# Homestead Bay Wastewater Treatment Plant

# Odour Impact Assessment Report

PREPARED FOR RCL | JULY 2025

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# Revision Schedule

| Rev No. | Date | Description | Signature or Typed Name (documentation on file) | | | |
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# 1.0 EXECUTIVE SUMMARY

This report has been prepared for RCL to provide an Odour Impact Assessment for the proposed Homestead Bay Wastewater Treatment Plant (WWTP). The Homestead Bay WWTP will treat wastewater from the new Homestead Bay Development. The WWTP has not yet been fully designed, however there has been concern that the meteorological conditions in the area, particularly the prevalence of inversion, would impact the ability to place a WWTP at the designated location.

Dispersion modelling has been undertaken to confirm whether, with a high level of covering, extraction and treatment of foul air, the site can achieve residual odour levels as published in the New Zealand Good Practice Guide for Assessing and Managing Odour. Odour control unit (OCU) discharge stack height was also investigated during future normal plant operations. CALPUFF modelling software has been used for this study.

This assessment utilises odour emission rates sourced from Stantec's global emission and contaminant load database, using the most representative data available. This assessment assumes a high level of covering and treatment from odorous sources (such as the inlet works and biosolids areas) as well as semi-odorous sources (such as aerobic zones of bioreactors) whilst very low odorous sources (treated water tanks) were left uncovered.

The odour impact has been assessed on a quantitative basis using Version 7 the CALPUFF atmospheric dispersion model.

Considering the conclusions provided in this investigation the following scenarios were considered for study.

- 6 m stack height and normal plant operations, and;
- 15 m stack height and normal plant operations

The dispersion modelling predictions were assessed against the New Zealand Good Practice Guide for Assessing and Managing Odour published odour impact criteria, as shown in Table 1-1, to determine whether site-wide regulatory compliance was achieved.

**Table 1-1: Odour Impact Assessment Criteria**

| Sensitivity of the receiving environment | Concentration[1] | Percentile |
|---|---|---|
| High - (worst-case impacts during unstable to semi-unstable conditions) | 1 ou | 0.1% and 0.5% |
| High - (worst-case impacts during neutral to stable conditions) | 2 ou | 0.1% and 0.5% |
| Moderate - (all conditions) | 5 ou | 0.1% and 0.5% |
| Low - (all conditions) | 5–10 ou | 0.5% |

The meteorological conditions are predominantly neutral, weakly stable and stable (see Table 1-2 below, approximately 77.5 % of the year modelled would be considered neutral to weakly stable and stable conditions).

[1] Note that the units 'ou/m$^3$' and the units 'ou' can be used interchangeably.

**Table 1-2 Meteorological stability conditions at site**

| Description | Pasquill-Gifford stability | No. of hours (total 8,760) | Totals |
|---|---|---|---|
| Very unstable | 1 | 14 | 1,966 - Unstable |
| unstable | 2 | 756 | |
| Weakly unstable | 3 | 1,196 | |
| Neutral | 4 | 3,973 | 3,973 - Neutral |
| Weakly stable | 5 | 1,330 | 2,821 - Stable |
| Very stable | 6 | 1,491 | |
| | | 8,760 | |

Table 4 of the New Zealand Good Practice Guide for Assessing and Managing Odour provides guidance on the types of land use and the corresponding general sensitivity of the receiving environment. A summary of the proposed assessment criteria used in this assessment, along with the justification behind them, is shown in **Error! Reference source not found.**.

**Table 1-3 Summary of land use sensitivity of the receiving environment and selected assessment criteria**

| Area | Land use | Sensitivity of receiving environment | Selected assessment criteria | Justification |
|---|---|---|---|---|
| Eastern area (east of SH6) | Rural | Low | 5 ou -10 ou at 99.5$^{th}$ percentile | Good practice guideline describes 'Rural' areas as having a sensitivity of 'low for rural activities. |
| West, north, and south of WWTP (west of SH6) | Rural<br>Residential | High (stable conditions) | 2 ou at 99.5$^{th}$ and 99.9$^{th}$ percentile | Good practice guideline states this as being 'moderate to high' however as there will be dwellings on this area, a conservative assessment of 'high' has been used.<br>Given there is over 77.5% of neutral and weakly stable conditions, a 2 ou criterion has been selected.<br>Boundary itself is proposed to be assessed at the 99.9$^{th}$ percentile. |

A summary table of the model results is shown in Table 1-4 which shows the 99.9$^{th}$ and 99.5$^{th}$ odour concentration at the WWTP boundary and within the new proposed Homestead Bay Development residential boundary for the 6 m OCU stack and for the 15 m OCU stack. The odour criteria is 2 ou for primarily neutral and stable atmospheric conditions in a highly sensitive environment. The odour concentration exceeds 2 ou at three receptors on the southern WWTP boundary for both OCU stack heights at both percentile limits by a small margin, i.e. 2.5 ou and 2.1 ou for the 99.9$^{th}$ and 99.5$^{th}$ percentiles.

Beyond the plant boundary the highest concentration at both percentile limits is < 2 ou, where the 15m stack predicts slightly lower concentrations than the 6 m stack. The residences within the residential boundary likely to be most exposed to odour of 1.5 to 1.9 ou are those located adjacent to the southern boundary, extending over a distance of 45 m to a depth of 15 m.

There is little difference between the two proposed OCU stack heights of 6 m or 15 m. This is not unexpected given the majority of the site's odour release is from the inlet works and sludge building ventilation, as well as due to the local meteorological conditions. The Inversion layers form regularly, and persist for long periods, this prevents vertical mixing. Regardless of whether the stack is 6 m or 15 m emissions will still get trapped below or within the same inversion layer, preventing the higher stack from achieving better dispersion. This indicates that appropriate covering and foul air capture strategies, whilst keeping extraction volumes low (and thereby keeping treated air discharge rates low) will yield better offsite impacts compared to raising stack heights.

**Table 1-4 99.9th and 99.5th odour concentration at the WWTP boundary and within the new proposed Homestead Bay Development residential boundary**

| OCU stack height (m) | WWTP Boundary | WWTP Boundary | Proposed Homestead Bay Development | Proposed Homestead Bay Development | Criteria |
|---|---|---|---|---|---|
| | **99.9th** | **99.5th** | **99.9th** | **99.5th** | |
| 6 m | 2.5 ou | 2.1 ou | 1.9 ou | 1.7 ou | 2 ou (primarily neutral, stable conditions in a highly sensitive environment) |
| 15 m | 2.5 ou | 2.1 ou | 1.8 ou | 1.6 ou | |

The findings indicate that the proposed Homestead Bay WWTP will have a small odour impact of 2.5 ou at the 99.9th percentile and 2.1 ou at the 99.5th percentile limits for a 6 m and a 15 m stack height at the southern boundary of the WWTP. There are no current sensitive receptors that exceed 0.3 ou, and there will only be a small area (45 m along the fence line, and 15 m deep) extending beyond the plant boundary into the proposed Homestead Bay Development where odour concentrations are expected to be between 1.5 and 1.9 ou.

The dispersion modelling has indicated that increasing the stack height from 6 m to 15 m results in only modest reductions in odour concentrations, largely due to the steep valley setting and frequent inversion layers that limit vertical dispersion. While a 6 m stack, which is relatively low, may be sufficient to achieve minimal plume lift above the local inversion base, the 15m stack height does not greatly improve ground level concentrations, plus it introduces a higher visual impact. It would be good practice to ensure the following is developed throughout the design of the WWTP and surroundings:

- Provide an OCU with a stack height that is at least 2 m above the height of the nearest building to aid in dispersion, and preferably above 8 m (given the expected heights of nearby buildings and structures).
- Site the OCU at a location that is furthest from potential complainants.
- Provide a 100 m buffer zone around the plant boundary would also mitigate odour impact when issues occur on site such as maintenance activities that may require opening of foul air covers.

In summary, the proposed mitigation will achieve the residual odour levels in accordance with the New Zealand Good Practice Guide for assessing and managing odour.

# 2.0 INTRODUCTION

## 2.1 BACKGROUND

The Homestead Bay wastewater treatment plant (WWTP) is planned to service the new Homestead Bay Development (and adjacent areas). The location of the WWTP is at the upper end of the development and it is anticipated that the terrain and the occurrence of inversion layers will cause odour from the WWTP to wash down onto the development and adjacent areas. An odour impact assessment has therefore been undertaken to determine residual odour impact based on a high level of covering, extraction and treatment of foul air from the site.

The design of the WWTP has not yet been finalised yet it is expected to consist of a membrane bioreactor (MBR) type treatment process with a packaged inlet works and sludge handling systems housed within a building. Given the terrain and inversion layers that commonly occur in the area, it is anticipated that the majority of odorous processes, including those areas that would be considered semi-odorous such as aerobic zones of the MBR, would be covered with foul air extracted and treated in an odour control unit (OCU) to a high level of treatment (i.e. with activated carbon polishing).

The CALPUFF suite of modelling software has been used for this odour impact study due to the complicated site topography and proximity to water bodies.

Two scenarios have been developed to determine if raising the stack height on the OCU discharge will provide any further benefits. It should be noted that whilst an increase in stack height is likely to improve dispersion, given the local meteorological conditions at this location, the benefits may only be minimal whilst a stack height increase will definitely come with a higher visual amenity impact for the site. The purpose of this odour impact assessment is therefore twofold being:

1. Determine if the residual odour impact, after covering, foul air capture and treatment, would meet the odour requirements within the Good Practice Guide for Assessing and Managing Odour, NZ and;
2. Determine if dispersion benefits of increasing the stack height would outweigh the visual amenity impact.

## 2.2 SCOPE OF WORK

The objectives of this odour study were to:

- Review the data and information relating to the proposed site and the proposed OCU configurations, including the site layout and processes, potential odour sources, and the location of off-site sensitive receptors.
- Prepare a site-wide odour emissions inventory for Homestead Bay Wastewater Treatment Plant including odour emission rates for each potential odour source using Stantec's odour emission global database for inclusion in the dispersion model for the following two scenarios:
    - OCU with a 6m stack height – Normal plant operations
    - OCU with a 15m stack height – Normal plant operations
- Prepare a 3-Dimensional CALMET meteorological data file based on observations for inclusion in the CALPUFF dispersion model.
- Develop and run the CALPUFF dispersion model for each scenario, incorporating a 3-Dimensional CALMET meteorological data file, fine-scale terrain and land use data, and odour emission source inputs to simulate odour dispersion conditions at the WWTP in order to predict the odour impact.
- Assess the potential odour impact using contour plots showing the 99.5$^{th}$ and 99.9$^{th}$ percentile odour levels and identify whether the modelling results satisfy the requirements specified in the Good Practice Guide for Assessing and Managing Odour, NZ.
- Produce an odour impact assessment report (this document) for RCL outlining the odour dispersion

modelling methodology, model inputs and assumptions, and modelling results in the form of isopleth contour plots showing odour concentration at modelled sensitive receptor locations.

The dispersion modelling predictions were assessed against the odour impact criteria published in the NZ Good Practice Guide for Assessing and Managing Odour to determine whether compliance was achieved. The 99.5th and 99.9th percentile modelling predictions were reported against the impact assessment criterion of 2 odour units (ou) at the boundary of the plant and at the nearest receptors.

The CALPUFF dispersion modelling and reporting was carried out in accordance with the following documents:

- Good Practice Guide for Assessing and Managing Odour, Ministry for the Environment, New Zealand, 2016.
- Good Practice Guide for Atmospheric Dispersion Modelling, Ministry for the Environment, New Zealand, 2004.
- Good Practice Guide for Assessing Discharges to Air from Industry, Ministry for the Environment, New Zealand, 2016
- Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessment of Air Pollutants in NSW, Australia. Prepared for NSW Office of Environment and Heritage (OEH), Sydney Australia. Barclay, J.J and Scire, J.S., Atmospheric Studies Group, TRC, 2011.

  [It should be noted that whilst this is an NSW document, it is referred to by many other EPAs across Australia and New Zealand.]
- Review of Odour Management in New Zealand, Technical Background Report, Ministry for the Environment, August 2002.
- The NZ Resource Management Act, RMA, 1991

# 3.0 STUDY AREA

## 3.1 LOCATION AND SURROUNDING LAND USE

The Homestead Bay WWTP will be located in the Jack's Point Resort zone within the Queenstown District and will serve as a vital infrastructure facility responsible for treating wastewater from the new proposed Homestead Bay Development before it is discharged back into the environment. Homestead Bay Development is a proposed lakeside suburb located to the south of the current Jacks Point residential area. The large scale master planned residential and mixed-use community will cover an area of approximately 200 ha and is expected to include up to 2,800 residential units, comprised of freehold, apartments, townhouses and medium density housing, along with commercial utilities such as shops and a supermarket. The project is listed in the Governments Fast-Track Approvals Bill, meaning it may bypass standard RMA processes via referral to an expert panel.

The current status under the Operative District Plan, the Homestead Bay site is zoned Rural, but it is being rezoned to a custom development Activity Area within the broader Jacks Point structure. This new zoning enables medium to higher density residential development, and allows for commercial, community and visitor accommodation uses, it also establishes a local centre and mixed-use precinct in support of the fast track application.

Currently, there is no reticulated wastewater, and a number of options have been investigated including connecting to Queenstown District Council network at Shotover Treatment Plant. However, on-site, centralised treatment is the preferred option for Homestead Bay. Homes would connect directly to sewer mains, without individual home primary (or septic) tanks. Sewage will then be pumped to a central treatment unit and treated effluent will then be dispersed via drip irrigation across land parcels. The drip setup mirrors systems already used successfully at Jacks Point.

The proposed WWTP will be surrounded by residences to the south and west, and State Highway 6 on the east. The current closest sensitive receptor is located approximately 491 m away. Once Homestead Bay Development has been developed, the nearest residential areas will be adjacent to the WWTP. The terrain to the east, within a few hundred metres of the WWTP, is complex and steep. Figure 3-1 illustrates the position of the WWTP and its surrounds, with the plant boundary highlighted in blue, the proposed boundary of the Homestead Bay Development in red and the proposed process units in pink (area and volume sources) and Xs (point sources).


**Figure 3-1 Google Earth image of Homestead Bay WWTP showing the plant boundary (blue) and future proposed Homestead Bay Development residential boundary (red)**

## 3.2 PROCESS DESCRIPTION

It should be noted that the design has not been progressed for the full processes at the WWTP. The assumed current preferred process description of Homestead Bay is summarised in Figure 3-2.

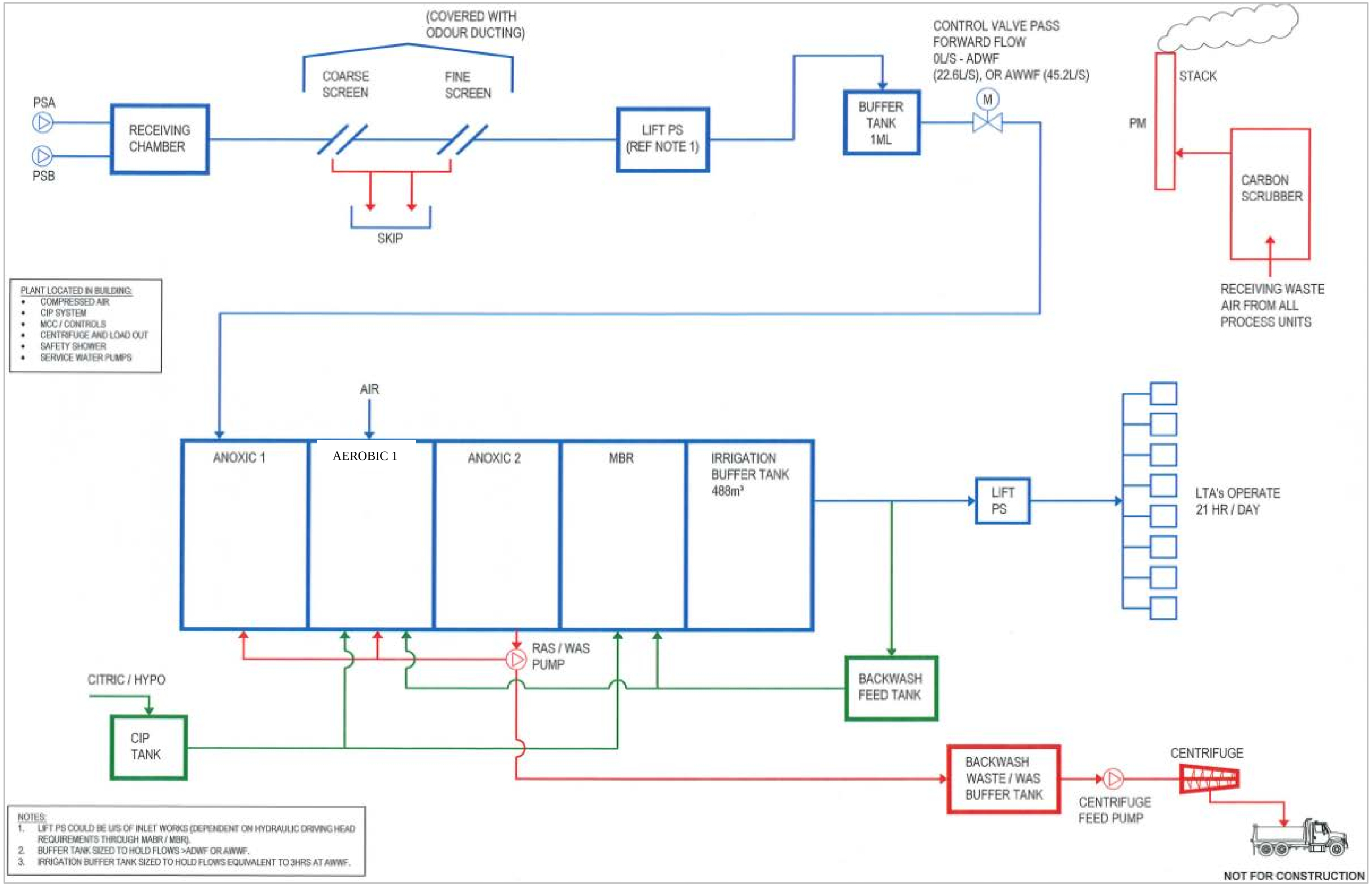



**Figure 3-2: Flow diagram of Homestead Bay WWTP**

The WWTP receives its inflow from the wastewater infrastructure in the Homestead Bay Development. Wastewater will enter a packaged inlet works (housed within a building) for screenings and grit removal before entering a buffer tank for flow balancing. Screenings and grit will be stored in enclosed bins. Screened and de-gritted wastewater will be pumped into a membrane bioreactor (MBR) for biological treatment. The process will include anaerobic, anoxic and aerobic zones. Mixed liquor will then undergo phase separation in aerated membrane tanks. Some treated effluent will be stored in a backwash feed tank before being used for membrane backwashes. The remaining treated effluent will be stored in an irrigation buffer tank before it is pumped into the irrigation system.

Waste activated sludge (WAS) will be wasted from the anoxic zone of the MBR before being stored in a WAS buffer tank. WAS will then be dewatered via a centrifuge with dewatered sludge stored in an enclosed sludge bin. The WAS buffer tank, centrifuges and associated dewatered sludge conveyors will be housed within the same building that the inlet works will in.

An odour control unit (OCU) will extract foul air from the following locations:

- Buffer tank
- Packaged inlet works
- Screenings conveyor(s)
- Screenings/grit bin(s)
- Lift pumping station
- Membrane bioreactor including
    - Anaerobic zone
    - Anoxic zone
    - Aerobic zone
    - Membrane tank
- Backwash waste / WAS buffer tank
- Centrifuge
- Dewatered sludge conveyor(s)
- Dewatered sludge bin

It is expected that the OCU will draw approximately 8,100 $m^3$/h and will involve a polishing treatment stage such that the discharge has an odour of <500 ou.

It has also been assumed that the inlet works / sludge building will have 4x axial fans which will essentially draw fresh air in from the base and discharge contaminated ‘building air’ through the top. The intent with the process unit extraction is to limit the amount of foul air that can be released to contaminate the building air, and then the building ventilation is to limit the amount of contaminated building air that wafts out through openings. Four axial fans each at 3.9 $m^3$/s have been assumed to give approximately 12 air changes from the building.

# 4.0 ASSESSMENT CRITERIA FOR ODOUR

## 4.1 LEGISLATIVE CONTEXT

In New Zealand, odour impact assessment is primarily governed by the Resource Management Act 1991 (RMA). The RMA provides the framework for managing environmental effects, including odour emissions, to ensure they do not cause significant adverse effects on the environment or public health. The RMA requires that any discharge of contaminants into the air, including odours, must not cause offensive or objectionable effects beyond the boundary of the property from which the discharge originates.

As detailed in Section 2.2 of this report, the Good Practice Guide for Assessing and Managing Odour, Ministry of Environment, New Zealand is adopted for the assessment criteria for odour. The recommendations in this guide are not legislative requirements under the RMA or any other legislation. However, they are based on expert opinion and consultation with practitioners involved in odour assessment, and regulators charged with managing offensive odours. As such they should be taken into account in decision-making processes.

The purpose of the RMA as specified in section 5(1) is "to promote the sustainable management of natural and physical resources". The relevant sections of the RMA with reference to odour and its impact includes:

- **Section 9:** Section 9 of the RMA allows a person to use land in any manner they like, provided it does not contravene a rule in a plan. If the activity does contravene a rule, then a resource consent is required (unless existing use rights already apply). Odour emissions from a land use may, therefore, be controlled if the plan restricts the use of land, and its associated effects, that cause the odour emission, and/or amenity requirements.
- **Section 15**: The compounds that cause odour effects are air contaminants, so their discharge is controlled under section 15 of the RMA. Under section 15(1), discharges from industrial or trade premises are only allowed if they are authorised by a rule in a regional plan, a resource consent, or regulations (such as a national environmental standard). If the activity is prohibited under the plan, then no resource consent can be obtained. In essence, if there are discharges of odour to air from an industrial or trade premises, the discharge will need to be either:
    - a permitted activity in a regulation or plan, or
    - authorised by a resource consent.

  If the discharges of odour to air are not from an industrial or trade premises then, unless there is a rule or regulation relating to the discharge, a consent is not needed.
- **Section 17:** Section 17 of the RMA imposes a general duty on every person to avoid, remedy or mitigate any adverse effect on the environment arising from any activities the individual may conduct or have carried out on their behalf. This applies regardless of whether the activity is carried out in accordance with any rule, plan or resource consent.
- **Section 17(3)(a)** allows an enforcement order to be made or served that can be made or served by the Environment Court or an Enforcement Officer. These require a person to cease doing something that is, or is likely to be, noxious, dangerous, offensive, or objectionable to such an extent that it has or is likely to have an adverse effect on the environment.
- **Section 108(2)(e):** In accordance with Section 108(2)(e) of the RMA, resource consents may include a condition requiring that the best practicable option is adopted to prevent or minimise any adverse effects caused by a discharge, provided that the inclusion of such a condition is the most efficient and effective means of preventing or minimising any actual or likely adverse effect on the environment.

The Health Act 1956 (Version as at the 30 June 2024) (Health Act) is relevant if odours are causing nuisance or health hazard. Territorial authorities and public health authorities (district health boards) have a duty to improve, promote and protect public health under the Health Act. In cases where odours are known or suspected to cause adverse health effects, councils should advise public health officers and/or the medical officer of health.

## 4.2 POTENTIAL ODOUR NUISANCE EFFECTS

The odour assessment contained in this report evaluates the potential for the activities and processes on-site at the WWTP to cause odour nuisance at the plant boundary as well as off-site sensitive receptors e.g., residential properties located in close proximity to the site boundary.

It is generally accepted that the following factors create odour nuisance or odour complaints:

- Frequency: How often a person is exposed to the odour. In this modelling report, the frequency aspect is addressed by the limits set in the percentile limits of the odour being present.
- Intensity: In this context, the intensity is the perceived strength of the odour. In this modelling report, this is addressed by the odour strength and reported in odour units (‘ou’), as described below.
- Duration: How long the odour is present for. In this modelling report, the frequency aspect is addressed by the limits set in the percentile limits and the averaging times of the odour being present.
- Offensiveness (often combined with Location or Context): This can be highly subjective. For instance, a person passing by a bakery may find the smell of baking pleasing, but a person living near a bakery exposed to the same odours continuously within their home may find the same baking odours highly offensive. Alternatively, many people would find rendering odours offensive on their own but in the context of that person being at the rendering facility, and expecting the odours to be present, they may find the odours unpleasant but not offensive. In the context of this report, it is assumed that odours being emitted from WWTP processes would be considered offensive.
- Location or Context: This can be highly subjective and the same analogies of the bakery and rendering plant described for ‘Offensiveness’ apply. The location or context can also be impacted by the sensitivity of the receiving environment as discussed below.

## 4.3 SENSITIVITY OF THE RECEIVING ENVIRONMENT

Under the RMA the sensitivity of the receiving environment must be taken into account and should be considered as part of any odour assessment. The degree of sensitivity in a particular location is based on characteristics of the land use, including the time of day and the reason why people are at the particular location (e.g., for work or recreation).

The proposed Homestead Bay Development and WWTP are located within an area identified as a ‘future urban area’ at the southern end of the Te Tapuae / Southern Corridor which is a ‘priority development area’ under the Queenstown Lakes Spatial Plan. It is also identified as an ‘Indicative Future Expansion Area’ in Chapter 4 – Urban Development of the Queenstown Lakes Proposed District Plan.

Urban designers, Urbanshift, have included a current masterplan for the new proposed development, as detailed in the Fast Track Application documents[2]. The current masterplan is shown in Figure 4-1 and includes the proposed density of the development, the location of a local shopping centre, open space areas as well as roading and trail linkages. The proposed WWTP is not shown but is expected to be located north of the shopping centre, in the medium residential density zone.

[2] Fast Track Referral Application for Homestead Bay, Assessment of Environmental Effects. Remarkable Planning. April 2024.

