table 2. Calculation of possible rates of deposition of fluoride and chloride at McLeod Rd and Plumpton Park on 24 January 2006.

Meteorological conditions:

1. Mean wind direction from 1330 to 2100 hrs was 73±2.1 degrees.
2. Mean wind speed from 1330 to 2100 hrs was 40.4±7.6 km/h.
3. Total precipitation at Waitangi Rd between 1330 and 2100 hrs was 5.6 mm.
4. Mean relative humidity from 1330 to 2100 hrs was 90±1.4 %.

Assumptions:

1. Precipitation recorded on 24 January was comprised of sea spray at solute concentrations equal to those in sea water.
2. Total precipitation at McLeod Road was approximately equal to that recorded at Waitangi Road.
3. Interception of suspended water droplets by vegetation is equal to rate of deposition into a standard rain gauge.
4. Total precipitation at Plumpton Park was 60 per cent of that at McLeod Road.
5. Precipitation was distributed uniformly to all leaf surfaces in a plant canopy.
6. All fluoride deposited on leaves was retained within leaves.

Potential fluoride and chloride deposition on leaves at McLeod Rd

			units	Fluoride	Chloride
Fluoride concentration in sea water:			mol/kg	0.000068	0.546
Specific leaf area			m^2/kg	40	40
Assume leaf area index of crop				2	2
Assume total precipitation		mm	5	5	5
	0.0				
Precipitation on	2	m^2 of leaf	kg water	0.05	0.025
Fluoride content of precipitation on 1k g of leaf			mol	0.0000034	0.0273
Fluoride content of precipitation on 1 kg of leaf			mg/kg	64.6	955500

Potential fluoride deposition on apple leaves at Plumpton Pk

			units	Fluoride	Chloride
Fluoride concentration in sea water:			mol/kg	0.000068	0.46
Specific leaf area			m^2/kg	10	10
Assume leaf area index of crop				4	4
Assume total precipitation			mm	3	3
	0.0				
Precipitation on	1	m^2 of leaf	7.5	7.5	0.0075
				0.000000127	0.00012750
Fluoride content of precipitation on 1 kg of leaf			mol	5	0
Fluoride content of precipitation on 1 kg of leaf			mg/kg	2.42	2.4225

Interpretation: Salt deposition could explain the fluoride concentration of 70 ug/g recorded in squash leaves and the 41 ug/g in elm leaves at the Mitchell property, McLeod Rd on 22 February 2006 (Tate 2006, Table 5). These calculations also account for the low fluoride concentration observed in apple leaves at the Dewar orchard (<10 ug/g, Tate 2006, Table 5).

Appendix D: CALPUFF Configuration

CALPUFF Parameters

Ravensdown Awatoto
CALPUFF MODEL
Acid Stack - Consent Limit of SO2 and SO3 emission rate. SO3 converted to SO4.

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	12
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-01-01-00-0000-2015-03-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-03-03-00-0000-2015-05-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-05-03-00-0000-2015-07-03-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-07-03-00-0000-2015-09-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-09-02-00-0000-2015-11-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2015-11-02-00-0000-2016-01-01-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-01-01-00-0000-2016-03-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-03-02-00-0000-2016-05-02-00-0000.DAT

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-05-02-00-0000-2016-07-02-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-07-02-00-0000-2016-09-01-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-09-01-00-0000-2016-11-01-00-0000.DAT
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET_2016-11-01-00-0000-2016-12-31-23-0000.DAT

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2015
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	3
NSE	Number of chemical species to be emitted	3
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	2
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	1
MDRY	Model dry deposition? (0 = no, 1 = yes)	1
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	2
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	1
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0

INPUT GROUP: 3 -- Species List		
Parameter	**Description**	**Value**
CSPEC	Species included in model run	SO2
CSPEC	Species included in model run	SO4
CSPEC	Species included in model run	SO3

INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	TTM
FEAST	False easting at projection origin (km)	1930.0
FNORTH	False northing at projection origin (km)	5630.0
UTMHEM	Hemisphere (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	39.416S
RLON0	Longitude of projection origin (decimal degrees)	176.833E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	85
NY	Meteorological grid - number of Y grid cells	98
NZ	Meteorological grid - number of vertical layers	12
DGRIDKM	Meteorological grid spacing (km)	0.2
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 45.0, 80.0, 130.0, 195.0, 275.0, 385.0, 540.0, 740.0, 1000.0, 1700.0, 3000.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	1922.2000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	5599.4000
IBCOMP	Computational grid - X index of lower left corner	41
JBCOMP	Computational grid - Y index of lower left corner	43
IECOMP	Computational grid - X index of upper right corner	85
JECOMP	Computational grid - Y index of upper right corner	98
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	F
IBSAMP	Sampling grid - X index of lower left corner	1
JBSAMP	Sampling grid - Y index of lower left corner	1
IESAMP	Sampling grid - X index of upper right corner	2
JESAMP	Sampling grid - Y index of upper right corner	2
MESHDN	Sampling grid - nesting factor	1

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	1
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	1
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	1
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10

INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		
Parameter	**Description**	**Value**
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0

INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30

INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1

INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	0
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1

INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	3
IPTU	Units used for point source emissions (e.g., 1 = g/s)	2
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0

INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0

INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6

INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0
NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0

INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0

INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0

INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0

INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	4365
NRGRP	Number of receptor group names	0

Appendix E: CALMET Configuration

CALMET Parameters

Hastings Awatoto 17 kmx19.6 km @200m resolution
Terrain from 8 m LINZ DEM | Land use from MfE LUDB 2018 | WRF prognostic data
2015 & 2016

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
GEODAT	Input file of geophysical data (GEO.DAT)	Hast_geo_RevisedTerrain.dat
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	surf.dat
PRCDAT	Input file of hourly precipitation data (PRECIP.DAT)	precip.dat
METLST	Output file name of CALMET list file (CALMET.LST)	CALMET.LST
METDAT	Output file name of generated gridded met files (CALMET.DAT)	CALMET.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NUSTA	Number of upper air stations	0
NOWSTA	Number of overwater stations	0
NM3D	Number of prognostic meteorological data files (3D.DAT)	24
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
IBYR	Starting year	2015
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	23
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
IRTYPE	Output run type (0 = wind fields only, 1 = CALPUFF/CALGRID)	1
LCALGRD	Compute CALGRID data fields (T = true, F = false)	T
ITEST	Flag to stop run after setup phase (1 = stop, 2 = run)	2
MREG	Regulatory checks (0 = no checks, 1 = US EPA LRT checks)	0

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	TTM
FEAST	False easting at projection origin (km)	1930.0
FNORTH	False northing at projection origin (km)	5630.0
UTMHEM	Hemisphere of UTM projection (N = northern, S = southern)	S
RLAT0	Latitude of projection origin (decimal degrees)	39.416S
RLON0	Longitude of projection origin (decimal degrees)	176.833E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-Region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	85
NY	Meteorological grid - number of Y grid cells	98
DGRIDKM	Meteorological grid spacing (km)	0.2
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	1922.2000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	5599.4000
NZ	Meteorological grid - number of vertical layers	12
ZFACE	Meteorological grid - vertical cell face heights (m)	0.00,20.00,45.00,80.00,130.00,195.00,275.00,385.00,540.00,740.00,1000.00,1700.00,3000.00

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
LSAVE	Save met fields in unformatted output file (T = true, F = false)	T
IFORMO	Type of output file (1 = CALPUFF/CALGRID, 2 = MESOPUFF II)	1
LPRINT	Print met fields (F = false, T = true)	F
IPRINF	Print interval for output wind fields (hours)	1
STABILITY	Print gridded PGT stability classes? (0 = no, 1 = yes)	0
USTAR	Print gridded friction velocities? (0 = no, 1 = yes)	0
MONIN	Print gridded Monin-Obukhov lengths? (0 = no, 1 = yes)	0
MIXHT	Print gridded mixing heights? (0 = no, 1 = yes)	0
WSTAR	Print gridded convective velocity scales? (0 = no, 1 = yes)	0
PRECIP	Print gridded hourly precipitation rates? (0 = no, 1 = yes)	0
SENSHEAT	Print gridded sensible heat fluxes? (0 = no, 1 = yes)	0
CONVZI	Print gridded convective mixing heights? (0 = no, 1 = yes)	0
LDB	Test/debug option: print input met data and internal variables (F = false, T = true)	F
NN1	Test/debug option: first time step to print	1
NN2	Test/debug option: last time step to print	1
LDBCST	Test/debug option: print distance to land internal variables (F = false, T = true)	F

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
IOUTD	Test/debug option: print control variables for writing winds? (0 = no, 1 = yes)	0
NZPRN2	Test/debug option: number of levels to print starting at the surface	1
IPR0	Test/debug option: print interpolated winds? (0 = no, 1 = yes)	0
IPR1	Test/debug option: print terrain adjusted surface wind? (0 = no, 1 = yes)	0
IPR2	Test/debug option: print smoothed wind and initial divergence fields? (0 = no, 1 = yes)	0
IPR3	Test/debug option: print final wind speed and direction? (0 = no, 1 = yes)	0
IPR4	Test/debug option: print final divergence fields? (0 = no, 1 = yes)	0
IPR5	Test/debug option: print winds after kinematic effects? (0 = no, 1 = yes)	0
IPR6	Test/debug option: print winds after Froude number adjustment? (0 = no, 1 = yes)	0
IPR7	Test/debug option: print winds after slope flow? (0 = no, 1 = yes)	0
IPR8	Test/debug option: print final winds? (0 = no, 1 = yes)	0

INPUT GROUP: 4 -- Meteorological Data Options		
Parameter	**Description**	**Value**
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	1
NSSTA	Number of surface stations	3
NPSTA	Number of precipitation stations	1
ICLDOUT	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MCLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads)	4
IFORMS	Surface met data file format (1 = unformatted, 2 = formatted)	2
IFORMP	Precipitation data file format (1 = unformatted, 2 = formatted)	2
IFORMC	Cloud data file format (1 = unformatted, 2 = formatted)	2

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
IWFCOD	Wind field model option (1 = objective analysis, 2 = diagnostic)	1
IFRADJ	Adjust winds using Froude number effects? (0 = no, 1 = yes)	1
IKINE	Adjust winds using kinematic effects? (0 = no, 1 = yes)	0
IOBR	Adjust winds using O'Brien velocity procedure? (0 = no, 1 = yes)	0
ISLOPE	Compute slope flow effects? (0 = no, 1 = yes)	1
IEXTRP	Extrapolation of surface winds to upper layers method (1 = none, 2 = power law, 3 = user input, 4 = similarity theory, - = same except layer 1 data at upper air stations are ignored)	-4
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	-1.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	-1
IPROG	Use prognostic winds as input to diagnostic wind model (0 = no, 13 = use winds from 3D.DAT as Step 1 field, 14 = use winds from 3D.DAT as initial guess field, 15 = use winds from 3D.DAT file as observations)	14
ISTEPPGS	Prognostic data time step (seconds)	3600
IGFMET	Use coarse CALMET fields as initial guess? (0 = no, 1 = yes)	0
LVARY	Use varying radius of influence (F = false, T = true)	F
RMAX1	Maximum radius of influence in the surface layer (km)	6
RMAX2	Maximum radius of influence over land aloft (km)	6
RMAX3	Maximum radius of influence over water (km)	30
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.1
TERRAD	Radius of influence of terrain features (km)	2
R1	Relative weight at surface of step 1 fields and observations (km)	2
R2	Relative weight aloft of step 1 field and observations (km)	2
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5E-006
NITER	Maximum number of iterations in the divergence minimization procedure	50
NSMTH	Number of passes in the smoothing procedure (NZ values)	2,11*4
NINTR2	Maximum number of stations used in each layer for interpolation (NZ values)	12*99
CRITFN	Critical Froude number	1
ALPHA	Empirical factor triggering kinematic effects	0.1
FEXTR2	Multiplicative scaling factor for extrapolation of surface observations to upper layers (NZ values)	12*0
NBAR	Number of barriers to interpolation of the wind fields	0
KBAR	Barrier - level up to which barriers apply (1 to NZ)	10
IDIOPT1	Surface temperature (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	-1
IDIOPT2	Temperature lapse rate used in the computation of terrain-induced circulations (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPT	Upper air station to use for the domain-scale lapse rate (between 1 and NUSTA)	-1
ZUPT	Depth through which the domain-scale lapse rate is computed (m)	200
IDIOPT3	Initial guess field winds (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPWND	Upper air station to use for domain-scale winds	-1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1.0, 1000.00
IDIOPT4	Read observed surface wind components (0 = from SURF.DAT, 1 = from DIAG.DAT)	0
IDIOPT5	Read observed upper wind components (0 = from UPn.DAT, 1 = from DIAG.DAT)	0

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
LLBREZE	Use Lake Breeze module (T = true, F = false)	F
NBOX	Lake Breeze - number of regions	0

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
CONSTB	Mixing height constant: neutral, mechanical equation	1.41
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOL	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning, - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m**3)	0
THRESHW	Overwater threshold boundary flux (W/m**3)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.DAT	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	1
ITPROG	3D temperature read option (0 = stations, 1 = surface from station and upper air from prognostic, 2 = prognostic)	2
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R**2)	1
TRADKM	Temperature interpolation radius of influence (km)	500
NUMTS	Maximum number of stations to include in temperature interpolation	5
IAVET	Conduct spatial averaging of temperatures? (0 = no, 1 = yes)	1
TGDEFB	Default overwater mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default overwater capping lapse rate (K/m)	-0.0045

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
JWAT1	Beginning land use category for temperature interpolation over water	999
JWAT2	Ending land use category for temperature interpolation over water	999
NFLAGP	Precipitation interpolation method (1 = 1/R, 2 = 1/R**2, 3 = EXP/R**2)	2
SIGMAP	Precipitation interpolation radius of influence (km)	100
CUTP	Minimum precipitation rate cutoff (mm/hr)	0.01

Appendix F: Evaluation of lower discharge velocity and temperature for Acid Plant stack

Figure 12.1: Comparison of predicted maximum 1-hour average SO_2 concentrations associated with the Acid Plant discharging at its maximum emission rate of 60 kg/hr (yellow contours) with conditions that give rise to lower velocity, temperature and emission rates (3 m/s, 50 °C, 20 kg/hr – blue contours).

