Health Effects Assessment

Reconsenting of Ravensdown Napier Works

Report Prepared for:

Ravensdown Ltd, Napier Manufacturing Works

Prepared by:

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Executive Summary

Potential Effects Covered

The potential human health effects of the proposed Ravensdown Napier air discharges on the receiving environment have been summarised. This has included a review of recent past exposures using ambient monitoring information. Additionally, consideration was given to effects of water discharges for human contact recreation and mahinga kai harvesting.

Effects arise through community interaction with potential hazards among the air emissions from the site activities, or water discharges. Potential routes of exposure were considered, to identify potential effects, and these included:

- Community inhalation of pollutants present in ambient air;
- Coastal water contact recreation, including the Waitangi Estuary;
- Gathering local food sources/mahinga kai.

Assessments Undertaken

Five components were used for the assessment of human health effects:

(1) *Community characterisation*

This included the identification of the location of residential and other sensitive community use and consideration of community health characteristics.

(2) *Identification of hazards*

Information sources for hazards included assessments by Tonkin + Taylor (Air Discharge Effects Assessment), Plant and Food Research (Vegetation Effects Assessment) and Streamlined Environmental (Estuarine Ecological Effects Assessment)[1]. To determine whether contaminants have hazardous potential for humans, both epidemiological and toxicological information were used, tailored to the hazard and potential for exposure.

Additionally, information was sourced about land and groundwater discharges from the following assessments: Ravensdown Stormwater and Process Water Discharge – Land Discharge Effects and Management; Aurecom (Ravensdown Napier stormwater and process water management); and the Napier Works Site Sustainability Project Water Discharge Strategy 2021.[2]

[1] See Section 8, References.
[2] See Section 8, References

(3) *Health effects from contaminants (exposure-response)*

Review and guideline documents from authoritative sources were identified for the hazards under assessment. Ministry for the Environment (MfE) and World Health Organisation (WHO) exposure-response and guideline exposure criteria were included to assess respirable particulate, fluorides, sulphur dioxide, sulphur trioxide, acid aerosols and hydrogen sulphide. Mahinga kai was assessed using dietary intake guidance from WHO.

(4) *Exposure assessment*

Information about exposure to contaminants included assessments by Tonkin + Taylor (Air Discharge Effects Assessment), Plant and Food Research (Vegetation Effects Assessment) and Streamlined Environmental (Estuarine Ecological Effects Assessment). The methods used to determine exposure included ambient air monitoring records, air dispersion modelling, plant sampling and water discharge quality assessment.

(5) *Characterisation of potential for health effects (public health risk)*

This component of the assessment interpreted exposure patterns among the community using exposure-response guidelines. Conclusions were made about the likelihood of health effects. The National Environmental Standard (NES), and ambient air exposure guidelines (WHO, MfE) are conservative and include protection of those who may be vulnerable to health effects because of age or personal health. Similarly the Drinking Water Standards (WHO, NZMOH) and Nutrient Reference Values and other food quality guidance provided by Food Standards Australia and New Zealand (FSANZ) are protective for people of all ages and personal health, including pregnancy and infancy.

Results of Assessments

(1) *Community characterisation*

Residential and other sensitive communities are mostly located in areas where modelled and measured air emissions show very low exposure. Exceptions include a cluster of residences to the north-east, proximate housing to the north/north-west and impacts in a non-residential area to the east accessed for coastal recreation.

(2) *Identification of hazards*

The main inhalation health hazards identified for humans were: particulates, fluorides, sulphur dioxide and sulphur trioxide. Hydrogen sulphide was identified as an odour hazard. Potential for drift off-site from irrigation discharges was also considered.

Water discharge contaminants were identified as not hazardous to humans through contact recreation. These are primarily an ecological hazard.

(3) *Health effects from contaminants (exposure-response)*

The exposure-response for health effects from particulates is determined in relation to overall mortality and cardio-respiratory morbidity. Health-based guidelines include both daily and annual exposure periods and PM_{10} and the finer $PM_{2.5}$.

The exposure-response for fluoride indicates that the main health effect is long-term exposure (months/years) through dietary exposure and relates to bone health.

The exposure-response for sulphur dioxide indicates that the main health effects are both acute (ten minute exposures, irritancy and asthma) and ongoing (daily exposures, respiratory and cardiovascular).

The exposure-response for sulphur trioxide and acid aerosols indicates acute irritancy and a contribution to longer-term health effects.

The exposure-response for hydrogen sulphide indicates odour effects at ambient exposures.

The relevant effects assessments for water contaminants are based on ecological effects in the estuarine and marine environments.

The assessment of stormwater and process water land discharges on surface water and other groundwater effects have been included through assessment of estuarine water quality.

Drinking water guidelines for human health are relevant where water is consumed. Household rainfall supply was not identified.

(4) *Exposure assessment*

The Discharge Effects Assessment concludes that inhalation exposure to particulate and fluorides is maximal to the east of the plant in a non-residential area. The most impacted locations where community residential assessment is relevant are among a cluster of residences to the north-east and, for acid plant discharges, an area to the west of the site. The residential locations with most impacted exposures for fluorides, particulate, sulphur dioxide and sulphur trioxide are below relevant assessment criteria/guidelines. Human residential exposure to these contaminants from Ravensdown Napier is below accepted toxicological thresholds for adverse health effects.

Exposure to the irrigation water was not considered a public health risk.

Contaminants in estuarine and coastal waters represent an ecological exposure and are not an issue for contact recreation.

Samples of watercress from Awatoto indicate fluoride content that will not produce health effects in the context of normal dietary exposure to fluorides.

(5) *Characterisation of potential for health effects (public health risk)*

Assessment of inhalation contaminant exposure patterns among the community at residential locations indicates less than minor health effects. Maximal particulate concentrations are located in a coastal carpark with short recreational exposures and correspondingly minor health effects.

The watercress samples indicate that mahinga kai is not a source of elevated health risk.

Suggested Approach for Effects Identified

Particulate

- Recommend a review of the ongoing suitability of the ambient monitoring sites.
- Recommend that the monitoring site selection includes representative community residential exposure.
- Recommend that $PM_{2.5}$ monitoring is included, together with PM_{10}.
- Recommend the further development and use of management plan(s) to reduce fugitive particulates from the Napier Works.

Sulphur dioxide

- Recommend that incident event investigation and mitigation continues, in case of any future unexpected events.
- Note that the planned replacement of the Acid Plant converter will reduce SO_2 emissions and this will further reduce and minimise effects.
- Recommend continued ambient monitoring, with a site representative of community exposure as well as an impacted site.

Fluorides

- Recommend continued ambient monitoring at a site representative of community exposure.

1 Introduction

1.1 Overview

Ravensdown Limited ('Ravensdown') operate a superphosphate manufacturing plant ('the plant') located at 200 Waitangi Road, Awatoto, Napier ('the site/the Napier Works').

Ravensdown manufactures and supplies soil amendment materials (fertilisers) alongside the provision of farm nutrient management systems. Ravensdown Napier Works is the co-operative's largest manufacturing centre for superphosphate and incorporates on-site manufacture of sulphuric acid.

Ravensdown's two key resource consents for the Napier Works, to discharge to air and to water, expire on 31 May 2022 and 31 October 2022 respectively. This health effects assessment report has been prepared in the context of planned application to replace both consents.

1.2 Background

The Ravensdown Napier Works is located in the Awatoto industrial area approximately 6.5 km south of Napier City and 11.5 km northeast of Hastings. It is a coastal location, with mixed land use beyond the industrial zone, including residential and horticultural. Land to the immediate south of the site is zoned River Conservation under the Napier District Plan.

For the air discharge, the following activities and discharges are relevant as potential sources of hazards to human health:

- Discharge of emissions from manufacturing and acid plant stacks.
- Fugitive emissions of particulate and fluorides to air from various site activities, including manufacturing and dispatch processes.

For the water discharge, the following activities and discharges are relevant as potential sources of hazards to human health, with these updated in relation to the discharge strategy:

- Discharge of treated process water and stormwater to land via irrigation and any associated effects on groundwater and to the drains leading to the Waitangi Estuary.

For assessment of effects related to human health, discharges are important as sources of potential exposure to pollutants. Routes of exposure that require assessment for the reconsenting include:

- Inhalation of pollutants in ambient air.
- Other exposures from human contact with the environment, for example potential collection of rainwater for household use, coastal recreation and mahinga kai.

1.3 Purpose and Scope of Assessment

The Health Assessment is provided in relation to community exposure to air quality through the following:

- Residential and community land use;
- Potential household collection and use of rainwater;
- Market gardening in the Meeanee area and horticulture in Awatoto;
- Traditional food gathering (mahinga kai);
- Coastal Recreation including the coastal cycleway;
- Travel past the site using the nearby state highway.

The assessment of human health risks (and thus human health effects) relies on evidence-based toxicological and epidemiological information contained in various authoritative reports issued by international organisations. It uses approaches recommended by the New Zealand Ministry of Health, and associated guidance documents.

The national and international sources of peer-reviewed information relied on in this assessment are presented in Appendix One.

2 Characterisation of the Community

2.1 Location of the assessment and sensitivity

Residential communities in proximity to the Site have been identified as sensitive to potential human health effects through air discharges. The assessment has noted the following residential locations:

- Residential zones approximately 1.8 km to north, 2.75 km to the south and 5.5 km to the west of the site. The zone to the North includes Waitangi Road, Awatoto Road, Te Awa Avenue, Kenny Road and adjacent residential streets.
- A localised group of houses to the east of despatch is included in the assessment.
- Recreational use at the beach 150 m to the east of the site, and associated car park and including the cycleway.
- Other recreational facilities including the Maraenui golf course.
- The Hohepa Homes residences, currently located on a farm approximately 2 km south of the site; elder care occurs at Harris House.
- Locations with minimal effects are included in order to provide a conservative assessment.