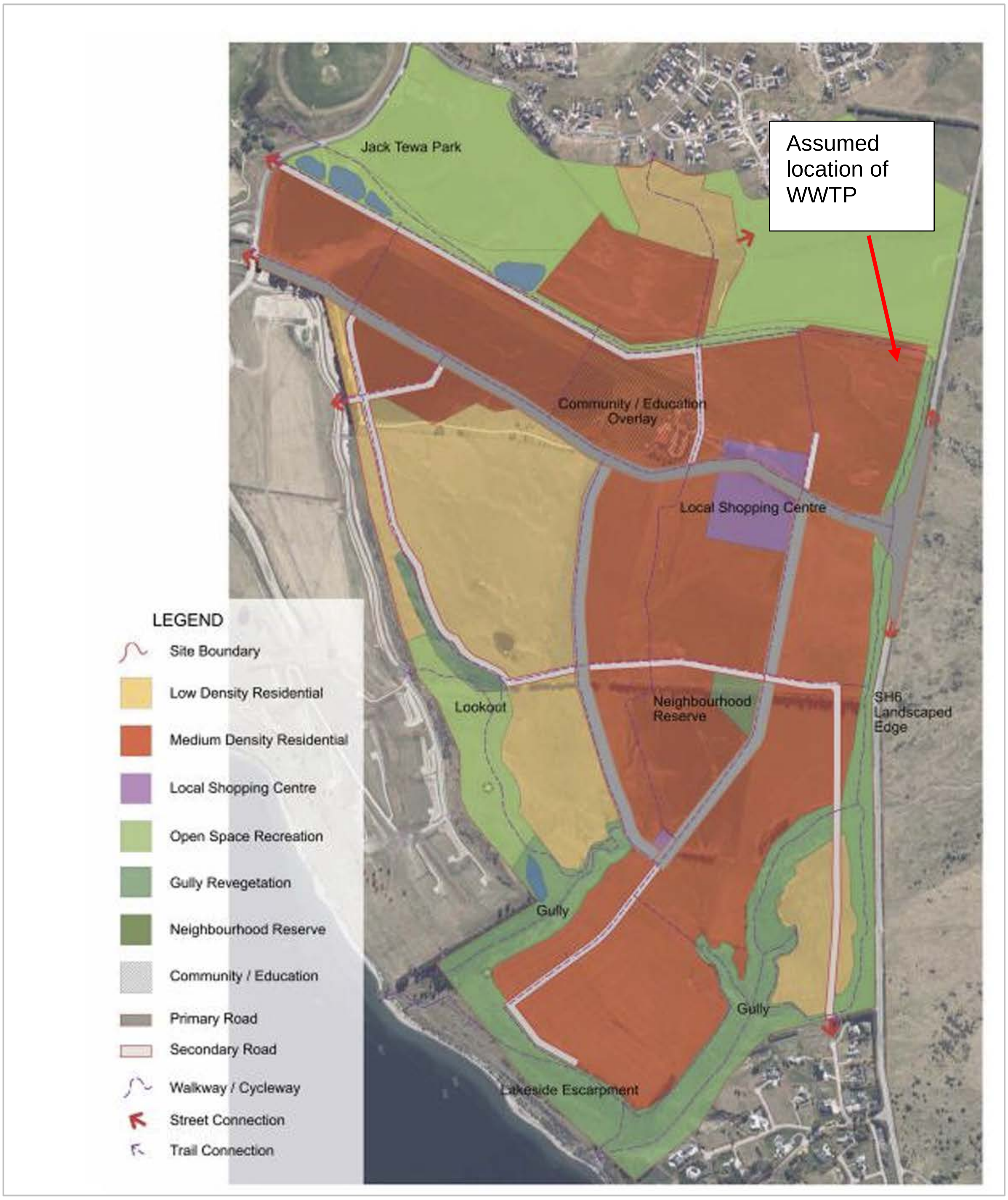



**Figure 4-1: Urban shift masterplan for the development of Homestead Bay (from Figure 4 of the Fast Track Assessment of Environmental Effects)**

Table 4 of the Good Practice Guide for Assessing and Managing Odour (NZ) provides guidance on the types of land use and the corresponding general sensitivity of the receiving environment. This has been recreated in Table 4-1.

**Table 4-1 Summary of type of land use and the general sensitivity of the receiving environment**

| Land use | Rating | |
|---|---|---|
| Hospitals, schools, childcare facilities, rest homes, marae | High | People of high sensitivity (including children, the sick and the elderly) are exposed, and/or<br>People are likely to be exposed continuously (up to 24 hours, seven days a week). |
| Residential | High | People of high sensitivity (including children and the elderly) are exposed.<br>People expect a high level of amenity in their home and immediate environs (i.e., curtilage).<br>People may be present all times of the day and night, both indoors and outdoors.<br>Visitors to the area are unfamiliar with any discharges and are more likely to be adversely affected (which can cause embarrassment to residents and raise awareness of the problem). |
| Open space recreational | Moderate to high | These areas are used for outdoor activities and exercise, in circumstances where people tend to be more aware of the air quality.<br>People of all ages and sensitivity can be present. |
| Commercial, retail, business | High | These areas may have high environmental values, so adverse effects are unlikely to be tolerated.<br>These areas have a similar population density to residential areas as people of all ages and sensitivity can use them.<br>Commercial activities may also be sensitive to other uses (e.g., food preparation affected by volatile organic compounds emissions from paint manufacture).<br>There can be embarrassment factors for businesses with clients on their premises.<br>Note: Need to consider the time of day, nature of activity, and likelihood of exposure (people are typically present less than 24 hours per day). |
| Rural residential / countryside living | Moderate to High | Population density is lower than in residential areas, so the opportunity to be adversely affected is lower. However, people of high sensitivity can still be exposed at all times of the day and night.<br>Often people move into these areas for a healthier lifestyle and can be particularly sensitive to amenity issues or perceived health risks. |
| Rural | Low for rural activities; moderate or high for other activities | A low population density means there is a decreased risk of people being adversely affected.<br>People living in and visiting rural areas generally have a high tolerance for rural activities and their associated effects. Although these people can be desensitised to rural activities, they may still be sensitive to other types of activities (e.g., industrial activities). |

| Land use | Rating | |
|---|---|---|
| Heavy industrial | Low | Adverse amenity effects tend to be tolerated, as long as the effects are not severe.<br>Many sources discharge into air, so there is often a mix of effects.<br>People who occupy these areas tend to be adult and in good physical condition, so are more likely to tolerate adverse effects, particularly if the source is associated with their employment.<br>Note: Need to consider the time of day, nature of activity, and likelihood of exposure (people are typically present less than 24 hours per day). |
| Light industrial | Moderate | These areas tend to be a mix of small industrial premises and commercial/retail/food activities. Some activities are incompatible with air quality impacts (such as food manufacturers not wanting odours from paint spraying), while others will discharge to air.<br>Note: Need to consider the time of day, nature of activity, and likelihood of exposure (people are typically present less than 24 hours per day). |
| Public roads | Low | Roads users will typically be exposed to adverse effects from air discharges for only short periods of time. |

Specific current sensitive receptors were also included in the dispersion model. Table 4-2 and Figure 4-2 show sensitive receptors included in this assessment.

**Table 4-2 Current Sensitive Receptors Surrounding the WWTP**

| Receptor Number | X Coordinate (km) | Y Coordinate (km) | Description |
|---|---|---|---|
| **1** | 322.906 | 5005.025 | Airport |
| **2** | 322.581 | 5005.716 | Residences |
| **3** | 322.628 | 5005.666 | Residences |
| **4** | 322.668 | 5005.640 | Residences |
| **5** | 322.727 | 5005.635 | Residences |
| **6** | 322.772 | 5005.643 | Residences |
| **7** | 322.843 | 5005.642 | Residences |
| **8** | 322.898 | 5005.630 | Residences |
| **9** | 322.939 | 5005.628 | Residences |
| **10** | 322.966 | 5005.625 | Residences |
| **11** | 322.994 | 5005.637 | Residences |
| **12** | 323.046 | 5005.637 | Residences |
| **13** | 323.061 | 5005.615 | Residences |
| **14** | 323.065 | 5005.586 | Residences |
| **15** | 323.079 | 5005.556 | Residences |
| **16** | 323.110 | 5005.557 | Residences |
| **17** | 323.139 | 5005.563 | Residences |

| Receptor Number | X Coordinate (km) | Y Coordinate (km) | Description |
|---|---|---|---|
| **18** | 323.147 | 5005.578 | Residences |
| **19** | 323.132 | 5005.601 | Residences |
| **20** | 323.130 | 5005.621 | Residences |
| **21** | 322.365 | 5005.643 | Sports playing fields |
| **22** | 322.184 | 5005.812 | Sports playing fields |
| **23** | 322.307 | 5004.353 | Residence southwest outside res zone |
| **24** | 322.986 | 5003.521 | Residences south of residential zone |
| **25** | 323.144 | 5003.603 | Residences south of residential zone |
| **26** | 323.171 | 5003.701 | Residences south of residential zone |
| **27** | 323.222 | 5003.734 | Residences south of residential zone |
| **28** | 323.289 | 5003.763 | Residences south of residential zone |
| **29** | 323.344 | 5003.791 | Residences south of residential zone |
| **30** | 323.207 | 5005.779 | Residence, Pendeen Cres |
| **31** | 323.229 | 5005.771 | Residence, Pendeen Cres |
| **32** | 323.261 | 5005.779 | Residence, Pendeen Cres |
| **33** | 323.299 | 5005.813 | Residence, Pendeen Cres |
| **34** | 323.138 | 5005.705 | Residence, Pendeen Cres |
| **35** | 321.328 | 5004.760 | Rural Residence, south |

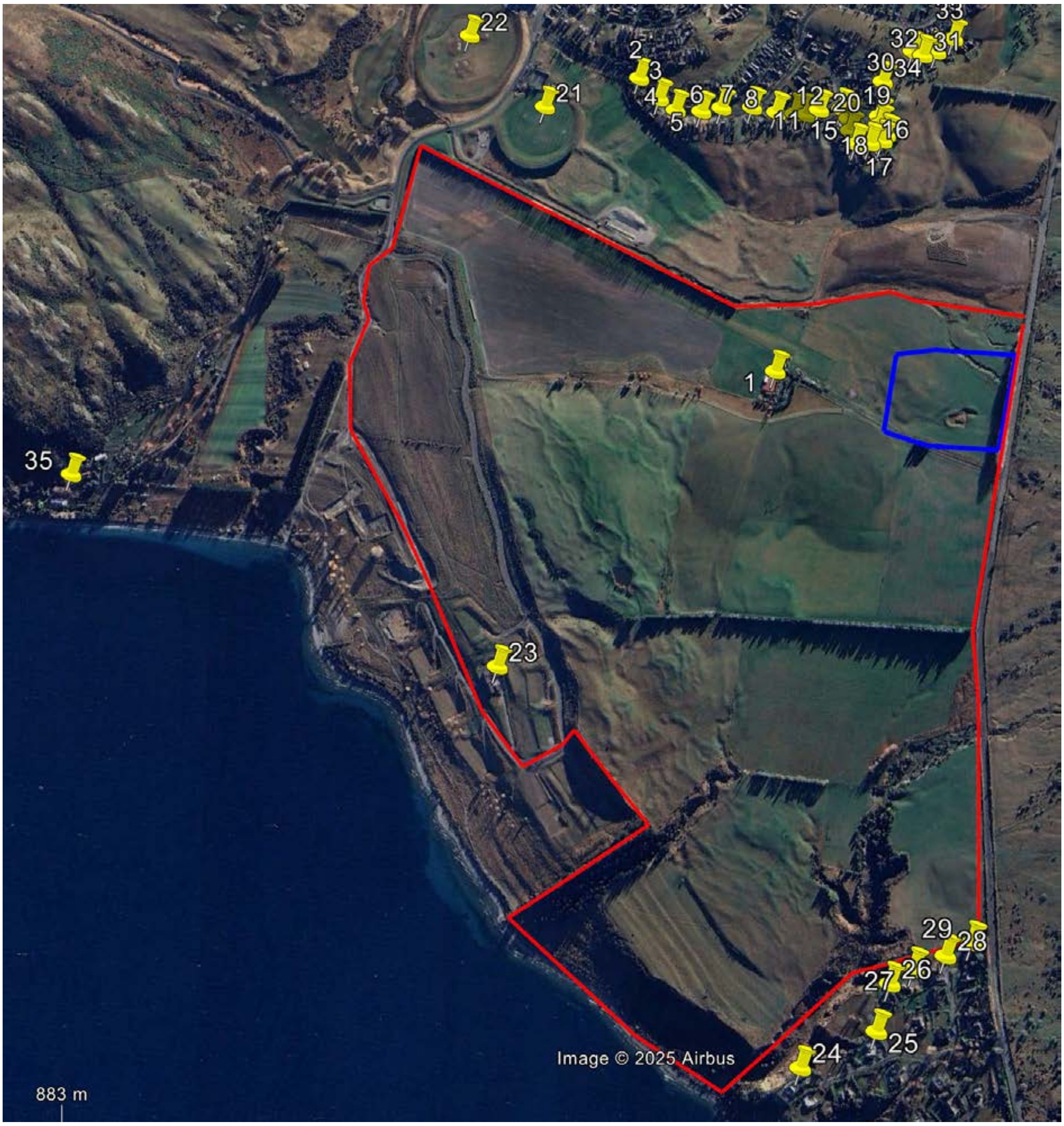



**Figure 4-2Sensitive Receptors Surrounding the WWTP**

## 4.4 ODOUR IMPACT ASSESSMENT CRITERIA

In New Zealand, the strength of odours for use in odour impact assessments is expressed in odour units (ou). The odour units are effectively dilution ratios. 1 ou is taken to be the lowest odour strength that the average person can detect in the most stringent of laboratory conditions. At this strength 50% of a statistical population would only be able to say that an odour was present but not recognise the smell. As an example, an odour strength of 500 ou means that the original odour would need to be diluted approximately 500 times to reach the 1 ou concentration.

Section 4.4.4 of the Good Practice Guide for Assessing and Managing Odour provides an odour modelling guideline value for comparison of the dispersion model outputs in odour units per cubic meter ($OU/m^3$)[3], with due consideration of the sensitivity of the proposed receiving environment. Table 4-2 lists the recommended odour-modelling guideline values as per Good Practice Guide for Assessing and Managing Odour.

**Table 4-3: Odour Impact Assessment Criteria**

| Sensitivity of the receiving environment | Concentration | Percentile |
|---|---|---|
| **High - (worst-case impacts during unstable to semi-unstable conditions)** | 1 ou | 0.1% and 0.5% |
| **High - (worst-case impacts during neutral to stable conditions)** | 2 ou | 0.1% and 0.5% |
| **Moderate - (all conditions)** | 5 ou | 0.1% and 0.5% |
| **Low - (all conditions)** | 5–10 ou | 0.5% |

**The various considerations for the application of these guidelines are:**

- Atmospheric stability has been accounted for in high sensitivity receiving environments (stability refers to the degree of mixing that occurs).
- Odour concentration percentiles were developed from dose/effect-based research correlating modelled concentrations with population annoyance[4].
- The concentration components in the table already include the peak-to-mean ratio adjustment for all source types and should be used as design ground-level concentrations for one-hour modelling averages.
- The guideline values are most applicable to odours of an unpleasant character. Odours which are less offensive in character (e.g., odours from food processing) may not be found as offensive in practice even if predicted to exceed the guideline values.

The site is considered a high sensitivity receiving environment. The meteorological conditions are predominantly neutral to weakly stable (see Table 4-4 below, approximately 45.5% would be considered neutral, 32.2% stable and weakly stable, and 22.4% of the time unstable and weakly unstable conditions).

**Table 4-4 Meteorological stability conditions at site**

| Description | PG stability | No. of hours (total 8760) | Totals |
|---|---|---|---|
| Very unstable | 1 | 14 | |
| unstable | 2 | 756 | 1,966 - Unstable |
| Weakly unstable | 3 | 1,196 | |
| Neutral | 4 | 3,973 | 3,973 - Neutral |
| Weakly stable | 5 | 1,330 | 2,821 - Stable |
| Very stable | 6 | 1,491 | |

[3] Note that this unit is interchangeable with ‘ou’.
[4] Review of Odour Management in New Zealand: Technical Report (Ministry for the Environment, 2002).

Taking into account the meteorological stability of the site and the sensitivity of the receiving environment, Table 4-5 provides the assessment criteria for different areas around the WWTP.

**Table 4-5 Summary of land use sensitivity of the receiving environment and selected assessment criteria**

| Area | Land use | Sensitivity of receiving environment | Selected assessment criteria | Justification |
|---|---|---|---|---|
| Eastern area (east of SH6) | Rural | Low | 5 ou - 10 ou at 99.5$^{th}$ percentile | Good practice guideline describes ‘Rural’ areas as having a sensitivity of ‘low for rural activities. |
| West, north, and south of WWTP (west of SH6) | Current Rural, but to become Development Activity Area | High (stable conditions) | 2 ou at 99.5$^{th}$ and 99.9$^{th}$ percentile | Good practice guideline states this as being ‘moderate to high’ however as there will be dwellings on this area, a conservative assessment of ‘high’ has been used.<br>Given there is over 75% of neutral and weakly stable conditions, a 2 ou criterion has been selected.<br>The boundary itself is proposed to be assessed at the 99.9$^{th}$ percentile. |

# 5.0 ASSESSMENT METHODOLOGY – METEOROLOGY

Three-dimensional meteorological modelling for a full year of hourly meteorology for the year 2023 has been conducted at the WWTP. Hourly surface meteorological data from nearby Queenstown Airport has been captured and refined for input into the CALMET meteorological model to create a 3-dimensional wind and temperature field over the WWTP.

This Chapter describes the climate of the Queenstown region and the main weather drivers of 2023. A historic comparison of the long term weather conditions to the year 2023 at key meteorological stations was conducted to ensure the viability and validity of 2023 as the chosen model year.

In addition, this Chapter describes the meteorological model methods and an evaluation of the data at the WWTP.

## 5.1 Climate of Queenstown Region for the Modelled Year

### 5.1.1 2023 Climate

The 2023 climate summary was sourced from the National Institute of Water and Atmospheric research (NIWA) from the NIWA Climate Summary Archives.0F[5]

2023 was New Zealand's 2nd warmest year on record. Globally, 2023 was the warmest year on record, with 86% of the planet's surface area experiencing above average temperatures. 2023 was also the 4th cloudiest year on record and was a wet year. The nationwide solar radiation anomaly was 97% of normal, while the nationwide rainfall was 104% of normal compared to the 1991 - 2020 long-term normal.

Average temperatures were between 0.51ºC and 1.20ºC above the 1991 – 2020 baseline for much of the country – including Otago and the Queenstown District. This warmth followed on from already elevated ocean temperatures, driven partly by the transition from La Nina to El Nino conditions across the Pacific, together with record breaking sea surface anomalies – such as 3.19ºC off the West Coast of the South Island in February. Annual rainfall was near or slightly below normal across Otago. Queenstown experienced an exceptionally wet day on 21 September, recording 87 mm in a single day and its wettest day in 24 years. This event was part of the southern New Zealand floods, triggering landslides, evacuations, and a state of emergency in the district.

### 5.1.2 Climate Drivers of 2023

Several climate drivers came together in 2023. The main climate driver was the transition of a La Nina event to an El Nino. La Nina is usually characterised by cooler than average ocean temperatures in the central and eastern equatorial Pacific, while El Nino is the opposite. Both La Nina and El Nino influence the atmospheric circulation patterns in the Pacific Ocean. Subtropical northeast winds were common in the first half of the year in the North Island while El Nino type south westerly winds dominated in the second half of the year.

In the Indian Ocean, a seesaw of sea-surface temperatures (SST) known as the Indian Ocean Dipole (IOD) transitioned to its positive phase during spring, 2023. This climate driver has historically been seen to amplify the circulation regimes associated with El Nino. However, despite this IOD event being one of the strongest on record, its impacts across NZ were muted in 2023.

Another key driver was the frequency of high pressure systems over the Tasman and east coast during the spring and autumn. These delivered dry warm spells interspersed with frontal rain and were particularly noticeable in Queenstown throughout autumn.

[5] https://niwa.co.nz/climate-and-weather/climate-summaries-0

### 5.1.3 Comparison of Modelled Year, 2023, with Historic Climate

#### 5.1.3.1 Wind speed and wind direction

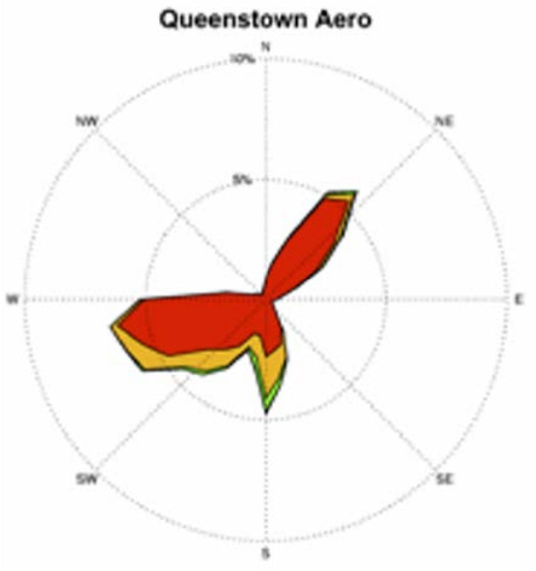
The decades long-term monthly wind speeds for Queenstown are compared to the 5-year 2020 – 2024 record and with the modelled year, 2023 and are shown in Table 5-1. Table 5-1 shows that 2023 has higher overall wind speeds than either the long term record or the more recent 5-year record. Winds are above average in 2023 in January, November and December. In addition, 2023 also shows more distinct seasonal variation, where winds are higher in summer and early spring, while the winter months remain relatively calm in comparison to other years. Spring is generally the windiest season throughout the region, whereas autumn records the lowest percentage of strong winds.

**Table 5-1 Long term and 2023 mean monthly wind speeds for Queenstown from all data available from 1981 – 2020.**

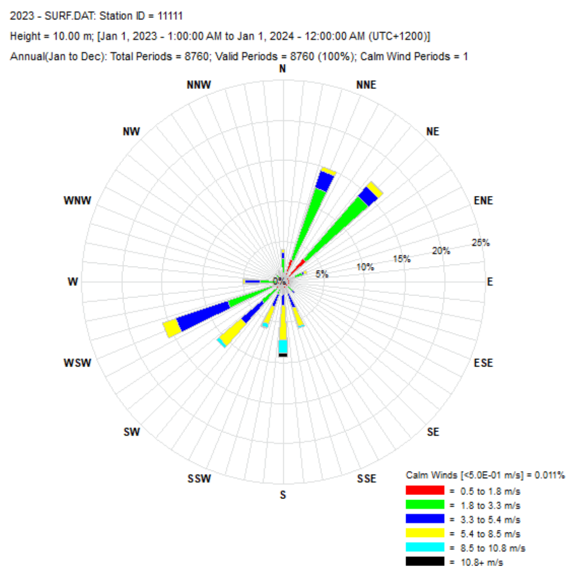
| Description | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Queenstown (long term record)[6],[7]** | 3.9 | 3.5 | 3.5 | 3.3 | 3.3 | 3.0 | 2.8 | 3.2 | 3.7 | 4.1 | 4.0 | 3.9 |
| **Queenstown 2020-2024** | 4.1 | 3.8 | 3.5 | 3.1 | 2.9 | 2.8 | 3.1 | 3.0 | 3.5 | 3.8 | 3.9 | 4.1 |
| **Queenstown 2023** | 4.3 | 3.8 | 3.7 | 3.0 | 2.8 | 2.5 | 3.4 | 3.3 | 3.7 | 4.1 | 4.2 | 4.4 |

Figure 5-1 shows the historic wind rose[8] at Queenstown airport compared to the modelled year, 2023. The annual wind rose shows strong topographic channelling where the dominant winds are predominantly aligned with the valley systems, i.e. from the east and northeast and from the southwest. Appendix B shows the annual wind roses for Queenstown for each year assessed, 2020 - 2024. The roses are in very good agreement with one another. The dominant wind directions come from the northeast (16.5%) and north northeast (15%) and are mainly in the 1.8 – 3.3 m/s range. Winds from the west southwest occur for approximately 15.8% of any year, and are generally associated with winds in the range from 3.3 – 5.4 m/s. Southwest winds and south winds account for 10.9% and 9.3% of all winds, respectively, and are noticeably stronger being primarily in the range 5.4 – 8.5 m/s. South southeast (6%) and south southwest (6%) winds occur with moderate frequency.

[6] National Institute of Water and Atmospheric Research (Year). *CliFlo (NIWA National Climate Database) – station data for Queenstown Aero AWS.* Accessed via NIWA DataHub
[7] Ministry for the Environment (2023). *Atmosphere and Climate Indicators 2023* (datasets for wind, temperature, rainfall)—derived from NIWA data, covering 1972–2022.
[8] A wind rose is a circular diagram that shows the frequency and direction of wind at a specific location over a set period. It visually represents how often the wind blows from each compass direction, often including wind speed ranges as well. The wind direction blows towards the centre of the rose.

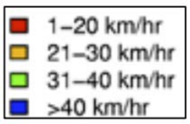



**Queenstown Airport, long term record (1981-2020)**




**Queenstown, 2023**

5km\hr = 1.4m/s
10km\hr = 2.8 m/s
20km\hr = 5.6 m/s
30km\hr = 8.3 m/s
40 km\hr = 11.1 m/s



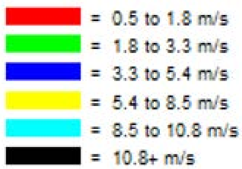




**Figure 5-1 Comparison of historic annual wind frequencies with modelled year, 2023 at Queenstown Airport**

## 5.1.3.2 Temperature

Figure 5-2 shows both the 2023 and the average 2020 - 2024 diurnal temperature distributions. Both 2023 and the average of 2020 - 2024 follow a typical diurnal pattern, where temperature is warmer in the daytime and cooler at night. The coolest surface temperature occurs at around 06h – 07h of approximately 6.5ºC, and the warmest temperature peaks at 15h of 15ºC. The 2023 temperatures are consistently slightly warmer than the 2020 - 2024 average, throughout the day. The difference is most noticeable between 12h and 16h, where 2023 is about 0.5 – 1ºC warmer. In the early morning and late evening show minor differences of 0.2-0.3ºC.

In summary, the prevailing wind patterns and temperature are consistent across all the years and the modelled year and provide sufficient evidence that 2023 is a suitable year for modelling purposes.

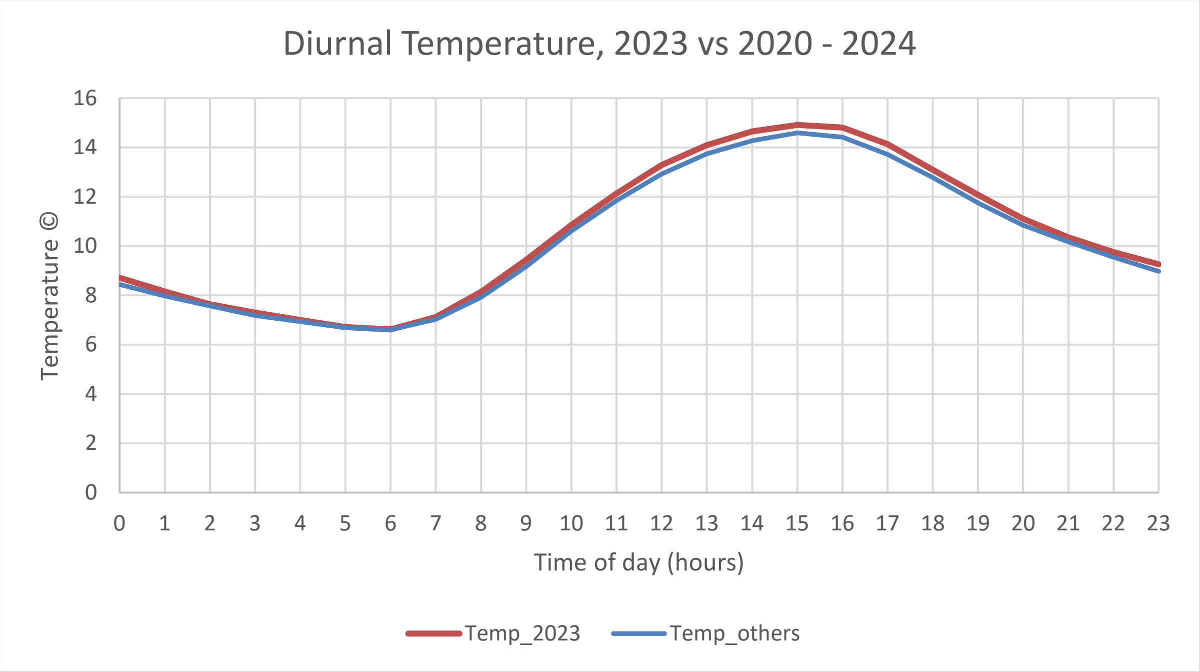



**Figure 5-2 Comparison of the average diurnal temperature distribution for modelled year, 2023 and the 5 year mean (2020-2024) at Queenstown Airport**

## 5.2 METEOROLOGICAL MODEL METHODOLOGY

### 5.2.1 Introduction

Three-dimensional meteorological modelling for a full year of hourly meteorology has been conducted at the proposed Homestead Bay WWTP. Hourly meteorological data from nearby Queenstown Airport has been captured and refined for input into the CALMET meteorological model to create a 3-dimensional wind and temperature field over the WWTP.