Appendix G: Model predicted concentrations for discrete receptors

Discrete receptor ID	Discrete receptor Name	Discrete receptor ID	Fluoride							Fluoride Deposition		SO_2			SO_3		Sulphur Deposition	PM_{10}		$PM_{2.5}$	
			1-hour	12-hour	24-hour	7-day	30-day	90-day	Annual	1-hour	Annual	1-hour	24-hour	Annual	1-hour	Annual	Annual	24-hour	Annual	24-hour	Annual
						(µg/m³)				(kg/ha/hr)	(kg/ha/yr)		(µg/m³)		(µg/m³)		(kg/ha/yr)	(µg/m³)		(µg/m³)	
1	Apollo Orchard	A1	0.9	0.33	0.17	0.04	0.003	0.002	0.002	1.1E-04	0.002	24	4.8	0.08	0.8	3.2E-04	0.06	0.15	1.1E-03	0.14	1.0E-03
2	Bayleaf Organics Orchard	A2	1.2	0.45	0.22	0.06	0.004	0.003	0.002	1.3E-04	0.002	27	6.1	0.09	0.8	3.7E-04	0.07	0.22	1.5E-03	0.19	1.4E-03
3	Brookfield Orchard	A3	2.6	1.14	0.57	0.19	0.019	0.017	0.012	2.1E-04	0.009	58	18.8	0.65	1.9	2.7E-03	**0.39**	0.61	8.3E-03	0.55	7.5E-03
4	Brookfields Winery	A4	1.6	0.74	0.37	0.14	0.010	0.007	0.005	1.2E-04	0.005	35	13.8	0.25	1.2	1.0E-03	0.15	0.38	3.6E-03	0.34	3.3E-03
5	Dewer Orchard	A5	2.6	0.90	0.62	0.17	0.013	0.010	0.008	2.5E-04	0.007	46	16.6	0.26	1.4	1.0E-03	0.20	0.58	5.3E-03	0.52	4.8E-03
6	Enzafruit	A6	1.6	0.40	0.23	0.09	0.008	0.006	0.004	1.6E-04	0.003	38	11.3	0.14	1.1	5.4E-04	0.10	0.30	2.5E-03	0.27	2.3E-03
7	Gibson Orchard	A7	3.2	1.38	0.76	**0.29**	**0.03**	**0.02**	0.01	2.4E-04	**0.013**	54	14.8	0.52	1.7	2.0E-03	0.35	1.29	9.3E-03	1.16	8.4E-03
8	Golden Del Orchard	A8	1.5	0.68	0.35	0.13	0.009	0.007	0.004	1.1E-04	0.004	34	12.4	0.23	1.1	9.6E-04	0.14	0.34	3.4E-03	0.31	3.0E-03
9	Hohepa Farm	A9	2.4	0.77	0.42	0.16	0.016	0.011	0.010	1.4E-04	0.005	61	12.3	0.37	1.9	1.5E-03	0.16	0.68	5.9E-03	0.61	5.4E-03
10	McKelvie Orchard	A10	1.0	0.54	0.28	0.06	0.005	0.004	0.002	9.9E-05	0.002	26	6.6	0.11	0.9	4.5E-04	0.07	0.46	1.7E-03	0.42	1.6E-03
11	Johnny Appleseed	A11	1.6	0.69	0.37	0.14	0.012	0.009	0.005	1.3E-04	0.005	35	9.1	0.27	1.1	1.1E-03	0.16	0.45	4.0E-03	0.41	3.6E-03
12	Mr Apple North	A12	1.2	0.55	0.28	0.07	0.005	0.004	0.003	1.1E-04	0.002	27	7.6	0.12	0.9	4.8E-04	0.08	0.47	1.9E-03	0.42	1.8E-03
13	Mr Apple South	A13	1.3	0.46	0.23	0.08	0.006	0.004	0.003	9.9E-05	0.003	31	8.3	0.15	1.0	6.2E-04	0.08	0.38	2.0E-03	0.34	1.8E-03
14	Plumpton Park	A14	2.0	0.75	0.42	0.11	0.010	0.008	0.006	2.1E-04	0.005	36	12.4	0.21	1.1	8.2E-04	0.15	0.39	4.1E-03	0.35	3.7E-03
15	Rivergold Orchard	A15	1.1	0.41	0.22	0.07	0.005	0.003	0.002	8.5E-05	0.002	24	8.0	0.12	0.8	5.3E-04	0.07	0.31	1.6E-03	0.27	1.5E-03
16	Ruby Glen Orchard	A16	1.3	0.39	0.23	0.07	0.005	0.004	0.002	1.0E-04	0.002	25	7.1	0.12	0.8	5.1E-04	0.07	0.47	1.8E-03	0.43	1.6E-03
17	The Vege Barn	A17	1.5	0.49	0.27	0.07	0.007	0.005	0.003	1.6E-04	0.003	31	10.1	0.15	0.9	5.7E-04	0.10	0.28	2.6E-03	0.25	2.3E-03
18	Vege Land	A18	1.3	0.45	0.24	0.07	0.006	0.005	0.003	1.5E-04	0.003	30	9.6	0.14	0.9	5.3E-04	0.09	0.26	2.4E-03	0.23	2.1E-03
19	Waitangi Regional Park	A19	4.1	1.18	0.69	0.25	0.028	0.019	0.017	2.4E-04	0.009	109	20.7	**0.66**	3.4	2.8E-03	0.35	0.71	9.7E-03	0.64	8.7E-03
20	Wells Orchard	A20	3.2	**1.4**	**0.75**	0.22	0.019	0.016	0.011	**2.9E-04**	0.010	50	18.0	0.37	1.6	1.4E-03	0.26	0.73	7.8E-03	0.65	7.0E-03
21	Samoan Assembly of God	C1	0.9	0.34	0.18	0.05	0.004	0.003	0.001	8.7E-05	0.001	22	8.3	0.07	0.6	3.1E-04	0.04	0.19	1.1E-03	0.17	1.0E-03
22	Beach	C2	35.7	11.02	7.98	3.26	0.547	0.427	0.375	1.1E-03	0.117	229	28.3	0.97	6.8	3.8E-03	0.54	11.7	2.0E-01	10.6	1.8E-01
23	Bette Christie Kindergarten	C3	0.9	0.30	0.15	0.05	0.004	0.003	0.002	7.6E-05	0.001	24	7.3	0.08	0.8	3.1E-04	0.04	0.16	1.1E-03	0.15	9.9E-04
24	Clive School	C4	1.2	0.56	0.31	0.07	0.005	0.005	0.003	8.3E-05	0.002	31	6.7	0.18	1.0	7.5E-04	0.08	0.33	2.4E-03	0.30	2.2E-03
25	Flowers by Chilton	C5	1.9	0.65	0.39	0.10	0.008	0.006	0.004	1.8E-04	0.004	34	11.0	0.18	1.0	6.8E-04	0.13	0.38	3.2E-03	0.35	2.9E-03
26	Maraenui Golf Club	C6	1.9	0.55	0.31	0.10	0.012	0.007	0.005	1.8E-04	0.004	37	7.6	0.16	1.1	6.1E-04	0.09	0.40	3.3E-03	0.36	3.0E-03
27	Hohepa Homes	C7	2.1	0.98	0.55	0.15	0.013	0.010	0.008	1.4E-04	0.005	54	12.3	0.37	1.7	1.6E-03	0.17	0.63	5.0E-03	0.57	4.5E-03
28	Learning Adventures	C8	0.8	0.32	0.16	0.04	0.003	0.002	0.001	7.3E-05	0.001	20	7.5	0.07	0.6	2.8E-04	0.03	0.16	1.0E-03	0.14	9.1E-04
29	Meeanee School	C9	1.7	0.53	0.28	0.08	0.008	0.006	0.004	1.6E-04	0.004	33	10.6	0.16	1.0	6.3E-04	0.11	0.36	3.0E-03	0.33	2.7E-03
30	Model Flying Hawkes Bay	C10	5.7	1.80	1.22	0.67	0.061	0.053	0.039	4.5E-04	0.028	160	36.4	2.27	5.2	9.6E-03	1.47	0.98	2.3E-02	0.89	2.1E-02
31	Napier Boys High School	C11	0.7	0.17	0.09	0.04	0.003	0.002	0.001	7.1E-05	0.001	16	2.7	0.06	0.5	2.5E-04	0.03	0.10	9.3E-04	0.09	8.4E-04
32	Pukemokimoki Marae	C12	0.9	0.31	0.20	0.04	0.003	0.002	0.001	9.8E-05	0.001	22	8.1	0.07	0.7	2.9E-04	0.04	0.23	1.1E-03	0.20	9.9E-04
33	Revival Centres Church	C13	1.2	0.59	0.32	0.08	0.005	0.005	0.004	7.7E-05	0.002	40	7.4	0.20	1.2	7.9E-04	0.07	0.27	2.6E-03	0.25	2.4E-03
34	Richmond School	C14	0.8	0.31	0.15	0.05	0.003	0.002	0.001	7.8E-05	0.001	22	7.5	0.07	0.7	3.0E-04	0.03	0.15	1.0E-03	0.13	9.4E-04
35	Summerset Te Awa	C15	1.3	0.36	0.18	0.06	0.008	0.005	0.003	1.3E-04	0.002	28	4.8	0.11	0.9	4.4E-04	0.06	0.32	1.9E-03	0.29	1.7E-03
36	Tiny Footsteps	C16	1.4	0.76	0.43	0.11	0.007	0.006	0.005	8.9E-05	0.003	41	9.0	0.24	1.2	9.8E-04	0.09	0.35	3.2E-03	0.31	2.9E-03
37	Voguehaven Rest Home	C17	1.3	0.52	0.32	0.08	0.006	0.005	0.004	8.2E-05	0.002	38	7.8	0.20	1.2	8.0E-04	0.07	0.34	2.7E-03	0.30	2.4E-03
38	Winstone Aggregates	C18	40.5	16.81	10.23	4.76	0.761	0.608	0.531	2.5E-03	0.190	204	43.8	1.31	4.9	3.6E-03	0.48	11.3	3.2E-01	10.2	2.9E-01
39	House North	C19	2.3	0.79	0.42	0.14	0.016	0.010	0.006	2.0E-04	0.004	41	6.8	0.18	1.2	6.9E-04	0.11	0.45	4.1E-03	0.41	3.7E-03
40	House Northwest	C20	4.3	1.56	0.92	0.34	0.026	0.022	0.014	4.6E-04	0.013	57	14.5	0.37	1.7	1.4E-03	0.26	0.95	9.1E-03	0.85	8.1E-03
41	House West	C21	3.0	1.18	0.63	0.25	0.022	0.016	0.010	2.3E-04	0.010	48	12.3	0.42	1.5	1.7E-03	0.27	1.12	7.5E-03	1.00	6.8E-03
42	House Southwest	C22	2.7	0.95	0.58	0.20	0.021	0.018	0.012	2.1E-04	0.010	53	15.2	0.61	1.7	2.5E-03	0.39	0.73	8.2E-03	0.66	7.3E-03
43	House South	C23	2.1	0.73	0.38	0.14	0.014	0.010	0.008	1.3E-04	0.004	54	10.0	0.30	1.7	1.3E-03	0.13	0.65	5.3E-03	0.58	4.8E-03
46	House Northeast	C24	12.4	4.58	2.58	0.84	0.115	0.077	**0.054**	8.0E-04	0.031	113	**23.6**	0.68	3.0	**2.2E-03**	0.37	**1.95**	**3.0E-02**	**1.76**	**2.7E-02**
44	Front Paddock	R1	35.7	10.76	7.33	3.62	0.495	0.424	0.280	1.8E-03	0.166	205	38.3	2.11	4.9	3.8E-03	1.01	10.2	2.1E-01	9.22	1.9E-01
45	Back Paddock	R2	12.9	3.55	2.79	1.21	0.143	0.134	0.095	9.4E-04	0.082	187	50.4	3.28	6.2	1.2E-02	2.51	3.24	5.8E-02	2.91	5.2E-02
			3.2864	1.4947	0.7986	0.3332	0.0725	0.0654	0.0990												

Discrete receptor ID	Discrete receptor Name	Discrete receptor ID	Fluoride (µg/m³)							Fluoride Deposition		SO_2 (µg/m³)			Sulphur Deposition
			1-hour	12-hour	24-hour	7-day	30-day	90-day	Annual	1-hour (kg/ha/hr)	Annual (kg/ha/yr)	1-hour	24-hour	Annual	Annual (kg/ha/yr)
1	Apollo Orchard	A1	0.5	0.21	0.11	0.03	0.002	0.002	0.001	8.5E-05	0.001	17	3.5	0.07	0.06
2	Bayleaf Organics Orchard	A2	0.6	0.20	0.12	0.04	0.003	0.003	0.002	1.0E-04	0.002	19	4.3	0.08	0.07
3	Brookfield Orchard	A3	1.8	0.51	0.28	0.13	0.018	0.016	0.011	1.2E-04	0.009	40	12.4	0.61	**0.37**
4	Brookfields Winery	A4	1.0	0.43	0.24	0.08	0.009	0.007	0.004	6.3E-05	0.004	24	9.9	0.24	0.14
5	Dewer Orchard	A5	1.6	0.49	0.37	0.13	0.012	0.010	0.007	1.8E-04	0.007	30	11.6	0.25	0.20
6	Enzafruit	A6	0.9	0.28	0.18	0.06	0.007	0.005	0.003	1.2E-04	0.003	26	8.3	0.13	0.10
7	Gibson Orchard	A7	2.33	**0.85**	**0.46**	**0.182**	**0.026**	**0.019**	0.012	1.4E-04	**0.013**	37	10.3	0.51	0.34
8	Golden Del Orchard	A8	0.9	0.39	0.20	0.08	0.008	0.006	0.004	6.2E-05	0.004	22	9.0	0.22	0.13
9	Hohepa Farm	A9	2.2	0.55	0.37	0.11	0.015	0.010	0.009	9.8E-05	0.004	42	8.6	0.35	0.15
10	McKelvie Orchard	A10	0.6	0.28	0.15	0.04	0.004	0.003	0.002	6.9E-05	0.002	17	4.5	0.10	0.07
11	Johnny Appleseed	A11	0.9	0.35	0.23	0.07	0.010	0.008	0.005	7.6E-05	0.004	23	6.4	0.26	0.16
12	Mr Apple North	A12	0.7	0.31	0.16	0.04	0.005	0.003	0.002	7.3E-05	0.002	19	5.2	0.11	0.07
13	Mr Apple South	A13	0.7	0.30	0.15	0.06	0.006	0.004	0.002	6.6E-05	0.002	21	6.0	0.14	0.08
14	Plumpton Park	A14	1.1	0.43	0.25	0.08	0.009	0.007	0.005	1.3E-04	0.005	24	8.4	0.20	0.15
15	Rivergold Orchard	A15	0.6	0.21	0.11	0.05	0.005	0.003	0.002	5.5E-05	0.002	17	5.7	0.12	0.06
16	Ruby Glen Orchard	A16	0.6	0.28	0.15	0.05	0.005	0.003	0.002	6.1E-05	0.002	17	5.3	0.11	0.07
17	The Vege Barn	A17	0.7	0.31	0.17	0.05	0.006	0.004	0.003	9.9E-05	0.003	21	7.0	0.13	0.10
18	Vege Land	A18	0.7	0.30	0.16	0.05	0.005	0.004	0.003	9.0E-05	0.003	21	6.6	0.13	0.09
19	Waitangi Regional Park	A19	3.9	1.00	0.66	0.18	0.027	0.017	0.016	1.9E-04	0.009	76	14.3	**0.63**	0.34
20	Wells Orchard	A20	2.30	0.77	0.42	0.14	0.018	0.015	0.010	**2.0E-04**	0.010	34	12.1	0.35	0.26
21	Samoan Assembly of God	C1	0.5	0.21	0.18	0.03	0.003	0.002	0.001	5.7E-05	0.001	15	6.3	0.07	0.04
22	Beach	C2	35.7	10.99	7.96	3.18	0.536	0.418	0.368	1.1E-03	0.114	141	18.8	0.82	0.51
23	Bette Christie Kindergarten	C3	0.4	0.16	0.14	0.03	0.003	0.002	0.001	5.1E-05	0.001	18	5.5	0.07	0.03
24	Clive School	C4	0.7	0.26	0.15	0.04	0.005	0.004	0.003	5.7E-05	0.002	22	4.7	0.17	0.07
25	Flowers by Chilton	C5	1.0	0.30	0.24	0.07	0.007	0.005	0.004	1.3E-04	0.004	23	7.5	0.16	0.12
26	Maraenui Golf Club	C6	1.1	0.51	0.26	0.07	0.011	0.007	0.004	1.2E-04	0.003	25	5.1	0.15	0.09
27	Hohepa Homes	C7	1.7	0.59	0.32	0.10	0.012	0.009	0.007	9.6E-05	0.004	38	8.5	0.35	0.16
28	Learning Adventures	C8	0.4	0.19	0.16	0.03	0.003	0.002	0.001	4.9E-05	0.001	15	5.8	0.07	0.03
29	Meeanee School	C9	0.8	0.35	0.18	0.05	0.007	0.005	0.003	9.4E-05	0.003	22	7.3	0.15	0.11
30	Model Flying Hawkes Bay	C10	5.2	1.65	0.83	0.37	0.054	0.047	0.035	2.8E-04	0.024	107	23.6	2.14	1.42
31	Napier Boys High School	C11	0.3	0.13	0.07	0.03	0.003	0.002	0.001	5.3E-05	0.001	12	1.9	0.06	0.03
32	Pukemokimoki Marae	C12	0.5	0.20	0.18	0.03	0.003	0.002	0.001	6.5E-05	0.001	15	6.1	0.07	0.04
33	Revival Centres Church	C13	0.7	0.35	0.19	0.05	0.005	0.004	0.003	5.2E-05	0.002	28	5.0	0.18	0.07
34	Richmond School	C14	0.4	0.18	0.15	0.03	0.003	0.002	0.001	4.8E-05	0.001	16	5.7	0.07	0.03
35	Summerset Te Awa	C15	0.8	0.23	0.13	0.05	0.007	0.004	0.002	7.3E-05	0.002	19	3.0	0.10	0.06
36	Tiny Footsteps	C16	0.9	0.41	0.23	0.07	0.006	0.006	0.004	6.0E-05	0.002	29	6.1	0.22	0.09
37	Voguehaven Rest Home	C17	0.7	0.33	0.20	0.05	0.005	0.004	0.003	4.8E-05	0.002	27	5.3	0.18	0.07
38	Winstone Aggregates	C18	40.5	16.81	10.23	4.32	0.737	0.590	0.517	2.4E-03	0.189	102	19.1	0.80	0.46
39	House North	C19	1.7	0.79	0.42	0.10	0.015	0.009	0.006	1.6E-04	0.004	28	4.6	0.16	0.10
40	House Northwest	C20	3.1	0.85	0.55	0.26	0.025	0.020	0.013	3.3E-04	0.013	38	9.2	0.35	0.26
41	House West	C21	1.9	0.72	0.39	0.16	0.021	0.015	0.010	1.3E-04	0.010	33	8.8	0.41	0.27
42	House Southwest	C22	1.9	0.57	0.39	0.13	0.019	0.017	0.011	1.3E-04	0.009	37	10.1	0.58	0.38
43	House South	C23	1.8	0.47	0.31	0.09	0.013	0.009	0.008	8.4E-05	0.004	37	6.5	0.28	0.13
46	House Northeast	C24	12.3	4.49	2.53	0.07	0.110	0.070	**0.050**	6.6E-04	0.027	113	**15.6**	0.68	0.32
44	Back Paddock	R1	35.7	9.87	6.17	2.69	0.416	0.364	0.241	1.4E-03	0.137	107	16.6	1.11	0.63
45	Front Paddock	R2	12.9	2.76	1.90	0.80	0.127	0.116	0.082	5.9E-04	0.068	124	33.5	2.86	2.28
			2.37	0.90	0.51	0.23	0.07	0.06	0.09						

Source of Data: *Aug20_Discrete-Receptors.xls*

ID_Receptor	X	Y
	[m]	[m]
A1	1933198	5617105
A2	1934298	5616925
A3	1935310	5613252
A4	1933933	5613992
A5	1935401	5615366
A6	1935284	5616345
A7	1935324	5614310
A8	1933776	5613972
A9	1936986	5612732
A10	1933094	5615495
A11	1934055	5612974
A12	1933396	5615499
A13	1933068	5614594
A14	1934925	5615399
A15	1932526	5614524
A16	1932996	5615015
A17	1934200	5615729
A18	1934038	5615768
A19	1936949	5613283
A20	1935591	5615060
C1	1935361	5618173
C2	1937085	5614374
C3	1935584	5618215
C4	1936874	5610993
C5	1934722	5615692
C6	1936334	5616323
C7	1936819	5612444
C8	1935375	5618339
C9	1934351	5615530
C10	1936451	5613681
C11	1936492	5618746
C12	1935123	5618224
C13	1936243	5610847
C14	1935476	5618274
C15	1936412	5617228
C16	1936659	5611481
C17	1936127	5610834
C18	1936988	5614598
C19	1936793	5616270
C20	1936065	5615180
C21	1935093	5614350
C22	1935219	5613428
C23	1937049	5612578
R1	1936771	5614514
R2	1936541	5614153

Appendix H: Contour plots

A1 Existing site configuration

A1.1 Fluoride

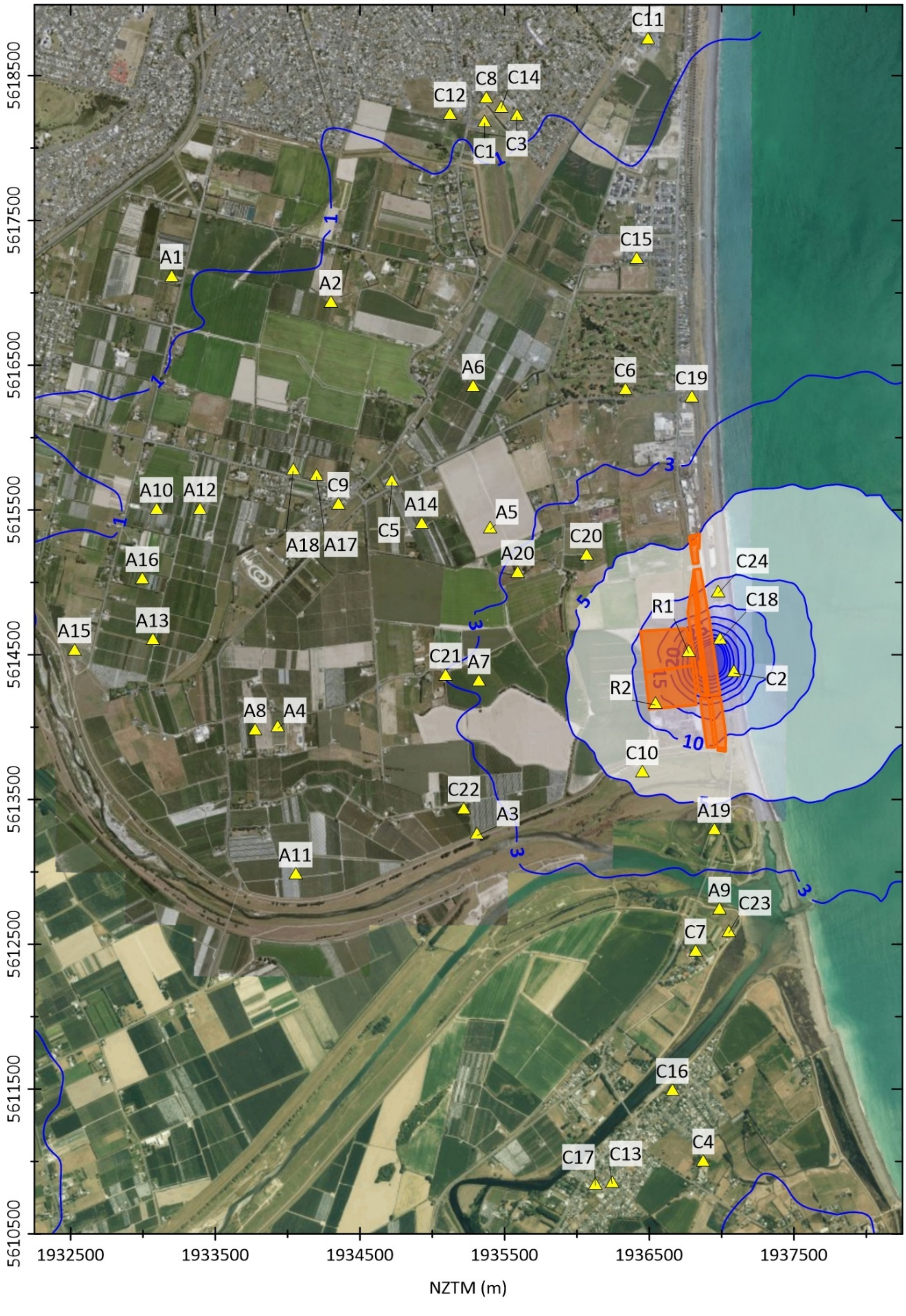

Figure 1: Predicted maximum 1-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

