Data and Information Committee Agenda 8 Sept 2021

Meeting will be conducted electronically and livestreamed to the Otago Regional Council YouTube Channel

Members:

Hon Cr Marian Hobbs, Co-Chair	Cr Michael Laws
Cr Alexa Forbes, Co-Chair	Cr Kevin Malcolm
Cr Hilary Calvert	Cr Andrew Noone
Cr Michael Deaker	Cr Gretchen Robertson
Cr Carmen Hope	Cr Bryan Scott
Cr Gary Kelliher	Cr Kate Wilson

Senior Officer: Sarah Gardner, Chief Executive

Meeting Support: Liz Spector, Governance Support Officer

08 September 2021 02:00 PM

Agenda Topic Page

Minutes of a meeting of the Data and Information Committee held in the Council Chamber on 9 June 2021 at 9:00 AM

Membership

Hon Cr Marian Hobbs	*(Co-Chair)*
Cr Alexa Forbes	*(Co-Chair)*
Cr Hilary Calvert	
Cr Michael Deaker	
Cr Carmen Hope	
Cr Gary Kelliher	
Cr Michael Laws	
Cr Kevin Malcolm	
Cr Andrew Noone	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Kate Wilson	

Welcome

Co-Chairperson Forbes welcomed Councillors, members of the public and staff to the meeting at 02:02 pm. Staff present included Sarah Gardner (Chief Executive), Nick Donnelly (GM Corporate Services), Gwyneth Elsum (GM Strategy, Policy and Science), Gavin Palmer (GM Operations), Richard Saunders (GM Regulatory), Amanda Vercoe (GM Governance, Culture and Customer), Liz Spector (Governance Support), Anne Duncan, Ann Yang, Jean-Luc Payan, Julie Everett-Hincks, Sarah Harrison, Kyle Balderston, Philip Waters, Sam Thomas, Rachel Ozanne, Hugo Borges, Garry Maloney and Julian Phillips.

1. APOLOGIES

Resolution

That the apologies for Cr Hope be accepted.

Moved: Cr Calvert
Seconded: Cr Noone
CARRIED

2. PUBLIC FORUM

No public forum was held.

3. CONFIRMATION OF AGENDA

Co-Chair Forbes reordered the agenda, moving the Contact Recreation report to last per a staff request.

4. CONFLICT OF INTEREST

No conflicts of interest were advised.

5. CONFIRMATION OF MINUTES

Resolution

That the minutes of the meeting held on 10 March 2021 be received and confirmed as a true and accurate record.

Moved: Cr Wilson
Seconded: Cr Hobbs
CARRIED

6. ACTIONS

There are no outstanding actions from resolutions of the Committee.

7. MATTERS FOR CONSIDERATION

7.1. Otago Greenhouse Gas Profile 2018/19 financial year

The Otago Greenhouse Gas (GHG) inventory for 2018/19 financial year provides an overview of greenhouse gas emissions within Otago between July 2018 and June 2019. The emission data is shown by Otago's districts and sectors defined in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) and provides baseline data to understand Otago's emissions and monitor progress of any mitigation options. Anne Duncan (Manager Strategy), Ann Yang (Senior Economic Analyst) and Gwyneth Elsum (GM Strategy, Policy and Science) were present to speak to the report and respond to questions. Gerri Ward (Director of Climate Change and Sustainability, EY) and Tim Torreele (Senior Analyst, EY) were present via Zoom. Dr Duncan noted a late dataset on powernet electricity emissions had come in after compilation of the document and will be incorporated moving forward.

Mr Torreele reviewed a presentation with the Councillors and responded to questions. Cr Laws asked why carbon sequestration only took into account benefits of trees over five metres, as much of Central Otago was planted with fruit orchards that, while never would attain that height, did have a positive impact on carbon in the atmosphere. Mr Torreele said he would review and respond in the future. Cr Malcolm noted that Otago had plenty of trees, however, not many of them would ever reach heights over five metres due to the geographic nature of the area. After further questions and discussions, Mr Torreele said there was work to be done to incorporate more Otago-specific information in the national statistics.

Cr Forbes noted three local government entities are currently undertaking this emission inventory and asked if it would be more prudent to have the inventory done by one organisation. Dr Duncan said it would be more efficient to have one inventory and work between Queenstown, Dunedin and the regional council was underway to develop such a partnership approach. After further discussion of the report, Co-Chair Forbes asked for a motion.

Resolution

That the Committee:

1) ***Receives*** *this report.*
2) ***Notes*** *that the Otago Greenhouse Gas Inventory has been prepared in collaboration with Otago's Territorial Authorities as a compilation of emissions for each District/City.*
3) ***Notes*** *the Inventory Report and the baseline data that will be publicly available to build understanding and support further investigations and future regional planning in Otago.*
4) ***Notes*** *the further use of the inventory to inform development of mitigation options and scenarios for Otago.*
5) ***Notes*** *that the Otago Regional Council will seek to lead/initiate the Otago Greenhouse Gas Inventory every two years in cooperation with Otago's District/City councils.*
6) ***Refer*** *this report to the 13 October Strategy and Planning Committee meeting to review the five-metre tree rule and other methods of capturing carbon sequestering of tussocks, soil, and other horticultural activity.*
7) ***Refer*** *this report to the Mayoral Forum to establish a collaborative operation with the Otago Territorial Local Authorities.*

Moved: Cr Laws
Seconded: Cr Wilson
CARRIED

Cr Hobbs left the meeting at 02:30 p.m.

7.2. Lake Buoy Programme

This paper was provided to inform and update the Committee on the purchase of monitoring buoys for Lake Wakatipu and Lake Wanaka and to provide an overview of the performance of the Lake Hayes buoy in its first two operational years. Hugo Borges (Scientist - Lakes), Julie Everett-Hincks (Manager Science) and Gwyneth Elsum (GM Strategy, Policy and Science) were present to respond to questions about the paper.

After a discussion of the report, Co-Chair Forbes asked for a motion.

Resolution

That the Committee:

1) ***Receives** this report.*

Moved: Cr Malcolm
Seconded: Cr Noone
CARRIED

7.3. Coastal Monitoring Programme

This report outlined the stages of gathering data/information underway which would inform the *Regional Plan: Coast* review and the pathway to the creation of a coastal monitoring programme. Sam Thomas (Coastal Scientist), Julie Everett-Hincks (Manager Science) and Gwyneth Elsum (GM Strategy, Policy and Science) were present to speak to the report and respond to questions.

Following discussion of the report, Co-Chair Forbes called for a motion.

Resolution

That the Committee:

1) ***Receives** this report.*

2) ***Notes** that Otago's SOE Coastal Monitoring programme is currently under development and will follow a four-staged process over 6 years. A paper will be presented to the Strategy and Planning Committee in 2022 outlining monitoring options for an SOE (State of the Environment) network and seeking Council approval for programme implementation.*

Moved: Cr Noone
Seconded: Cr Robertson
CARRIED

Cr Forbes called for a 5-minute adjournment at 3:39pm.
Cr Forbes called the meeting back to order at 3:44 p.m.

7.4. Contact Recreation 2020-2021

The report summarised contact recreation (swimmability) monitoring undertaken in Otago's rivers, lakes and coastal waters between 7 December 2020 and 31 March 2021. This monitoring is undertaken at 27 freshwater or coastal sites at weekly intervals over the summer months and is focused on human health risks relating to faecal contamination and/or potentially toxic cyanobacteria. Rachel Ozanne (Water Quality Scientist), Julie Everett-Hincks (Manager Science), and Gwyneth Elsum (GM Strategy, Policy and Science) were present to speak to the report and respond to questions.

Following an in depth discussion of the report by Councillors, Cr Wilson moved:

Resolution

That the Data and Information Committee*:*

1) ***Receives** this report.*
2) ***Expresses** its congratulations and appreciation for the work of Dame Carolyn Burns to increase public awareness of the importance of the ecological health of lakes in New Zealand.*

Moved: Cr Wilson
Seconded: Cr Noone
CARRIED

7.5. Quarterly Urban Monitoring Report
The report was provided to note the quarterly urban monitoring report, up to and including, March 2021, as required by Clause 3.9 of the National Policy Statement on Urban Development 2020. Philip Waters (Senior Analyst Urban Development), Kyle Balderston (Team Leader Urban Development) and Gwyneth Elsum (GM Strategy, Policy and Science) were present to speak to the report and respond to questions.

Cr Deaker said he understood compilation of this report was a requirement under the NPS-UD, but he wasn't clear how the information would be used. Mr Waters noted Dunedin City and Queenstown Lakes District produce their own similar reports, but the ORC's role was to provide a regional snapshot of anticipated growth and could be helpful to the TAs. Cr Malcolm asked if it would be more efficient to have one of the entities compile the report and then provide or sell to the other entities.

Following further discussion of the report, Co-Chair Forbes asked for a motion.

Resolution

That the Data and Information Committee*:*

1) Receives *this report.*

Moved: Cr Noone
Seconded: Cr Wilson
CARRIED

7.6. Active faults in the Dunedin City and Clutha Districts
This report was provided to inform the Committee of the outcome of the GNS Science review of active faulting and folding in the Dunedin City and Clutha districts. Sharon Hornblow (Natural Hazards Analyst), Jean-Luc Payan (Manager Natural Hazards), Gavin Palmer (GM Operations) and David Barrell (Engineering Geologist, GNS) were present to speak to the report and respond to questions. Mr Barrell also ran through a slide presentation and discussed his report. Mr Barrell noted all of the information will be going into the National database.

Following discussion of the report, Co-Chair Forbes called for a motion.

Resolution

That the Committee:

1) ***Receives*** *this report.*
2) ***Notes*** *that this information will be publicly available through ORC's Natural Hazards Database.*
3) ***Notes*** *this information will be provided to Dunedin City and Clutha District councils for incorporation into building control, utility infrastructure and land use planning decisions.*

4) ***Directs*** *that a report be provided to the Strategy and Planning Committee by 31 December 2021 on options for incorporating this information and other fault information held by ORC into planning frameworks across Otago.*

Moved: Cr Calvert
Seconded: Cr Kelliher
CARRIED

7.7. Queenstown and Dunedin Q3 FY21 Patronage Report

This report was provided to update the Committee on the performance of its public transport and total mobility services for the three quarters of the 2020/21 financial year. Garry Maloney (Manager Transport), Julian Philips (Implementation Lead - Transport), and Gavin Palmer (GM Operations) were present to speak to the report and respond to questions.

Cr Wilson asked if it would be possible to get detailed patronage information on specific sections of routes through Arrowtown and Queenstown as she thought parts of those routes might have higher demand than others. Mr Phillips said staff could provide more detail about that through a system report and can include in the future. Cr Calvert asked if it would be possible to have previous period comparisons in the report to follow trends in usage. Mr Phillips agreed to include this data in future reports.

Cr Scott asked about the upcoming end of the $2 fare trial and its implications. Mr Maloney said this was part of the draft Regional Public Transport Plan which would be in deliberations over its submissions the following week. He said after that process, the resulting information would come back to Council. Cr Calvert asked if the ORC decided to continue the $2 bus fares, where the funds to support this could come from. Mr Maloney said this would incur a substantial cost as the current budget is built on the assumption of fare revenue being equal to the previous year.

After further discussions of the report, Co-Chair Forbes asked for a motion.

Resolution

That the Committee:

1) ***Receives*** *the Q3FY21 Patronage Report.*

Moved: Cr Malcolm
Seconded: Cr Kelliher
CARRIED

8. CLOSURE

There was no further business and Co-Chairperson Forbes declared the meeting closed at 04:50 pm.

___________________________ ___________________

Chairperson Date

Action Register – Data and Information Committee at 2 Sept 2021

Meeting Date	Item	Status	Action Required	Assignee/s	Action Taken	Due Date	Completed (Overdue)
09/06/2021	SPS2126 Otago Greenhouse Gas Profile 2018/19 financial year	Assigned	Refer the Greenhouse Gas Profile 2018/19 to the 13 Oct 21 Strategy & Planning Committee to review the 5m tree rule and other methods of capturing carbon sequestering of tussocks, soil and other horticultural activity. **Res DAIC21-101**	General Manager Strategy, Policy and Science, Manager Strategy		13/10/2021	
9/06/2021	SPS2126 Otago Greenhouse Gas Profile 2018/19 financial year	In Progress	Refer the Greenhouse Gas Profile 2018/19 to the Otago Mayoral Forum to establish a collaborative operation with the Otago Territorial Local Authorities. **Res DAIC21-101**	General Manager Governance, Culture and Customer	**2/09/2021 Marianna Brook:** The GHG inventory and associated regional collaboration will be on the agenda of the 24 September 2021 Mayoral Forum meeting.	30/09/2021	
09/06/2021	SPS2132 Coastal Monitoring Programme	Assigned	Present a paper to the Strategy and Planning Committee in 2022 outlining monitoring options for a State of the Environment network and seek Council approval to implement the programme. **Res DAIC21-103**	General Manager Strategy, Policy and Science, Manager Science		30/06/2022	
09/06/2021	HAZ2106 Active faults in the Dunedin City and Clutha Districts	Assigned	Provide a report to the Strategy and Planning Committee by 31/12/2031 on options for incorporating the GNS Science active fault report and other fault information held by ORC into planning frameworks across Otago. **DAIC21-106**	General Manager Operations, Manager Natural Hazards		31/12/2021	

7.1. Air Quality 2010-2019 SoE Report

Prepared for:	Data and Information Committee
Report No.	SPS2143
Activity:	Environmental: Air
Author:	Sarah Harrison, Air Quality Scientist
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	8 September 2021

PURPOSE

[1] This paper presents a report on the state and trends of air quality in the Otago region for 2010 – 2019 as part of ORC's obligations under the *Resource Management Act 1991*.

EXECUTIVE SUMMARY

[2] Air quality monitoring data, namely PM_{10} (particulate matter with a diameter of less than 10 micrometres (µm)) has been analysed for the years 2010 – 2019. The current state of PM_{10} concentrations is that they are exceeding the limits set out for human health under the National Environmental Standards for Air Quality (NESAQ) in seven of our monitored towns: Alexandra, Arrowtown, Balclutha, Clyde, Cromwell, Milton and Mosgiel.

[3] The main emission source of PM_{10} is woodsmoke from home heating sources in winter. A significant influencing factor is the weather and local meteorology, as calm winds and temperature inversions cause the accumulation of home heating emissions within an airshed. This occurs frequently in winter during the presence of stable, high-pressure weather systems.

[4] Trend analysis shows that over the years PM_{10} concentrations deriving from home heating emissions have improved. These improvements have occurred in the towns that have the strictest Air Plan rules for wood burners, and where air quality strategy implementation work has been undertaken – Alexandra, Arrowtown, Cromwell, Clyde and Milton. The towns which have high pollution nights in winter, and no incentives to improve air quality such as Balclutha and Mosgiel have shown either a degrading trend (Balclutha) or a trend of improvement that may be driven by additional factors (Mosgiel).

RECOMMENDATION

That the Committee:

*1) **Notes** this report.*

BACKGROUND

[5] ORC operates a State of the Environment (SOE) air quality monitoring network of eight sites across the region. The primary parameter monitored is PM_{10}. Anthropogenic PM_{10} is produced by combustion sources such industrial activity, vehicle exhaust and solil'm d-fuel burning for home heating; also, by vehicle movements or processes that create dust. The NESAQ for PM_{10} is 50 µg/m³ for a 24-hour average, however, there is no known safety threshold for human health.

[6] The aim of this state and trends report for air quality is to assess the current state of PM_{10} against national standards and guidelines. Further, we describe the pressures and influences on PM_{10}, namely meteorology, climate, topography and emissions characteristics in Otago towns. The spatial and temporal trends were analysed, with the long-term trends describing the rate of increase (degrading trend) or decrease (improving trend) of concentrations. National context, health and cultural impacts are also discussed, as well as the current monitoring knowledge gaps.

DISCUSSION

[7] The current *state* of air quality in Otago (represented by years 2017-2019) shows that seven of the eight monitoring sites are non-compliant with the NESAQ for PM_{10}. This means they have more than one exceedance of 50 µg/m³ over a 24-hour period annually. The compliant site is Central Dunedin, which has different typical emission sources, meteorology and climate from the other sites. PM_{10} concentrations vary greatly between airsheds, as well as within airsheds, which is demonstrated by the relocation of two sites, Arrowtown in 2014 and Alexandra in 2017.

[8] All other monitoring sites - Alexandra, Arrowtown, Clyde, Cromwell, Milton and Mosgiel record very high PM_{10} concentrations in winter, with numerous exceedances of the national standard (Table 1). Emissions inventories undertaken in Otago have indicated that up to 99% of winter PM_{10} emissions in Otago towns are caused by home heating appliances such as wood, multi fuel and coal burners. At a national level, four of Otago's towns (Alexandra, Arrowtown, Cromwell and Milton) had the highest number of exceedances in 2016 across all monitored towns in New Zealand.

[9] *Trend* analysis undertaken at each site indicates that reductions in PM_{10} concentrations have occurred over the past ten years (Table 2). The greatest improvements can be seen in Central Dunedin and Clyde, with 5.3% and 3.5% reductions in PM_{10} concentrations per year between 2010 and 2019. Arrowtown has also shown improvement, with a 3.6% per year reduction between 2015 and 2019, with indications that this is a continuation of the trend prior to the site relocation in 2014. Alexandra, Cromwell, Milton and Mosgiel also have winter trends that indicate improvement in air quality.

[10] **Table 1 Number of NESAQ exceedances per site (24-hour average >50 µg/m³)**

Site	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Alexandra - 65 Ventry Street	51	40	40	46	51	22	38			
Alexandra - 5 Ventry Street								3	2	6
Arrowtown - School	39	27	24	15						
Arrowtown - Alexander Place					48	30	32	45	29	19
Balclutha	2	4	13	4	3	9	10	14	5	
Central Dunedin	11	14	1	1	0	0	0	0	1	0
Clyde	40	23	9	10	21	10	18	23	6	4
Cromwell	43	27	30	33	49	27	34	41	13	13
Milton	46	20	37	44	14	30	35	48	16	20
Mosgiel	8	8	NA	5	5	7	9	9	4	4

Note: Alexandra and Arrowtown sites were relocated due to site availability and implications are expanded upon in the SOE report.

[11] **Table 2 Winter trend analysis results summary**

Site	Time range	Winter trend	Annual change	Total change
Arrowtown	2014 - 2019	Improving	-3.5%	-18%
Alexandra	2010 - 2016		-2.3%	-16%
Balclutha	2010 - 2018	Degrading	1.3%	12%
Central Dunedin*	2010 - 2019	Improving	-5.3%	-53%
Clyde			-3.5%	-35%
Cromwell			-1.3%	-13%
Milton			-2.7%	-27%
Mosgiel			-1.8%	-18%

*Trend analysis undertaken for Central Dunedin was on year-round data, not winter only

[12] In the past, ORC has undertaken strategy implementation in certain towns to swap older burners for low-emission appliances, and this work likely contributed to the positive trends seen in the data in Air Zone 1 (Alexandra, Arrowtown, Clyde and Cromwell) and Milton even though further work would be required to achieve NESAQ compliance.

[13] There are several knowledge gaps for the monitoring of air quality in Otago. It would be beneficial to obtain updated information on the following pollutants in addition to $PM_{2.5}$, for which monitoring instruments are currently being added to the SOE network: nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and benzo(a)pyrene.

[14] Further studies could also be carried out a) within airsheds to continue developing our understanding of spatial variability of air quality, b) at Port Chalmers to determine the influence port operations have on the surrounding airshed, c) to measure the real-life

emissions from ultra-low emission burners, and d) to investigate outdoor burning in Otago.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[15] ORC's air quality monitoring programme is aligned with ORC's strategic directions, and supports:

a. Providing the best available information on Otago's air quality;
b. Designing interventions to achieve good air quality.

[16] The SOE report will also be an important source of information, for the Air Plan review, which will commence in 2022-2023, for notification in 2025.

Financial Considerations

[17] N/A

Significance and Engagement Considerations

[18] N/A

Legislative and Risk Considerations

[19] The NESAQ is being reviewed by the Ministry for the Environment to include 24-hour and annual limits for $PM_{2.5}$, while retaining the existing PM_{10} limits. The proposed $PM_{2.5}$ 24-hour hour limit is the same as the WHO guideline of 25 μg/m³, which is likely to produce more frequent and higher magnitude exceedances in Otago towns that already record high numbers of exceedances for PM_{10}.

Climate Change Considerations

[20] Air quality and climate change are interlinked and impact each other. Many air pollutants affect the amount of sunlight absorbed in the atmosphere and this impacts heating and cooling. An option for future research for Otago would be monitoring of black carbon, a climate pollutant emitted via incomplete combustion and a component of PM.

[21] Changes in climate impacts air quality as more frequent temperature extremes and stable highs may promote the formation and accumulation of some pollutants and may cause higher levels of both dust and pollens. Long term monitoring of both PM_{10} and $PM_{2.5}$ will provide for tracking trends of these natural sources compared to combustion sources. Changes to temperatures in Otago may also impact the way Otago residents heat and cool their homes.

Communications Considerations

[22] A media release will be prepared for this report and the report uploaded onto ORC's website.

[23] There is current local and national media interest in air quality issues in Central Otago.

[24] SoE air quality data is made available to the public via upload to the Land Air Water Aotearoa (LAWA) website on an hourly basis.

NEXT STEPS

[25] The monitoring network is currently undergoing an upgrade to include monitoring for $PM_{2.5}$ in anticipation of the release of the reviewed NESAQ.

[26] The current LTP has budget for an outdoor burning investigation and monitoring for other pollutants (SO_2, NO_2) in year 2.

[27] Annual air quality reports are presented each year. The next SOE report for air quality will be written in 2026.

ATTACHMENTS

1. So E Air Quality State and Trends 2010-2019 [**7.1.1** - 73 pages]

State and Trends of Air Quality in the Otago Region 2010 – 2019

September 2021

Otago Regional Council

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Published September 2021

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Otago Regional Council

Executive summary

Otago Regional Council (ORC) operates a State of the Environment (SoE) air quality monitoring network at eight sites throughout the region – Alexandra, Arrowtown, Balclutha, Central Dunedin, Clyde, Cromwell, Milton and Mosgiel. The aims of the programme include reporting data in accordance with the National Environmental Standards for Air Quality (NESAQ) and the Resource Management Act (RMA), and to develop understanding of the influences of emissions and meteorology on pollutant concentrations. Over the past 15 years this monitoring has focused on PM_{10}, small particles with a diameter of less than 10 micrometres.

This report evaluates the PM_{10} results from the last ten years (2010 –2019) of air quality monitoring. The report assesses the current state and the long-term trends of PM_{10} in Otago airsheds.

Results indicate that for most of the year, air quality in Otago is very good, with annual PM_{10} values meeting national and international guidelines for ambient air. However, during winter months higher PM_{10} concentrations are observed in many towns, caused by home heating emissions combined with calm weather and temperature inversions. Alexandra, Arrowtown, Cromwell and Milton regularly exceed the NESAQ for PM_{10} up to 20 times per winter. Other airsheds, such as Clyde and Mosgiel, exceed the standard up to ten times per winter. Central Dunedin is currently the only site compliant with the NESAQ.

Recognising the challenge of improving air quality in Central Otago and Milton, ORC set strict rules for domestic heating appliances in the Otago Regional Plan: Air Plan. To assist residents meeting these rules, ORC operated the Clean Heat Clean Air programme (CHCA), a financial incentive that has improved both insulation and heating appliances. Long-term trend analyses indicate that PM_{10} concentrations have reduced in Alexandra, Arrowtown, Clyde, Cromwell and Milton due to these incentives, however this has not been enough to meet the NESAQ in these towns.

Understanding the required strategies for each airshed to reduce emissions and become compliant with the national standards will be an important next step for Otago's air quality programmes. The results of this report will be used to inform future work on air quality strategy and policy in Otago.

Otago Regional Council

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Glossary

AAQG	Ambient Air Quality Guidelines (2002)
Airshed	Area designated by a regional council for air quality management
BAM	Beta Attenuation Monitor
CHCA	Clean Heat Clean Air
Coarse PM	Particulate matter sized between 2.5 and 10 µm in diameter
CO	Carbon monoxide
Exceedance	Where a contaminant exceeds its threshold concentration
Fine PM	Particulate matter less than 2.5 µm
HAPINZ	Health and Air Pollution in New Zealand Study
MfE	Ministry for the Environment
NESAQ	National Environmental Standard for Air Quality (2004)
NO_2	Nitrogen Dioxide
PM	Particulate Matter
$PM_{2.5}$	Particulate matter less than 2.5 µm in diameter
PM_{10}	Particulate matter less than 10 µm in diameter
SFB	Solid-fuel burner (wood, pellets and coal)
SO_2	Sulphur dioxide
ULEB	Ultra-low emission burner
Ultra-fine PM	Particulate matter less than 1 µm in diameter
µm	Micrometre, one millionth of a metre
$\mu g/m^3$	Microgram per cubic metre, unit of concentration
WHO	World Health Organization

1. Introduction

Clean outdoor (ambient) air is fundamental for human health and the natural environment. Ambient air quality is affected by the amounts and types of pollutants that are emitted into air, and the meteorological conditions that impact their dispersion. Otago has a varied and complex topography, producing varying climate zones from alpine to coastal environments.

Of the ambient air pollutants in New Zealand, particulate matter (PM) is the main concern in Otago, with many airsheds regularly failing to meet national standards. The main emission source of PM in Otago is solid fuel burning (wood, coal or pellets) for home heating, with lesser additional influence from vehicle emissions, industry, outdoor burning, and natural sources (ORC, 2016).

Four previous SoE reports have evaluated air quality in Otago. Two reports were released in 2005 for the period 1997 to 2004. The first was for PM_{10} (ORC, 2005a), and the second reported on sulphur dioxide, nitrogen dioxide and carbon monoxide (ORC, 2005b). Two further PM_{10} reports were released for the period of 2005 to 2008 (ORC, 2009) and 2005 to 2014 (ORC, 2016).

This report evaluates the results of the SoE monitoring for PM_{10} over the ten-year period of 2010 to 2019 and examines the current state and temporal trends. The differences between this report and the previous reports are: inclusion of analyses of home heating methods and subsequent emissions in key Otago towns due to the recent completion of two emissions inventories of 2016 and 2019; as well as spatial variability results within two airsheds due to monitoring site relocations.

1.1. Purpose of the report

This report aims to:

- Report the current state of PM_{10} in relation to the relevant standards and guidelines
- Evaluate the spatial and temporal trends of PM_{10} for the last ten years
- Inform future air quality policy and strategy work for Otago

1.2. Scope and outline

This report presents and analyses data collected by the monitoring network for the last ten years. Relevant information from other investigations, such as spatial studies and emissions inventories will also be included.

The following sections are included in this report:

- Section 2 describes the current air quality assessment framework
- Section 3 describes Otago's monitoring network
- Section 4 presents the current state of PM_{10} in an analysis of the three most recent years' data (2017-2019)
- Section 5 provides analyses of the temporal trends for 2010-2019 and describes the spatial distribution of PM_{10} in various towns
- Section 6 discusses the pressures and influences on air quality
- Section 7 discusses the results of the analyses, the health and cultural impacts of air pollution, and outlines the current knowledge gaps

2. Air quality assessment framework

2.1. National air quality indicators for ambient pollutants

The national Ambient Air Quality Guidelines (AAQG) were first established in 1994 by the Ministry for the Environment (MfE), based on international public health information (MfE, 2002). The AAQG was revised in 2002, and recommends limits on concentrations for certain ambient air pollutants.

In 2004 the National Environmental Standards for Air Quality (NESAQ) were adopted (revised in 2011) and established mandatory minimum requirements for five pollutants – PM_{10}, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3). The objectives of these standards are to provide an acceptable level of protection to human health and the environment. These standards are currently being revised to include $PM_{2.5}$ (particulate matter with a diameter of less than 2.5 micrometres). Table 1 provides the current ambient air quality standards and guidelines for the relevant pollutants.

Pollutant	Limit type	Threshold concentration (µg/m³)	Averaging period	Number of allowable exceedances
PM_{10}	Standard	50	24-hour	1 per year
	Guideline	20	Annual	n/a
Nitrogen dioxide (NO_2)	Standard	200	1-hour	9 per year
	Guideline	100	24-hour	n/a
Carbon monoxide (CO)	Standard	10	8-hour running	1 per year
	Guideline	30	1-hour	n/a
Ozone (O_3)	Standard	150	1-hour	none
	Guideline	100	8-hour running	n/a
Sulphur dioxide (SO_2)	Standard	350	1-hour	9 per year
	Standard	570	1-hour	none
	Guideline	120	24-hour	n/a

Table 1 New Zealand standards and guidelines for ambient pollutants

Otago Regional Council's (ORC) current monitoring programme focuses on measuring PM_{10}, the most significant pollutant of concern both regionally and nationally. Earlier monitoring (1997 – 2004) of NO_2, SO_2 and CO indicated these pollutants were not present in significant concentrations and are expected to be below the standard and guideline limits. Ozone is a secondary pollutant formed during photochemical reactions between oxygen and nitrogen dioxide, when exposed to light. During a study on photochemical pollution potential in New Zealand (McKendry, 1996) no towns or cities in Otago were identified as having conditions conducive to the formation of ozone. More information for NO_2, SO_2, CO and ozone is provided in Appendix 4.

2.2. International air quality indicators

New Zealand standards and guidelines are consistent with the World Health Organization (WHO) recommendations (WHO, 2006) for NO_2, CO and O_3. In the cases of PM and SO_2 there are some significant differences.

Regarding particulate matter, international researchers agree that adverse health effects associated with $PM_{2.5}$ are greater than those associated with PM_{10}. As a result, many agencies including WHO, the European Union, the United States and Australia have introduced $PM_{2.5}$ standards alongside their PM_{10} standards. In formulating PM guidelines and standards, WHO assume that the ratio of $PM_{2.5}$ to PM_{10} is 0.5, thereby setting the $PM_{2.5}$ daily guideline limit at 25 µg/m³, which is half that of PM_{10}.

The WHO lowered the SO_2 24-hour guideline value from 120 µg/m³ to 20 µg/m³ in 2005. The lowered value may be relevant in areas with coal-powered industrial plants and in areas where coal burning is heavily used for domestic heating.

Table 2 lists the relevant WHO guidelines for various ambient air pollutants where they differ significantly from the NESAQ.

Pollutant	Threshold concentration (µg/m3)	Averaging period
$PM_{2.5}$	25	24-hour
	10	annual
Nitrogen dioxide NO_2)	40	annual
Sulphur dioxide (SO_2)	20	24-hour
	500	10-minute

Table 2 World Health Organization guideline values for $PM_{2.5}$, NO_2 and SO_2

2.3. Particulate matter

Particulate matter (PM) refers to particles or aerosols that are suspended in the atmosphere. PM can be natural or anthropogenic (produced by human activity) in origin and can either be directly emitted or formed in the atmosphere as a result of chemical reactions between other pollutants. Therefore, PM occurs in a range of sizes and chemical compositions. PM can be grouped into two categories – 'fine' and 'coarse'. Fine particulate matter consists of particle sizes up to 2.5 µm in diameter ($PM_{2.5}$). Coarse particulate matter is the group of particles with diameter sizes between 2.5µm and 10 µm. PM_{10} is the fine and the coarse fractions combined.

Fine particulate matter, or $PM_{2.5}$, is a result of incomplete combustion such as vehicle emissions, and the combustion of wood and coal for industry or heating. It is comprised of organic and inorganic compounds, metals and black carbon (soot). These particles can remain suspended in the air for many days and can be transported hundreds of kilometres.

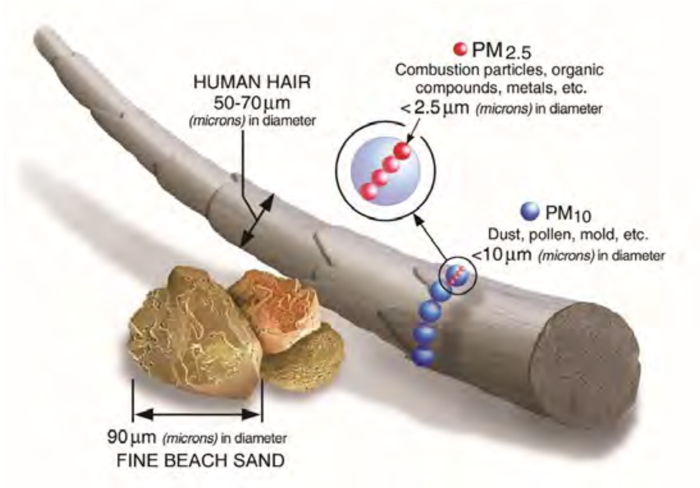

Figure 1 Comparison of particle sizes. Source: United States Environmental Protection Agency

Coarse particulate matter ($PM_{10-2.5}$) is a product of mechanical forces such as wind erosion, crushing and abrasion. Natural sources include pollen, soils and sea salt. Anthropogenic sources include dust suspended from roads and industrial activity. Coarse PM tends to fall out of suspension within minutes or hours and can travel up to 50 kilometres from the source.

Both short and long-term exposure to particulate matter can cause and exacerbate serious health issues, specifically to the respiratory and circulatory systems. The most vulnerable to PM are the young, the elderly and anyone with pre-existing conditions. Fine and ultra-fine (PM_1 and smaller) are the most dangerous as smaller particles can penetrate the respiratory system further and enter the blood stream (WHO, 2013). Currently there is no established safety threshold for exposure to particulate matter.

2.4. Otago airshed management

2.4.1. Airsheds

The Otago region has four designated Airsheds which were gazetted[1] in 2005 in accordance with NESAQ requirements. The Airsheds are ranked from Airshed 1 (most degraded air quality) to Airshed 4 (not expected to be degraded). Twenty-two towns and cities have been allocated into one of these four airshed groups based on similarities in their geography, climate and air pollution potential (Figure 2). Rural areas outside of town boundaries are considered to be a fifth airshed, where air quality is expected to be good.

2.4.2. Air Zones

The twenty-two airsheds are also categorised into management areas under the Air Plan, called Air Zones (Table 3). Air Zone 1 and 2 consists of towns expected to exceed the NESAQ for several days

[1] Gazetted airshed refers to those notified in the New Zealand Gazette

(>10), and a few days (<10) a year, respectively. Air Zone 3 are towns that are not expected to exceed the NESAQ. Maps of individual airsheds can be found in Appendix A1.

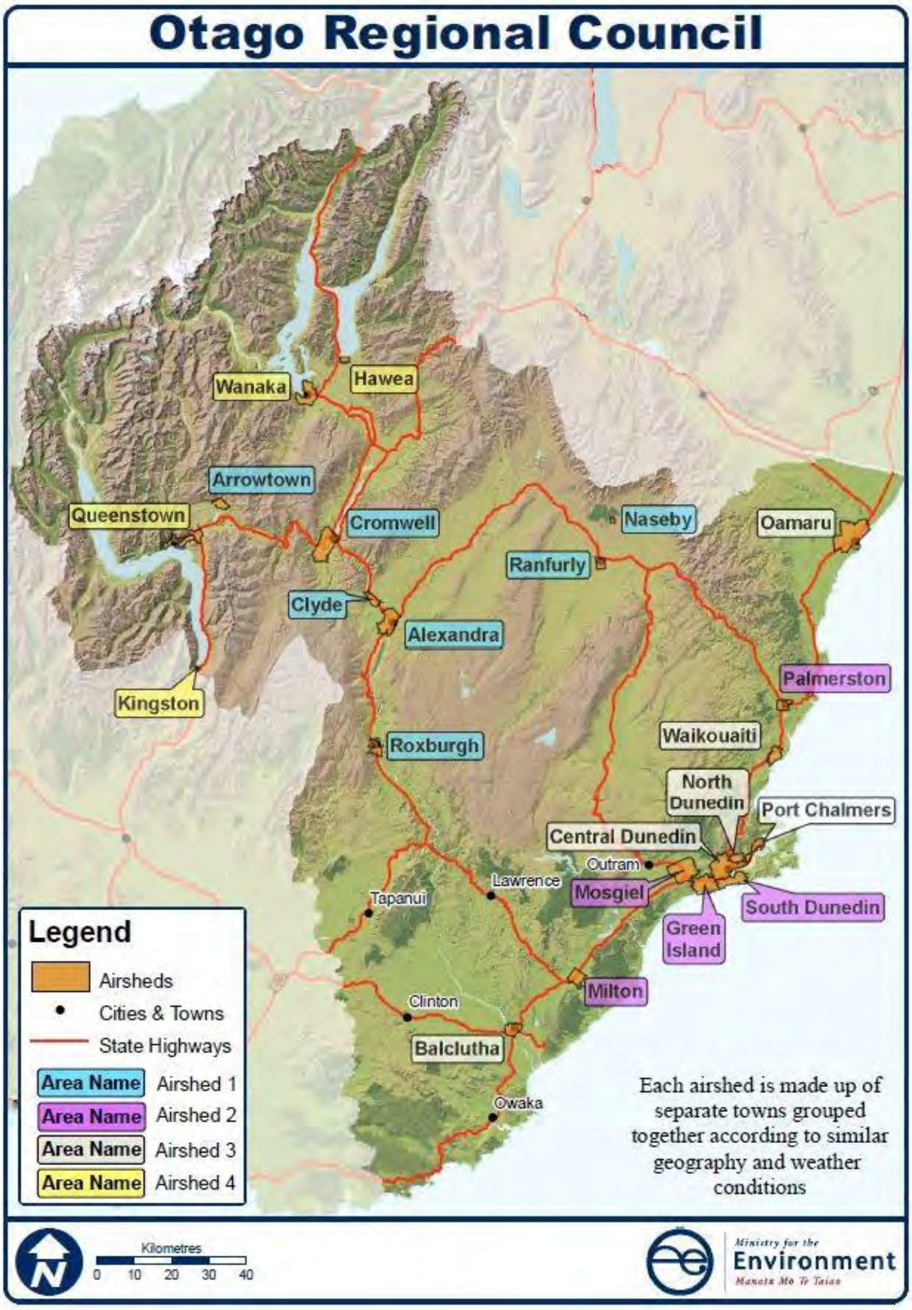

Figure 2 **Otago Regional Council gazetted airsheds**

Otago Regional Council

<table>
<tr><th>Town</th><th>Gazetted Airshed (MfE)</th><th>ORC Air Zone</th></tr>
<tr><td>Alexandra</td><td rowspan="7">1</td><td rowspan="4">1</td></tr>
<tr><td>Arrowtown*</td></tr>
<tr><td>Clyde</td></tr>
<tr><td>Cromwell</td></tr>
<tr><td>Naseby</td><td rowspan="18">2</td></tr>
<tr><td>Ranfurly</td></tr>
<tr><td>Roxburgh</td></tr>
<tr><td>Green Island</td><td rowspan="5">2</td></tr>
<tr><td>Milton</td></tr>
<tr><td>Mosgiel*</td></tr>
<tr><td>Palmerston</td></tr>
<tr><td>South Dunedin</td></tr>
<tr><td>Balclutha</td><td rowspan="6">3</td></tr>
<tr><td>Central Dunedin *</td></tr>
<tr><td>North Dunedin</td></tr>
<tr><td>Oamaru</td></tr>
<tr><td>Port Chalmers</td></tr>
<tr><td>Waikouaiti</td></tr>
<tr><td>Hawea</td><td rowspan="4">4</td></tr>
<tr><td>Kingston</td></tr>
<tr><td>Queenstown</td></tr>
<tr><td>Wanaka</td></tr>
<tr><td><Rest of Otago></td><td>5</td><td>3</td></tr>
</table>

*Contains the regulatory monitoring site for the NESAQ Gazetted Airshed

Table 3 Airshed and Air Zone designations for Otago

3. Air quality monitoring network

3.1. Background

ORC operates a long-term air quality monitoring network in the region. Monitoring began in 1997, and since that time ambient pollutants including PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO have been monitored in 50 locations throughout Otago. Most of the monitoring performed over the last 15 years has been in response to the requirements of the NESAQ.

A variety of monitors and monitoring techniques have been employed to define and characterise air quality, both temporally and spatially. During this ten-year reporting period (2010-2019), monitoring has focused on PM_{10}.

Otago's large area, with varying terrain and climate make it challenging to provide a true and complete representation of ambient air quality. Therefore, monitoring sites are situated where it is considered that the most people may experience exposure to the highest concentrations of pollution.

3.2. Monitoring objectives

The objective of Otago's air quality monitoring programme is to provide scientifically robust data for the following purposes:

- To manage the region's air resource
- To fulfil the statutory requirements of the Resource Management Act 1991 (RMA)
- To measure and report on compliance with national standards and guidelines
- To measure the effects of ORC's air quality management initiatives

A range of monitoring activities and special investigations are needed to fulfil these objectives. In addition to continuous site monitoring, other research includes emissions inventories, source apportionment studies and spatial studies.

3.3. Monitoring programme

There are two types monitoring site used in the air quality monitoring network:

a) Key indicator monitoring - performed at long-term sites that run continuously in Arrowtown, Central Dunedin and Mosgiel. These sites are representative of the different MfE airshed categories and are considered characteristic of Otago's townships. Results from these sites are used to report to MfE on compliance with NESAQ and to track long-term trends
b) Survey monitoring - undertaken at sites that only run during winter months (May to August inclusive). Results are used to quantify air quality during winter and assist in tracking trends.

Table 4 lists all the sites monitored over the last ten years.

Site	Airshed	Air Zone	Purpose	Length of record
Arrowtown	1	1	Key indicator – Year-round	2007 - present
Mosgiel	2	2		2005 - present
Central Dunedin	3	2		2006 - present
Alexandra*	1	1	Year-round	2004 - present
Balclutha	2	2	Survey – winter only	2009 - 2018
Clyde	1	1		2008 - present
Cromwell	1	1		
Milton	2	2		

*Alexandra was the Key indicator for Airshed 1 for 2004-2017

Table 4 Air monitoring sites and their purpose in the network

3.4. Monitoring methods

3.4.1. Particulate matter monitoring and measurement

PM_{10} is monitored using two types of beta attenuation monitor (BAM), manufactured by MetOne in the USA. BAMs measure the particle mass density by comparing the sample deposited on the filter tape with the blank tape; as the particle mass increases, the beta count decreases. Standard sampling methods are required for regulatory reporting for compliance with the NESAQ. The BAM1020 is accepted by the US Environmental Protection Agency (USEPA) as an equivalent reference method for measuring PM_{10}. BAM1020 are used at the continuous sites Alexandra, Arrowtown, Central Dunedin and Mosgiel. The Dunedin BAM1020 installation is shown in Figure 3.

The winter only sites are monitored using an Environmental Beta Attenuation Monitor (EBAM). The EBAM is not considered an equivalent reference method, but it is designed to provide accurate daily PM_{10} averages. All stations are sited and operated where possible, using ASNZS 3580.1.1:2016.

3.4.2. Meteorological monitoring and measurement

Air temperature, wind speed and wind direction all influence the accumulation and dispersion of pollutants. These parameters are recorded continuously at the PM_{10} monitoring sites in order to describe localised meteorological effects on PM_{10}.