The three-dimensional gridded output of the CALMET model has been used as input to CALPUFF, an advanced Lagrangian puff dispersion model. This section describes the meteorological modelling methods that have been conducted as well as provide an evaluation of the data set at the WWTP.

### 5.2.2 Model Overview

CALPUFF[9] is a multi-layer, multi-species, non-steady-state Lagrangian Puff dispersion model used to simulate the effects of time and space varying meteorological conditions on pollutant transport. The model consists of three main components:

- CALMET[10], a diagnostic 3-dimensinonal meteorological model
- CALPUFF, an air quality dispersion model
- CALPOST, a post-processing model

Geophysical data including land use and terrain elevations at 150 m are also processed and introduced into the wind field.

CALPUFF is recommended for use in all applications experiencing one or more of the following, most of which are relevant to the WWTP site:

- Complex terrain

[9] J.Scire, D.Strimaitis, B.Yamartino. 2000. A User's Guide for the CALPUFF Dispersion Model
[10] J.Scire, F. Robe, M.Fernau, B. Yamartino. 2000. A User's Guide for the CALMET Meteorological Model

- Non-steady state atmospheric conditions
- Surface temperature inversions
- Periods of light winds

In order to capture important topography induced flows, CALMET was used to develop a 3-dimensional hourly gridded meteorological domain. Inputs into CALMET included fine-scale terrain (150 m resolution) and detailed fine scale land use as well as surface observation meteorological data and prognostic model upper air data from CSIRO's The Air Pollution Model (TAPM).

The latest versions of the models were used in this analysis; CALMET Version 6.5.0 (Level 150223), CALPUFF Version 7.2.1 (Level 150608) and TAPM Version 4.05.

### 5.2.3 Meteorological Models

Two advanced State-of-Science models have been used to develop the three-dimensional meteorological wind fields in this assessment:

- **TAPM (The Air Pollution Model), developed by CSIRO DAR Melbourne (Hurley 2008[11])**
- CALMET a diagnostic meteorological model (Scire et al 2000[12]).

CALMET is a diagnostic meteorological model that produces three-dimensional wind fields based on parameterised treatments of terrain effects such as slope flows and terrain blocking effects. Meteorological observations are used to determine the wind field in areas of the domain within which the observations are representative. Fine scale terrain effects were determined by the diagnostic wind module in CALMET.

In this application six hourly vertical profiles of winds and temperature were extracted from the 1 km, innermost nest from the TAPM developed gridded 3-dimensional data. This data was input into the CALMET model along with surface observations from Queenstown Airport in a manner recommended by (Barclay and Scire 2011[13]).

### 5.2.4 Overview of the TAPM Model

The TAPM air pollution model predicts 3-dimensional meteorology and air pollution concentrations. The model is a PC-based interface that is connected to databases of terrain, vegetation and soil type, leaf area index, sea-surface temperature and synoptic scale meteorological analysis. TAPM has a long history of use in Australia and New Zealand.

#### 5.2.4.1 Development of TAPM over the WWTP

The nearest radiosonde station to Queenstown is Invercargill which is located approximately 155 km to the southeast of Queenstown. Invercargill launches rawinsonde balloons twice a day at 11h and 23h NZST. While the data is representative of the upper air over Invercargill, it is not representative of the upper air over the Queenstown region. In addition, the twice daily profiles provide a coarse temporal resolution whereas the TAPM modelled data is hourly.

Appendix D shows annual TAPM predicted wind roses at a location (4 km north) of the proposed Homestead Bay WWTP. The wind roses are shown at 20 m, 30 m, 50 m, 75 m, 100 m and 1,000 m. At 50 m, 75 m and 100 m the wind directions are still strongly terrain channelled, where the prevailing winds are from the northeast and the southwest. Strong winds > 8.5 m/s occur for 15.3% of the time above 50 m primarily from the south southwest. At 100 m, strong winds > 8.5 m/s occur for 18.6% of time from the same wind direction. At 1,000m, the wind rose pattern shows predominantly westerly flows and more than 53.5% of all winds are strong (> 8.5 m/s).

[11] Hurley, P. 2008. TAPM V4. User Manual. CSIRO Marine and Atmospheric Research Internal Report No. 5.
[12] Scire J.S, F. Robe, M. Fernau, R Yamartino, 2000: A User's Guide for the CALMET Meteorological Model.
[13] Barclay, J.J and J.S. Scire. 2011. Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessments of Air Pollutants in NSW, Australia. NSW Office of Environment and Heritage, Sydney Australia. Atmospheric Studies Group, TRC, Boston, USA.

In summary, the TAPM predicted prevailing winds are consistent with conditions expected around Homestead Bay.

Six TAPM vertical profiles were extracted from the innermost 1 km gridded nest and were carefully placed at low points in the main valley across the entire model domain. Low points in the valley were chosen to capture stable atmospheric conditions and inversion layers. Because of the good quality of the surface meteorological station and the desire to not be over reliant on the TAPM upper air winds, the surface winds in the model were vertically extrapolated to approximately 70 m above the surface. Beyond 800 m the TAPM winds were used exclusively to the highest vertical level at 3,000 m. However, the TAPM vertical temperature profiles were used exclusively by the CALMET model in all vertical layers to determine the strength and frequencies of the inversion layers.

#### 5.2.4.2 TAPM Model Domain and Settings

TAPM data was used to provide essential upper air data to support the CALPUFF dispersion modelling. Four TAPM modelling domains (30 km, 10 km, 3 km and 1 km) were used to develop the 1 km 3-dimensional meteorological fields. The first coarse domain was at a grid size of 30 km followed by a 10 km nested second domain followed by a 3 km nest and finally a 1 km innermost nest. The detailed configuration is listed in Table 5-2 below.

**Table 5-2 TAPM model domain configuration**

| | Domain 1 | Domain 2 | Domain 3 | Domain 4 |
|---|---|---|---|---|
| **Grid Cells** | 30 x 30 | 30 x 30 | 30 x 30 | 30 x 30 |
| **West-East Range (km)** | 900 km | 300 km | 90 km | 30 km |
| **South-North Range (km)** | 900 km | 300 km | 90 km | 30 km |
| **Grid Size (km)** | 30 | 10 | 3 | 1 |
| **Surface Elevation (m)** | 10 | 10 | 10 | 10 |
| **Top of grid Elevation (m)** | 14000 | 14000 | 14000 | 14000 |
| **Vertical Levels** | 30 | 30 | 30 | 30 |

The TAPM model domain configuration has 30 vertical layers from the surface to 8,000 m. Sixteen of the vertical layers are in the lower boundary layer, below 1,000 m, i.e., 10, 25, 50, 75, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 750, 1,000 m. The height of the layers ranges from 10 m above the surface to 8,000 m.

The location of the TAPM vertical profiles is shown in Figure 5-5.

### 5.2.5 TAPM Temperature Profile Evaluation

Surface inversions occur when the air temperature increases with height, this is the reverse of the normal temperature lapse rate where temperature decreases with height. Surface inversions usually form on calm clear nights due to radiational cooling, after sunset, the ground rapidly loses heat via longwave radiation, and the air in contact with the ground becomes cooler than the air above it. With little or no wind to mix the layers, the cooler air becomes trapped beneath warmer air, creating a stable stratification. Inversions can last from sunset until sunrise and can persist longer in winter or snowy conditions. Inversions inhibit vertical mixing of air and can trap odour/pollutants close to the surface. Multi-layer inversions are frequent occurrences in and around Queenstown. Elevated terrain can block or redirect airflow, leading to subsidence inversions higher up, where descending air warms and creates another stable layer. Cold air drainage from surrounding slopes to lower areas can reinforce this stratification, resulting in multiple stacked inversion layers.

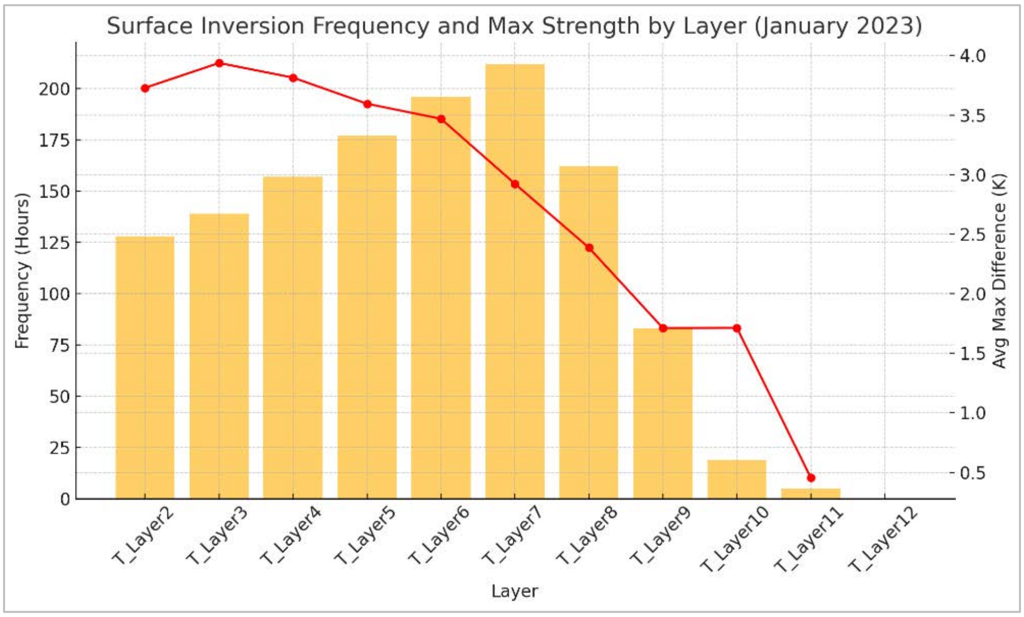
Due to the concern that inversion conditions will reduce odour dispersion from the proposed Homestead Bay WWTP, an analysis of the frequency and inversion strength during August (winter) and January (summer) 2023 was conducted to:

1. Assist with the correct placement of the TAPM upper air profiles to make sure that the TAPM dispersion model was able to adequately generate the expected multi-level inversion layers and;

2. Analyse the frequency and strength of the inversion layers in a summer and winter month, to understand the dispersion potential from Homestead Bay WWTP

Figure 5-3 shows schematic plots of the frequency (number of hours) of temperature inversions (relative to the surface temperature) for January and August 2023. Figure 5-4 shows the average inversion strength by time of day for January and August 2023.

Figure 5-3 shows that surface and multiple above-surface inversion episodes occur during both winter and summer with a higher frequency of occurrence during the winter months. In January there was a total of 232 hours that experienced a positive temperature difference between the surface and a layer aloft. In January the vertical layers most likely to experience frequent and strong inversions occurred in levels 3 to 6 (50 m – 140 m) above the surface. Above 150 m the strength and frequency of the inversions drops off sharply. In August there was a total of 370 hours that experienced positive temperature differences between the surface and above. The vertical layers with the highest frequency and strength occurred between level 2 and level 4 (30 m – 70 m). Similarly, to summer, the strength and frequency of the inversions drops off above 150 m.



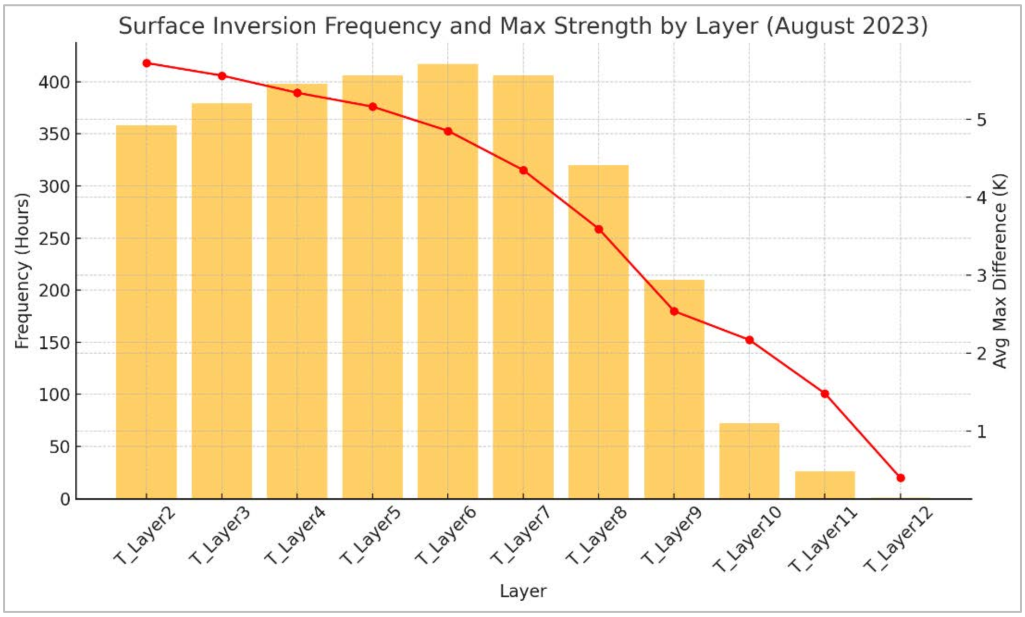




**Figure 5-3 Inversion frequency and strength per vertical layer for January (top) and August (bottom). The red line marks the temperature inversion strength between each layer compared to the surface temperature**

Figure 5-4 shows that in summer the strongest inversions (~ 4.5ºC) occurred around sunrise from 05h, and then weakened sharply by 07h (1.3ºC) and then reaching a minimum in the middle of the day, before increasing again after sunset. In winter, the strongest inversions (~ 6.2ºC) occurred from before sunrise (04h) until 06h or 07h at sunrise after which they declined sharply to be at a minimum at 10h, whereafter they gradually increased in strength. The low sun angle and reduced solar insolation during the wintertime will be the main reason for the stronger and more frequent inversion layers over the course of a day.

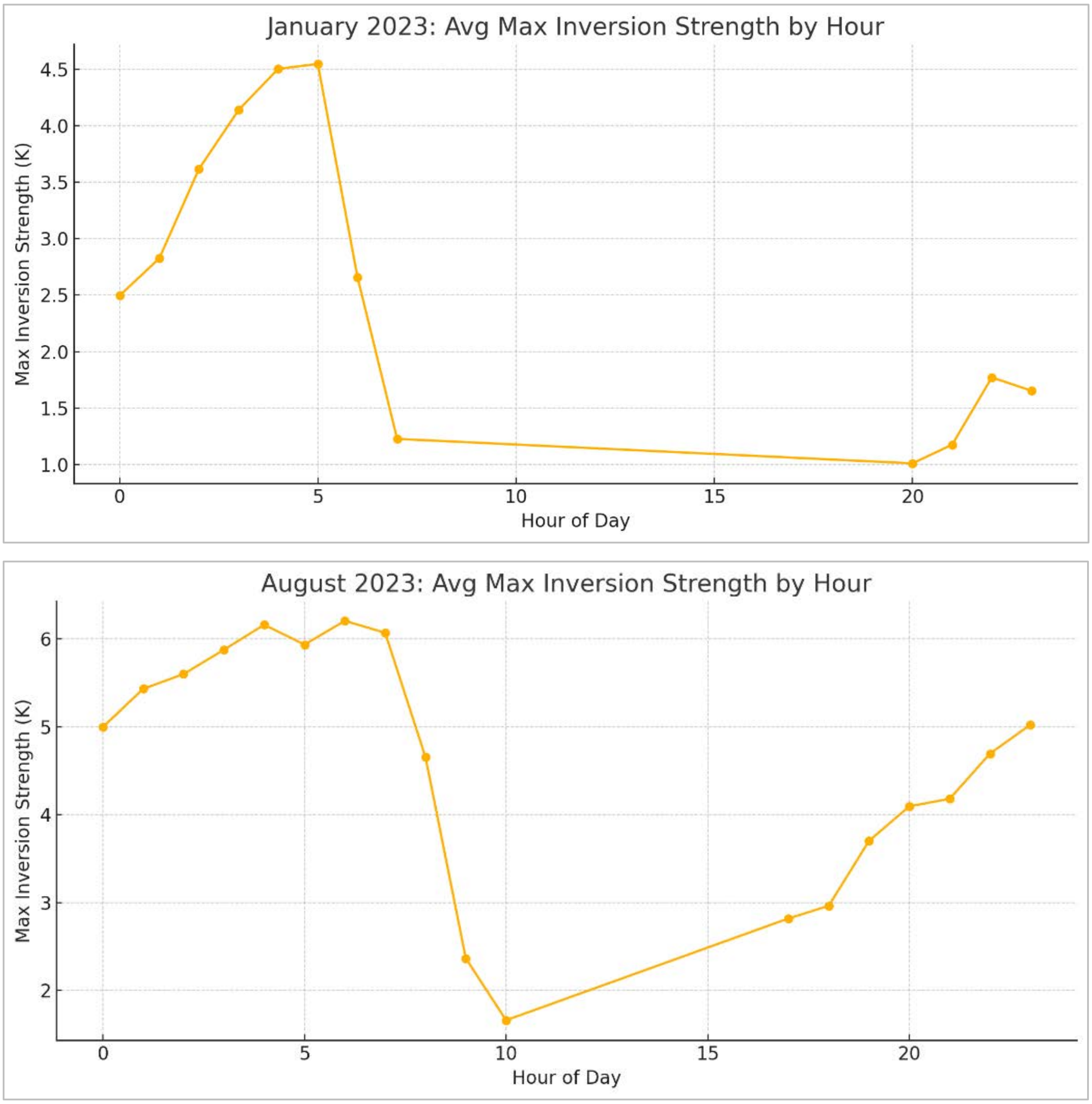



**Figure 5-4 Average maximum inversion strength by hour for January (top) and August (bottom), for 2023**

In summary, understanding the likely strength and frequency of inversion layers in the Homestead Bay region is crucial for accurately assessing odour dispersion from the WWTP. Strong and persistent inversions can limit vertical air movement and trap odorous emissions close to the ground. The model has effectively captured these patterns and will provide a reliable basis for designing targeted and effective odour mitigation.

### 5.2.6 Overview of the CALMET Model

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers. The diagnostic wind field module uses a two-step approach to the computation of the wind fields (Douglas and Kessler, 1988[14]). In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field.

[14] Douglas S and R. Kessler, 1999. Users Guide to the Diagnostic Wind Field Model (Version 1.0), Systems Application, Inc. San Rafael, CA

The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field to produce a final wind field. The techniques used in the CALMET model are briefly described below.

**Step 1 Wind Field**

**Kinematic Effects of Terrain**: The approach of Liu and Yocke (1980[15]) is used to evaluate kinematic terrain effects. The domain-scale winds are used to compute a terrain-forced vertical velocity, subject to an exponential, stability-dependent decay function. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence-minimization scheme to the initial guess wind field. The divergence minimization scheme is applied iteratively until the three-dimensional divergence is less than a threshold value.

**Slope Flows**: The slope flow algorithm in CALMET is based on the shooting flow algorithm of Mahrt (1982[16]). This scheme includes both advective-gravity and equilibrium flow regimes. At night, the slope flow model parameterizes the flow down the sides of the valley walls into the floor of the valley, and during the day, upslope flows are parameterized. The magnitude of the slope flow depends on the local surface sensible heat flux and local terrain gradients. The slope flow wind components are added to the wind field adjusted for kinematic effects.

**Blocking Effects**: The thermodynamic blocking effects of terrain on the wind flow are parameterized in terms of the local Froude number (Allwine and Whiteman, 1985[17]). If the Froude number at a particular grid point is less than a critical value and the wind has an uphill component, the wind direction is adjusted to be tangent to the terrain.

**Step 2 Wind Field**

The wind field resulting from the adjustments described above of the initial-guess wind is the Step 1 wind field. The second step of the procedure involves the introduction of observational data into the Step 1 wind field through an objective analysis procedure. An inverse-distance squared interpolation scheme is used, which weighs observational data heavily in the vicinity of the observation station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The resulting wind field is subject to smoothing, an optional adjustment of vertical velocities based on the O'Brien[18] (1970) method, and divergence minimization to produce a final Step 2 wind field.

### 5.2.6.1 CALMET Meteorological Modelling Domain Configuration

The meteorological modelling domain expands an area of 26.85 km in the east west direction and 29.85 km in the north-south direction. The model domain was made large enough to capture the main weather events and complex topography that will influence the dispersion of pollutants over the WWTP. At 150 m grid resolution, the horizontal grid is fine enough to capture all the local dominant geophysical features including the complex topography to the east, west and north of the plant, as well as the main valley axes. The CALMET domain consists of 179 x 199 grid cells in the x and y directions, respectively. In the vertical, a stretched grid is used with a fine resolution in the lower layers in order to resolve the boundary layer with a somewhat coarser resolution aloft. The twelve vertical levels are: 10, 30, 50, 70, 100, 140, 240, 480, 820, 1,250, 1,750, and 2,500 m.

Unfortunately, the WWTP location does not have its own on-site meteorological data. As a result, the modelling in the nearfield is an interpolation of the Queenstown Airport data, taking into account terrain and land use. Measurements from the Queenstown Airport include hourly values of wind speed and wind direction, temperature, relative humidity pressure and cloud cover and cloud ceiling height. Cloud cover is considered a critical parameter as it is used to determine the hourly varying atmospheric stability over the WWTP.

[15] Liu, M.K. and M. A. Yocke, 1980: Siting of wind turbine generators in complex terrain. J. Energy, **4**, 10:16
[16] Mahrt, L., 1982: Momentum Balance of Gravity Flows. Journal of Atmos. Sci., 39, 2701-2711
[17] Allwine, K.J. and C.D. Whiteman, 1985: MELSAR: A mesoscale air quality model for complex terrain: Volume 1--Overview, technical description and user's guide. Pacific Northwest Laboratory, Richland, Washington.
[18] O'Brien, J.J., 1970: A note on the vertical structure of the eddy exchange coefficient in the planetary boundary layer. J. Atmos. Sci., 27, 1213-1215

The locations and details of the surface observation station used in this assessment is shown in Figure 5-5 and detailed in Table 5-3. Figure 5-5 also shows the CALMET meteorological model domain as well as the location of Queenstown Airport and the six TAPM upper air profiles.

**Table 5-3 Surface meteorological station used in the meteorological modelling.**

| Surface Station Name | Station ID number | X Coordinate (km) | Y Coordinate (km) | Anemometer Height | Meteorological data available |
|---|---|---|---|---|---|
| Queenstown Airport | NZPRM 11111 | 321.9332 | 5012.5656 | 10 | Wind speed, wind direction, temperature, relative humidity, pressure cloud cover & height |

The location and details of the TAPM vertical profiles are detailed in Table 5-4. The TAPM modelling domain was centred over the WWTP on a UTM coordinate system.

**Table 5-4 TAPM vertical profile used in the meteorological modelling**

| Surface Station Name | Station ID number | X Coordinate (km) | Y Coordinate (km) | Meteorological data available |
|---|---|---|---|---|
| TPM1 | 11111 | 332.4236 | 5014.2129 | Wind speed, wind direction, temperature, pressure, relative humidity and geopotential height |
| TPM2 | 22222 | 324.1442 | 5013.8518 | |
| TPM3 | 33333 | 322.9002 | 5008.8494 | |
| TPM4 | 44444 | 321.6199 | 4996.7076 | |
| TPM5 | 55555 | 318.9912 | 5001.8532 | |
| TPM6 | 66666 | 310.0983 | 5005.7123 | |

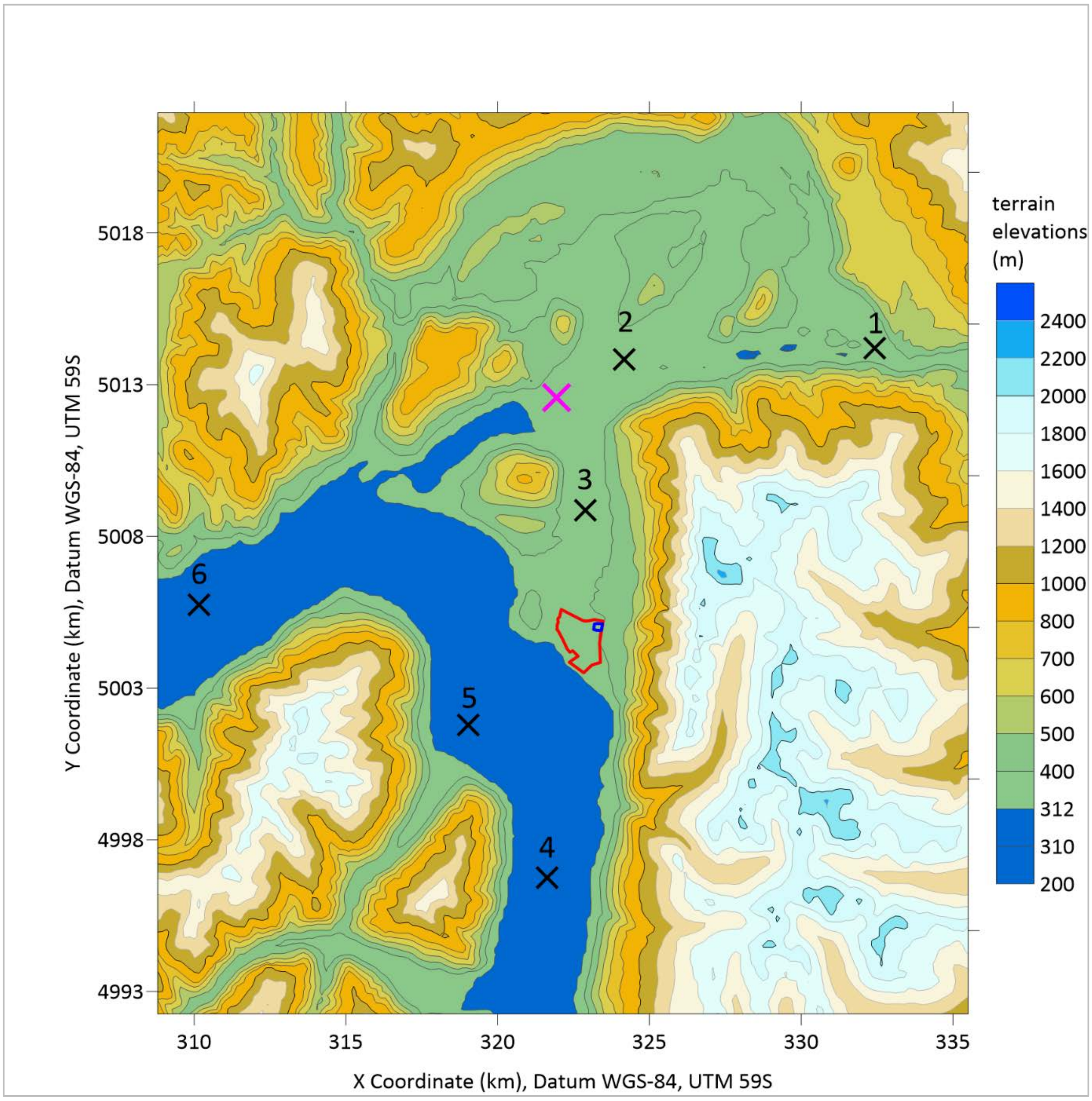



**Figure 5-5 CALMET model domain and location of the Queenstown Airport meteorological station (pink cross). The TAPM upper air profiles are also shown (black crosses). The red boundary is the new proposed Homestead Bay Development residential boundary, and the blue boundary is the proposed WWTP.**

## 5.2.7 Geophysical Data

### 5.2.7.1 Terrain

As well as meteorological data CALMET also requires gridded terrain and land use data. The WWTP is located south of Queenstown airport within the main valley and is located directly west of the north-south orientated Remarkable Ranges.