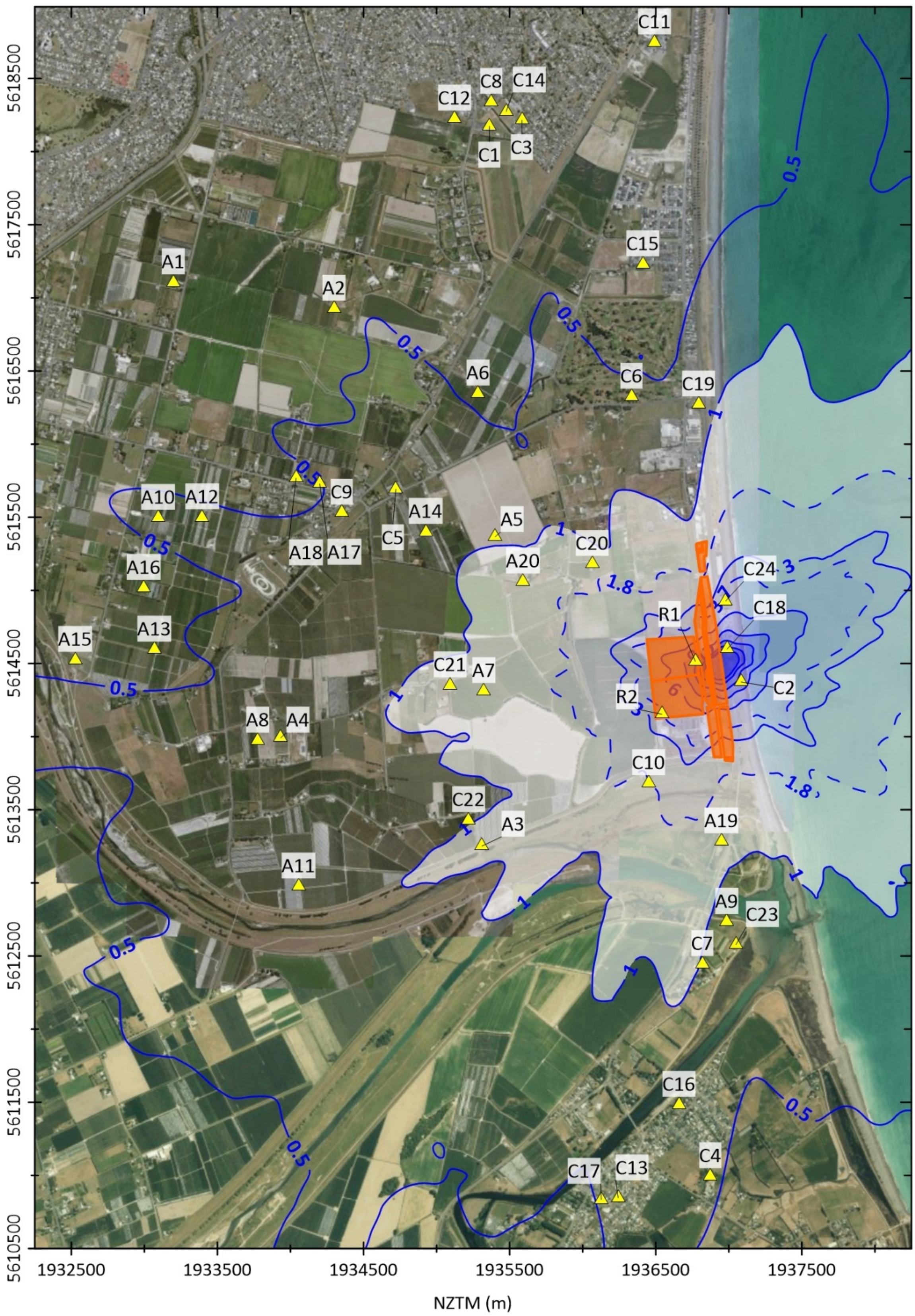

Figure 2: Predicted maximum 12-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

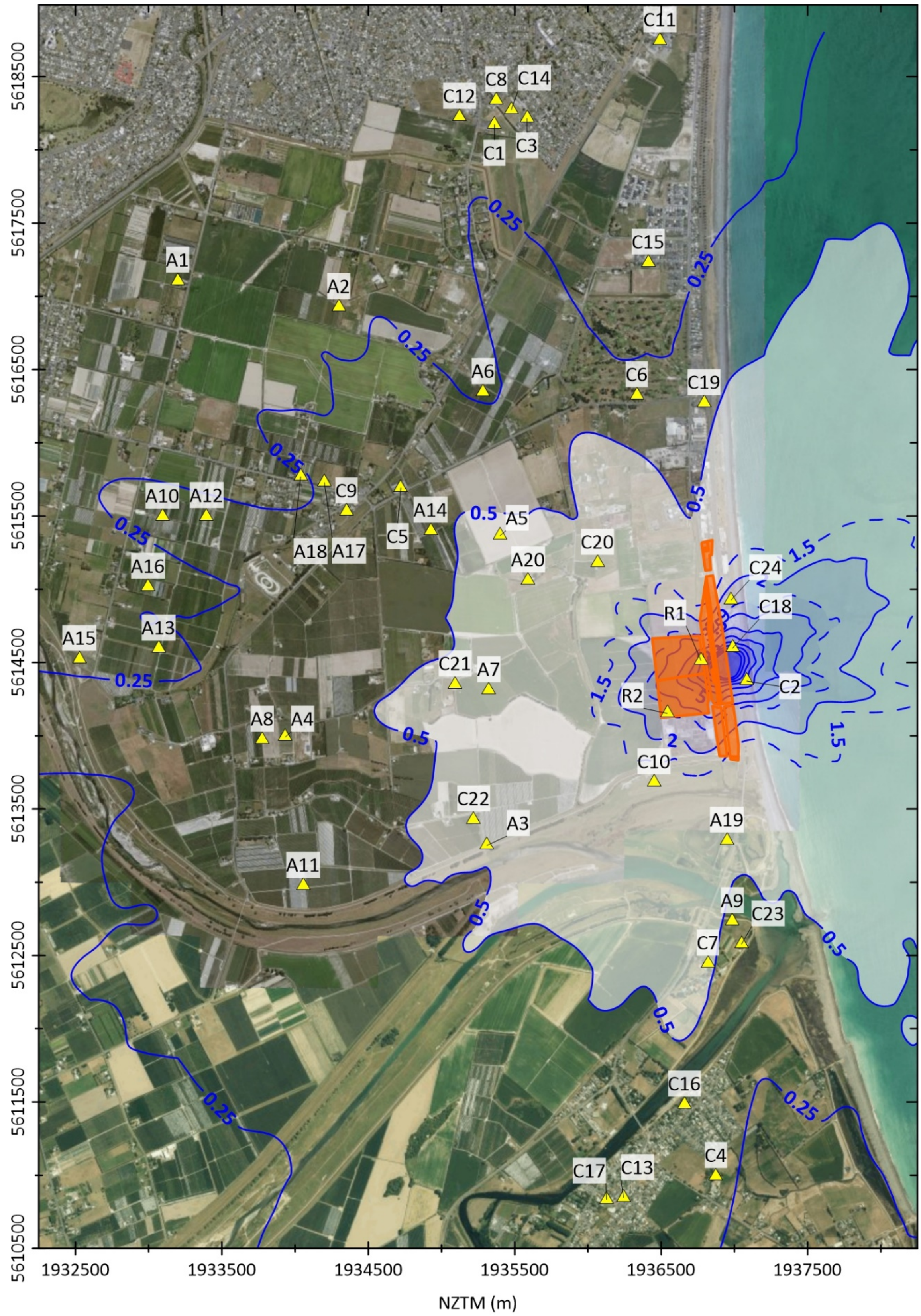

Figure 3: Predicted maximum 24-hour average fluoride GLC (µg/m³) – based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

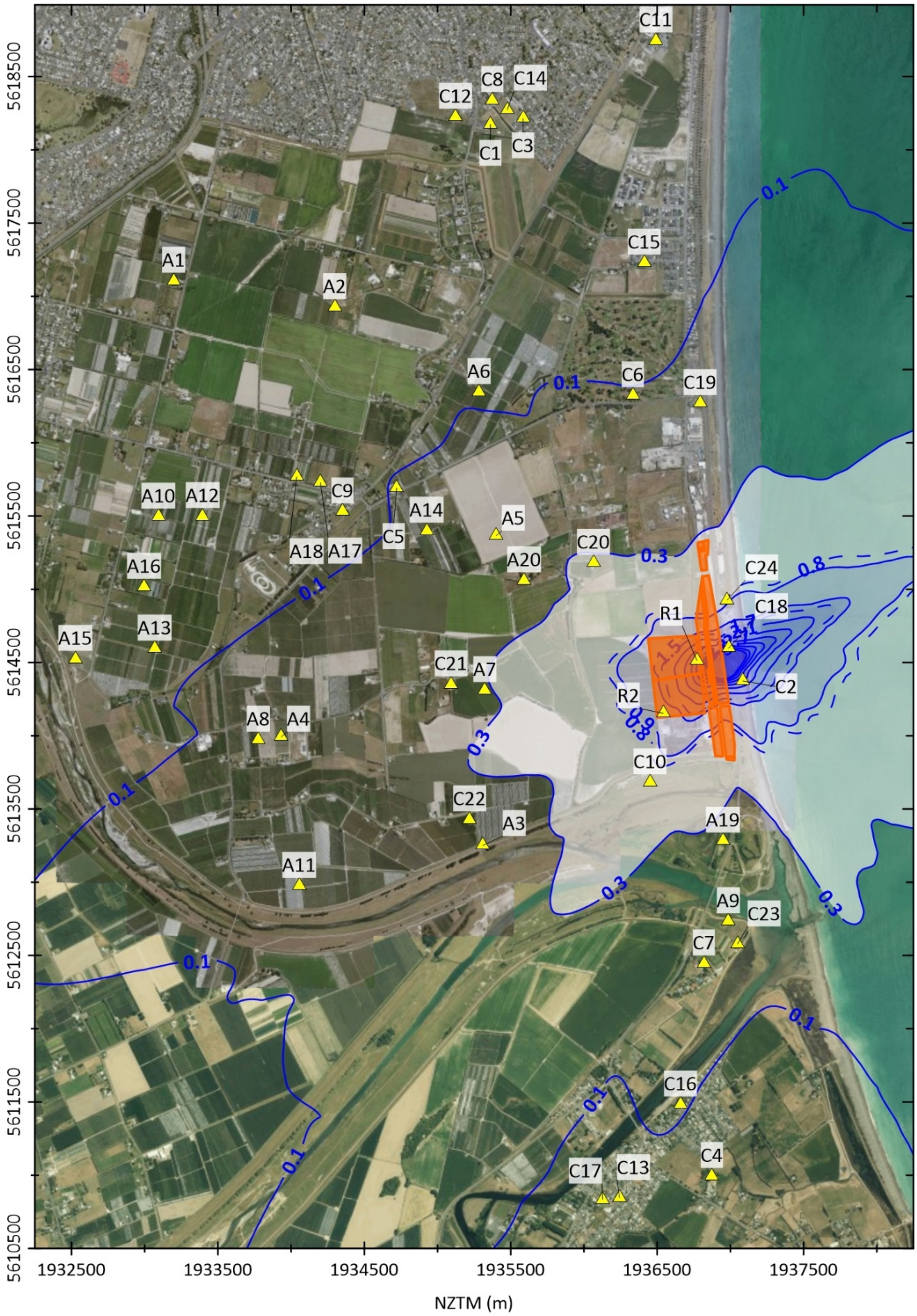

Figure 4: Predicted maximum 7-day average fluoride GLC (µg/m³)– based on peak emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

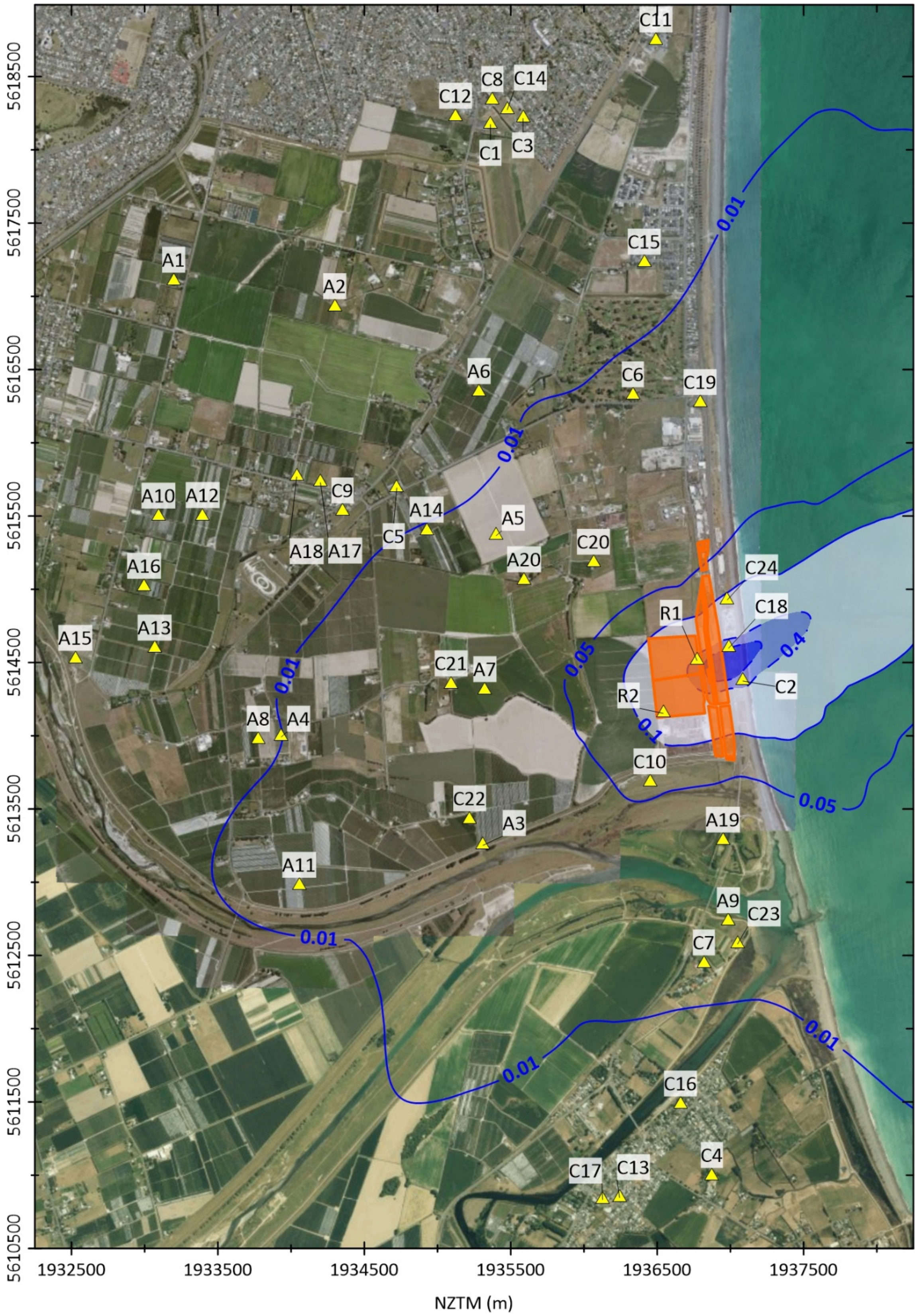

Figure 5:Predicted maximum 30-day average fluoride GLC (µg/m³) – based on 75th%ile of measured emission rates. Existing site configuration - site stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

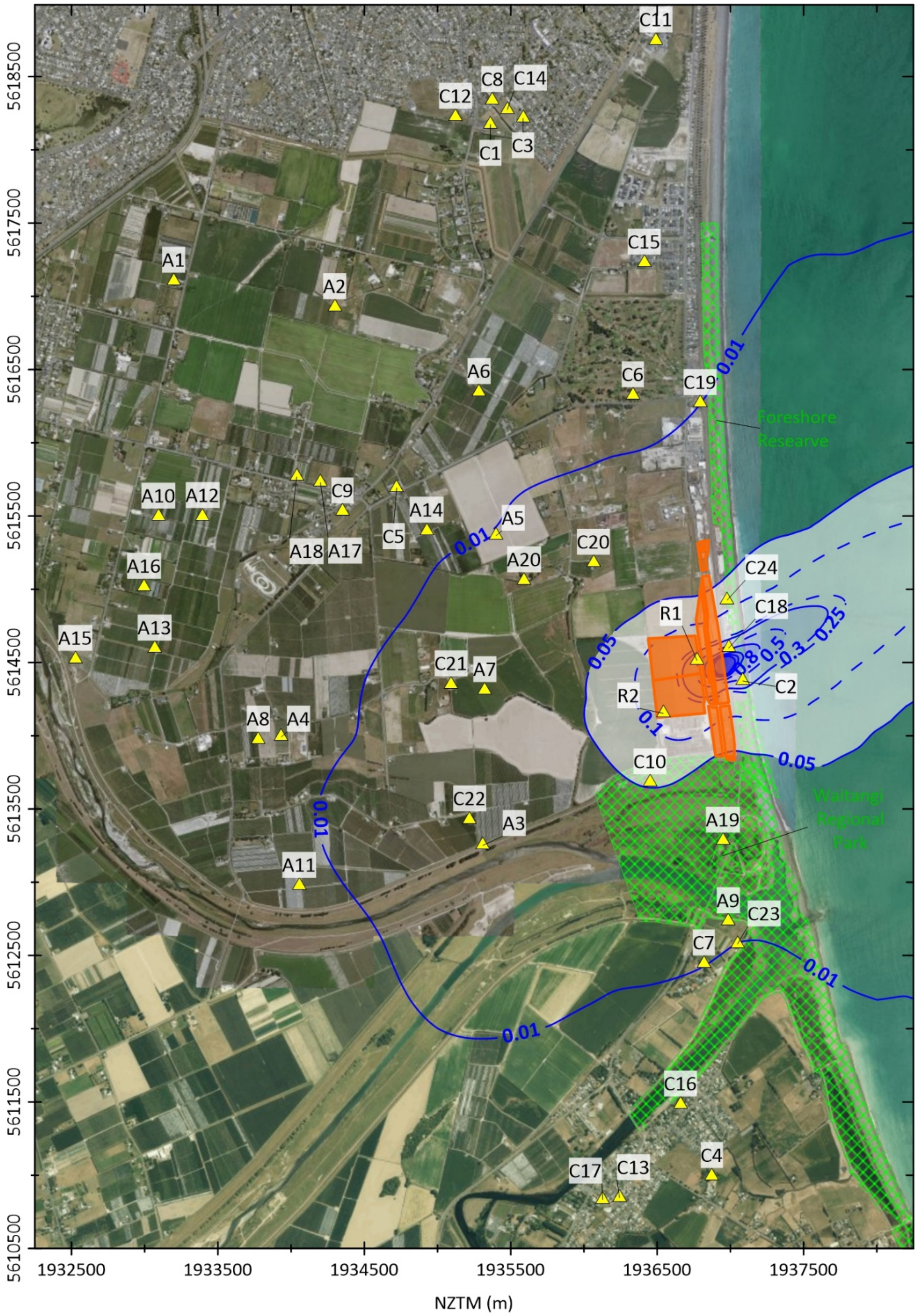

Figure 6: Predicted maximum 90-day average fluoride GLC (µg/m³)– based on 75th%ile of measured emission rates. Existing site configuration stack and fugitive emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