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Figure 3 **PM_{10} and meteorology site in Central Dunedin and the filter tape a BAM1020 monitor; each filter tape spot represents one hour of sampled PM_{10}**

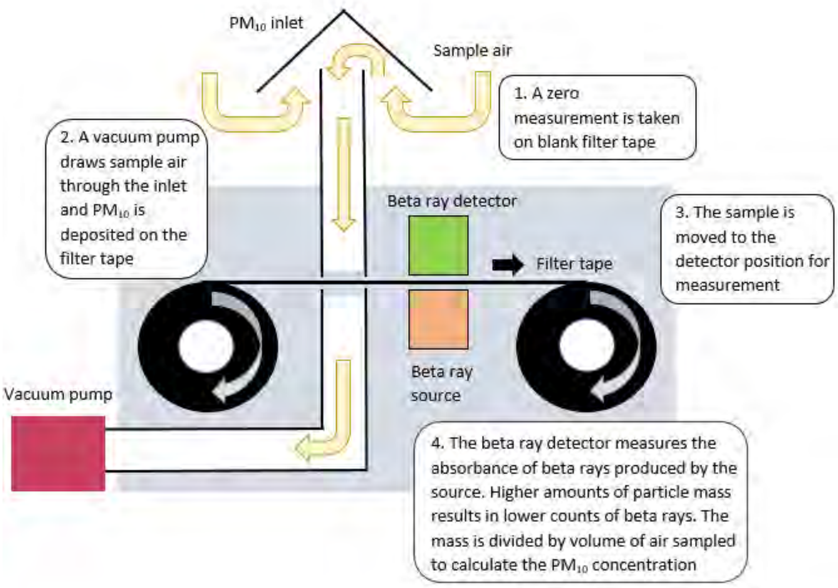

Figure 4 **Principles of BAM operation**

4. State of Otago's air quality

This section compares the last ten years of PM_{10} data from each monitoring site with the relevant standards and guidelines and describes the current state of air quality in Otago.

4.1. Compliance with standards and guidelines

4.1.1. 24-hour PM_{10} standard

The following table shows the number of NESAQ exceedances, where PM_{10} exceeds 50 µg/m³ over an average of 24-hours (midnight-midnight). The number of exceedances at a given site can vary vastly between years, for example the number of exceedances between 2017 and 2018 decreases by more than half at Clyde, Cromwell and Milton (Table 5), due to meteorological variation between the years. Central Dunedin is the only site that is currently compliant with the NESAQ, with one exceedance in the last three years. The NESAQ allows one exceedance per year; only after a second one is the airshed considered in breach of the standard.

Site	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Alexandra - 65 Ventry Street	51	40	40	46	51	22	38			
Alexandra - 5 Ventry Street								3	2	6
Arrowtown - School	39	27	24	15						
Arrowtown - Alexander Place					48	30	32	45	29	19
Balclutha	2	4	13	4	3	9	10	14	5	
Central Dunedin	11	14	1	1	0	0	0	0	1	0
Clyde	40	23	9	10	21	10	18	23	6	4
Cromwell	43	27	30	33	49	27	34	41	13	13
Milton	46	20	37	44	14	30	35	48	16	20
Mosgiel	8	8	NA	5	5	7	9	9	4	4

Table 5 **Number of NESAQ exceedances per site for 2010-2019. Shaded squares represent sites that were not in operation. Alexandra and Arrowtown monitors were relocated due to site availability and are discussed further in Section 6.**

4.1.2. Annual PM_{10} guideline

The following graph shows the annual averages of the year-round sites relative to the AAQG and WHO guideline of 20 µg/m³. Central Dunedin has been meeting the annual guideline since 2012, which indicates good air quality at this site. For the last two years all the other sites have also met the guideline, and 2017 was the most recent year for Arrowtown to be above the limit (Figure 5). Some sites show variation between years and further analysis of trends is undertaken in Section 5.

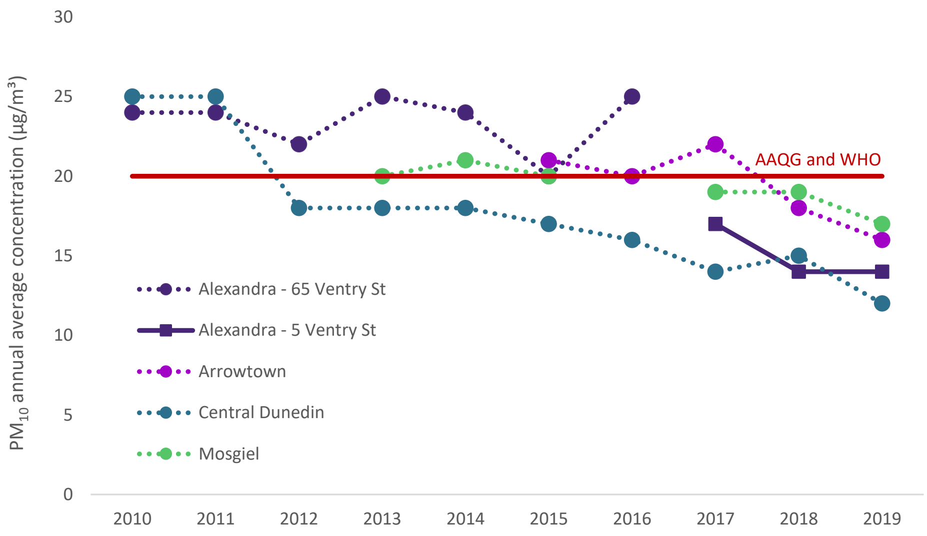

Figure 5 **Annual average PM_{10} for 2010-2019 compared with the annual AAQG and WHO guideline**

4.2. Statistics

Data from 2017-2019 is presented to show the current state of air quality at each site for comparison purposes. The three-year period was chosen to represent the current state because it should smooth some of the variation in particulate concentrations due to changing weather patterns year to year. Additionally, three years is too short to discern any significant change in PM_{10} due to interventions designed to reduce emissions.

Table 6 shows that Arrowtown and Milton have the highest values for the following: winter means (39 and 36 µg/m³) maximum daily concentration (158 and 154 µg/m³) and average number of exceedances over the last three years (31 and 28). Apart from Dunedin, Clyde has the lowest winter mean of 25 µg/m³, and Mosgiel and the current Alexandra site have the least number of exceedances on average, with 5.3 and 3.7 respectively. This data also indicates that it is normal for the airsheds Arrowtown, Cromwell and Milton to experience between 15 and 50 exceedances in a given year, and that winter means can vary greatly between years. A comprehensive list of parameters is given by site in Appendix 3:

Figure 6 ranks the sites in order of their winter average PM_{10} and shows that for most sites high winter averages and high numbers of exceedances occur together. Balclutha and Mosgiel go against this pattern slightly as they have a lower exceedance count for their winter averages. Figure 7 plots the relationship between winter average and number of exceedances for all sites. The relationship indicates that a winter average of below at least 20 µg/m³ is required to meet the NESAQ.

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Site	Maximum 24-hour average concentration	2nd highest 24- hour average concentration	Mean winter PM_{10}				Average number of exceedances
			2017	2018	2019	Average	
Alexandra (5 Ventry Street)	98	91	26	23	23	24	3.7
Arrowtown (Alexander Place)	158	132	47	38	32	39	31.0
Balclutha	98	69	34	26	NA	29	9.5
Central Dunedin	52	41	15	15	12	14	0.3
Clyde	87	74	32	22	22	25	11.0
Cromwell	123	100	43	27	26	32	22.3
Milton	154	137	46	32	29	36	28.0
Mosgiel	95	89	26	26	25	26	5.3

*Balclutha was decommissioned after winter 2018

Table 6 **Maximum and second highest 24-hour average concentration, winter mean and average number of exceedances of the NESAQ for 2017-2019**

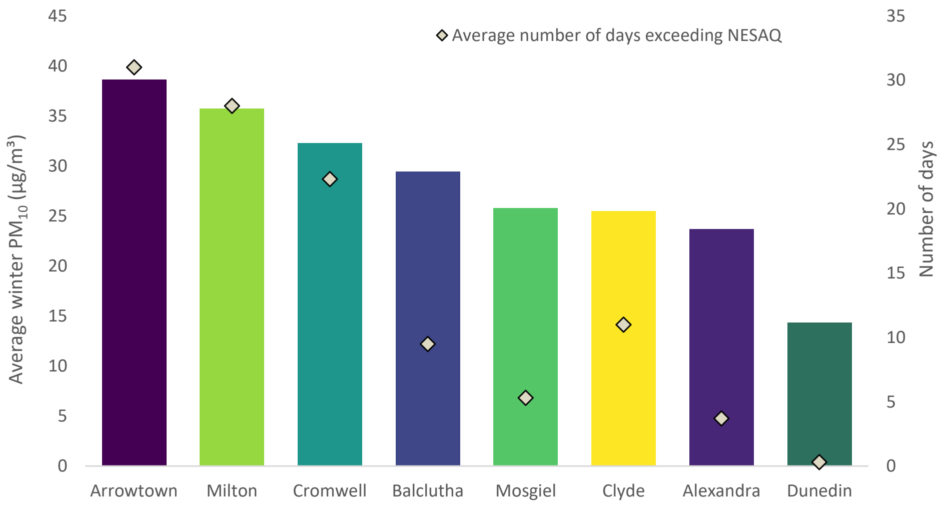

Figure 6 **Average winter PM_{10} (bars) and average number of exceedances (points) for Otago's SOE sites 2017-2019**

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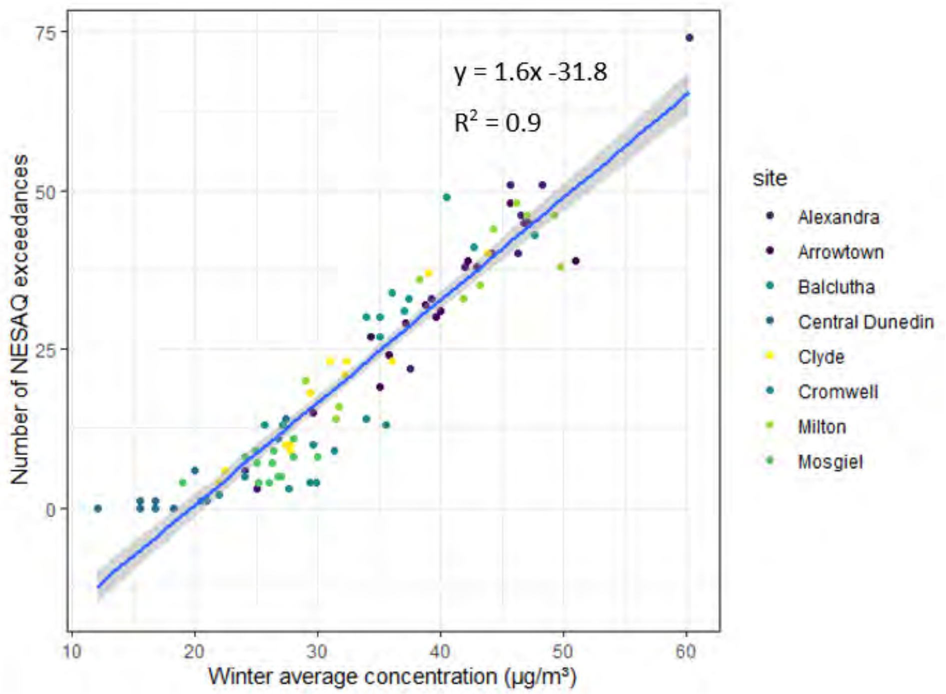

Figure 7 **Relationship between number of exceedances and winter average PM_{10} concentration for every year of monitoring (2005-2019)**

4.3. State: Key indicator sites

Arrowtown, Central Dunedin and Mosgiel are the three indicator monitoring sites for Otago, with each town representing one of the three airshed groups. Each site has different emission source characteristics and a unique relationship between climate and topography. The timeseries graph of these sites show that Central Dunedin has the most consistent concentrations throughout the year, which reflects the mixed emission sources (home heating, industrial and vehicle), and a climate conducive to dispersion of PM. Arrowtown data shows extreme seasonality of high winter concentrations and very low summer concentrations, with Mosgiel a mixture of these two extremes: moderate 24-hour averages all year with some seasonal variation in winter (Figure 8).

Between 2017 and 2019 Arrowtown had the largest range of 24-hour average concentrations and the highest frequency of days that exceed the NESAQ limit. Mosgiel PM_{10} also exceeded several times, and Dunedin only the once (Figure 9). Many of the highest values for Arrowtown and Mosgiel occurred in 2017, which was estimated to have more cold and calm conditions than 2018, producing higher PM_{10} concentrations. The difference between 2017 and 2018 highlights that inter-annual variation in pollutant concentrations can be quite high.

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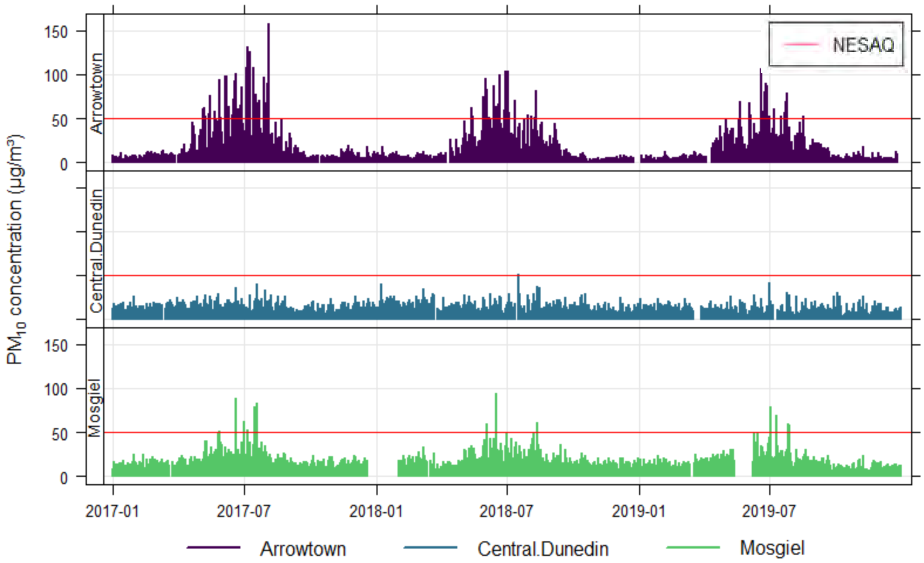

Figure 8 **Timeseries of PM_{10} at key indicator sites for 2017-2019 (24-hour average)**

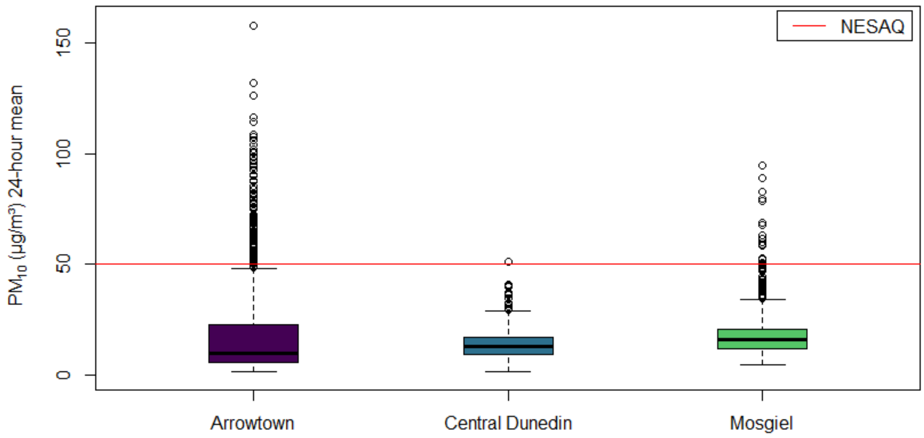

Figure 9 **Distribution of PM_{10} at key indicator sites 2017-2019, see Appendix A3 for plot interpretation**

4.4. State: Survey sites

Alexandra, Clyde, Cromwell and Milton are the survey sites in Otago, meaning that they are only monitored during winter (excepting Alexandra which is year-round) to record exceedances and track trends in these locations. The 2017-2019 boxplot for the survey sites show that all sites regularly exceed the NESAQ limit. Similarly to Figure 8 many of the highest pollution nights occur in 2017. In Milton the highest 25th percentile of days are above the NESAQ limit. Milton and Cromwell have the largest range of 24-hour averages (Figure 10).

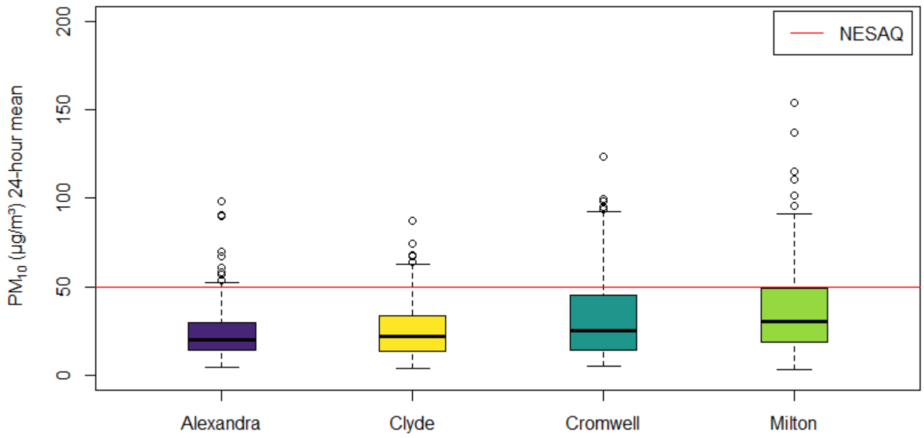

Figure 10 **Distribution of PM_{10} at survey sites during 2017-2019 (winter-only)**

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5. Temporal and spatial trends in ambient air quality

Air quality varies greatly both spatially between and within airsheds, and temporally over short and long-term periods. Spatial variability can be attributed not only to different sources of pollutants, but to large scale weather differences between airsheds, and micro-climates within airsheds. Temporal changes can result from multiple factors including regulatory requirements, changes to fuel choices, addition or removal of point sources of emissions, and natural variability of weather patterns.

5.1. Short-term temporal trends

5.1.1. Short-term trends: key indicator sites

Patterns in particulate concentrations can be seen at various timescales, i.e., hourly, daily, weekly and seasonal. The following graphs show the three key indicator sites data compared at these scales for the years of 2017 - 2019. All three sites have different patterns over the different time scales. The daily pattern for Dunedin shows a rise of PM during the morning which remains constant then decreases through the evening. Arrowtown, and to a lesser extent Mosgiel, show distinct bi-modal peaks during the day. These are common in towns with domestic heating emissions as the main emission source (ORC, 2016). Concentrations in both towns increase at around 4pm, as temperature decreases and fires start being lit within residential homes, and remain high until midnight. In the morning at 8-9am they rise again to a smaller peak (Figure 11B).

Similarly, Arrowtown has very high monthly means (up to 50 µg/m³) in the winter months, and very low means (<5 µg/m³) in the summer months. Mosgiel monthly averages are similar to Dunedin's during non-winter months, but display a peak of up to 30 µg/m³ in winter. Dunedin has very consistent PM_{10} concentrations throughout the year, with each monthly mean falling between 12 and 15 µg/m³ (Figure 11C). Dunedin is the only site that displays a weekly pattern, with significantly lower daily concentrations on Saturday and Sunday, which indicates traffic and industry as a major source (Figure 11D).

Figure 12 shows the hourly patterns during winter months only, which displays the full extent of Arrowtown and Mosgiel's morning and evening peaks during the colder months. Arrowtown concentrations are roughly double that of Mosgiel's, with an hourly mean of up to 80 µg/m³ during the evening peak.

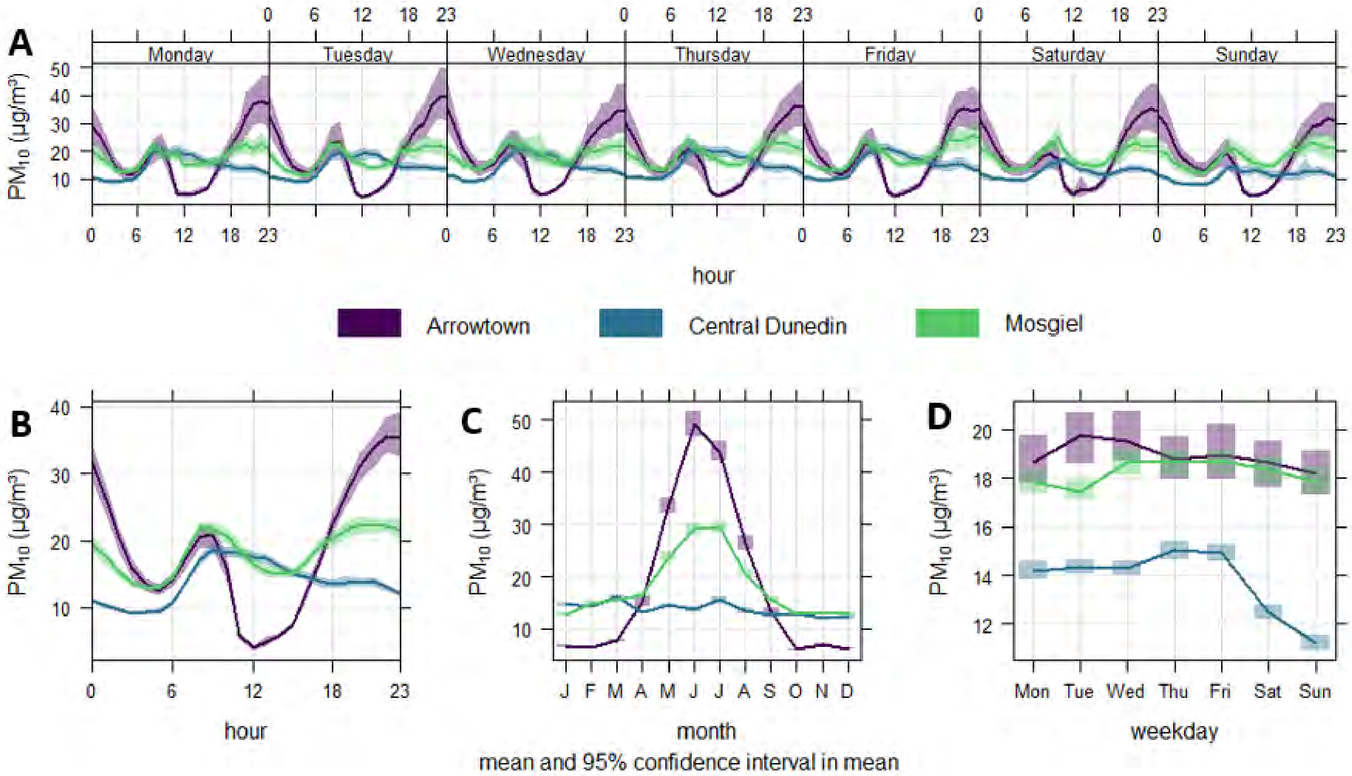

Figure 11 **Key indicator sites: daily, monthly and weekday patterns, see Appendix A3 for plot interpretation**

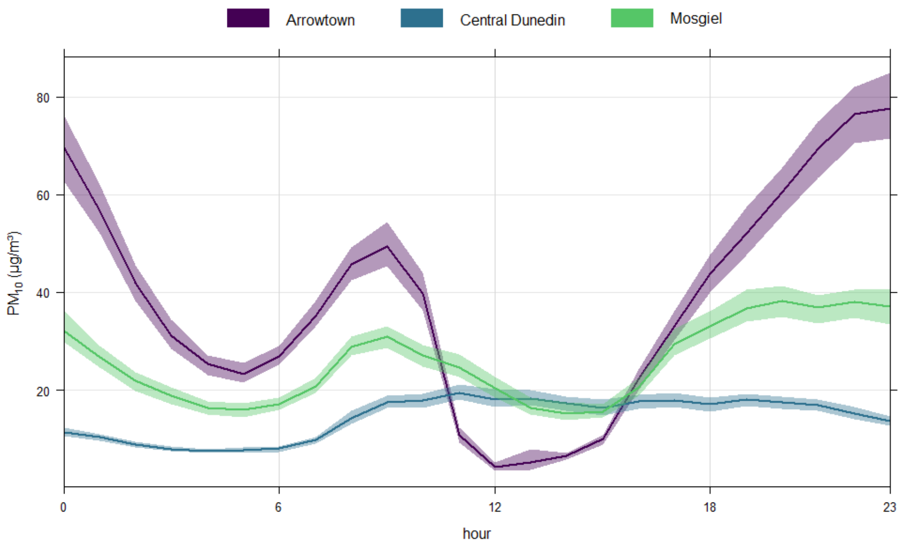

Figure 12 **Key indicator sites: diurnal PM_{10} concentrations for winter (May-August) months**

5.1.2. Short term trends: survey sites

The four winter-only survey sites – Alexandra, Clyde, Cromwell and Milton – show temporal patterns similar to Arrowtown's with bi-modal daily peaks. Alexandra's evening peak doesn't continue increasing, and flattens out between 6pm and midnight (Figure 13B), indicating an increased dispersion of pollutants, which is discussed further in Section 5.3. Milton and Cromwell have higher daily and monthly averages compared to Alexandra and Clyde, but all sites reach their annual peak in the month of July (Figure 13B and C).

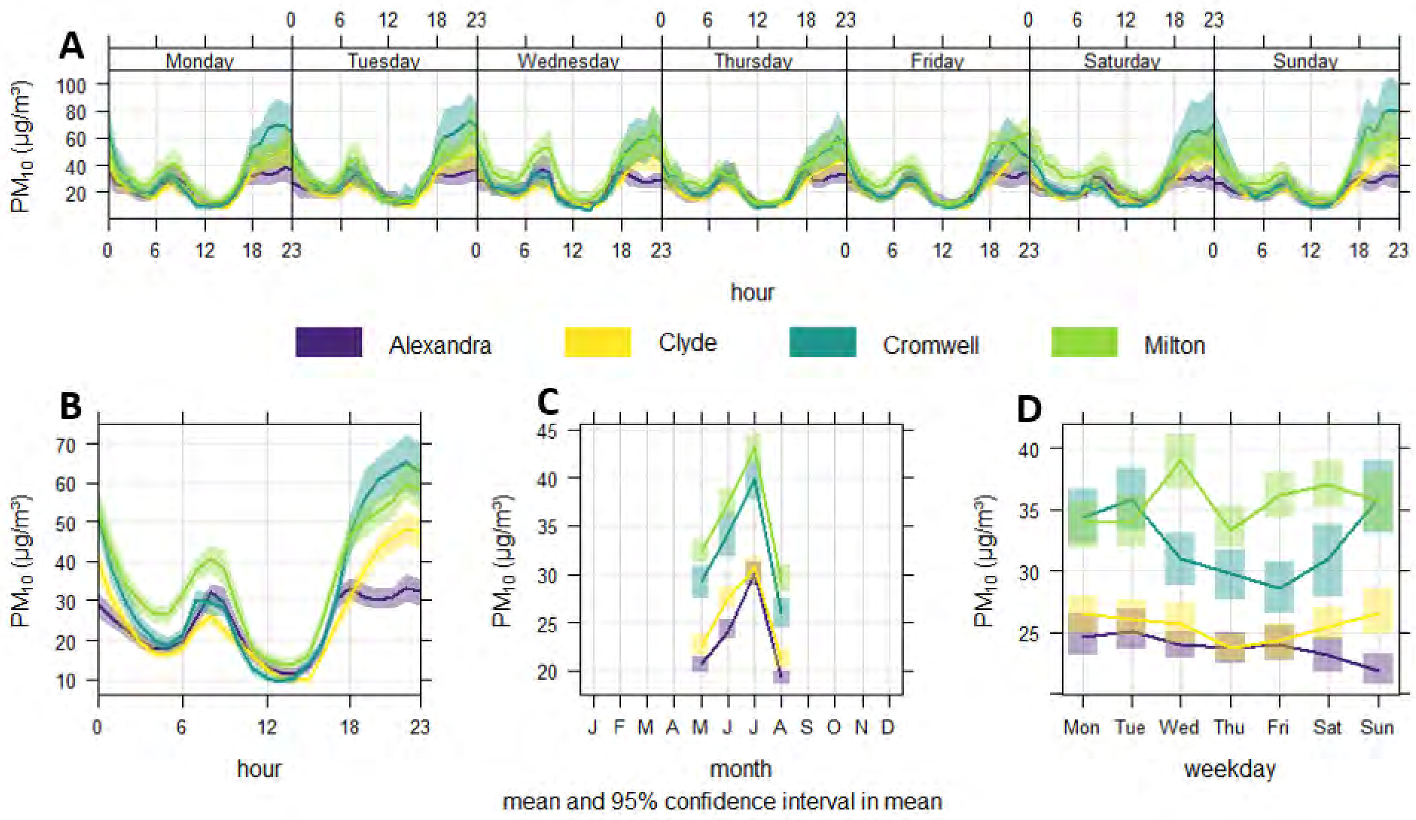

Figure 13 **Survey sites: daily, monthly and week day patterns for winter (May-August) months**

5.2. Long-term temporal trends

Statistical testing of long-term air quality data can be used to infer the effectiveness of clean air policies on emissions, provided that the impact of meteorology and other variables such as urban growth, are accounted for. For example, changes in air quality concentrations between towns can be compared to assess relative effectiveness of the programmes aimed at improving air quality. Long-term analysis was undertaken to determine whether PM_{10} concentrations are increasing, decreasing or unchanged over a specified time-period. The analysis tests whether the slope of the trend is different from zero (i.e., no trend) at the 95% confidence limit (p-value, 0.05). The trend results are presented as a percentage change per year so that the scale and direction of change can be compared between sites.

For this report trend analyses were performed at all sites for the last five and ten years. However, some sites have been re-located to an area with different typical concentrations within this timeframe, such as Alexandra and Arrowtown. Analysis can only be performed using data from a single location over consecutive years, so these two sites have slightly different time frames for their trends.

Trends were evaluated using two types of techniques – the Theil-Sen and the smooth-trend. The Theil-Sen is a non-parametric regression analysis customised for air quality data (Carslaw and Ropkins, 2012). Theil-Sen analyses work best when applied to monotonic trends i.e., data that is either increasing or decreasing steadily.

The smooth-trend analysis fits a smooth line to the dataset using the median and 95th percentile concentrations. The line is fit to show important features and variation within the data without including excessive noise from the dataset (Carslaw, 2019). Both analyses were applied to de-seasonalised data to remove the seasonal trends of high winter concentrations and low summer concentrations.

5.2.1. Trend results for key indicator sites

Theil-Sen analyses were done for year-round and winter-only (May-August inclusive) monthly mean data for Arrowtown, Central Dunedin and Mosgiel. Arrowtown and Mosgiel data were deseasonalised. A five-year and a ten-year analysis was conducted. Table 7 shows the results of these analyses.

Site		Ten-year trend 2010-2019		Five-year trend 2015-2019	
		Average % change per year [95% confidence interval]	Significance	Average % change per year [95% confidence interval]	Significance
Arrowtown[1]	Year-round			-3.6 [-6.5, -1.6]	p <0.001
	Winter			-3.5 [-5.1, -1.4]	0.001< p <0.01
Central Dunedin	Year-round	-5.3 [-5.8, -4.6]	p <0.001	-6.4 [-7.9, -4.9]	p <0.001
Mosgiel	Year-round	-3 [-3.8, -2.1]	p <0.001	-1.9 [-3.7, -0.6]	not significant
	Winter	-1.8 [-1.8, -1.8]	p <0.001	1.6 [1.5, 5.6]	p <0.001

[1]Arrowtown site was relocated in 2014, Theil-Sen analysis was applied to data for years 2014-2019 (winter only) and 2015-2019 (year-round, this accounts for 2015 being the first full year of data after relocation).

Table 7 **Theil-Sen analysis results of PM_{10} monthly means at the key indicator sites**

There has been a statistically significant 3.6% decrease of PM_{10} concentrations per year in Arrowtown, which equates to an 18% decrease in total since 2015. These values are similar to the previous analysis on Arrowtown 2006-2013 data, where a 4% decrease per year was reported for winter months. This confirms that Arrowtown PM_{10} concentrations have been decreasing consistently since the monitoring started; this trend is shown in both site locations and agrees with the latest emissions inventory for Arrowtown that indicated between 2006 and 2016 there was a 48% reduction in PM_{10} emissions (Wilton, 2017). The smooth trend analysis shows that the 95th percentile has been decreasing over the years, while the mean has stayed roughly the same (Figure 14A). This means that the highest pollution days have been decreasing in magnitude over time.

Central Dunedin shows significant PM_{10} decreases for both the ten- and five-year Theil-Sen trend analyses, between 5 and 7% per year. The improvement seen in Dunedin was partially due to the resource consent renewals during the early 2010's, where stricter conditions were introduced, but also the adoption of NESAQ-compliant home-heating. This decrease can be seen in the 95th percentiles for the smooth-trend for years 2010-2013 (Figure 14B). The years 2010 and 2011 were also notable for having high amounts of crustal matter (dust), due to construction and associated increase in vehicle activity (Davy *et al.*, 2011) at both the site of the Forsyth Barr Stadium and the university campus, which contributed towards the 24-hour exceedances and higher monthly averages (Figure 15). Figure 15 also shows that excluding these two years, it is clear that monthly averages have been declining since 2012. The five-year trend improvement may be due to a range of factors, such as further combustion technology improvements for industry and/or vehicles, or land use changes in the area, but further analysis of emission sources in Dunedin is required to confirm this.

Mosgiel shows a change in trends between the ten- and five-year trend analyses. Over the ten years PM_{10} concentrations were decreasing by 3% per year, and 1.8% per winter. Some of this has been attributed to the same industrial consent restrictions that improved concentrations in Central Dunedin, and/or the expiry of some consents (ORC, 2016). The winter percentage decrease is lower than the overall improvement, which indicates that there either haven't been significant improvements made to home heating emissions, or the urban growth within the airshed has cancelled out some of the improvement that otherwise may have occurred. Over the short-term, winter concentrations have increased by 1.6% per year, and there is no significant trend for the year-round data. Because this is a short-term trend, this will be subject to change when more data is available. The monthly 95th percentile and median have decreased between 2010 and 2013 (Figure 14C), which is similar to the pattern seen at Central Dunedin for the same time period.

A: Arrowtown

B: Central Dunedin

C: Mosgiel

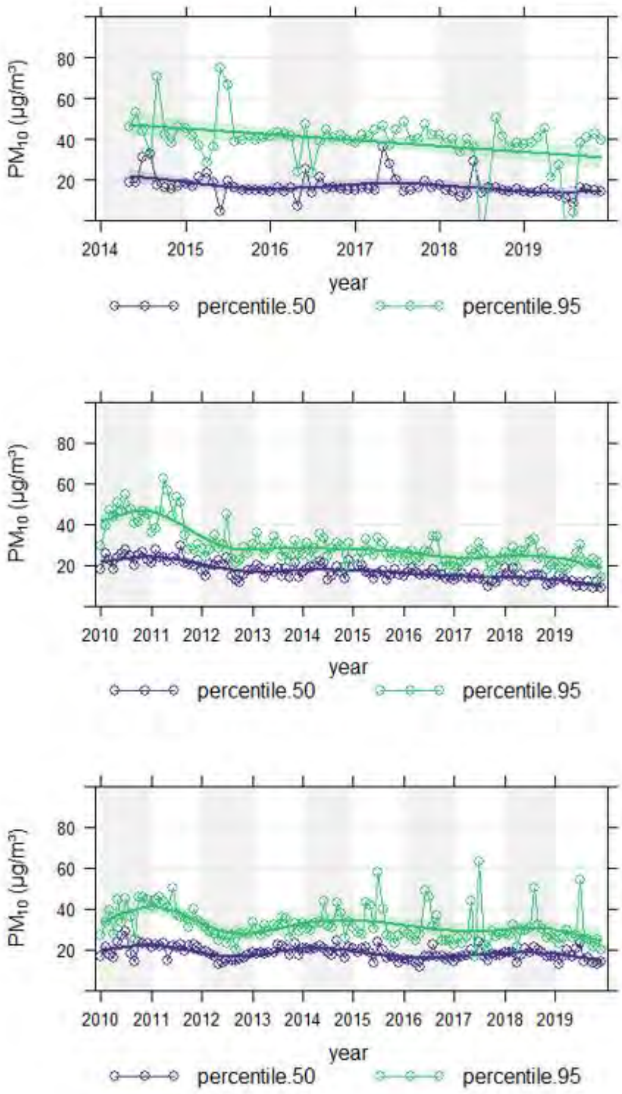

Figure 14 **Smooth-trend analysis for the key indicator sites – 95th percentile and median (based on 95th percentile and median 24-hour average in each month) indicate decreasing concentrations over time. The 95th percentile displays the top 5% 24-hour averages. The Arrowtown 95th percentile has negative values in 2018 and 2019 due to having lower concentrations than normal on high pollution nights.**

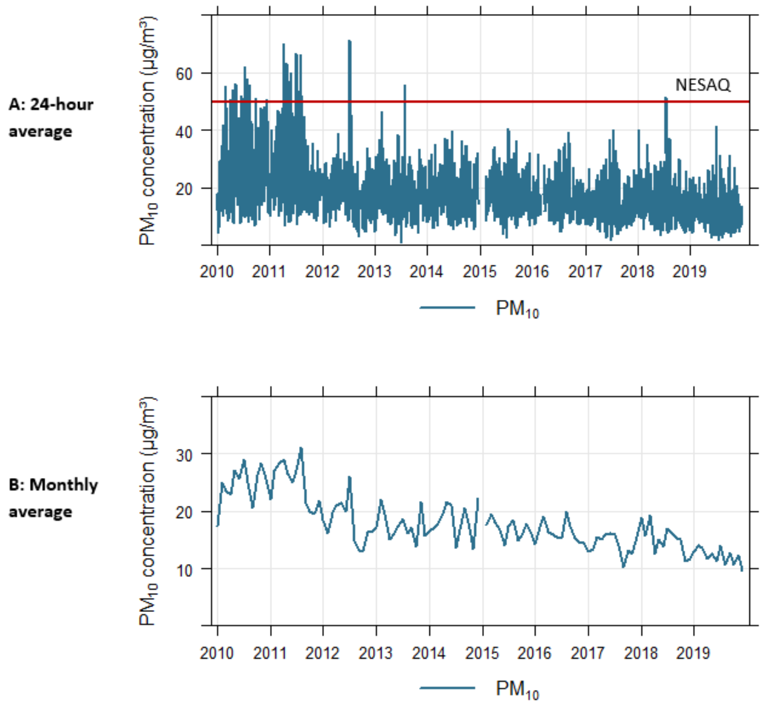

Figure 15 **24-hour and monthly average PM_{10} for Central Dunedin (2010-2019)**

5.2.2. Trend results for survey sites

Table 8 displays the Theil-Sen results for the survey sites during winter months; the data for all sites were deseasonalised.

Site		ten-year trend 2010-2019		five-year trend 2015-2019	
		Average % change per year [95% confidence interval]	Significance	Average % change per year [95% confidence interval]	Significance
Alexandra[1]	Year-round	-0.9 [-.2.0, 0.4]	not significant		
	Winter	-2.3 [-2.8, -1.2]	*p* <0.001		
Balclutha[2]	Winter	1.3 [0.2, 2.5]	0.01< p <0.05		
Clyde		-3.5 [-4.1, -2.6]	*p* <0.001	-6.0 [-9.8, -3.5]	*p* <0.001
Cromwell		-1.3 [-2.1, -0.4]	0.01< p <0.05	-6.3 [-6.1, -2.7]	*p* <0.001
Milton		-2.7 [3.3, -2.0]	*p* <0.001	-7.4 [-10.5, -3.7]	*p* <0.001

[1] Alexandra site was relocated in May 2017, Theil-Sen analysis was applied to data for years 2010-2016
[2] Balclutha site was decommissioned in September 2018, Theil-Sen analysis was applied to data for years 2010-2016

Table 8 **Theil-Sen analysis results of PM_{10} at the survey sites**

Otago Regional Council

Alexandra shows a statistically significant decrease in concentrations for winter values only, of 2.3% per year, which means that winter concentrations improved by 16% in total over the seven years. There is no significant trend for the year-round data, but seasonal analysis show that summer concentrations are increasing slightly, which may counteract the other seasons. The smooth-trend analysis indicates that the de-seasonalised monthly 95th percentiles and medians do not trend upwards or downwards but remain consistent (Figure 16A).

Balclutha demonstrates an increase in concentrations between 2010 and 2018, with the years 2012 and 2017 showing higher monthly 95th percentiles in the smooth trend analysis (Figure 16B).

Clyde, Cromwell and Milton have all experienced significant decreases in PM_{10} concentrations over the five- and ten-year time periods. Clyde showed a 35% improvement over the ten years, which can be seen in the smooth-trend plot (Figure 16C). In the Clyde and Cromwell sites the impact of 2017, a cold winter, can be seen as a peak of the median and 95th percentile in the smooth-trend analyses.

Cromwell shows the least improvement, with only 13% over the last ten years, which is estimated to be attributed to urban growth and contribution of new burners adding to the airshed, offsetting the improvements made via the implementation incentives.

Milton has improved by 27% in total over the last ten years. Clyde, Cromwell and Milton each demonstrate a larger rate of improvement in the five-year trend (between 6 and 7% improvement per year), than the ten-year trend, but further data for future years is required to confirm this.

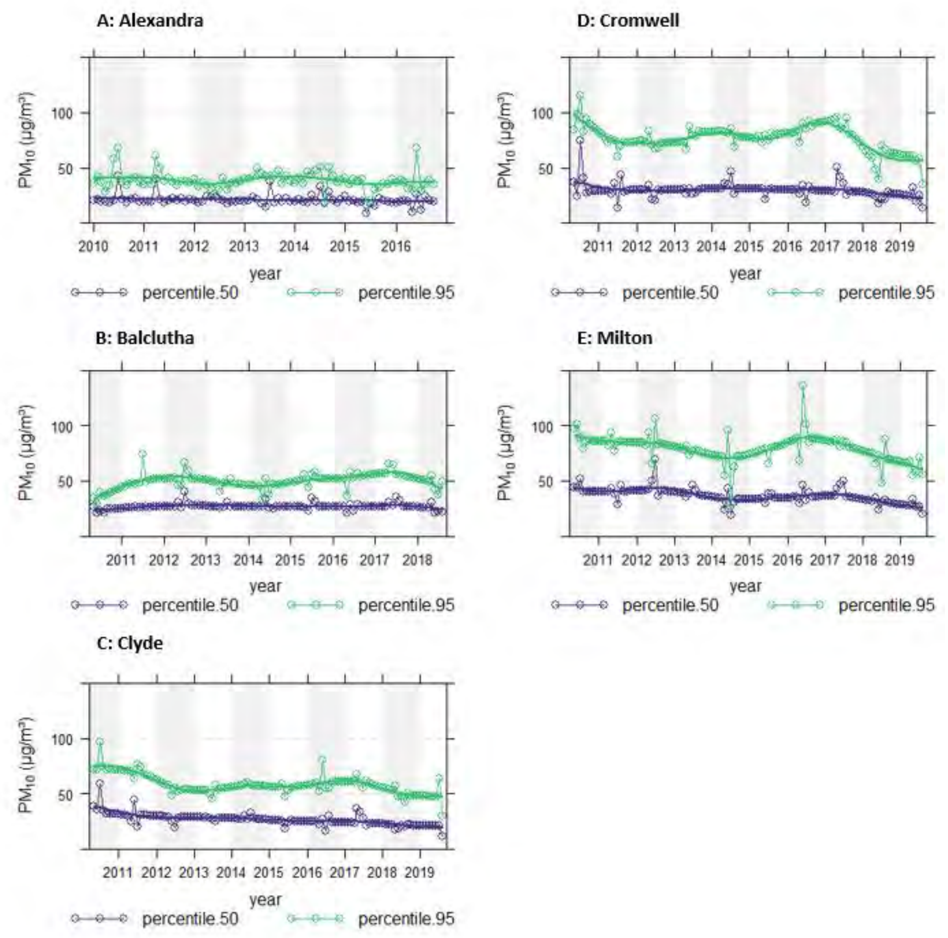

Figure 16 **Smooth-trend analysis for the survey sites – 95th percentile and median (based on 95th percentile and median 24-hour average in each month). Alexandra smooth trend is based on year-round data.**

5.3. Spatial distribution of PM_{10}

Stationary instruments in the air quality network provide long-term PM_{10} readings at a single point in each town. Depending on the size of the town and the complexity of its terrain, results from a single monitor may not be representative of the entire area. The NESAQ requires monitoring to be undertaken where the air quality standards are likely to be breached by the greatest margin or the highest frequency.