It is important that the model domain be made large enough to capture the large-scale synoptic flow patterns as well as the topographically induced flows from surrounding topography. As the dominating flows are from the north and the south associated with the orientation of the main valleys the model domain has been centred directly over the proposed WWTP.

Gridded terrain elevations for the modelling domain were derived from 30 m (approximately 1 arc-seconds) Shuttle Radar Topography Data (SRTM). Elevations are in meters (m) relative to mean sea level, and the spacing of the elevations along each profile is 1 arc-seconds, which corresponds to a spacing of approximately 30 m. Figure 5-5 shows the CALMET model domain, and topography as used in the model.

#### 5.2.7.2 Land Use

Land use data are processed to produce a 150-meter resolution gridded field of fractional land use categories with a Datum of WGS-84. Figure 5-6 show the dominant land use types over the model domain.

Land use data was derived from the LCDB v5.0 – Land Cover Database version 5.0, for mainland, New Zealand. The data base is a multi-temporal, thematic classification of New Zealand's land cover. It identifies 33 mainland land cover classes (35 classes once the offshore Chatham Islands are included). The classification was revised between versions 1, 2, and 3 but has been consistent thereafter, and always with backward compatibility maintained. Land cover features are described by a polygon boundary, a land cover code, and a land cover name at each nominal time step; summer 1996/97, summer 2001/02, summer 2008/09, summer 2012/13, and summer 2018/19. The data set is designed to complement in theme, scale and accuracy, New Zealand's 1:50,000 topographic database. The data is available from the Land Resource Information System (LRIS) Science Information website[19]

The NZ map classes were transformed to CALMET's 37 USGS land use categories, which are then mapped into 14 CALMET land use categories within the MAKEGEO program. Surface properties such as albedo, Bowen ratio, roughness length, and leaf area index are computed proportionally to the fractional land use.

[19] https://lris.scinfo.org.nz/

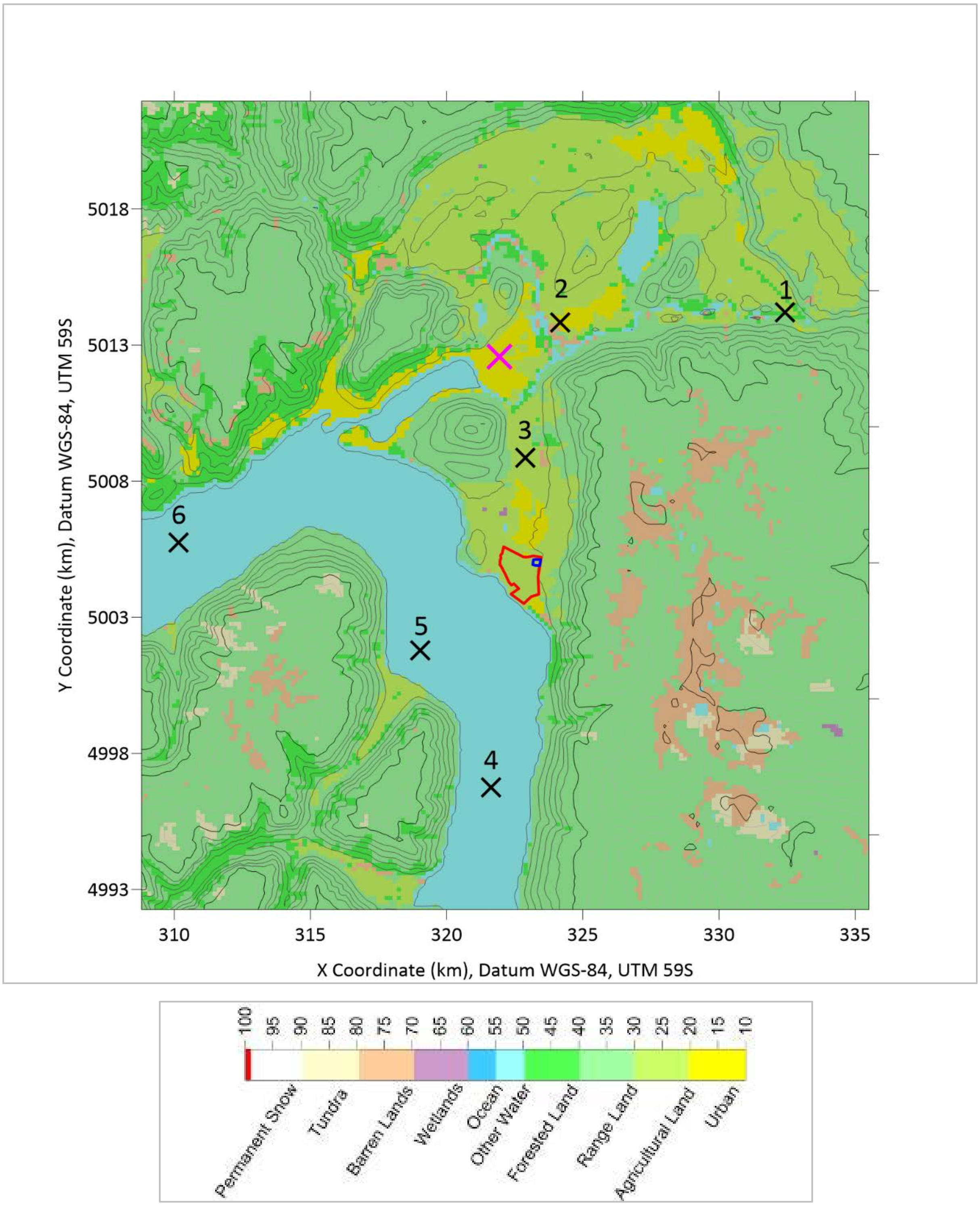



**Figure 5-6 Dominant land use types used in the model**

### 5.2.8 CALMET Model Switches

The initial guess wind field in this assessment is a domain mean wind determined primarily by the surface station, Queenstown Airport. Vertical extrapolation of the surface winds at the WWTP, using similarity theory was conducted up to approximately 70 m. The TAPM vertical profile data was relied upon fully to determine the upper air wind field above 800 m.

**Step 1 Wind Field**

In developing the Step 1 wind field, CALMET adjusts the initial guess field to reflect effects of the terrain, including slope flows and blocking effects. Slope flows are a function of the local slope and altitude of the nearest crest. The crest is defined as the highest peak within a radius TERRAD around each grid point. The value of TERRAD is determined based on an analysis of the scale of the terrain. For this application, a value of 5.5 km was chosen. This value is based on the characteristic length scale of the surrounding terrain. The Step 1 field produces a flow field consistent with the fine scale CALMET terrain resolution (150 m).

**Step 2 Wind Field**

In Step 2, observations are usually incorporated into the Step 1 wind field to produce a final wind field. Each observation site influences the final wind field within a radius of influence (parameters RMAX1 at the surface and RMAX2 aloft). Observations and Step 1 wind field are then weighted by means of parameters R1 at the surface and R2 aloft. At a distance R1 from an observation site, the Step 1 wind field and the surface observations are weighted equally. For this application, four surface observation sites have been used to develop the surface flow field.

This second step in the processing of the wind field by the diagnostic model consists of four sub steps; interpolation; smoothing; O'Brien adjustment of vertical velocities and divergence minimisation. The interpolation scheme employed by the model allows observational data to be heavily weighted in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions where there is no observational data. In this assessment a maximum surface weighting of 5.0 km (RMAX1) was applied, whilst the relative weighting of the first guess field and observation in the surface layer were given a weighting of 3.0 km (R1). Above the surface, the maximum weighting of 4.0 km (RMAX2) was applied, whilst the relative weighting of the first guess field and observation in all layers aloft was given a weighting of 3.0 km (R2). This means the TAPM vertical profiles were allowed to influence an area of approximately 6 km around each profile.

**Table 5-5 Critical CALMET (User-defined) model switches and their options in this assessment.**

| Seven Critical User Defined Parameters | Value | Description |
|---|---|---|
| **RMAX1** | 5 km | Maximum radius of influence over land in the surface layer (km) |
| **R1** | 3 km | Relative weighting of the first guess field and observations in the surface layer (km) |
| **RMAX2** | 4 km | Maximum radius of influence over land aloft (km) |
| **R2** | 3 km | Relative weighting of the first guess field and observations aloft (km) |
| **TERRAD** | 5.5 km | Radius of influence of terrain features |
| **BIAS** | -1.0, -0.8 and -0.5 for levels 1, 2 and 3, thereafter 0 until last four levels of 0.5, 1,1,1 | Bias parameters are used here to remove the influence of TAPM in the winds above the surface to approximately 60-70m. From approximately 800m above the ground TAPM data is relied upon fully |

### 5.2.9 Meteorological Model Evaluation

A full evaluation of the output of the CALMET model has been conducted and is discussed below. CALMET has been evaluated in multiple formats which are briefly described as follows:

- Spatial wind field plots – hourly snapshots of wind speed and wind direction
- Wind Rose Plots – graphical tool to show whether modelled wind speed and direction are similar to the nearest relevant observation point (Appendix B and C)

- Scatter plots –these plots are used to compare 2 sets of values or pairs. These plots will be used to show the relationship between the meteorological variable versus time of day (Appendix A).

The output of CALMET has been evaluated over the centre of the WWTP at grid point X = 323.387 km, Y = 5005.053 km, UTM 59S.

Table 5-6 shows a breakdown of the wind speeds by category measured at Queenstown airport and those predicted at the WWTP. Very light winds (<0.5 m/s) are infrequent at Queenstown airport and at Homestead Bay, but light winds < 1.8 m/s occur for approximately 18% of the time, and can occur during any time of the day, but tend to occur 7% more at night and during the winter months. Winds in the range of 1.8 – 3.3 m/s occur for approximately 36% of the year. The bulk of the winds are in the ranges 0.5 – 3.3 m/s which accounts for 53.2% of the entire year. Moderate winds (3.3 – 5.4 m/s) are also frequent occurring for 25.7% of the entire year, and winds in the range 5.4 m/s – 8.5 m/s occur for 16.9% of the time. Strong winds (>8.5 m/s) are infrequent and only occur for 4% of the year.

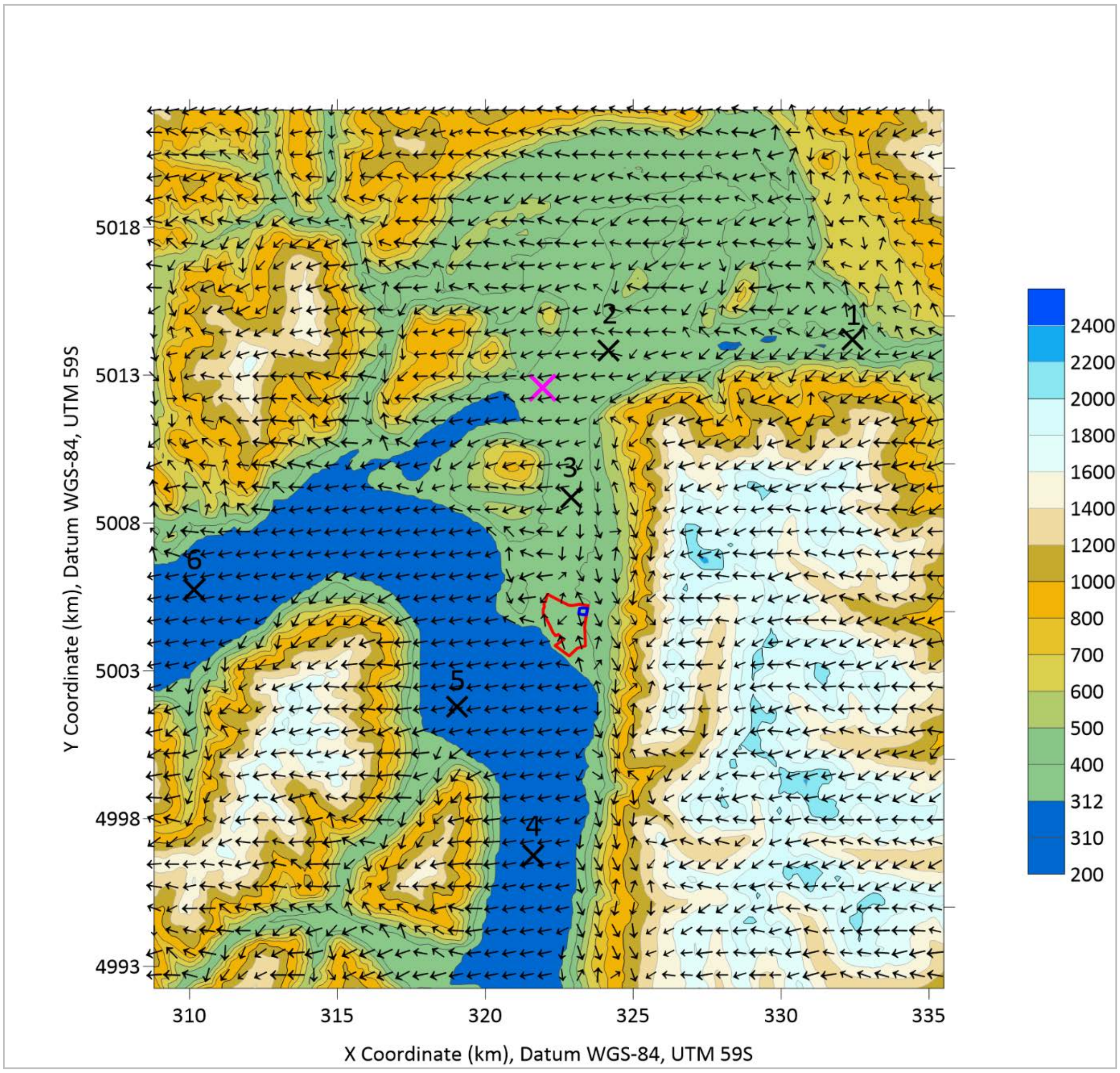
In general, the winds at the WWTP can be described as mostly light to moderate and suggests that the WWTP is in a reasonably well dispersed environment.

**Table 5-6 Wind speeds by category for Queenstown Airport (observed and predicted) vs predicted winds at the location of the proposed WWTP, Homestead Bay.**

| Observed/ Predicted | Name of Station | <0.5 | 0.5-1.8 | 1.8–3.3 | 3.3–5.4 | 5.4–8.5 | 8.5–10.8 | > 10.8 | Valid Periods |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | m/s | | | | |
| Observed | Queenstown Airport | 0.01% | 17.9% | 39.0% | 22.9% | 16.6% | 2.9% | 0.7% | 8760 |
| Predicted | Queenstown Airport | 0.05% | 19.4% | 38.3% | 22.6% | 16.2% | 2.9% | 0.6% | 8760 |
| Predicted | Homestead Bay WWTP | 0.1% | 17.1% | 36.1% | 25.7% | 16.9% | 3.3% | 0.7% | 8760 |

#### 5.2.9.1 Spatial wind field plot

Figure 5-7 shows a snapshot of the output of CALMET as a spatially varying 10 m wind field for the 31st of August 2023 at hour 01h. The weather conditions at this time were stable with light winds < 1.8 m/s at the WWTP. The spatial wind field plot is typical of light variable winds across the model domain, under north easterly winds. What is important to point out is that at Queenstown airport the winds are easterly, but at Homestead Bay they are mostly from the north due to terrain channelling effects.




**Vector Length 0.1 inch = 0.1 m/s, 0.25 inch = 8 m/s. (this hour 0.1 m/s – 1 m/s)**

**Figure 5-7 Snapshot of winds at 10 m at 01h on the 31st August 2023 under stable atmospheric conditions. The red boundary is the new proposed Homestead Bay Development residential boundary, and the blue boundary is the proposed WWTP.**

### 5.2.9.2 Scatter Plots

Appendix A includes hourly diurnal scatter plots of each of the following parameters; wind speed (m/s), wind direction (deg), temperature (K), Relative Humidity (%), Pasquill Gifford stability class (1-6), the maximum of the convective and mechanical mixing heights (m), short wave solar radiation (W/m$^2$) and friction velocity (u*) at the location of the WWTP. The scatter plots display every single hour of data for every year and provide an excellent easy to view graphical display which can be used to evaluate the meteorological data and ensure that the data falls within the expected meteorological boundaries.

The temperature shows a normal diurnal pattern with the highest temperatures occurring between 14h and 15h and the lowest temperatures occurring in the early morning around 07h. The lowest temperature is -5.2 ºC at 07h, and the maximum temperature is approximately 30.4ºC at 15h. The annual relative humidity ranges from 16% to 100% with the average at 69%. On a daily basis there is a diurnal pattern to relative humidity which is usually at its lowest in the mid-afternoon. The stability profile is normal, showing very unstable atmospheric conditions during the daytime from 08h to 13h. Weakly unstable conditions occur between 07h and 18h during the daytime. Neutral conditions occur whenever the wind is moderate to strong and can occur at any time of the day. Stable conditions tend to occur at night up until sunrise and after sunset. Stable atmospheric conditions are associated with very light winds and calm conditions. Temperature inversions are common in stable conditions.

The mixing height pattern shows that the highest mixing levels generally occur in the middle of the afternoon from 14h and 15h, although high mixing levels (2,000 m – 2,500 m) also occur in the middle of the night which is primarily due to strong winds. There is a general collapse of the mixing height at sunset where the mixed layer collapses back to < 500 m and further dropping to 50 m at night.

#### 5.2.9.3 Wind Roses

Appendix C includes hourly annual, seasonal and time of day wind roses at Queenstown Airport and those predicted at the WWTP. The predicted wind roses at the WWTP are significantly different to those at the airport, as expected. The airport is dominated by winds from the east northeast and from the west southwest. These winds are aligned with the main valley axes in which the airport resides. In comparison the WWTP is located in a north-south aligned valley system, hence the east and northeast winds monitored at the airport become more northerly at the WWTP as the prevailing flow is modified and channelled by the Remarkable ranges. At the airport, the winds are predominantly from the north east in winter and predominantly from the west southwest in summer. During the summer months, west southwest flows are the prevailing winds, especially during the afternoon as the west coast sea breeze penetrates the interior. Interestingly, the WWTP does not experience west southwest winds in the summer, instead the summertime winds are from the south, due to the blocking and terrain channelling effect of the Remarkable Ranges which cause the west southwest winds to swing to the south.

Southerly flow is a dominant wind at the WWTP, unlike at the airport. The southern north-south Lake Wakatipu and the extension of the Remarkable Ranges towards Kingston acts to funnel winds originally from the west and south west to a southerly direction. The CALMET model is ideally suited to modelling the winds at the WWTP as the model physics is able to generate the flow at the location of the WWTP, even without any meteorological input at that point. Figure 5-7 shows how a prevailing easterly flow at the airport is actually a northerly flow at the WWTP. Through the model's complex terrain algorithms, the model has been successful at generating realistic wind flow patterns at the site.

# 6.0 ASSESSMENT METHODOLOGY – DISPERSION

## 6.1 CALPUFF MODEL

The atmospheric dispersion modelling assessment was conducted through the use of CALPUFF (Version 7.2.1, Level 150608), which is the latest version of the model. Ground-level odour concentrations were predicted over a regular Cartesian receptor grid covering a region of approximately 4 km by 4 km area (in the X and Y directions). The CALPUFF modelling area was centred over the proposed Homestead Bay WWTP.

## 6.2 MODEL INPUTS

The following parameters were included in the dispersion modelling of odours from the Homestead Bay WWTP facility:

- A 26.85 km x 29.85 km Cartesian, computational dispersion grid within the same size meteorological model domain with a 150 m grid resolution over which the 3-dimensional wind and temperature field were created to model the 2023 meteorological data. The meteorological data input into CALPUFF was in the form of 12 binary files which included 1 surface station and 6 vertical profiles of temperature and wind speed from the TAPM model;
- A geophysical dataset including terrain and land use data, is used to simulate the effects of the land surface on plume dispersion. The SRTM (Shuttle Radar Topography Mission) terrain data has a resolution of approximately 30 m. Land use data was derived from the ESA WorldCover global and cover data base, using 2021 imagery;
- A finely spaced receptor file (specific locations on the ground at which ground-level concentrations are computed) containing terrain elevations sourced from the SRTM3 data. The final receptor grid is shown in Figure 6-1. Terrain effects were modelled using the partial plume path adjustment method. A total of 8,159 (Nested Grid receptors - 8,062, Plant Boundary receptors - 62, and Sensitive receptors - 35) were used in the modelling (explained further in Section 6.3);
- Odour source details such as location, dimensions, discharge parameters and emission rates. Odour emission rates (OERs) specified in ou.m$^3$/s were used for point sources and volume sources, whereas specific odour emission rates (SOERs) specified in ou.m/s were used for area sources. SOERs and odour concentration values were taken from typical odour emissions from similar process units observed at other sites. Constant emission rates were assumed for all sources;
- Downwash has been considered for point sources in the vicinity of the sludge building. The OCU stacks were not considered for downwash due to their relative far distance from the inlet works and sludge building.
- Background concentrations of odour or other pollutants have been assumed to be negligible and therefore have not been included in the model.

## 6.3 RECEPTOR NETWORK

In this assessment, a detailed finely spaced receptor network was generated out to 7.0 km in the x-direction from the site boundary and for 9 km in the y-direction from the site boundary, thereby covering a region of 14 km x 18 km all around the proposed WWTP. The current residences surrounding the WWTP have been treated as sensitive receptors, where each receptor bears a unique terrain height, specific to that location only. The proposed Homestead Bay Development area has been modelled with a fine receptor network at 25 m interval. Each 25 m spaced receptor has also been provided its own unique terrain elevation. A total of 8,159 receptors have been used in this assessment. There are:

- 62 plant boundary receptors, spaced at approximately 25 m along the Homestead Bay WWTP plant boundary;
- 8,062 nested grid receptors including:

  - 2,984 receptors spaced at 25 m intervals, throughout the proposed new Homestead Bay Development residential boundary;
  - 912 receptors spaced at 150 m intervals, extending 4,000 m in the x direction and 6,000 m in the y direction, from the plant boundary of the WWTP;
  - 4,166 receptors spaced at 250 m intervals, extending 14 km in the x direction and 18 km in the y direction where the WWTP is located in the centre of the grid.
- 35 sensitive receptors (current existing residential homes and sports grounds) located in all directions from the proposed WWTP.

Figure 6-1 shows the entire receptor network used in the model, relative to the Homestead Bay WWTP location (blue boundary). Black cross hair cursors represent the two outer nested grids of arbitrary receptors. Magenta receptors mark the locations of the current sensitive receptors. The grey meshed area within the residential boundary is modelled with a fine scale 25 m receptor grid interval.

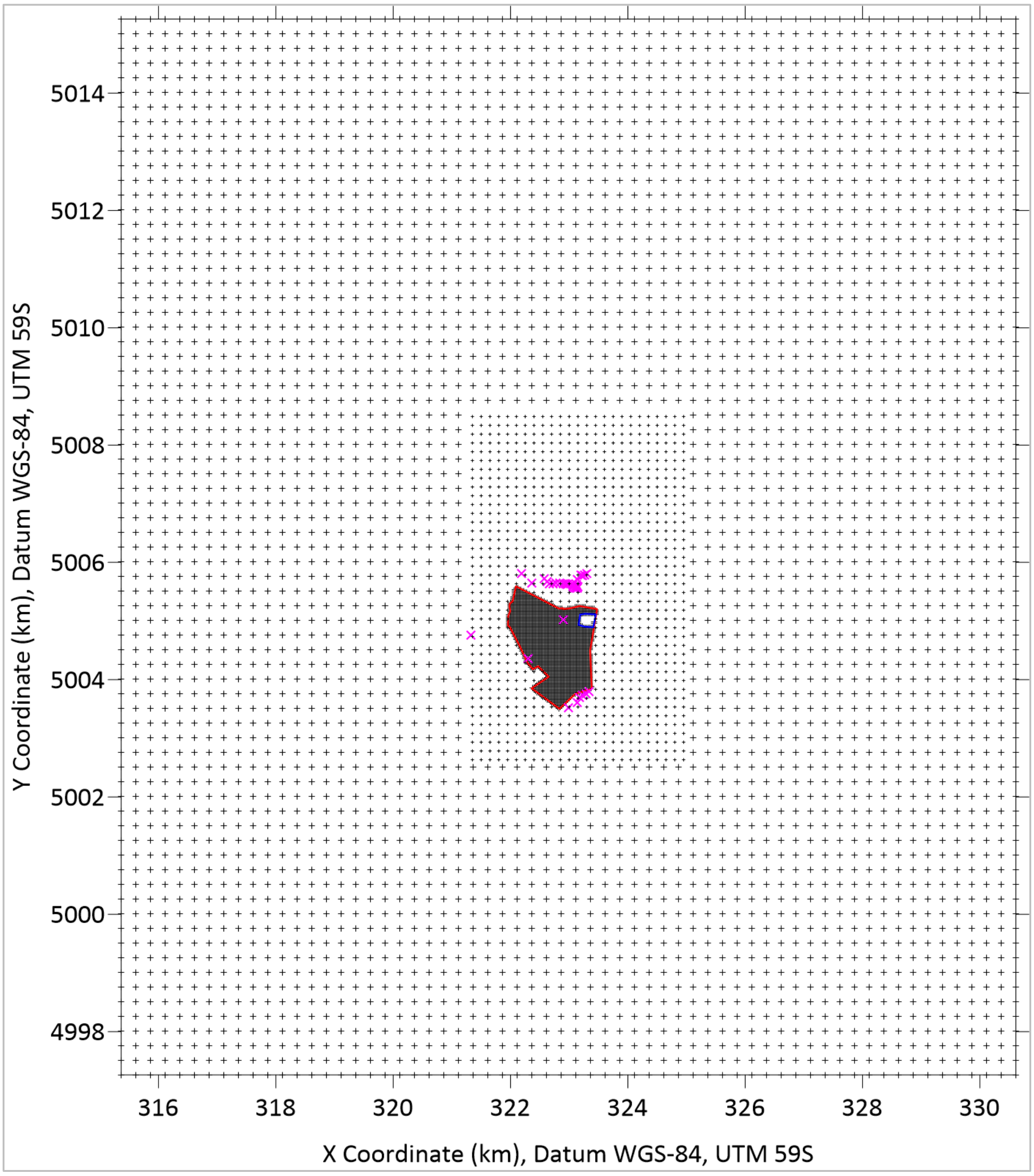



**Figure 6-1: Receptors used in the Dispersion Model**

## 6.4 BUILDING DOWNWASH

The inlet works and sludge building was input into the CALPUFF model using the Building Profile Input Program (BPIP) and the effects of building downwash were modelled in CALPUFF using the Plume Rise Model Enhancements (PRIME) module. Four exhaust vents were located on the top of the inlet works and sludge building and are all wake affected stacks. Figure 6-2 shows the odour sources modelled at the WWTP. The inlet works and sludge building and their associated exhaust vents on the roof are also shown.