The land immediately surrounding the site is largely used for commercial activities and is considered to have a lesser sensitivity to air effects. This includes:

- Land to the north-west zoned wastewater treatment;
- The discontinued gravel operations by Winstone Aggregates immediately east of the Napier Works;
- BioRich Ltd composting and green waste management, located to the south and west of the Napier Works;
- Higgins Contractors operate an asphalt plant and associated activities north of the Napier Works;
- Activities in the main industrial zone located north of the site – wool-scouring, fisheries, recycling, rendering and transport services.

Land to the west of the site is predominately rural under the Napier District Plan, with horticultural and pastoral agriculture including apple orchards and vineyards. These horticultural crops are assessed in the Vegetation Effects Assessment according to relevant guidelines.

Figure 1 displays the locations (receptors) assessed for exposure to contaminants in ambient air. [3] A key is included below.

[3] Figure 4.2 and Table 4.1 from Tonkin + Taylor (November 2021) report prepared for Ravensdown Limited.

Figure 1: Location of the Health Effects Assessment (Air).

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 West
	C24	House (cluster) Northeast

2.2 Demographic characteristics

The New Zealand Population Census provides information at intervals about the location and composition of the resident population. The Ministry of Health describes the population of the Hawke's Bay District Health Board area (2020/21 estimates) as follows[4]: " tends to be older than the national average; has a higher proportion of Maori living there compared to the national average and a lower proportion of Pacific people; and has proportionally more people in the more deprived section of the population."

This health effects assessment uses health-based guidelines that are intended to be inclusive for a community that might have high health need because of demographic characteristics.

2.3 Health characteristics

The Health Risk Assessment process developed and recommended by the World Health Organisation ('WHO') encompasses a broad range of outcomes consistent with the definition of health. Particular attention is given to the population subgroups that may be more susceptible to exposure to contaminants. The WHO expert review reports for ambient air quality and air pollution policies (WHO 2000; 2006; 2013) include protection of those who may be more vulnerable to adverse health effects because of age or health difficulties. Likewise, the international expert panels (European Food Safety Authority 'EFSA'; WHO/FAO) for food contamination specifically consider vulnerable consumers, including young children. The NZ Drinking Water Standards (2018) and the documentation in the WHO drinking water guidelines (2017) also relates risk assessments to those who may be vulnerable to health effects, including reproductive risk.

It is assumed in this assessment that there are people with a variety of health characteristics including pregnancy, and that people living in the assessment area experience a range of health problems encountered in the general population such as diabetes, respiratory and cardiovascular disease. It is also assumed that the exposed population includes long-term residents and that some people will have a life-time of exposure to the ambient environment and local foods. The adoption of these assumptions is precautionary and ensures that this assessment is appropriately conservative.

Given that this protective approach underpins the guidance for protection against adverse effects relied on in this Assessment, the conclusions can be anticipated to generally apply to the community regardless of individual health status or age. The likely level of risk is related to time present at

[4] Ministry of Health My DHB (page last updated 23 March 2021), www.health.govt.nz

locations with elevations of contaminants. Area locations assessed to have low-risk exposure concentrations will have a low risk for health effects.

This assessment recognises that the health characteristics of the residents affected by the Proposal generally share similarities with the resident population of Napier District and the wider Hawke's Bay. Also, The Hohepa Homes provide educational and residential services for children, young people and adults with intellectual disabilities and are part of the current resident community.

2.4 Cultural characteristics

People living in the Hawke's Bay include 27.2% Maori compared to a national average of 16.6%.[5]

The Hawke's Bay Regional Council identify the location and extent of iwi and hapū as follows:

- The Napier Works lies within the Ngati Kahungunu iwi boundary and Te Taiwhenua o Heretaunga;
- Mana Ahuriri is listed as a treaty partner for the area;
- Heretaunga Tamatea is listed as a treaty partner for the area.

Additionally, several hapū affiliated with local marae on the Heretaunga Plains have a relationship with the rivers and coastline in the area of the Napier Works:

- Kohupatiki Marae, Farndon Road, Clive;
- Ruahapia, 79 Ruahapia Road, Hastings;
- Waiohiki Marae, 40-44 Waiohiki Road, Napier;
- Matahiwi Marae, 376 Lawn Road, Clive;
- Waipatu Marae, SH2, Waipatu.

2.5 Sensitive receptors - air

Community facilities that have been identified as generally sensitive receptors for air exposure include:

- Marae
- Schools
- Kindergarten
- Elder care facilities

The locations for community facilities are assessed with regard to exposure to concentrations of air contaminants over relevant time periods.

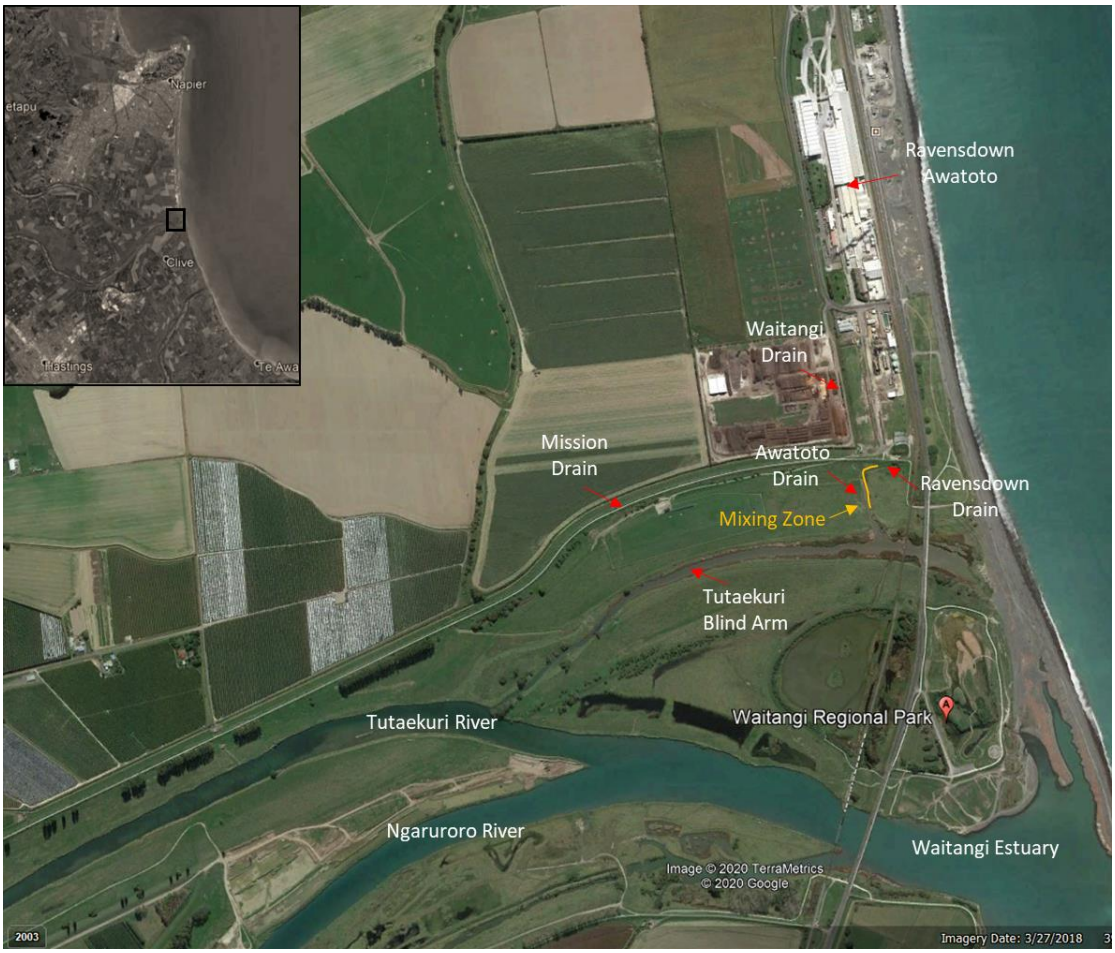
[5] My DHB, www.health.govt.nz, estimates for 2020/2021.

Non-sensitive community locations include the recreational walkway and the highway. Sensitivity to contaminant discharges to air is related to exposure concentrations, repeated exposure over time as well as proximity.

2.6 Receiving environment – water

The receiving environment for the existing Ravensdown water discharge and the proposed secondary discharge option described in the Ravensdown Napier Sustainable Site Project Water Discharge Strategy is a series of drains that lead to the Tutaekuri River, and ultimately the Waitangi Estuary. The landuse of the river catchment is largely pastoral and agricultural. The location of relevant features is displayed by the Streamlined Environmental baseline ecological assessment[6] (Figure 1), copied as Figure 2.

Figure 2: Location of the Health Effects Assessment (Water)



[6] Phillips, N., De Luca, S., Stewart, M., Leitch, K., McDermott, K., Eivers, R. (2021) Ravensdown Napier Baseline Technical Investigations. RVD1901, Streamlined Environmental, Hamilton,157pp

2.7 Receiving environment – land

The land situated on Waitangi Road immediately to the west of the Ravensdown site is the proposed receiving environment for treated irrigation water and the primary discharge option as described in the Ravensdown Napier Sustainable Site Project Water Discharge Strategy. This land is currently grazed and cropped and is located within the Napier City Council drinking water supply 'Source Protection Zone'.

Millner et. Al. (2021)[7] concluded that: "the discharge of treated process water stormwater to land, based on analysis of soil chemistry, geology (including depth to confined aquifer), and agricultural systems, will have no effect on the current condition of the source protection zone. This is because the annual additions of contaminants in the treated irrigation water are quantitatively small and will either be utilised and removed in the harvested forage or bound tightly to soil colloids on site and the site sits over a thick layer of low permeability sediments."