Mobile monitoring across a town using a portable air monitor offers a spatial snapshot of ambient air quality. As of 2019 ORC has conducted 14 spatial studies to either provide context for the existing monitoring or investigate relative PM levels in towns without monitors. New technology has also been developed in the form of low-cost sensors, multiple units of which can be deployed in a network to allow the detection of spatial and temporal differences in PM concentrations across an airshed.

It has been found that PM can vary from one street to the next, depending on emissions and wind conditions. Nocturnal wind drainage can have the effect of pushing the concentrations towards one part of town, such as the southern area in Milton; or of dispersing pollutants and reducing the relative concentrations such as in the central area of Balclutha.

Housing age and housing density can also contribute to the variation, with the central area of older housing in Cromwell experiencing the highest concentrations of that airshed, while the denser housing areas of towns such as Wanaka also show that high PM_{10} can occur in pockets across an airshed in complicated concentration gradients.

Topography can also have a significant influence on particulate dispersion, along with nocturnal drainage winds, allowing PM_{10} to accumulate in topographical basins, in a zone of convergence like central Alexandra, or up against barriers such as hills in north-east Arrowtown.

These spatial differences were demonstrated by the relocation of two monitoring sites – Alexandra and Arrowtown. Both were relocated due to loss of site availability, and demonstrate the complexity of air quality in small urban areas. In the case of Alexandra, the current site was moved 700 m to the southeast of the original site, and has been recording lower PM_{10} concentrations than the previous site. The morning and evening peaks are much smaller, which indicates that there are fewer pollutant sources, and/or more favourable dispersion conditions (Figure 17). The previous site had more frequent calm periods (25%, where calm is equal to a wind speed of 0 m/s) than the current site (0%), which indicates an increased likelihood of pollutants accumulating rather than dispersing. Wind direction also varies between the sites, with the previous site's dominant wind direction from the north to northeast directions, the direction of residential areas and the newer site having one dominant wind direction of the northeast, which is adjacent to the commercial area of town (Figure 18).

The meteorology of the Alexandra basin is very complex and has a significant part to play in the spatial and temporal characteristics seen in the data. Spatially, the previous site was found to be an area of katabatic convergence of air flows from the northeast and southeast directions (Tate, 2011) which are likely to create an area of stagnant air for pollutants to accumulate (Price, 2014). Temporally, PM_{10} data in Alexandra has been identified as having a unique dip in evening concentrations, essentially creating a third diurnal peak. This can be seen in both sets of data in Figure 17. This dip is likely to be caused by turbulence in the boundary layer, causing a period of vertical pollution dispersion (Price, 2014).

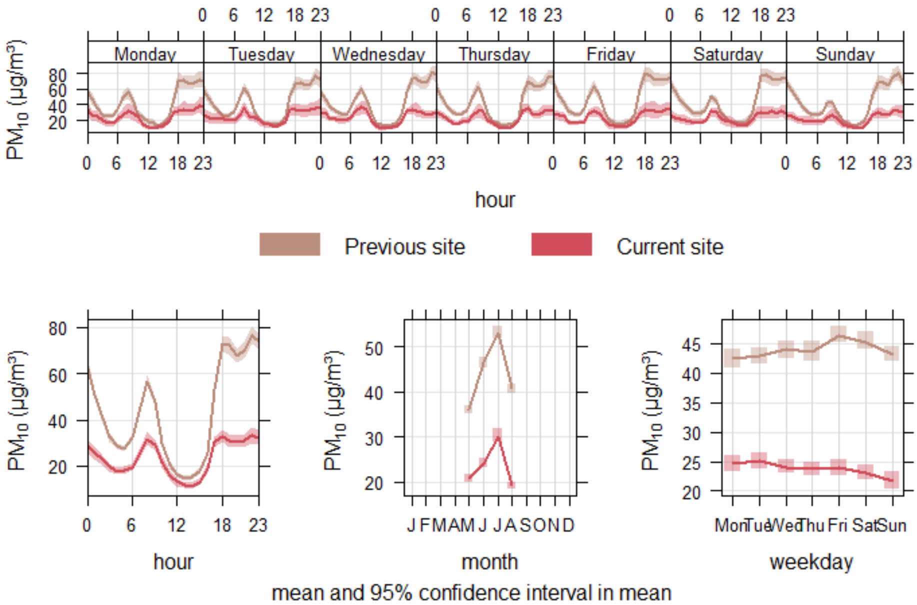

Figure 17 **Winter temporal variation between different monitoring locations in Alexandra where recorded PM_{10} concentrations are much lower at the current site**

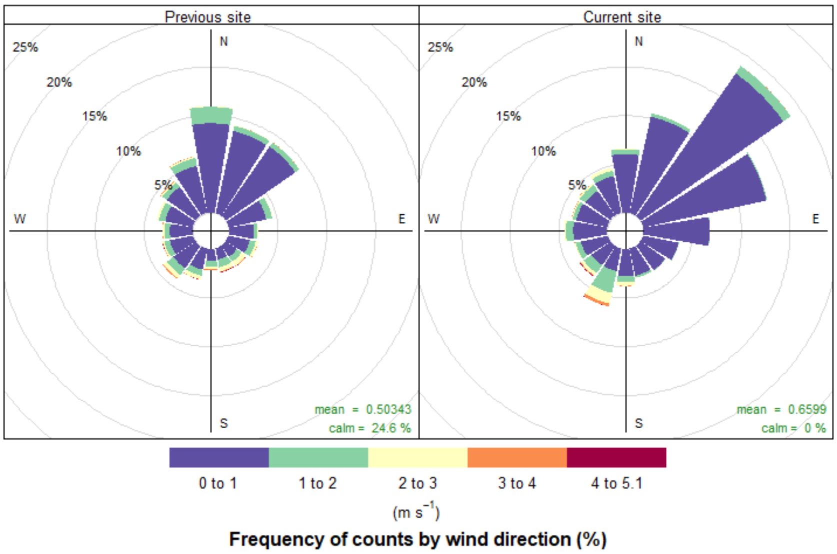

Figure 18 **Alexandra: winter wind roses (1-hour average) for the previous and current site location, showing a change in wind speeds and predominant direction.**

The site relocation in Arrowtown, 400m to the east of the previous site, has resulted in slightly higher concentrations being recorded than those at the previous site, with diurnal patterns indicating a later evening peak, and much slower dispersion time in the early hours of the morning (Figure 19). This is likely due to Arrowtown having a clear pollution gradient, from low PM in the northwest, to higher PM to the southeast, where the new site is located (Longley, 2020). It is probable that low north-westerly breezes cause concentrations to accumulate at the eastern side of the town where the mountains act as a barrier to dispersion. In addition, the wind direction is different between the sites, with the previous site having a predominantly westerly wind direction and the current site having a predominantly northerly wind (Figure 20). This may indicate that the breeze turns northerly as it moves south along the river valley, bringing the accumulated particulate matter with it.

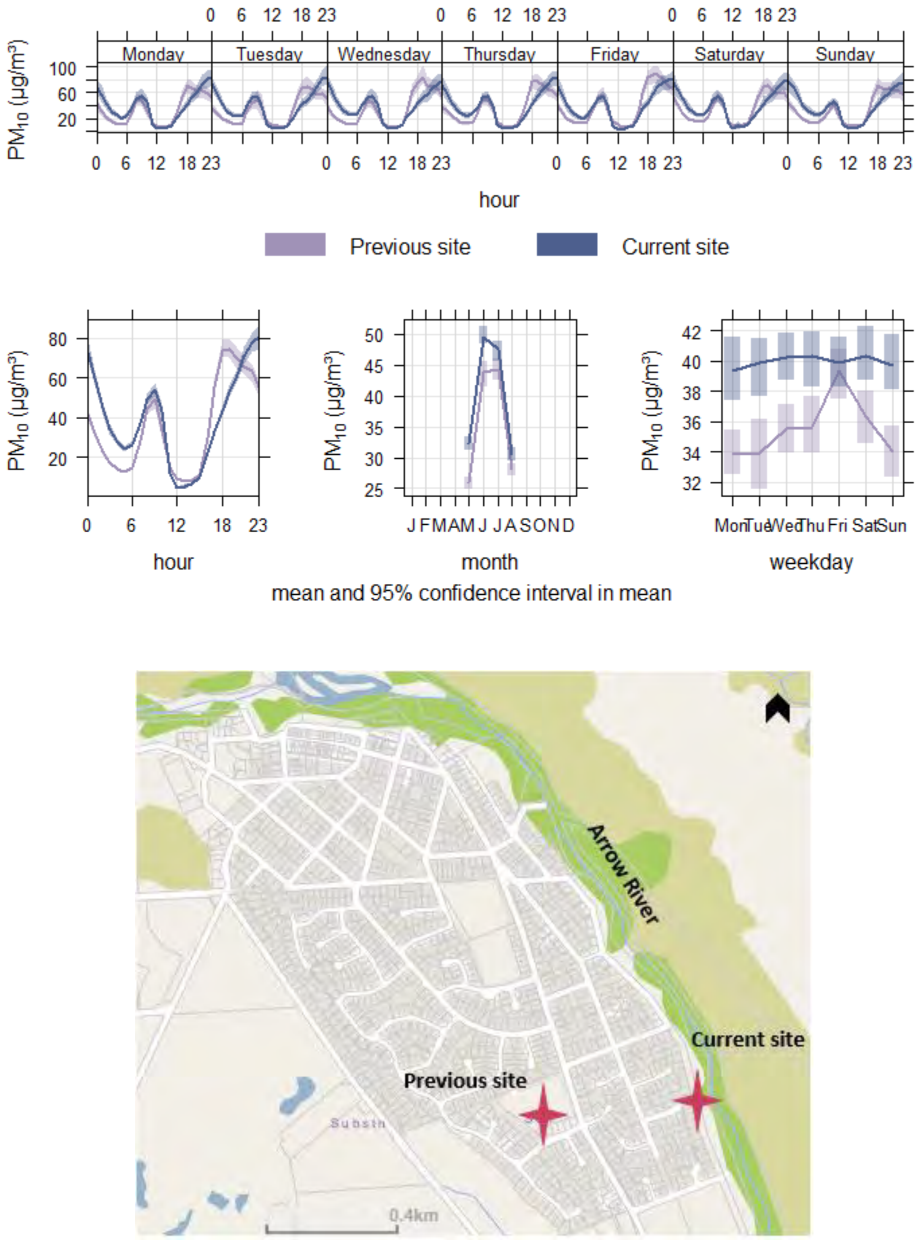

Figure 19 **Temporal variation between different monitoring locations in Arrowtown where recorded PM_{10} concentrations are slightly higher at the current site**

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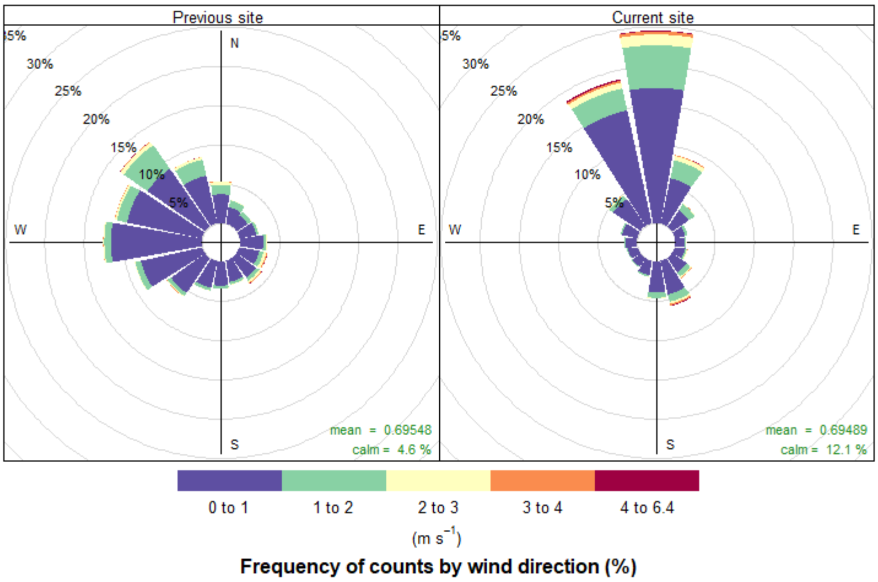


Figure 20 **Arrowtown: winter wind roses (1-hour average) for the previous and current site location, showing a change in predominant wind direction.**

6. Pressures and influences on air quality

As discussed in Section 5, ambient air quality at any location is the result of a complex relationship between the type and amount of emissions, and the meteorology and topography. This section discusses the major emission sources found in Otago and the meteorological conditions that affect them.

6.1. Emissions

Woodsmoke is the main source of PM_{10} emissions in Otago. However, it is made up of several other components, many of which are toxic and/or carcinogenic, which can vary depending on what is burnt and how it is burnt. For example, lead can be emitted from burning old painted wood, and arsenic is an emission from burning treated wood. Incomplete combustion, caused by reduced air flow to the fire, produces pollutants such as benzo(a)pyrene, a polycyclic aromatic hydrocarbon (PAH) which is a human carcinogen and black carbon which is a climate change pollutant. Gases such as oxides of nitrogen and carbon monoxide are also produced by the burning of wood and other biomass (Naeher *et. al*., 2007).

6.1.1. Household emissions

To obtain information on home heating emissions, both census data and emissions inventories are used. Census data provides the fuel types used in home heating and emissions inventories are a tool for compiling total estimated emissions for a town using fuel types, burner age estimations and fuel usage.

6.1.2. Wood burners

Data from the most recent census (Statistics New Zealand, 2018) can provide trend information when compared to census results from 2006 and 2013. The number of wood burners being used for domestic heating, and the percentage of total households that this number represents, are shown for key towns in Table 9. The percentage of wood burners being used has dropped in each of these towns, but due to an increasing number of homes over time, the actual numbers of wood burners has gone up in most towns (e.g. Alexandra, Arrowtown, Clyde, Cromwell and Mosgiel).

Currently, in Otago, the use of wood burners is reported in 51% of all households, well above the national average of 31%. Much higher than average percentages of wood use are reported in Clyde and Milton (62% and 67% respectively).

Site	2006		2013		2018	
	# wood burners	% wood burners	# wood burners	% wood burners	# wood burners	% wood burners
Alexandra	1,101	55%	1,083	51%	1,206	51%
Arrowtown	549	62%	555	57%	579	57%
Balclutha	960	58%	963	58%	849	50%
Clyde	252	64%	273	62%	333	62%
Cromwell	864	59%	981	56%	1,200	56%
Dunedin	22,602	50%	21,918	47%	20,082	41%
Milton	558	68%	585	69%	576	67%
Mosgiel	2,037	48%	1,989	44%	2,055	41%

Table 9 Census data on reported wood burner use for Otago towns

The most recent emissions inventories were undertaken in the towns of Alexandra, Arrowtown, Milton and Mosgiel (Wilton 2016); and Clyde, Cromwell and Wanaka (Wilton 2019). The following graphs show the different proportions of types of wood burner used in each airshed, and the subsequent emissions these burners account for. Each airshed is dominated by wood burner use, however there are higher frequencies of multi-fuel burners in Milton and Mosgiel compared to other airsheds. Wanaka has the highest number of open fires (Figure 21).

The different types of burners impact the quantity of PM_{10} emissions. Mosgiel has the highest daily emissions in winter, with 362 kg/day, and the highest emission density, 630 g/ha. Most of these are from wood-burners, but the difference between Figure 21 and 21 illustrate the disproportionate amount of emissions from multi-fuel burners, relative to the burner numbers.

The emission densities are also affected by the size (area) of the airshed. Arrowtown and Milton's winter emissions are both around 100 kg/day, which is among the lowest, however they both have relatively small airsheds, with 236 and 202 hectares respectively. This results in these two towns having among the highest emission densities of 397 and 488 g/ha. Conversely Wanaka has high emissions of 300 kg/day in winter, and the lowest emission density of the airsheds, at 105 g/ha, due to having a large airshed area (Figure 22). Comparing emissions densities between years in future studies will help identify emissions trends through time, and further assess strategies to reduce them.

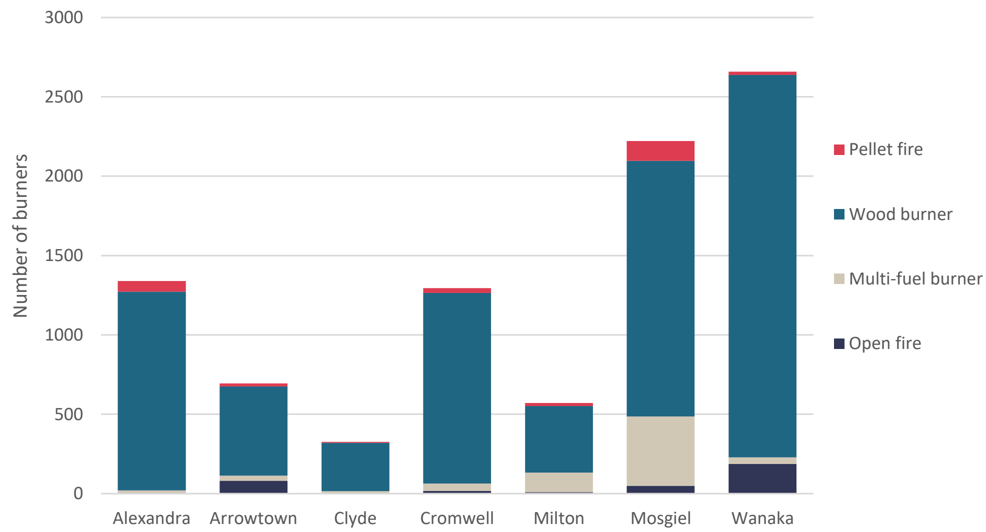


Figure 21 **Number of households with solid-fuel burners (2016 and 2019 emission inventories)**

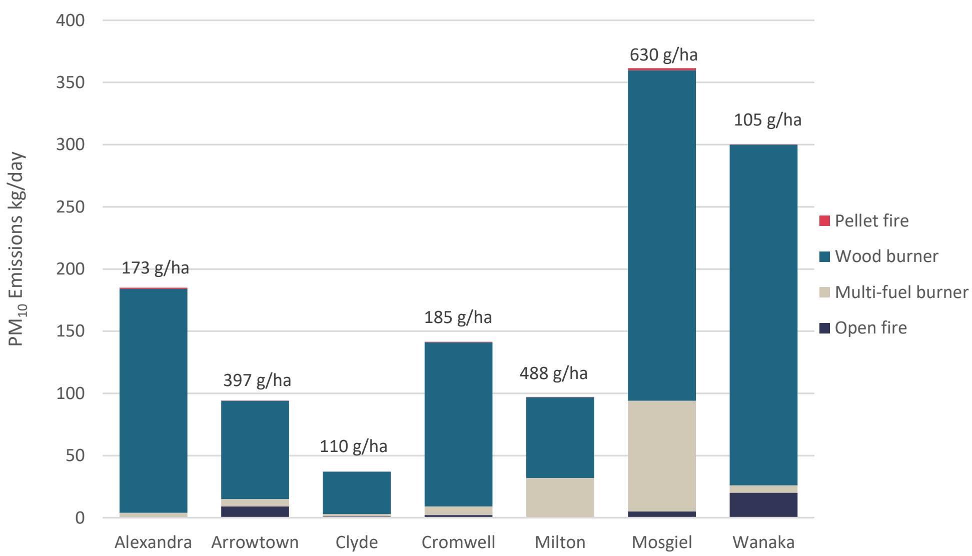


Figure 22 **Winter PM_{10} emissions (kg/day) by appliance type for Otago towns, with emissions density (g/ha/day) above each bar (2016 and 2019 emission inventories)**

Otago Regional Council

Wood burner age also has an impact on emissions, with burners more than 15 years old contributing significantly to each airsheds' total emissions (Figure 23). Alexandra, Arrowtown, Cromwell and Clyde have all had past campaigns encouraging upgrading of older burners during the late 2000's onwards, so there is a higher proportion of newer burners of less than 10 years old in these towns. Milton has also been part of these campaigns but has been slightly less successful in switching to newer burners. Mosgiel and Wanaka have the highest number of older burners, which is in accordance with not having had any active management for replacing them with low-emission appliances.

As a requirement of the NESAQ, all wood burners installed after 1 September 2005 on sections smaller than two hectares are required to have an emission rate of less than 1.5 grams of PM_{10} for every kilogram (g/kg) of dry wood burnt and to be no less than 65% efficient.

The Air Plan sets stricter standards in Air Zone 1 towns, requiring all domestic-heating appliances to be fully compliant with either 0.7 g/kg or 1.5 g/kg emission standards (depending on the date of installation) as of 1 January 2012. It was originally estimated that replacement of all older, non-compliant solid-fuel burners with new, lower-emitting efficient wood burners would lead to the required reduction in PM_{10} emissions to achieve compliance with the NESAQ (ORC, 2016).

In Air Zone 2, it was expected that the natural rate of replacement for older heating appliances at end of life would result in the PM_{10} reductions required to achieve NESAQ compliance.

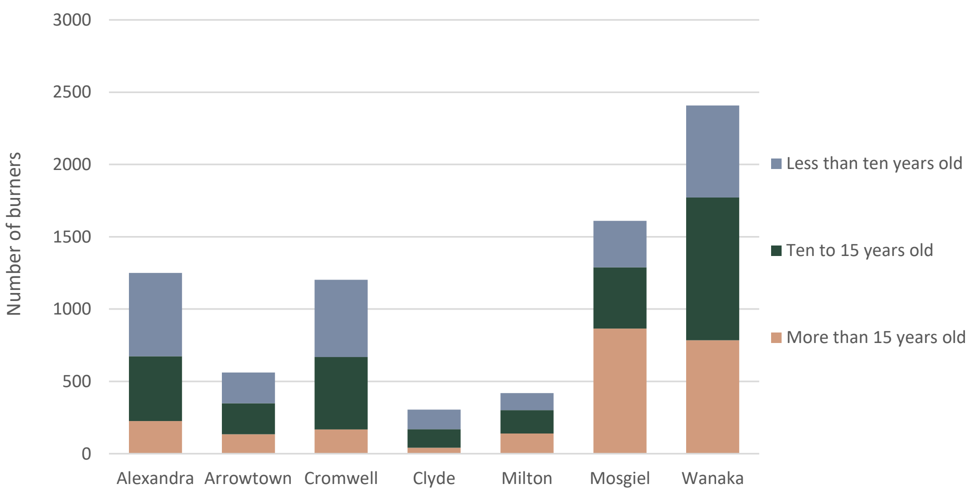


Figure 23 **Age of wood burners in Otago towns (2016 and 2019 emission inventories)**

6.1.3. Coal burners

In the 2018 Census, 4.8% of all Otago households (4134 dwellings) reported using coal for domestic heating, down from 14% in 2013. This is above the national average of 1.2%, with most of the usage reported in southern areas of Otago. The number of coal burners has reduced over time, to less than 4% in most districts. Of the five Otago territorial areas, the Clutha district has the highest percentage of households (20%, 1401 dwellings) using coal for home heating (Figure 24).

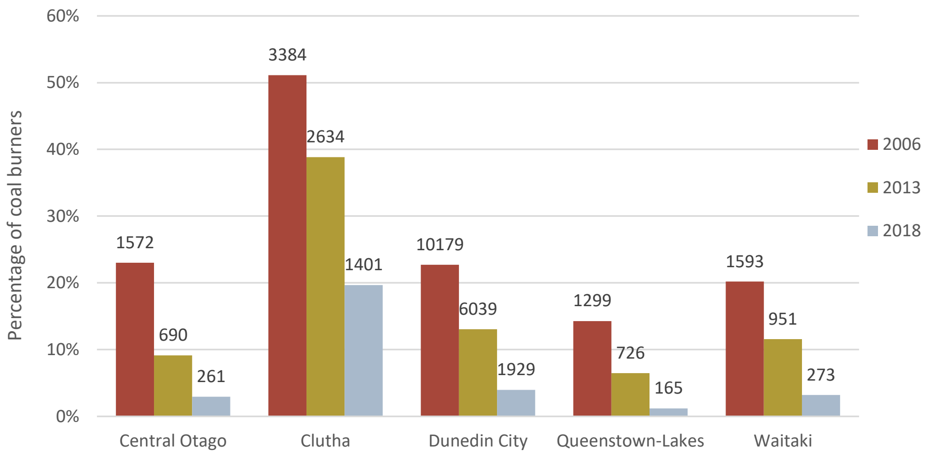


Figure 24 **Percentage of households that use a coal burner for domestic heating from 2006 to 2018. The number of coal burners present in each district are displayed above each bar**

6.1.4. Other sources of heat

In addition to solid-fuel burners, other sources of heating reported in the 2018 census include heat pumps, electric heaters, mains and bottled gas, and pellet burners. Heat pumps are the most widely used form of heating, with anywhere between 37% and 64% of households (depending on district) reporting its use. Dunedin City district records the highest percentage of heat pump and electricity use, with 64% and 47% respectively (Table 10).

Pellet burners and bottled gas are not commonly used, and mains gas is used more frequently in Queenstown Lakes (16%) followed by Central Otago (9%). Other sources of heating may include diesel burners, and solar power, and varies among the districts, between 10% and 20% of households.

District	Heat pump	Electric heater	Mains gas	Bottled gas	Other
Central Otago	50%	31%	9%	3%	17%
Clutha	37%	26%	3%	4%	14%
Dunedin City	64%	47%	5%	3%	10%
Queenstown-Lakes	52%	40%	16%	2%	20%
Waitaki	49%	34%	4%	3%	10%

Table 10 **Percentage of households using other sources of heating in 2018**

6.1.5. Emissions from outdoor burning

Nationally, outdoor burning is estimated to account for 22% of PM_{10} emissions (Metcalfe *et al.* 2015). However, its impact on regional air quality has not been quantified. The Air Plan provides for most outdoor burning as a permitted activity, with rules related to the nature of the material burned and the distances to the property boundaries. The strictest rules are for residential properties in Air Zones 1 and 2 (Table 7).

Rule	Air Zones 1 & 2		Air Zone 3	
	Residential	Non-residential	Residential	Non-residential
Only paper, cardboard, vegetative matter, untreated wood is to be burned	✓	✓	✓	n/a
Material must be dry	✓	✓	✓	n/a
Material must come from property where it's being burned	✓	✓	✓	n/a
Distance to boundary from fire	50m	100m	n/a	n/a
Smoke or odour or PM must not be offensive or objectionable at or beyond the property boundary	✓	✓	✓	✓

Table 11 ORC Air Plan: outdoor burning rules

In almost all instances[2], the discharge of contaminants from a variety of materials, such as tyres, treated timber and painted material is prohibited (the Air Plan, Section 16.3.3.1).

Rural-outdoor fires have, on occasion, been known to result in smoky conditions in and around nearby residential areas. Over the past four years ORC has received, on average, approximately 600 complaints per year related to air quality. Of these, 20% relate to outdoor burning.

6.1.6. Industrial discharges

Industrial and commercial discharges to air are regulated through the Air Plan, with larger discharges requiring consent. In 2007, ORC signalled to all industrial and commercial dischargers in Otago with permits for coal-fired boilers that upgrades would be required when renewing their permits. As a result, about a dozen consents have been renewed, with significantly reduced emissions in Central Dunedin. It is estimated that about 10 tonnes of PM_{10} have been removed from the Central Dunedin airshed annually due to this initiative (ORC, 2016).

[2] Except for certain activities such as incineration and Fire Services training activities

6.2. The influence of weather on air quality

Long-term weather patterns (climatology) and short-term weather features (meteorology) both affect the characteristic ambient air quality of a location. Otago has a wide range of topographical and climatological features that influence daily and seasonal particulate concentrations. This section discusses the relationship between climate/weather and air quality, as illustrated in the three key indicator sites.

6.2.1. Arrowtown

Arrowtown is a small town in the Queenstown Lakes District, and has very poor air quality during winter months, due to home heating emissions, but is profoundly influenced by the weather and topography. Arrowtown has a dry climate with extreme temperatures during winter and summer. It is not unusual for overnight temperatures in winter to reach -5° C for several consecutive nights.

Anticyclones, or high-pressure systems are responsible very calm atmospheric conditions which can lead to low wind speeds and strong temperature inversions. During an inversion, a layer of cold, dense air is trapped at the surface below warmer and more buoyant air as a result of rapid cooling of the ground surface. These events cause PM emissions to become trapped near the ground instead of being able to disperse into the atmosphere because vertical mixing is inhibited (Figure 25).

The relationship between air temperature and PM_{10} in Arrowtown indicates that the high pollution nights occur when daily temperatures drop below about 5°C, and when average wind speeds are below 2 m/s. (Figure 26). Figure 27 shows that most hourly wind speeds are below 2 m/s, and the dominant wind direction is from the north. The highest hourly concentrations of PM_{10} occur when wind speed is very low, and these concentrations originate from the west of the monitor (Figure 28). This relationship is further demonstrated in Figure 29, which shows that the highest hourly concentrations of PM_{10} occur at the lowest wind speeds and temperatures.

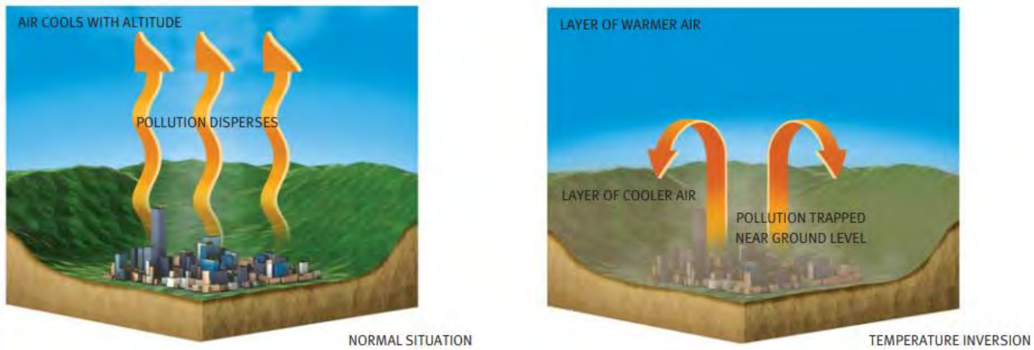


Figure 25 **A temperature inversion traps cool air and pollutants at ground level. Source: Ministry for the Environment**

Otago Regional Council

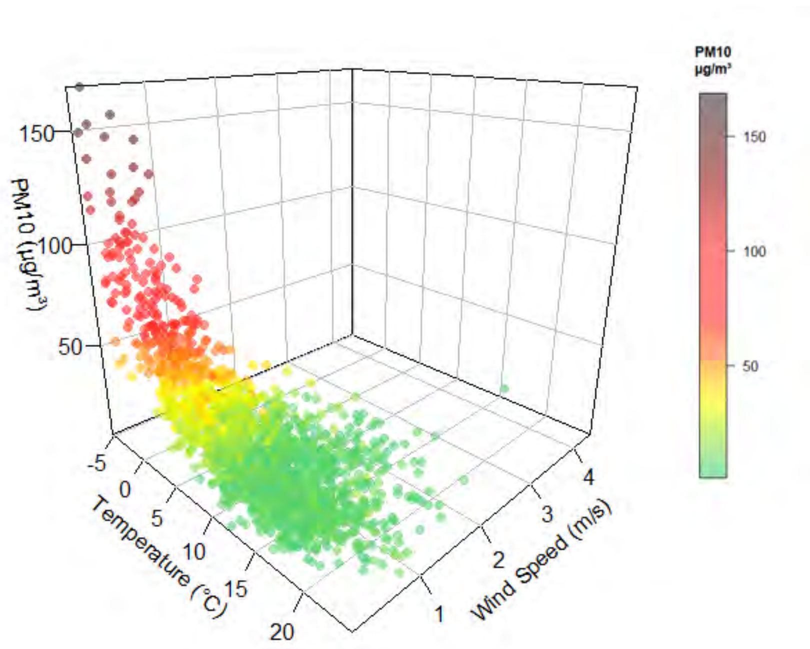


Figure 26 **Arrowtown: Three-axis plot of the relationship between PM_{10}, air temperature and wind speed (24-hour average)**

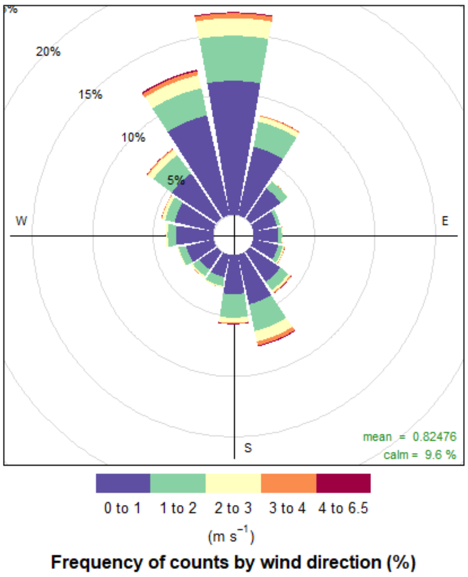


Figure 27 **Arrowtown: wind rose (1-hour average)**

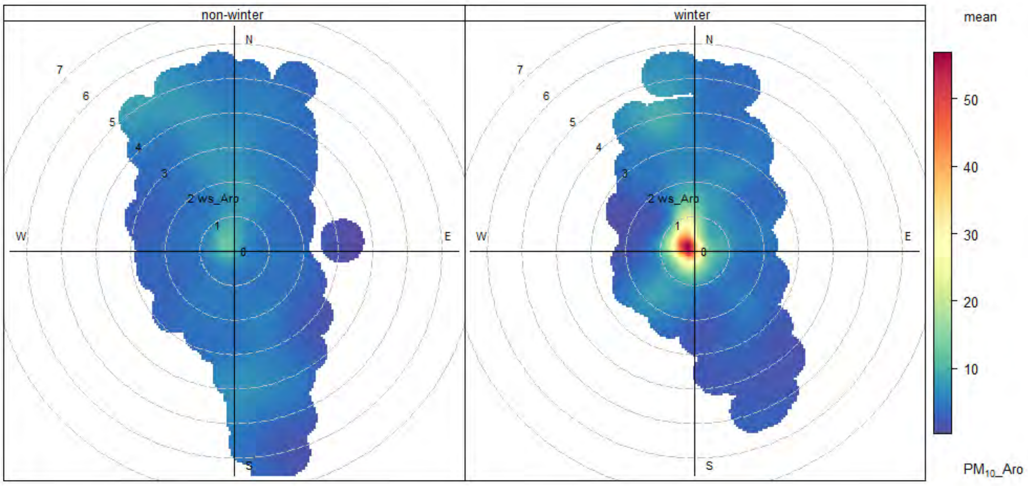
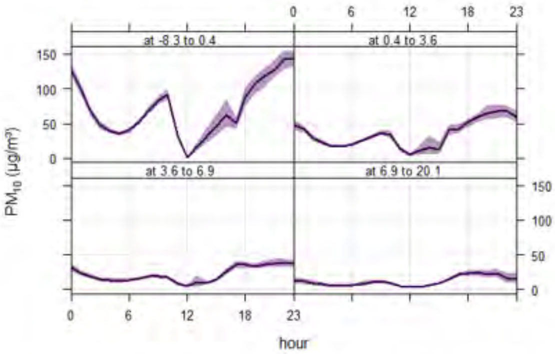


Figure 28 **Arrowtown: Bivariate polar plot of non-winter (Sep-Apr) and winter (May-Aug) PM_{10} by wind speed and direction (1-hour average), showing high winter concentrations at low wind speeds from the north and west directions. See Appendix A3 for plot interpretation.**



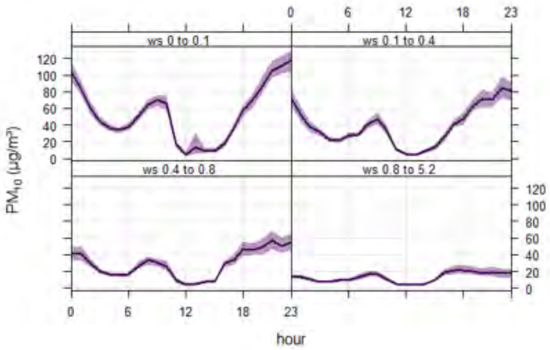


Figure 29 **Arrowtown: winter diurnal PM_{10} at temperatures and wind speeds divided by quantiles of equal sizes. High concentrations and dirunal peaks occur at the lowest quantiles of temperature and wind speeds.**

Otago Regional Council

6.2.2. Central Dunedin

The Central Dunedin airshed's daily PM_{10} concentrations are not correlated with air temperature, and moderate pollution levels occur throughout the range of temperatures experienced. Higher PM_{10} concentrations usually occur at lower wind speeds but this relationship is not very strong (Figure 30).

Compared to the inland airsheds, Dunedin weather is characterised by milder temperatures and stronger, coastal winds. Prevailing winds are from west-northwest and the northeast to east-northeast directions (Figure 31). This air movement helps disperse pollution, lowering the overall PM_{10} concentrations. The air quality monitor is located within the university campus, in an area of mixed industrial, commercial and residential property, 500 m east of the main highway. This site also has the potential influence of natural PM_{10} such as sea salt – up to 20% of coarse PM fraction in 2011 (Davy *et al*., 2011). Consequently, it has a complicated pattern of contributing emission sources that are not particularly seasonal (Figure 32).

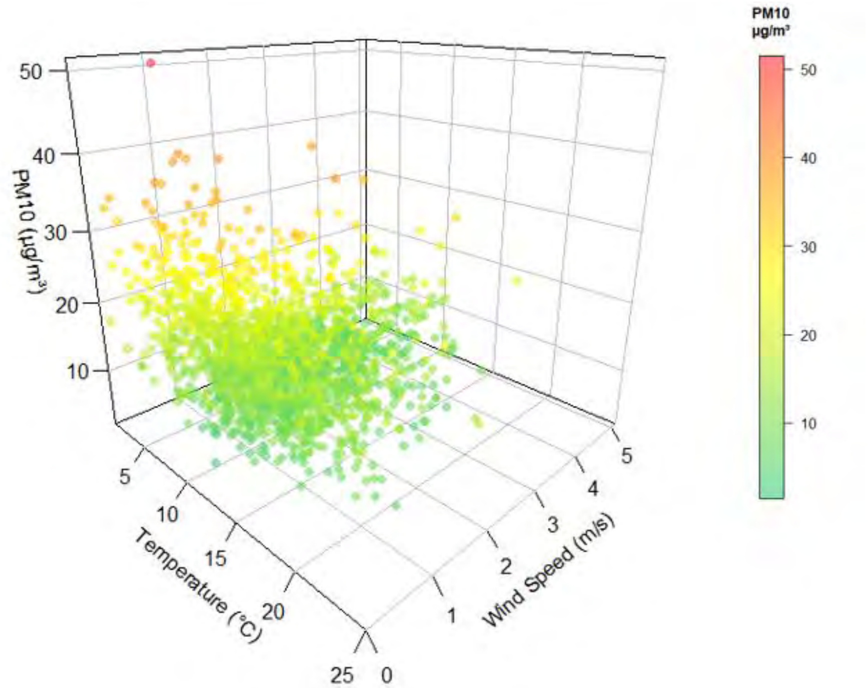


Figure 30 **Central Dunedin: Three-axis plot of the relationship between PM_{10}, air temperature and wind speed (24-hour average)**

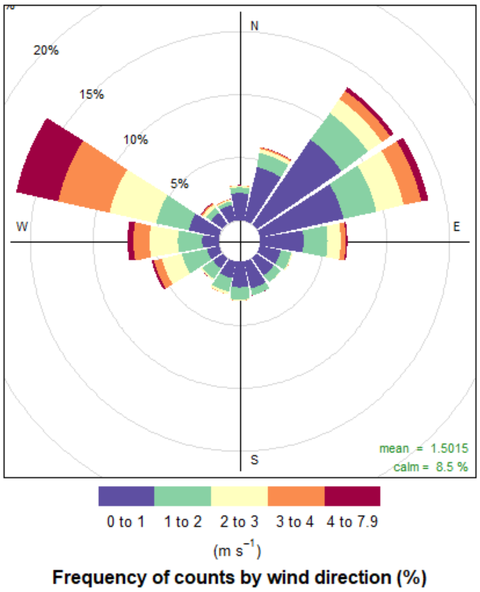


Figure 31 **Central Dunedin: wind rose (1-hour average)**

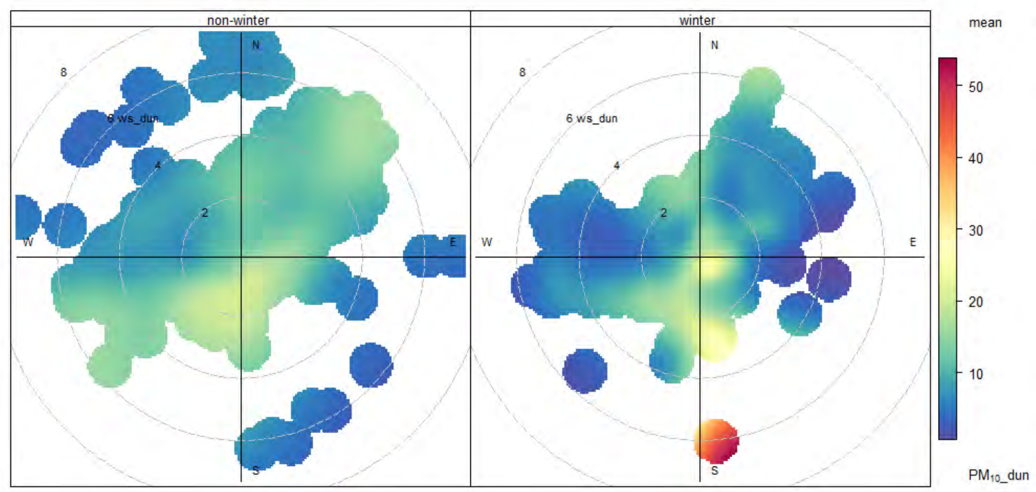


Figure 32 **Central Dunedin: Bivariate polar plot of non-winter (Sep- Apr) and winter (May-Aug) PM_{10} by wind speed and direction (1-hour average). Dunedin has a more complex pattern of emission sources than the other sites.**

Otago Regional Council

6.2.3. Mosgiel

Mosgiel is a town located on the Taieri Plain just inland from Dunedin and has weather characteristics that are a combination of the coastal and continental climates. Temperatures are more extreme than in Dunedin but not as extreme as Arrowtown, and wind speeds are low enough that temperature inversions often form on the Taieri Plain. The monitoring instrument is located in central Mosgiel.