A1.2 Sulphur dioxide

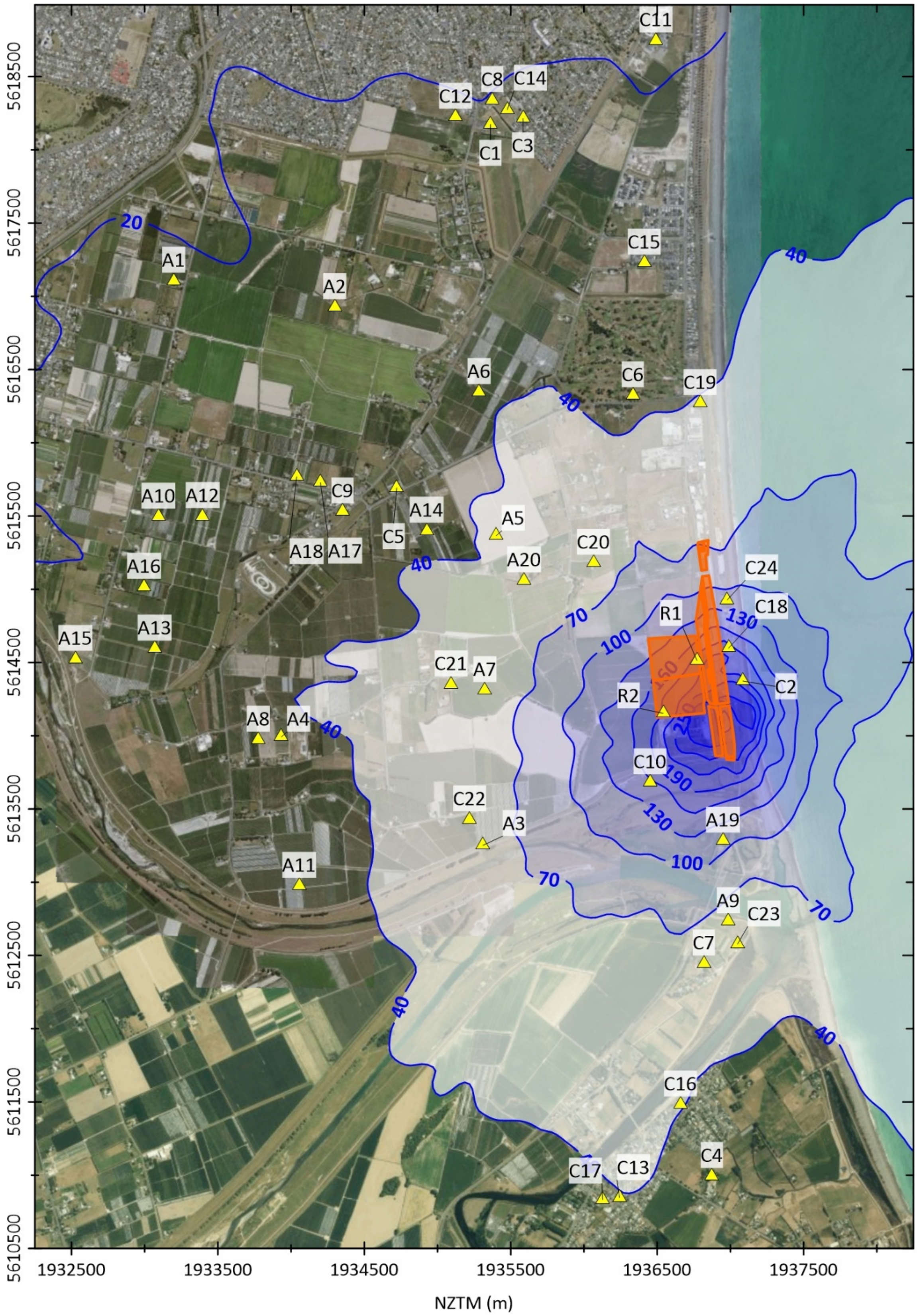

Figure 7: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC ($\mu g/m^3$) – based on peak emission rates. Existing site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

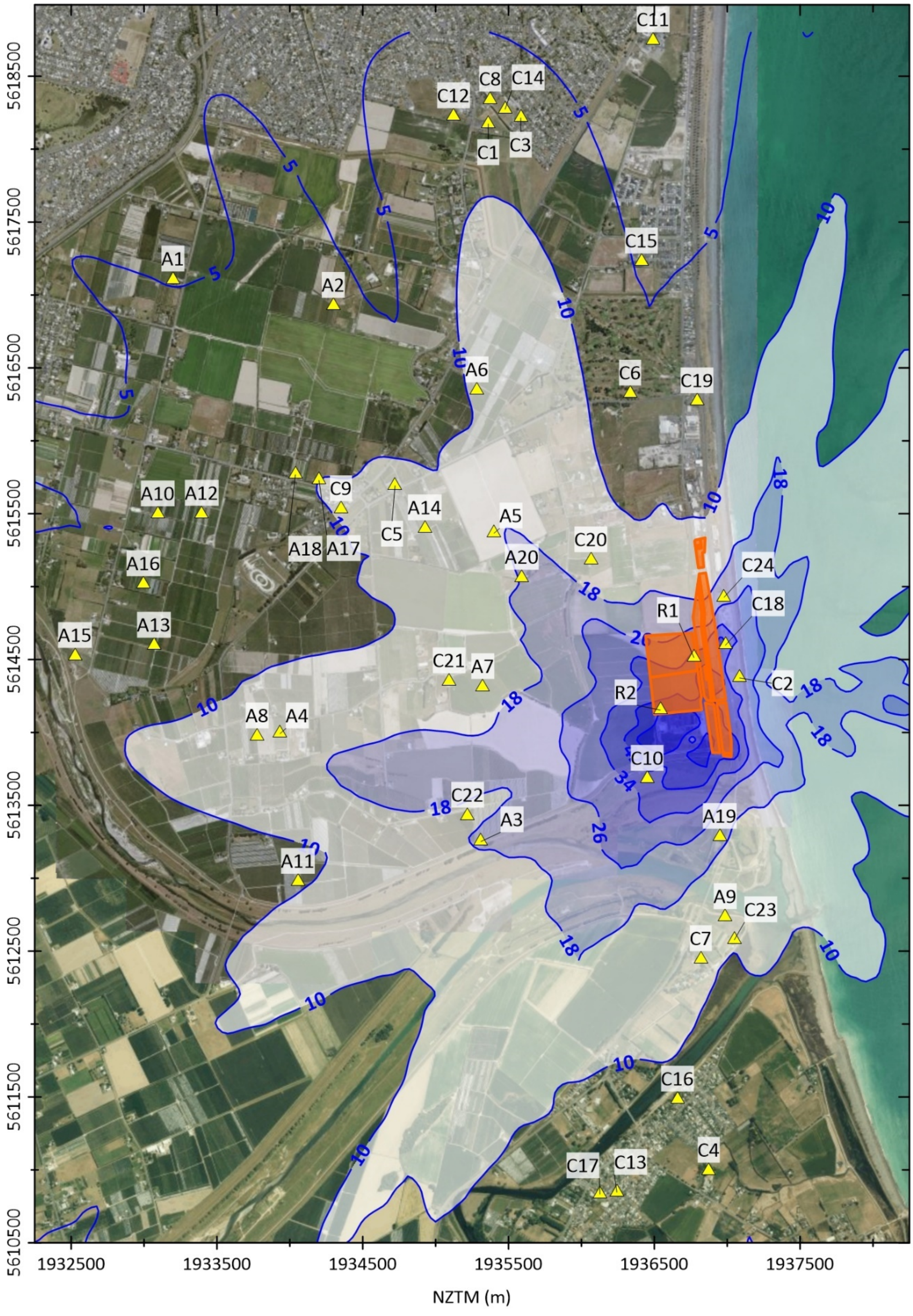

Figure 8: Predicted maximum 24-hour average SO_2 GLC (µg/m³)– based on peak emission rates. Existing site configuration - site emissions only. Figure includes all sensitive locations.

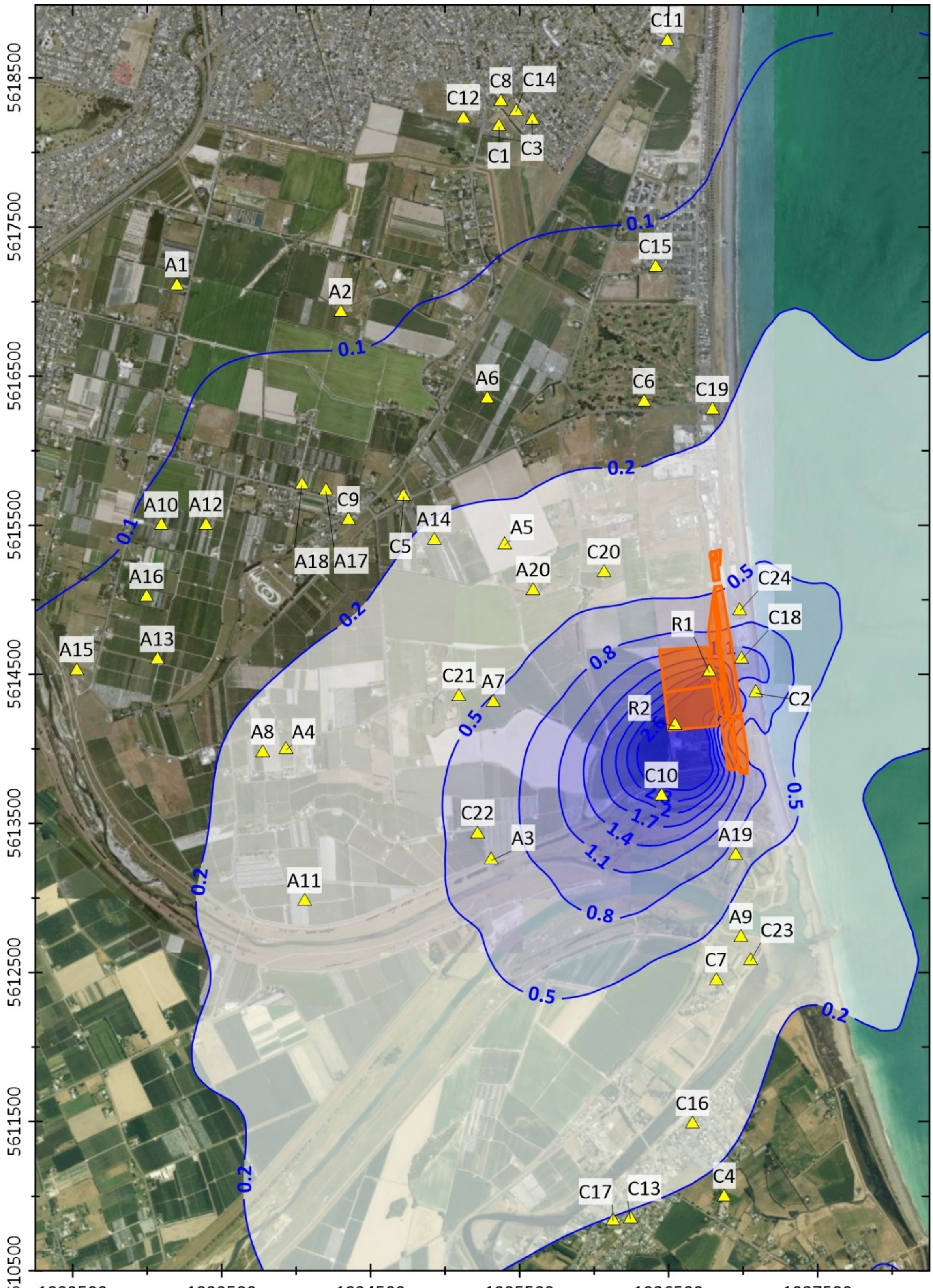

Figure 9: Predicted annual average SO_2 GLCs (µg/m³)– based on the 75th percentile of stack testing data. Existing site configuration - site emissions only. Figure includes all sensitive locations.

A1.3 Sulphur trioxide

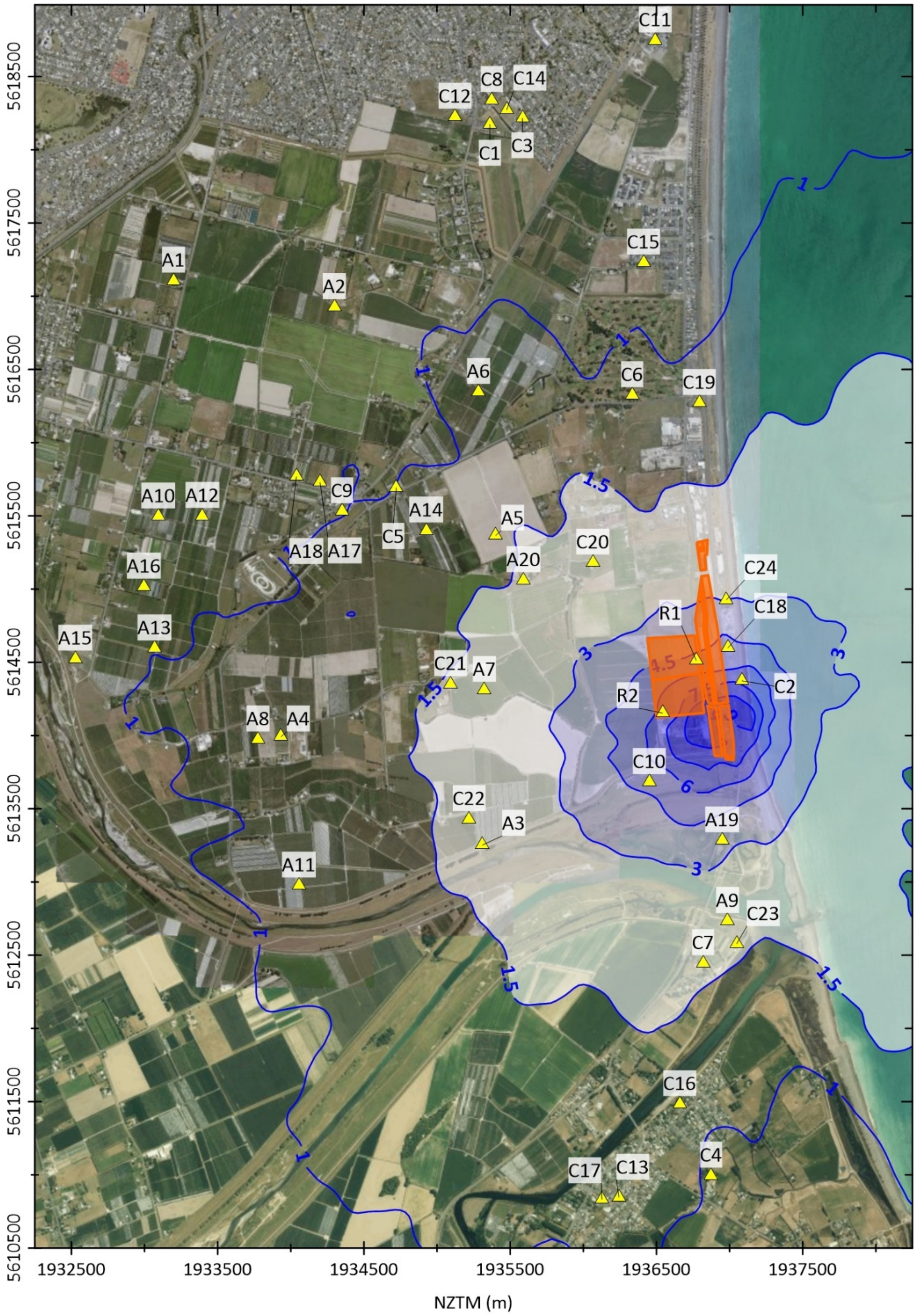

Figure 10: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_3 GLC (µg/m³) – based on peak emission rates. Existing site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

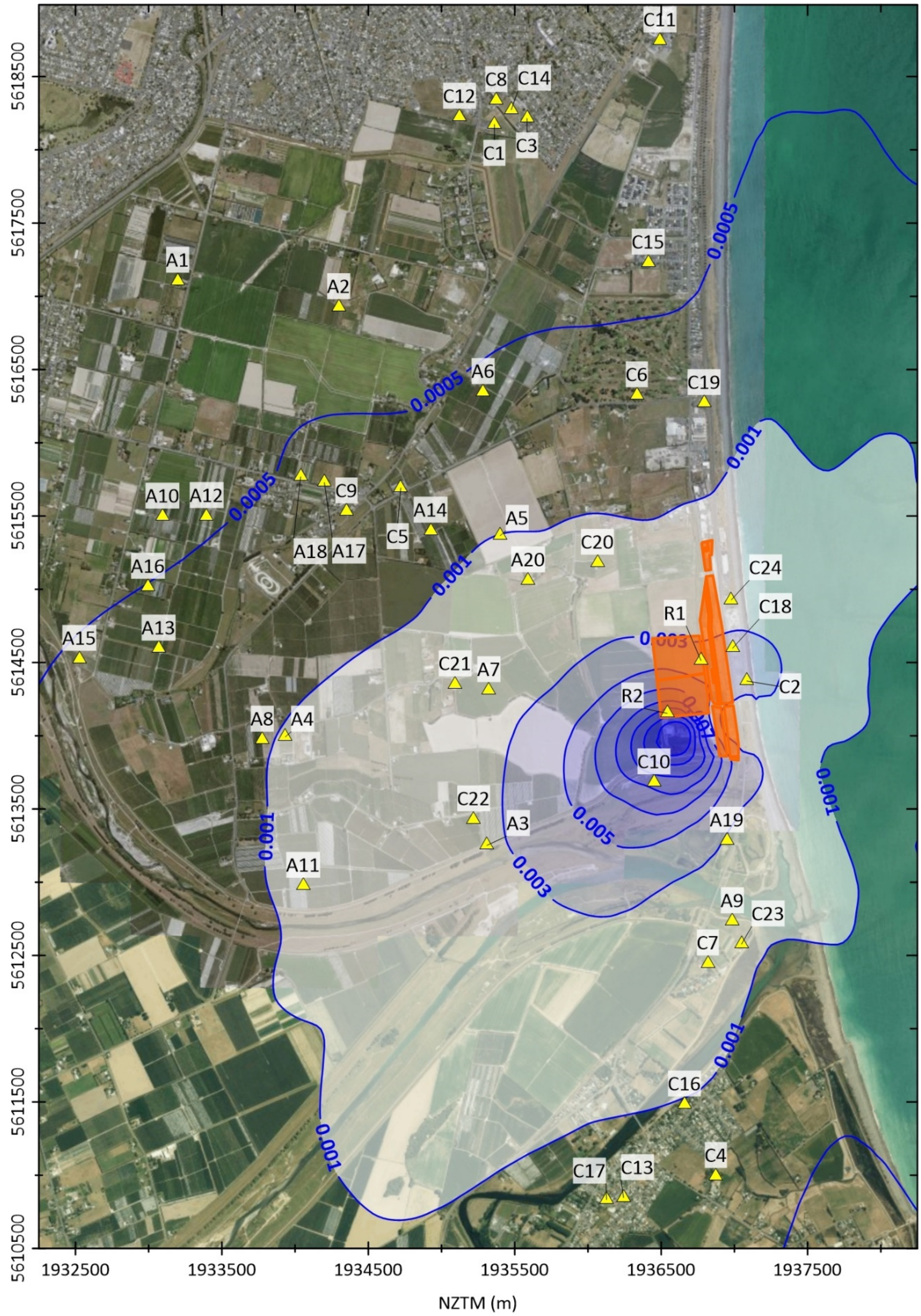

Figure 11: Predicted annual average SO_3 GLCs (µg/m³)– based on the 75th percentile of stack testing data. Existing site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