2.8 Receiving environment – reported experiences

Ravensdown maintain a register of reported experiences, such as odour or dust problems. The current historic register contains reported incidents that comprise amenity concerns related to air discharges and these are assessed by T+T (November 2021).

None of the current reports appeared related to health effects assessment.

[7] Ravensdown Stormwater and Process Water Discharge – Land Discharge Effects and Management. November 2021.

3 Identification of the Hazards

The Identification of Hazards examines whether a contaminant has the potential to cause harm to human health. Hazard Assessment includes both the presence of a potential exposure route and the potential to cause adverse effects.

The Characterisation of Risk likely from a hazard requires assessments of Dose-Response (numerical relationship between exposure and effects) and Exposure (the frequency, timing and route of contact with a hazard).

3.1 Site activities associated with hazards - Air.

The following site activities are associated with presence of hazards and the potential for health effects to arise through emissions to air. Figures 2.1 and 2.10 in the T+T air report (2021) summarise and show the location of the site activities.

- Bulk materials transport, mostly phosphate rock and sulphur. These are transferred to the site from the Port of Napier on covered trucks.
- Rock phosphate is received over an intake system into three enclosed rock stores and contained there, prior to further processing on-site. In its raw state the phosphate rock has a range of consistencies, from sand-like to coarse chip. Phosphate rocks contain varying amounts of fluoride and metal compounds.
- Two sulphur stores contain up to 20 kT of prilled sulphur, treated to reduce hydrogen sulphide (H_2S) emissions. Future state will be a single store holding 29 kT, with completion in next few years.
- The sulphur melter uses an indirect steam heating process, with steam and hydrogen sulphide (H_2S) discharged through vents.
- Sulphuric acid production, where molten sulphur is burned with dried air to form sulphur dioxide (SO_2). SO_2 is converted to sulphur trioxide (SO_3) using a vanadium pentoxide catalyst. The SO_3 is scrubbed from the gas stream and reacted with water to produce concentrated sulphuric acid (H_2SO_4). A double absorption process is used.
- The acid plant does not operate continuously. There are planned maintenance shutdowns. A diesel powered process is used to generate low pressure steam and re-heat the catalyst before start up. The start-up procedure and shut down processes have been refined to minimise SO_2 emissions.
- Rock phosphate mixing and grinding is necessary to produce a raw material that can react with acid to make superphosphate. In the milling plant the mix is ground to the consistency of talcum powder (more than 80% passing through a 75 micron sieve) and conveyed to a storage tank.
- Rock acidulation – The finely ground rock phosphate is fed into the Broadfield Mixer with H_2SO_4 , water and hydrofluoric silicic acid (FSA) and sometimes additional sulphur. The initial reaction happens quickly and creates phosphoric acid and gypsum; an ongoing reaction (weeks) uses up the phosphoric acid to produce monocalcium phosphate. The product from the Mixer continues to react and cure inside a chamber called the ‘Den’ for approximately 20 minutes.

The cured material is crushed, granulated and conveyed into storage sheds for maturation.

- The 'Den Scrubber' system absorbs fluoride gases from the process and the fluoride-laden Scrubber water feeds back into the mixer.
- Fluoride gases and particulate (organic fluoride compounds) are released during granulation and conveying to storage and these are collected through a second 'Hygiene Scrubber' system, controlling fluoride levels within the building.
- Fluoride emissions associated with the Scrubbers are discharged through the manufacturing stack(s).
- Dust is generated from the grinding and manufacturing of superphosphate and this is collected through bag house systems, associated with each mill ('Bradley Mills'). Dust collected on the filter bags is reused in the plant. Residual particulate matter escapes to the atmosphere.
- The acid plant operates two cooling towers and these release evaporated water.
- Dispatch process – a loader collects cured superphosphate from the storage sheds and feeds it into a dressing plant to break up lumps prior to loading into trucks for dispatch. Some cured superphosphate is fed into a blending plant to produce customised products, also dispatched by truck in bulk.

3.2 Identification of Hazards - Discharges to Air

3.2.1 Stack sources

The potentially hazardous discharges to air from stack or vent sources are:

- Acid plant stack emissions: SO_2, SO_3 and some H_2SO_4 acid aerosols.
- Manufacturing plant stack emissions: fluoride, SO_2, acidic gases and particulate.
- Residual particulate matter from the Bradley Mills bag filters.

3.2.2 Fugitive sources

The hazardous discharges to air from site fugitive emissions are (identified in the T+T Report (3.1.3):

- Dust from wind erosion of surfaces and stockpiles.
- Dust generated by vehicle movements.
- Dust from handling of materials, including loading and unloading.
- Exhaust emissions (e.g. SO_x, NO_x, and PM) from heavy vehicles.
- H_2S (rotten egg odour) from the melting of sulphur.
- Sulphur dioxide from the manufacturing of sulphuric acid.
- Fugitive acidic gases (e.g. SO_3, H_2SO_4, and FSA) from the Acid Plant or Manufacturing Plant.
- Fugitive fluoride emissions from the manufacturing process.
- Volatile gas releases from the superphosphate piles and Manufacturing Plant stack (superphosphate type odour).

- Water vapour.
- Emissions associated with diesel combustion from on-site vehicles, machinery and the start-up boiler.
- "Upset" emissions from the processes, for example from a fire.

3.2.3 Assessment of hazardous discharges to air

Assessment of hazardous discharges to air requires quantification of exposure concentrations for relevant time periods.

Ambient monitoring assessments include all emissions including fugitive and also include background contaminants. Dispersion modelling predicts ground level concentrations related to emission rates from a source and can include provision for background concentrations.

Fugitive fluoride emissions and mitigation for these is assessed in the T+T report (3.2.1). Fugitive sources of fluoride cannot be readily quantified directly. Instead, an evaluation was conducted through a review of ambient monitoring and the predicted fugitive discharge was included in the dispersion modelling.

The method used to assess cumulative effects of all gaseous fluorides from the site is detailed by T+T (6.1.4) and includes the manufacturing building and to a lesser degree the superstore building.

The contaminant emission rates and averaging periods used in the dispersion modelling are summarised in the T+T report (Section 3.4.2, Table 3.3). Sulphur dioxide, SO_3, fluoride, PM_{10} and $PM_{2.5}$ have been assessed. This assessment comprises two emission scenarios:

(1) the existing site, and
(2) that associated with planned site improvements (i.e., the new combined Manufacturing Stack and the upgraded Acid Plant converter).

The wind flow information that determines the dispersion of site emissions in the receiving environment is provided in the T+T report (4.3 Meteorology and topography).

Emissions of NO_x and CO associated with diesel combustion during a cold start-up of the acid plant have been assessed as infrequent and at a small scale (T+T, 3.2.6). Therefore NO_2 and CO have not been included for specific health effects assessment.

3.3 Site activities associated with hazards - Water

The discharge from the Ravensdown Napier Works is comprised of both stormwater and process water, collected in a covered drain system and pumped to a storage pool or settling pond.[8] The discharge collection system also receives truck wash run-off.

Streamlined Environmental (November 2021) assess the discharge taking into account the proposed upgrades and describe the following site activities as associated with the presence of hazards:

- Stormwater from approximately 8 hectares within the site, likely to contain hydrocarbons, heavy metals and suspended and dissolved material from fertiliser processing and handling.
- Truck wash water.
- Cooling water from air compressors, hydraulic drives and acid plant.
- Boiler rinse water.
- The Settling Pond is the final control point prior to discharge from site and the collection point for stormwater monitoring samples. It has three potential sources of water from the site:
    - Drain water
    - Acid plant cooling tower
    - Fresh water and groundwater from below
- Settling Pond discharge is controlled by two pumps, one for baseflow and one during storm conditions.

3.4 Identification of Hazards - Discharges to Water

The Streamlined Environmental Baseline Technical Investigations Report identifies the following ecological hazards in the discharge (Table 5)[9]:

- pH, suspended solids, discharge rate.
- Fluoride concentration.
- Sulphur.
- Total phosphorus and soluble reactive phosphorus.
- Metals (copper, zinc, cadmium, chromium and aluminium).

3.4.1 Water quality monitoring - ambient

The locations of water quality monitoring sites are shown in the Streamlined Environmental Baseline Technical Investigations Report (4.3, Figure 3). They present a visual summary of the significant and meaningful ambient monitoring trends, for sulphur, fluoride and aluminium (4.6.2, Figure 8). Trends have been analysed from

[8] Streamlined Environmental Estuarine Ecological Assessment (November 2021, 3.1).
[9] Streamlined Environmental Ecology Baseline Technical Investigations Report (June 2021, 4.6).

June 2014 to June 2019. There has been no significant change in concentrations of cadmium, chromium, copper, nickel and zinc at any of the ambient water quality sites, nor at any sites associated with rainfall samples. Between 2014 and 2019 there were increasing trends in fluoride in storm associated (rainfall) samples at all sites upstream of or adjacent to the plant. There has been no change in fluoride concentrations within the mixing zone or at downstream sites.

3.4.2 Process chemicals assessment

Ravensdown Napier uses nine process chemicals (in formulations) as part of the operation of the plant.[10] In addition, Sandfords truck wash enters the Ravensdown collection system and contributes to process chemicals. Accordingly, Streamlined Environmental (June 2021) identified the process chemicals with potential to enter the water discharge and carried out an assessment of risk. The methodology is detailed in 6.2 and includes ecotoxicological assessment and worst-case scenario risk assessment using highly conservative assumptions. None of the chemicals that were assessed are likely to bioaccumulate. One chemical in use at Sandfords as a road film remover, was assessed with potential for adverse ecological effects. This has been replaced and an update to the process chemicals included for risk assessment is presented in the Estuarine Ecological Assessment (Table 2, page 20).