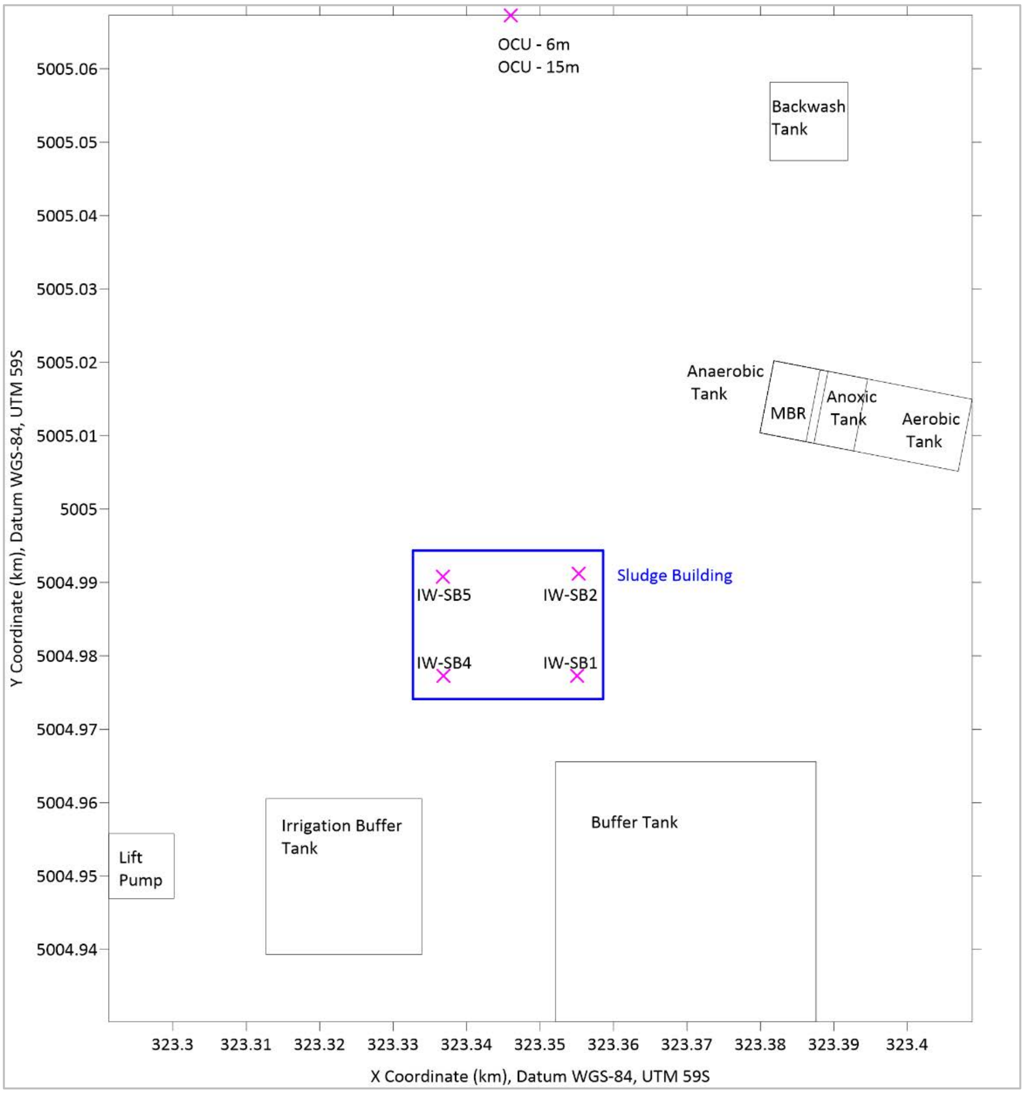



**Figure 6-2: Odour sources (black) and the Inlet Works and Sludge building (blue) with magenta crosses as point sources**

## 6.5 ODOUR SOURCES AND EMISSION RATES

### 6.5.1 Description of Model Scenarios

Odour control systems are generally designed to meet a required discharge odour concentration, however, a low odour concentration in the treated air stream may not be sufficient to achieve a boundary odour criterion due to emissions from other site sources, challenging topography, or local meteorological conditions. Dispersion modelling is used to assess the impact of the proposed odour control option whilst also including other odour sources, including residual odour release from covered and extracted sources.

The dispersion modelling has been completed for the current normal plant operation with different scenarios assuming an OCU stack height of 6 m or 15 m.

### 6.5.2 Omitted Sources

A number of process units on-site were not included in the odour dispersion model of Homestead Bay WWTP. These sources are listed below.

- UV system (if required) – This source is not odorous

### 6.5.3 Current Operations

The odour emission sources included in the dispersion modelling are represented as either point sources, volume sources or area sources. These are shown in Figure 6-2 with details provided in Table 6-1 for area sources, Table 6-2 for point sources, and

Table 6-3 for the volume source.

The characteristics of each source type are outlined briefly below:

***Area*** sources are usually low-lying odour emission sources such as tanks, ponds and stockpiles; where ambient conditions of wind and temperature determine the rate of odour emission from the source. The emission rate is a surface flux rate per unit area or a 'Specific Odour Emission Rate' (SOER), in ou.$m^3/m^2/s$. Note this is the same as ou.$m^2/s$ which is the nomenclature adopted in this report.

***Point*** sources are odour emission sources such as stacks, where there is a relatively high velocity of air through a relatively small orifice. A wake-affected point source is where the discharge of the point source is within the zone of disturbed air that is created as the wind passes around or over nearby structures such as building or trees. Wake-free point sources are where the discharge of the point source is more than 2.5 times the height of the largest nearby building, therefore surrounding buildings do not influence the stack top airflow. To calculate the odour emission rate for a point source, the specified volumetric air flow rate is multiplied by the monitored odour concentration value. This provides an 'Odour Emission Rate' (OER) in ou.$m^3/s$. Note this is the same as ou/s which is the nomenclature adopted in this report. Point sources at height tend to have good dispersion characteristics when compared to a similar odour emissions from area or volume sources.

***Volume*** sources are commonly modelled to represent fugitive emissions from within a building, for example emissions through doorways or under unsealed building eves, based on the prevailing meteorological conditions.

SOERs for area sources were derived from Stantec's global odour database. The results were heavily influenced by recent (2025) sampling from a similar sized MBR plant in Queensland, as well as from Sydney Water's best practice odour emissions database.

**Table 6-1 Homestead Bay WWTP Area Sources**

| Process Units | Model ID | base elevation (m) | height (m) | Easting UTM 59S (km) | Northing UTM 59S (km) | Area | Contain'd | SOER (uncovered) (ou.m/s) | OER (ou.m$^3$/s) |
|---|---|---|---|---|---|---|---|---|---|
| Buffer Tank | BUFF-TNK | 390.8 | 3.5 | 323.3699 | 5004.9479 | 314.16 | 99% | 1.8 | 5.65 |
| Anaerobic Tank | ANAER-TNK | 390.8 | 3.0 | 323.3799 | 5005.0104 | 75.00 | 99% | 1.5 | 1.13 |
| Anoxic Tank | ANOX-TNK | 390.8 | 3.0 | 323.3799 | 5005.0104 | 130.00 | 99% | 0.5 | 0.65 |
| Aerobic Tank | AEROB-TNK | 390.8 | 3.0 | 323.3799 | 5005.0104 | 275.00 | 99% | 0.2 | 0.51 |
| MBR | MBR | 390.8 | 3.0 | 323.3799 | 5005.0104 | 64.00 | 99% | 0.19 | 0.12 |
| Irrigation Buffer Tank | IRR-TNK | 390.8 | 4.0 | 323.3233 | 5004.9499 | 113.09 | 0% | 0.05 | 5.65 |
| Lift Pump Station to irrigation | LIFTPUMP | 390.8 | 4.0 | 323.2957 | 5004.9514 | 19.64 | 0% | 0.05 | 0.98 |
| Backwash Feed Tank | BAKWSH-TNK | 390.8 | 3.0 | 323.3866 | 5005.0528 | 28.27 | 0% | 0.05 | 1.41 |

**Table 6-2 Homestead Bay WWTP Point sources**

| Process Units | Model ID | Base elevation (m) | Stack height (m) | Easting UTM 59S (km) | Northing UTM 59S (km) | Diameter (m) | Velocity (m/s) | Flow rate (m$^3$/s) | Odour (ou) | OER (ou.m$^3$/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| Inlet Works / Sludge Building Exhaust 1 | IW-SB2 | 390.8 | 9.0 | 323.3622 | 5004.9955 | 0.70 | 10.13 | 3.90 | 100 | 390 |
| Inlet Works / Sludge Building Exhaust 2 | IW-SB3 | 390.8 | 9.0 | 323.3603 | 5004.9810 | 0.70 | 10.13 | 3.90 | 100 | 390 |
| Inlet Works / Sludge Building Exhaust 3 | IW-SB4 | 390.8 | 9.0 | 323.3311 | 5004.9824 | 0.70 | 10.13 | 3.90 | 100 | 390 |
| Inlet Works / Sludge Building Exhaust 4 | IW-SB5 | 390.8 | 9.0 | 323.3322 | 5004.9980 | 0.70 | 10.13 | 3.90 | 100 | 390 |
| OCU – 6 m stack | OCU-6m | 390.8 | 6.0 | 323.3461 | 5005.0673 | 0.437 | 15.00 | 2.25 | 500 | 1125.0 |

| Process Units | Model ID | Base elevation (m) | Stack height (m) | Easting UTM 59S (km) | Northing UTM 59S (km) | Diameter (m) | Velocity (m/s) | Flow rate ($m^3/s$) | Odour (ou) | OER ($ou.m^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|
| OCU – 15 m stack | OCU-15m | 390.8 | 15.0 | 323.3461 | 5005.0673 | 0.437 | 15.00 | 2.25 | 500 | 1125.0 |

**Table 6-3 Homestead Bay WWTP Volume source**

| Process Units | Model ID | Base elevation (m) | Effective height (m) | Easting UTM 59S (km) | Northing UTM 59S (km) | Sigma y (m) | Sigma z (m) | Odour (ou) | OER ($ou.m^3/s$) |
|---|---|---|---|---|---|---|---|---|---|
| Inlet Works / Sludge Building | IW-SB1 | 390.8 | 2.75 | 323.3740 | 5004.9679 | 0.79 | 10.13 | 100 | 0.94 |

# 7.0 ODOUR IMPACT ASSESSMENT RESULTS

The odour concentrations are shown as isopleth contour lines for the 99.9$^{th}$ and 99.5$^{th}$ percentile levels which represent the 8$^{th}$ highest and 44$^{th}$ highest concentrations in the whole year at every single receptor, respectively. Put another way, the odour isopleths represent areas where odour concentrations are exceeded during 0.1% and 0.5% of the time.

An isopleth contour represents a line that connects points of equal concentration. Each line marks a boundary where the concentration is the same, so areas inside the line have odour concentrations equal or greater than the line's value and areas outside have lower odour concentrations. Isopleth concentration lines help visualise odour dispersion and show where concentration thresholds are reached.

Table 7-1 shows the 99.9$^{th}$ and 99.5$^{th}$ odour concentration at the WWTP boundary and within the new proposed Homestead Bay Development residential boundary for the 6 m OCU stack and for the 15 m OCU stack scenarios. The odour criterion is 2 ou for primarily neutral and stable atmospheric conditions in a highly sensitive environment. The odour concentration exceeds 2 ou at three receptors on the southern WWTP boundary for both OCU stack heights at both percentile limits by a small margin, i.e. 2.5 ou and 2.1 ou for the 99.9$^{th}$ and 99.5$^{th}$ percentiles respectively.

Beyond the plant boundary the highest concentration at both percentile limits is < 2 ou, where the 15 m stack predicts slightly lower concentrations than the 6 m stack. The residences likely to be most exposed to odour between 1.5 ou to 1.9 ou are those located in the new Homestead Bay Development, 45 m along the southern plant boundary and within 15 m of the WWTP.

There is little difference between the two proposed OCU stack heights of 6 m or 15 m. This is not unexpected. The Inversion layers form regularly and persist for long periods preventing vertical mixing. Regardless of whether the stack is 6 m or 15 m emissions will still get trapped below or within the same inversion layer, preventing the higher stack from achieving better dispersion.

**Table 7-1 99.9$^{th}$ and 99.5$^{th}$ odour concentration at the WWTP boundary and within the new proposed Homestead Bay Development residential boundary**

| OCU stack height (m) | WWTP Boundary | WWTP Boundary | Proposed Homestead Bay Development | Proposed Homestead Bay Development | Criteria |
|---|---|---|---|---|---|
| Percentile | **99.9$^{th}$** | **99.5$^{th}$** | **99.9$^{th}$** | **99.5$^{th}$** | |
| 6 m | 2.5 ou | 2.1 ou | 1.9 ou | 1.7 ou | 2 ou (primarily neutral, stable conditions in a highly sensitive environment) |
| 15 m | 2.5 ou | 2.1 ou | 1.8 ou | 1.6 ou | |

## 7.1 6 M OCU STACK HEIGHT

**Figure 7-1** and Figure 7-2 show the 99.9$^{th}$ and 99.5$^{th}$ highest ground level odour concentrations for a 6 m OCU stack height. The concentration isopleths are shown for 0.05, 0.1, 0.25, 0.5, 1.0 and 1.5 ou. Most of the western locations within the proposed Homestead Bay Development boundary are likely to experience odour concentration in the region of 0.05 ou to 0.1 ou, while those in the centre of the development, approximately 177 m to 370 m from the southern boundary of the WWTP are likely to experience between 0.25 and 0.5 ou. Between 60 m and 177 m, locations are likely to experience between 0.5 and 1.0 ou, while those locations 15 m to 60 m may experience odour between 1 ou to 1.5 ou, whilst just a few receptors < 15 m from the plant boundary will experience odour between 1.5 and 1.9 ou. For the 99.5$^{th}$ percentile limit the odour concentrations at all distances from the WWTP plant boundary are lower than what has been described for the 99.9$^{th}$ percentile results.

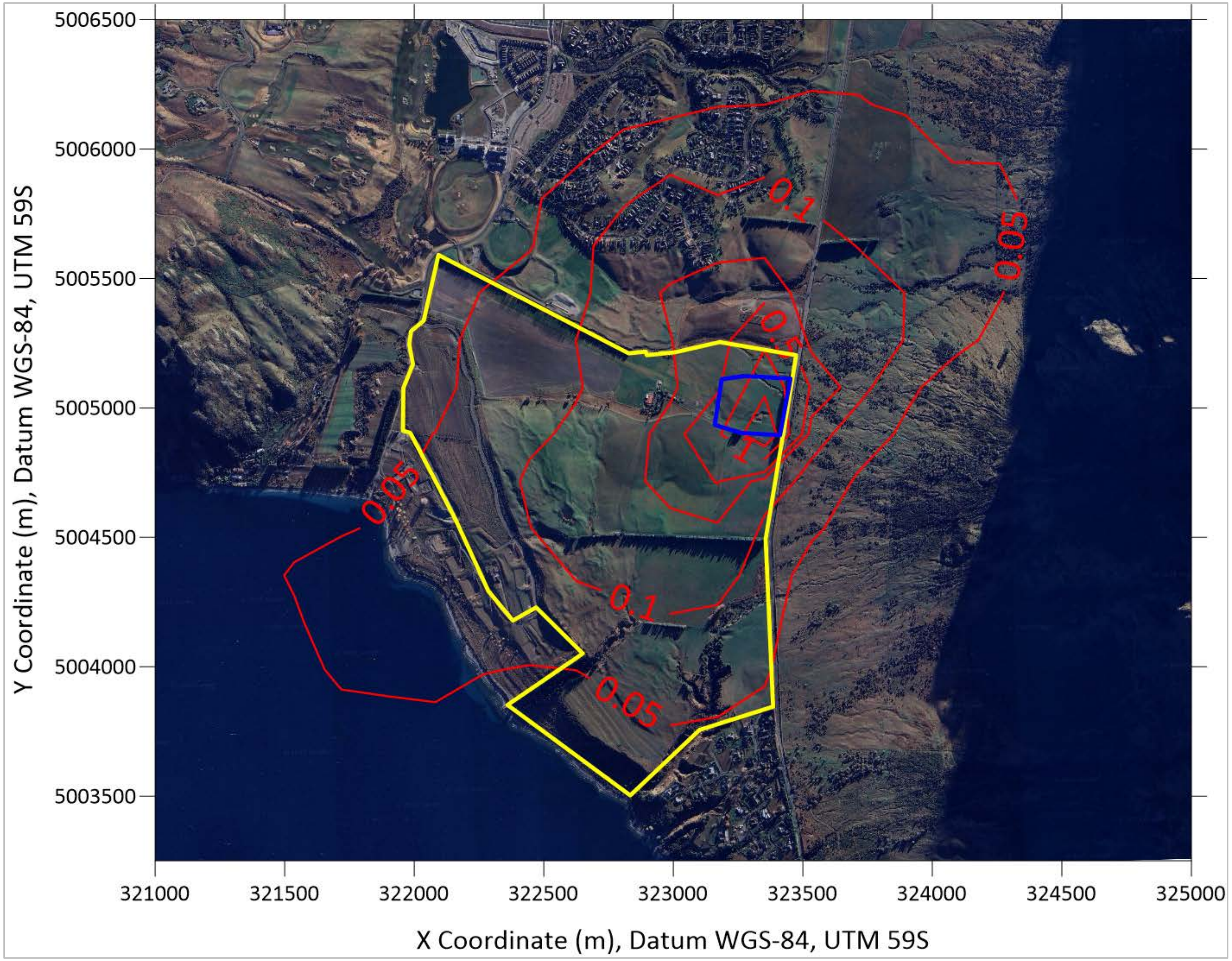



Figure 7-1 99.9th Percentile 1-hour average odour concentration for a 6 m OCU stack height

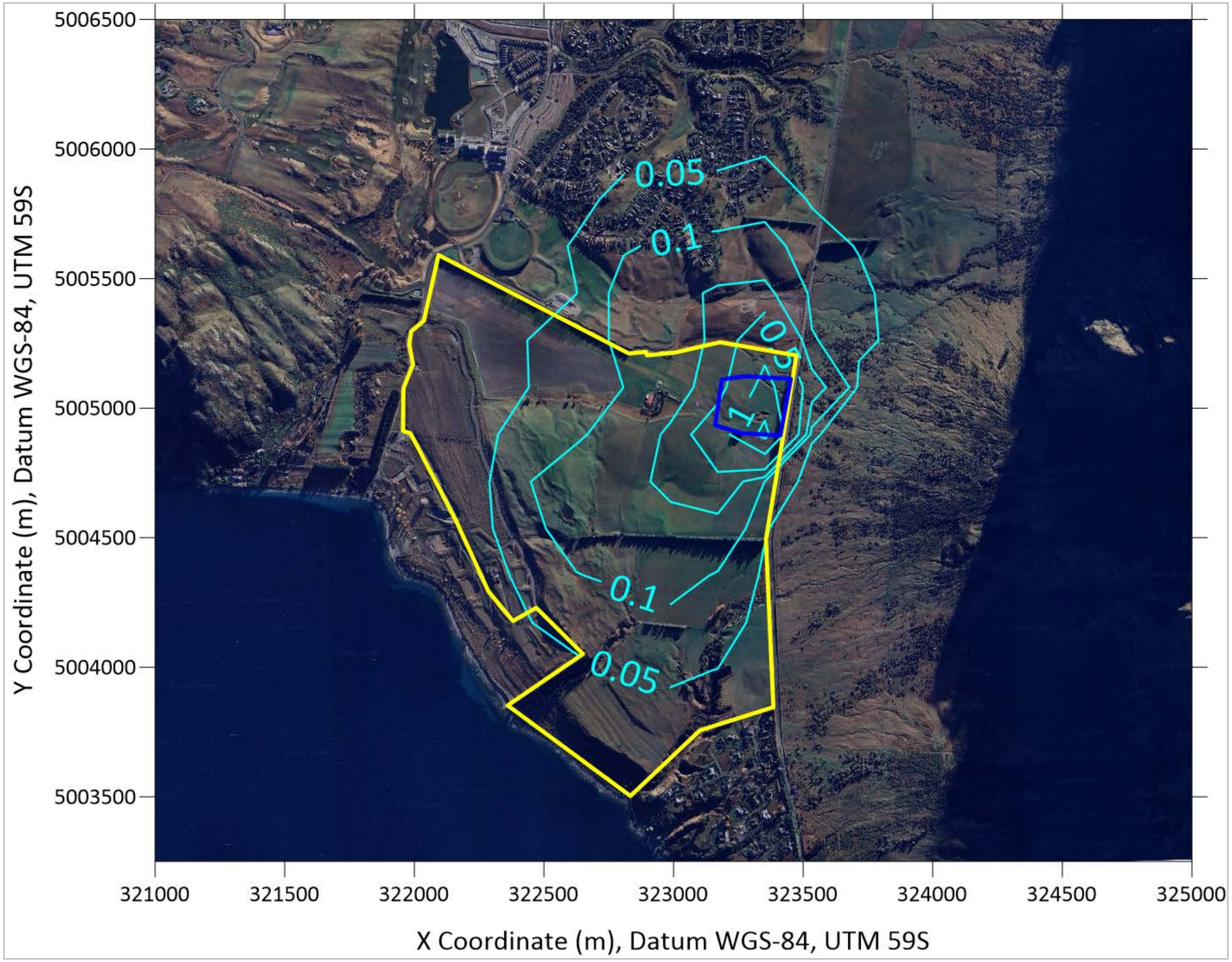



**Figure 7-2 99.5th Percentile 1-hour average odour concentration for a 6 m OCU stack height**

## 7.2 15 M OCU STACK HEIGHT

Figure 7-3 and Figure 7-4 show the 99.9$^{th}$ and 99.5$^{th}$ highest ground level odour concentrations for a 15 m OCU stack height. The concentration isopleths are shown for 0.05, 0.1, 0.25, 0.5, 1.0 and 1.5 ou. The odour footprint is very similar to that of the 6 m OCU stack, especially close to the WWTP for both percentile limits. Similarly to the 6 m OCU stack scenario, the 99.5$^{th}$ percentile odour concentrations are slightly lower than the 99.9$^{th}$.

Therefore, despite the 15 m stack being significantly taller than the 6 m stack, the presence of frequent and persistent inversion layers as well as complex valley dynamics can results in similar, near-ground odour impacts as the 6 m tack. Both stacks fail to escape the trapping effects of the local microclimate.

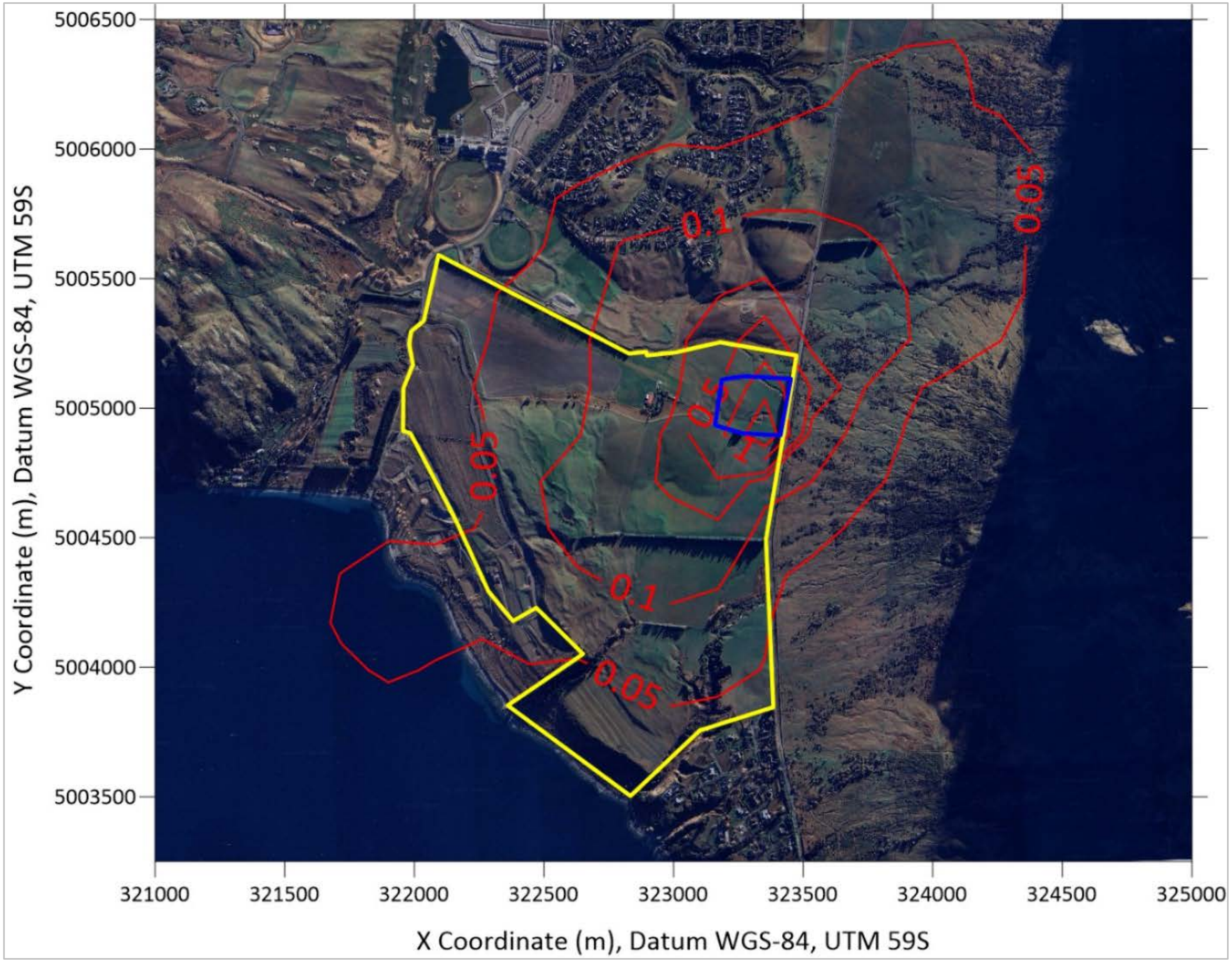



**Figure 7-3 99.9th Percentile 1-hour average odour concentration for a 15m OCU stack height**

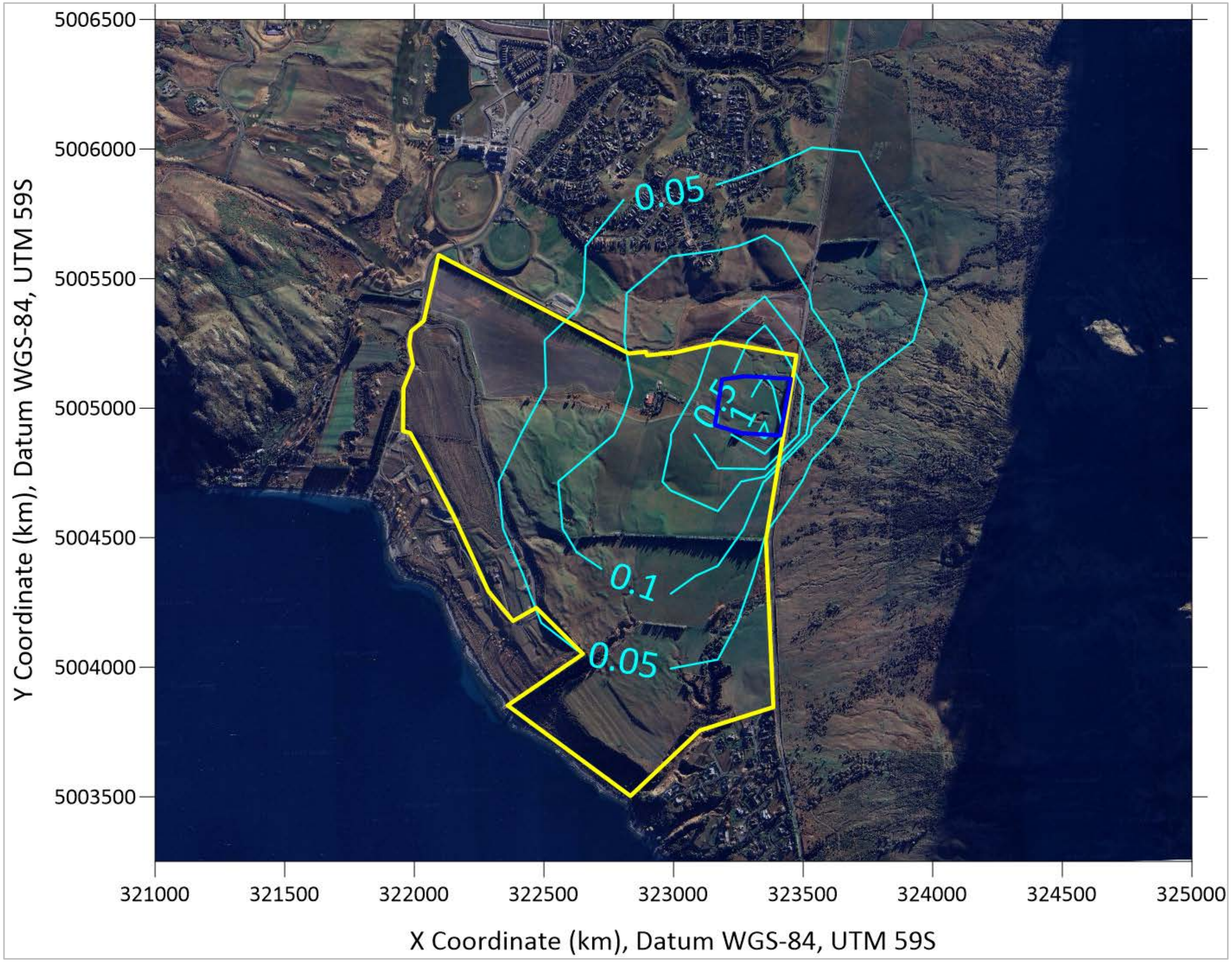



**Figure 7-4 99.5th Percentile 1-hour average odour concentration for a 15m OCU stack height**

## 7.3 CURRENT SENSITIVE RECEPTORS

Table 7-2 provides the predicted odour concentrations at each of the current sensitive receptors. The highest odour concentration was 0.3 ou at receptor #16, located at the southern end of Hacket Road, for the 6 m stack at the 99.9th percentile. The predicted concentrations were very similar for the 15 m stack height.