A1.4 Particulate matter

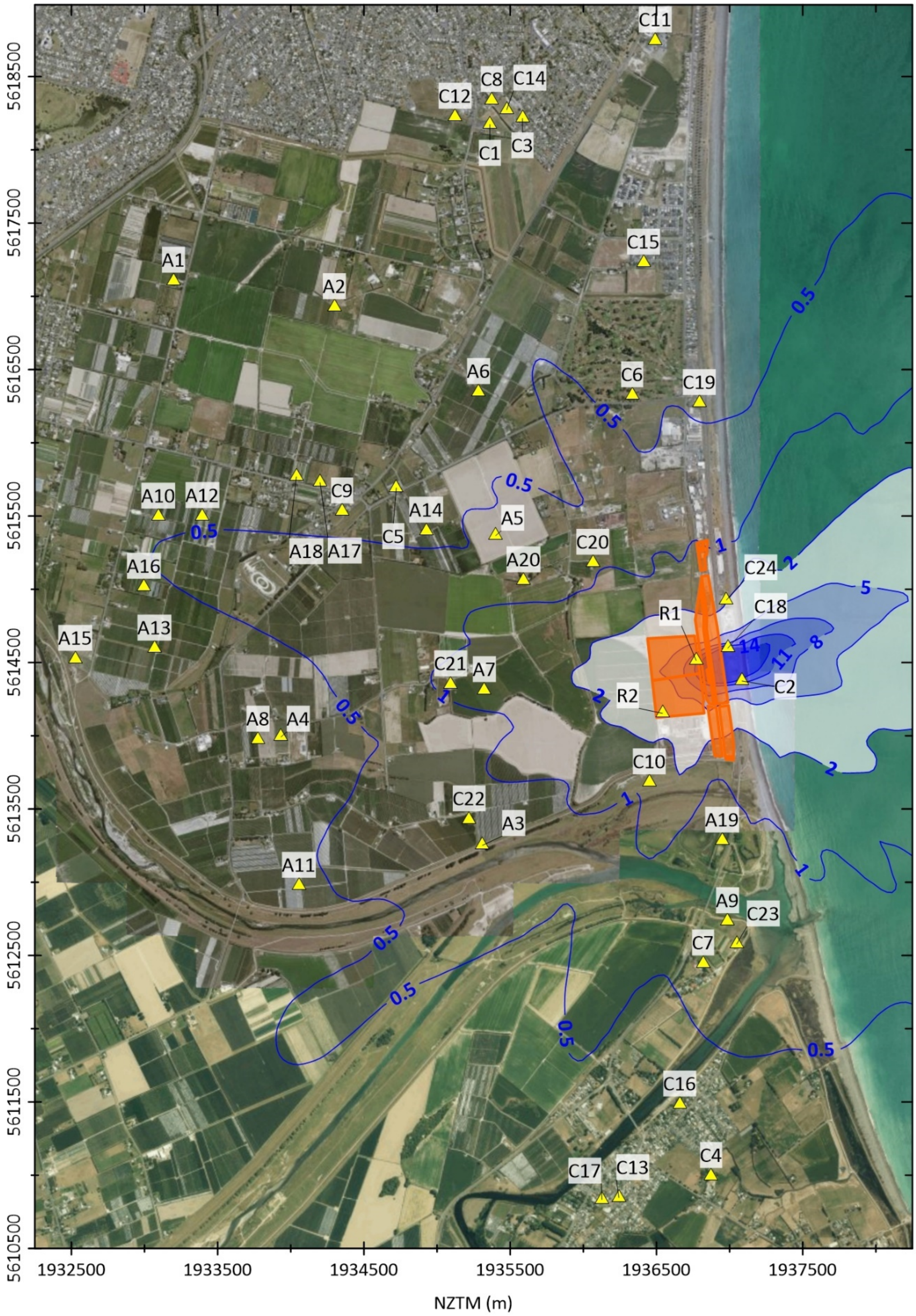

Figure 12: Predicted maximum 24-hour average PM_{10} GLC (µg/m³) – based on peak emission rates. Site emissions only. Figure includes all sensitive locations.

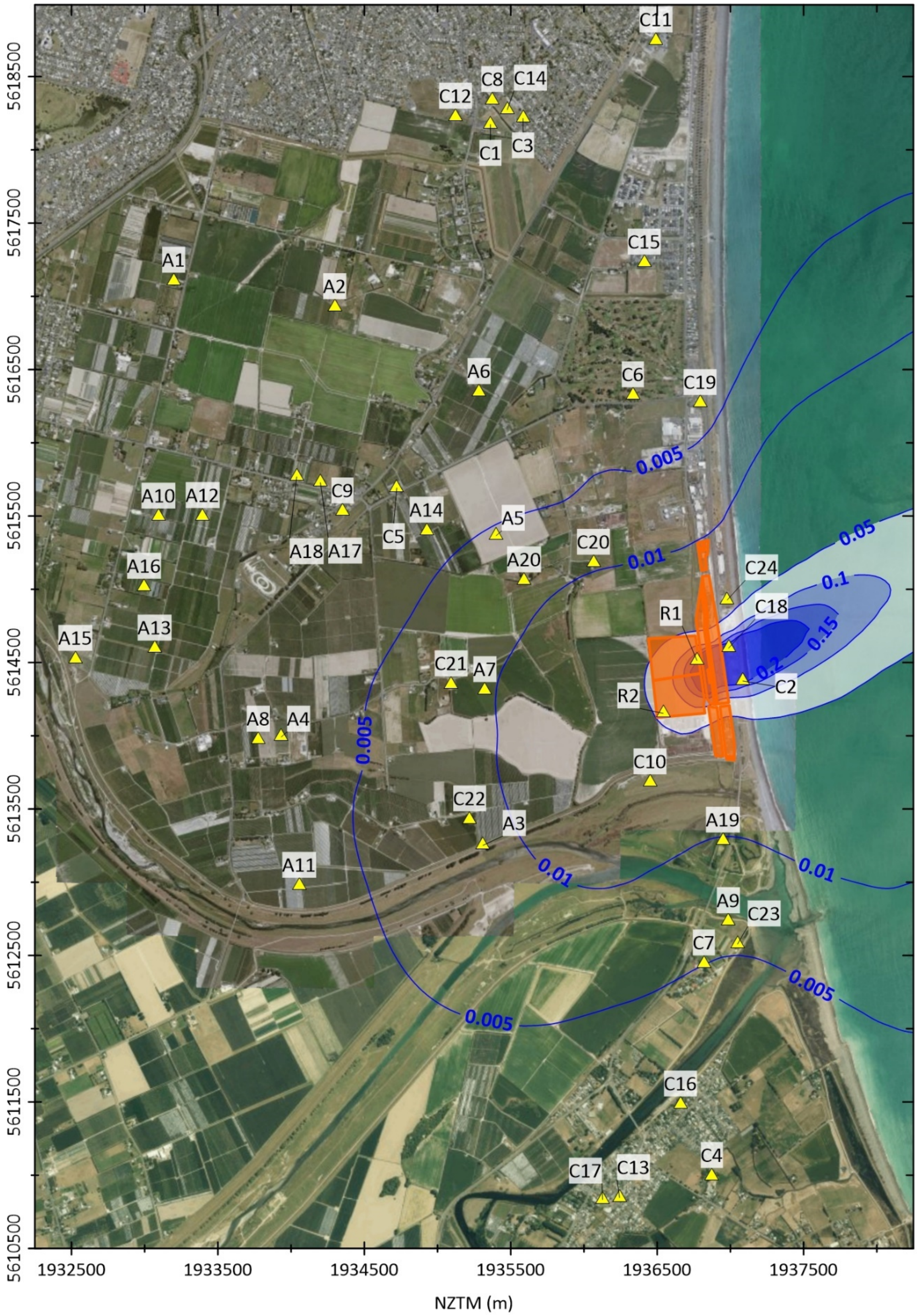

Figure 13: Predicted maximum annual average PM_{10} GLC (µg/m³) – based on the 75th percentile of stack testing data. Site emissions only. Figure includes all sensitive locations.

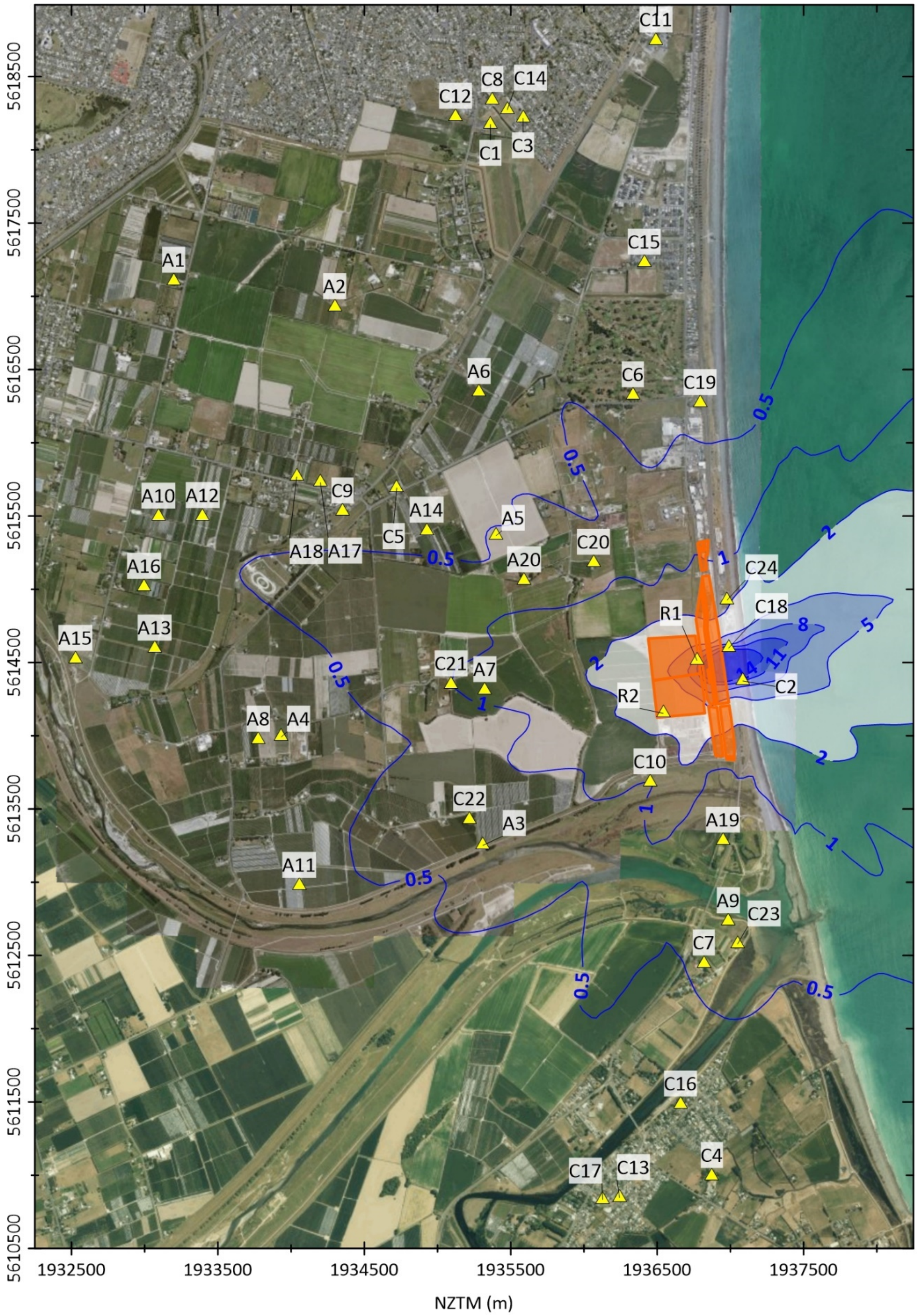

Figure 14: Predicted maximum 24-hour average $PM_{2.5}$ GLC (µg/m³) – based on peak emission rates. Site emissions only. Figure includes all sensitive locations.

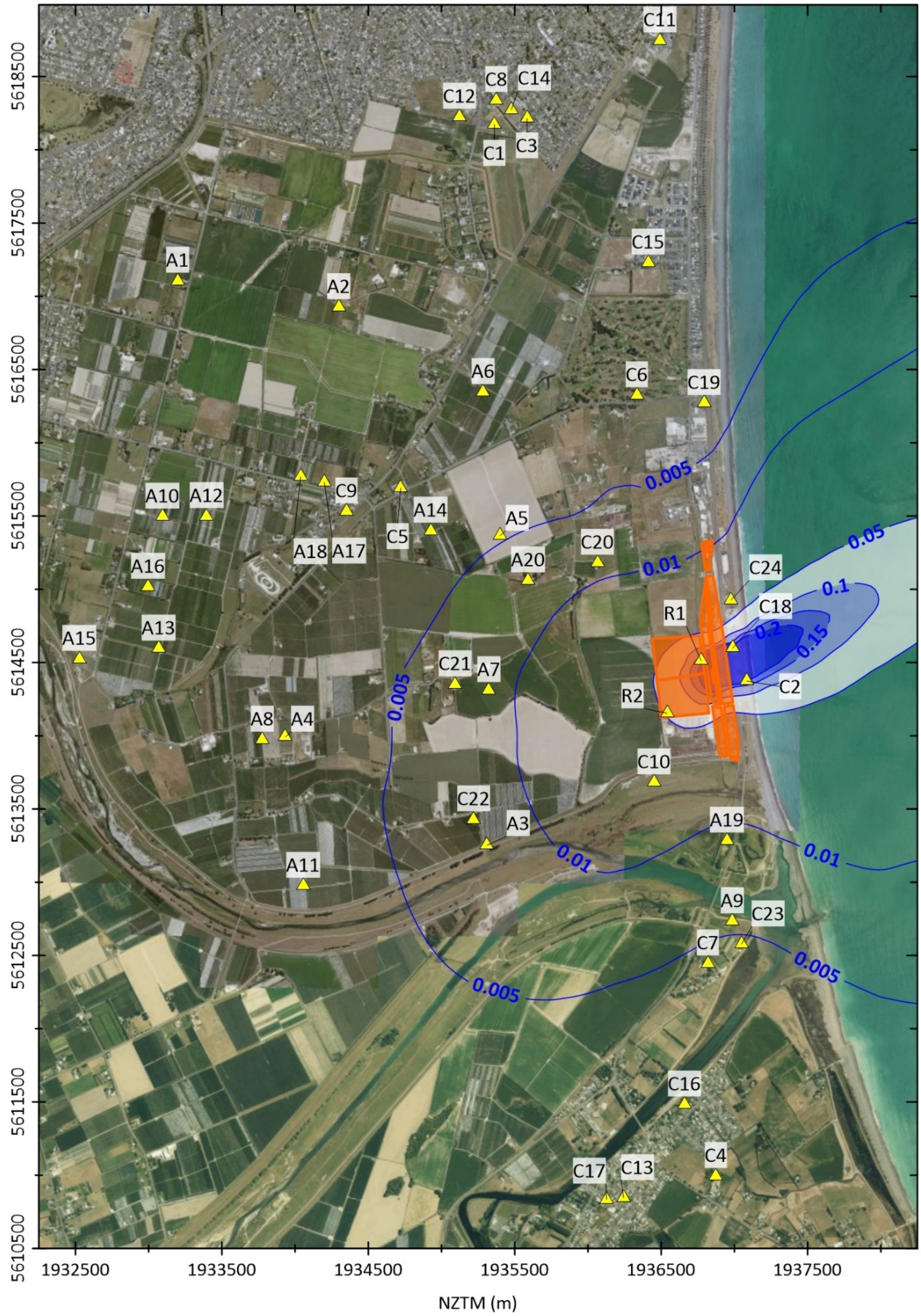

Figure 15: Predicted maximum annual average $PM_{2.5}$ GLC (µg/m³)– based on the 75th percentile of stack testing data. Site emissions only. Figure includes all sensitive locations.