3.4.3 Discharge water quality

Streamlined Environmental (November 2021) have assessed potential effects on current and future water quality by comparison with relevant guidelines and standards, as well as consideration of upstream water quality and its influence on water quality downstream of the discharge. Assessments included receiving environment concentrations and potential ecological effects.

The overall discharge management strategy includes the introduction of proposed treatment devices, planned to improve discharge water quality. These are summarised in Streamlined Environmental (November 2021) Table 8, and the predicted improvements are presented in Tables 9 and 10 as a comparison of existing and proposed discharge characteristics.

Stage 1 includes a Clarifier (and Holding Pond) and Bioretention Device. Stage 2 includes a new Settling Pond, Constructed Wetland and Discharge Pond. Following the proposed treatments hazardous parameters are predicted to be substantially reduced.

Streamlined Environmental (November 2021, section 4.5, ecotoxicity of the discharge) assess historic sampling of the quality of the water discharge. Some assessments of the past undiluted discharge exceeded relevant water quality guidelines. However once reasonable mixing was allowed for (at 100:1) the

[10] Phillips et al. Streamlined Environmental Ravensdown Napier Baseline Technical Investigations Report (June 2021, section 6).

concentrations of aluminium, cadmium, chromium, copper, nickel and fluoride would be below guidelines. With ecotoxicity assessment all results met the “no toxicity” criterion of no significant effect at a 1:100 dilution. The diluted discharge was not considered toxic to any test species, after dilutions of 13-fold and 25-fold.

Assessment of the public health effects from discharge water quality included consideration of contact recreation and consumption of wild harvested food. Whitebait are spawning inside the mixing zone. The ecological health of mahinga kai has been considered by Plant and Food (November 2021) using sampled plant species in the estuarine environment.

3.5 Assessment of hazards - Discharges to Ground

The sustainable site project water discharge strategy includes a future land-based disposal of treated process water and stormwater, using spray irrigation onto land used for animal feed crops.

The potential for the water to be a spray drift hazard to people off-site has been assessed.

The potential for this water discharge to affect the Napier City source of artesian water for drinking purposes has also been assessed.

4 Health effects from contaminants (exposure-response)

The potential to produce health effects from exposure to the identified hazardous contaminants depends on the amount and duration of exposure. The time period for assessment of effects from exposure can vary according to the types of effects.

The air contaminants included for exposure-response assessment are:

- Fluoride (inhalation)
- Sulphur dioxide (inhalation)
- Sulphur trioxide and sulphuric acid mist (inhalation)
- Particulate matter (inhalation) – PM_{10} and $PM_{2.5}$
- Hydrogen sulphide (inhalation)

The baseline ecological and water quality effects assessment (Streamlined Environmental June 2021) reports that ambient water quality at monitoring sites and water discharge quality testing indicates discharges are not likely to have adverse ecological effects outside the mixing zone. The Estuarine Ecological Assessment (November 2021) includes an assessment of the water discharge following proposed treatments. A substantial improvement in discharge quality is summarised (Streamlined November 2021, Tables 9 and 10).

The aquatic contaminants are primarily assessed in this human health report for potential effects through recreational exposure. No further exposure-response information is required for human health assessment through contact recreation, where ecological effects are assessed as minor/less than minor.

4.1 Fluoride - Inhalation

Fluoride is a trace element in rock phosphates, and in sedimentary rocks is especially present as silicates. When superphosphate is manufactured and cured, silicon tetrafluoride particulate is released and also some hydrofluorosilisic acid aerosols and gaseous fluoride. Soluble and gaseous fluoride are highly absorbed if inhaled. Fluorosilicates are insoluble particulate and poorly absorbed from inhalation, but if swallowed can be absorbed from the gut in varying amounts. The analytical process for fluoride concentrations reports a gaseous fluoride equivalency. However human exposure to fluorides from superphosphate processing comprises a mixture of organic fluoride containing compounds with some gaseous component. The relevance of noting this for the use of exposure-response information for fluorides is that some occupational safety guidance for exposures to gaseous fluoride concentrations do not apply directly to superphosphate manufacturing exposures.

The California Office of Environmental Health Hazard Assessment (OEHHA) publish ambient air Reference Exposure Limits (RELs) for human health relevant for particulate fluorides.

For fluoride inhalation, the air exposure takes place in the context of daily fluoride intake from ingestion of water, toothpastes, supplements and food. For human intake of fluoride, most arises each day from ingestion not inhalation. Daily intakes in New Zealand have been appraised by Food Standards Australia New Zealand ('FSANZ') and updated guidance for reference values for daily intake were released in 2017.[11] Further detail is provided in Appendix Two.

Appendix Two contains further explanation about health effects related to human fluoride intake, with relevance to the likely daily intakes in the Hawke's Bay.

T+T (2021) set out the relevant fluoride assessment criteria for ambient air quality in their Table 6.4. The critical levels set for fluoride in air in NZ are intended for protection of ecosystems and the various concentrations according to type of land use are set out below.

Table 1: critical levels for fluoride to protect ecosystems (MfE and MOH AAQG 2002)

Time period averaged	Special land use	General land use	Conservation area
	μg/m^3	μg/m^3	μg/m^3
12-hour	1.8	3.7	
24-hour	1.5	2.9	
7-day	0.8	1.7	
30-day	0.4	0.84	
90-day	0.25	0.5	0.1

The WHO (2000) discusses a one hour reference exposure level (REL) to protect against acute respiratory irritation and indicates that to be about 600 μg/m^3 for hydrogen fluoride exposure. Also that prolonged exposure of humans to air concentrations in the range 100 to 500 μg/m^3 for fluoride leads to impairment of lung function and skeletal fluorosis. WHO concludes that fluoride levels in ambient air that prevent effects on plants "will also sufficiently protect human health."[12]

T+T (2021) have used a one hour Acute REL from the California Office of Environmental Health Hazard Assessment (OEHHA) intended to protect against acute respiratory and eye effects. This assessment criteria is 240 μg/m^3 and is consistent with the WHO opinion about irritant short-term exposures.

The OEHHA also include Chronic RELs for fluorides related to consistent, ongoing exposure through inhalation. This Chronic REL for fluorides (inhalation) is 13 μg/m^3 to protect human health (including bone and teeth) from long-term effects. The relevant assessment period to apply for human health is the annual average.

[11] Ministry of Health and Australian Government National Health and Medical Research Council. Nutrient reference values for Australia and New Zealand. Fluoride (updated 2017). www.nrv.gov.au
[12] WHO. Air Quality Guidelines for Europe. Chapter 6. (2000)

4.2 Sulphur dioxide inhalation

Sulphur dioxide is a respiratory irritant and elevated exposures are well-established as a source of respiratory symptoms (eye, nose, throat, airways) including provocation of bronchospasm (asthma reactions) in susceptible individuals. Associated systemic difficulties can include aggravation of cardiac problems or headache.

Table 2 summarises some of the documented information about health effects from short elevated exposures to sulphur dioxide at various concentrations, with effects determined by direct human observation. These observational data have indicated levels for acute effects from ambient sulphur dioxide.

Although this documentation is historic, it draws on direct experimentation and observation in humans as well as animals. That information is still used as reliable guidance and has not been replaced with data from alternate methods.

Table 2: Summary of health effects from acute exposure to sulphur dioxide

SO_2 concentration in air, µg/m³ [duration of exposure]		**Health effect on inhalation***
≥260µg/m³	[10 minutes]	Some extremely sensitive to SO_2 exposure people with asthma may experience bronchoconstriction during exercise
<650µg/m³	[short term]	No effect of sulphur dioxide is seen on the airways of sensitive individuals in the general population who take exercise [IARC, 1992]
700µg/m³	[5 -10 minutes]	People with asthma may experience bronchospasms during exercise as an immediate response without delayed or prolonged effects beyond 4 hours
>700µg/m³	[short term]	People with asthma may experience increased frequency or duration of attacks, depending on amount of exposure
700 - 1,400µg/m³	[short term]	People with asthma may develop symptoms and a decrease in lung function
790 - 2,600µg/m³		Concentrations of SO_2 that could possibly be detected by taste or smell
2,600µg/m³	[1 to 6 hours]	Constriction of upper airways in young, healthy (20-28 years of age) adult males
<2,600µg/m³	[short term]	No effects have been reported for healthy adults
2,600µg/m³	[40 minutes]	A slight increase in subjective, mild, upper respiratory symptoms, such as sore throat and ability to taste and smell sulphur dioxide with no effects on lung function parameters, have been reported in healthy adults
2,800µg/m³	[short term]	Older adults at increased risk of respiratory disease. Some people may experience worsening of chronic bronchitis

* Information was generated from ATSDR, 1998a; Patty's Industrial Hygiene and Toxicology: Chapter by Bingham et al, 2001; IARC, 1992.

More recent research about sulphur dioxide has focussed on the public health consequences of variation of daily and annual exposures in the urban environment associated largely with mixed combustion activities including transport. For mortality outcomes, controlling particulate exposure has been observed to be essential, especially fine particulate. Acidic aerosol particles if present in the emissions require separate assessment, additional to the sulphur dioxide gaseous exposure assessments.

WHO have released new guidance about protection from chronic health effects from air contaminants (22 September 2021). This includes a recommendation for a daily average exposure guideline for sulphur dioxide of 40 μg/m^3 as the 99th percentile of an annual distribution of daily values.

The National Environmental Standard (NES) in New Zealand provides an assessment criteria for sulphur dioxide and this has been incorporated for the health effects assessment. The NES criteria are set out in Table 6 in this report.

4.3 Sulphur trioxide inhalation

Table 3 summarises health effects from exposure to sulphuric acid aerosol concentrations, when inhaled. These form from the combination of SO_3 and water, and the table below incorporates the outcomes from exposure to gaseous SO_3.