High daily PM_{10} concentrations are most often correlated to cold temperatures and lower wind speeds (Figure 33). At 47%, Mosgiel has a very high percentage of calm winds. The predominant wind directions are west-southwest, north-northeast and the southeast directions (Figure 34). The bivariate polar plot of Mosgiel shows that it has multiple sources of emissions in non-winter months (September to April) with the south-east direction shown to have higher concentrations occurring when wind speeds are between 3 and 5 m/s, which indicates they are sources further away from the monitor. During winter months (May to August) the high concentrations occur at low wind speeds, which indicates emission sources from home heating (Figure 35).

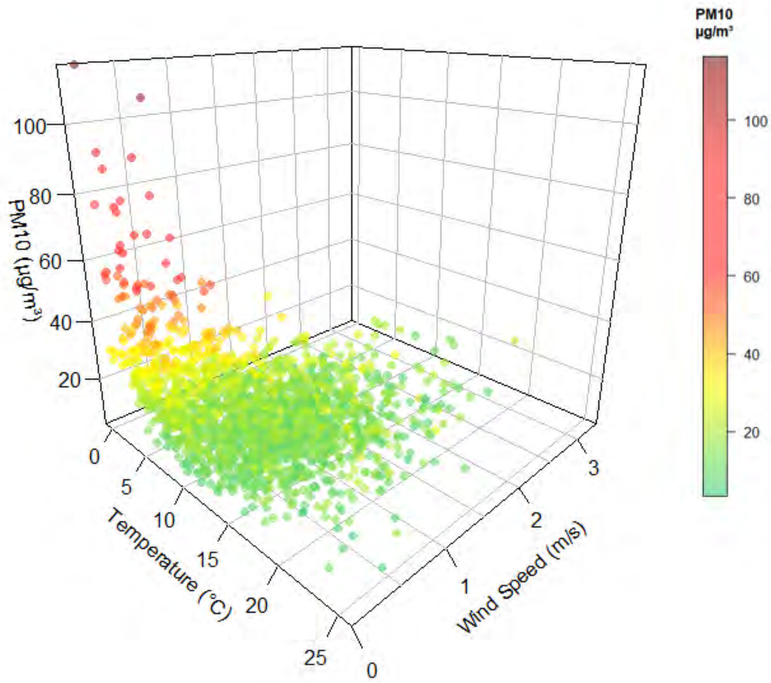


Figure 33 **Mosgiel: Three-axis plot of the relationship between PM_{10}, air temperature and wind speed (24-hour average)**

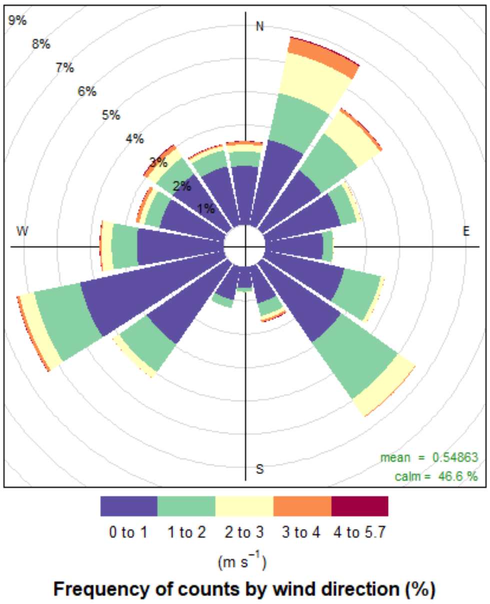


Figure 34 **Mosgiel: wind rose (1-hour average)**

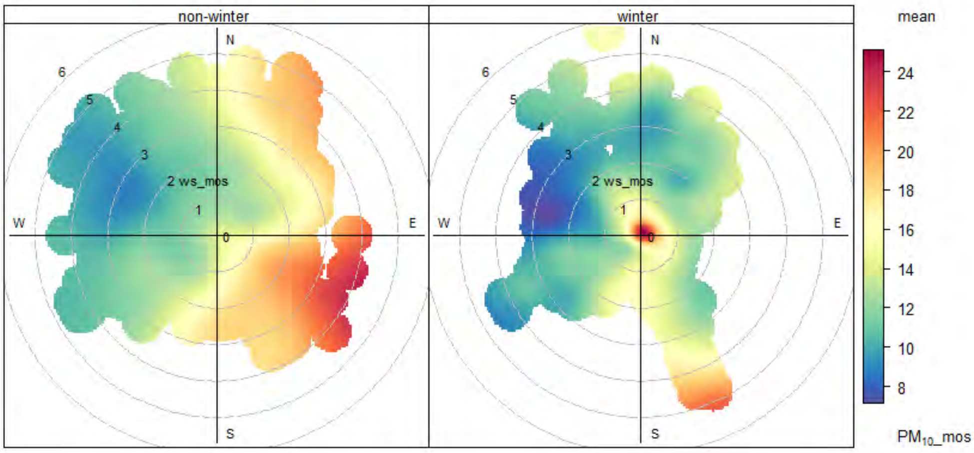


Figure 35 **Mosgiel: Bivariate polar plot of non-winter (Sep- Apr) and winter (May-Aug) PM_{10} by wind speed and direction (1-hour averages), showing high winter concentrations at low wind speeds, and moderate concentrations from the south-east at higher wind speeds during non-winter months.**

7. Discussion

7.1. State and trends 2010 – 2019

Air quality monitoring results indicate a wide range of ambient air quality throughout the region over the last ten years. Emissions from solid-fuel burners used for domestic heating are the primary contributor of PM_{10} in the residential areas of Otago (Wilton 2016 and 2019), which means that degraded air quality occurs in winter.

Central and local government programmes to improve insulation and upgrade wood burners in towns such as Alexandra, Arrowtown, Clyde, Cromwell and Milton have resulted in the replacement of over 1,400 appliances. While this has led to a reduction in emissions in these towns, this has not been enough for concentrations to meet the NESAQ limit for PM_{10}. Trend analysis shows that there have been significant decreases in PM_{10} concentrations in each of these towns but not to the extent originally predicted for Otago's air quality management strategy (ORC, 2007). The current strategy (ORC, 2018) recognises this, and has been adjusted to promote the installation of cleaner heating in Otago towns, such as ultra-low or no-emission appliances.

In Air Zone 2 towns, such as Balclutha and Mosgiel, PM_{10} has been exceeding the limits set by the NESAQ to provide a minimum level of health protection, and there are no consistent downward trends for winter concentrations. Relying on the natural rate of burner replacements to improve air quality over time and achieve compliance with the NESAQ has not proven to be successful, and active management would be beneficial in these areas.

Central Dunedin has experienced the most significant improvement in air quality over the last ten years. The improvements are due to a combination of the introduction of new resource consent limits for industrial and commercial discharges, and improvements to home heating methods. This continued steadily over the years as industrial emissions control technology continues to improve. Dunedin is no longer considered a polluted airshed and has not breached the NESAQ in the last five years.

The contrast between Dunedin and the other airsheds highlights the challenges of improving air quality when the main emission sources are individual wood burners in areas where local weather patterns lead to high pollution nights. There is no single approach to meeting these challenges, but education, engagement and financial incentives are very important factors in air quality implementation projects. Technology advances in the home heating and building industries must not be overlooked in their impact on air quality and potential for providing solutions to reduce pollutant emissions.

7.2. National context

In 2018 MfE and Stats NZ released the latest national summary of air quality data. Nationally, many other regions have also struggled to meet the NESAQ for PM_{10}. In particular, the South Island has had more challenges meeting the standard due to the colder climate, but there are some parts of the North Island that also experience high PM_{10} concentrations. The 22 airsheds that had more than one exceedance in 2016 were all in the South Island, apart from Masterton, Tokoroa and Rotorua. The majority of the airsheds with exceedances were residential, or partially residential sites. In 2016 Otago sites had the highest frequency of exceedances (Figure 36).

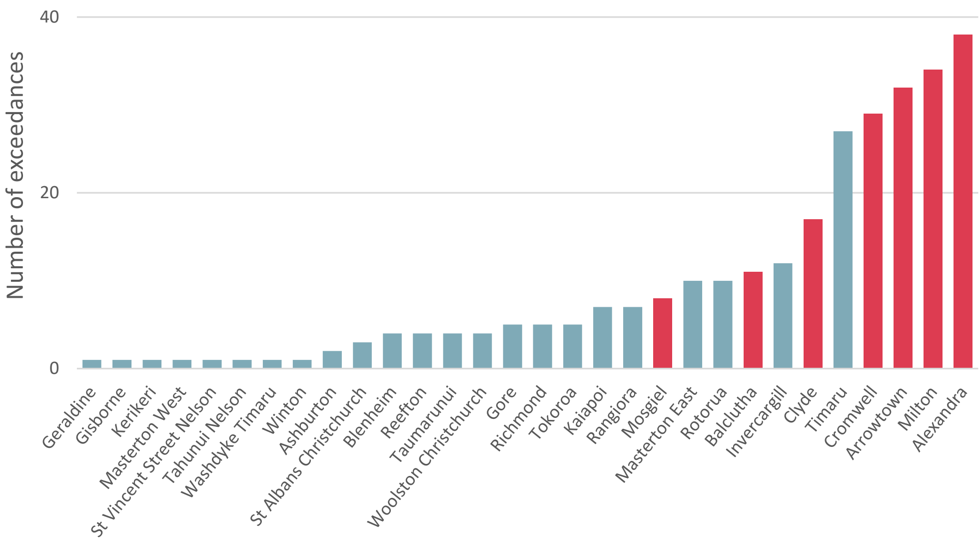


Figure 36 **Number of NESAQ annual PM_{10} exceedances in New Zealand monitoring stations for 2016, Otago airsheds in red. Source: MfE and Stats NZ (2018)**

7.3. Health impacts of air pollution

As discussed in section 2.2, exposure to particulate matter can cause and aggravate existing health issues, on both short and long-term scales. PM exposure mostly affects the respiratory and cardiovascular systems (Figure 37). Short term exposure can result in reversible symptoms such as respiratory irritation and heart-rhythm disturbances but can also result in inflammation of lungs and blood vessels. Repeated exposure can lead to chronic respiratory and cardiovascular diseases such as lung cancer and chronic obstructive pulmonary disease (Kuschel *et al*., 2012). The pyramid of health effects (Figure 38) describes that the most severe conditions occur to the smallest proportion of a population, and these incur the greatest social costs.

The impacts of air pollution on individuals varies by unique factors (age, health status, etc) and exposure (proximity to pollution sources). The groups within the population that are more affected by air pollution are children, the elderly, those with pre-existing conditions such as asthma, other lung and heart conditions, pregnant women and Māori (MfE, 2011b).

The impact of air quality on health is well documented. Conversely, there is global evidence that when air pollution is reduced there are subsequent health improvements, both with legislative intervention, such as clean air regulations, residential wood burning interventions, low emission zones for traffic within major cities; and by unplanned events such as industry strikes and economic recessions (WHO, 2013).

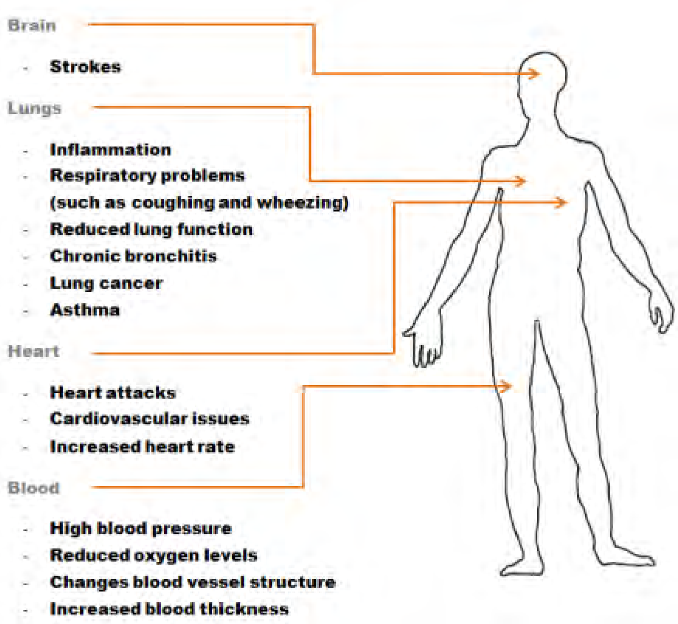


Figure 37 **Types of heath effects from PM_{10} exposure. Source MfE (2011b), adapted from Aphekom (2011)**

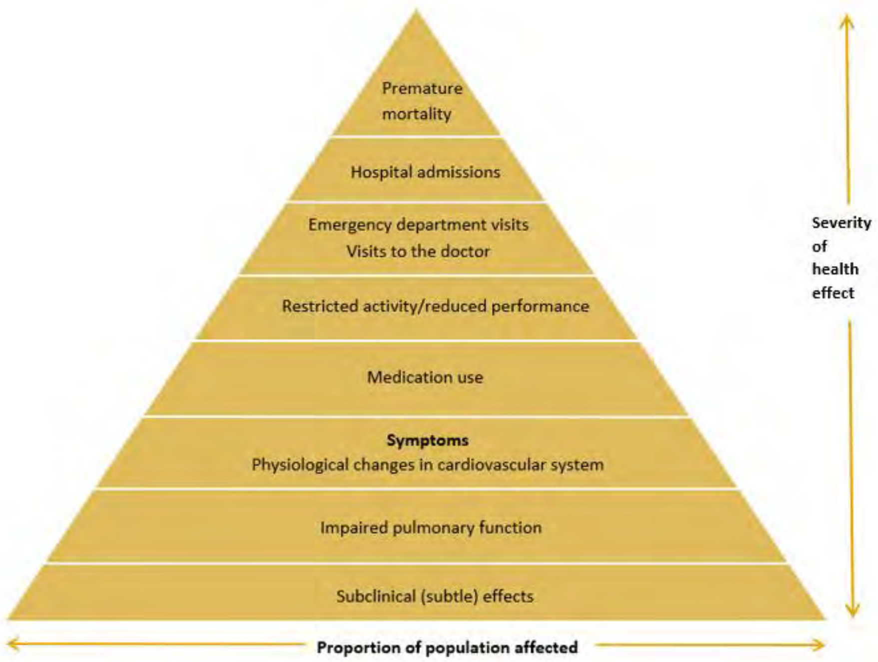


Figure 38 **Pyramid of health effects for PM_{10}. Source: WHO (2006)**

The Health and Air Pollution in New Zealand (HAPINZ) exposure model was developed to estimate the health impacts and social costs of anthropogenic air pollution in New Zealand. It was found that the overall social cost is $4.28 billion per year, or $1,061 per person. Table 12 shows the estimation of the HAPINZ model for Otago districts. These estimates were determined from the exposure of the census area unit (CAU) populations to 2006 PM_{10} concentrations, and the estimated health impacts of annual PM_{10} (long-term effects; premature mortality), and daily PM_{10} (short-term effects; hospital admissions and restricted activity days). Restricted activity days are days when symptoms limit usual daily activities such as work and school.

District (population in 2018)	Number of cases per 100,000			Restricted activity days
	Premature mortality in adults over 30 years	Cardiac hospital admissions (all ages)	Respiratory hospital admissions (all ages)	
Central Otago (21,558)	51	10	10	45,838
Clutha (17,667)	24	4	6	19,232
Dunedin City (126,255)	26	5	7	23,828
Queenstown Lakes (39,153)	8	1	3	17,605
Waitaki (22,308)	63	8	10	34,476
Total	**171**	**28**	**36**	**140,979**

Table 12 **Estimated number of premature deaths, hospital admissions and restricted activity days for Otago districts in 2016. Source: MfE and Stats NZ (2018)**

7.4. Cultural impacts of air pollution

Kāi Tahu whānui are takata whenua of the Otago region, incorporating seven papatipu rūnaka. Three of these rūnaka, Te Rūnanga o Ōtākou, Kāti Huirapa Rūnaka ki Puketeraki, and Te Rūnanga o Moeraki, are located in Otago. A further four, Hokonui Rūnanga, Waihōpai Rūnaka, Awarua Rūnanga, and Ōraka-Aparima Rūnaka, are situated in the Southland district, but with shared authority in the inland parts of Otago.

In Te Ao Māori the concept of whakapapa is integral, as whakapapa connects all people, lifeforms, and the natural world to a common origin. As such, all natural resources such as air, land, water, and indigenous biodiversity are taoka – treasured resources provided by the gods to sustain life. In Kāi Tahu traditions, the air and atmosphere were created after Tāwhirimātea, a child of Rakinui and Papatūānuku, fled with Raki into the sky and took control of wind and weather.

Air pollution has negative impacts on the mauri of air as a taoka, and other taoka such as living things that require clean air. Discharges to air may adversely affect significant places and taoka such as marae, wāhi tapu, mahika kai, water, and indigenous flora. From the Kāi Tahu perspective, the taoka must be passed intact to the next generation and be enhanced where it is degraded.

7.5. Knowledge gaps

There are several monitoring related knowledge gaps in Otago for pollutants $PM_{2.5}$, benzo(a)pyrene and NO_2 and SO_2, as well as the spatial distribution of PM_{10} and port emissions.

$PM_{2.5}$ is the majority component of PM_{10} emitted as wood or coal smoke (MfE and Stats NZ, 2018). In winter, in Otago Air Zone 1 towns it is estimated to be up to 90% of the PM_{10} (ORC, 2019). ORC is in the process of updating the monitoring network to include $PM_{2.5}$, which we are currently only able to estimate based on PM_{10} concentrations, and an understanding of the $PM_{2.5}$ to PM_{10} ratio. Monitoring $PM_{2.5}$ will be a requirement for the forthcoming update to the NESAQ which will include limits for $PM_{2.5}$. If the new standard adopted is the same as the WHO limit of 25 µg/m³ (24-hour average), then greater reductions of emissions will be required to meet this, than is currently required to meet the PM_{10} standard.

It would also be beneficial to establish a baseline of benzo(a)pyrene, which is strongly correlated to woodsmoke and PM_{10}. In addition, monitoring NO_2 and SO_2, would provide up to date data for industry and vehicle related combustion sources in urban areas.

The unexpected relocations of the sites at Alexandra and Arrowtown highlight the need to further study the spatial differences within monitored towns. In the past this has been undertaken every few years, but current technology exists for establishing networks of low-cost sensors to identify spatial patterns within a town.

Another knowledge gap is the emissions from Port Chalmers. Ports within New Zealand are often monitored for $PM_{2.5}$ and/or SO_2, and even though the Port is not covered under the NESAQ or the Otago Air Plan, it is located within an airshed and it would be beneficial to develop an understanding of the pollutants that are emitted there.

Furthering our understanding of emissions and emission sources is important to Otago's air quality programmes. Otago's last source apportionment study was last undertaken in 2011 in Dunedin. Due to the industry improvements the proportion of PM sources will be different now. Undertaking new source apportionment investigations for Dunedin and Mosgiel, the airsheds with the most diverse emission sources, would provide current information on the sources and relative contributions of PM.

More information is needed further our understanding of the relationships between emissions and concentrations in Otago airsheds. A tool to help with this is the emissions inventory, which relies on accurate estimations of emissions factors. A knowledge gap in New Zealand is the performance of ultra-low emission burners (ULEB) in a real-life setting. ULEB are now the only wood burner that can meet Air Zone 1 rules upon installation; with a large proportion of these now being installed it is important to future work to have an emissions factor for ULEBs. This information, in addition to the periodic updating of emission inventories will help improve understanding of the emissions in each town.

Outside of urban air quality, one of the main pollution sources is outdoor burning. The impacts of outdoor burning in Otago is currently unquantified as methods for assessment have not been determined beyond estimations from emission inventories.

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Appendix 1: Airshed and Air Zone boundary maps

Figure 39 **Alexandra: airshed and Air Zone boundaries**

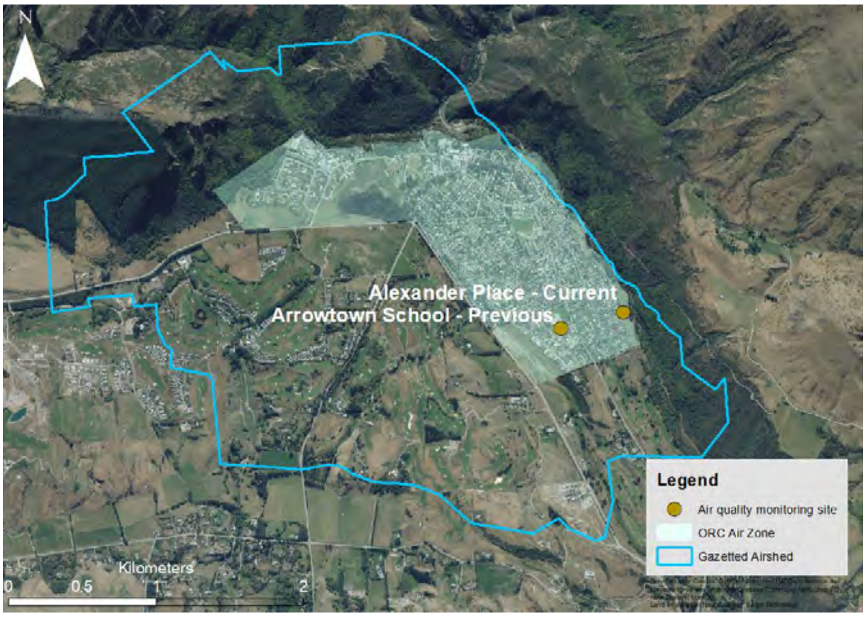


Figure 40 **Arrowtown: airshed and Air Zone boundaries**

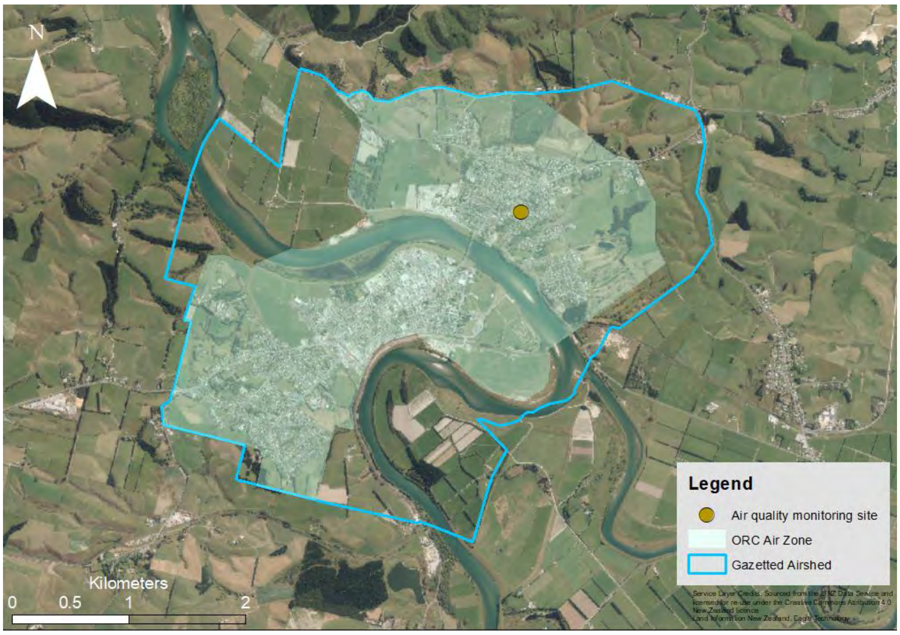


Figure 41 **Balclutha: airshed and Air Zone boundaries**

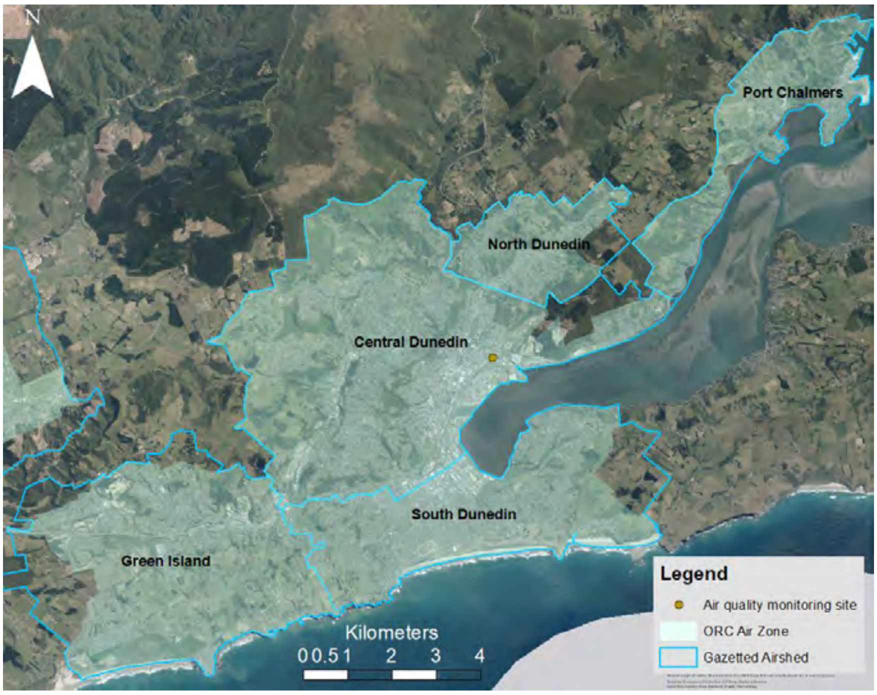


Figure 42 **Dunedin: airshed and Air Zone boundaries**

Figure 43 **Clyde: airshed and Air Zone boundaries**

Figure 44 **Cromwell: airshed and Air Zone boundaries**

Figure 45 **Milton: airshed and Air Zone boundaries**

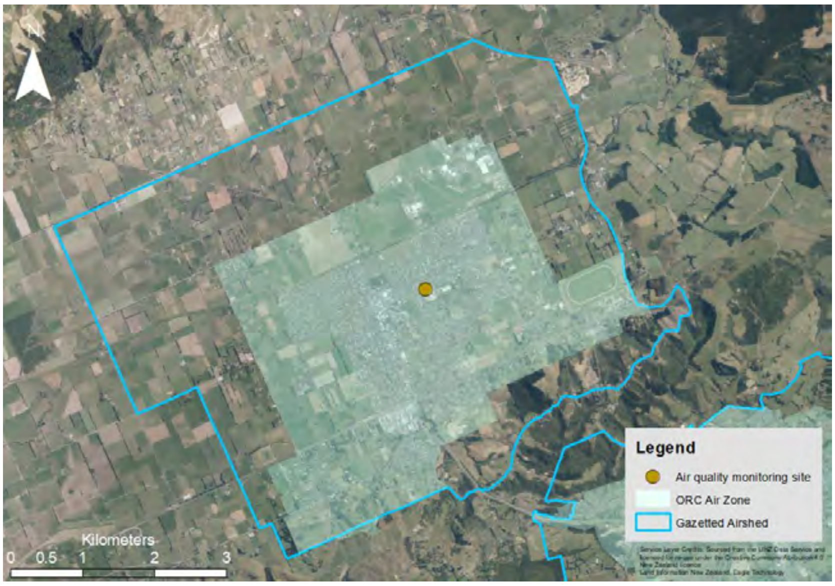


Figure 46 **Mosgiel: airshed and Air Zone boundaries**

Appendix 2: Box plots of winter PM_{10} distribution

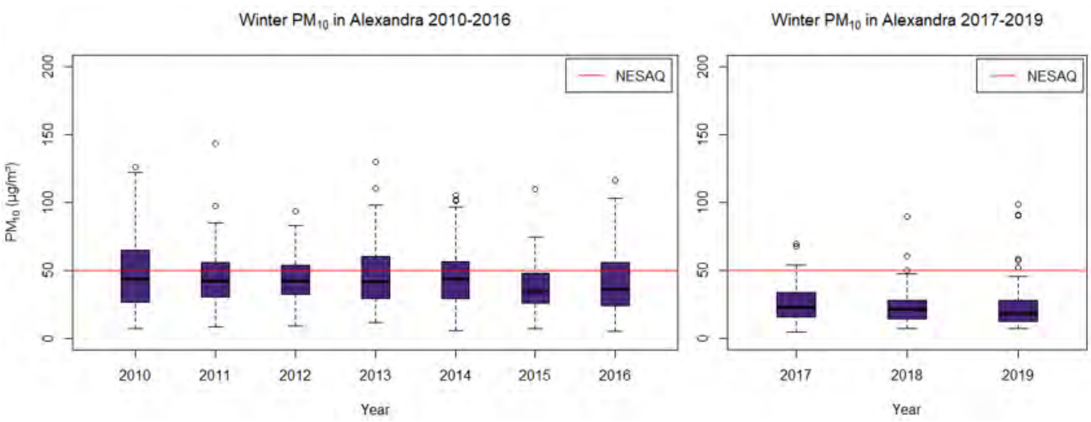


Figure 47 **Alexandra: PM_{10} distribution for winter months (May-August) 24-hour average, different site locations represented by different graphs**

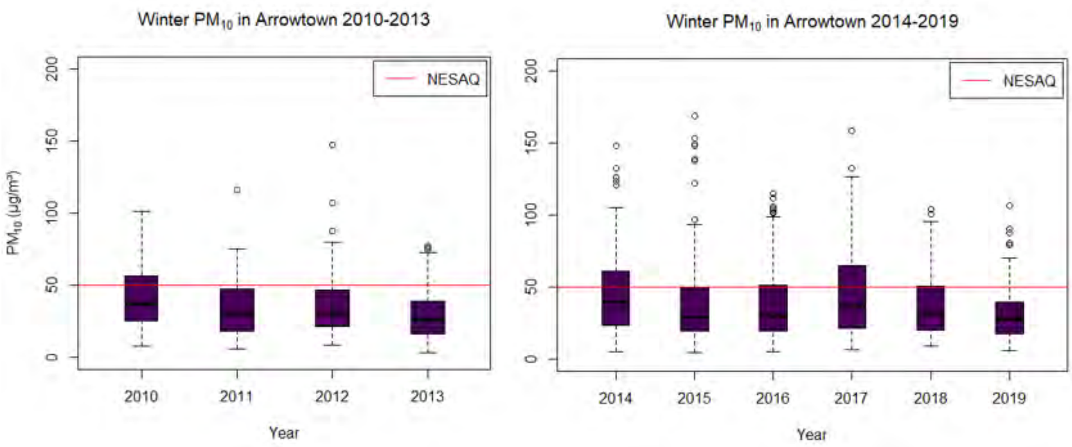


Figure 48 **Arrowtown: PM_{10} distribution for winter months (May-August) 24-hour average, different site locations represented by different graphs**

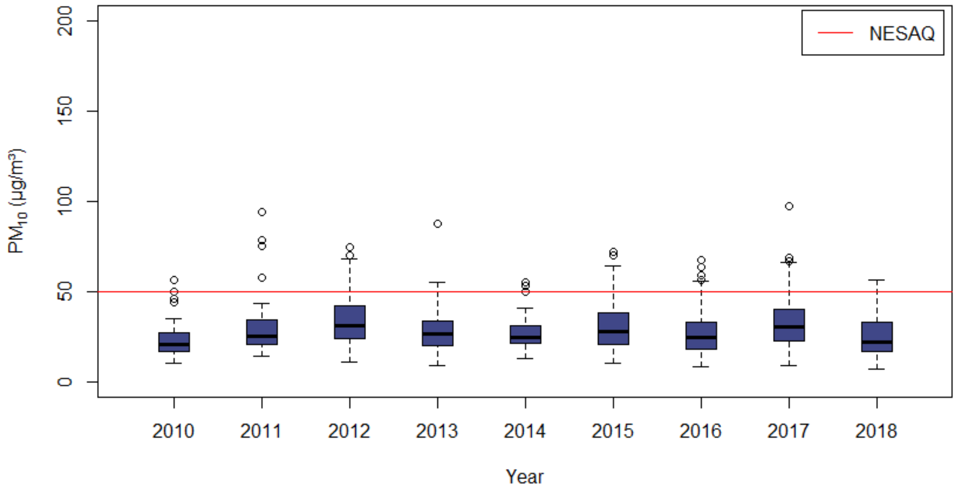


Figure 49 **Balclutha: PM_{10} distribution for winter months (May-August) 24-hour average**

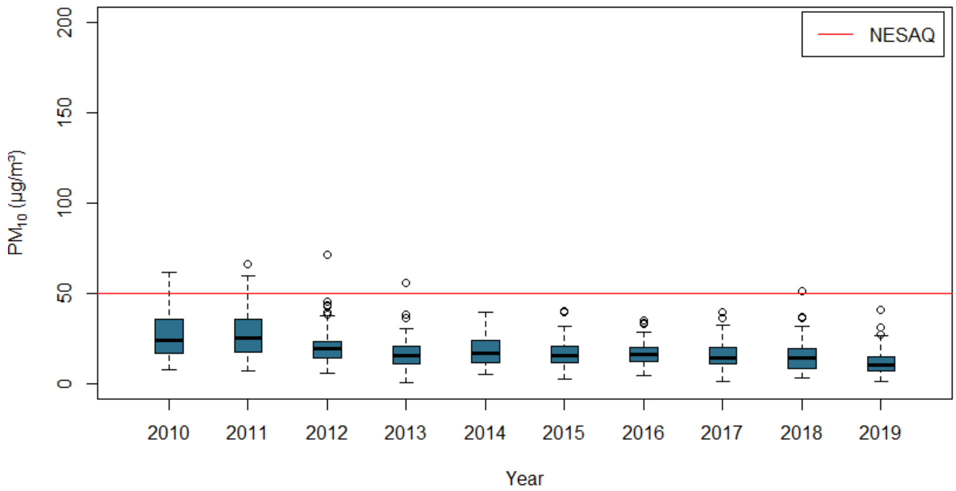


Figure 50 **Central Dunedin: PM_{10} distribution for winter months (May-August) 24-hour average**

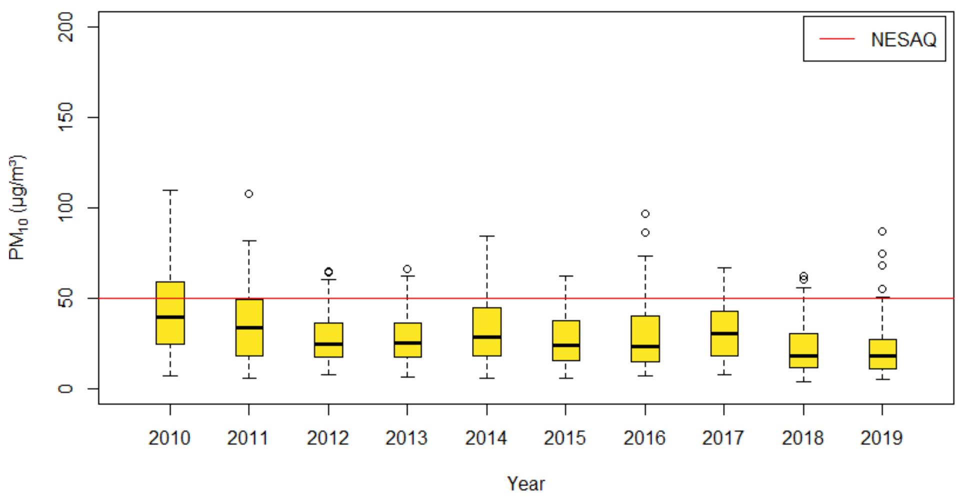


Figure 51 **Clyde: PM_{10} distribution for winter months (May-August) 24-hour average**

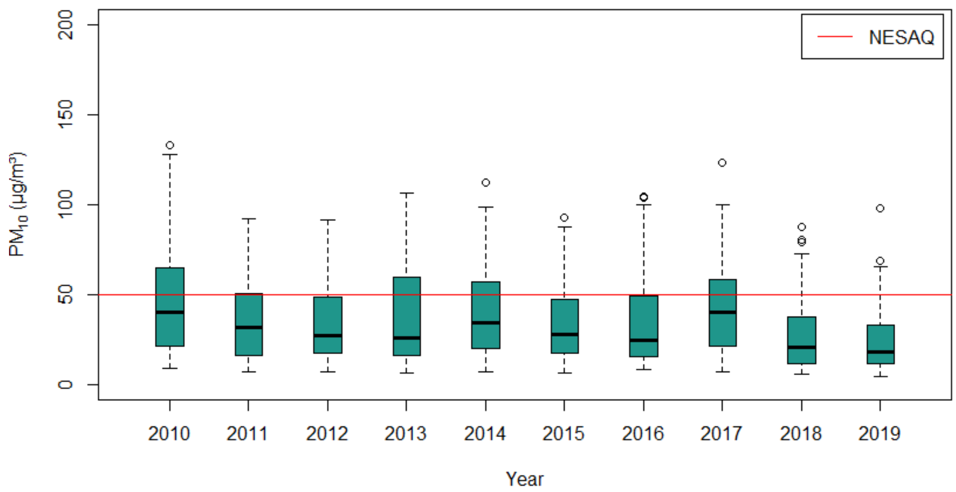


Figure 52 **Cromwell: PM_{10} distribution for winter months (May-August) 24-hour average**

Otago Regional Council

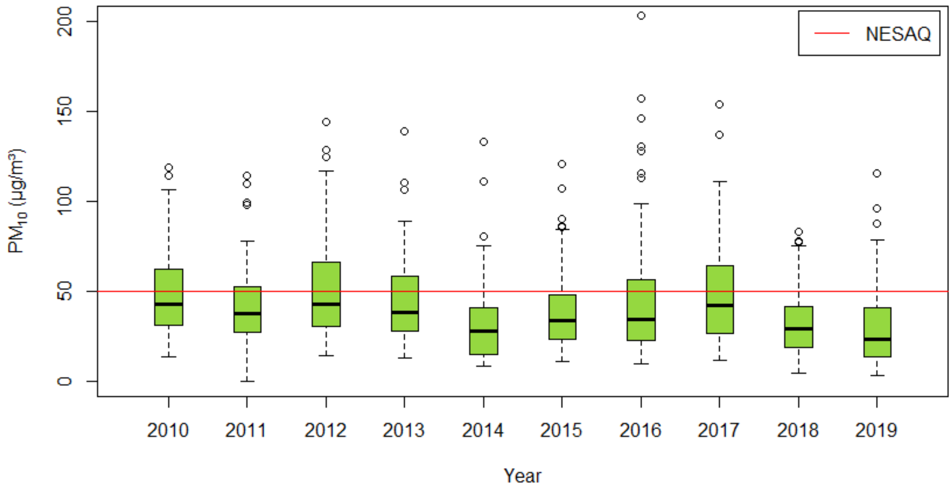


Figure 53 Milton: PM_{10} distribution for winter months (May-August) 24-hour average

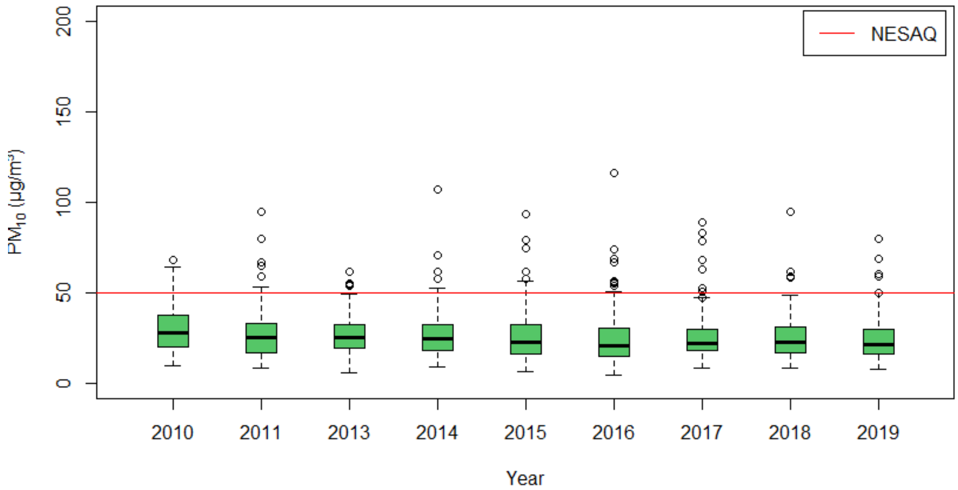


Figure 54 Mosgiel: PM_{10} distribution for winter months (May-August) 24-hour average

Appendix 3: Data presentation

R Statistical Software was used to produce the following plots and analyses:

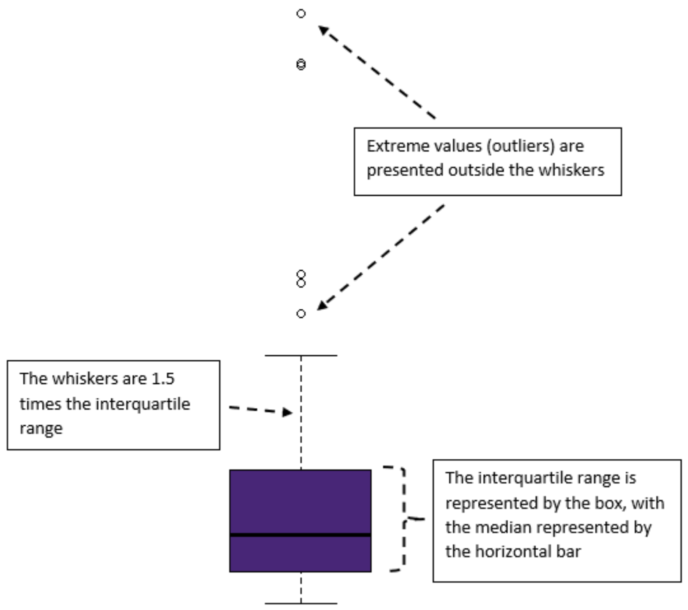


Figure 55 **Box and whisker interpretation**

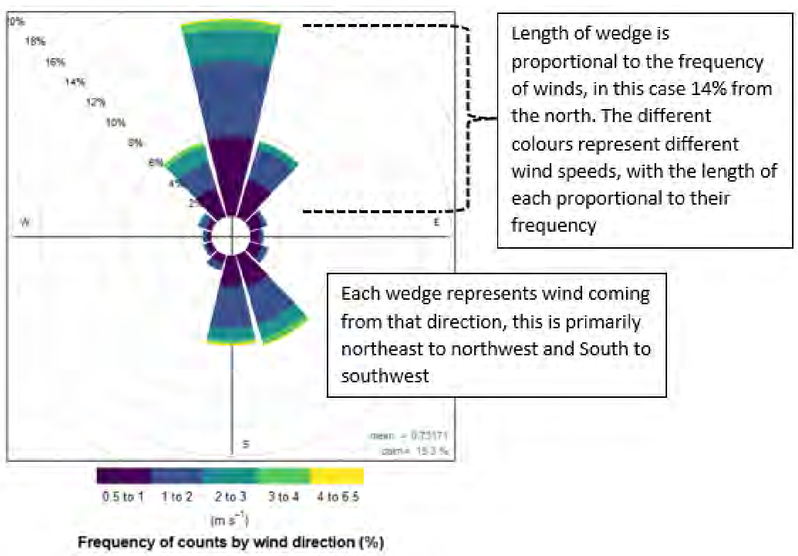


Figure 56 **Wind rose interpretation. These plots show wind speed and wind direction.**