A1.5 Fluoride and sulphur deposition

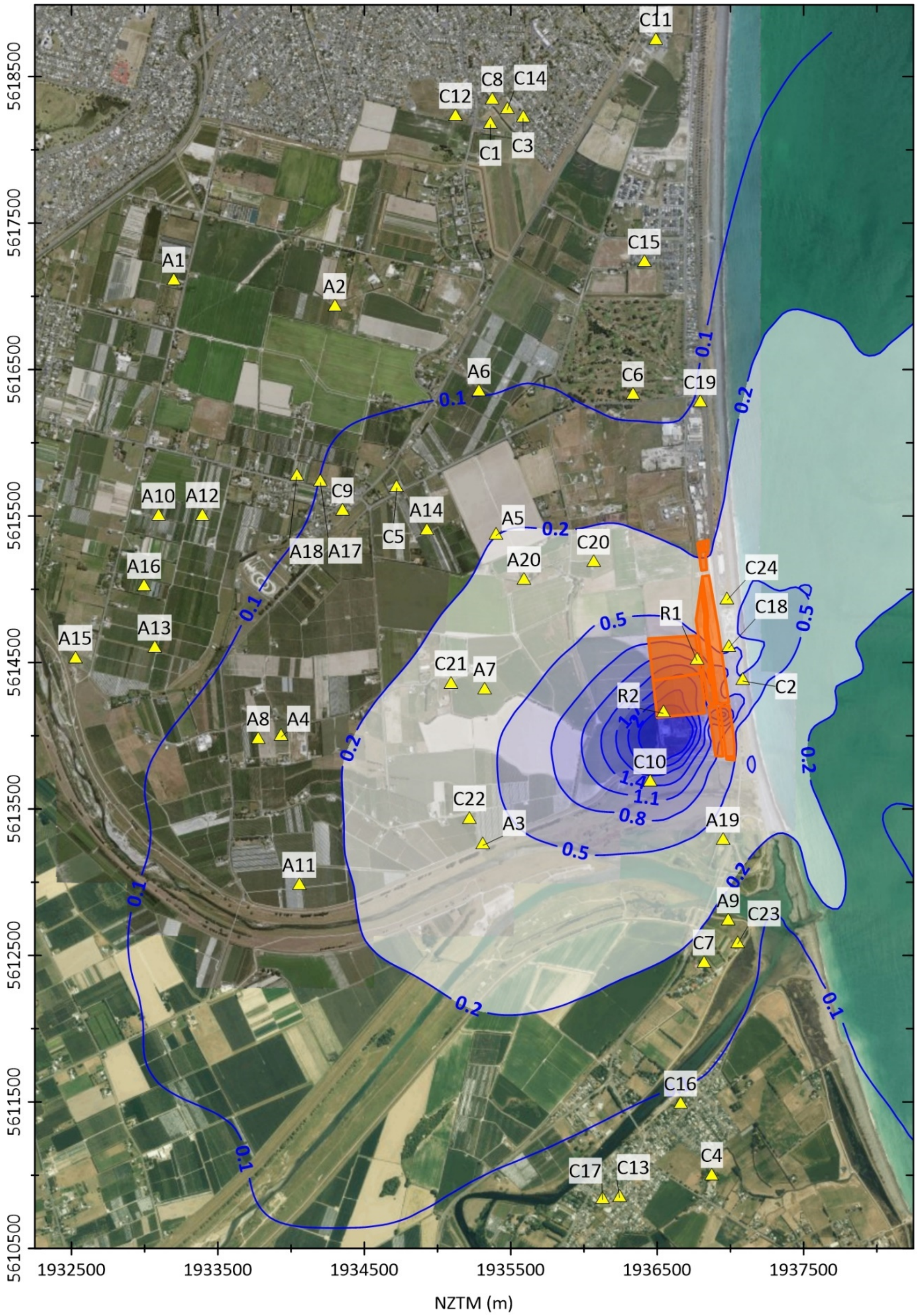

Figure 16: Predicted annual total sulphur deposition rate (kg/ha/yr) – based on the 75th percentile of stack testing data. Existing site configuration - site emissions only. Figure includes all sensitive locations.

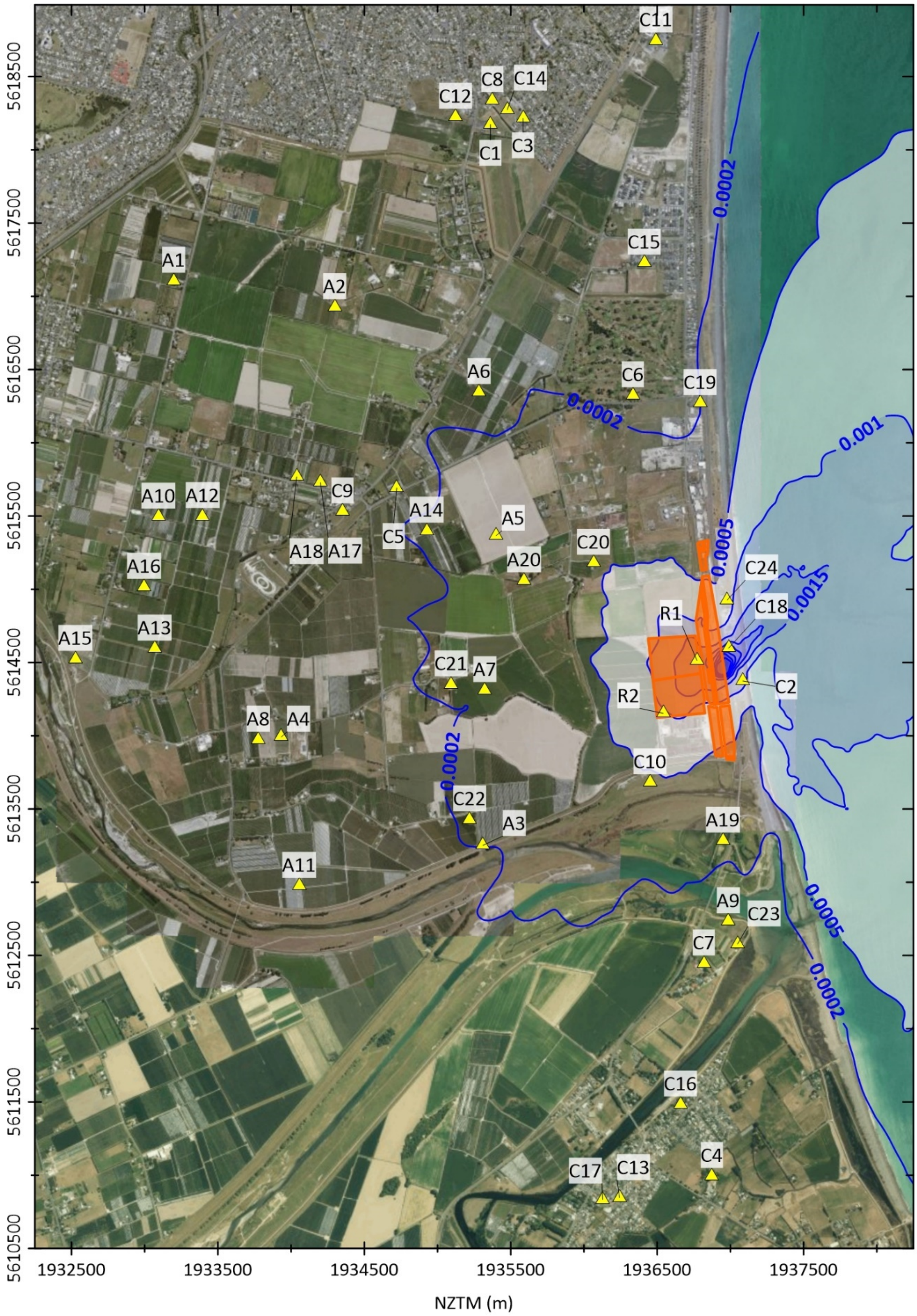

Figure 17: Predicted maximum 1-hour fluoride deposition (kg/ha/hr). Existing site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon. Figure includes all sensitive locations.

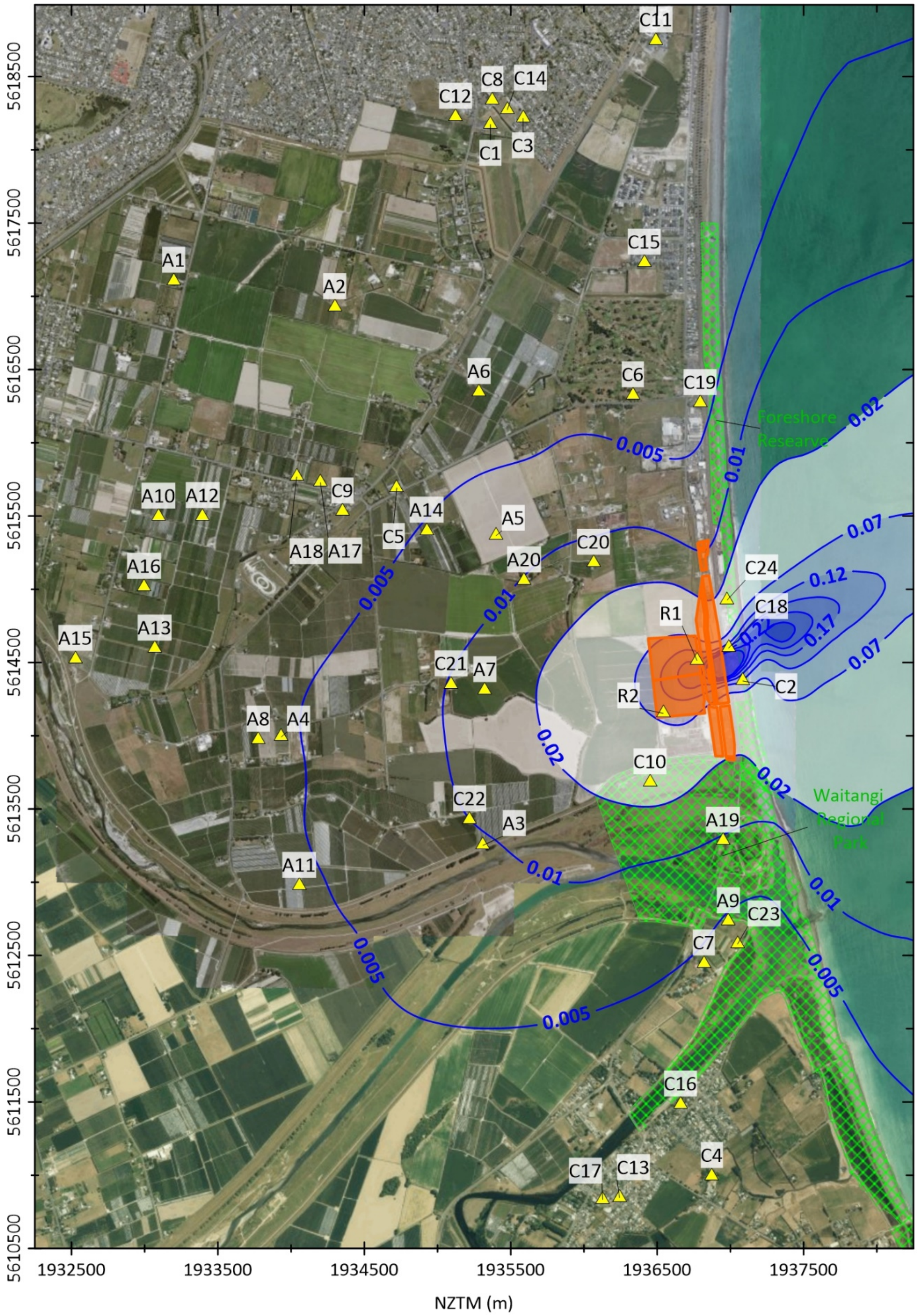

Figure 18: Predicted maximum annual fluoride deposition (kg/ha/yr). Existing site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon. Figure includes all sensitive locations.

A2 Site improvements

A2.1 Fluoride

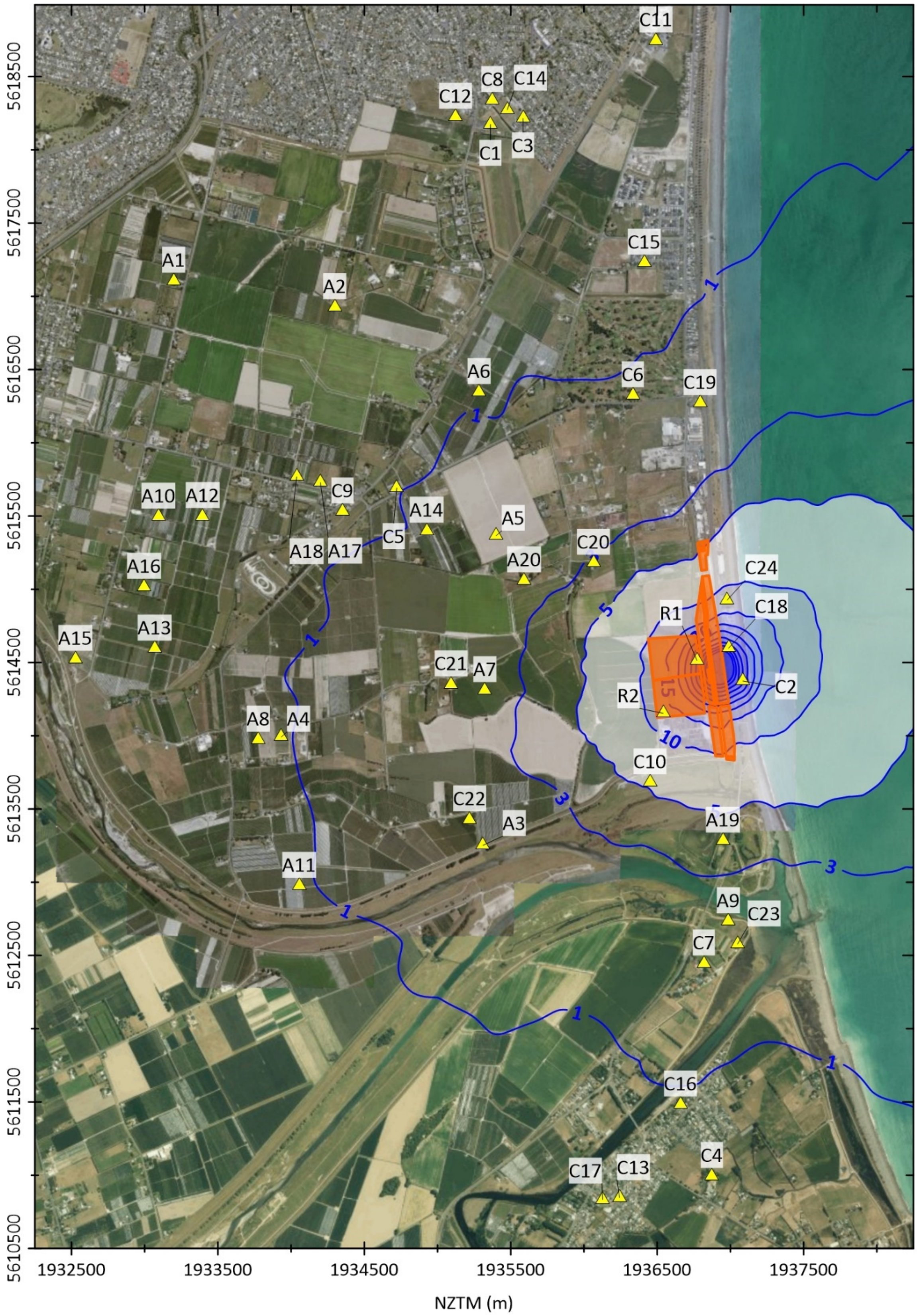

Figure 19: Predicted maximum 1-hour average fluoride GLC (µg/m³) – based on peak emission rates. Proposed site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

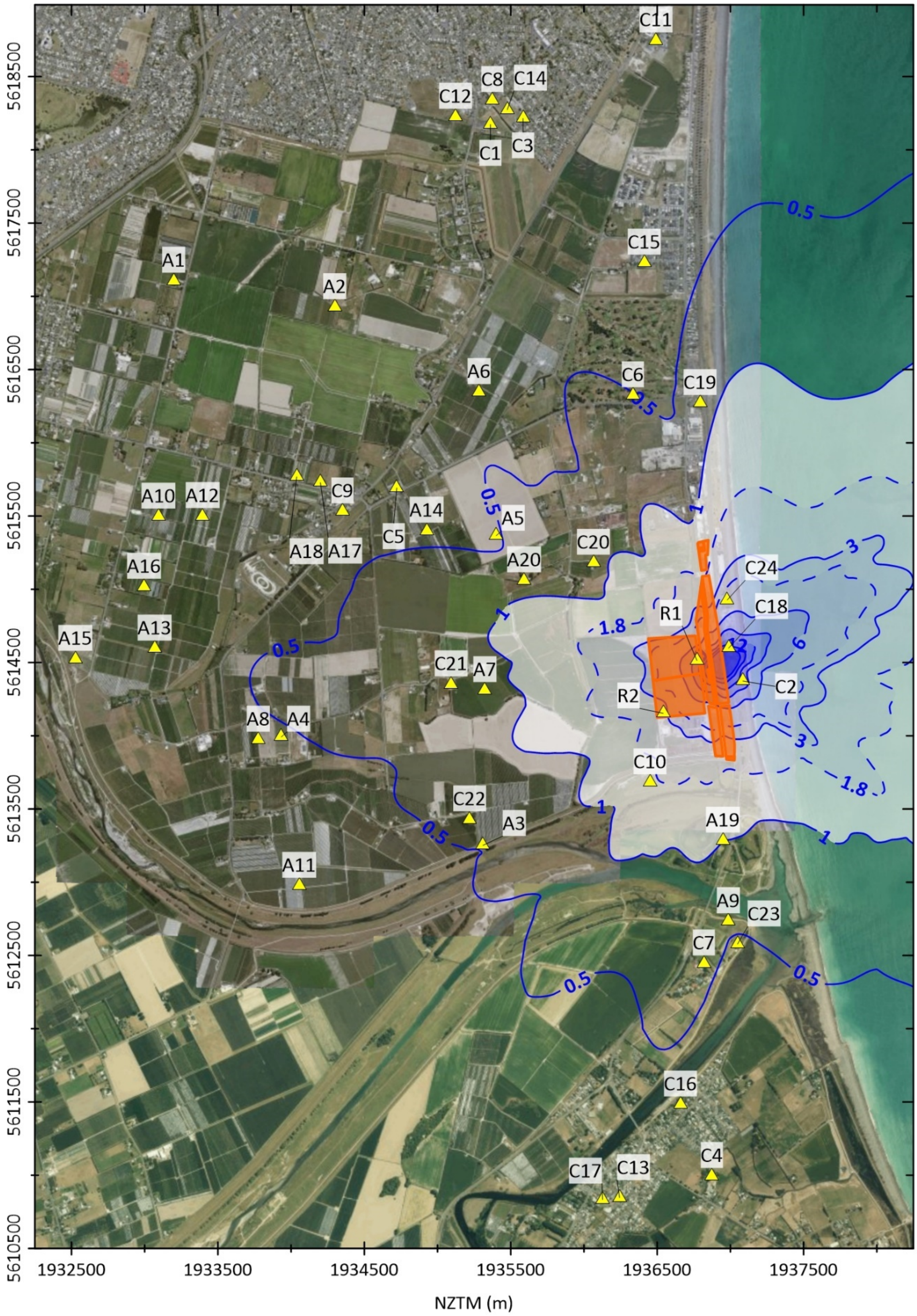

Figure 20: Predicted maximum 12-hour average fluoride GLC (µg/m³)– based on peak emission rates. Proposed site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