Table 3: Summary of health effects from exposure to sulphuric acid aerosols

SO_3 concentration in air, μg/m^3 [duration of exposure]		**Health risk on inhalation**
70 μg/m^3 100 μg/m^3	[40 mins] [50 mins]	The lowest concentrations reported for people with asthma where transient changes in pulmonary function tests were seen during exercise (ATSDR, 1998b)
≥100 μg/m^3	[upto 1 hr]	A reduced rate in bronchial mucociliary clearance have been reported for normal subjects (ATSDR, 1998b)
350 – 1000 μg/m^3	[5 -15 minutes]	Concentration that could be detected by odour, taste, or irritation (ATSDR, 1998b)
3000 μg/m^3	[5 -15 minutes]	Concentration that is noticed by the most people (ATSDR, 1998b)
5000 μg/m^3	[5 -15 minutes]	Concentration that is considered very objectionable by some people (ATSDR, 1998b)
15 000 μg/m^3	[5 -15 minutes]	NIOSH Immediately Dangerous to Life or Health Concentration

* Information was generated from ATSDR, 1998b; Patty's Industrial Hygiene and Toxicology: Chapter by Bingham et al, 2001; IARC, 1992.

Experimental studies of humans and animals report that short- term exposure to sulphuric acid aerosols may result in changes in lung function and can affect the

clearance of particles from the respiratory tract. The SO_3 gaseous discharges and sulphuric acid mist from the acid plant are assessed as equivalent for exposure-response health effects.

4.4 Particulate inhalation

People with pre-existing lung disease, young children and the elderly are most likely in New Zealand to suffer adverse health effects from inhalation of particulate matter.[13]

The WHO review of evidence on health aspects of air pollution (REVIHAAP, 2013) examined the adverse outcomes associated with particulate exposure. The research consensus has been that $PM_{2.5}$ is the critical exposure for adverse health outcomes. Some, but not all, of the previously observed association of adverse health outcomes with PM_{10} can be attributed to the hazardous smaller fractions contained within the size range for particulate smaller than 10 micron in diameter.

The WHO expert review consensus process updated their global ambient air quality guidelines and released new documentation on 22 September 2021. This has confirmed the importance of prevention of particulate exposure. Previous recommended guideline concentrations have been reduced, based on an updated understanding of the increased risk to overall mortality that arises following particulate exposure, especially to fine particulate.

The National Environmental Standard (NES) in New Zealand provides an assessment criteria for particulate and this has been incorporated for the health effects assessment. The NES criteria are set out in Table 6 in this report.

4.5 Hydrogen sulphide inhalation

Hydrogen sulphide is a colourless gas, mostly arising in the world atmosphere from natural sources such as volcanic activity. It is an odorant in very low doses but can have irritant health effects in high concentrations. Hydrogen sulphide is not regarded as a cumulative poison.

The unpleasant symptoms experienced by some people when exposed to hydrogen sulphide odour are a result of sensory stimulation and vary individually with the interpretation placed on the significance of the smell.

Complaints of odour effects can be most frequent in situations where variable presence of low concentrations produces intermittent odour. Hence odour symptoms are not related to increasing exposures. If exposure continues, most people experience adaptation where the odour becomes less noticeable over time.

[13] Our Air 2018 report (Ministry for the Environment & Stats NZ, 2018)

Based on occupational exposure studies, eye irritation arises at exposure to concentrations of hydrogen sulphide tens of thousands of times greater than the odour threshold.

Table 4: Summary of health effects from exposure to **hydrogen sulphide**

Short term exposure concentration µg/m^3	**Health Effect (inhalation)**
1,400,000 - 2,800,000	Immediate collapse
750,000 - 1,400,000	Strong CNS stimulation followed by respiratory arrest
450,000 - 750,000	Pulmonary oedema with risk of death
210,000 - 350,000	Loss of olfactory sense
70,000 - 140,000	Serious eye damage
15,000 - 30,000	Threshold for eye irritation
7	WHO guideline (half hourly average) for odour, no natural geothermal source
0.2 - 2.0	Lowest odour detection

World Health Organisation Air Quality Guidelines for Europe (2nd edition), page 147

5 Exposure Assessment

5.1 Exposure information – background concentrations

T+T (2021) present a table (5.3) to summarise the background concentrations used for the modelling assessment. This is reproduced below as Table 5:

Table 5: Background concentrations

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)

T+T explain their estimate that there is minimal background exposure to fluoride in ambient air in the area under assessment. Minor exposure arises from the fluorides present in salt spray from the ocean.

For sulphur dioxide, background concentration has been derived from the ambient monitoring taking into account wind direction.

The background PM_{10} and $PM_{2.5}$ values for the Awatoto area are based on the HBRC monitoring site at Awatoto (T+T, 5.4.3). For $PM_{2.5}$ the 24-hr average background concentration has been adopted from an updated Waka Kotahi New Zealand Transport Agency (NZTA) interactive air quality map, based on the average of the fourth highest $PM_{2.5}$ concentration measured in each of the three monitoring years considered (2017, 2018, 2019). The annual average for PM_{10} in the Waka Kotahi background map is 18.5 µg/m³ (T+T, 5.4.3 para 5). A representative 24-hour average for PM_{10} is derived by T+T using the same methodology as for $PM_{2.5}$.

Regarding the adopted background particulate values, T+T note that:

- There will be an element of double counting of Ravensdown's emissions in the modelling because they are included in the monitoring data used for the background estimation.

- The analysis of maximum concentrations measured at the HBRC site demonstrates that those events (a) do not occur when winds are by and large from the Ravensdown site and (b) occur under relatively calm conditions whereas peak impacts from Ravensdown are expected to occur under relatively strong wind conditions.

5.2 Exposure information - ambient fluoride

The ambient monitoring data provides information about the average exposures to ambient fluoride with proximity to the site and distance from the coast. This is clearly depicted in T+T (Figure 5.4, reproduced below) 7-day averages for June from January 2015-August 2021.

T+T time series plots for the five monitoring sites (T+T, Figure 5.2) show overall compliance with the consent limits set. The 7-day average total fluoride consent limit is set at 0.8 µg/m³ at the off-site community locations Brookfields Orchard and Plumpton Park.

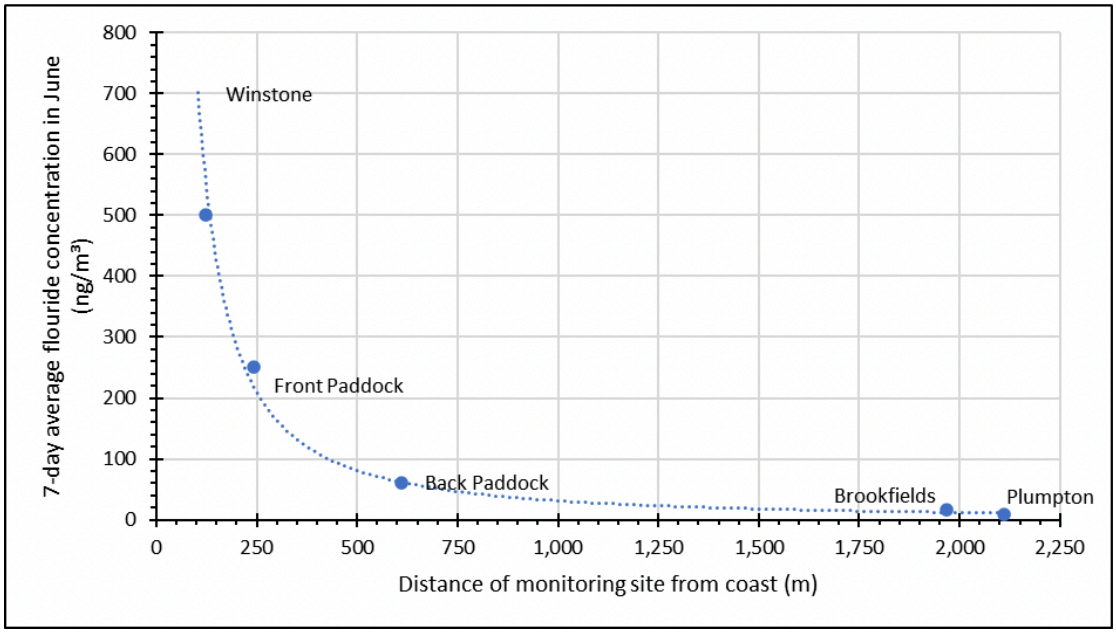


Figure 5.4: ensemble average of 7-day average fluoride concentrations for June from January 2015-August 2021 for each of the five ambient fluoride monitoring sites. (From T+T 2021).

5.3 Exposure information - ambient sulphur dioxide

Ravensdown undertakes ambient monitoring of SO_2 at two locations:

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

The off-site location is analysed for ambient information relevant to the NES. T+T report polar plots in their Figures 5.7 and 5.8 and these show that concentrations are typically associated with the acid plant stack. A timeseries plot of one-hour SO_2 measurements (T+T, Figure 5.5) showed sporadic outlier high values in 2016 and 2018 and March 2021. An event due to a fire in the Melter Storage Tank was associated with raised concentrations on 3 and 4 March 2021.

5.4 Exposure information - ambient particulate matter

The HBRC Awatoto site is situated on Waitangi Road and monitors PM_{10} and $PM_{2.5}$. The location is impacted by sea spray and wind-blown dust from sea breezes. Analysis by T+T shows (T+T, Table 5.2):

- There have been 24 exceedances of the 24-hr standard for PM_{10} since 2012 and 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 relevant 24-hour guideline for $PM_{2.5}$ in 2017.
- No exceedances occurred (2016, 2017, 2018, 2019 and 2020) of the relevant annual average guideline for $PM_{2.5}$ (10 µg/m³).