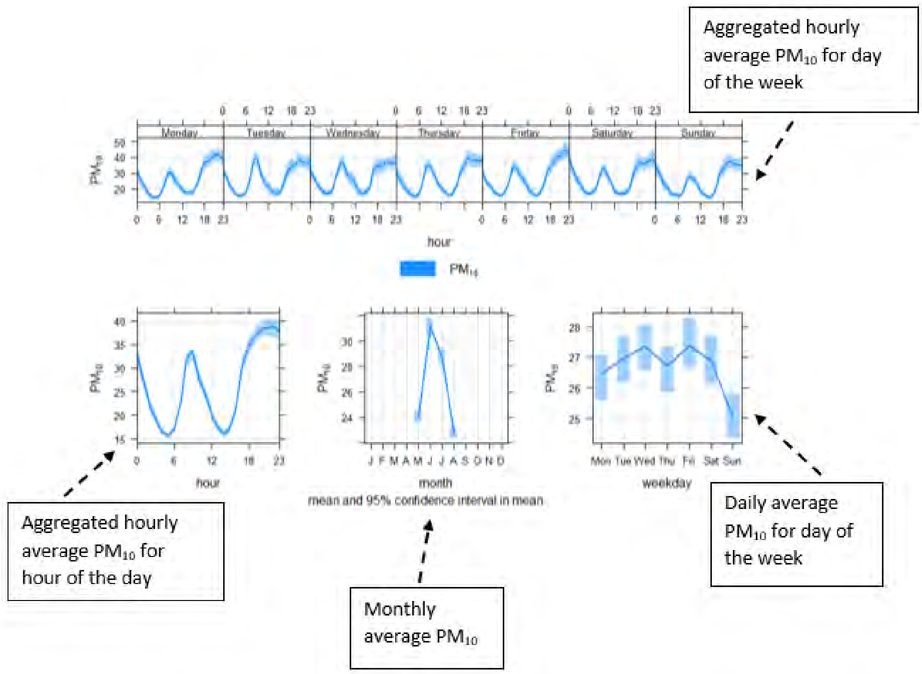


Figure 57 **Time variation plot interpretation. These plots show the mean (line) and 95% confidence intervale of the mean (shaded bars) of a pollutant averaged over different timescales.**

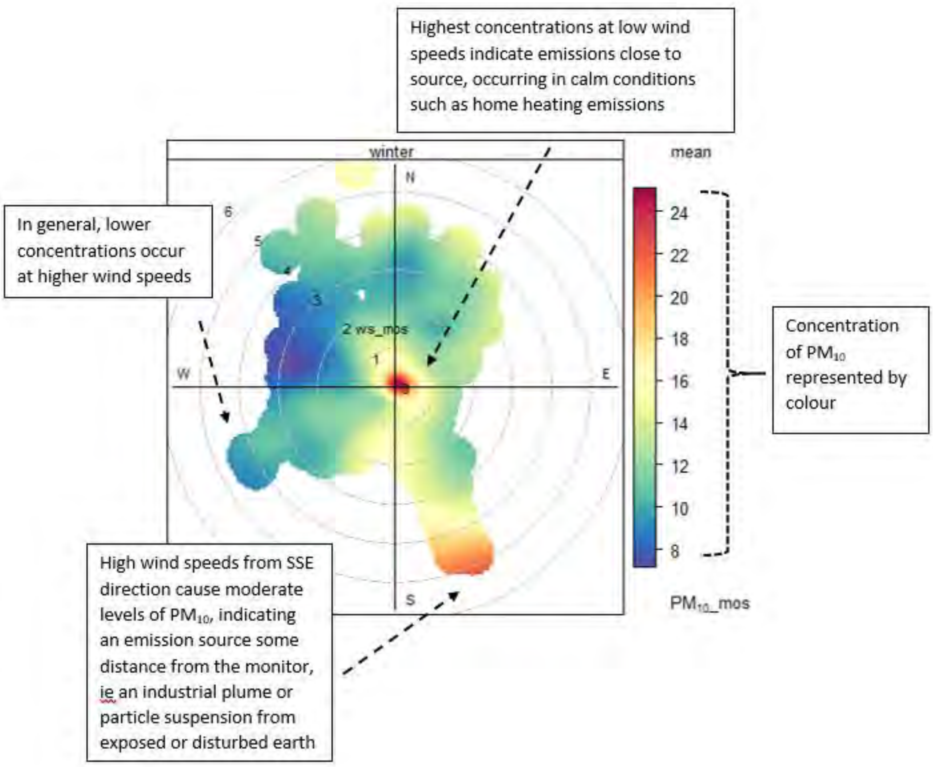


Figure 58 **Bivariate polar plot interpretation. These plots present smoothed PM_{10} concentrations plotted by wind speed (distance to centre of plot) and wind direction (polar co-ordinates), and are used to infer sources of pollution.**

Appendix 4: Summary statistics

PM_{10} (µg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Site Location	65 Ventry Street							5 Ventry Street		
Minimum	2	3	1	4	3	2	2	4	3	4
25th Percentile	9	9	8	9	8	8	9	9	8	8
Median	13	15	13	16	14	13	16	13	11	10
Mean	24	24	22	25	24	20	25	17	14	14
75th Percentile	29	36	33	35	36	30	35	22	17	15
Maximum	126	143	93	130	105	110	116	70	90	98
NESAQ exceedances	51	40	40	46	51	22	38	3	2	6
% valid	98%	86%	100%	89%	98%	97%	75%	59%	99%	95%

Table 13 Alexandra: summary statistics for PM_{10}

PM_{10} (µg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Site Location	Arrowtown School*				Alexander Place					
Minimum	8	6	9	4	3	2	1	3	2	1
25th Percentile	26	19	22	16	7	7	6	7	6	5
Median	37	30	31	26	16	10	10	11	10	8
Mean	42	34	36	30	28	21	20	22	18	16
75th Percentile	57	47	47	39	41	26	24	25	24	22
Maximum	101	116	147	77	148	169	115	158	104	106
NESAQ exceedances	39	27	24	15	48	30	32	45	29	19
% valid	100%	100%	100%	100%	65%	80%	93%	96%	93%	95%

*Arrowtown was a winter only site during 2010-2013

Table 14 Arrowtown: summary statistics for PM_{10}

PM_{10} (µg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018
Minimum	11	14	11	10	13	10	8	9	7
25th Percentile	17	21	24	20	21	21	19	23	17
Median	21	26	31	27	25	28	25	31	22
Mean	22	30	34	28	27	31	27	34	26
75th Percentile	28	34	42	34	32	38	33	40	33
Maximum	56	94	75	88	55	72	67	98	56
NESAQ exceedances	2	4	13	4	3	9	10	14	5
% valid	100%	50%	92%	100%	64%	98%	98%	86%	93%

Table 15 Balclutha: summary statistics for PM_{10} (winter only)

PM_{10} (μg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	4	7	3	1	5	3	5	2	3	1
25th Percentile	15	17	13	12	13	12	12	10	10	8
Median	23	23	17	17	17	16	16	13	14	11
Mean	25	25	18	18	18	17	16	14	15	12
75th Percentile	31	30	23	22	23	20	18	18	19	15
Maximum	62	70	71	56	40	41	39	40	51	41
NESAQ exceedances	11	14	1	1	0	0	0	0	1	0
% valid	98%	93%	90%	97%	95%	85%	85%	98%	97%	95%

Table 16 Central Dunedin: summary statistics for PM_{10}

PM_{10} (μg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	8	6	8	6	6	6	7	8	4	2
25th Percentile	25	18	18	18	18	16	15	18	12	11
Median	40	34	25	26	29	24	24	31	18	18
Mean	44	36	28	28	32	27	29	32	22	22
75th Percentile	59	50	36	36	45	38	41	43	30	27
Maximum	110	107	65	66	84	63	97	67	62	87
NESAQ exceedances	40	23	9	10	21	10	18	23	6	4
% valid	100%	72%	100%	98%	100%	100%	98%	98%	100%	100%

Table 17 Clyde: summary statistics for PM_{10} (winter only)

PM_{10} (μg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	9	7	8	7	7	7	8	7	6	5
25th Percentile	22	17	18	17	20	18	15	22	12	12
Median	40	32	27	26	35	28	25	40	21	18
Mean	48	35	34	37	41	35	36	43	27	26
75th Percentile	65	51	49	60	57	47	50	58	37	33
Maximum	133	92	91	107	112	93	105	123	88	98
NESAQ exceedances	43	27	30	33	49	27	34	41	13	13
% valid	100%	79%	99%	95%	100%	86%	98%	98%	80%	97%

Table 18 Cromwell: summary statistics for PM_{10} (winter only)

PM_{10} (µg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	14	11	14	13	8	11	10	12	5	3
25th Percentile	31	27	31	28	15	23	23	27	19	14
Median	43	37	43	38	28	34	65	42	30	24
Mean	49	41	50	44	31	38	45	46	32	29
75th Percentile	61	52	66	58	41	48	56	64	42	41
Maximum	119	114	144	139	133	121	203	154	83	115
NESAQ exceedances	46	20	37	44	14	30	36	48	16	20
% valid	98%	61%	81%	100%	81%	100%	94%	99%	95%	97%

Table 19 **Milton: summary statistics for PM_{10} (winter only)**

PM_{10} (µg/m³) 24-hour mean	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	7	7		6	7	5	4	5	6	5
25th Percentile	15	17		14	15	13	12	13	13	11
Median	20	23		18	19	17	15	16	17	15
Mean	24	26		20	21	20	19	19	19	17
75th Percentile	29	31		24	25	23	22	21	22	20
Maximum	105	95		62	107	93	116	89	94	80
NESAQ exceedances	8	8		5	5	7	9	9	4	4
% valid	68%	46%	28%	95%	98%	92%	70%	95%	90%	92%

Table 20 **Mosgiel: summary statistics for PM_{10}**

Appendix 5: Other ambient pollutants

A5.1 Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless and tasteless gas, most commonly caused by human activities. Breathing carbon monoxide affects the oxygen-carrying capacity of blood and can result in mental confusion, heart problems and a general decline in a person's wellbeing. Prominent sources include vehicle exhaust, and the combustion of wood and coal.

A5.2 Nitrogen dioxide

Nitrogen dioxide (NO_2) is a brownish acidic gas and is highly corrosive. It forms from chemical reactions involving nitrogen oxide and other oxides, typically during combustion of fossil fuels. Inhalation is associated with aggravating respiratory diseases such as asthma and lung infections, with resulting increases in hospital admissions. Vehicle emissions are the main source of NO_2 in urban areas.

A5.3 Sulphur dioxide

Sulphur dioxide (SO_2) gas is colourless and has a characteristically pungent smell. It is produced during the combustion of sulphur-containing fossil fuels such as coal. Respiratory problems are the most common complaint with increased inhalation of SO_2. It also has links to cardiovascular disease. Common sources in Otago include the combustion of coal in industrial activity or domestic heating.

A5.4 Ozone

Ozone is a secondary pollutant formed from other compounds during photochemical reactions, and it results in smog. Effects of high ozone concentrations include increased respiratory and cardiovascular disease. Short term effects include irritation of the eyes, nose and throat, and headaches. Ozone is not readily formed in Otago as it requires an abundance of sunlight and the presence of other pollutants.

7.2. The Environmental Monitoring and Reporting Framework - a Regional Sector Strategic Initiative

Prepared for:	Data and Information Committee
Report No.	ENV2101
Activity:	Environmental: Air Environmental: Land Environmental: Water
Author:	Abi Loughnan, National Project Manager EMaR/LAWA
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	8 September 2021

PURPOSE

[1] This paper informs council about the Environmental Monitoring and Reporting (EMaR) framework and the Land, Air, Water Aotearoa (LAWA) project.

[2] The EMAR framework and LAWA project are regional sector strategic initiatives and are hosted by Otago Regional Council on behalf of the sector.

EXECUTIVE SUMMARY

[3] The Environmental Monitoring and Reporting (EMAR) framework's overall aim is to make fundamental changes to how the regional sector delivers environmental monitoring and reporting functions through the following data and information projects:

a. NEMS (National Environmental Monitoring Standards) – consistent approach to the collection of environmental data.
b. EDMS (Environmental Data Management System) – improved access to high quality data through driving consistency in the management and storage of environmental data.
c. LAWA (Land, Air, Water Aotearoa) – telling the story of our environment through sharing high quality data and information online, to enable informed decision making.

[4] ORC hosts the EMAR framework and LAWA project on behalf of the project partners.

RECOMMENDATION

That the Committee:

*1) **Notes** this report.*

BACKGROUND

[5] Demand is increasing in all sectors of the community for readily available, high quality environmental data and information for decision making. In response to this, regional councils across New Zealand ('regional sector'), in partnership with the Ministry for the Environment developed an Environmental Monitoring and Reporting (EMaR) Framework

in 2014. This has been a journey over the last seven years to become more consistent and integrated in the collection and presentation of regional sector environmental data. The partnership now also includes Statistics New Zealand, Department of Conservation and the Cawthron Institute.

[6] Data will be available for central Government, among others, for national reporting purposes. One of the key outcomes is the provision of environmental information for the Land, Air, Water Aotearoa (LAWA) website (www.lawa.org.nz).

[7] As the environmental monitoring and reporting system matures, this will provide for a higher-quality debate about the challenges New Zealand faces in managing its environment and natural resources.

DISCUSSION

[8] The Environmental Monitoring and Reporting (EMAR) framework's overall aim is to make fundamental changes to how the Regional Sector delivers environmental monitoring and reporting functions through the following data and information projects:

a. NEMS (National Environmental Monitoring Standards) – consistent approach to the collection of environmental data.
b. EDMS (Environmental Data Management System) – improved access to high quality data through driving consistency in the management and storage of environmental data.
c. LAWA (Land, Air Water Aotearoa) – telling the story of our environment through sharing high quality data and information online, to enable informed decision making.

[9] The EMAR framework projects are strategic initiatives for the regional sector and central government partner agencies involved in national environmental reporting.

[10] ORC hosts the EMAR framework and LAWA project on behalf of the project partners.

[11] The EMAR projects support capability and capacity building for the regional sector, by helping to address the following key trends identified for the regional sector's environmental data and information:

a. Increasing legislative obligations to provide broad range of environmental and national hazard information
b. Increasing demand for information on natural resources, especially areas of bottlenecks or quality problems (e.g. water)
c. Growing interest in areas of natural significance, biodiversity and coastal processes and natural resource protection more generally
d. Growing demand for open access and transparency in data provision, and greater expectations from community re: participation in decision making
e. Continued growth – both volume and complexity of data, and analytical tools to make sense of the data
f. New opportunities and disruptions from new digital technologies (e.g. particularly in the analytical and publication spaces)

(Source: Sapere Research Group, 2016, *Future challenges and opportunities in the provision of resource information for the Regional Sector*).

[12] The National Environmental Monitoring Standards (NEMS) are a series of environmental monitoring standards that prescribe clear guidance on processes, methodologies, and techniques to be applied as standard practice for monitoring environmental parameters across New Zealand. The NEMS project is/has been resourced (both direct funding and in-kind support) by the regional sector, central government agencies, crown research institutes and electricity companies. Further information can be found on the NEMS website (www.nems.org.nz).

[13] The Environmental Data Management System (EDMS) project is focusing on addressing the inconsistencies in the management and storage of environmental data by councils. Across the sector's environmental monitoring system, there are 16 different systems for the collection, storage, monitoring and reporting of time-series environmental data. There are inconsistencies in implementation even where common software solutions exist. Compounding the problem further, is the reality that there is a lack of consistency in terms of processes, quality assurance and standards applied to the sector's environmental data assets. The EDMS project is being funded by the regional sector.

[14] The Land, Air, Water Aotearoa (LAWA) website (www.lawa.org.nz) was launched in 2014, with the aim to connect communities to their environment by sharing high quality environmental data and information. There are over 5,000 monitoring sites over seven topics published on LAWA, and the website continues to build momentum as a recognised platform for the sector's State of the Environment data and information. The LAWA project is resourced (direct funding and in-kind support) by the regional sector (ranges from senior managers and technical specialists across the Special Interest Group (SIG) network covering the land, air and water domains, environmental managers and communication managers), the Ministry for the Environment, Department of Conservation, Statistics New Zealand and the Cawthron Institute. The Tindall Foundation was a founding supporter.

[15] LAWA is well regarded by the public, and with over 4 million page views to date, it is increasingly being used and recognised both within New Zealand and internationally, furthering the reach and value of the environmental data collected by the regional sector. Can I swim here? is the most popular topic and provides the latest water quality results as soon as they are available for over 700 swim sites across New Zealand.

[16] The top Otago pages viewed on LAWA include sites from the recreational water quality, air quality, river and lake quality and water quantity topics. People who are viewing the Otago region's pages are based throughout New Zealand, and most of these visitors find LAWA via google searches, typing the website name in directly, or are referred by the ORC website. Users from all age groups are visiting the Otago pages on LAWA with the majority of visitors being female. See Appendix A for a report on users visiting Otago pages on LAWA from 1 July 2020 – 30 June 2021.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[17] The EMAR portfolio projects are strategic initiatives for the regional sector and are included in the sector's business case. The work programmes for these projects are informed by current and emerging national policy requirements for environmental monitoring and reporting.

Financial Considerations

[18] The EMAR portfolio projects have their own funding arrangements.

Significance and Engagement Considerations

[19] Not Applicable

Legislative and Risk Considerations

[20] Not Applicable

Climate Change Considerations

[21] Data available could be an input into Climate Change science.

Communications Considerations

[22] Communications about the LAWA website follows an engagement process with communications managers from the LAWA project partners.

NEXT STEPS

[23] The EMAR portfolio projects continues to work with project partners and stakeholders to ensure alignment of common strategic priorities. For example, the LAWA project is looking at future improvements to the website by considering how LAWA can further support national environmental data and reporting requirements on the sector (e.g. NPS-FM 2020), and what opportunities there are to further support the sector's engagement with our communities through the provision of data and information.

ATTACHMENTS

1. LAWA Report _ Otago Region 1 Jul 2020-30 Jun 2021 [**7.2.1** - 2 pages]

LAND AIR WATER AOTEAROA

WEBSITE REPORT - OTAGO

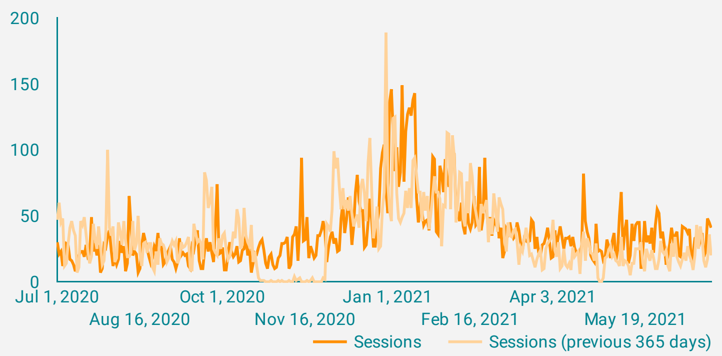
Data from Google Analytics

OTAGO REGIONAL INFORMATION

Jul 1, 2020 - Jun 30, 2021

Sessions	Users	Pageviews	Number of Sessions per User	Avg. Session Duration
13,561	8,489	36,285	1.6	00:01:48
↑ 1,220	↓ -295	↑ 3,105	↑ 0.19	↑ 00:00:01

How are site sessions trending?

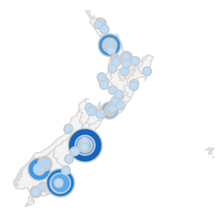


What are the top pages being viewed?

	Page	Pageviews ▾
1.	/explore-data/otago-region/	3,304
2.	/explore-data/otago-region/swimming/lake-hayes-at-mill-creek-shallows/swimsite	1,889
3.	/explore-data/otago-region/air-quality/	1,739
4.	/explore-data/otago-region/river-quality/	1,392
5.	/explore-data/otago-region/air-quality/mosgiel/mosgiel	971
6.	/explore-data/otago-region/lakes/	867
7.	/explore-data/otago-region/air-quality/arrowtown/arrowtown	789
8.	/explore-data/otago-region/swimming/brighton-beach-otokia-creek/swimsite	765
9.	/explore-data/otago-region/swimming/manuherikia-at-shaky-bridge/swimsite	740
10.	/explore-data/otago-region/water-quantity/monitoring-sites/dart-river-at-the-hillocks/	729

1 - 10 / 782 < >

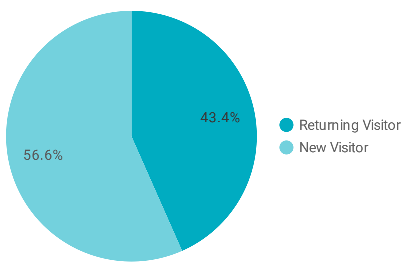
Sessions by location



	City	Sessions ▾
1.	Christchurch	3,742
2.	Dunedin	3,313
3.	Auckland	1,574
4.	Queenstown	1,339
5.	(not set)	998
6.	Wellington	795
7.	Wanaka	507
8.	Invercargill	121
9.	Tauranga	112
10.	Lower Hutt	68

1 - 100 / 203 < >

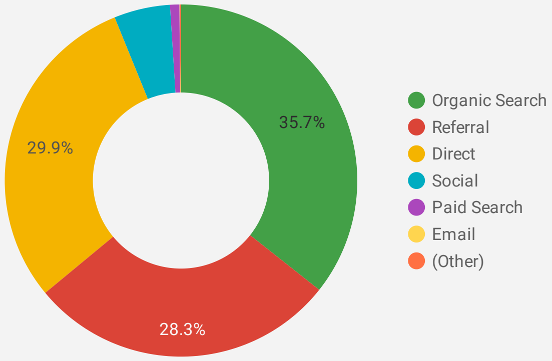
New vs. Returning Users



OTAGO REGIONAL INFORMATION

Jul 1, 2020 - Jun 30, 2021

Which channels are driving engagement?

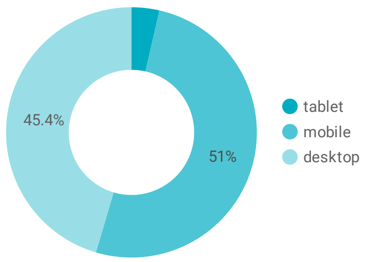


	Source / Medium	Sessions
1.	google / organic	4,614
2.	(direct) / (none)	4,047
3.	orc.govt.nz / referral	2,795
4.	m.facebook.com / referral	541
5.	bing / organic	157
6.	l.facebook.com / referral	118
7.	google / cpc	116
8.	mfe.govt.nz / referral	109
9.	goodwaterinotago.orc.govt.nz / referral	100
10.	metservice.com / referral	84
11.	i.stuff.co.nz / referral	84
12.	dunedin.govt.nz / referral	76
13.	stuff.co.nz / referral	75
14.	arrowtownvillage.nz / referral	53
15.	classroom.google.com / referral	44
16.	blackboard.otago.ac.nz / referral	31
17.	duckduckgo / organic	30
18.	ecan.govt.nz / referral	28
19.	environment.govt.nz / referral	26
20.	qldc.govt.nz / referral	25

1 - 20 / 116

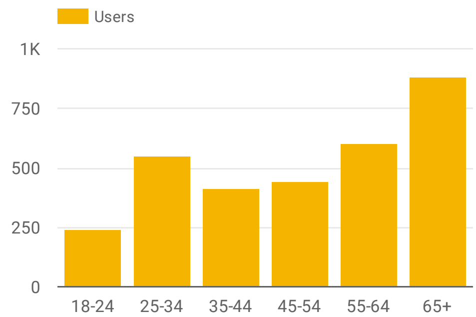
How are we being viewed?

Top Devices by Users

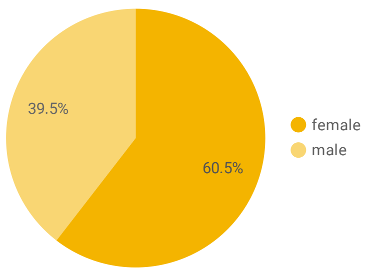


Who's looking?

Age



Gender



7.3. SoE Monitoring Biannual Update

Prepared for:	Data and Information Committee
Report No.	SPS2149
Activity:	Environmental - Water
Author:	Eike Breitbarth, Manager Environmental Monitoring
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	8 September 2021

PURPOSE

[1] This paper informs council about the data capture and quality produced from the environmental monitoring network operated by the ORC Environmental Monitoring team. The report covers the period 1 July 2020 – 30 June 2021.

EXECUTIVE SUMMARY

[2] The data report of the Environmental Monitoring (EM) team of the ORC summarises capture and data quality of the State of the Environment (SoE) and project monitoring in Otago for the past year. The EM team currently maintains a hydrological network of 273 sites, of which there are 169 SoE sites and 104 project sites. The monitoring network includes surface water hydrography, water temperature, rain fall, and ground water. This report reflects data collected from telemetered on-line monitoring infrastructure. Monitoring of water quality other than temperature and oxygen concentrations, biodiversity, air quality, and climate are not included in the report.

[3] This paper and report are informing council about the performance of the hydrological network operated by the EM team. The report is not advising about environmental parameters such as e.g., river levels and flow or water quality and thus is not describing the state of the environment in Otago nor is it indicative of any environmental changes.

[4] This report deviates to a certain extent from the previous report (SPS2108, 1 March 2021). A new data management software for the ORC has been implemented (Aquarius). The transfer from the previously used Hilltop software to Aquarius has been an involved process and data processing by the EM team has been on hold for an interim time during the system changeover. Thus, a significantly larger proportion of QC200 (raw data) than in previous reports is evident in the current report. The data is still being processed and their QC level will change with a subsequent report to this one once data processing is complete.

[5] For the period 1 July 2020 – 30 June 2021, 99.3% of hydrological network data capture was archived. Data quality is categorized into quality code (QC) levels, as defined by the National Environment Monitoring Standards (NEMS). QC levels range from QC0 (missing data) to QC600 (highest standard). Quality code targets depend on the monitoring type, with SoE surface hydrology targeted at QC600, while groundwater and project sites are generally targeted at QC500. Of all SoE site data archived (river stage and flow, groundwater, rainfall, water temperature, and dissolved oxygen in water), a total of 39% were of the highest quality standard (QC600), with 31% at QC500 level, while for project

sites 18% were at QC600 and 47% at QC500, respectively. The portion of raw data (QC200) is 18% for SOE sites and 26% for project sites, reflecting the effect of the change in data acquisition software when data processing was on hold.

RECOMMENDATION

That the Committee:

1) ***Notes*** *this report.*

BACKGROUND

[6] Environmental monitoring is a fundamental building block of the ORC and forms the bases for environmental analysis, planning, and decision making. Data produced are of crucial importance to a wide range of stakeholders involving sectors such as water users, source water protection for drinking water, and public health. River level and flow measurements, as well as rain sensor data are further elemental to flood prediction and flood monitoring.

[7] Continuous data are publicly available through the ORC-Water Info website (https://www.orc.govt.nz/managing-our-environment/water/water-monitoring-and-alerts) and these are easily accessed through an interactive map. The webpage also displays any alerts (e.g., low flow or flooding) and informs about rating changes and site maintenance. A further flood alert is available through region specific Twitter alerts. Water quality (including contact recreation) and air quality data are publicly available through the LAWA website (https://www.lawa.org.nz/explore-data/otago-region/). Reports of historic data are frequently produced by the EM data team on request.

[8] The monitoring network and its maintenance operate 365 days/year and relies strongly on continuous on-line field measurements, that are telemetered back to the office. This is complemented by manual in-field validation measurements for e.g., water flow, rainfall, and water quality. Further, a wide range of parameters such as water temperature or level in some groundwater bores are downloaded from deployed sensors during field visits and verified during additional manual measurements. The technical maintenance of the field infrastructure and telemetry network is carried out by the EM team.

[9] The monitoring network is differentiated into standard SoE sites and project sites. Project sites are installed based on requests from other teams (mainly the Science team) and are generally designed for temporary investigations. However, these sites frequently become a permanent part of the network.

[10] Quality coding of the data depends on the installation type (instrumentation) and is verified by the EM data team constantly. Quality coding standards are set by the National Environment Monitoring Standards (NEMS, http://www.nems.org.nz/) and are observed NZ wide. Quality codes are QC600 and QC500, which both describe a high level of accuracy and differ operationally. Further codes are QC400 (poor), QC300 (synthetic), QC200 (raw data), and QC0 (missing data). Until telemetered data are verified by the EM data team, all data are coded as QC200 (raw data).

DISCUSSION

[11] The report refers to the time period 1 July 2020 – 30 June 2021, covering data capture and quality analysis for surface water hydrography, rainfall, groundwater, as well as water temperature and oxygen content.

[12] Surface Water Hydrography:
A key component of surface SoE reporting are data on river level (stage) and flow (discharge), which are produced from telemetered sites continuously measuring the water level in the rivers. The quality control target for SoE surface water measurements is QC500 or better, depending on site and installation type. 82% of the captured stage data was at QC500 level or higher (40% thereof at QC600). Of the flow data, 84% of the captured data was QC500 or higher, of which 48% were at QC600 level. The QC200 levels of ~ equal 7% for stage and discharge are the lowest levels for the SoE network (except groundwater (see below)), indicating that priority was given to hydrographic data processing. It should be noted, that QC500 is a high level of data quality, but that the measurement resolution drops from +/- 3mm to +/-10mm. (NEMS, http://www.nems.org.nz/assets/Documents/NEMS-14/Water-Level-v3.0.pdf).

[13] Rainfall:
For the SoE rainfall sites, 51% of data was reported as QC600, while 19% was coded to OC500. 25% of the captured data remain unverified (QC200). Less than 1.15% of the expected data is missing, which is relatively low. The lost data largely correspond to alpine sites that are inaccessible during winter and are subjected to snow fall.

[14] Groundwater:
The SoE groundwater sites performed well. 71% comply with the set target of QC500 and 21% are classed as QC400 (poor). 4% are still classified as raw data (QC200) and 2% data capture was lost. Of the manually measured and project sites 86% achieve the QC500 standard, while 14% are classified as raw data (QC200).

[15] Water quality:
49% for telemetered SoE water temperature sites, and 66% for manually downloaded field deployed temperature loggers achieved QC500 or QC600 standards. Here the proportion of the raw data is still relatively high 37% and 28% for SOE and project sites, respectively. Data quality of the deployed oxygen sensors was 42% QC500 or higher with the remaining fraction largely yet to be processed (QC200).

[16] General trend in data quality:
Data capture and quality produced of the ORC environmental monitoring network are of a high standard overall. Comparing full calendar year analysis of 2020 vs. the 2021 calendar year to date though, a lower proportion of QC500 and QC600 data and an increase of unverified raw data (QC200) are evident. This ratio shift was to a large extent due to disruptive events associated with the change to the Aquarius data acquisition platform on data processing at the time. Data processing has been delayed during the past months and thus resulted in the increased proportion of the QC200 raw data. Ongoing data processing will result in this proportion being reduced significantly during the upcoming months and an increase in the QC500 and QC600 levels is expected.

CONSIDERATIONS

Policy Considerations

[17] The SoE network monitoring as well as project sites are being used to support the development of the Land and Water Plan. The SoE Network also supports air quality modelling in compliance with the National Environmental Standard and Regional Air Plan. It will inform the Regional Air Plan Review planned in 2022.

Financial Considerations

[18] Nil

Significance and Engagement

[19] The EM team is an essential service provider to ORC internal and external stakeholders, as well as to the public in general, and to Civil Defence. Data produced are of direct importance for guidance and decision making for public health and safety, environmental and cultural values, and the Otago economy.

Legislative Considerations

[20] Nil

Risk Considerations

[21] Data reported to the highest quality standard are essential for natural resource management. For example, highly accurate river level and flow data are crucial for irrigation take allocations. This data is frequently scrutinized and challenged by stakeholders. Flood monitoring and modelling/prediction strongly depend on uninterrupted accurate data flow. Compromises in data quality and data capture can have adverse effects on Civil Defence decisions.

NEXT STEPS

[22] The ORC SoE monitoring network will be reviewed in order to implement the upcoming monitoring requirements of the recently revised National Policy Statement – Freshwater Management (NPS-FM). Structure and management of the network will be reviewed for technology and 'future proofing', internal operation processes, and resourcing, with the goal to continuously achieve a continuously high level of service.

[23] An update of data capture and data quality of State of the Environment and project hydrological monitoring will be provided at future Data & Information Committee meeting.

ATTACHMENTS

1. E M-data Report 30 Aug 2021 [**7.3.1** - 7 pages]

Otago Regional Council

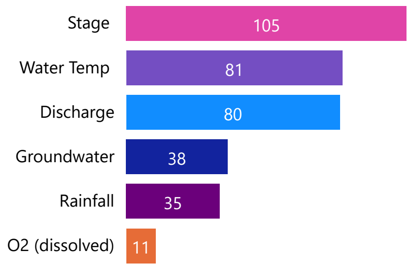
Environmental Data Report

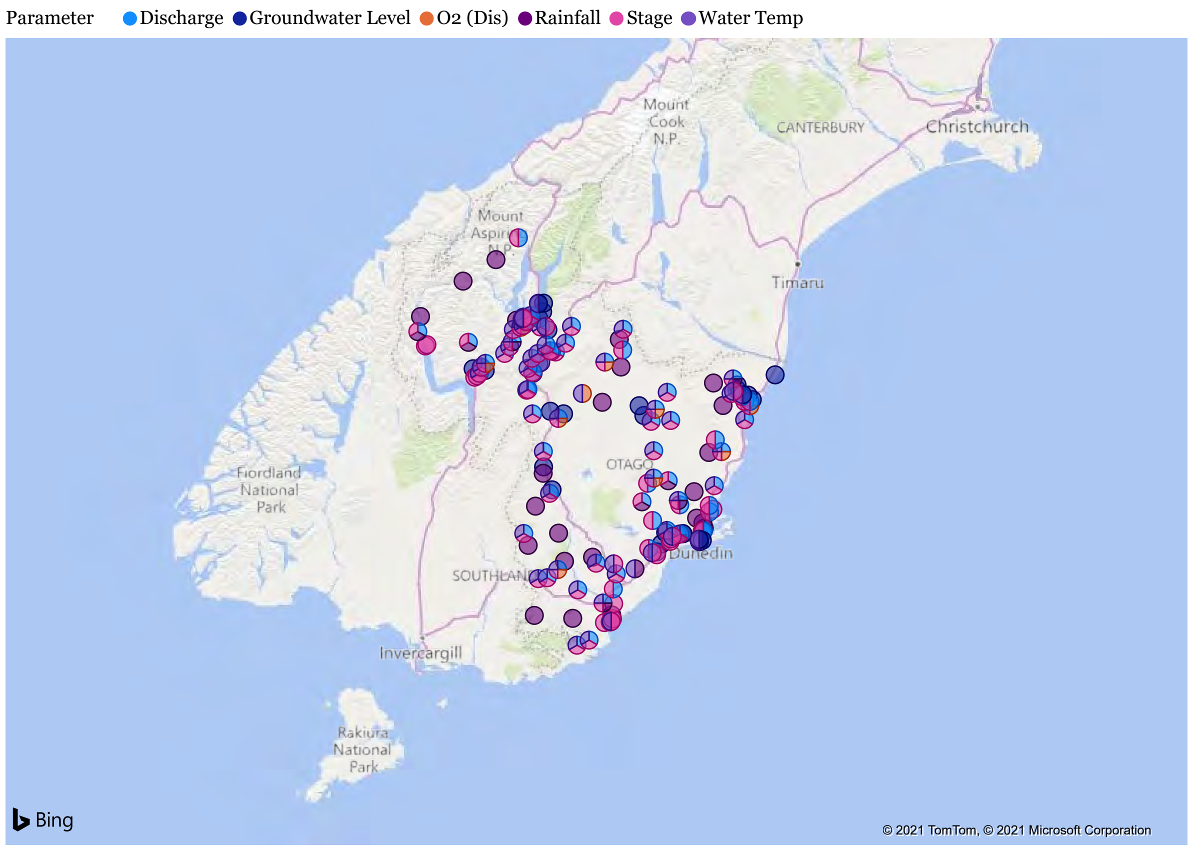
Environmental Monitoring Team

2021/08/30

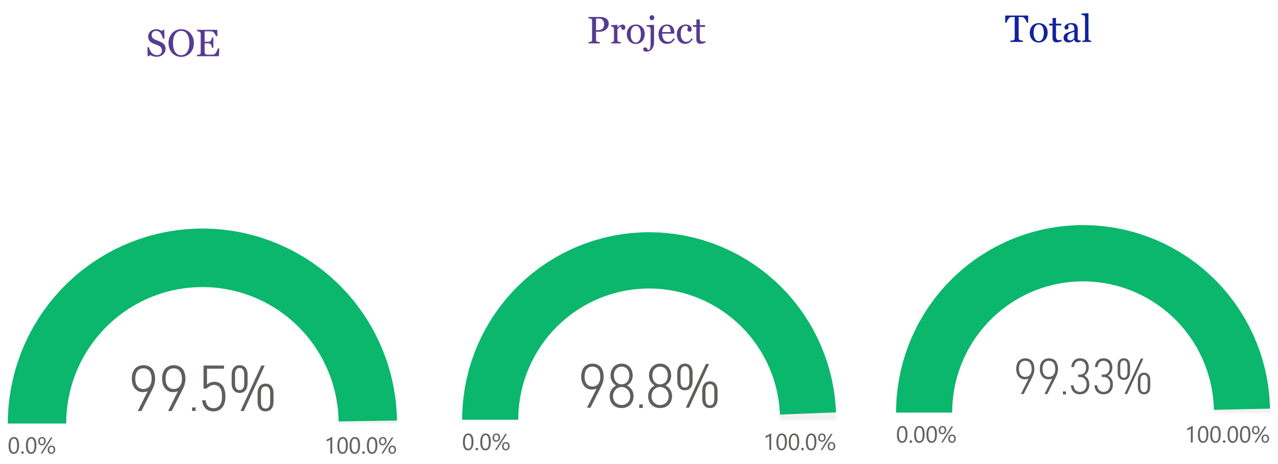
Overview of Telemetered Sites

Telemetred Site Distribution by Parameter





Data capture during 2020.7.1-2021.6.30



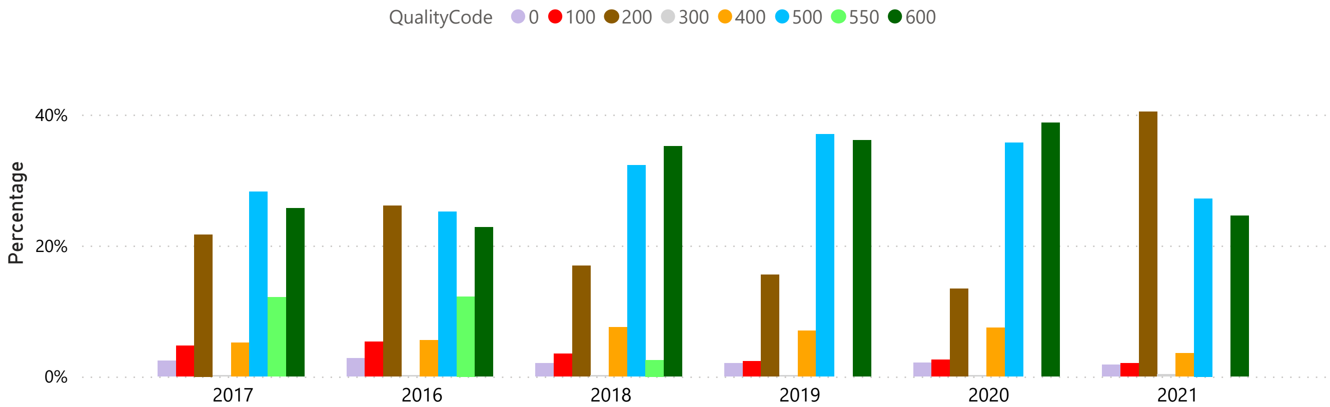
Data and Information Committee 2021.09.08

Data Quality between 2016-2021

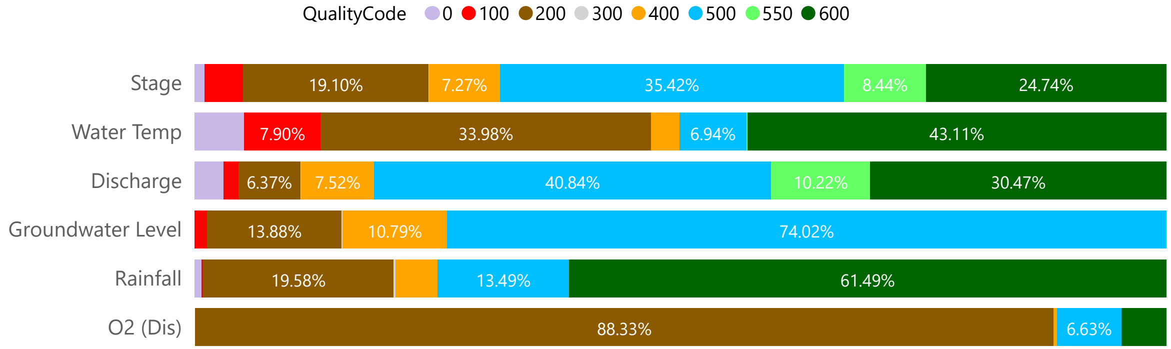
Year

- [ ] 2016
- [ ] 2017
- [ ] 2018
- [ ] 2019
- [ ] 2020
- [ ] 2021

Proportion of Quality Code by Year



Proportion of Quality Code by Parameter



Parameter

- [ ] Discharge
- [ ] Groundwater Level
- [ ] O2 (Dis)
- [ ] Rainfall
- [ ] Stage
- [ ] Water Temp

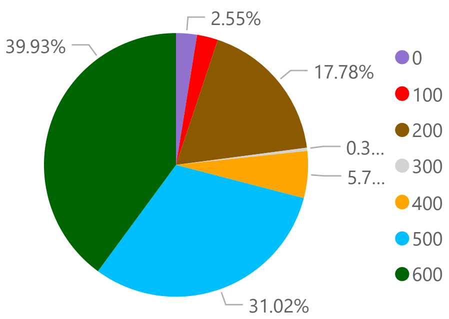
Data and Information Committee 2021.09.08

Data Quality during 2020-2021 - SOE Sites

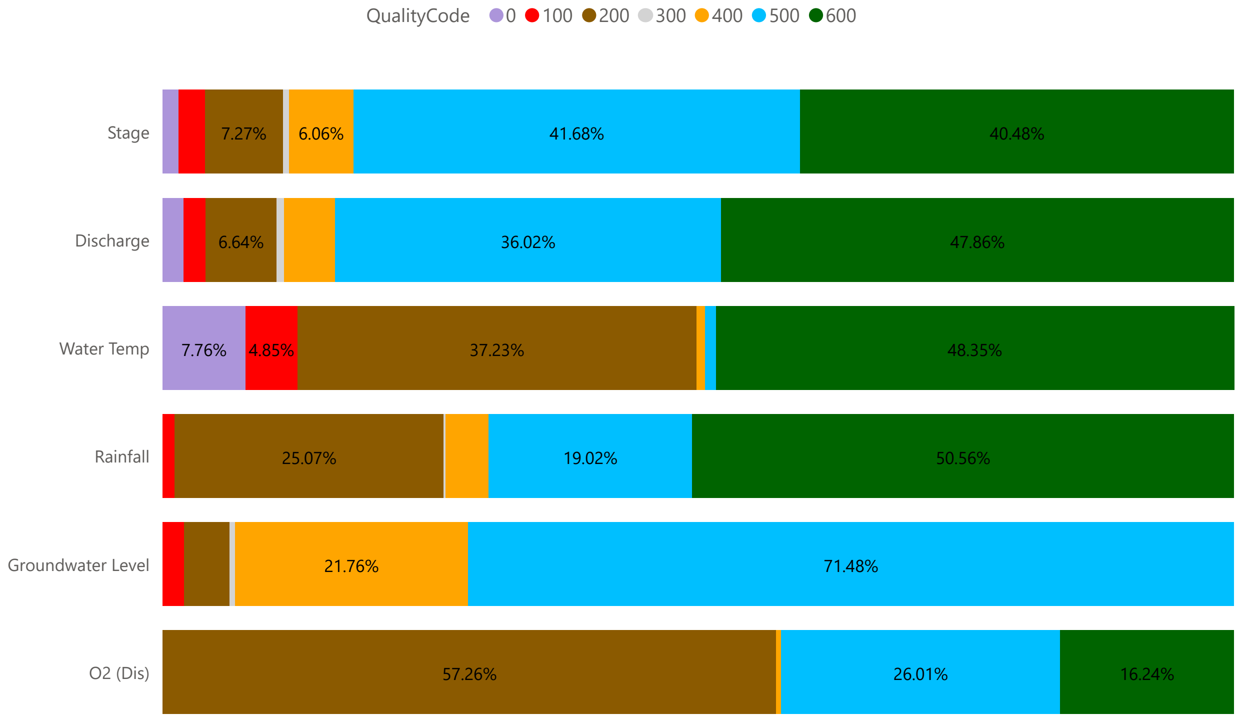
SiteGroup/LocationName

- Project
- SOE

Proportion of Quality Code



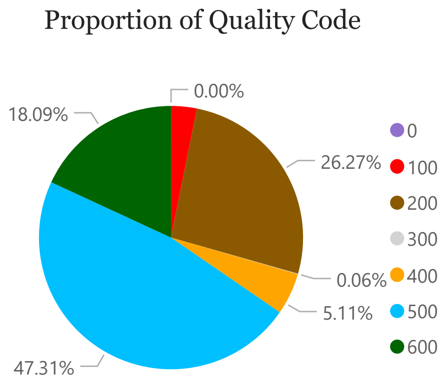
Proportion of Quality Code by Parameter

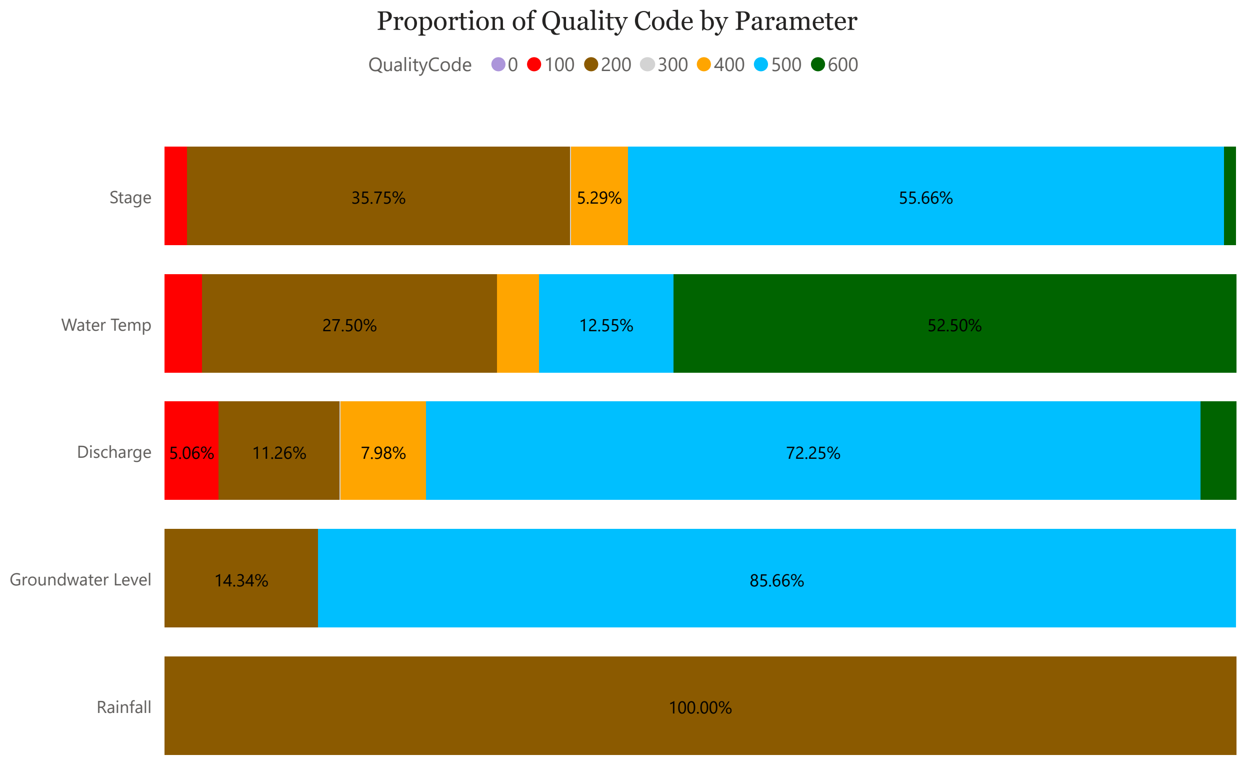


Data Source : The data is exported from Aquarius Time Series and time range is from 1/07/2020 00:00 to 30/06/2021 00:00.