**Table 7-2 Predicted odour concentrations at current sensitive receptors**

| Receptor Number | Description | 6 m 99.5th | 6 m 99.9th | 15 m 99.5th | 15 m 99.9th |
|---|---|---|---|---|---|
| | | ou | | | |
| 1 | Airport | 0.1 | 0.2 | 0.1 | 0.2 |
| 2 | Residences | 0.0 | 0.1 | 0.0 | 0.1 |
| 3 | Residences | 0.1 | 0.1 | 0.0 | 0.1 |
| 4 | Residences | 0.1 | 0.1 | 0.0 | 0.1 |
| 5 | Residences | 0.1 | 0.1 | 0.1 | 0.1 |
| 6 | Residences | 0.1 | 0.1 | 0.1 | 0.1 |
| 7 | Residences | 0.1 | 0.1 | 0.1 | 0.1 |
| 8 | Residences | 0.1 | 0.1 | 0.1 | 0.1 |
| 9 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 10 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 11 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 12 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 13 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 14 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 15 | Residences | 0.2 | 0.2 | 0.1 | 0.2 |
| 16 | Residences | 0.2 | 0.3 | 0.1 | 0.2 |
| 17 | Residences | 0.2 | 0.3 | 0.1 | 0.2 |
| 18 | Residences | 0.2 | 0.2 | 0.1 | 0.2 |
| 19 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 20 | Residences | 0.1 | 0.2 | 0.1 | 0.1 |
| 21 | Sports playing fields | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | Sports playing fields | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | Residence southwest outside res zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | Residences south of residential zone | 0.0 | 0.1 | 0.0 | 0.1 |
| 25 | Residences south of residential zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | Residences south of residential zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | Residences south of residential zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | Residences south of residential zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | Residences south of residential zone | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | Residence, Pendeen Cres | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | Residence, Pendeen Cres | 0.1 | 0.1 | 0.1 | 0.1 |
| 32 | Residence, Pendeen Cres | 0.1 | 0.1 | 0.1 | 0.1 |
| 33 | Residence, Pendeen Cres | 0.1 | 0.1 | 0.1 | 0.1 |
| 34 | Residence, Pendeen Cres | 0.1 | 0.1 | 0.1 | 0.1 |
| 35 | Rural Residence, south | 0.1 | 0.1 | 0.1 | 0.1 |

# 8.0 CONCLUSION

Stantec has been engaged to conduct an odour impact assessment for the proposed Homestead Bay WWTP. The assessment uses advanced dispersion modelling to evaluate potential odour impacts, considering anticipated odour sources and two odour control options, a 6 m high OCU stack and a 15 m high OCU stack. Modelling outcomes have been assessed at the plant boundary, the new proposed Homestead Bay Development and at the current nearby sensitive receptors in order to determine the odour impact of the WWTP.

The proposed WWTP will be located at the north eastern end of the new Homestead Bay Development boundary and will serve as a vital infrastructure facility responsible for treating wastewater from the proposed development, before it is discharged back into the environment. Homestead Bay is anew suburb located south of current Jacks Point, which is part of the Queenstown District.

The odour impact has been assessed on a quantitative basis using the latest version of the CALPUFF atmospheric dispersion model. This assessment utilises odour emission rates sourced from Stantec's global emission and contaminant load database, using the most representative data available, where the process units were not sampled.

The goal of the dispersion modelling exercise with respect to odour impacts at and beyond the site boundary was twofold being:

1. Determine if the residual odour impact, after covering, foul air capture and treatment, would meet the odour requirements within the Good Practice Guide for Assessing and Managing Odour, NZ and;
2. Determine if dispersion benefits of increasing the stack height would outweigh the visual amenity impact.

The dispersion modelling has indicated that increasing the stack height from 6 m to 15 m results in only modest reductions in odour concentrations, largely due to the steep valley setting and frequent inversion layers that limit vertical dispersion. While a 6 m stack, which is relatively low, may be sufficient to achieve minimal plume lift above the local inversion base, the 15m stack height does not greatly improve ground level concentrations, plus it introduces a higher visual impact. It would be good practice to ensure the following is developed throughout the design of the WWTP and surroundings:

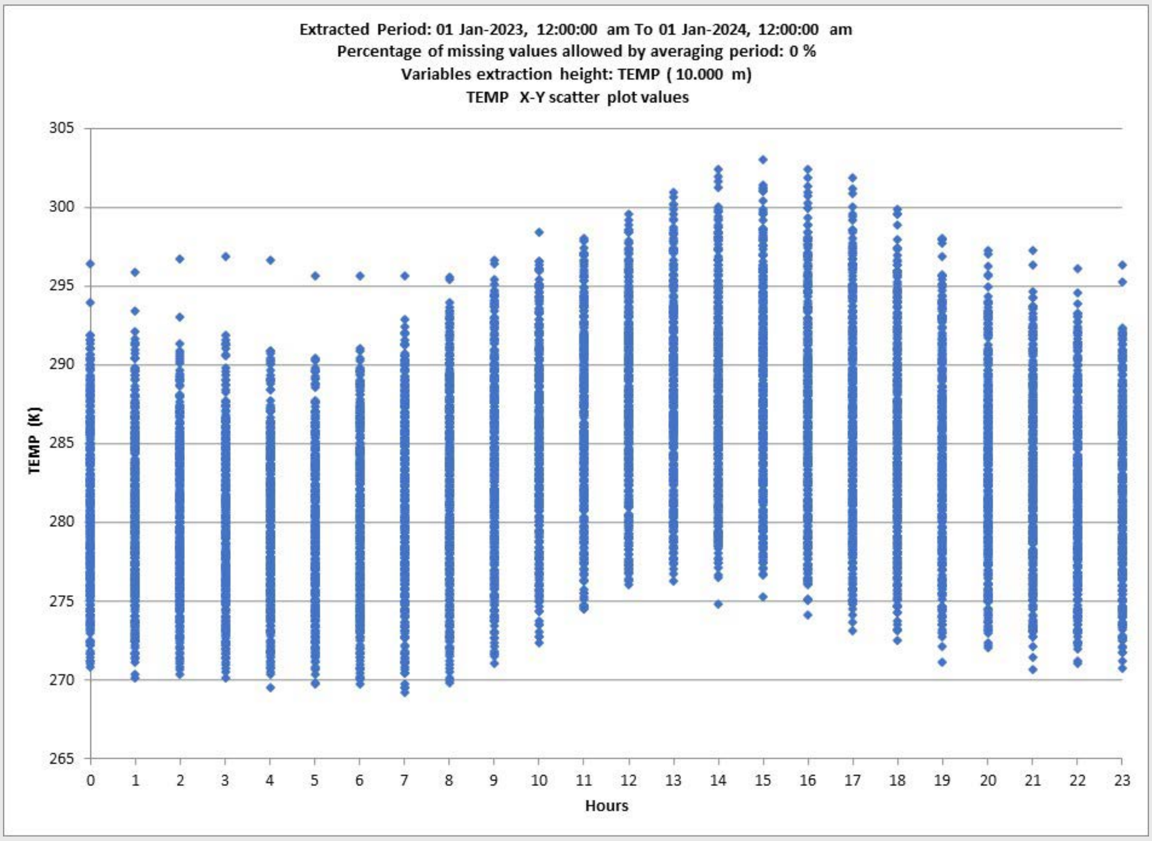
- Provide an OCU with a stack height that is at least 2 m above the height of the nearest building to aid in dispersion, and preferably above 8 m (given the expected heights of nearby buildings and structures).
- Site the OCU at a location that is furthest from potential complainants.
- Provide a 100 m buffer zone around the plant boundary would also mitigate odour impact when issues occur on site such as maintenance activities that may require opening of foul air covers.

# Appendices

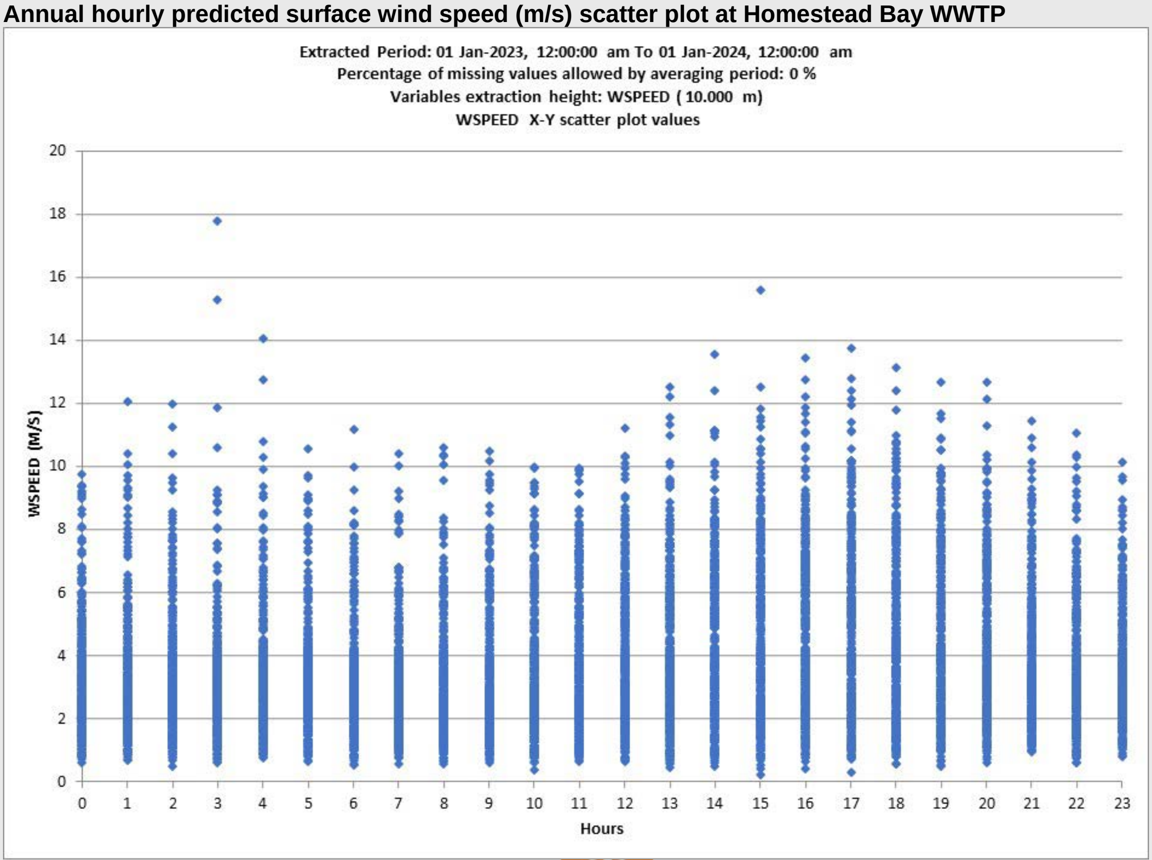
We design with community in mind

# Appendix A SCATTER PLOTS AT HOMESTEAD BAY WWTP

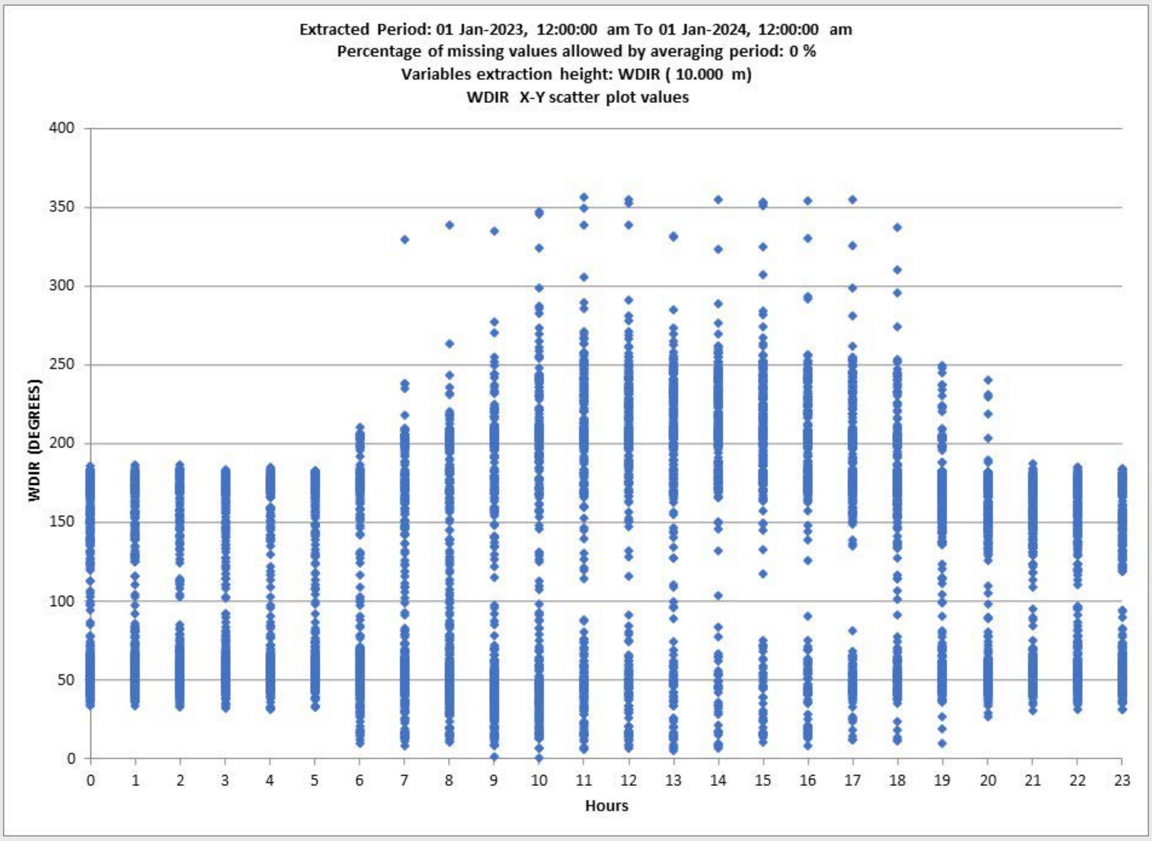
**Annual hourly predicted surface temperature (deg C) scatter plot at Homestead Bay WWTP**



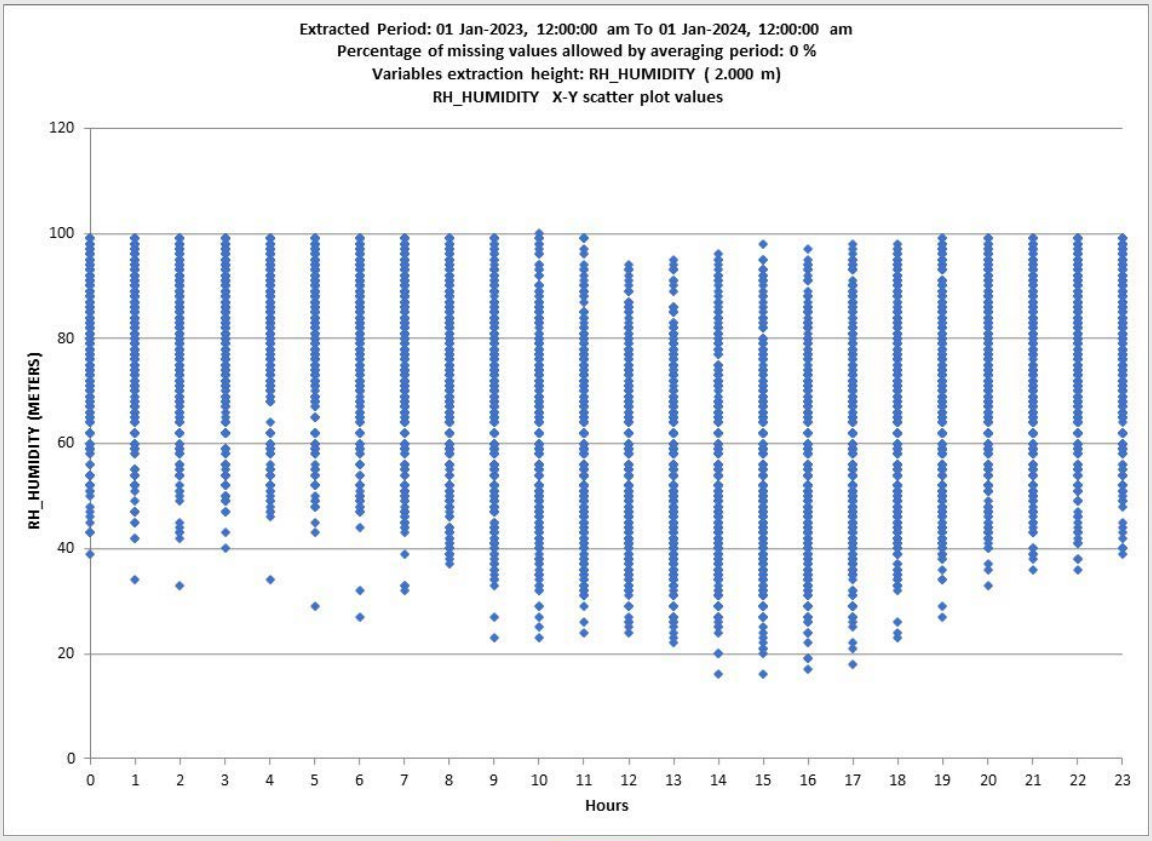

**Annual hourly predicted surface wind speed (m/s) scatter plot at Homestead Bay WWTP**



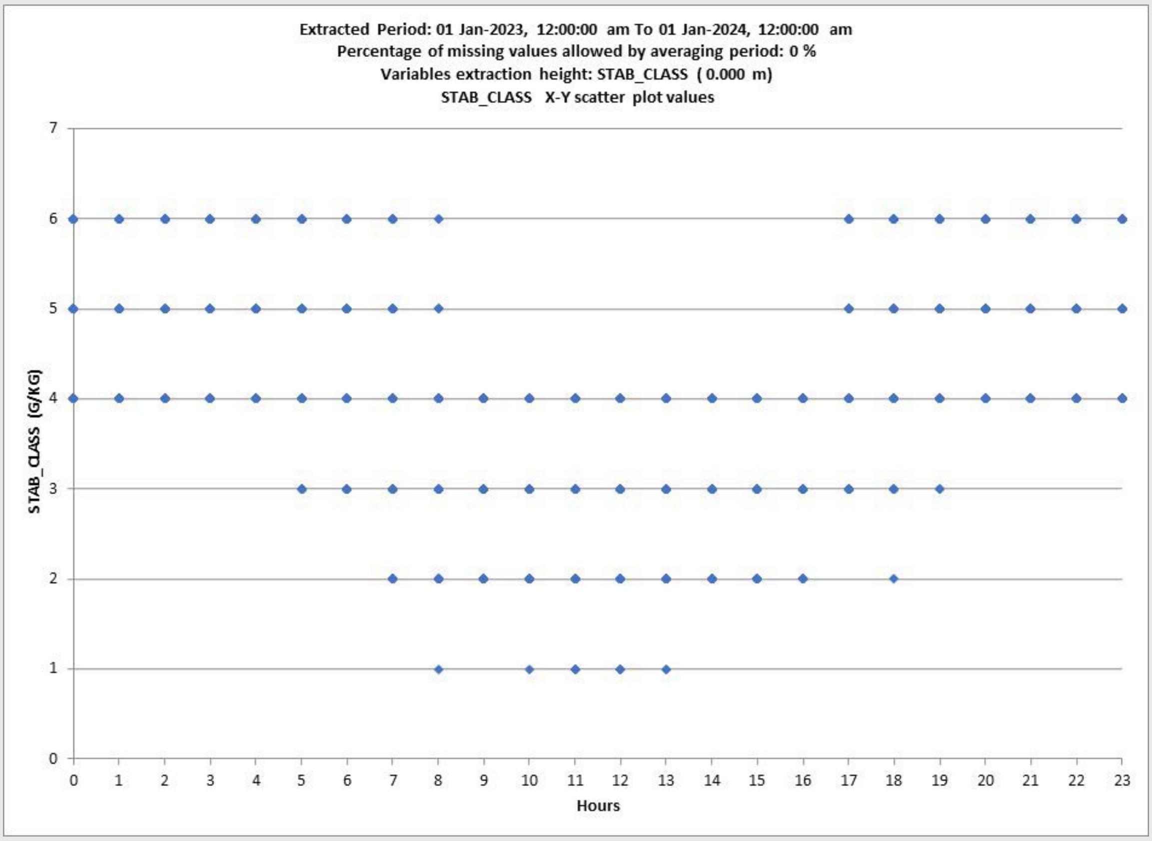
**Annual hourly predicted surface wind direction (deg) scatter plot at Homestead Bay WWTP**



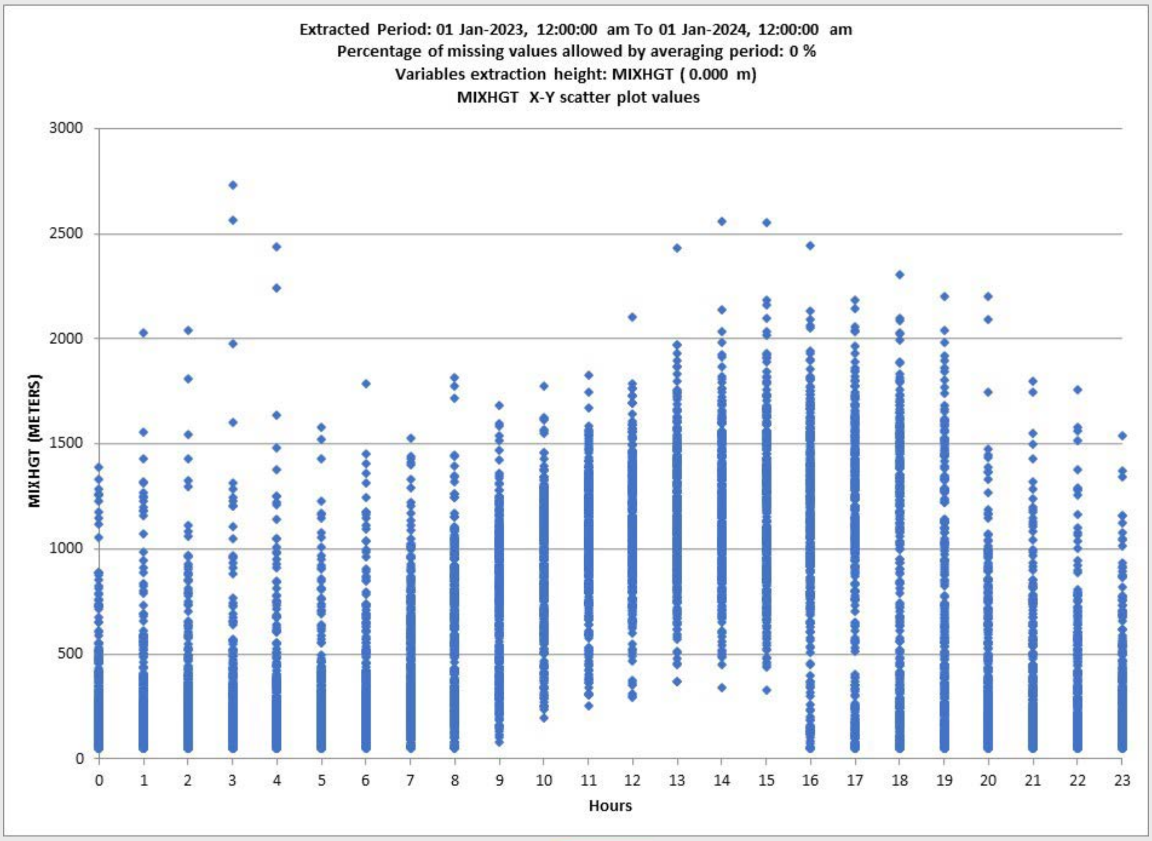

**Annual hourly predicted surface relative humidity (%) scatter plot at Homestead Bay WWTP**



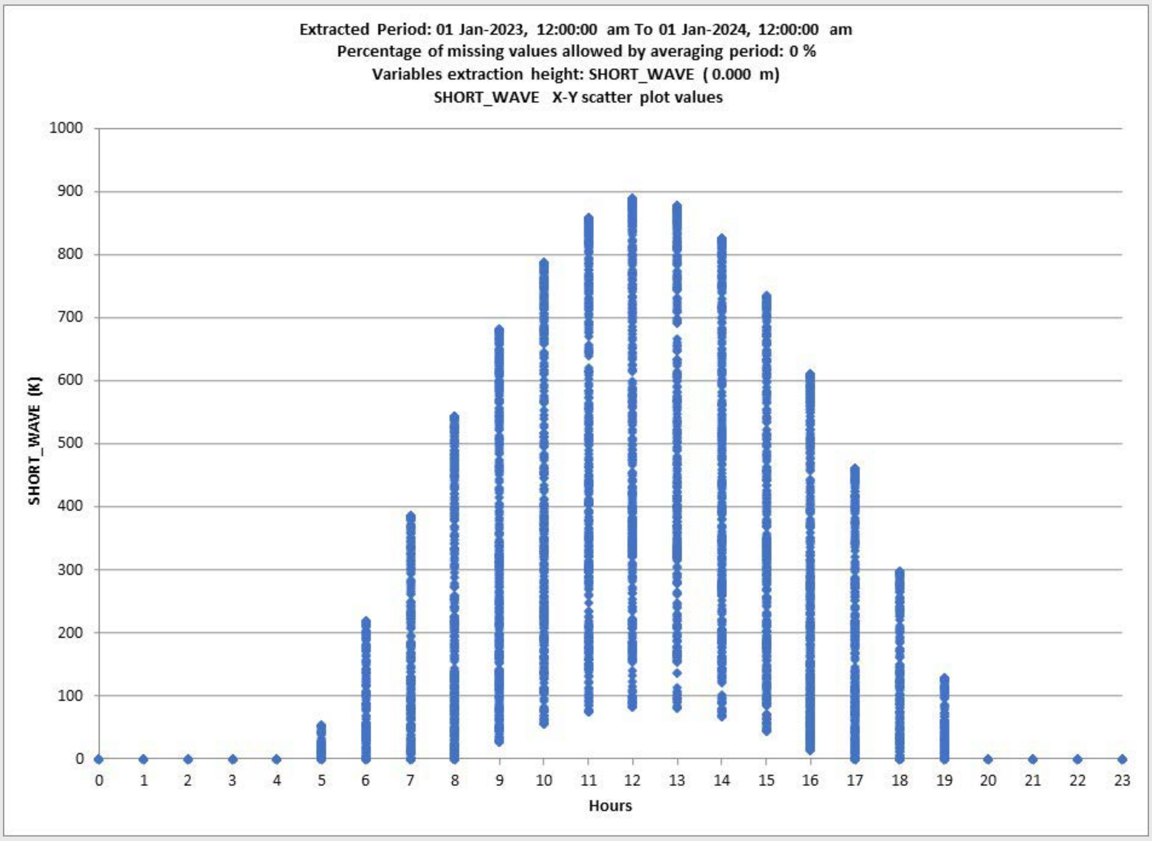
**Annual hourly predicted surface stability (1-6) scatter plot at Homestead Bay WWTP**