A polar plot produced by T+T (Figure 5.13) indicates that the peak 1-hourly average PM_{10} concentrations at the HBRC monitoring site are not typically associated with winds blowing from the direction of the Ravensdown site (south-southeast to south). An exceedance in a 24-hour average timeseries plot on 1 August 2017 was also assessed to be unlikely to reflect emissions from the Ravensdown site because of the range of wind directions on that day (refer T+T, Figure 5.14).

Ravensdown undertakes ambient monitoring at the former **Winstone site** and this is situated within an unpaved aggregate yard. PM_{10} concentrations measured at this site frequently exceed the NES_{AQ}. This is not a location where people are expected to be present, other than briefly.

5.5 Exposure information - ambient H_2S

The main on-site source of hydrogen sulphide (H_2S) is the storage and melting of sulphur. Other activities in the vicinity, including composting, also emit H_2S.

Ambient air monitoring at the Archimedes site includes H_2S as an odour requirement rather than for health effects assessment. When interpreting the ambient monitoring information against wind direction, T+T note high concentrations downwind of the compost facility and slightly elevated hourly averages when downwind of the sulphur melter. These results are displayed by T+T in their Figure 5.19.

5.6 Dispersion modelling assessment criteria

T+T explain (6.1.3.1) that the choice of ambient air quality assessment criteria (for the protection of human health) used to evaluate the results of dispersion modelling is based on MfE (2016a) guidance, which sets out the criteria to be used in order of priority. For completeness, criteria for NO_2 and CO are included because these are associated with diesel combustion during the Acid Plant start-up.

T+T set out the relevant ambient air quality assessment criteria (Table 6.2) and this is reproduced below, Table 6:

Table 6: 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	OEHHA
H_2S*	7	1-hour	AAQG
NO_2	200	1-hour	NES_{AQ}
	100	24-hour	AAGL
	40	Annual	WHO (2005)
CO	30,000	1-hour	AAQG
	10,000	8-hour running mean	NES_{AQ}

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

5.7 Exposure information – discharges of fluoride (modelled)

The model-predicted maximum 1-hour, 12-hour, 24-hour, 7-day, 30-day and 90-day average ground level concentrations (GLCs) due to fluoride emissions from the new manufacturing stack configuration to be installed at the site are summarised by T+T (Table 6.6). Refer Table 7 below. Note that the 1-hour maximal modelled exposure close to the site to the east has been compared with the OEHHA Acute REL for human exposure to hydrogen fluoride (HF). The ground level concentrations to the east are influenced by fugitive emissions. The long-term exposures to compare with the OEHHA Chronic REL (13 µg/m³) are relevant at locations with human residential occupancy, rather than the unoccupied land to the east of the site with the most impacted concentrations.

Table 7: Summary of predicted fluoride GLC (stack and fugitive combined) 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 general land use location	1-hour	East of site	77	77	240
	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	0.8	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)	0.054	0.10	0.25
Most impacted residence where exposure is relevant	Annual	Northeast House (C24)	0.54	0.10	13

Notes:
1-hour assessment criteria is the OEHHA Acute REL for human exposure to HF.
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 75 percentile of measured emission rates.
Background concentrations in all cases are 0.045 µg/m³based on analysis provided in Section 5.2

A further assessment was conducted for the new combined Manufacturing stack and a lower discharge rate, including predicted fugitives in combination with stack emissions. The model-predicted maximum 1-hour, 12-hour, 24-hour, 7-day, 30-day and 90-day average ground level concentrations (GLCs) due to fluoride emissions from the revised scenario are summarised by T+T (Table 6.13). Refer Table 8 below.

Table 8: Summary of predicted fluoride GLC (new stack configuration and fugitive combined) 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 general land use location	1-hour	East of site	77	77	240
	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	0.9	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
Most impacted residence where exposure is relevant	Annual	Northeast House (C24)	0.05	0.09	13

1-hour assessment criteria is the OEHHA Acute REL for human exposure to HF.
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 75 percentile of measured emission rates. Background concentrations in all cases are 0.045 µg/m³

The OEHHA provide a Chronic inhalation REL for long-term bone effects from fluorides. This criteria is 13 µg/m^3 and can be compared with the most impacted residential inhalation exposure at 0.09 µg/m^3 (annual average), refer Table 8.

5.8 Exposure information – discharges of SO_2 (modelled)

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 by T+T (Table 6.7). Refer Table 9 below.

Table 9: 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

NOTE: Site discharges plus background. Background concentrations are in square brackets.

Based on normal operations, proposed consent limits for short-term impacts. Annual average based on 75th percentile of measured rates.

Annual average results relate to vegetation impacts

A further assessment was conducted of modelled predictions for maximum 1-hour, 24-hour and annual average ground level concentrations (GLCs) due to SO_2 emissions from the Ravensdown site. The further assessment included the proposed new converter and combined manufacturing plant stack (refer T+T, Table 6.14).

Table 10: Summary of predicted SO_2 GLC compared with assessment criteria with proposed new converter

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

NOTE: Site discharges plus background. Background concentrations are in square brackets.

Lower proposed maximum emission rate of 40kg/hr for the Acid Plant with converter upgrade.

Annual average results relate to vegetation impacts

T+T (Section 6.4) explain that an evaluation shows good performance for the dispersion model predictions against measured concentrations of SO_2 at the Winstone site.

The relationship between monitored and measured concentrations of 1-hour SO_2 is displayed by T+T (their Figure 6.35, reproduced below as Figure 3).

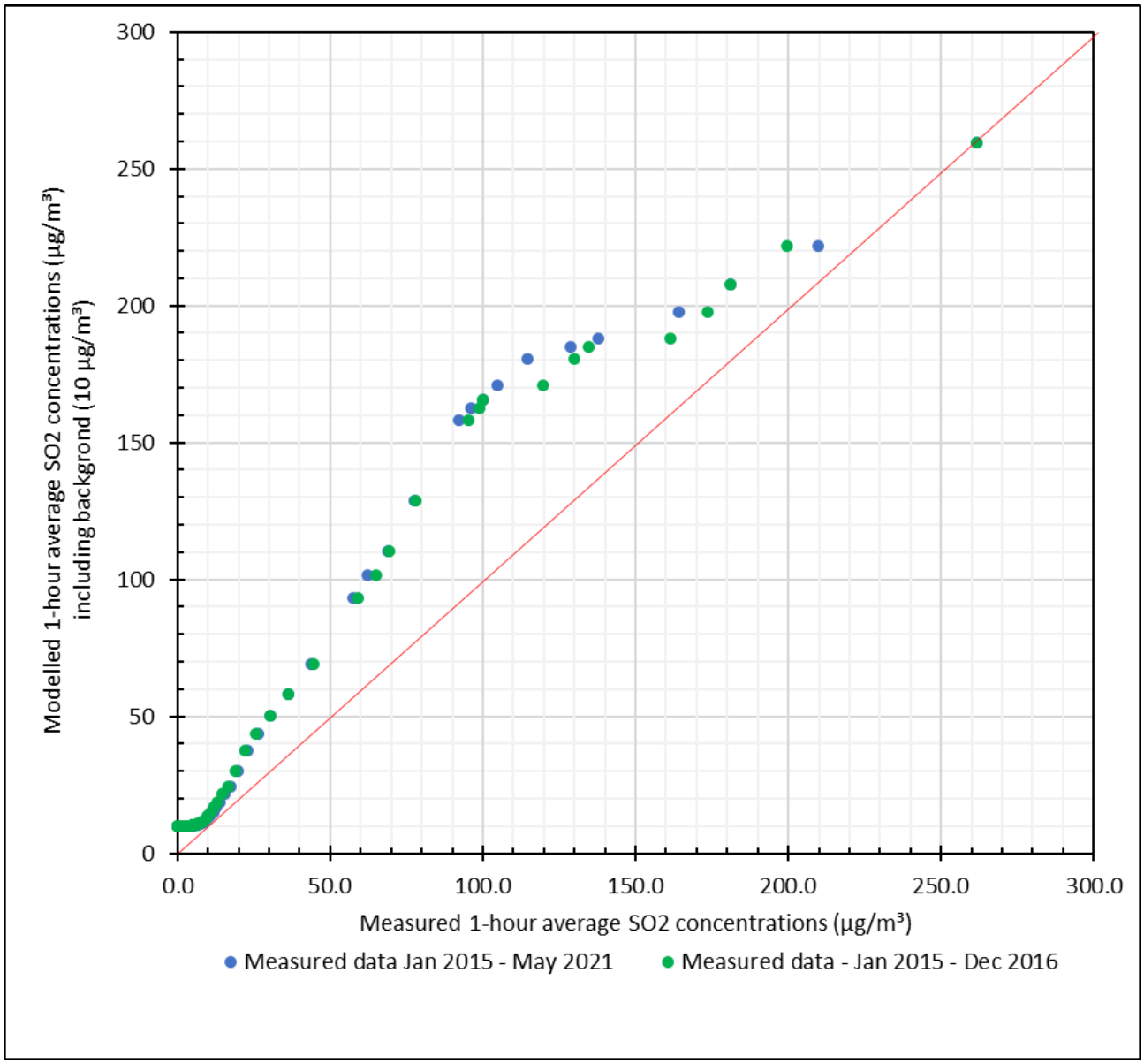


Figure 3:
Relationship between monitored and measured concentrations of 1-hour SO2.

5.9 Exposure information – discharges of SO_3 (modelled)

The model-predicted maximum 1-hour and annual average ground level concentrations (GLCs) due to SO_3 emissions from the Acid Plant are summarised by T+T (Table 6.8). Refer Table 11 below.

Table 11: 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 Residential Northwest	0.002	0.002 [0]	1

NOTE: Site discharges plus background. Background concentrations are in square brackets.

The assessment criteria relate to sulphuric acid mist and are for human health, published by the OEHHA. They protect against respiratory effects.