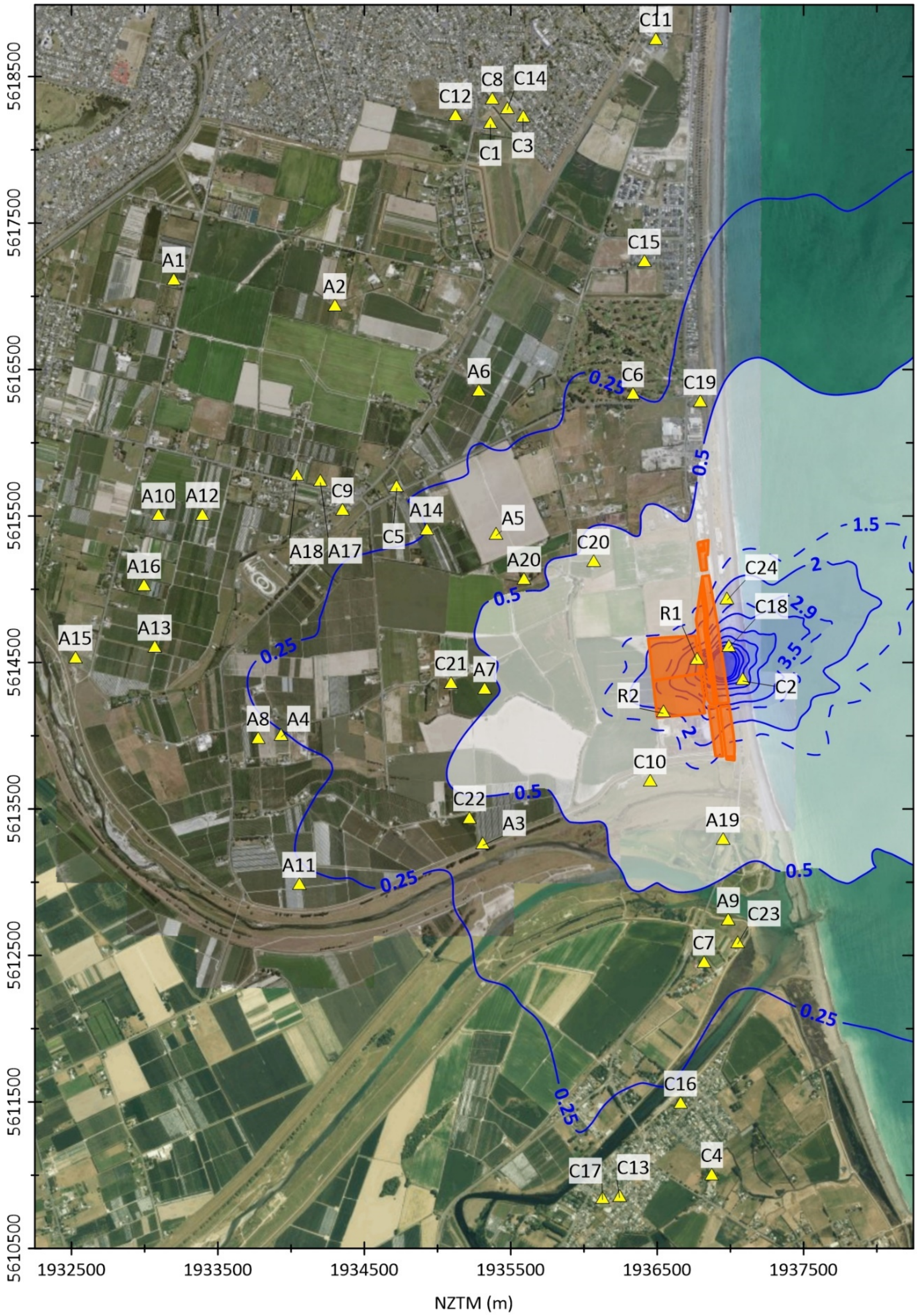

Figure 21: Predicted maximum 24-hour average fluoride GLC (µg/m³)– based on peak emission rates. Proposed site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

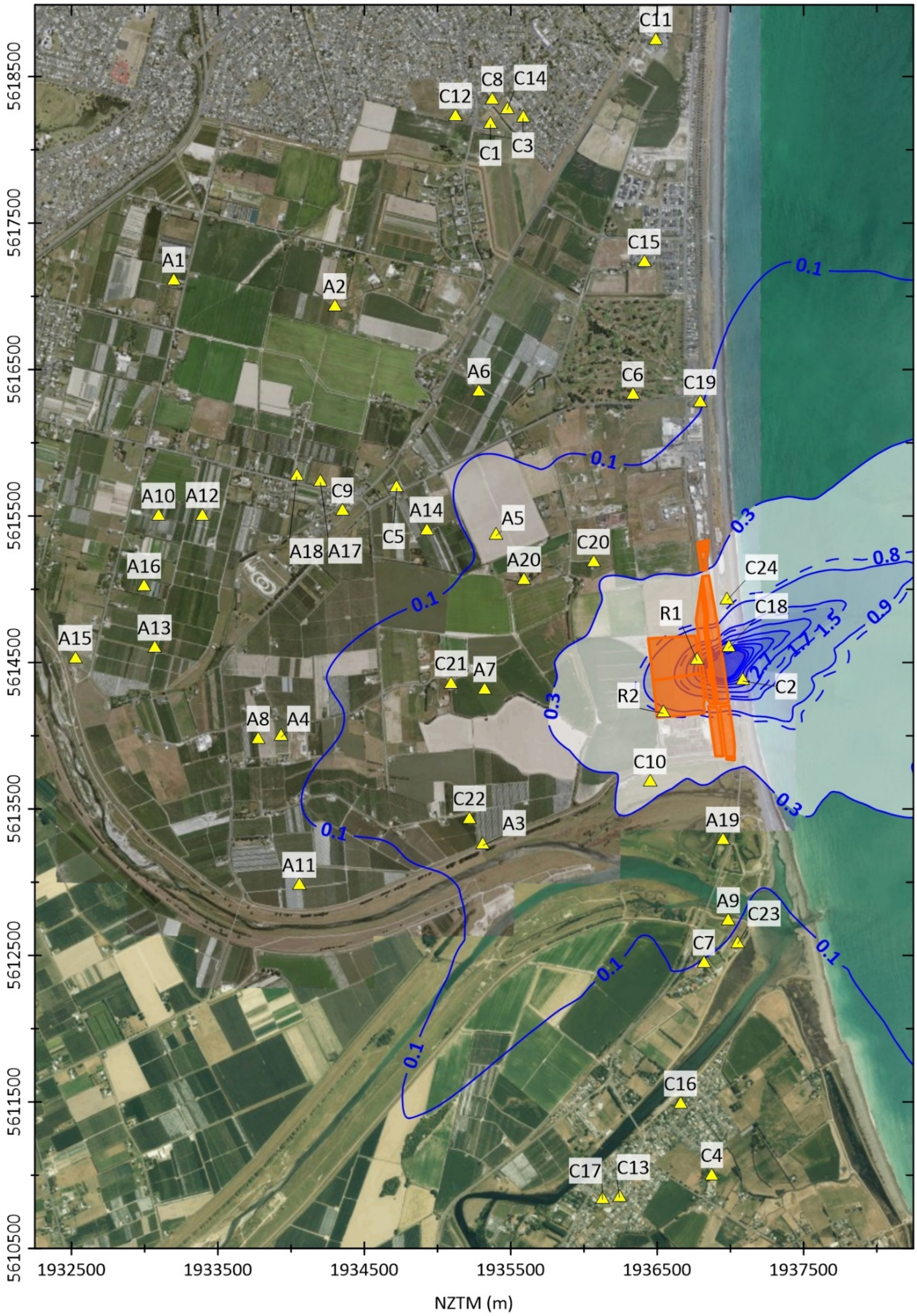

Figure 22: Predicted maximum 7-day average fluoride GLC (µg/m³) – based on peak emission rates. Proposed site configuration - fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

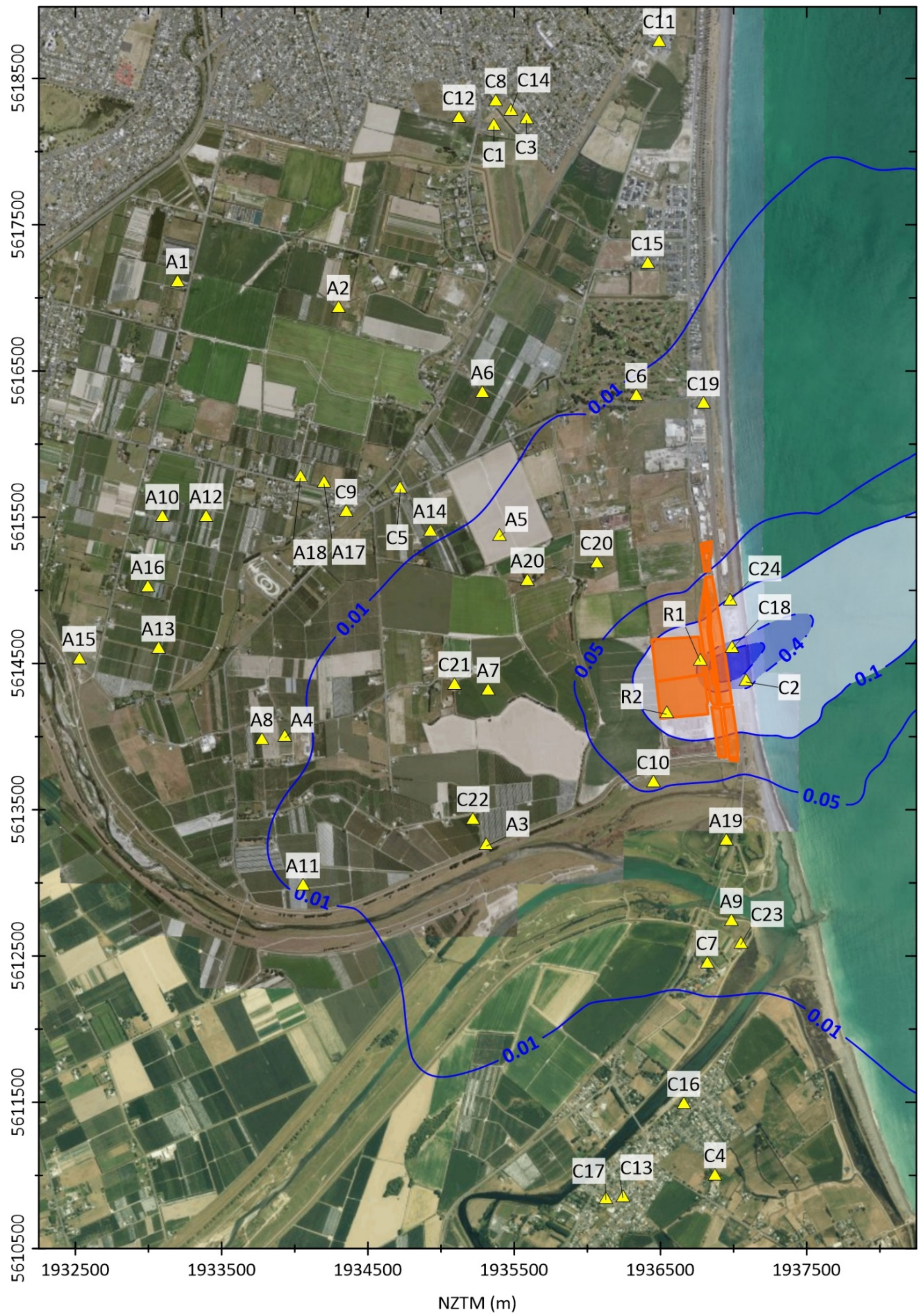

Figure 23:Predicted maximum 30-day average fluoride GLC (μg/m³)– based on 75th%ile of measured emission rates. Proposed site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

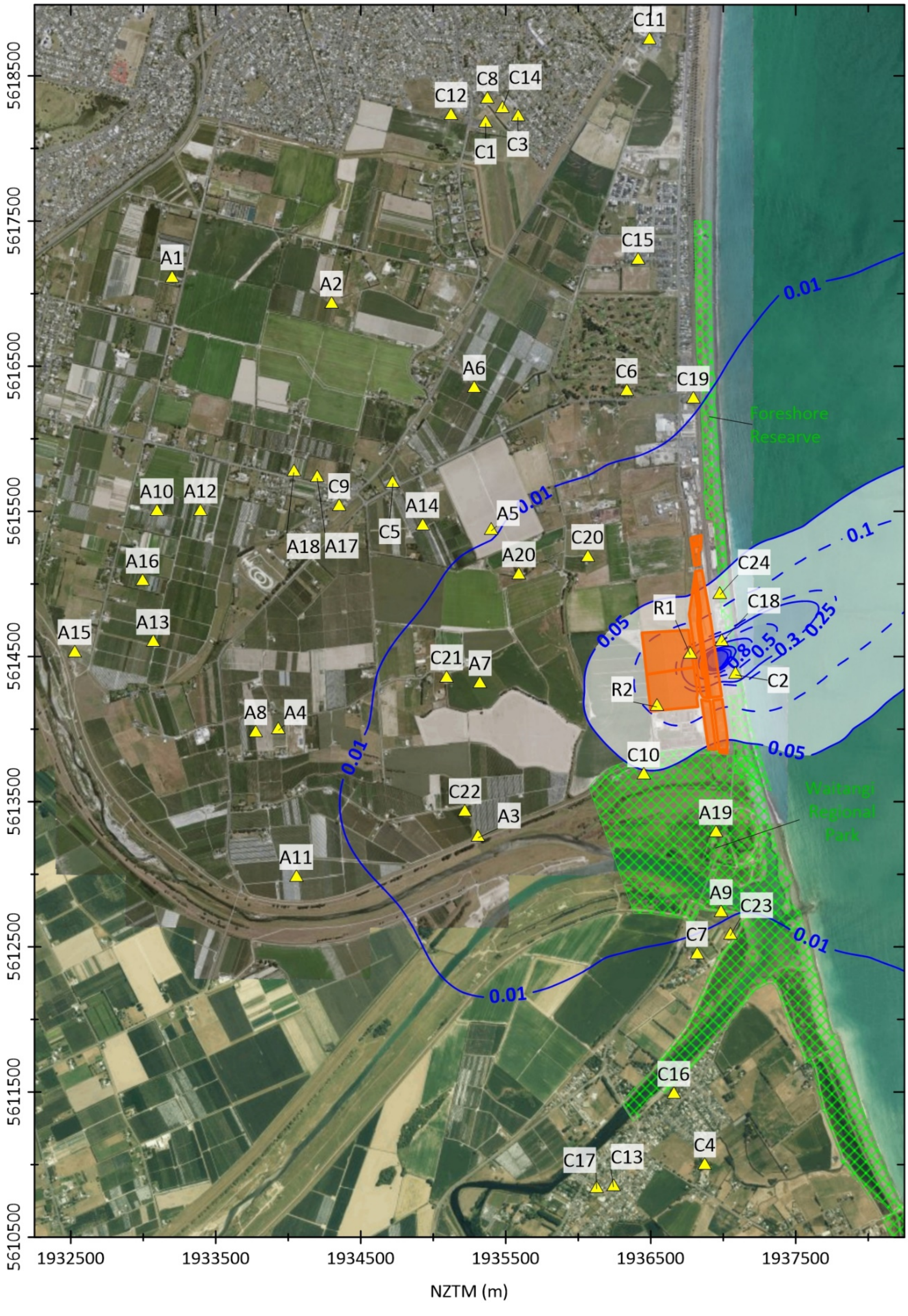

Figure 24: Predicted maximum 90-day average fluoride GLC (µg/m³)– based on 75th%ile of measured emission rates. Proposed site configuration – fugitive and stack emissions only. Ravensdown site extent indicated by the orange polygon. Dashed contour lines indicate the general and special land use values. Figure includes all sensitive locations.

A2.2 Sulphur dioxide

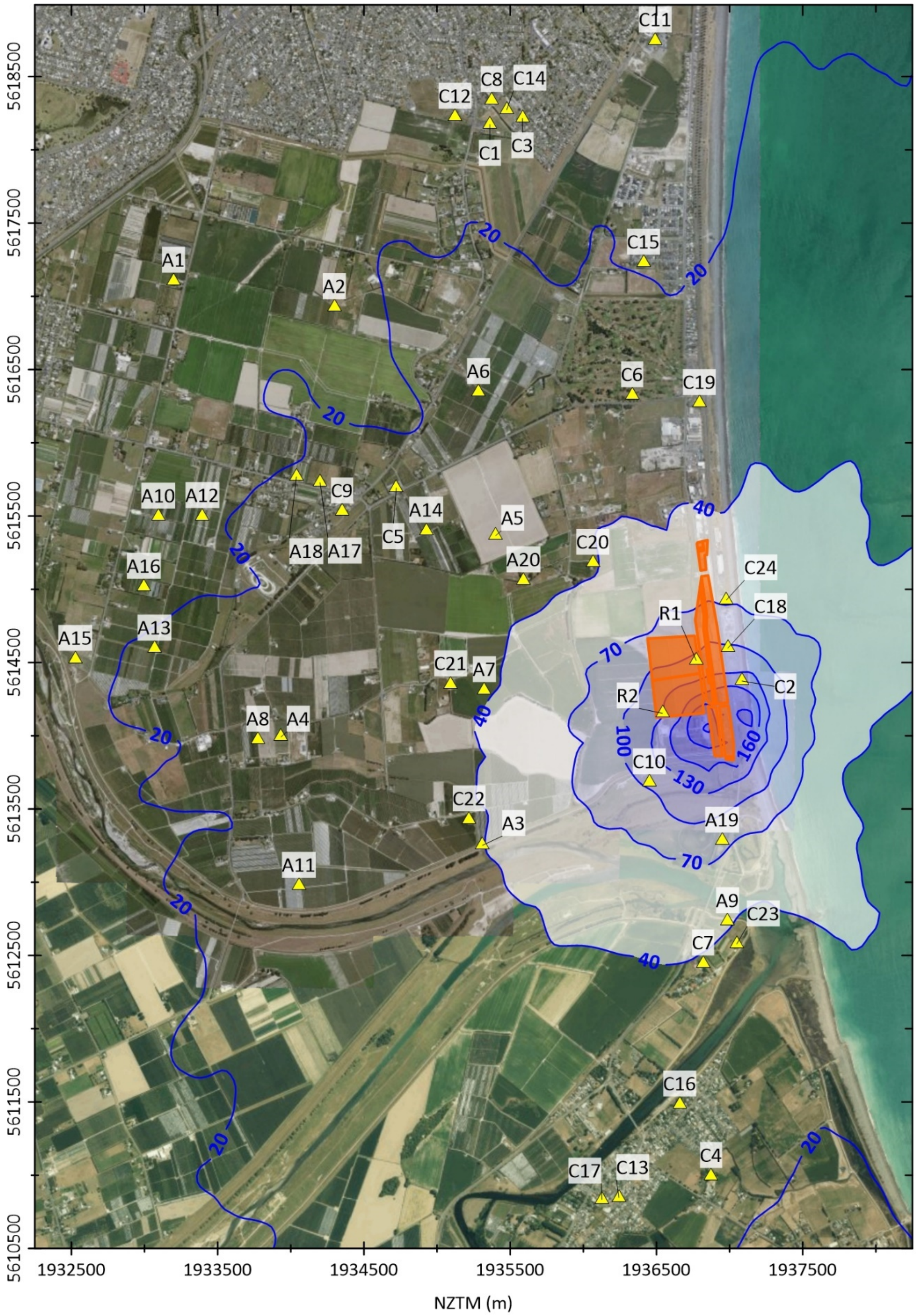

Figure 25: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC (µg/m³) – based on peak emission rates. Proposed site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