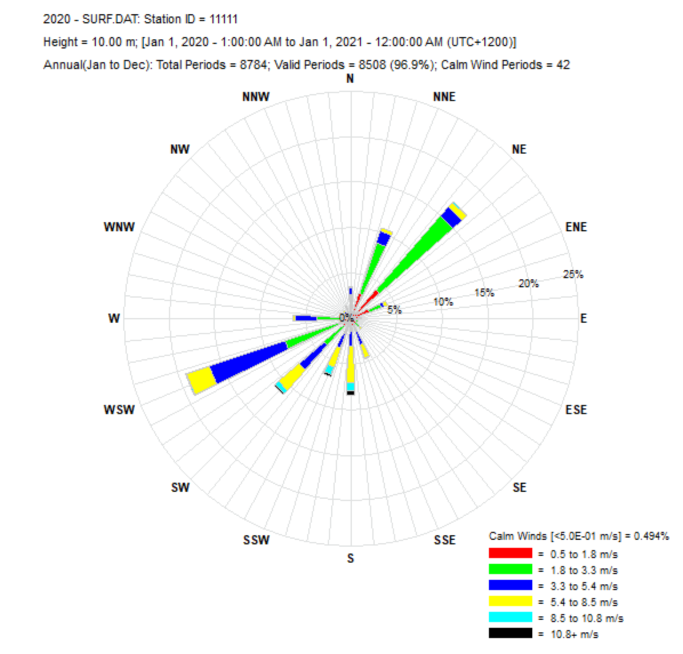

**Annual hourly predicted mixing height (m) scatter plot at Homestead Bay WWTP**



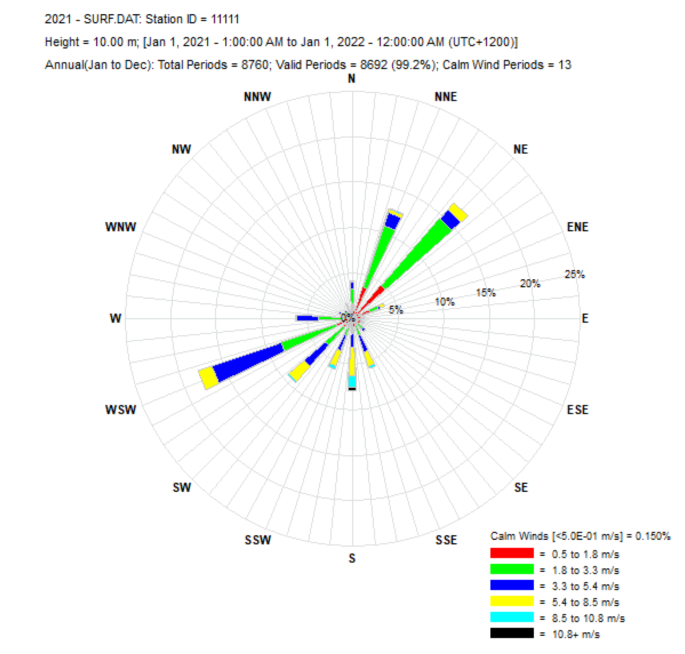
**Annual hourly predicted solar radiation (W/m$^2$) scatter plot at Homestead Bay WWTP**



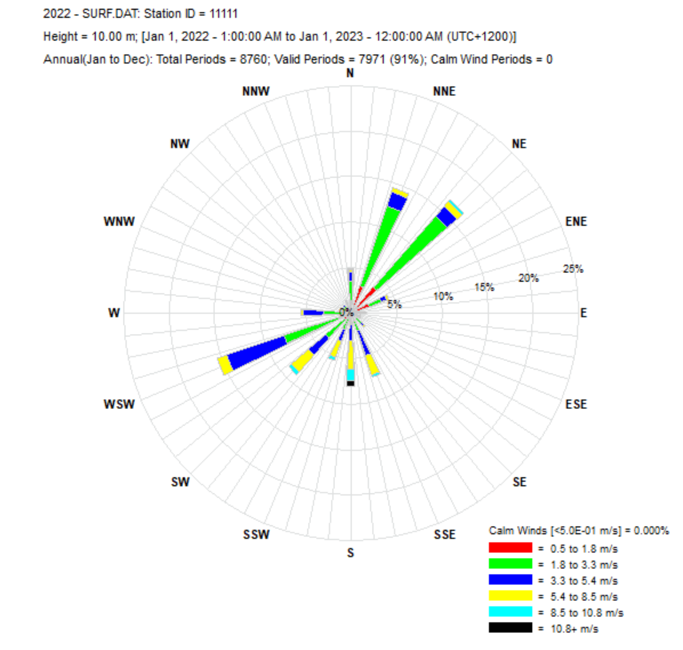
# Appendix B ANNUAL, WIND ROSES FOR QUEENSTOWN FOR 2020-2024



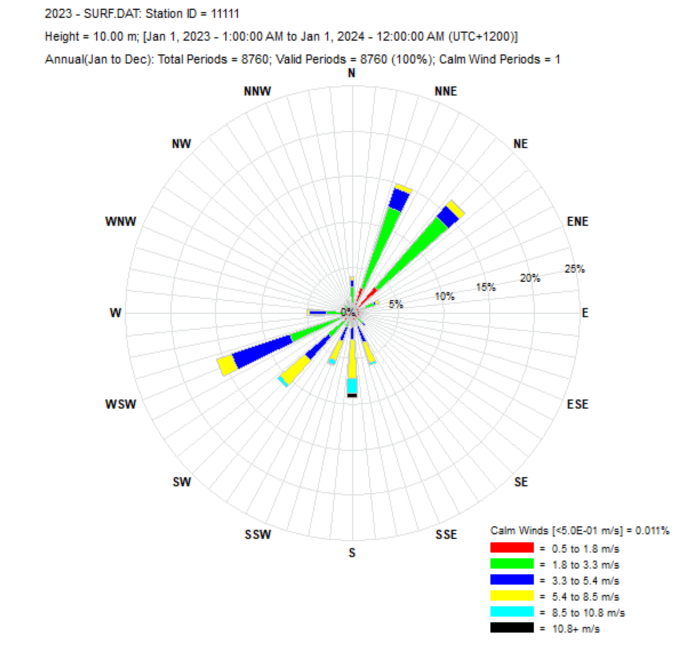

**Queenstown Annual 2020**




**Queenstown Annual 2021**

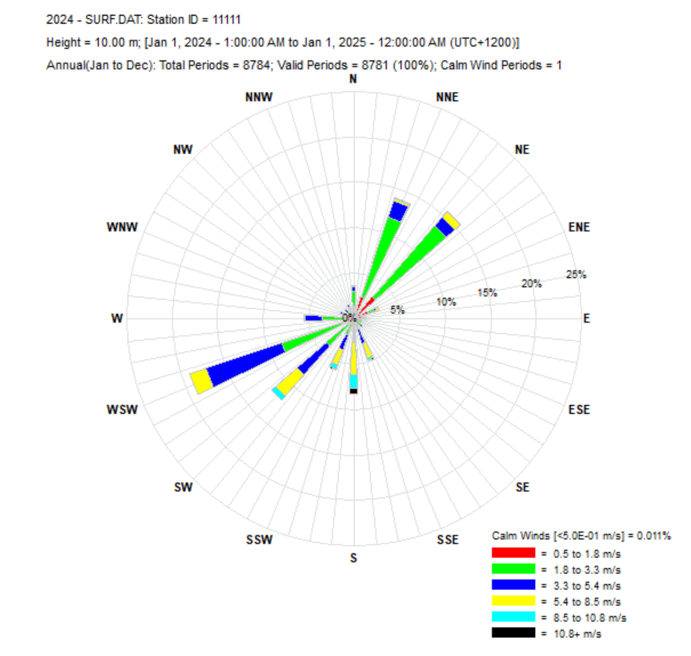



**Queenstown Annual 2022**

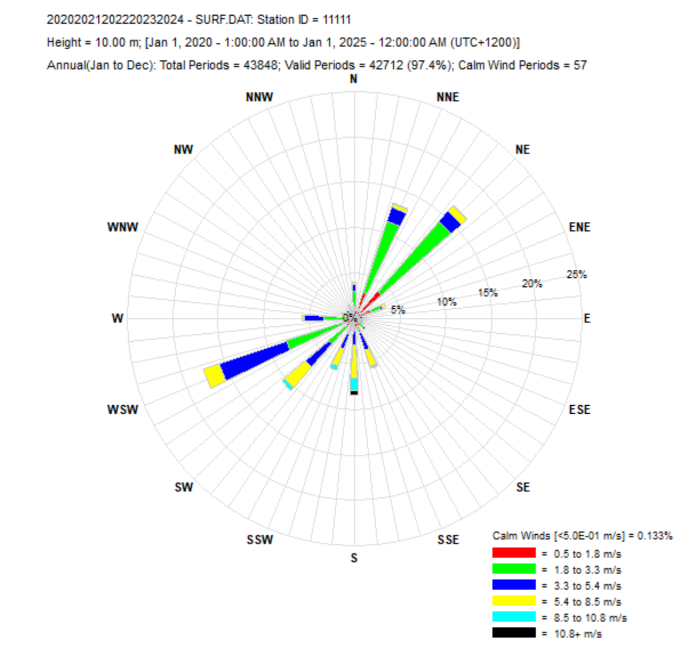



**Queenstown Annual 2023**

Appendix B TAPM (predicted), annual upper air data at Homestead Bay WWTP

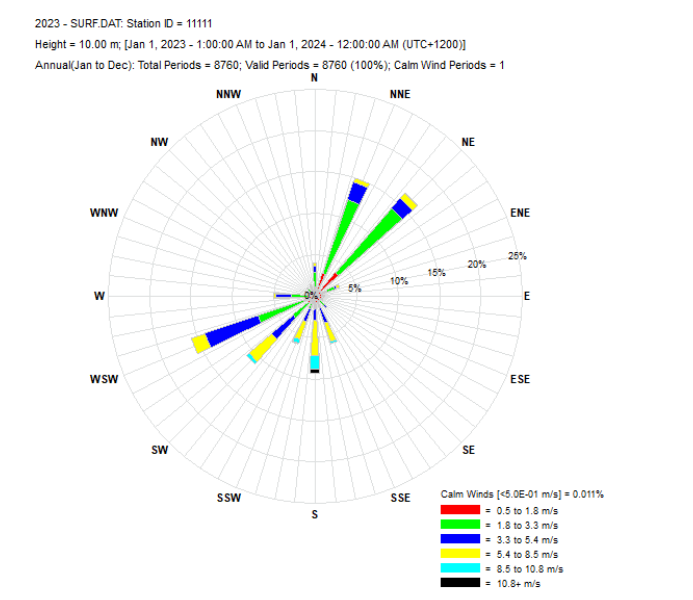



**Queenstown Annual 2024**

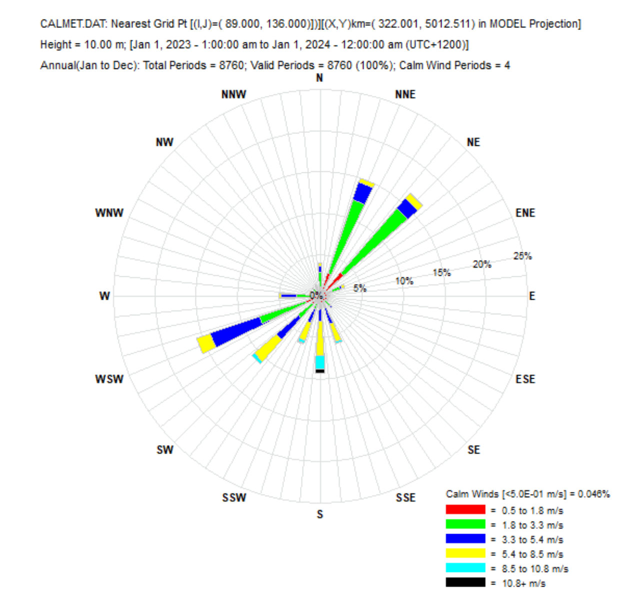



**All 5 years together**

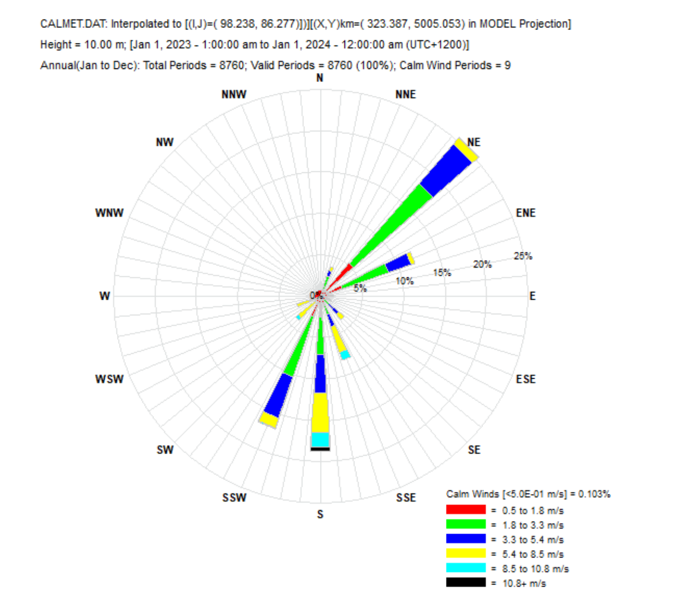
# Appendix C ANNUAL, SEASONAL AND TIME OF DAY WIND ROSES FOR QUEENSTOWN (OBSERVED) AND HOMESTEAD BAY WWTP (PREDICTED)




**Queenstown, Annual 2023 (Observed)**

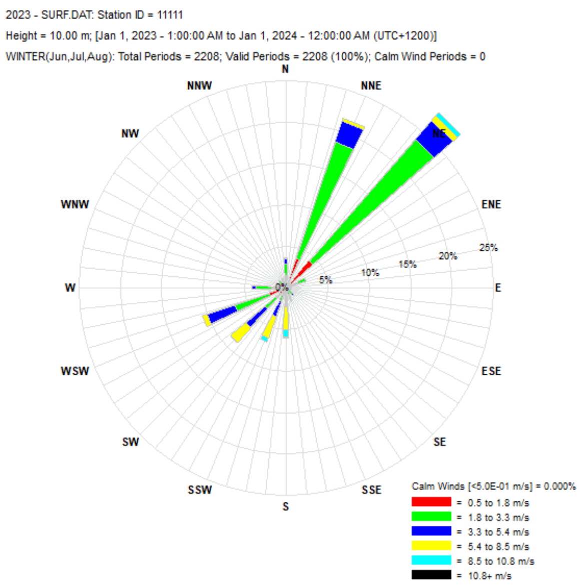



**Queenstown, Annual 2023 (Predicted)**

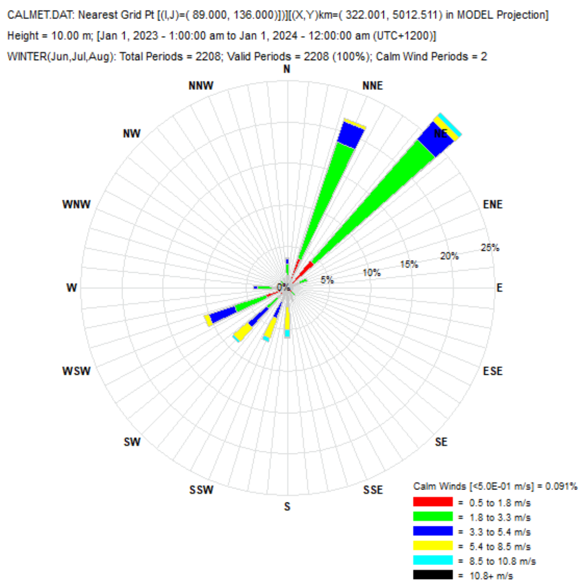



**Homestead Bay, Annual, 2023 (Predicted)**

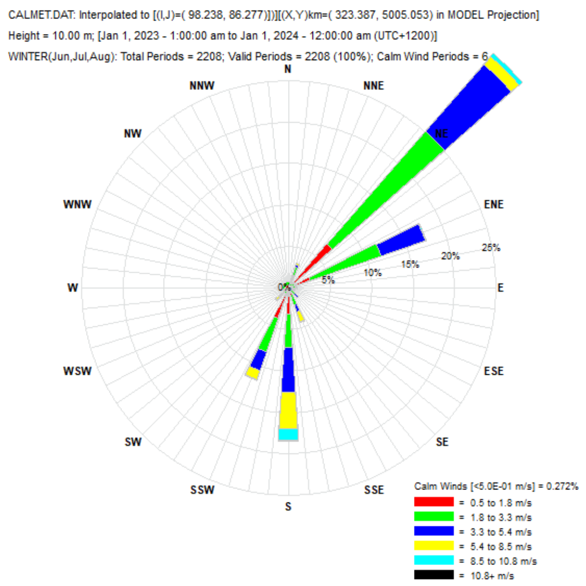
Appendix C  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Winter 2023 (Observed)**

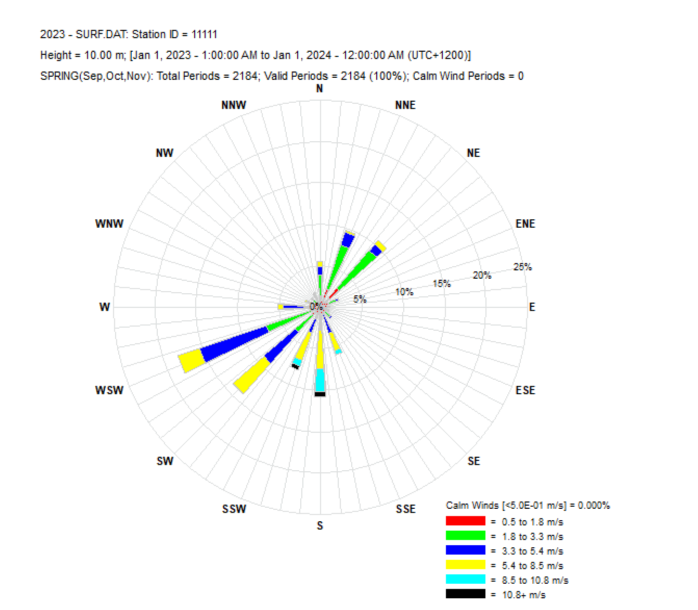



**Queenstown, Winter 2023 (Predicted)**

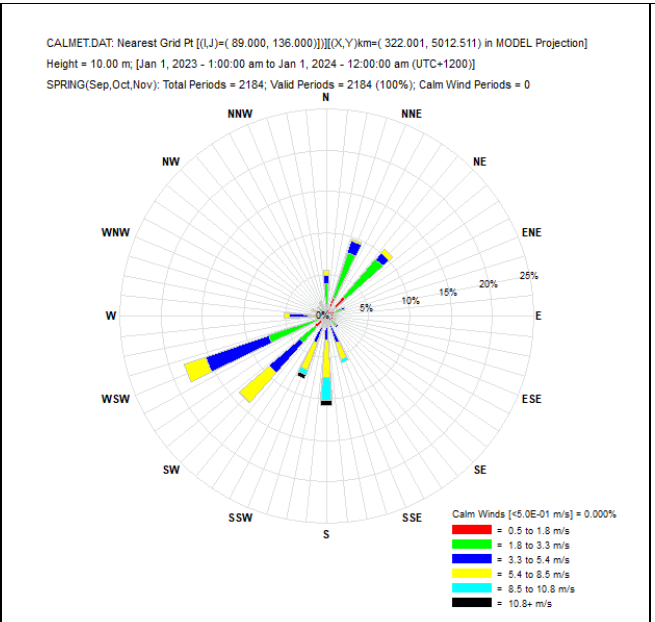



**Homestead Bay, Winter, 2023 (Predicted)**

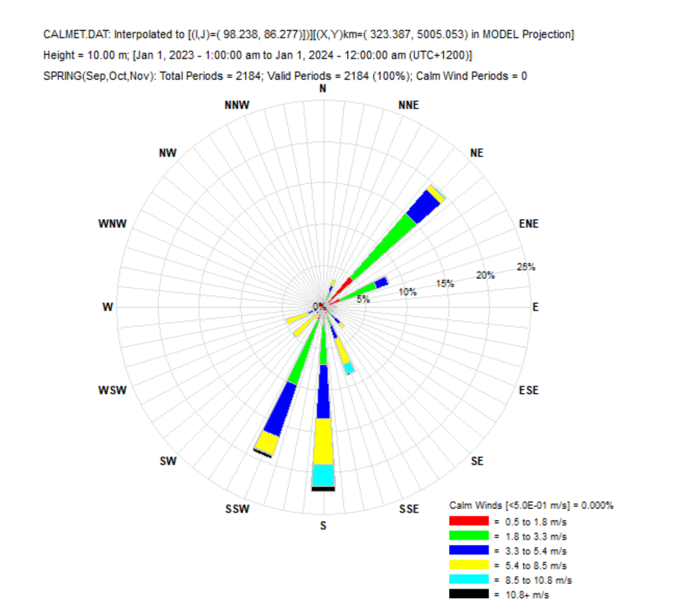
Appendix C  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Spring 2023 (Observed)**

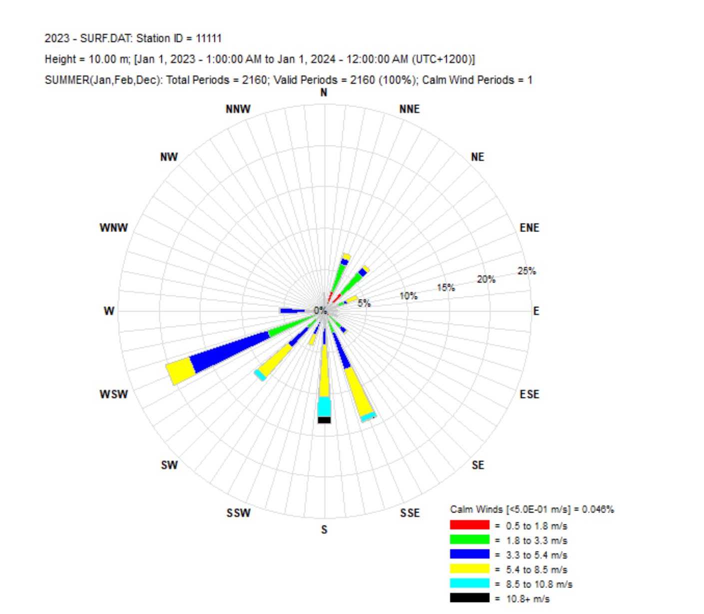



**Queenstown, Spring 2023 (Predicted)**

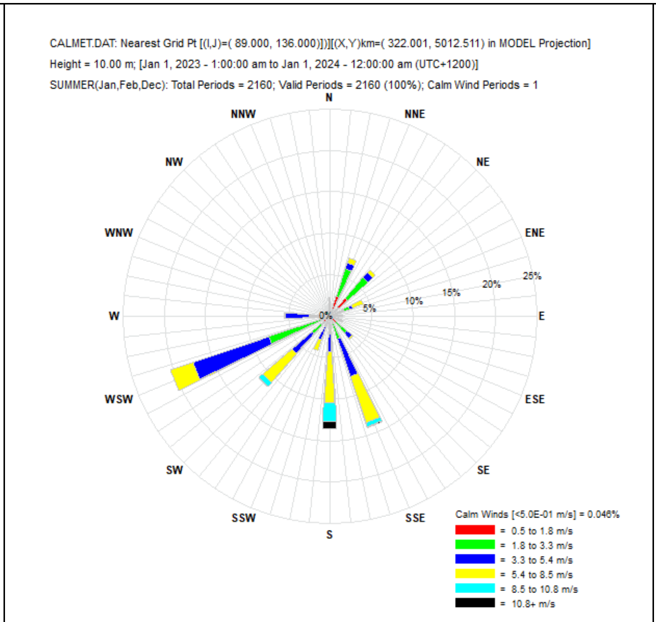



**Homestead Bay, Spring, 2023 (Predicted)**

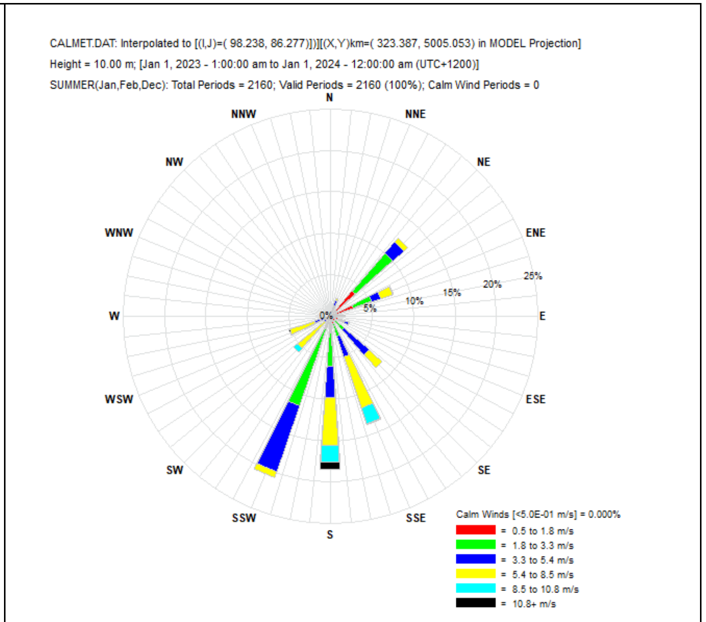
Appendix C  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Summer 2023 (Observed)**