Data Quality during 2020-2021 - Project Sites

SiteGroup/LocationName
- Project
- SOE

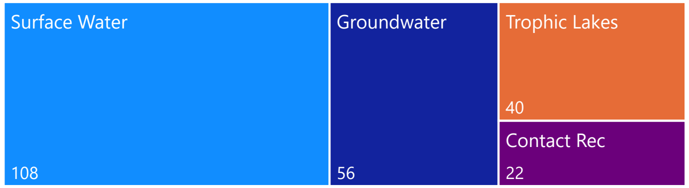




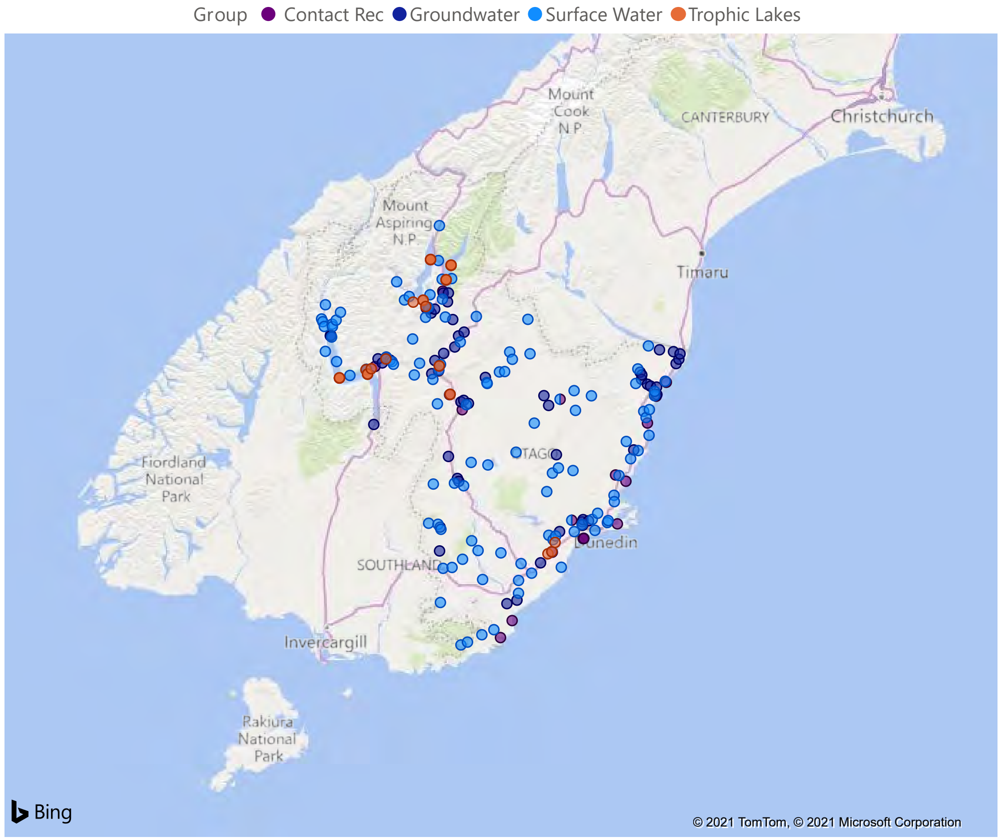
Data Source : The data is exported from Aquarius Time Series and time range is from 1/07/2020 00:00 to 30/06/2021 00:00.

Overview of Water Sampling Sites and Runs

Site Count by Group (226 in total)



Distribution of Otago Water Sampling Sites



7.4. LakeSPI Report

Prepared for: Data and Information Committee

Report No. SPS2147

Activity: Governance Report

Author: Hugo Borges, Scientist - Lakes

Endorsed by: Gwyneth Elsum, General Manager Strategy, Policy and Science

Date: 8 September 2021

PURPOSE

[1] To report on the ecological condition of six lakes in the Otago region (Hāwea, Wakatipu, Wānaka, Hayes, Dunstan, and Onslow) using the Lake Submerged Plant Indicator (LakeSPI) developed by NIWA.

EXECUTIVE SUMMARY

[2] Otago Regional Council has contracted NIWA to assess and report on the LakeSPI for six lakes in Otago (Attachment 1).

[3] Monitoring the Lake Submerged Plants Indices is a requirement of the National Policy Statement for Freshwater Management 2020 (NPS-FM 2020) and must be conducted at least once every three years. This is the first time ORC has collected LakeSPI information in the Otago region's lakes and this analysis will be incorporated into our State of the Environment (SOE) programme from now on.

[4] The LakeSPI indices for the six Otago lakes studied in the report ranged from 40% to 82%. Using this information, the lakes were categorised into one of five categories (excellent, high, moderate, poor, and non-vegetated) and compared with 314 lakes nationally. The Otago region has a higher proportion of lakes in the excellent, high, and moderate LakeSPI categories when compared with lakes nationally.

[5] Three Otago lakes were found to be in excellent condition: Hāwea, Wakatipu, and Wānaka. These three lakes have substantial native vegetation, with very little impact from invasive weed species. Lake Onslow was categorised to be in high condition with a well-developed native plant community and/or limited impacts from invasive species. Lakes Dunstan and Hayes were categorised as being in moderate condition due to some impact from invasive weeds and/or the restricted development of native plant communities.

RECOMMENDATION

That the Committee:

1) ***Receives*** *this report.*

BACKGROUND

[6] LakeSPI (pronounced "lake spy") is a management tool that uses Submerged Plant Indicators (SPI) for assessing the ecological condition of New Zealand lakes and to monitor trends in the ecological and biological condition of lakes.

[7] Aquatic plants can be divided into distinct depth-related community types ranging from the lake margin down to the deepest plant growth where light penetration becomes limiting for plant growth. This is shown in the depth profile drawing (Figure 1), of the general vegetation structure of many New Zealand lakes.

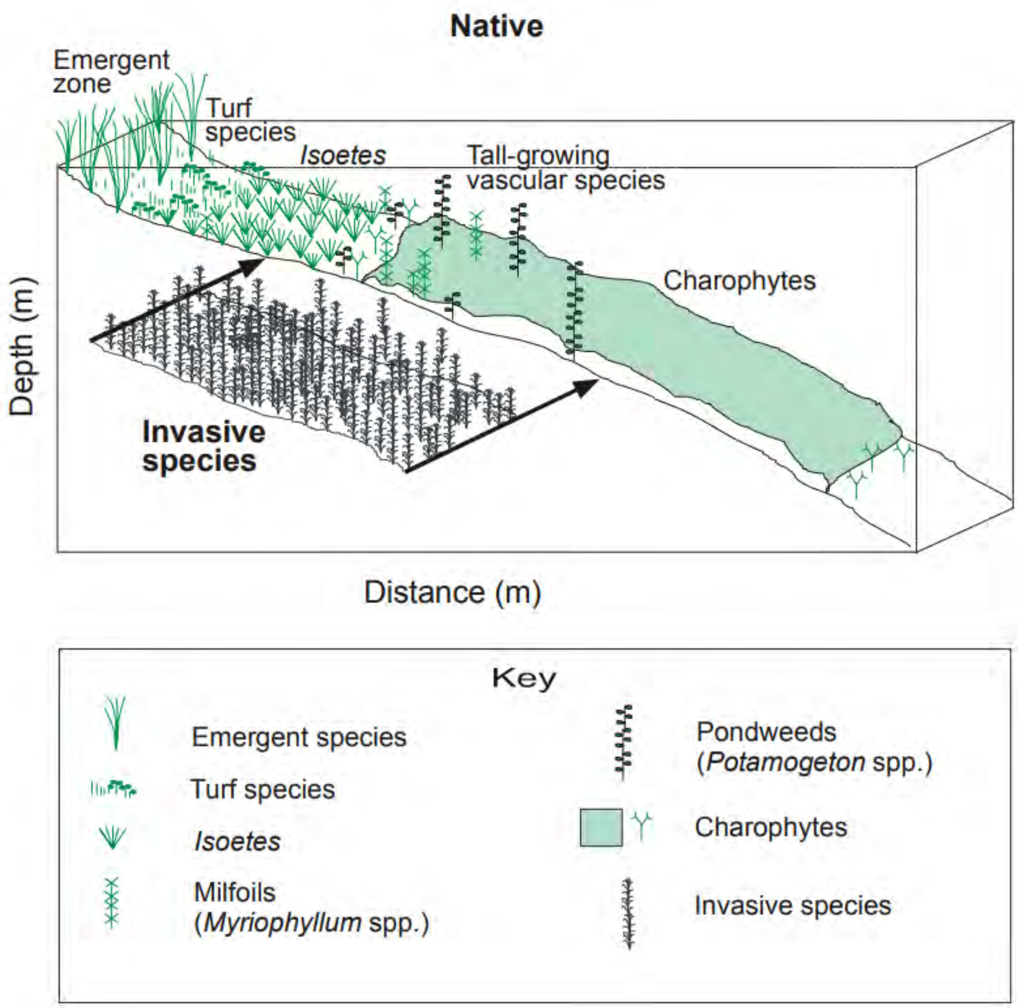


Figure 1 - Depth profile illustrating the main components of native lake vegetation and the region of substitution by invasive species[1].

[8] The above 'typical vegetation profile' describes native community types found widely throughout New Zealand lakes irrespective of lake size. However, this changes whenever invasive submerged species become established in a lake. All the main invasive weed

[1] Extracted from Clayton, J., Edwards, T. (2006) LakeSPI – A Method for Monitoring Ecological Condition in New Zealand Lakes. Technical Report, Version Two. June 2006: 67

species which affect lake vegetation structure are tall-growing angiosperms, with a distinctive difference in growth from the native milfoils and pondweeds. These invasive species can form extremely dense growths that exclude all other vegetation. They typically occupy the mid-depth range of lakes and are most common between two to eight metres in depth. Although they can grow to a depth of ten metres, their greatest impact tends to be between two to five metres where they are able to exclude most native species. There are several different invasive species present throughout New Zealand, each with their own characteristics.

[9] Key features of aquatic macrophyte[2] structure and composition are used to generate three LakeSPI indices (Figure 1):

- 'Native Condition Index' – This describes the native character of vegetation in a lake based on the diversity and quality of the indigenous plant communities.
- 'Invasive Condition Index' – This describes the invasive character of vegetation in a lake based on the degree of impact from invasive weed species.
- 'LakeSPI Index' – This is a combination of components from both the native condition and the invasive condition of a lake and provides an overall indication of the lake ecological condition.

[10] LakeSPI provides a cost-effective management tool that is relatively straightforward in its application, and which is relevant for use by ORC in all lakes where submerged vegetation is present.

[11] LakeSPI can be used in many ways depending on the needs of individual lakes or for a selection of lakes. The LakeSPI indices will allow ORC to:

- Ensure national bottom lines, as set under the NPS-FM 2020, are not reached for lakes in the Otago region (Figures 2 and 3).
- Assess and compare the ecological condition of different lakes within or between regions.
- Rank the state of lakes in the region and prioritise those most in need of protection, surveillance, or management.
- Monitor trends occurring in lakes over time.
- Compare current lake condition with indices generated from historical vegetation records.
- Make comparisons between dissimilar lakes with different depths and from different regions.
- Provide relevant information for regional and national reporting requirements, including operational monitoring and state of the environment reporting.
- Help assess the effectiveness of catchment and lake management initiatives.

[2] Aquatic plant large enough to be seen by the naked eye

[12] It is intended that LakeSPI will complement rather than replace other lake assessment methods.

Table 11 – Submerged plants (natives)

Value (and component)	Ecosystem health (Aquatic life)
Freshwater body type	Lakes
Attribute unit	Lake Submerged Plant (Native Condition Index)
Attribute band and description	**Numeric attribute state (% of maximum potential score)**
A Excellent ecological condition. Native submerged plant communities are almost completely intact.	>75%
B High ecological condition. Native submerged plant communities are largely intact.	>50 and ≤75%
C Moderate ecological condition. Native submerged plant communities are moderately impacted.	≥20 and ≤50%
National bottom line	**20%**
D Poor ecological condition. Native submerged plant communities are largely degraded or absent.	<20%

Monitoring to be conducted at least once every three years, following the method described in Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2*. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (*see* clause 1.8)

Scores are reported as a percentage of maximum potential score (%) of the Native Condition Index, and lakes in a devegetated state receive scores of 0.

Figure 2 - National Policy Statement for Freshwater Management 2020 attribute table 11 for native submerged plants.

Table 12 – Submerged plants (invasive species)

Value (and component)	Ecosystem health (Aquatic life)
Freshwater body type	Lakes
Attribute unit	Lake Submerged Plant (Invasive Impact Index)
Attribute band and description	**Numeric attribute state (% of maximum potential score)**
A No invasive plants present in the lake. Native plant communities remain intact.	0%
B Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.	>1 and ≤25%
C Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaced by invasive weed beds particularly in the 2 – 8 m depth range.	>25 and ≤90%
National bottom line	**90%**
D Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. The species concerned are likely hornwort and Egeria.	>90%

Numeric attribute state to be calculated annually following the method described in Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2.* National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (*see* clause 1.8)

Figure 3 - National Policy Statement for Freshwater Management 2020 attribute table 12 for invasive species submerged plants.

DISCUSSION

[13] Lakes Hāwea, Wakatipu, Wānaka, Hayes, Dunstan, and Onslow were assessed in this report. The current LakeSPI status for these lakes includes three ranked in excellent condition, one in high condition and two in moderate condition categories (Table 1). The lakes in excellent condition were Hāwea, Wakatipu, and Wānaka. These lakes have substantial native vegetation (Native Condition Index > 75%), with very little impact from invasive weed species (Invasive Impact Index < 13%). Lake Onslow was categorised in high condition with a well-developed native plant community and/or limited impacts from invasive species. Lakes Dunstan and Hayes were categorised in moderate condition. These two lakes show some impact from invasive weeds and/or the restricted development of native plant communities.

[14] Lakes Hāwea, Wakatipu, and Wānaka fall into the A band for the native submerged plants attribute of NPS-FM 2020, Lakes Onslow and Dunstan in B, and Hayes into C band.

[15] In the invasive submerged plants attribute of the NPS-FM 2020, most of our lakes fall into the B band (Lakes Hāwea, Wakatipu, Wānaka, and Onslow), while lakes Dunstan and Hayes are placed in the C band.

[16] None of the Otago lakes surveyed were categorised as in poor or non-vegetated condition.

Table 1 – A summary of the current LakeSPI Indices for six lakes in the Otago Region in order of their overall lake condition and NPS-FM 2020 attribute band.

Lake	Most Recent LakeSPI Survey	LakeSPI Index (%)	Native Condition Index (%)	NPS-FM 2020 Atribute band (native)	Invasive Impact Index (%)	NPS-FM 2020 Atribute band (invasive)	Overall Condition (LakeSPI status)
Hāwea	26/02/2020	82	80	A	12.6	B	Excellent
Wakatipu	2/11/2020	81	77.3	A	11.9	B	
Wānaka	4/11/2020	78	78.7	A	20.7	B	
Onslow	6/11/2020	67	53	B	17.3	B	High
Dunstan	5/11/2020	49	57.2	B	55.6	C	Moderate
Hayes	26/02/2020	40	29.3	C	45.2	C	

[17] The most common weeds present in the Otago lakes were Elodea, *Juncus bulbosus*, and lagarosiphon. An ongoing lagarosiphon management programme is in place to prevent the spread of lagarosiphon in Wānaka and Wakatipu. If the control programme for Lake Wānaka and Wakatipu was discontinued and lagarosiphon was allowed to spread unchecked, we could expect a significant decrease in LakeSPI scores in the future. Comparable results would be anticipated for other lakes of the region.

[18] Deep water bryophyte plants, a globally rare vegetation, were previously found in lake Wakatipu in 1982 and 1992 but were not recorded in NIWA's 2020 LakeSPI. This might be due to the 20m diving limitation. NIWA has recommended an investigation to establish presence/absence of deeper growing bryophytes in the Otago lakes. The viability of this project will be assessed by ORC science team.

[19] LakeSPI surveys are scheduled to happen every three years in all SOE monitored lakes in Otago, in accordance with the NPS-FM requirements and NIWA's recommendations.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[20] LakeSPI surveys fit with ORC's Strategic Directions to monitor and investigate water quality and ecosystem health (NPS-FM 2020).

Financial Considerations

[21] The current Long-Term Plan (2021-2031) allocated $480,000 in the State of Environment monitoring programme budget for future submerged plant surveys in eight Otago lakes every three years.

Significance and Engagement Considerations

[22] N/A

Legislative and Risk Considerations

[23] N/A

Climate Change Considerations

[24] LakeSPI results will provide an important source of data and information for future predictive climate change models and will support research in this area, as submerged plants are most affected by temperature increases and indirect impacts on water clarity.

Communications Considerations

[25] LakeSPI data will be available in the LAWA and NIWA's LakeSPI website.

[26] LakeSPI data will be incorporated in future Surface Water State of the Environment reports.

NEXT STEPS

[27] Next LakeSPI surveys will be performed in the year 2021/2022 in Lakes Tuakitoto, Waihola and Tomahawk lagoon. And then every three years for Lakes Hāwea, Wakatipu, Wānaka, Hayes, Onslow, Dunstan, Tuakitoto, Waihola, and Tomahawk lagoon.

ATTACHMENTS

1. Assessment of six lakes in the Otago Region using LakeSPI [**7.4.1** - 44 pages]

Assessment of six lakes in the Otago Region

using LakeSPI

Prepared for Otago Regional Council

June 2021

Climate, Freshwater & Ocean Science

Prepared by:
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Quality Assurance Statement		
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	Approved for release by:	Michael Bruce

Contents

Tables

Figures

Executive summary

Otago Regional Council contracted NIWA to report on the ecological condition of six lakes in the Otago region using LakeSPI (Submerged Plant Indicators). LakeSPI is a bioassessment method that uses the degree of development by native submerged plants, and level of impact by non-native, invasive weeds to indicate a lakes ecological condition. Lakes were assessed over two survey occasions in February and November 2020.

LakeSPI indices for the six Otago lakes (Hāwea, Wakatipu, Wānaka, Onslow, Dunstan, Hayes) ranged from 40% to 82% and lakes were categorised into five categories according to the value of the most recent LakeSPI Index and compared with 314 lakes nationally.

Excellent: three lakes in the Otago Region had a LakeSPI Index > 75% that classified them to be in excellent ecological condition according to LakeSPI. This included lakes Hāwea, Wakatipu and Wānaka. These water bodies had substantial native vegetation with no or very little impact from invasive weed species. A high proportion of Otago lakes fall into this excellent category compared with lakes nationally.

High: one lake had a LakeSPI Index > 50-75% that classified it to be in high ecological condition. Lake Onslow supported a well-developed native plant community and had only limited impacts from invasive species. The introduced rush *Juncus bulbosus* was the only invasive species recorded from the shallow margins of Lake Onslow and it was having little impact on the submerged vegetation.

Moderate: two lakes were categorised in moderate condition with LakeSPI indices of > 20-50%. This included lakes Dunstan and Hayes. Both of these lakes reflected differing degrees of impact from invasive weeds and/or restricted development of native plant communities. A higher proportion of Otago lakes fall into this moderate category compared with lakes nationally.

Poor and non-vegetated: none of the Otago lakes had LakeSPI indices < 20%, that would categorise them in poor condition, or vegetation covers < 10% that would classify them as non-vegetated.

LakeSPI results were also compared with historical vegetation surveys to identify changes over time. Lakes Hāwea and Hayes appear to have remained in a stable condition since 1983 and 1992 respectively. Lakes Wakatipu and Wānaka both showed probably signs of decline since the earliest surveys in 1982 mainly on account of an overall reduction in the depth extent of vegetation. There were no previous submerged vegetation surveys of Lakes Onslow and Dunstan.

LakeSPI surveys can be used to ensure national bottom lines, as set under the National Policy Statement for Freshwater Management 2020, are not exceeded for lakes of the Otago region. All six of the Otago lakes surveyed for this report were above the national bottom lines set for component indices, the *Native Condition Index* and *Invasive Impact* and maintained their position within their current scoring band.

It is recommended that a schedule for LakeSPI monitoring be developed with priorities and timing for re-surveys based on perceived lake value, stability and known threats to the lakes. LakeSPI surveys are generally recommended every five years for lakes that are considered stable. However, some significant changes in the depth extent of deeper growing plants (> 20 m) in Lakes Wakatipu and Wānaka would benefit from monitoring on a more frequent basis (e.g., every 2-3 years).

An investigation to establish the presence/absence of globally threatened deep-water bryophytes in these lakes would also be recommended.

1 Introduction

1.1 Background

The Otago Regional Council (ORC) is responsible for managing Otago's water resources (ORC 2020), including 63 lakes in the region that are 10 hectares in size or larger. ORC have a duty to monitor, report and make information available about the state of the freshwater environment and must also plan and regulate to protect water resources with minimised or mitigated impacts to the natural environment.

Amongst the threats to lakes in the region are land use changes and agricultural intensification which can result in increased nutrient loads to water bodes. The introduction of alien aquatic invaders such as weeds or algae puts further pressure on vulnerable native ecosystems.

Lake surveys using LakeSPI (Submerged Plant Indicators), a biomonitoring method used to assess the ecological condition of lakes, was carried out in six lakes (Dunstan, Hāwea, Hayes, Onslow, Wakatipu, Wānaka) in 2020.

This report provides LakeSPI results for each lake accompanied by a brief description of vegetation character, notes on any historical vegetation surveys carried out and a discussion of LakeSPI results and any impacts or threats that may be facing these lakes. Where possible, recent LakeSPI results were also compared with those generated from historical vegetation surveys to identify changes over time.

LakeSPI results for two further Otago lakes (Diamond and Moke) carried out for Department of Conservation in 2007 (de Winton and Champion 2008) are not discussed in this report but are included in the national comparison summary (Section 4.2).

1.2 Study lakes

Six lakes located within the Otago Region have been assessed for this report: Dunstan, Hāwea, Hayes, Onslow, Wakatipu and Wānaka (Figure 1).

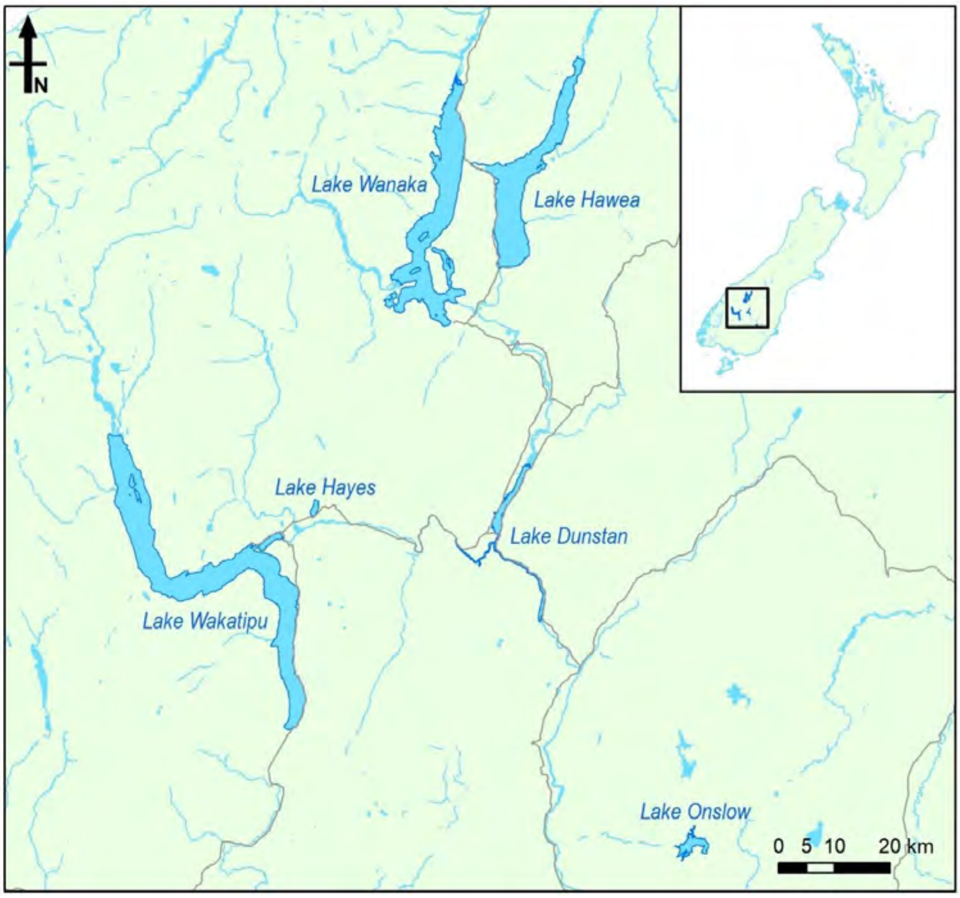


Figure 1: Map showing location of the six Otago lakes surveyed using LakeSPI for this report.

2 Methods

2.1 LakeSPI

LakeSPI is a management tool that uses Submerged Plant Indicators (SPI) for assessing the ecological condition of New Zealand lakes and for monitoring changes in lakes. Key features of aquatic vegetation structure and composition are used to generate three LakeSPI indices:

- 'Native Condition Index' – This captures the native character of vegetation in a lake based on diversity and extent of indigenous plant communities. A higher score means healthier, deeper, diverse beds.
- 'Invasive Impact Index' – This captures the invasive character of vegetation in a lake based on the degree of impact by invasive weed species. A higher score means more impact from introduced species, which is often undesirable.
- 'LakeSPI Index' – This is a synthesis of components from both the native condition and invasive impact condition of a lake and provides an overall indication of lake condition. The higher the score the better the condition.

Key assumptions of the LakeSPI method are that native plant species and high plant diversity represents healthier lakes or better lake condition, while invasive plants are ranked for undesirability based on their displacement potential and degree of measured ecological impact (Clayton and Edwards 2006, de Winton et al. 2012). Up to six native plant communities are recognised by LakeSPI: Emergents, Turf plants, Charophytes, Isoetes, Milfoils, and Pondweeds. In addition, up to 10 invasive weed species are recognised and contribute to the Invasive Impact Index.

Because lakes have differing physical characteristics that can influence the extent and type of submerged vegetation, each of the LakeSPI indices are expressed in this report as a percentage of a lake's maximum scoring potential. Scoring potential reflects the maximum depth of the lake to normalise the results from very different types of lakes. A lake scoring full points for all LakeSPI indicator criteria would result in a theoretical LakeSPI Index close to 100%, a Native Condition Index of 100% and an Invasive Impact Index of 0%.

A complete description of measured characteristics is given in the technical report and user manual at www.lakespi.niwa.co.nz/about but includes measures of diversity from the presence of key plant communities, the depth extent of vegetation and the extent that invasive weeds are represented. The LakeSPI method is supported by a web-reporting service found at www.lakespi.niwa.co.nz, where scores for lakes assessed to date can be searched and displayed. This secure and freely-accessible data repository allows agencies to compare lake scores with other lakes regionally and nationally as required.

2.2 Field surveys

The LakeSPI method (Clayton and Edwards 2006) was applied to 3-5 LakeSPI baseline sites (Appendix B) selected within each of the six Otago lakes. Lakes Hāwea and Hayes were assessed in February 2020, and lakes Dunstan, Onslow, Wakatipu and Wānaka in November 2020 (Table 1). Baseline sites were selected to be representative of maximal vegetation development and situated away from local influences such as streams. Where possible sites were also aligned with those where historical survey data was available.

At each site divers recorded relevant vegetation characteristics on data sheets. Observations were then entered into the NIWA LakeSPI database and used to calculate LakeSPI indices for each lake. Additionally, an inventory of all submerged plant species encountered was also made (Appendix A). Speices lists are beyond the scope of a regular LakeSPI survey but have been provided as additional records to support the lake by lake interpretation of results.

All equipment and boats were decontaminated between sites according to NIWA's standard operating procedures to prevent the spread of freshwater invasive species (Burton 2019). These precautions equal or exceed the Check, Clean, Dry protocols (MPI 2017).

Table 1: Otago lakes surveyed using LakeSPI in 2020 showing maximum lake depth, date of survey and number of sites surveyed.

Lake	Lake depth (m)	Survey date	Baseline sites
Lake Dunstan	40	5 November 2020	5
Lake Hāwea	384	26 February 2020	5
Lake Hayes	32.9	26 February 2020	5
Lake Onslow	9.5	6 November 2020	3
Lake Wakatipu	380	2 November 2020	5
Lake Wānaka	311	4 November 2020	5

2.3 LakeSPI status

For ease of reporting results, five lake condition categories are used to provide a description of a lakes status at the time of a survey. These categories are allocated according to the LakeSPI Index score:

Score	=	LakeSPI Category
>75%	=	Excellent
>50-75%	=	High
>20-50%	=	Moderate
>0-20%	=	Poor
0%	=	Non-vegetated

2.4 LakeSPI stability

Changes in LakeSPI indices can be assessed over multiple surveys to provide an indication of current stability in lake condition and the direction of any change. Where historical vegetation data was available, LakeSPI indices were generated from information recorded from the same current day baseline site locations. Guidelines (Figure 2) based on expert judgement suggest a scale of probabilities for ecologically significant change in lake condition over longer periods and multiple surveys, using averaged LakeSPI indices over repeated surveys. These guidelines considered variation by different observers and the response of LakeSPI scores to major ecological events in lakes. The significance for the various levels of change are:

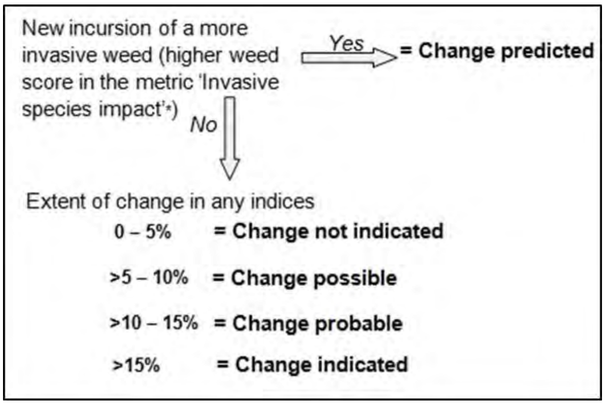


Figure 2: Guidelines for assessing the ecological significance of change in LakeSPI Indices over multiple surveys of a given lake.

In addition, the likelihood of a statistically significant change in LakeSPI scores over time was based on analysis of the direction and magnitude of change in indices across the surveyed sites. A paired t-test (GraphPad InStat) was used to compare site results between surveys at the significance level p <0.05.

2.5 National Policy Statement for Freshwater Management

In the National Policy Statement for Freshwater Management 2020 (NPS-FM 2020) that came into force in August 2020, component indices of LakeSPI, *Native Condition Index* and *Invasive Impact Index* were adopted as new ecosystem health attributes with national bottom lines (Table 2). If the identified bottom lines are not met, or declines are observed (e.g., movement to a lower band), regional councils are tasked with working towards desired outcomes (presumably undertaking remedial actions to improve indices to a desired level) through non-statutory action plans.

Table 2: NPS-FM attribute bands for the Native Condition Index and Invasive Impact Index (LakeSPI).

Attribute band	Native Condition Index	Invasive Impact Index
A	>75%	0
B	>50 and ≤75%	>1 and ≤25%
C	≥20 and ≤50%	>25 and ≤90%
National bottom line	20%	90%
D	<20%	>90%

3 LakeSPI report cards

This section provides individual report cards for the Otago lakes surveyed in 2020 using LakeSPI. Table 3 presents LakeSPI results for each lake in order of their LakeSPI Index scores, with the indices presented as a percentage of maximum scoring potential. In the following section lakes are discussed in alphabetical order.

Table 3: Summary of current LakeSPI Indicesfor six lakes in the Otago Region in order of their overall lake condition.

Lake	Most Recent LakeSPI Survey	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)	Overall Condition
Hāwea	26/02/2020	82	80	13	Excellent
Wakatipu	02/11/2020	81	77	12	
Wānaka	04/11/2020	78	72	12	
Onslow	06/11/2020	67	53	17	High
Dunstan	05/11/2020	49	57	56	Moderate
Hayes	26/02/2020	40	29	45	

3.1 Lake Dunstan (Clutha Arm)

3.1.1 Results

Lake condition:	Moderate
Lake type:	Man-made reservoir/Hydro
Lake maximum depth:	40 m
Max depth of vegetation:	13.7 m

Lake Dunstan Submerged Plant Indicators

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
November 2020	Moderate	48.7%	57.2%	55.6%

Figure 3: LakeSPI results for Lake Dunstan. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Dunstan is categorised as being in moderate condition with a current LakeSPI Index of 49% (Figure 3).

The invasive weed lagarosiphon (*Lagarosiphon major*) dominated the mid-depth zone (c. 2 – 5.5 m) forming stands of weed up to 2.5 m high at all five sites (Figure 4f). Other invasive species included elodea (*Elodea canadensis*) and the invasive buttercup *Ranunculus trichophyllus.* Elodea was present at three sites forming clumps in water deeper than lagarosiphon, down to a maximum depth of 7 m. *Ranunculus trichophyllus* was recorded from one site in water less than 2 m deep.

Two native pondweeds (*Potamogeton cheesemanii*, *Potamogeton ochreatus*) and a milfoil (*Myriophyllum triphyllum*) (Figure 4c,d) were also recorded in the mid-depth zone. *Potamogeton ochreatus* was recorded at a maximum depth of 8 m.

In deeper water, native charophytes formed meadows (>75% cover) beyond the lagarosiphon beds extending across the lake bottom to a maximum depth of 13.7 m (average depth 8.7 m). Six native charophyte species (Table 1, Figure 4e) were recorded with the most prevalent in deeper water being *Chara australis*, *Chara globularis*, *Nitella* sp. aff. *cristata* and *Nitella tricellularis*.

In shallower water (<2 m deep), seven low growing native turf plants (Figure 4a,b) were recorded (Table 1).

At the time of recent survey, through-water visibility was good and estimated by divers to be c. 3 m.

Historic vegetation notes prior to LakeSPI surveys: A spot survey of submerged vegetation carried out at one site in February 2007 (NIWA unpublished records) recorded a similar species list to that found during the recent survey. The exception was fewer low growing turf and charophyte species recorded in 2007 compared with the 2021 survey.

The introduced pondweed *Potamogeton crispus* was observed in 2007 but not recorded in 2021, as were low growing turf plants *Crassula sinclairii, Limosella lineata* and *Nitella hyalina*.

3.1.2 Discussion

Lake Dunstan is categorised in a moderate condition with a LakeSPI Index of 49% (Figure 3). A Native Condition Index of 57% reflects some well-developed native plant communities, particularly in deeper water, while a similar Invasive Impact Index of 56% represents the extensive weed beds of lagarosiphon (*Lagarosiphon major*) that dominate the mid-depth zone (c. 2 – 5.5 m).

Prior to the creation of Lake Dunstan, formed by the flooding of the Clutha and Kawarau Rivers, aquatic vegetation was not a feature of these rivers since there was little suitable habitat for aquatic plant growth (Clayton 1993). Since its completion in 1993, the lake bed has been colonised by a diversity of aquatic plant species from plant propagules and seed washed in, particularly by the Clutha and Kawarau Rivers, but also from some of the tributaries and flooded ponds on semi-wetland areas (Clayton 1993). Lagarosiphon was an early coloniser in Lake Dunstan and was already present around Bendigo at the head of Lake Dunstan, as well as in the Clutha River from the outlet at Lake Wānaka. Today, lagarosiphon in Lake Dunstan is likely to be at habitat saturation and the full impact of lagarosiphon has been evident for several years.

The shallow flat gradients around much of the lake, make it particularly suited to invasion by submerged weeds. Much of the eastern shoreline has moderately steep gradients which limits the width of lagarosiphon beds relative to the western shoreline.

Although not currently known to be in the South Island, hornwort (*Ceratophyllum demersum*), New Zealand's worst submerged weeds species, continues to pose a significant threat to Lake Dunstan. Hornwort would likely displace all deeper growing native plant communities present in the lake by occupying a deeper depth range than lagarosiphon. Should hornwort make its way into Lake Dunstan we could expect to see a significant decline in LakeSPI scores in the future.