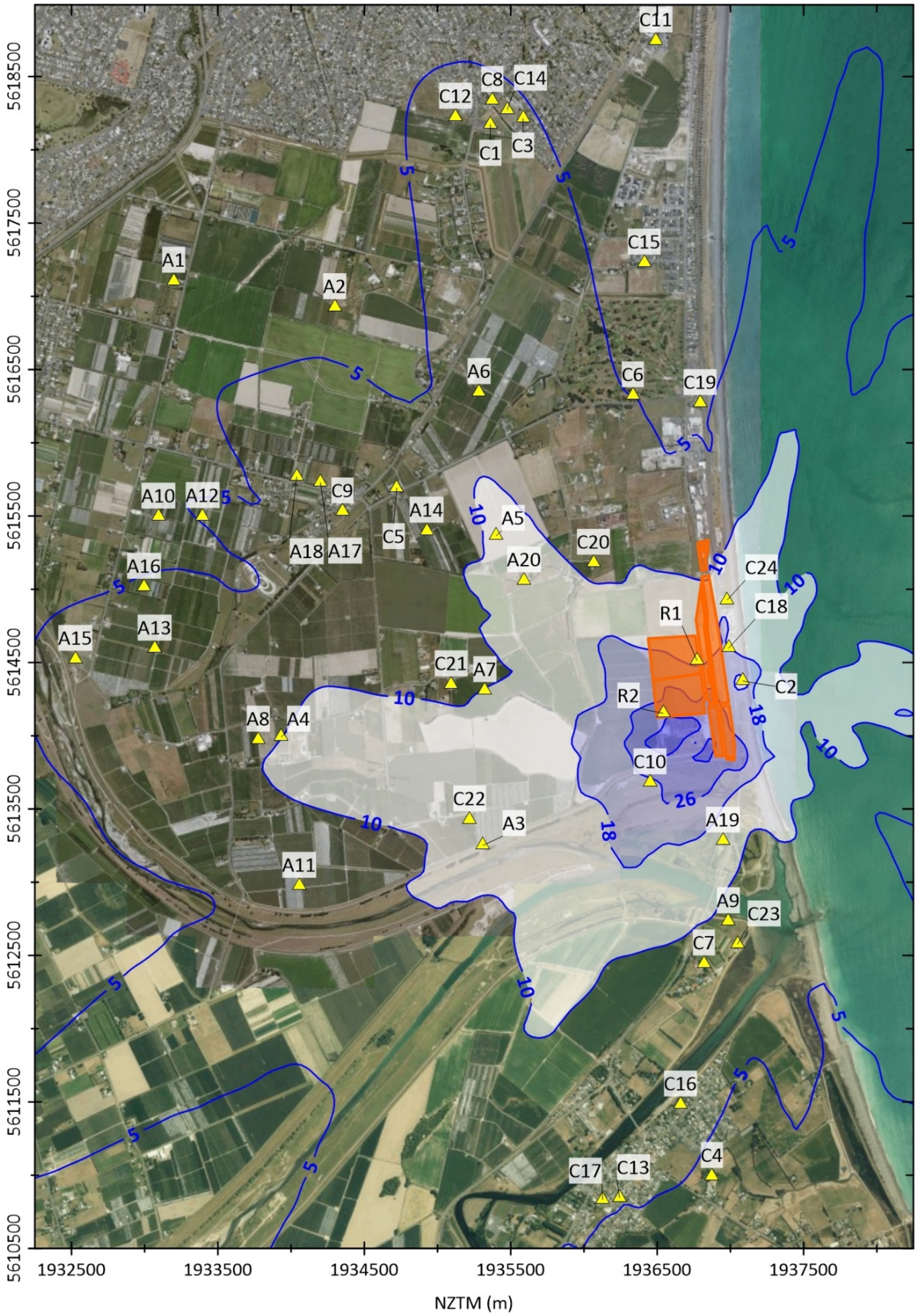

Figure 26: Predicted maximum 24-hour average SO_2 GLC (µg/m³) in the immediate surroundings – based on peak emission rates. Proposed (bottom) site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

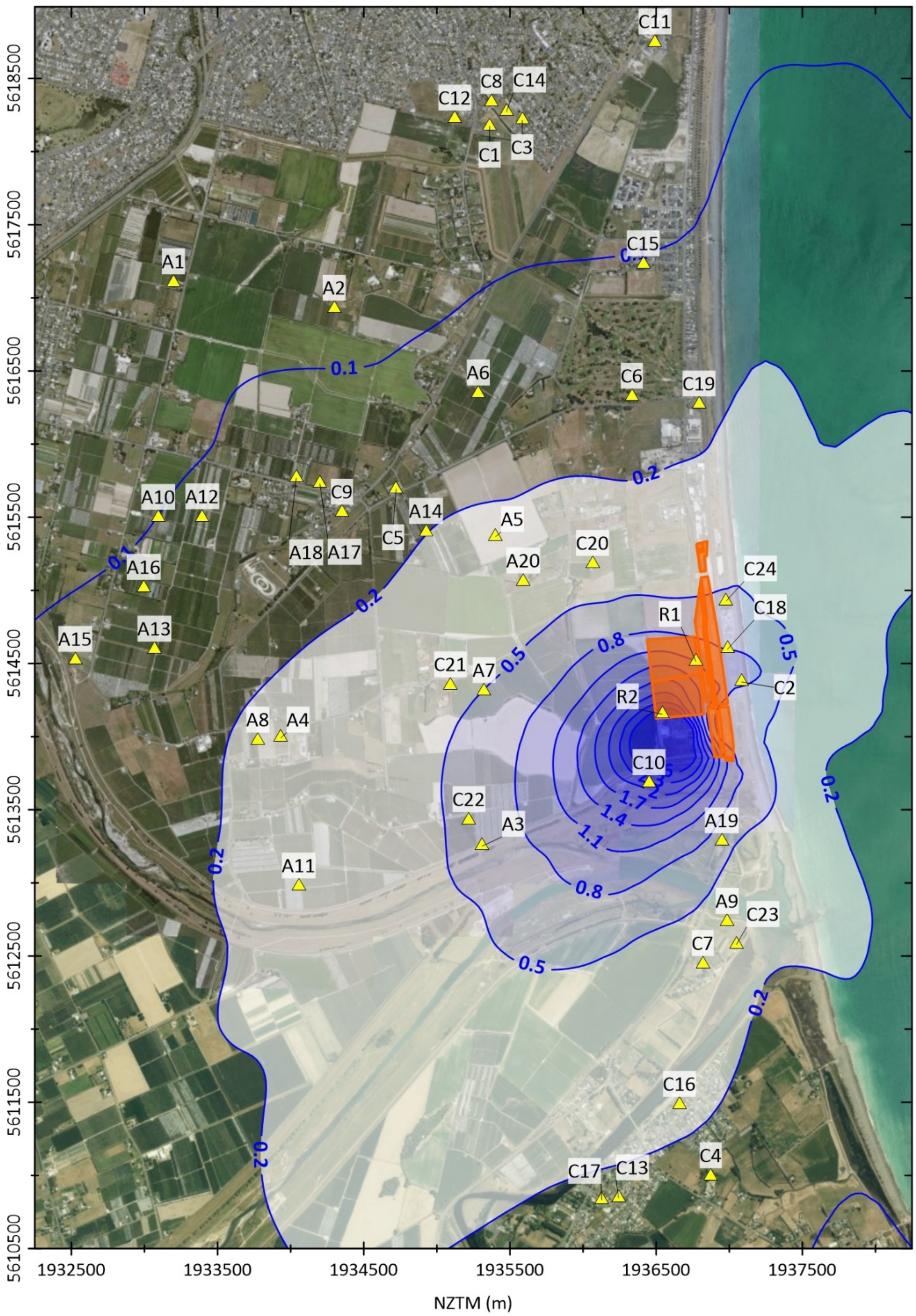

Figure 27: Predicted annual average SO_2 GLCs (μg/m³) in immediate surroundings – based on the 75^{th} percentile of stack testing data. Proposed site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

A2.3 Fluoride and sulphur deposition

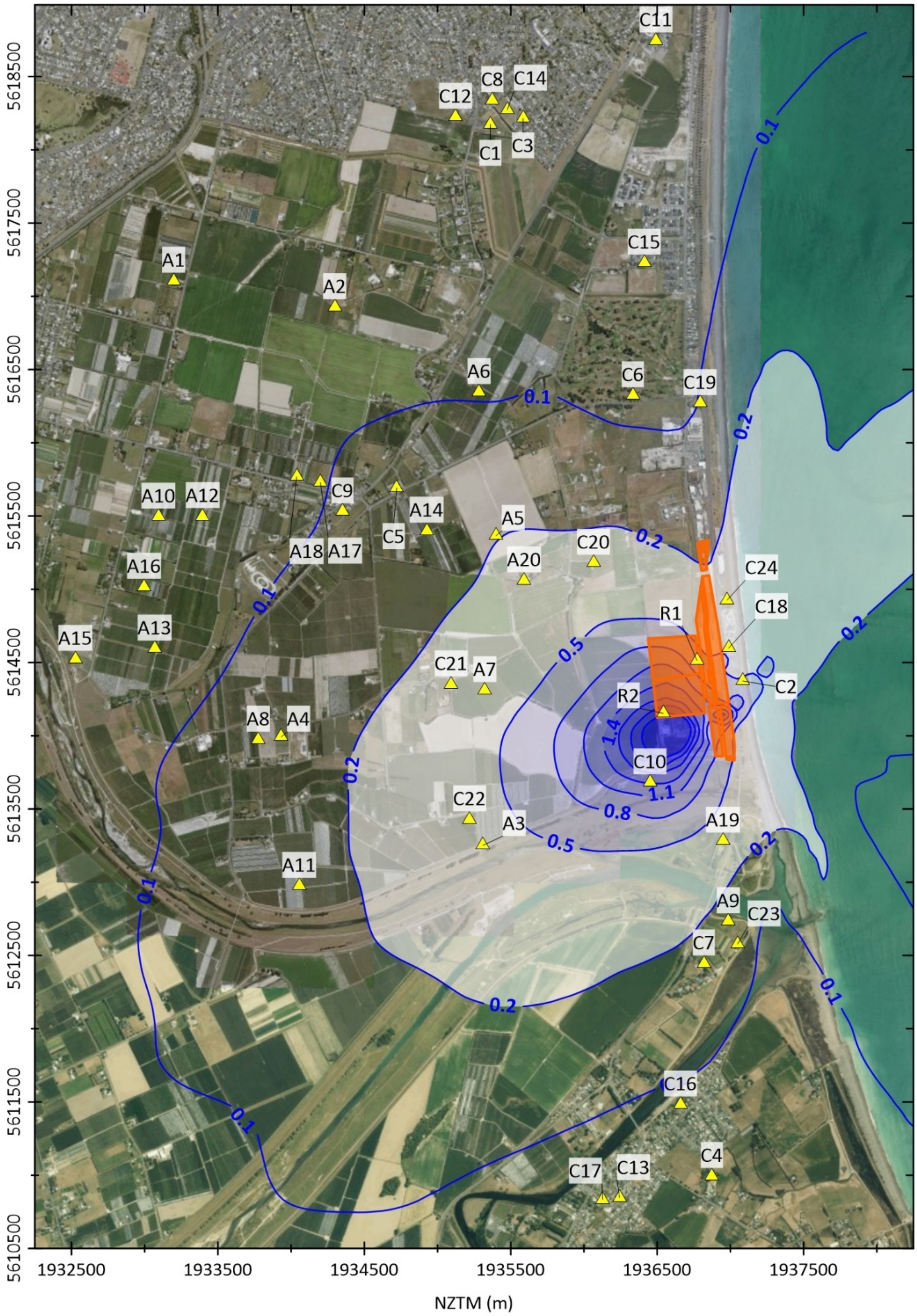

Figure 28: Predicted annual total sulphur deposition rate (kg/ha/yr) – based on the 75th percentile of stack testing data. Proposed site configuration - site emissions only. Ravensdown site extent indicated by the orange polygon. Figure includes all sensitive locations.

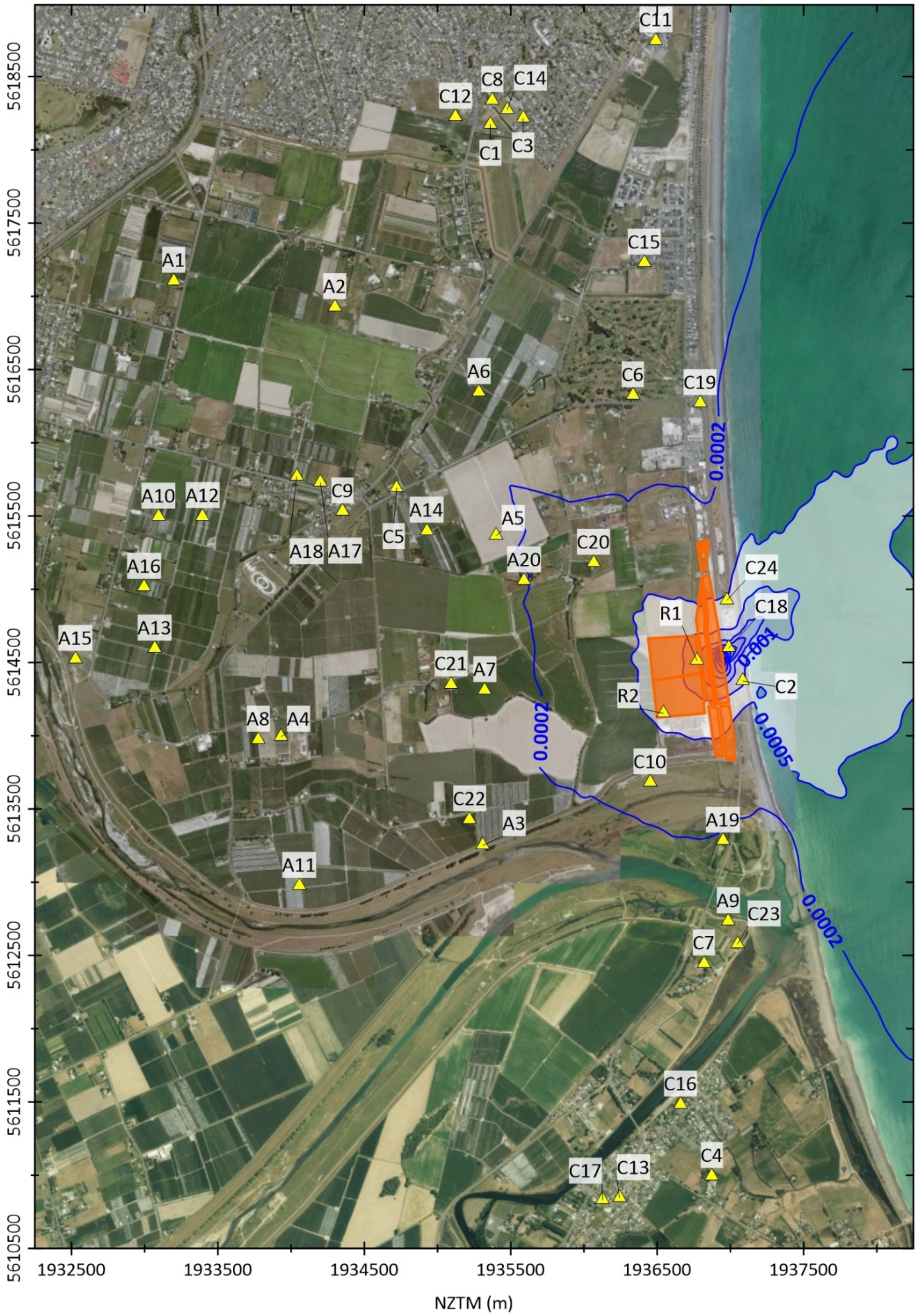

Figure 29: Predicted maximum 1-hour fluoride deposition (kg/ha/hr). Proposed site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon. Figure includes all sensitive locations.

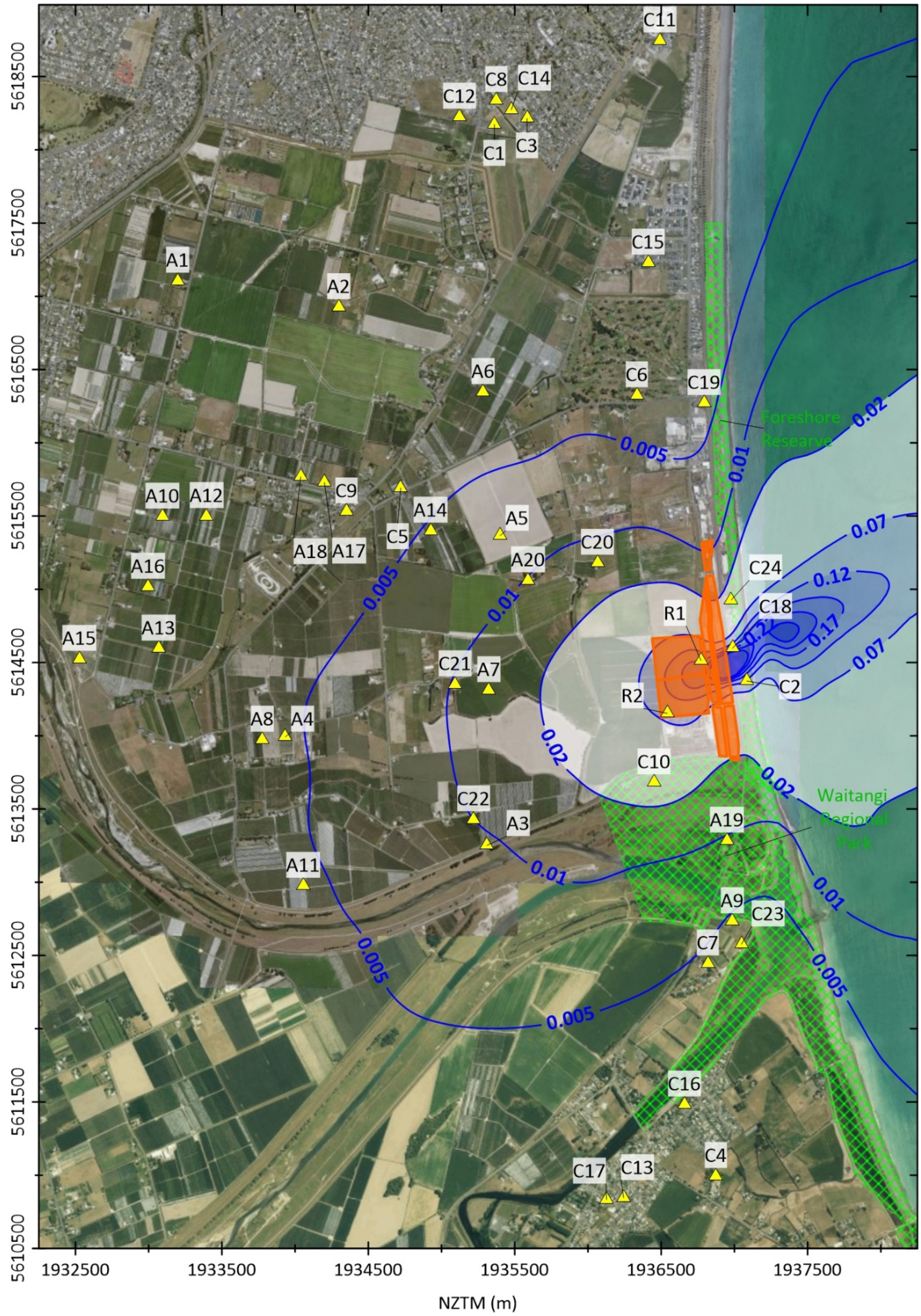

Figure 30: Predicted maximum annual fluoride deposition (kg/ha/yr). Proposed site configuration – fugitive and stack emissions only. Ravensdown owned land shown by the orange polygon. . Figure includes all sensitive locations.