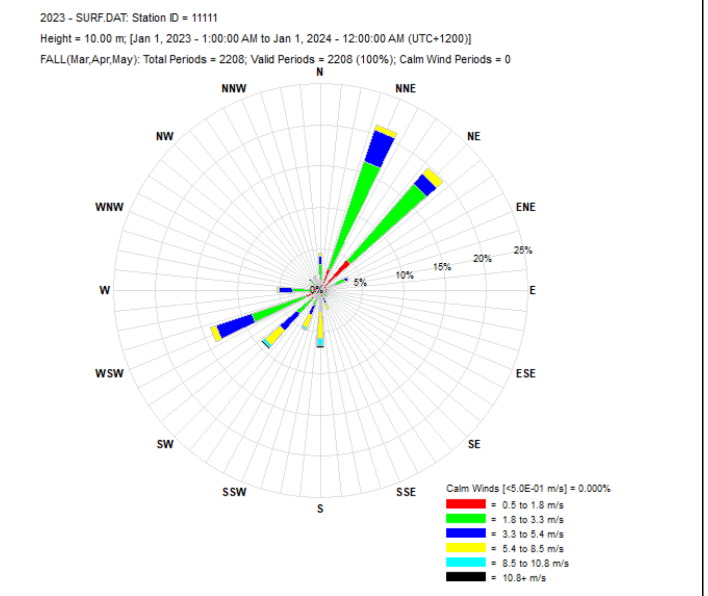



**Queenstown, Summer 2023 (Predicted)**

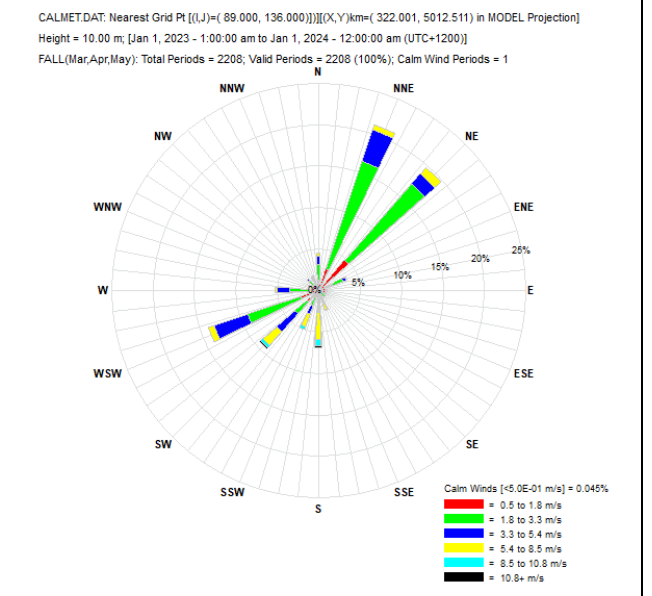



**Homestead Bay, Summer, 2023 (Predicted)**

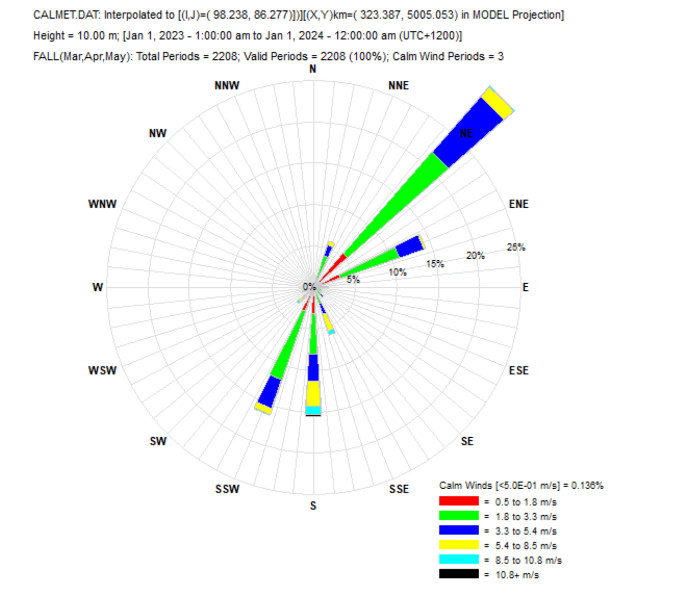
Appendix C TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Autumn 2023 (Observed)**

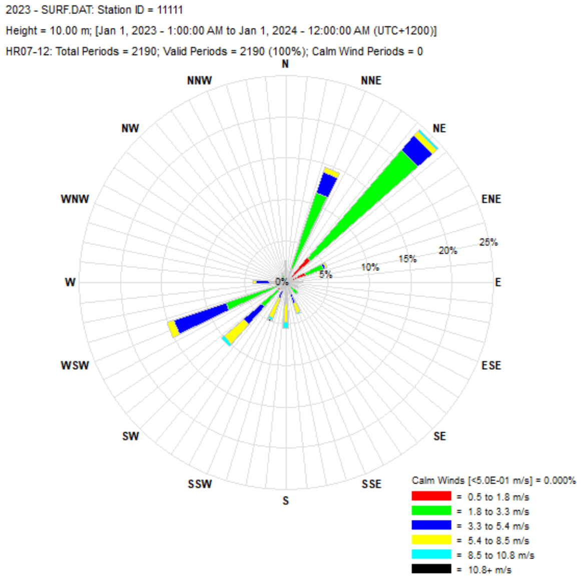



**Queenstown, Autumn 2023 (Predicted)**

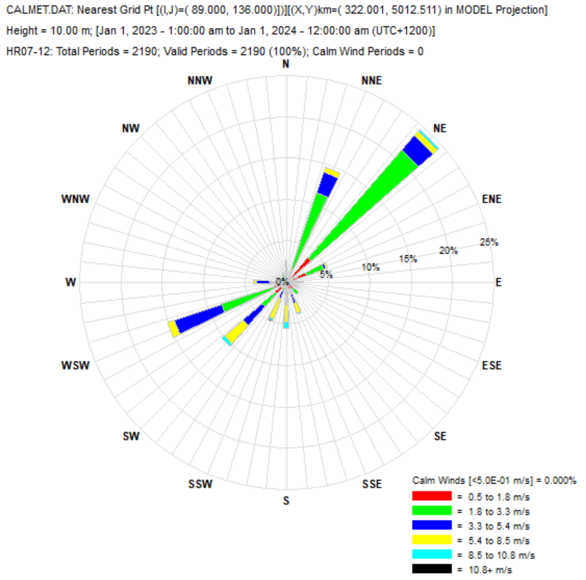



**Homestead Bay, Autumn, 2023 (Predicted)**

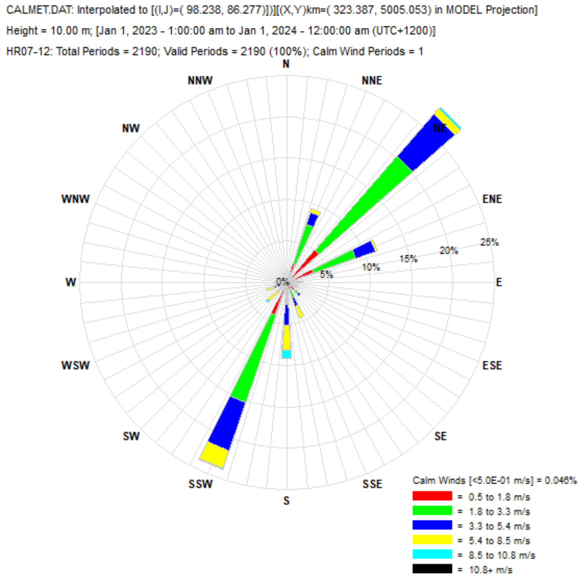
Appendix C TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Morning (07h-12h), 2023 (Observed)**

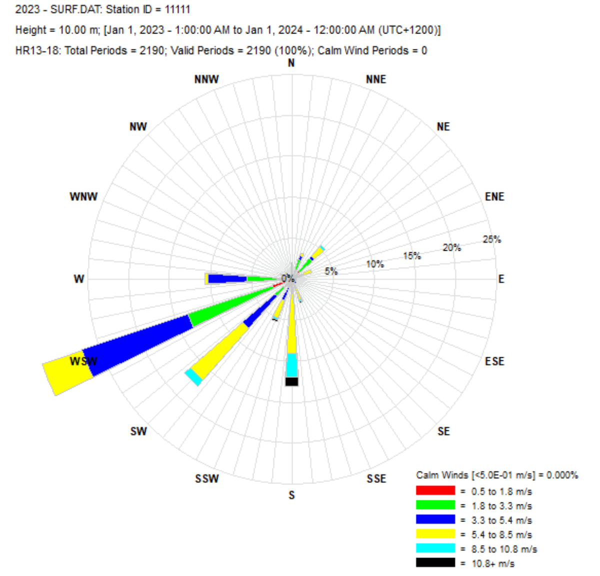



**Queenstown, Morning (07h-12h), 2023 (Predicted)**

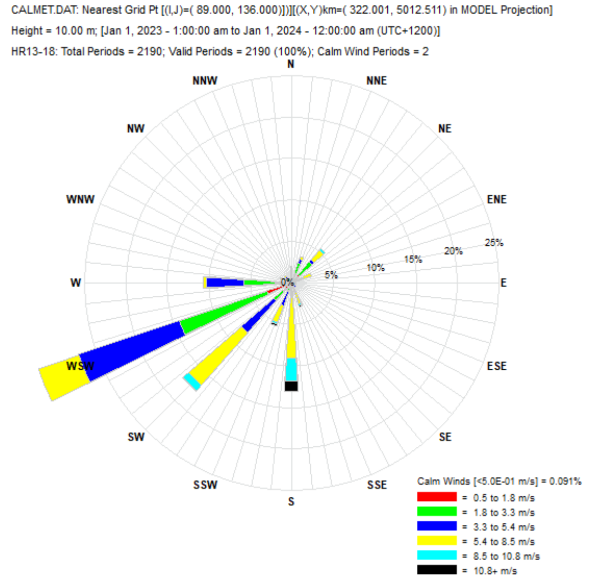



**Homestead Bay, Morning (07h-12h), 2023 (Predicted)**

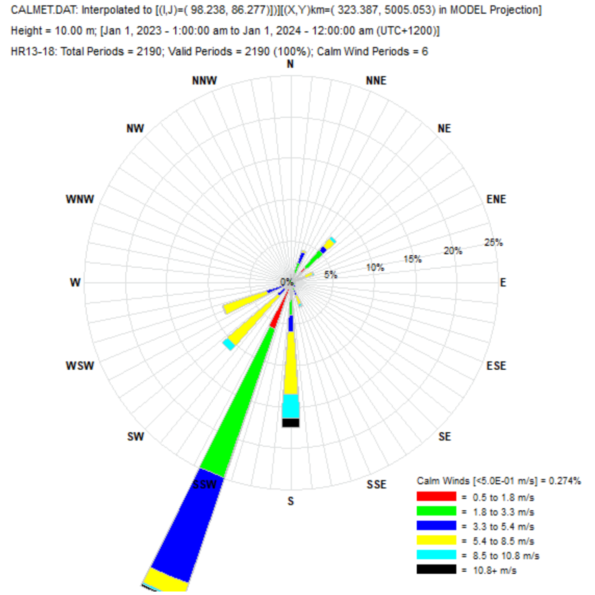
Appendix C  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Afternoon (13h-18h), 2023 (Observed)**

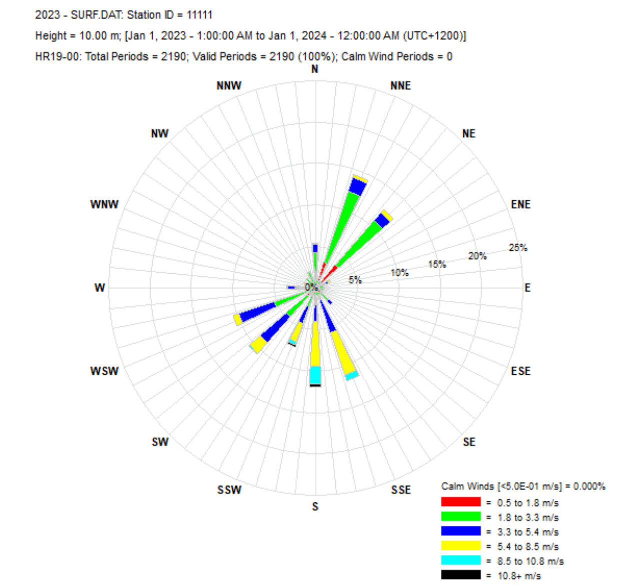



**Queenstown, Afternoon (13h-18h), 2023 (Predicted)**

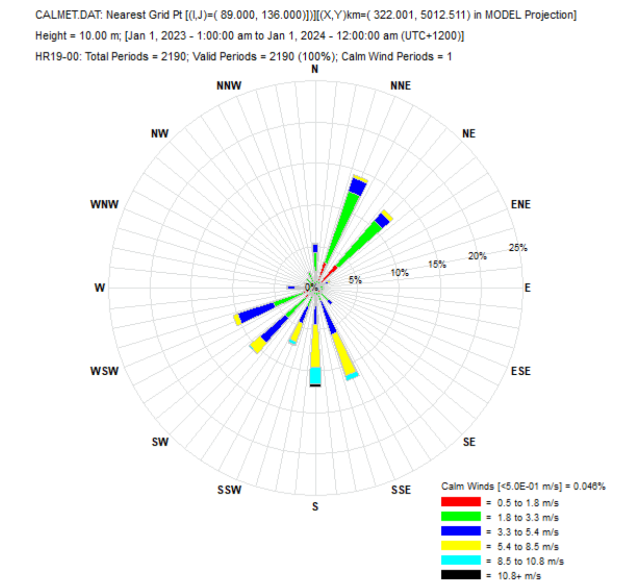



**Homestead Bay, Afternoon (13h-18h), 2023 (Predicted)**

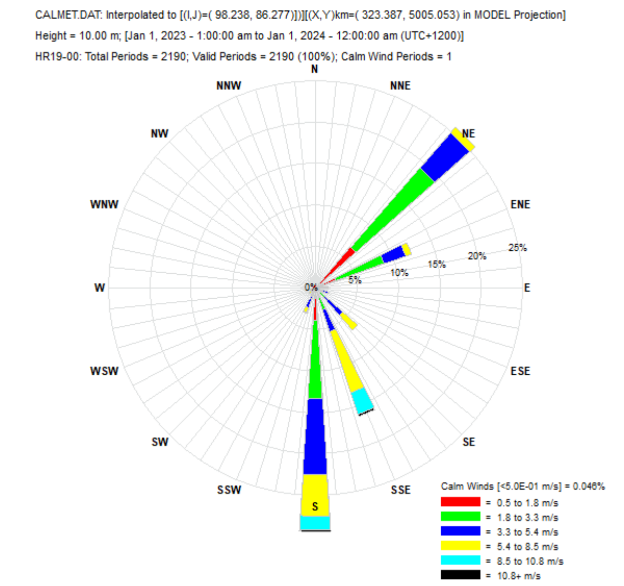
Appendix C TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Evening (19h-00h), 2023 (Observed)**

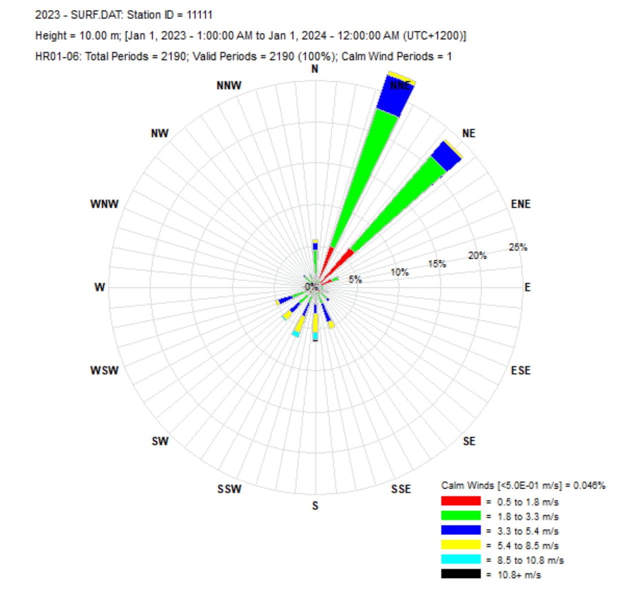



**Queenstown, Evening (19h-00h), 2023 (Predicted)**

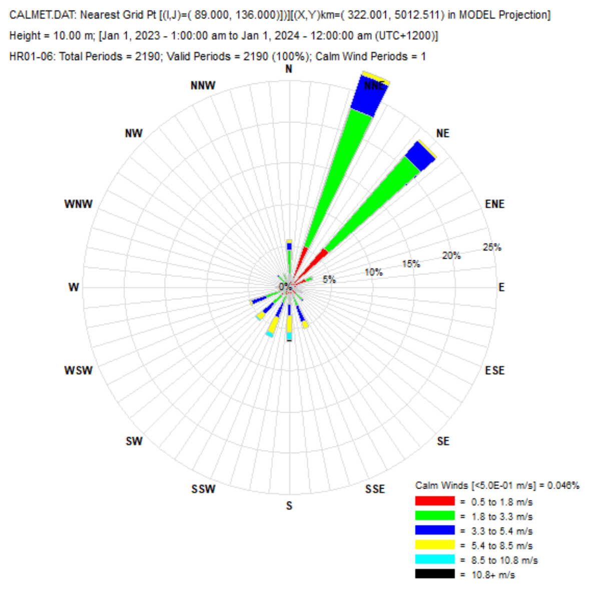



**Homestead Bay, Evening (19h-00h), 2023 (Predicted)**

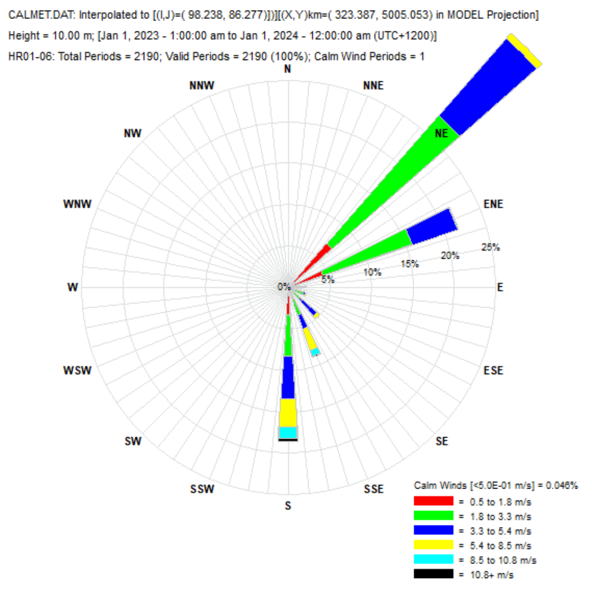
Appendix C  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**Queenstown, Night (01h-06h), 2023 (Observed)**

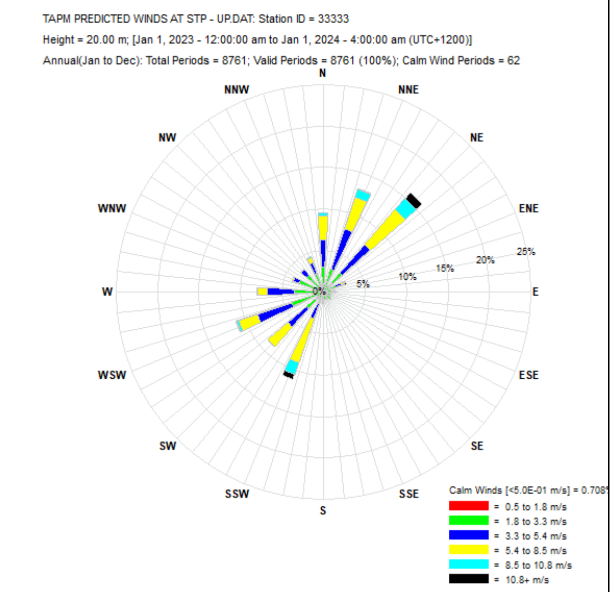



**Queenstown, Night (01h-06h), 2023 (Predicted)**

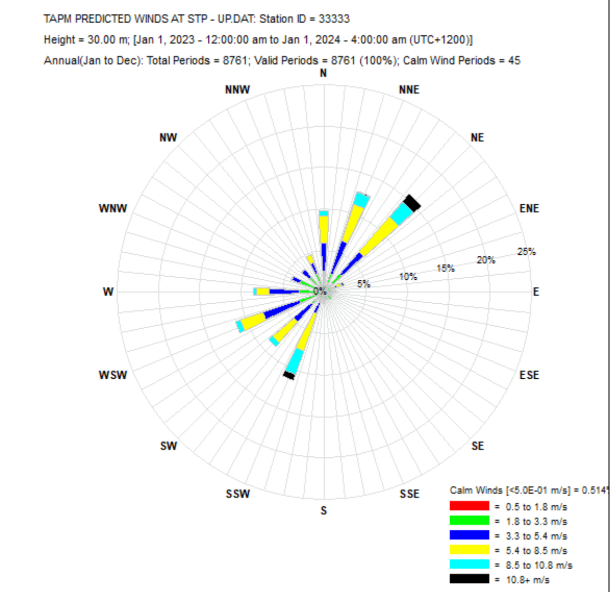



**Homestead Bay, Night (01h-06h), 2023 (Predicted)**

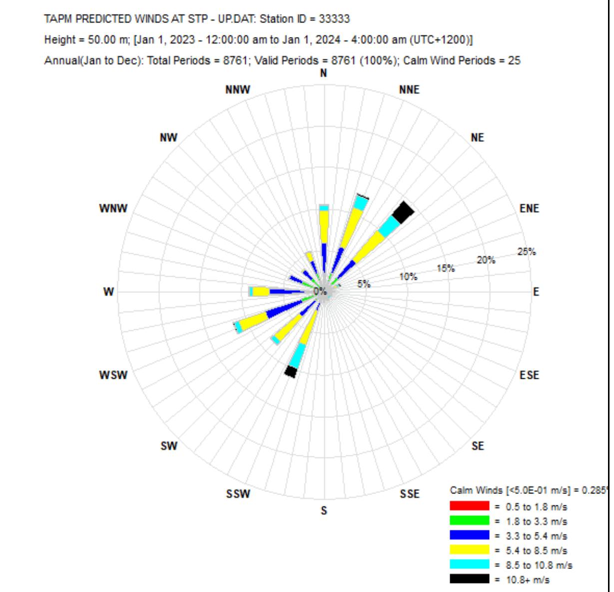
# Appendix D  APPENDIX D  TAPM (PREDICTED) ANNUAL UPPER AIR DATA AT HOMESTEAD BAY, QUEENSTOWN




**TAPM, Homestead Bay, Annual 2023, 20m**

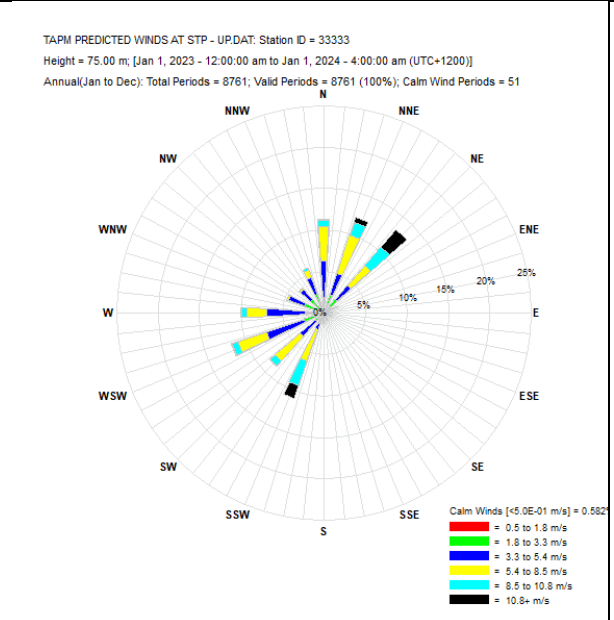



**TAPM, Homestead Bay, Annual 2023, 30m**

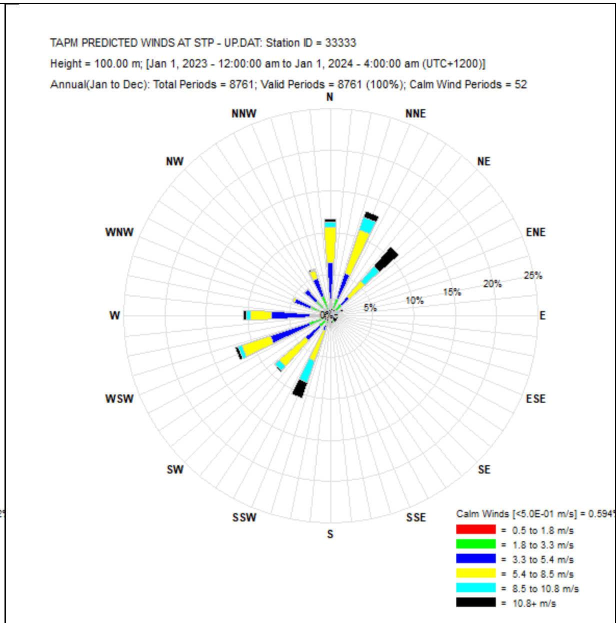



**TAPM, Homestead Bay, Annual 2023, 50m**

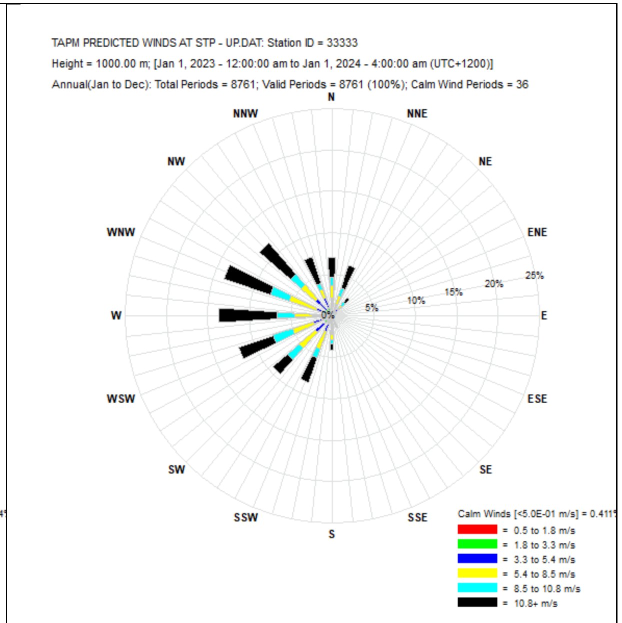
Appendix D  TAPM (predicted), annual upper air data at Homestead Bay WWTP




**TAPM, Homestead Bay, Annual 2023, 75m**




**TAPM, Homestead Bay, Annual 2023, 100m**




**TAPM, Homestead Bay, Annual 2023, 100m**

# CREATING COMMUNITIES

Communities are fundamental. Whether around the corner or across the globe, they provide a foundation, a sense of belonging. That's why at Stantec, we always **design with community in mind**.

We care about the communities we serve—because they're our communities too. We're designers, engineers, scientists, and project managers, innovating together at the intersection of community, creativity, and client relationships. Balancing these priorities results in projects that advance the quality of life in communities across the globe.

**Australian offices:**
Adelaide, Albany, Brisbane, Busselton, Gold Coast, Melbourne, Perth, Rockhampton, Sydney