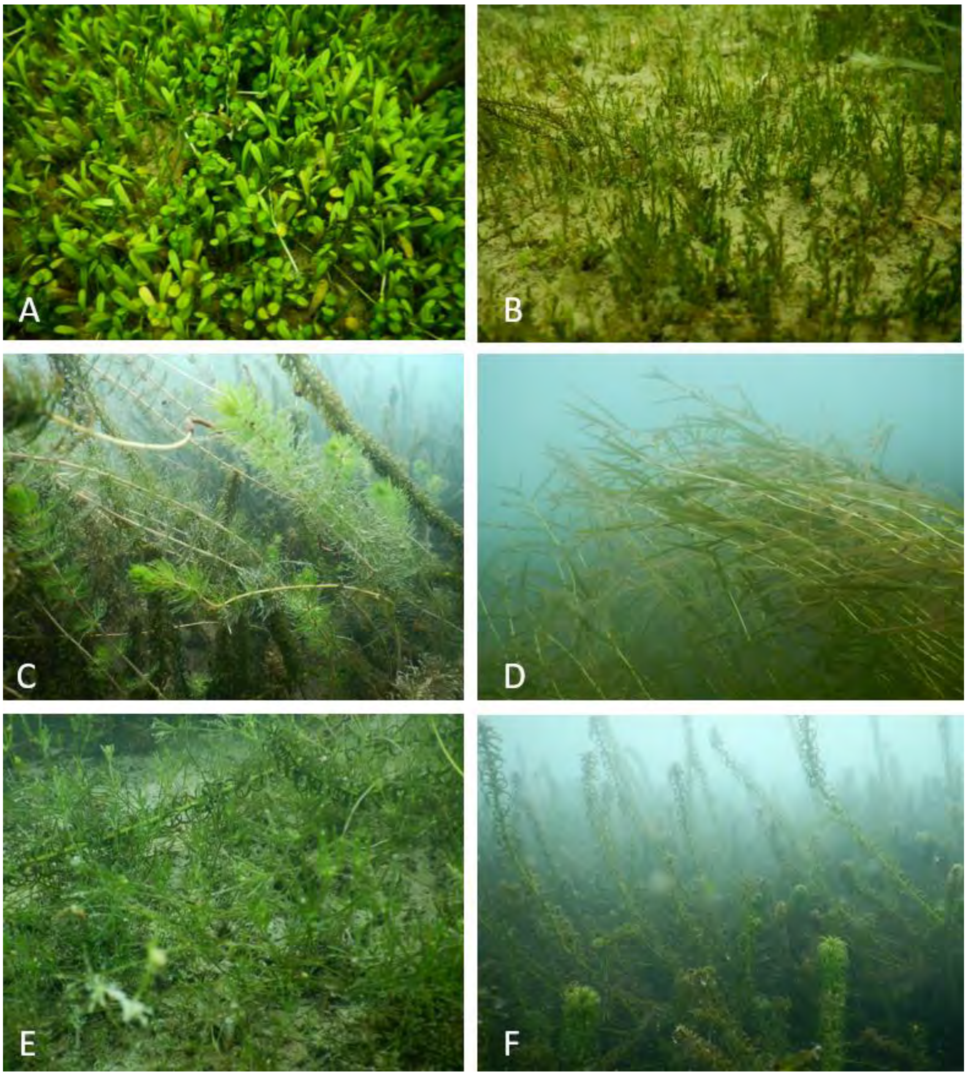
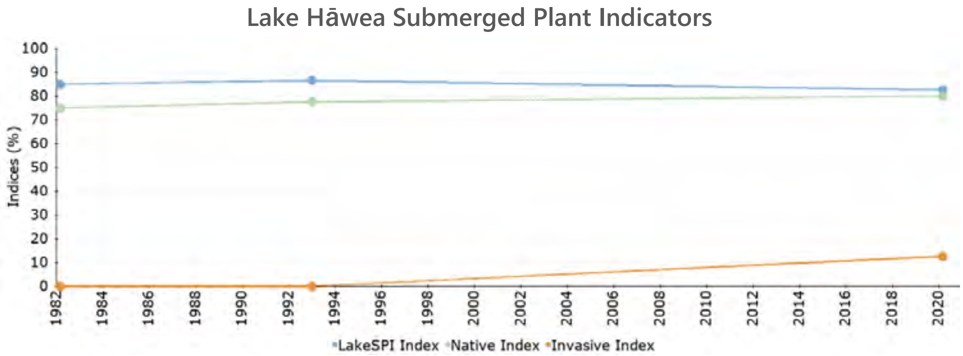


Figure 4: **Lake Dunstan.** A) Low growing turf plants, mainly *Glossostigma diandrum*, B) low growing turf plant *Myriophyllum pedunculatum*, C) milfoil (*Myriophyllum triphyllum)* in foreground, D) pondweed (*Potamogeton ochreatus*), E) charophytes, F) invasive *Lagarosiphon major* weed bed.

3.2 Lake Hāwea

3.2.1 Results

Lake condition:	Excellent
Lake type:	Glacial/Hydro
Lake maximum depth:	384 m
Max depth of vegetation:	20+ m



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2020	Excellent	82.4%	80.0%	12.6%
December 1992	Excellent	86.5%	77.5%	0.0%
February 1982	Excellent	85.0%	75.0%	0.0%

**1982 & 1992 based on limited data from historic sites - 1992 (six sites), 1982 (13 sites).*

Figure 5: LakeSPI results for Lake Hāwea. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Hāwea is categorised as being in excellent ecological condition with a current LakeSPI Index of 82% (Figure 5). This high score reflects the presence of an extensive native plant community with little impact from invasive weed species.

Water level was high at the time of the survey (345 masl), and only a few isolated plants were observed above c. 7.5 m depth. Beyond this depth, six native charophyte species were recorded (*Chara australis, Chara braunii, Nitella claytonii, Nitella tricellularis, Nitella pseudoflabellata* and *Nitella stuartii*) that contributed to high cover meadows (>75% cover) that occurred at all five LakeSPI sites. Charophyte meadows (> 75% cover) were recorded to a maximum depth of 20.7 m (Figure 6a, b), while lower covers of charophytes extended into deeper water at all sites. No general zonation pattern was observed in charophyte species over the depth range with all species exceeding 20 m in depth.

Other native plant species included three tall growing vascular species, two pondweeds (*Potamogeton cheesemanii* and *Potamogeton ochreatus*) and milfoil (*Myriophyllum propinquum*). Pondweeds (Figure 6c) were present at low to moderate covers at all sites, and a single plant of *M. propinquum* was observed at one site.

Elodea (*Elodea canadensis*) (Figure 6d, e) was the only invasive plant species recorded in Lake Hāwea but was not widespread. Elodea was recorded from two sites, with very low covers observed at one site, and high covers (>75%) at another extending down to c. 7.7 m depth.

At the time of survey, underwater visibility was estimated by divers to be c. 5 m. Freshwater mussels (*Echyridella menziesii*) were common at all sites (Figure 6f).

Historic vegetation notes prior to LakeSPI surveys: Surveys of the lake were undertaken at 13 sites in 1982 (Clayton et al. 1986) and six sites in 1992 (Clayton 1993). They reported a similar assemblage of charophyte species to those recorded in 2020. However, no native vascular species (e.g., pondweeds and milfoils) were recorded in the 1982 survey. During the 1992 survey, elodea was extensive between 4-6 m depth in inlets and lagoons associated with Lake Hāwea but not in the main lake basin (Clayton 1993). Occasional short growing (< 0.2 m) plants of *Myriophyllum triphyllum* and *Potamogeton cheesemanii* were also recorded .

3.2.2 Discussion

Lake Hāwea appears to have remained in a stable condition since 1982, with only a small decline in the LakeSPI Index in response to an increase in the Invasive Impact Index, from 0 to 13% (Figure 5). A low Invasive Impact Index of 13% reflects the minimal impact elodea was having at two of the five LakeSPI sites during the recent survey. While elodea was first recorded in the lake during the 1992 survey, it was not captured in the LakeSPI scores due to its limited presence mostly restricted to areas outside of the main body of the lake.

During the February 2020 survey, the water level in Lake Hāwea was close to its maximum operating level of 346 masl (ORC monitoring website), with a maximum operating range of 8 m being in place since 1984 (Clayton 1993). Large fluctuations in water level restricts the growth of submerged vegetation in the lake to depths below c. 8 m, preventing the establishment and growth of shallow low mound plant communities, including turf plants and *Isoetes alpina* dominated swards, that are commonly present in neighbouring Lake Wānaka. The absence of vascular species (e.g., pondweeds and milfoils) noted during the 1982 and from the main body of the lake in 1992, is likely also a result of this as they usually occupy this 0 – 8 m depth range. Vascular and turf species recorded from historic surveys were mostly confined to seepage areas where they would be buffered somewhat from desiccation as a result of large water level fluctuations.

Elodea was the only invasive species recorded in Lake Hāwea during the recent survey, recorded from two of the five LakeSPI sites. Lake Hāwea is adjacent to Lake Wānaka, which is a potential source of the invasive weed lagarosiphon (*Lagarosiphon major*) that can be transported to other lakes on contaminated boats and fishing equipment. However, it is unlikely that lagarosiphon would establish and have significant impacts in Lake Hāwea on account of the wide water level fluctuations, which have a greater range (8 m) that the depth range recorded for lagarosiphon (maximum depth of 6.5 m).

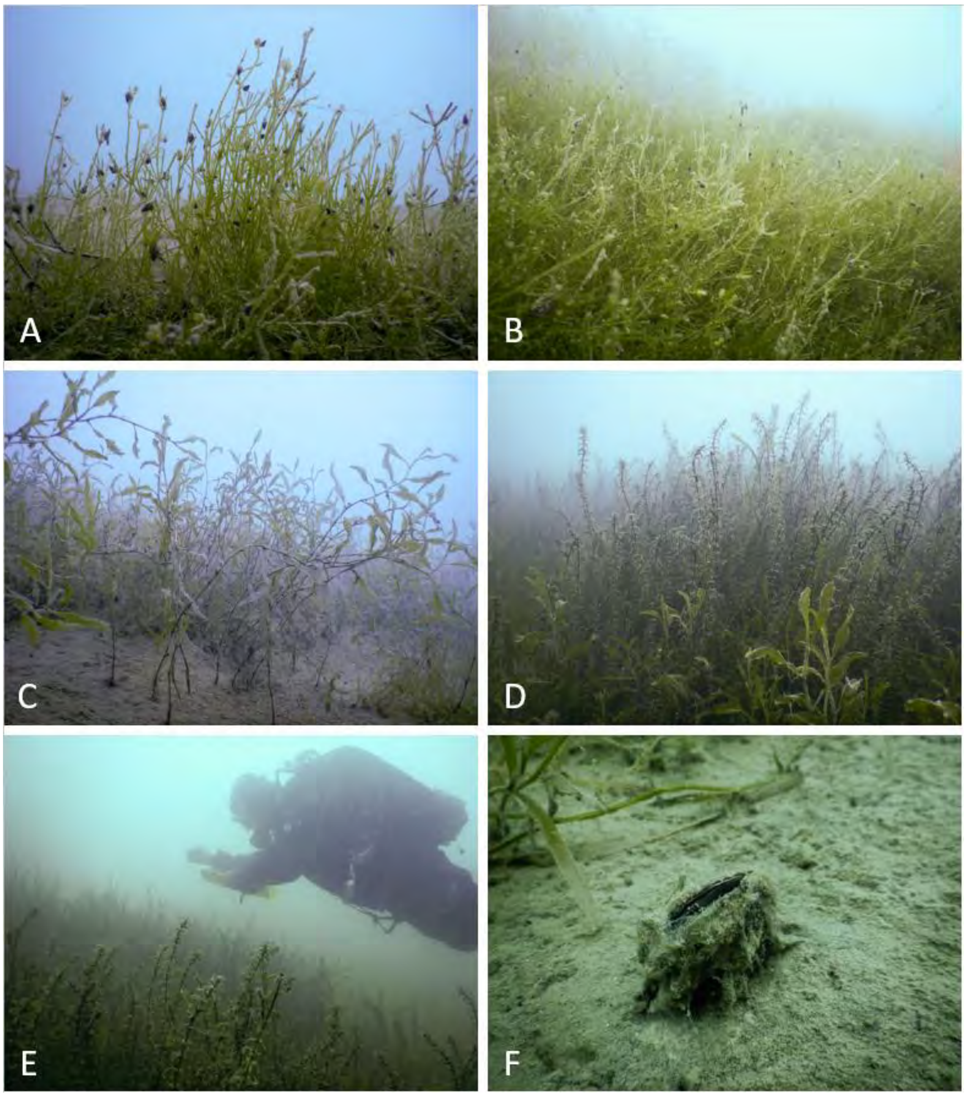
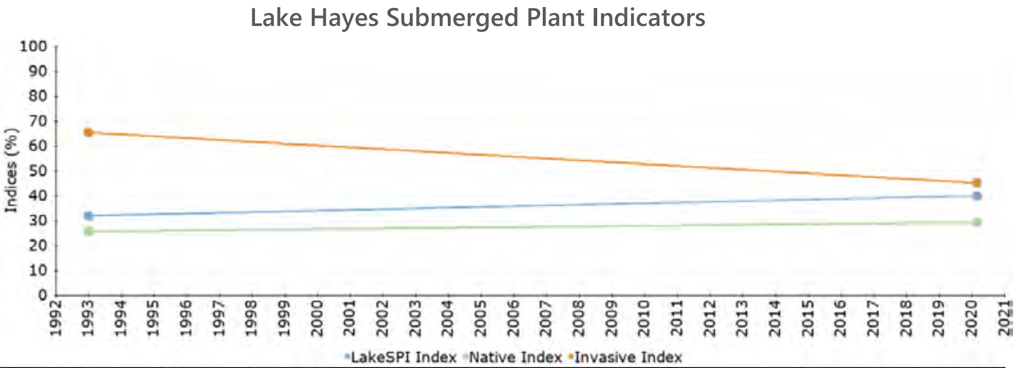


Figure 6: **Lake Hāwea.** A) & B) native charophytes, C) native pondweed (*Potamogeton ochreatus*), D) invasive bed of elodea with native pondweeds in front, E) diver swimming over elodea weed bed, F) freshwater mussel.

3.3 Lake Hayes

3.3.1 Results

Lake condition:	Moderate
Lake type:	Glacial
Lake maximum depth:	32.9 m
Max depth of vegetation:	4.9 m



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
February 2020	Moderate	40.0%	29.3%	45.2%
December 1992	Moderate	32.0%	25.6%	65.4%

Figure 7: **LakeSPI results for Lake Hayes.** LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Hayes is categorised as being in moderate condition with a current LakeSPI Index of 40% (Figure 7).

Native plants were present in shallow water c. <2 m depth, particularly at the northern end of the lake. In this depth zone (0 – 2 m) low growing turf species included *Eleocharis pusilla, Glossostigma diandrum*, *Glossostigma elatinoides, Limosella lineata, Lilaeopsis ruthiana, Myriophyllum pedunculatum* and *Ranunculus limosella*. Other native species growing in the shallows and extending deeper to c. 4 m, included three charophytes (*Chara australis*, *Chara globularis*, *Nitella hyalina*), Isoetes (*Isoetes alpina*), Ruppia (*Ruppia polycarpa*) and taller vascular species including three pondweeds (*Potamogeton ochreatus*, *Potamogeton cheesemanii*, *Stuckenia pectinata*) and milfoil (*Myriophyllum triphyllum*) (Figure 8). Charophytes formed a meadow (>75% cover) at one site at depths between 1.6 – 3.4 m. Sixteen native submerged plant species were recorded in 2020 (Appendix 1, Table 1).

Elodea (*Elodea canadensis*) was the only invasive plant species observed (Figure 8d, e). While elodea was present at all sites, plants were low growing (<0.5 m height) and exceeded a 10% cover at only two sites. At these two sites, elodea covers were high (>95%), forming weed beds down to a maximum depth of 4.9 m.

At the time of survey, underwater visibility was estimated by divers to be c. 2 m. An algae bloom was present in the surface waters and more concentrated at the southern end of the lake. An unidentified epiphytic growth, resembling the appearance of wool, was noted covering plants at one site at the north-western end of the lake (Figure 8e). No freshwater mussels (*Echyridella menziesii*) were observed.

Schools of juvenile perch (*Perca fluviatilis*) were present in the shallows (Figure 8f) and while no adults were seen at the time of the survey, many fish depressions were observed in sediments on the lake bottom. Eel tracks were also recorded.

Historic vegetation notes prior to LakeSPI surveys: A survey of the lake in 1992 (Clayton 1993) recorded a similar assemblage of plant species to those recorded in 2020. Species diversity in 1992 was also relatively high with 14 submerged species recorded. However, the introduced species *Ranunculus trichophyllus*, common at five of the six sites surveyed in 1992, was not recorded during the 2020 survey. Elodea was present to a maximum depth of 7 m.

3.3.2 Discussion

Lake Hayes appears to remain in a relatively stable but degraded condition, with an increase in the LakeSPI Index from 32% in 1992 to 40% in 2020, resulting from a lower Invasive Impact Index at the time of the February 2020 survey (Figure 7). The Invasive Impact Index decreased from 65% in 1992 to 45% in 2020 mainly on account of lower invasive species covers, with elodea exceeding a 10% cover at only two of the five LakeSPI sites and had a reduced depth range. The maximum depth of elodea exceeding a 10% cover was 4.9 m (average 1.9 m) in 2020, compared with 7 m (average 4.75 m) in 1993. However, this apparent improvement must be interpreted carefully, as it is likely that the reduced depths and highly variable covers of elodea observed during the more recent survey reflects the eutrophic state of Lake Hayes (LAWA 2020) and unfavourable water clarity for deeper growing plants.

Despite the eutrophic state of Lake Hayes, the lake continues to maintain a high diversity of submerged plants, particularly in shallower water (<2 m) at the northern end of the lake around the boat access areas.

Lake Hayes remains at moderate risk of invasion by lagarosiphon from other infested water bodies in the region. If lagarosiphon were introduced into Lake Hayes, it is uncertain what extent impact this species would have, on account of the lake's eutrophic conditions and low water clarity (Clayton 1993).

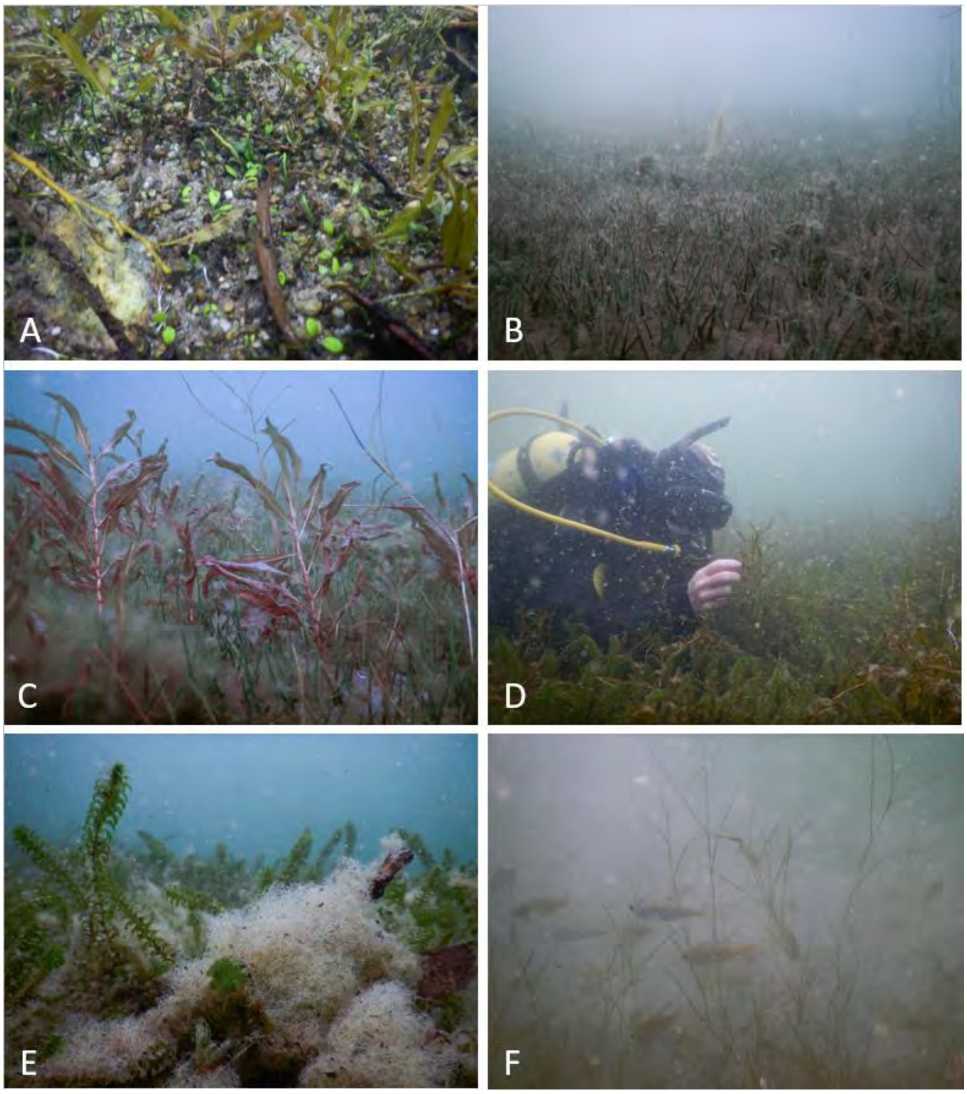


Figure 8: **Lake Hayes.** A) mixed native turf community in shallows, B) native turf plants (*Limosella lineata*), C) native pondweed (*Potamogeton cheesemanii*), D) diver identifying native pondweeds growing through elodea weed bed, E) elodea weed bed showing epiphytic algae observed covering plants at one site, F) juvenile perch swimming amongst native pondweed (*Stuckenia pectinata*).

3.4 Lake Onslow

3.4.1 Results

Lake condition:	High
Lake type:	Man-made reservoir/Hydro
Lake maximum depth:	9.5 m
Max depth of vegetation:	2.7 m

Lake Onslow Submerged Plant Indicators

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
November 2020	High	66.7%	53.0%	17.3%

**LakeSPI results based on only 3 sites (accessed from road and farm tracks).*

Figure 9: LakeSPI results for Lake Onslow. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Onslow is categorised as being in high condition with a LakeSPI Index of 67% (Figure 9).

Eleven native submerged plant species formed a mixed assemblage of plants in shallow water(<2.7 m). Plants included two charophytes (*Nitella leonhardii*, *Nitella pseudoflabellata*), a pondweed *Potamogeton ochreatus*, milfoil *Myriophyllum propinquum*, and seven low growing turf species (Appendix 1, Figure 10). Plants were generally low growing and covers of individual species were variable between sites. Charophyte meadows (>75% cover) were recorded from two of the three sites extending down to a depth of 1.4 and 2 m.

The introduced rush, *Juncus bulbosus* (Figure 10e) was the only invasive species recorded. This rush was present at all three sites but formed only low covers (< 5 %) in shallow water < 1 m deep.

At the time of the survey the through-water visibility estimated by divers was c. 2 m.

Freshwater crayfish (*Paranephrops zealandicus*) were observed in the lake (Figure 10f).

Historic vegetation notes prior to LakeSPI surveys: A spot survey of the submerged vegetation carried out at one site adjacent to the boat ramp in 1992 (Clayton 1993), recorded *Myriophyllum propinquum*, *Potamogeton ochreatus, Elatine gratioloides, Eleocharis pusilla, Limosella lineata* and a *Callitriche* species. No charophytes were recorded, and submerged vegetation was absent from other areas inspected.

3.4.2 Discussion

Lake Onslow has a high LakeSPI Index of 67% (Figure 9) which is representative of those waterbodies that generally have a diverse native plant community with only limited impacts from invasive species. The introduced rush *Juncus bulbosus* was the only invasive species recorded from the lake and it was having little impact on the submerged vegetation, reflected by a low Invasive Impact Index of 17.3%.

Lake Onslow was formed in 1890 by the damming of the Teviot River and Dismal Swamp. A survey of the submerged vegetation at one site in 1992 (Clayton 1993) recorded a similar assemblage of native species to those observed in 2020 but it did not record any charophytes. The absence of charophytes in 1992, following a rise in water levels since 1982, was suggested by Clayton 1993 to be due to unfavourable conditions for aquatic plant growth at the time, with turbidity and fluctuating water levels cited as the main inhibiting factors. During the 2020 survey, charophytes were recorded from all sites and formed high cover meadows (>75% cover) at two of the three sites in shallow water (<2 m).

Lake Onslow remains at risk of invasion from other invasive species, particularly lagarosiphon (*Lagarosiphon major*) already present in the region, with contaminated boat traffic and fishing gear representing the most likely vectors of spread.

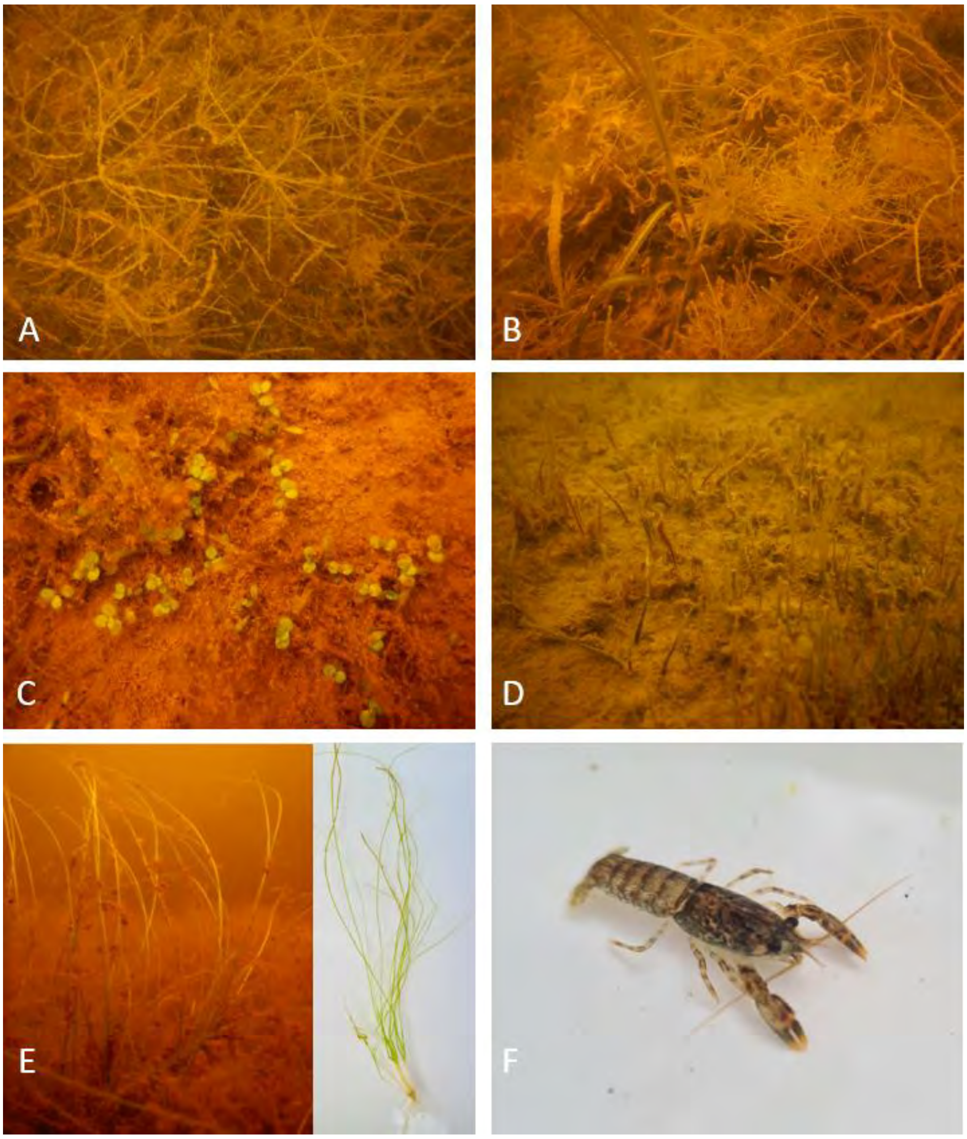
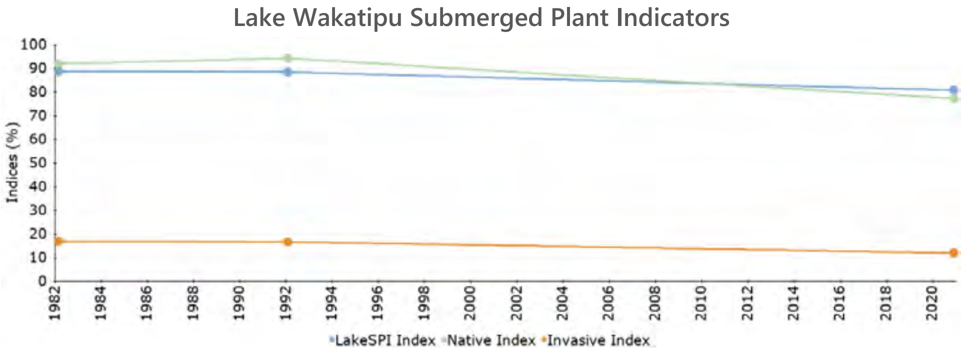


Figure 10: Lake Onslow. A) Charophyte *Nitella leonhardii*, B) Pondweed (*Potamogeton ochreatus*) in bottom left corner and milfoil (*Myriophyllum propinquum*), C) Low growing turf plant *Elatine gratioloides*, D) Turf plants *Lilaeopsis ruthiana* and *Eleocharis pusilla*, E) Introduced rush *Juncus bulbosus*, I) Freshwater crayfish (*Paranephrops zealandicus*).

3.5 Lake Wakatipu

3.5.1 Results

Lake condition:	Excellent
Lake type:	Glacial
Lake maximum depth:	380 m
Max depth of vegetation:	20+ m



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
November 2020	Excellent	80.8%	77.3%	11.9%
January 1992	Excellent	88.5%	94.2%	16.7%
February 1982	Excellent	88.8%	92.0%	17.0%

Figure 11: LakeSPI results for Lake Wakatipu. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Wakatipu is categorised as being in excellent condition with a current LakeSPI Index of 81% (Figure 11).

Native Isoetes (*Isoetes alpina*) dominated the shallow littoral zone at four of the five sites, forming swards of typically high covers (51 – 100% cover) to depths of up to 7.4 m (average depth 4.8 m) (Figure 12a,b). Five other native turf plants (*Elatine gratioloides*, *Eleocharis pusilla*, *Glossostigma diandrum*, *Trithuria inconspicua* subsp. *brevistyla*, *Limosella lineata*) were recorded in water < 1 .3 m deep, all at low covers except for *Glossostigma diandrum* that formed higher covers at one site.

Tall growing native species included a milfoil (*Myriophyllum triphyllum*) and two pondweeds *(Potamogeton cheesemanii*, *Potamogeton ochreatus*) (Figure 12d, e). Both milfoils and pondweeds formed low covers amongst the *Isoetes* sward growing down to a maximum depth of 2.2 m and 11.1 m respectively.

Charophytes were the most abundant community being comprised of 10 species (Appendix A, Table 1). The most prevalent of these species were *Nitella claytonii* (Figure 12c), *Chara australis* and *Nitella tricellularis* which formed variable low to high covers at most sites beyond the swards of *Isoetes*. High cover charophyte meadows (> 75% cover) were recorded from three of the five sites to a maximum depth of 12.2 m. Meadows were predominantly comprised of *Nitella claytonii* (two sites) and *Nitella pseudoflabellata* (one site). *Nitella claytonii* was the deepest growing charophyte species with lower covers extending down to depths beyond 20 m at most sites.

Native bryophytes formed low covers (<25 %) at four of the five sites. The bryophytes were loosely attached to rocks and plants generally in water < 3 m but were recorded growing down to a maximum depth of 7.4 m at one site. No bryophytes were recorded beyond this depth.

The introduced weed species elodea (*Elodea canadensis*) was the only invasive species recorded in the lake (Figure 12f). Low growing (< 0.5 m high) plants of this species were recorded from two of the five sites growing down to a maximum depth of 7.2 m. At one site (Site A – opposite Pig Island, Appendix B), only scattered plants of elodea were observed, and covers were low (< 5% cover). At the second site (Site E – Sunshine Bay), elodea was recorded growing amongst other species with covers up to 75%.

At the time of survey, the through-water visibility was estimated by divers to be between 5 – 6 m. Freshwater mussels (*Echyridella menziesii*) were recorded at four sites. Didymo was observed in very shallow areas at one site.

Historic vegetation notes prior to LakeSPI surveys: The earliest description of aquatic plants in Lake Wakatipu appears to be that of Hill (1970). Hill made surface observations and described Lake Wakatipu as supporting quite dense stands of native vegetation but also noted large beds of elodea in the vicinity of Queenstown Bay through Frankton Arm. Hill recorded the following species: *Myriophyllum propinquum*, *Myriophyllum triphyllum*, *Potamogeton cheesemanii*, *Potamogeton ochreatus*, *Ranunculus fluitans* (now *Ranunculus trichophyllus*), *Elodea canadensis*, Chara and/or Nitella spp., *Isoetes alpina* and some turf species.

In Feb 1982, the Aquatic Plant Group of the Ministry of Agriculture and Fisheries provided the first full description of the submerged vegetation from the main body of Lake Wakatipu in which 50 profiles were dived (NIWA APDB unpublished data) . In January 1992 this survey was repeated at 30 sites (de Winton et al. 1993). The 1993 report details the presence of *Isoetes alpina* forming extensive swords in shallow water to a depth of 9 m, and a rich diversity of charophytes (8 species) forming meadows from < 10 m depth to a maximum of 60 m. A deep-water bryophyte community was also recorded at depths c. 30 – 60 m.

Little change in the submerged vegetation in Lake Wakatipu was noted between the 1982 and 1992 surveys (de Winton et al. 1993) and both data sets showed similar vegetation patterns. There were no major changes in the composition of the main communities and dominant species, nor had the depth extent of vegetation changed significantly. No new invasive plant introductions occurred although an increase in the frequency of elodea was noted.

3.5.2 Discussion

Lake Wakatipu is categorised as being in excellent condition, representative of those lakes that maintain a well-developed native plant community in the absence or with limited impacts from any invasive weed species. This is reflected in a high LakeSPI Index of 81% (Figure 11).LakeSPI scores for Lake Wakatipu show little change in the lakes condition between earlier surveys in 1982 and 1992 (Figure 11). Over the longer term however, between 1992 and 2020 (23 year time frame), LakeSPI results show a statistically significant decline in the Native Condition Index primarily resulting from a reduction in the depth extent of native charophytes. In 1992, charophytes were recorded to growing to a maximum depth of 46 m (average depth of 36.5 m) and high-cover charophyte meadows (> 75% cover) extended down to a maximum depth of 46 m (average depth 36 m). During the recent 2020 survey, while charophytes >10% cover were recorded growing down to at least 20 m (depth limit of divers) at three of the four baseline sites assessed in 1992, high-cover meadows were absent from the other two sites and extended down to a maximum depth of only 8.3 m and 12 m (average 5.1 m). Deep water vegetation is dependent on adequate light for net photosynthesis. Water clarity is therefore one of the major factors determining the maximum depth to which submerged plants can grow indicating a marked reduction in the water clarity of Lake Wakatipu since these early surveys.

In 2020 a rich array of 10 charophytes were recorded from Lake Wakatipu (Appendix A, Table 1). There are few similar examples of lakes with this number of charophyte species elsewhere in New Zealand. Charophytes included species *Nitella claytonii*, *Nitella stuartii* and *Nitella subtillissima* that are restricted to the South Island only. Another species of interest was a small turf forming species, *Trithuria inconspicua* described as at risk ‘nationally vulnerable’ by de Lange (2018).

Deep-water bryophytes recorded during the 1982 and 1992 to c. 60 m, were not observed during the 2020 survey. However it is possible that they may have been present, but not seen during this recent 2020 survey with dives not proceeding beyond a depth of 20 m.

Elodea remains the only invasive weed species to be recorded in the main body of Lake Wakatipu during this survey. The introduced buttercup *Ranunculus trichophyllus* recorded in 1992, was not recorded during the 2020 survey.

Incursions of lagarosiphon have been detected and eradicated from Lake Wakatipu since at least 2007 and this weed continues to pose a significant threat (de Winton 2016). The closest proximity of lagarosiphon comes from an infestation in the upper Kawarau River, as well as boat dispersed sources from Lake Dunstan and possibly Lake Wānaka. The greatest impact of lagarosiphon introduction would likely be confined to the Frankton Arm and in relatively wave protected areas such as Queenstown Bay and Kingston (Clayton 1993), but lagarosiphon has been removed from shoreline near to Walter Peak, proving that it could establish widely.

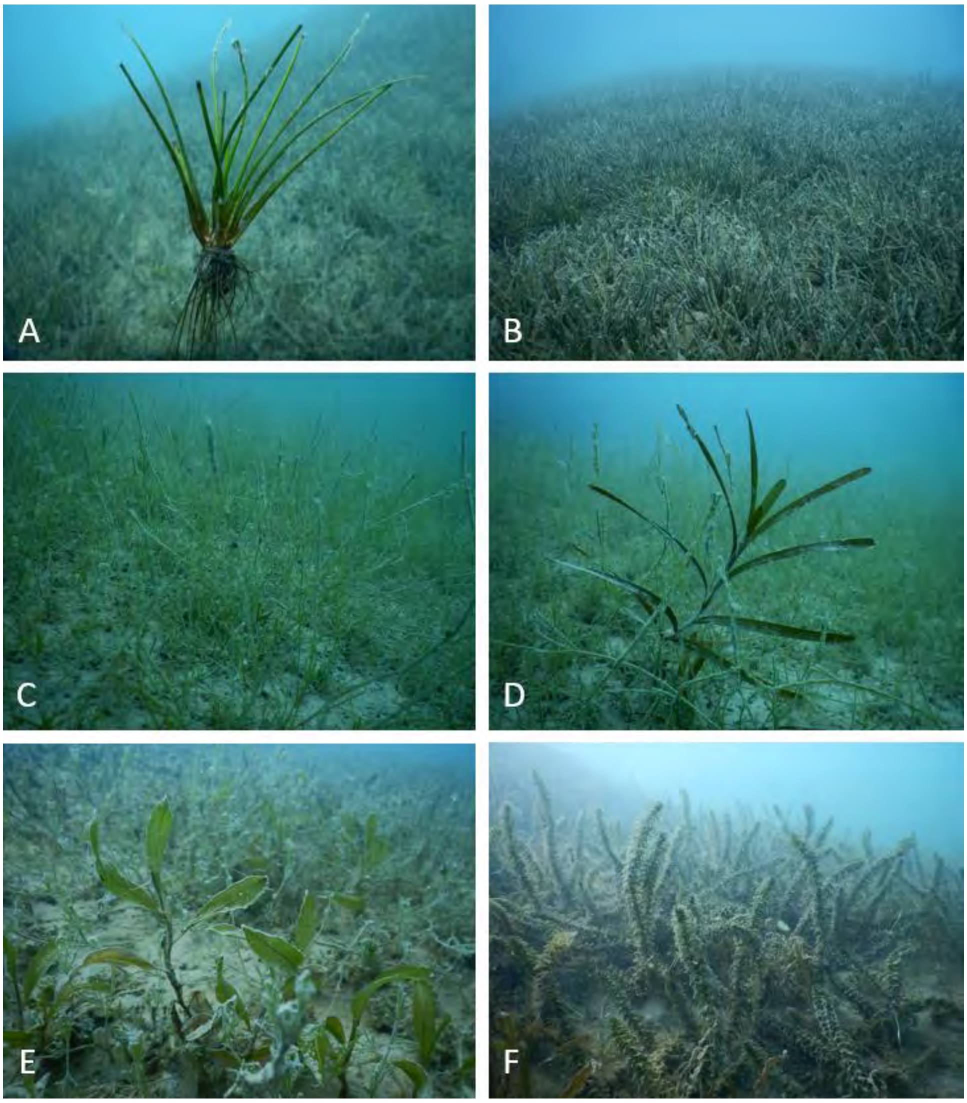
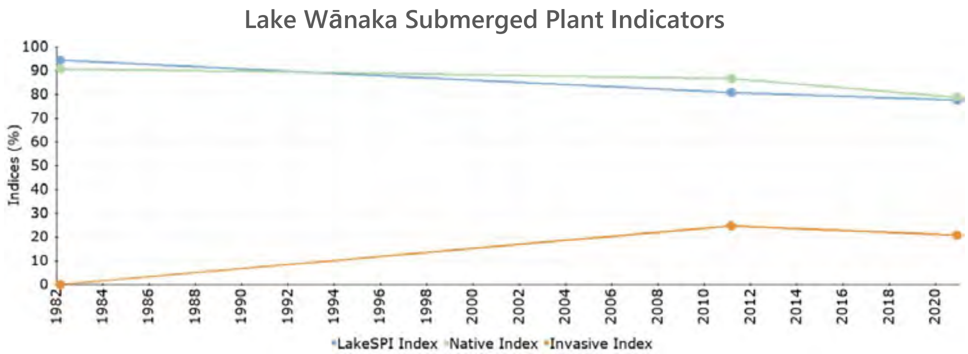


Figure 12: **Lake Wakatipu.** A & B) Isoetes (*Isoetes alpina*), C) charophytes (*Nitella claytonia*), D) pondweed (*Potamogeton ochreatus*) growing amongst charophytes, E) pondweed (*Potamogeton cheesemanii*), F) invasive weed elodea (*Elodea canadensis*).

3.6 Lake Wānaka

3.6.1 Results

Lake condition:	Excellent
Lake type:	Glacial
Lake maximum depth:	311 m
Max depth of vegetation:	20+ m



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
November 2020	Excellent	77.6%	78.7%	20.7%
February 2011	Excellent	80.7%	86.7%	24.7%
February 1982	Excellent	94.4%	90.7%	0.0%

**2011 data based on only three baseline sites.*

Figure 13: LakeSPI results for Lake Wānaka. LakeSPI indices expressed as a percentage of lake maximum potential.

Lake Wānaka is categorised as being in excellent condition with a current LakeSPI Index of 78% (Figure 13).

Native Isoetes (*Isoetes alpina*) dominated the shallow littoral zone at all five sites, forming high cover swards (51 – 100% cover) from c. 1.5 m extending down to a maximum depth of 9.1 m (average depth 7.2 m) (Figure 14a,b). Four other low growing native turf plants (*Elatine gratioloides*, *Eleocharis pusilla*, *Glossostigma diandrum, Lilaeopsis ruthiana*) were recorded in this shallow zone forming variable but typically low covers (< 50%) at all five sites.

Tall growing native species included a pondweed *(Potamogeton cheesemanii*) (Figure 14b,c) and two milfoils (*Myriophyllum propinquum*, *Myriophyllum triphyllum*) (Figure 14d).

Both pondweeds and milfoils were recorded forming only low covers (< 25%) growing amongst other plants down to a maximum depth of 11.8 m and 6 m respectively. A plant of *Myriophyllum propinquum* was recorded from one site.

Charophytes were the most abundant community being comprised of eight species (Appendix A, Table 1). The most prevalent of these species were *Nitella claytonii*, *Nitella tricellularis* and *Chara braunii* which formed variable low to high covers at all sites beyond the swards of *Isoetes*. High cover charophyte meadows (> 75% cover) were recorded from four of the five sites to a maximum depth of 17.5 m (average depth at sites present was 13.4 m) . *Nitella claytonii*, *Chara braunii* and *Nitella tricellularis* were the deepest growing charophyte species extending down to depths between c. 10 - 20+ m. Charophytes exceeded 20 m depth at two at two of the five sites.

Elodea (*Elodea canadensis*) was the only invasive species recorded in the lake (Figure 14f). It was recorded from four of the five sites growing at depths between 4.3 – 7.7 m. Covers were low (< 5%) at two sites but formed higher covers (up to 95%) at the other two. Elodea was low growing and did not exceed 0.4 m in height. Lagarosiphon (*Lagarosiphon major*) was not recorded from a LakeSPI site.

Native bryophytes were recorded from four sites in shallow water < 2.5 m deep. No bryophytes were recorded from deeper-water.

At the time of survey, the through-water visibility was good and estimated by divers to be between 3 – 6 m. Freshwater mussels (*Echyridella menziesii*) were observed at four of the five sites (Figure 14e).

Historic vegetation notes prior to LakeSPI surveys: Surveys of the lake undertaken at 50 sites in 1982 (Clayton et al. 1983), recorded a similar assemblage of the most prevalent species to those recorded in 2020. Species listed in 1982 that were not recorded in 2020, included *Chara globularis*, *Crassula sinclairii, Juncus* sp*., Limosella lineata*, *Myriophyllum pedunculatum*, *Pilularia novae-hollandiae, Potamogeton ochreatus, Ranunculus limosella. Triglochin striata, Utricularia dichotoma,* and the introduced buttercup *Ranunculus trichophyllus*.