5.10 Exposure information - discharges of PM_{10} (modelled)

The model-predicted maximum 1-hour, 24-hour and annual average ground level concentrations (GLCs) due to PM_{10} emissions from the Bradley Mills are summarised by T+T (Table 6.9).

The most impacted community receptor, C24, is a cluster of residential dwellings, in proximity to the site to the northeast. Refer Table 12 below.

Table 12: 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
Most impacted location, non-residential	24-hour	Winstone		75 [48]	

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

The modelling contours for predicted maximum 24-hour average and annual average PM10 GLC (T+T, Figures 6.16 and 6.17) demonstrate that most effects arise to the east of the site over the coast and ocean.

The most impacted location in the modelling is at the former Winstone industrial site to the east. This is not a community residential receptor. It is however currently near to a recreational area and public carparking that may be briefly occupied.

5.11 Exposure information – discharges of $PM_{2.5}$ (modelled)

The model-predicted maximum 1-hour, 24-hour and annual average ground level concentrations (GLCs) due to $PM_{2.5}$ emissions from the Bradley Mills are summarised by T+T (Table 6.10). Refer Table 13 below.

Table 13: 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	C24	1.8	17.1 [15.3]	25
	Annual	C24	0.027	6.0 [6]	10

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

The most impacted community receptor, a group of residential dwellings to the northeast of the site, has been assessed with predicted maximal 24-hour average exposure from the Bradley Mills at 1.8 µg/m³. The annual average $PM_{2.5}$ exposure from site emissions is predicted to be negligible and is not expected to add measurably to the estimated background concentration. Sensitive community receptors for health effects from air contaminants, including the Hohepa Homes and local schools, will have minimal exposure to particulate from the rock phosphate milling.

5.12 Exposure information - daily intake (inhalation) for fluoride

The WHO estimates the average volume of inhaled air in an adult person at about 20 m^3 per day (WHO, 1984). Assessing a predicted average ambient air concentration of fluoride at 0.09 µg/m^3 (annual average) at the most impacted residence, normal breathing would contribute an averaged amount of inhaled fluoride equivalent to about 1.8 µg per day. This assumes all inhaled fluoride is absorbed and not exhaled without absorption.

Inhalational intake of fluoride from ambient air that meets vegetation guidelines can be considered as negligible and not a source of health effects (WHO, 2000).

5.13 Fluoride ingestion from mahinga kai (wild harvested food)

An assessment of mahinga kai was organised following discussions between interested parties, meeting as a Technical Focus Group (TFG). The purpose was to compare fluoride concentrations in edible and taonga plants growing at Awatoto with other comparison locations and to interpret results as potential dietary intake.

The sampling locations and species were selected together with the mana whenua. The process and methodology for sampling and analysis and details of the results are described by Dr Trolove.[14]

The locations were:

- The Waitangi Estuary, located adjacent to the Ravensdown site and therefore the most likely location to show increased fluoride concentrations.
- The Tukituki River mouth, as a suitable control location. It is also located close to the coast, so would also receive any fluoride in ocean spray, yet is far enough from Awatoto not to be significantly affected by any fluoride in emissions from Ravensdown site.
- The Whakatu location, selected for importance to the mana whenua, since their land and marae is located there.

Three plant species were selected for sampling (20 September 2021):

- Watercress (kowhitiwhiti, Nasturtium officinale) because this is commonly collected by Maori for food.
- Horse's mane weed (*Ruppia megacarpa*) because this is an important food source for fish and waterfowl.
- Nga raho a tuna (Kukuraho, River bulrush, *Bolboschoenus fluviatilis*) because this was historically harvested for food, and is possibly the reason for the name of the area (Awatoto = blood-red river), due to the reddish orange brown colour of iron oxides on the roots of this plant at times. So this species has significance in this area for Maori.

Of the species collected for sampling, the watercress was selected for health effects assessment, as the best representation of an edible species commonly consumed as mahinga kai. Potentially edible shoots of watercress were collected, and any inedible stems or roots removed. All plants are reported to appear healthy and the smaller size of the watercress from Awatoto was attributed to recent grazing.

[14] Plant and Food Research (2021). Sampling plants of significance to mana whenua. Appended to the Vegetation Report.

Fluoride was below detection in all samples except for the watercress and kukuraho at Awatoto, which grew within 700 m of the Napier Works. The fluoride concentration in Awatoto watercress was 11 mg/kg dry weight. This result was reported as "within the normal range commonly found in plants, and did not appear to be causing any harm."

For food intake evaluation (fluoride ingestion) the results are expressed as concentration in whole food weight rather than the dry weight result from laboratory analysis. A conversion factor has been used, with 92.7% moisture reduction at the laboratory (Hill laboratories, 4 October 2021). Following this adjustment the fluoride concentration in Awatoto watercress was 0.8 mg/kg fresh weight.

For ingestion assessment an average portion size of 100 g was selected, with a predicted amount of fluoride of 0.08 mg.

- If an adult consumed 100 g of the Awatoto watercress twice a week as an ongoing food, this would add 0.023 mg to the average daily intake for fluoride.
- For comparison the WHO typical adult daily intake from diet and water is 2 to 4 mg/day, refer Appendix 2.
- An ingestion intake of 0.023 mg/day from watercress adds approximately 1% to the typical daily intake expected.

Collecting watercress from Awatoto as mahinga kai is not predicted to increase fluoride intake significantly.

5.14 Exposure to irrigation water

Potential human exposure to the irrigation water if spray drift were to occur off-site can be minimised through design and management of the irrigator, site buffering with shelterbelts and distance to public areas (Millner et al, 2021)[15]. There will be no people on site when the irrigator is operating.

15 Ravensdown Stormwater and Process Water Discharge – Land Discharge Effects and Management. October 2021.

6 Characterisation of Health Effects

6.1 Summary of assessed exposures: Air (inhalation) – community and residential

Fluoride

Ambient air exposures from fluoride discharges have been assessed using criteria that are highly conservative for human health. In summary, amounts of fluoride in air that comply with guidelines to protect vegetation contribute negligible addition to background fluoride intakes from usual consumption patterns of food and water.

Sulphur dioxide

Ambient air exposures from sulphur dioxide discharges have been assessed using criteria that are conservative for human health. NES_{AQ} criteria are predicted to be met. The exposures to sulphur dioxide are below those associated with health effects of respiratory irritation and asthma, even among sensitive people.

Sulphur trioxide

Ambient air exposures from sulphur trioxide discharges have been assessed using criteria that are conservative for human health. The exposures to sulphur trioxide at community locations are below those associated with health effects (respiratory irritation).

Particulate – PM_{10} and $PM_{2.5}$

Ambient air exposures from particulate discharges have been assessed using NES_{AQ} criteria that are conservative for human health. NES_{AQ} criteria have not been met at all times within the Awatoto airshed, using monitoring information from coastal locations. Maximal near off-site particulate concentrations to the east occur where there is no residential use and people may be briefly present using the coastal carpark or beach walkway. Predictive modelling of particulate (PM_{10} and $PM_{2.5}$) from the Bradley Mills indicates a minor contribution to combined particulate exposure at residential receptors.

Hydrogen sulphide

Ambient air exposures from hydrogen sulphide have been assessed using MfE criteria for odour. Measured concentrations at the monitoring sites indicate elevations near the site to the south and south west, but not in residential community locations. The assessed exposures are below concentrations associated with irritant health effects.

6.2 Summary of assessed exposures: drinking water

Residential use of rainwater for household supply has not been identified in proximity to the modelled sulphur and fluoride deposition patterns.

The discharge of treated water to land has been assessed to have no effect on the current condition of the source protection zone for Napier City drinking water.

6.3 Summary of assessed exposures: Mahinga kai

Watercress was sampled from a location at Awatoto, within 700 m of the site. There was 11 mg/kg dry weight reported and this was converted to 0.8 mg/kg fresh weight, for food ingestion assessment. If an adult consumed 100 g of the Awatoto watercress twice a week as an ongoing food, this would add 0.023 mg to the average daily intake for fluoride. For comparison the WHO typical adult daily intake from diet and water is 2 to 4 mg/day. An ingestion intake of 0.023 mg/day from watercress adds approximately 1% to the typical daily intake expected.

Collecting watercress from Awatoto as mahinga kai is not predicted to cause health effects.

6.4 Summary of assessed exposures: Coastal recreation

The health effects from coastal recreational activity have been assessed, including the Waitangi Estuary and open coast.

- The Streamlined Environmental (November 2021) assessment of effects from the proposed discharge indicate that the marine environment will be acceptable for contact recreation. Human health effects are not predicted.

- The Waitangi estuary assessment for human health effects includes both air quality (inhalation) and water quality (contact), based on predicted exposures with the proposed water and air discharge upgrades. Human health effects are not predicted.

- The former Winstone site has assessed air quality that is compromised at times, if assessed using criteria for residential exposure. The usual duration of exposure is not similar to residential land use. Accordingly, the short temporary use of this coastal access area by people is assessed with predicted exposures below those associated with health effects (normal operations).

- For running, walking and biking along the coastal pathway, assessment of low likelihood of human health effects relates to a short exposure time.

6.5 Overall characterisation of effects

The assessment included residences in proximity to the site, schools and residential facilities. People with sensitivity to health effects were included through the use of conservative health-based guidelines developed to protect health among the whole community including those with vulnerability due to age or personal health.

The residential dwelling with closest proximity to discharges has been assessed and air discharges from Ravensdown Napier are not likely to lead to health effects.

The overall conclusion from the assessment of potential for adverse human health effects from the proposed discharges to air and water from the Ravensdown Napier Works is to characterise health effects as less than minor.

7 Suggested Approach for Effects Identified

Particulate

- Recommend a review of the ongoing suitability of the ambient monitoring sites.
- Recommend that the monitoring site selection includes representative community residential exposure.
- Recommend that $PM_{2.5}$ monitoring is included, together with PM_{10}.
- Recomend the further development and use of management plan(s) to reduce fugitives from despatch, stores, and materials delivery.

Sulphur dioxide

- Recommend that the incident event investigation and mitigation continues, in case of any future unexpected events.
- Note that the planned replacement of the Acid Plant converter will reduce SO_2 emissions and this will further reduce and minimise effects.
- Recommend continued ambient monitoring at a site representative of community exposure, as well as an impacted site.

Fluorides

- Recommend continued ambient monitoring at a site representative of community exposure.

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Appendix One

The following New Zealand national agencies (and collaborating Australian agencies) provide sources of criteria or methodologies for use in environmental health assessments:

- Ministry of Health ('MoH')
- Ministry for the Environment ('MfE')
- Ministry of Primary Industries ('MPI')
- Food Standards Australia and New Zealand ('FSANZ')
- National Health and Medical Research Council ('NHMRC') Australia.

Appendix Table 1 International Sources of background information

International information source	Comment	Resource location
Agency for Toxic Substances and Disease Registry (ATSDR)	An agency of the US Dept of Health and Human Services – takes responsive public health actions and provides health information to prevent harmful exposure and disease related to toxic substances.	www.atsdr.cdc.gov
ACGIH	The American Conference of Governmental Industrial Hygienists is a leading source of scientific guidelines	www.acgih.org
CONTAM	Expert Panel on Food Contaminants - a joint process of FAO and WHO	www.fao.org
EFSA	European Food Safety Authority – funded by the European Union to assess risk throughout the foodchain and provide scientific advice	www.efsa.europa.eu
Food and Agriculture Organisation (FAO)	The UN specialised agency for Agriculture. Joint processes for food safety and standards for food traded for human use are established by FAO and WHO.	www.fao.org
FSANZ	Food Standards Australia and New Zealand, formerly ANZFSA	www.foodstandards.govt.nz

International information source	Comment	Resource location
Hazardous Substances Data Bank	HSDB is a comprehensive, scientifically reviewed, factual database with records for more than 4,500 toxic or potentially toxic chemicals	US National Library of Medicine
International Agency for Research on Cancer	IARC, part of the WHO, co-ordinates and conducts research on the causes of human cancer, the mechanisms of carcinogenesis, and develops scientific strategies for cancer control.	www.iarc.fr
JECFA	Joint Expert Committee on Food Additives - a joint process of FAO and WHO	www.fao.org
MEDLINE	Database of more than 10m references to articles published in 4,300 refereed biomedical journals – maintained by NLM.	MEDLINE online access
NICNAS	Australian National Industrial Chemicals Notification and Assessment Scheme helps protect the Australian People and the environment by assessing the risks of industrial chemicals and providing information to promote their safe use.	Nicnas.gov.au
OEHHA	California Office of Environmental Health Hazard Assessment Our mission is to protect and enhance the health of Californians and our state's environment through scientific evaluations that inform, support and guide regulatory and other actions.	0ehha.ca.gov
REACH	European Programme for Assessment of Chemicals, a regulation of the European Union	Echa.europa.eu
US Environmental Protection Agency (EPA)	Government environment agency of the United States, EPA provides leadership in the nation's environmental science, research, education and assessment efforts and aims to protect human health and safeguard the natural environment.	www.epa.gov
World Health Organisation (WHO)	WHO, a United Nations specialised agency for health, established April 7 1948, includes 192 Member States. It gives worldwide guidance in the field of health; sets	www.who.org

International information source	Comment	Resource location
	global standards; co-operates with governments in strengthening national health programmes; and assists in developing and transferring appropriate health technology, information and standards.	

Toxicological and epidemiological information

Assessment as to the likelihood of adverse health effects from environmental exposure relies on both epidemiological and toxicological information. Epidemiological information comes from studies of outcomes or risk factors among groups of people and uses a variety of statistical methods. Toxicological information comes from studies of people, animals, tissues or cells and uses direct experimental methods. These varied types of information need to be used together, and placed in a context of the characteristics of the people exposed to the risk, in order to adequately assess likelihood of effects. The associations that can be determined through epidemiological analysis require concomitant toxicological and medical research to determine biological mechanisms in order to determine likely causation. An associated methodological matter is to identify uncertainties in the key information, as this clarifies the reliability of an assessment.

Acute and chronic health effects and exposure times

Generally, health effects associated with a contaminant can be either or both acute and chronic. Acute effects are those that arise rapidly at the time of exposure, and short-term guidelines are usually determined to prevent exposure amounts that might give rise to acute effects.

Chronic effects are those that develop over time or with a delayed onset, usually after repeated or ongoing exposures. An example of chronic effects is the development of respiratory problems from exposure to particulate. For some contaminants it is possible for chronic effects to develop at ambient concentrations below those at which acute effects arise, but the averaging period of relevance will be longer. For the assessment of long-term risks, the pattern of daily averages is useful rather than a worst-case day in an annual period. This especially applies to assessment of intakes over time through food.

Appendix Two

Basis for health effects assessment

New Zealand has regulated national environmental standards for air quality (the 'NES') under the Resource Management Act, administered by the Ministry for the Environment ('MfE'). The intent of the NES regulations is for consistency to protect the environment and population health. These are supplemented by ambient air quality guidelines and other guidance documents issued by the MfE.

New Zealand and Australia use a combined approach to food standards, and use guidance from Australasian and the WHO/FAO expert panels. Food Standards Australia and New Zealand ('FSANZ') sets regulated standards, healthful diet guidelines and publishes information about typical dietary intakes.

For nutrient reference values (NRV), FSANZ refer to the NHMRC (2006) documentation that is based on exposure and effects assessments. Fluoride is included by FSANZ as an assessable nutrient and the recommendations for daily intakes were revised for fluoride in 2017.[16]

Dietary exposure to trace elements (including fluoride) is assessed for public health purposes using the context of a standardised diet pattern. The methods for establishing the simulated population diet and for sampling a range of foods for constituent analysis is based on the WHO recommended approach to National Diet Studies.

Fluoride daily intake and human health effects

Australia and New Zealand have pursued public policy to adjust fluoride intake at the population level with the aim of preventing dental caries.[17]

The revision (2017) of daily Acceptable Intakes (AI) for fluoride has produced the following guidance, with a lowering of recommended amounts for young children. The revision notes that: "The recommendations for the revised AI and UL for fluoride for 0-8 year olds have no implications for the current Drinking Water Guidelines in Australia, the current Drinking Water Standards for New Zealand or for recommendations on fluoride ingestion from toothpaste."

[16] Ministry of Health and Australian Government National Health and Medical Research Council. Nutrient reference values for Australia and New Zealand. Fluoride (updated 2017). www.nrv.gov.au

[17] As above. Update 1.1 Revision of Fluoride (2017).

Appendix Table 2: Acceptable Intake for fluoride (NRV, 2017):

Age group	Female	Male
0-6 months	-	-
7-12 months	0.5 mg/day	0.5 mg/day
1-3 years	0.6 mg/day	0.6 mg/day
4-8 years	1.1 mg/day	1.1 mg/day
9-13 years	2.0 mg/day	2.0 mg/day
14-18 years	3.0 mg/day	3.0 mg/day
19-30 years	3.0 mg/day	4.0 mg/day
31—50 years	3.0 mg/day	4.0 mg/day
51-70 years	3.0 mg/day	4.0 mg/day
70 + years	3.0 mg/day	4.0 mg/day

Pregnancy and lactation 3 mg/day

There are also higher Upper Levels of Intake recommended for use in the NRV (2017), but the usual exposure in the Hawke's Bay is expected to be in the range of the AI.

Fluoride intake, health effects and metabolism

Most of the fluoride within the human body is found in the mineralised bone crystals (hydroxyapatite). Fluoride from inhalation or ingestion first enters the blood. Fluoride does not build up in blood or soft organs (muscles, kidneys, liver, heart or brain) but it does build up in bones. About half of daily fluoride intake reacts with the surface structure of the bone and half is lost in the urine, when the kidney filters substances out of the blood. The kidneys are not strained by fluoride excretion but if a person has poor kidney health the elimination of fluoride may be altered. The liver is not affected by fluoride and does not have a role in fluoride processing.

Over time, fluoride can migrate more deeply into the bone crystal. It is also released from the surface bone cells back into the blood and some is removed in the urine. It is usual for amounts of fluoride in bone to increase with age. The fluoridated bone becomes denser.

Fluoride has been extensively studied in relation to fluoridation of water. It is concluded that there is no evidence that fluorides increase cancer risk (WHO, IARC 1998).

There is no evidence for humans that fluoride exposures are harmful to pregnancy or fertility, the endocrine system, nerves or the brain.

A NZ review for the National Fluoridation Information Service found no evidence of harm among numerous studies stating that they studied a link between IQ in children and fluoride, as a neurological outcome.[18]

Amounts of fluoride and adverse health effects

There is clear evidence that skeletal fluorosis and an increased risk of bone fractures occur at total intakes of 14 mg fluoride/day. With excess exposure over time, skeletal fluorosis can develop with resulting back and joint pain.

Appendix Table 3: daily intake and risk for adverse effects

Amounts of fluoride ingested	**Health effect reported (WHO, IPCS 2002)**
1 – 3 mg/day	Beneficial human health effects – prevents dental caries
2 – 4 mg/day	Typical daily intake
>6 mg/day	Increased risk of bone effects has been reported
>14 mg/day	Skeletal fluorosis and an increased risk of bone fractures have been reported
320 – 640 mg of fluoride, single dose	Acute toxic effects may arise in association with fluoride exposure

[18] Fluoride neurotoxicity (2011). Ministry of Health online catalogue. www.moh.govt.nz