A spot survey undertaken at one site in 2001 (unpublished NIWA APDB data) recorded the presence of the invasive weed species elodea and lagarosiphon. Lagarosiphon was first recorded from Lake Wānaka in 1972 (Hughes and McColl 1980) but was not recorded from any of the 50 sites surveyed during the 1982 survey.

3.6.2 Discussion

Lake Wānaka has a high LakeSPI Index of 78% and Native Condition Index of 79% (Figure 13), reflective of those lakes that maintain a well-developed native plant community with only limited impacts from invasive weed species. A low Invasive Impact Index of 21% reflects the presence of elodea at three of the five survey sites in 2020.Over the longer term, LakeSPI results for Lake Wānaka show a probable change in lake condition (Figure 2) with the LakeSPI Index declining from 94 % in 1982, to 78 % in 2020 (Figure 13: LakeSPI results for Lake Wānaka.). This change corresponds with an increase in the Invasive Impact Index from 0 % to 21 % over this same 38 year time frame (1982 – 2020) reflecting greater impacts from invasive weed species lagarosiphon (*Lagarosiphon major*) and elodea (*Elodea canadensis*).

Both species were recorded from two of the three sites assessed in 2011. Lagarosiphon was not observed at a LakeSPI site in 2020.

Aside from the negative influence of invasive species on LakeSPI scores, LakeSPI results also show a significant decrease in the depth extent of native vegetation from most sites over this same time longer term time period (1982 to 2020). In 1982, high-cover charophyte meadows (> 75% cover) were recorded from all five sites extending down to an average depth of 21.4 m. In 2020, the average depth of charophyte meadows at four sites (they were not present from one site) had reduced to 13.4 m. As deep water vegetation is dependent on adequate light for net photosynthesis, water clarity is one of the major factors determining the maximum depth to which submerged plants can grow. Therefore this reduction in plant depth extent is likely the result of declining water clarity in Lake Wānaka since the 1982 survey.

An ongoing lagarosiphon management program undertakes to prevent the spread of lagarosiphon and progressively contain it to parts of the lake (de Winton and Clayton 2016). Should control works within Lake Wānaka cease and lagarosiphon be allowed to spread unchecked, we could expect a significant decrease in LakeSPI scores in the future.

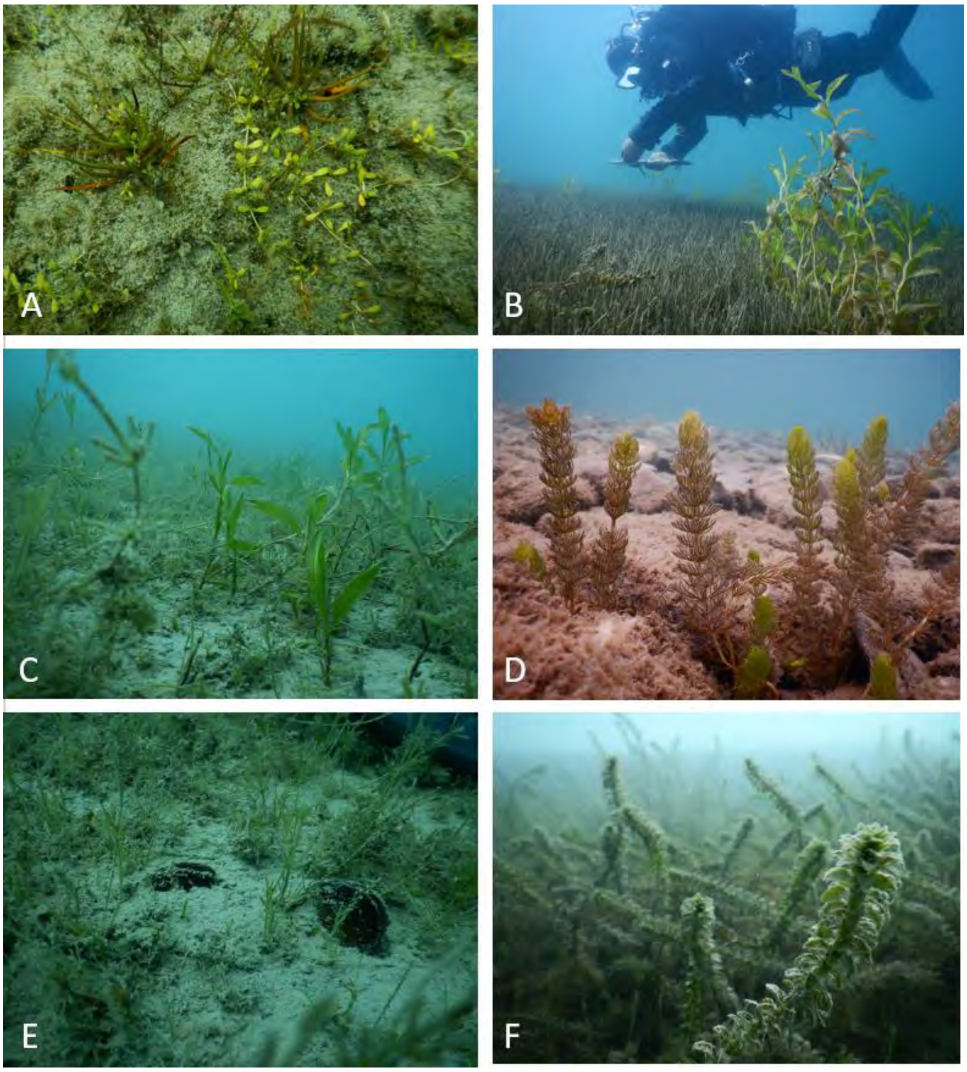


Figure 14: **Lake Wānaka.** A) Low growing turf species (*Isoetes alpina* and *Glossostigma diandrum*), B) diver swimming over carpet of Isoetes (*Isoetes alpina*) with pondweed (*Potamogeton cheesemanii*) in right bottom corner, C) pondweeds (*Potamogeton cheesemanii*) growing amongst charophytes, D) milfoils (*Myriophyllum triphyllum*), E) Freshwater mussels in centre amongst charophytes, F) invasive weed elodea (*Elodea canadensis*).

4 Discussion

Six lakes in the Otago Region were assessed for this report. Current LakeSPI status for these lakes comprises three ranked in excellent condition, one in high condition and two in moderate condition categories (Table 4).

Table 4: Summary of 2020 LakeSPI results for lakes in the Otago region with overall condition category and invasive weed history.

Lake	LakeSPI Index (%)	Overall Condition	Rank in region	Worst weed present
Hāwea	82	Excellent	1	Elodea
Wakatipu	81	Excellent	2	Elodea
Wānaka	78	Excellent	3	Elodea (Lagarosiphon off site)
Onslow	67	High	5	*Juncus bulbosus*
Dunstan	49	Moderate	6	Lagarosiphon
Hayes	40	Moderate	7	Elodea

NOTE: Lakes Moke and Diamond (surveyed in 2007) were ranked 4th and 8th respectively.

4.1 Lake condition

Lakes in excellent condition include Hāwea, Wakatipu and Wānaka. These lakes have substantial native vegetation (Native Condition Index > 72%), with very little impact from invasive weed species (Invasive Impact Index < 13%). All three of these lakes are known for their exceptional water clarity and colour and score highly on account of the >20 m depth limit that vegetation can grow to, and also the low development of invasive weeds under highly oligotrophic conditions. Elodea (*Elodea canadensis*) was the only invasive weed species recorded from LakeSPI sites in these three lakes (Table 4). While Lake Wānaka has been invaded by the more serious weed lagarosiphon (*Lagarosiphon major*), current management initiatives (de Winton and Clayton 2016) have restricted the distribution of this weed and it was not recorded from LakeSPI sites during the current 2020 survey.

Lake Onslow was categorised in high condition with a well-developed native plant community and/or limited impacts from invasive species. The introduced rush *Juncus bulbosus* was the only invasive species recorded from the lake and it was having little impact on the submerged vegetation.

Lakes Dunstan and Hayes were categorised in moderate condition with LakeSPI scores ranging from 40% - 49% (Table 4). These two lakes reflect differing degrees of impact from invasive weeds and/or the restricted development of native plant communities. Lake Dunstan was being impacted on by the invasive weed lagarosiphon but also maintained elements of native vegetation. Only elodea was recorded from Lake Hayes, but plant covers, and depths were highly variable between sites likely reflecting the lakes poor water quality (LAWA 2020).

None of the Otago lakes surveyed for this report were categorised in poor or non-vegetated condition.

4.2 National comparison of current status

Compared with lakes nationally, the Otago Region has a higher proportion of lakes in the excellent, high and moderate LakeSPI categories than is the case nationally (Figure 15). In contrast, none of six lakes surveyed for this report, or for a previous report (Lakes Diamond and Moke - de Winton and Champion 2008), have lakes in the lowest quality categories (poor and non-vegetated) according to LakeSPI.

Importantly, the current sample set of surveyed lakes for the Otago region is small, so care must be taken when interpreting this overall comparison.

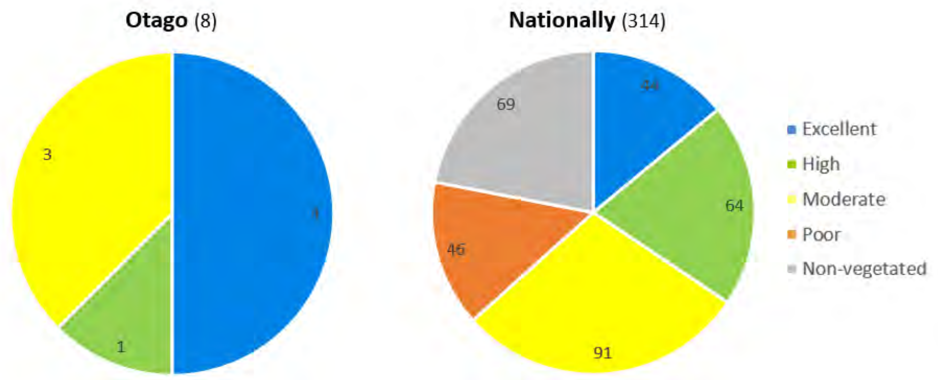


Figure 15: Proportion of lakes that fall into each of five categories of LakeSPI Index for the region (8) and nationally (314)with the number of lakes assessed shown in parentheses.

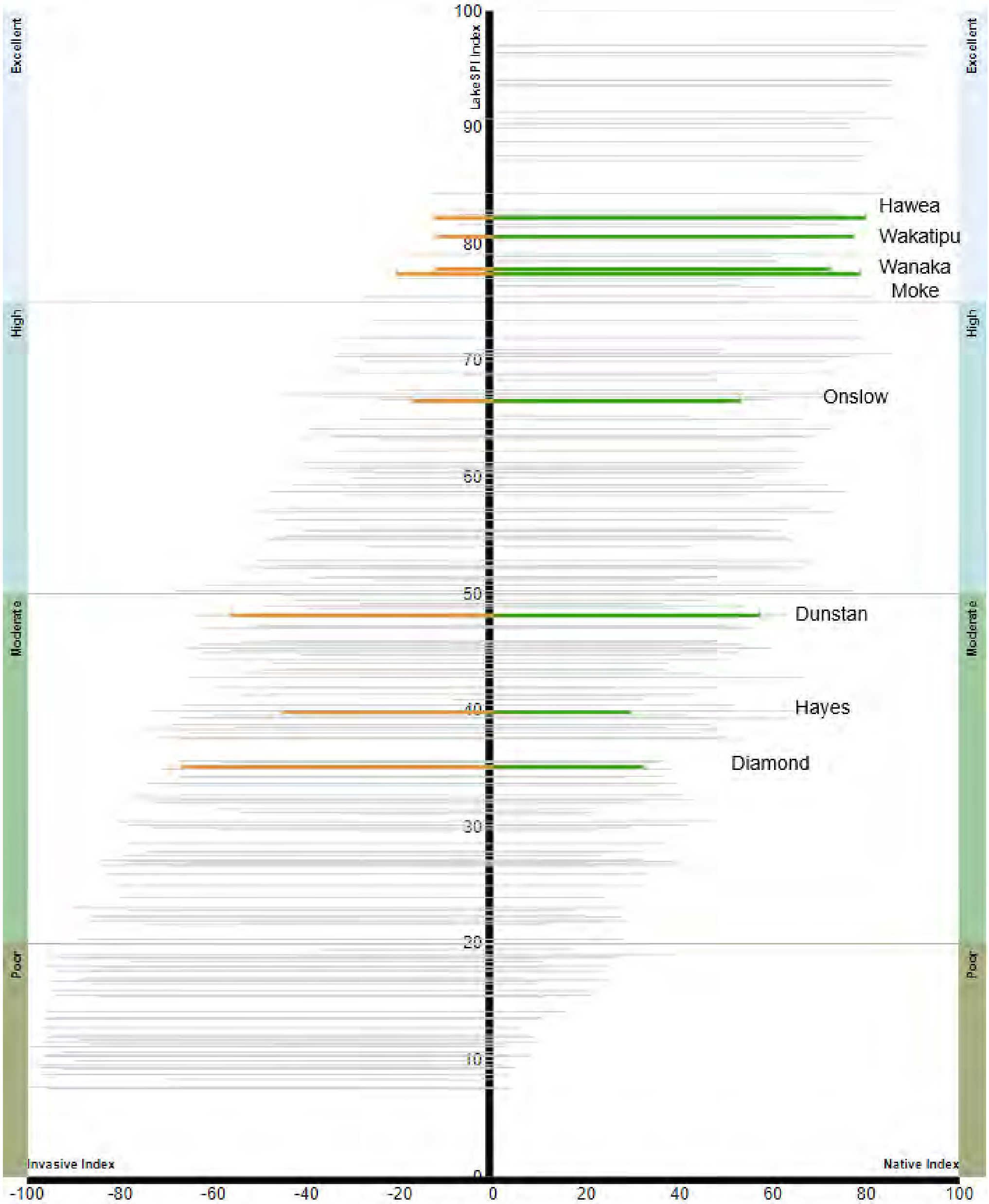


Figure 16: LakeSPI Indices based on the latest results of 314 lakes in grey, showing the scores for the Otago Lakes as a red line. LakeSPI scores are plotted on the vertical axis, with the Native Condition Index plotted on the right-hand horizontal axis, and the Invasive Impact Index on the left hand to show the negative influence on the LakeSPI score.

4.3 National Policy Statement for Freshwater Management 2020

Under the new National Policy Statement for Freshwater Management 2020 (NPS-FM 2020) that came into force in August 2020, all six of the Otago lakes were above the national bottom lines set for the component indices of LakeSPI, the *Native Condition Index* and *Invasive Impact Index* (Table 2). Where comparisons with earlier data was available, all lakes maintained their position within their current scoring band.

Lake Hayes was the only lake that sat close to a national bottom line. The Native Condition Index for Lake Hayes is 29% (Figure 7), with the national bottom line requiring that the Native Condition Index remain above 20% (Table 2).

4.4 Deep water bryophytes

New Zealand's deepest-growing freshwater plants are deep-water bryophytes, with around 40 species of mosses and liverworts found in clear South Island lakes to depths greater than 10 m and up to 70 m (de Winton and Beever 2004). Deep-water bryophyte communities are a globally rare vegetation, with 16 of the 51 lakes recorded globally as supporting these communities occurring in New Zealand (de Winton and Beever 2004). These included the Otago lakes Hāwea, Wānaka, Wakatipu, Lochnagar and Alta. Deep-water bryophytes recorded during the 1982 and 1992 surveys of Lake Wakatipu were not observed during the 2020 survey. However. dives in 2020 did not proceed beyond a depth of 20 m so it is possible that they may have been present in deeper water.

5 Recommendations

It is recommended that a schedule for LakeSPI monitoring be developed with priorities and timing for re-surveys based on perceived lake value, stability and known threats to the lakes.

LakeSPI surveys are generally recommended every five years for lakes that are considered stable. However, some significant changes in the depth extent and covers of deeper growing plants in Lakes Wakatipu and Wānaka mean there would be benefit from monitoring on a more frequent basis (e.g., every 2-3 years).

An investigation to establish the presence/absence of deeper growing bryophytes in these lakes would also be recommended.

6 Acknowledgements

Considerable thanks to Hugo Borges (ORC) for arranging permissions for access to Lakes Hayes and Onslow, and for his company during the survey of Lake Wakatipu. The considerable efforts of the NIWA field team of Mary de Winton, Susie Elcock and Neil Blair are also acknowledged.

Figure 17: Hugo Borges (ORC) on Lake Wakatipu in October 2020.

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Appendix A Species list for six lakes in the Otago Region.

Table 1: Submerged aquatic plant species recorded for six lakes in the Otago Region, based on LakeSPI surveys carried out in 2020.

	Dunstan	Hāwea	Hayes	Onslow	Wakatipu	Wānaka
Invasive species						
Elodea canadensis	✓	✓	✓		✓	✓
Juncus bulbosus				✓		
Lagarosiphon major	✓					
Ranunculus trichophyllus	✓					
Tall native vascular plants						
Myriophyllum propinquum		✓		✓		✓
Myriophyllum triphyllum	✓		✓		✓	✓
Potamogeton cheesemanii	✓	✓	✓		✓	✓
Potamogeton ochreatus	✓	✓	✓	✓	✓	
*Stuckenia pectinata**			✓			
Charophytes						
Chara australis	✓	✓	✓		✓	✓
Chara braunii	✓	✓			✓	✓
Nitella claytonii		✓			✓	✓
Nitella sp. aff. *cristata*	✓					
Chara fibrosa					✓	✓
Chara globularis	✓		✓			
Nitella sp. *hookeri* var. *masonae*					✓	✓
Nitella hyalina			✓		✓	✓
Nitella leonhardii				✓		
Nitella pseudoflabellata	✓	✓		✓	✓	✓
Nitella stuartii		✓			✓	
Nitella hookeri var. *subtilissima*					✓	
Nitella hookeri var. *tricellularis*	✓	✓			✓	✓
Turf plants						
Bryophyte spp.					✓	✓
Callitriche brutia				✓		
Crassula sinclairii				✓		
Elatine gratioloides	✓			✓	✓	✓
Eleocharis pusilla	✓		✓	✓	✓	✓
Glossostigma elatinoides			✓			
Glossostigma diandrum	✓		✓	✓	✓	✓
Isoetes alpina			✓		✓	✓
Lilaeopsis ruthiana	✓		✓	✓		
Limosella lineata			✓		✓	✓
Myriophyllum pedunculatum	✓		✓			
Pilularia novae-zelandiae	✓			✓		
Ranunculus limosella	✓		✓			
Ruppia polycarpa			✓			
Trithuria inconspicua					✓	

* At-Risk, naturally uncommon (de Lange et al. 2018) ** Nationally vulnerable (de Lange et al. 2018)

Appendix B Location of LakeSPI baseline sites for six lakes in the Otago Region

Table 2: Location of LakeSPI baseline sites for six lakes in the Otago Region.

Lake	Site	Location (Latitude, Longitude)	
Dunstan	A	-45.02494002	169.2094657
	B	-45.02206226	169.2282063
	C	-45.01169049	169.2291657
	D	-44.99105961	169.243207
	E	-45.0045212	169.2170699
Hāwea	A	-44.58254023	169.3190279
	B	-44.51553614	169.3040041
	C	-44.4367025	169.302626
	D	-44.46257693	169.2458949
	E	-44.59332221	169.2514978
Hayes	A	-44.96928326	168.8149724
	B	-44.98199986	168.8156903
	C	-44.99254094	168.8057055
	D	-44.98899582	168.7970729
	E	-44.96736724	168.8073014
Onslow	A	-45.553877	169.599425
	B	-45.535728	169.622107
	C	-45.526112	169.632421
Wakatipu	A	-44.90515281	168.4160187
	B	-45.0347559	168.4439134
	C	-45.07652376	168.508077
	D	-45.06110944	168.5868164
	E	-45.04836408	168.6223388
Wānaka	A	-44.65390644	169.0495732
	B	-44.63660024	169.0282062
	C	-44.56073614	169.0775632
	D	-44.52579609	169.0782889
	E	-44.6241506	169.0962682

7.5. Queenstown and Dunedin 2020-21 FY Public Transport report

Prepared for:	Data and Information Committee
Report No.	PPT2114
Activity:	Transport: Public Passenger Transport
Author:	Julian Phillips, Implementation Lead Transport
Endorsed by:	Gavin Palmer, General Manager Operations
Date:	31 August 2021

PURPOSE

[1] This report is provided to update the Committee on the performance of its public transport and total mobility services for the 2020/21 financial year.

[2] Monthly statistics comparing the previous two financial years are also provided. It also addresses customer enquiries and complaints, presents the results of the Dunedin and Queenstown customer satisfaction survey and provides information on the Total Mobility scheme and use of the Real Time information system.

EXECUTIVE SUMMARY

[3] In Dunedin, 2020/21 patronage is significantly higher, at 2,706,470 trips (+23% overall), than the previous 2019/20 period (2,199,254 trips), largely due to the 2019/20 period being affected by COVID travel-restrictions in 2020.

[4] Fare revenue for Dunedin for the same period is significantly lower due to the impact of the $2 fare trial; however, June 2021 (and preceding month) is significantly higher compared to June 2020, due to June 2020 being in the fare-free COVID travel period for Dunedin.

[5] Comparing the final month of the financial year, June 2021, with pre-COVID June 2019, patronage is significantly higher at +15% and indicative of the strong recovery of the Dunedin network post-COVID.

[6] Queenstown public transport activity remains significantly affected by COVID-19. For the 2020/21 financial year, patronage was significantly lower, at -29% overall, compared to 2019/20.

[7] Comparing the final month of the financial year, June 2021, with pre-COVID June 2019, patronage remains significantly lower at -36% and is consistent with expectations for the Queenstown Lakes District while borders are closed.

[8] This report compares the 2020/21 financial year with the most recent pre-COVID period, the 2018/19 financial year, to enable a more realistic comparison of both networks' performance.

[9] 852 complaints were received for the period November 2020 - July 2021, across both the Dunedin and Queenstown networks, equating to 0.033% of the trips taken for this period[1].

[10] The WKNZTA-ORC Customer Satisfaction surveys have been completed. This report presents the results of the Queenstown and Dunedin surveys, specifically the Overall Satisfaction with Service results of 96% and 94% respectively, which exceed the Annual Plan target of 85%.

[11] The Dunedin Real Time Tracking service (RTI) launched in May 2021, together with the introduction of the Transit app for both Dunedin and Queenstown.

[12] Reception to both RTI for Dunedin and the Transit app has been very positive, with detailed statistics provided later in the report.

[13] For Total Mobility, there was an increase of 18.5% in trips for Otago for 2020/21 compared to 2019/20, and a 31.4% increase in hoist trips.

RECOMMENDATION

That the Committee:

1) ***Notes*** *this report.*

BACKGROUND

[14] The Council (ORC) contracts public transport services in Dunedin and Queenstown to two transport operators; Ritchies and Go Bus. Network coverage is shown in Figures 2 and 3.

[15] Each Transport Operator is contracted to operate 'PTOM Units' (each unit being a collection of routes contracted to an operator, as defined by the 2014 Regional Public Transport Plan. PTOM stands for Public Transport Operating Model).

[16] There are 7 Units in total, 2 in Queenstown, both operated by Ritchies; and 5 in Dunedin, operated by both Ritchies and Go Bus.

[17] As can be seen in Figure 1, the Dunedin network comprises 23 routes that extend to Palmerston in the north and Mosgiel in the west. For the 2021/21 financial year, the Dunedin network carried 2,706,470 passengers; in the 2019/20 financial year, it was 2,199,254 passengers and 2,548,330 for 2018/19, noting that 2018/19 is the last full financial year where patronage was not affected by COVID restrictions.

[18] The Queenstown network comprises five routes that extend to Arrowtown in the east to Jack's Point in the south (see Figure 2). For the 2020/21 financial year, the Queenstown network carried 889,063 passengers; in the 2019/20 financial year, the network carried 1,249,503 passengers and 1,468,057 in 2018/19, noting that 2018/19 is the last full financial year where patronage was not affected by COVID restrictions.

[1] Detailed analysis of complaints commenced in November 2020.

[19] The following summarises patronage trends across both networks, comparing FY 2019/20 to FY 2020/21, with a comparison to the last full pre-COVID financial year, which is 2018/19 (as per the addendum to the report to the June 2021 meeting of the Data and Information Committee[2]). Monthly statistics comparing the previous years are also provided. It also addresses customer complaints, presents the results of the Queenstown and Dunedin customer satisfaction surveys and provides information on the Total Mobility scheme and use of the Real Time information system.

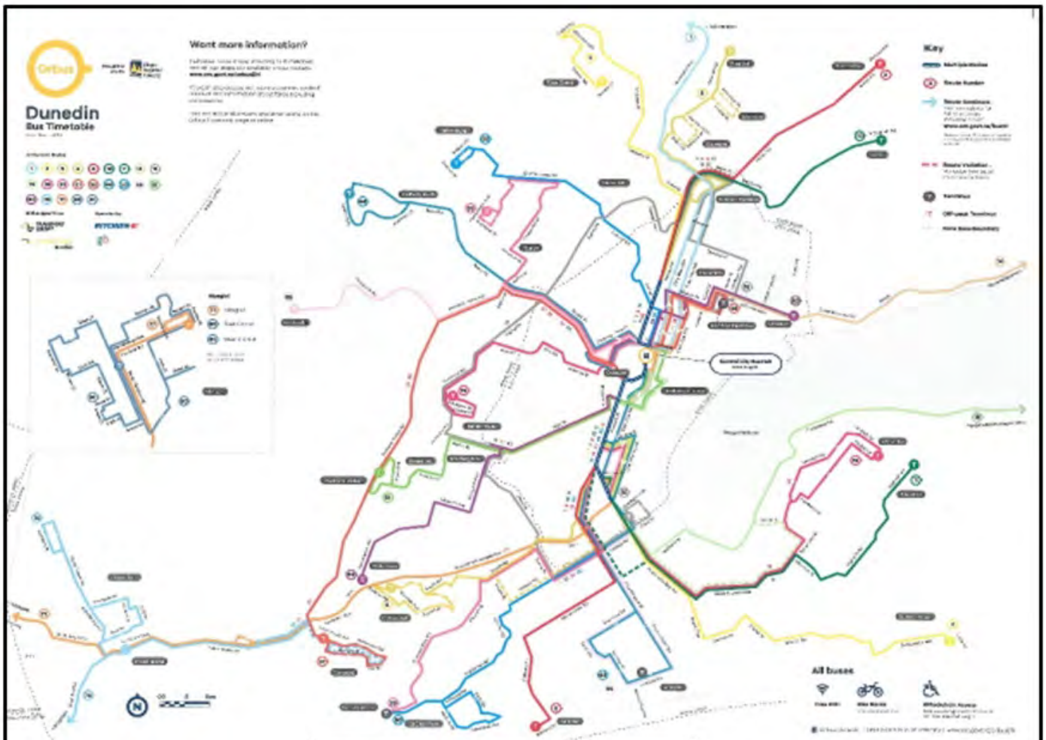


Figure 1: Dunedin Bus Network

[2] *Queenstown and Dunedin Q3 FY21 Patronage Report*, Report No. PPT2110, Prepared for Data and Information Committee, 9 June 2021.

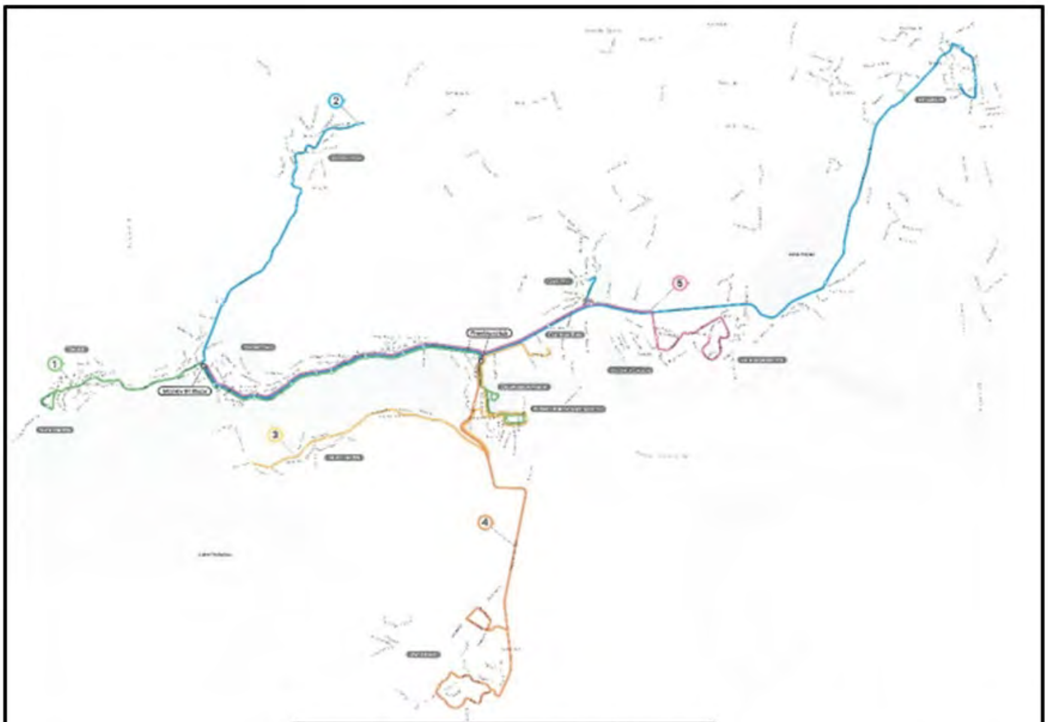


Figure 2: Queenstown Bus Network

DISCUSSION

PUBLIC TRANSPORT - DUNEDIN

[20] In Dunedin, 2020/21 patronage is significantly higher, at +23% overall, than the previous 2019/20 period, due to the 2020 period being affected by COVID travel restrictions.

[21] Fare revenue for 2020/21 is significantly lower due to the impact of the $2 fare trial and two months of free travel at the start of the new financial year; however, months such as June 2021 are significantly higher compared to 2020, due to the corresponding periods in 2020 being in the fare-free COVID travel period for Dunedin.

[22] Figures 3 and 4 compare the current financial year to the last full pre-COVID year, 2018/19. Figures 5, 6 and 7 show a detailed breakdown of statistics for the current financial year vs 2019/20.

Dunedin	July	August	September	October	November	December	January	February	March	April	May	June	Totals
2018/19 Patronage	**195,272**	**235,930**	**221,438**	**212,965**	**223,894**	**177,520**	**172,142**	**213,992**	**246,593**	**198,745**	**245,477**	**204,362**	**2,548,330**
2019/20 Patronage	220,652	235,666	230,329	224,285	226,692	182,910	181,525	228,477	175,526	26,802	68,709	197,681	**2,199,254**
2020/21 Patronage	293,294	278,162	209,278	224,799	223,263	190,821	160,848	201,611	250,266	195,795	243,550	234,783	**2,706,470**
2021/22 Patronage	231,082												**231,082**

Figure 3: 2020/21 patronage vs 2018/19

[23] Figure 3 evidences the post-COVID patronage recovery of the Dunedin network. 2020/21 patronage shows an increase of 6.2% when compared to 2018/19.

[24] Noting that July and August in 2020/21 were periods where fares were not charged, the data with these two months removed still displays increased patronage of 1% compared to 2018/19:

Dunedin	July	August	September	October	November	December	January	February	March	April	May	June	Totals
2018/19 Patronage			**221,438**	**212,965**	**223,894**	**177,520**	**172,142**	**213,992**	**246,593**	**198,745**	**245,477**	**204,362**	**2,117,128**
2019/20 Patronage			230,329	224,285	226,692	182,910	181,525	228,477	175,526	26,802	68,709	197,681	**1,742,936**
2020/21 Patronage			209,278	224,799	223,263	190,821	160,848	201,611	250,266	195,795	243,550	234,783	**2,135,014**
2021/22 Patronage													

Figure 4: 2020/21 patronage vs 2018/19, September to June

[25] The most recent two months of data, for June and July 2021, show an upward trend of 15% and 18% patronage growth respectively, when compared with 2018/19 figures.

Dunedin Public Transport Report

June 2021

Dunedin fare revenue for June 2021 is up compared to June 2020 when we were not charging fares but showing a decrease of 27% compared to June 2019. Patronage for the June is showing a 19% increase compared to June 2020 and a 15% increase from June 2019. Patronage for the financial year is 23% above the same period last year.

Fare Revenue June 2021

$294,653

▲ Up vs June 2020

▼ 27% vs June 2019

2020/21 Fare Revenue financial year to date

$2,651,673

▼ 30% vs 2019/2020 YTD

Patronage June 2021

234,783

▲ 19% vs June 2020

▲ 15% vs June 2019

2020/21 Patronage financial year to date

2,706,470

▲ 23% vs 2019/2020 YTD

Concession Type June 2021

Adult Card	56%
Adult Cash	4%
Child Card	24%
Child Cash	1%
SuperGold	16%

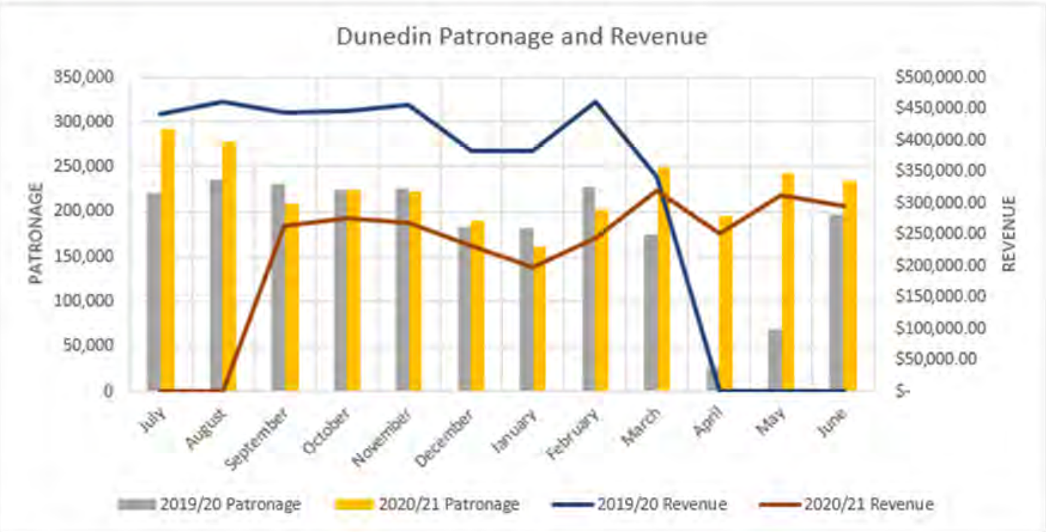


Figure 5: Dunedin Patronage and Revenue, FY 2020/21

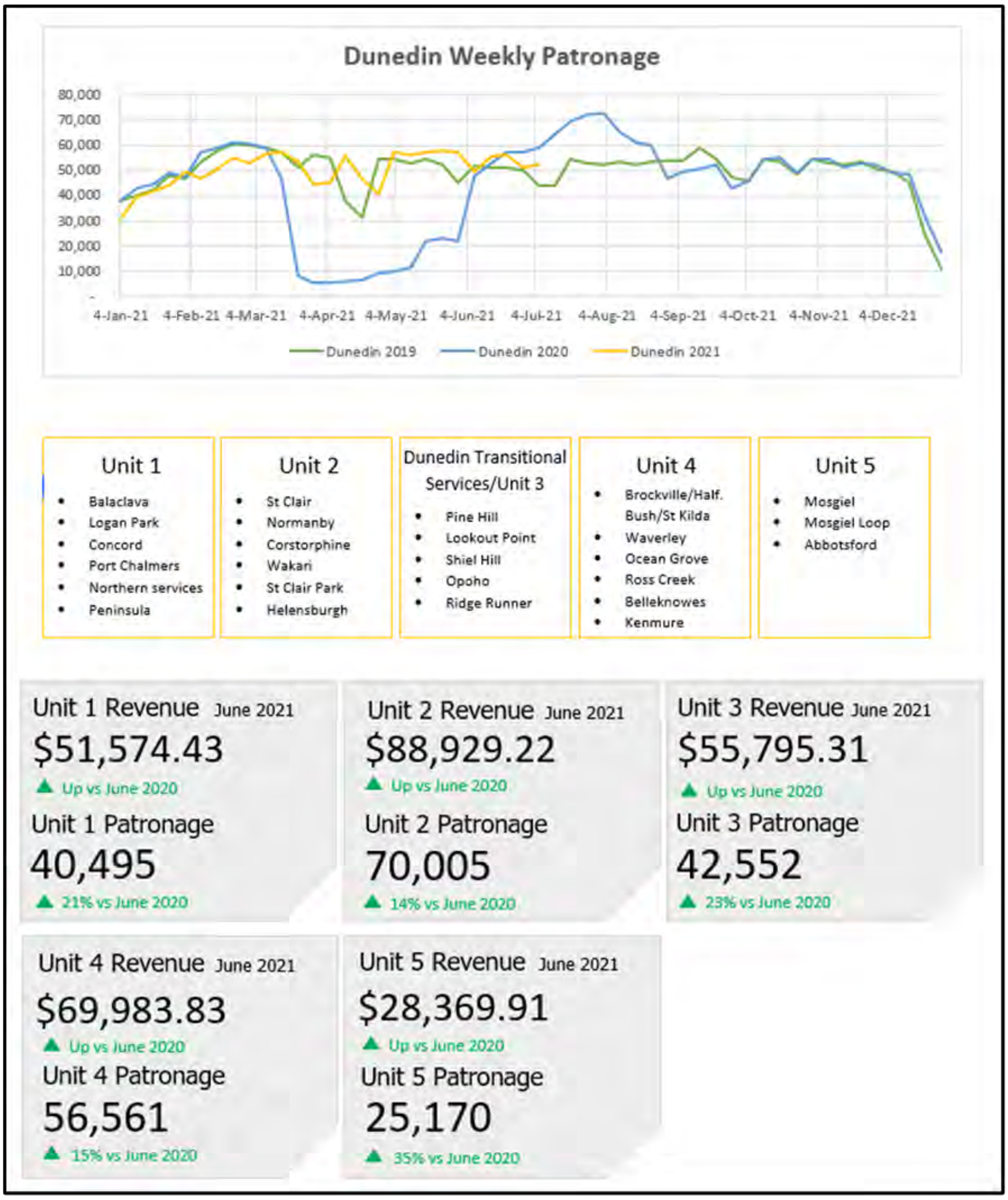


Figure 6: Dunedin weekly patronage, Unit Revenue and Unit Patronage

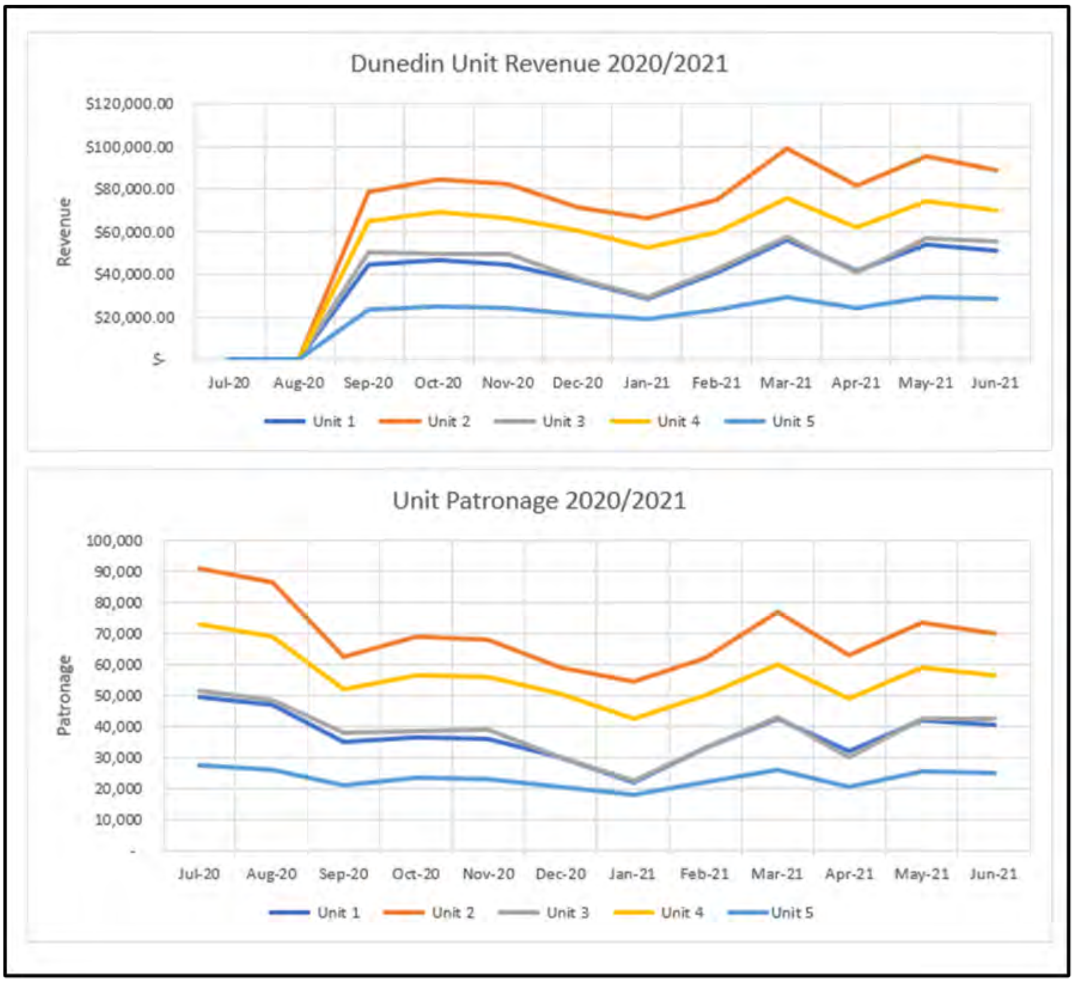


Figure 7: Dunedin Unit Revenue and Patronage

PUBLIC TRANSPORT – QUEENSTOWN

[26] Queenstown patronage and revenue continues to be low, a significant impact being measures implemented to address COVID-19, especially the border closure.

[27] Fare revenue for 2020/21 is significantly lower than 2019/2020 due to reduced patronage and approximately two and a half months of free travel at the start of the new financial year. Revenue for June 2021 is significantly higher compared to June 2020, due to the corresponding period in 2020 being in the fare-free COVID travel period for Queenstown.

[28] For the 2020/21 financial year, patronage is significantly lower, at -29% overall, compared to 2019/20, reflecting the impacts of COVID 19 on the Queenstown Lakes District.

[29] Comparing the final month of the financial year, June 2021, with pre-COVID June 2019, patronage remains significantly lower at -36% and is consistent with expectations, given the border closure.

[30] Figures 8 and 9 compare the current financial year to the last full pre-COVID year, 2018/19. Figures 10, 11 and 12 show a detailed breakdown of statistics for the current financial year vs 2019/20.

Queenstown	July	August	September	October	November	December	January	February	March	April	May	June	Totals
2018/19 Patronage	**122,752**	**117,442**	**103,974**	**111,657**	**125,600**	**118,997**	**136,055**	**129,439**	**134,084**	**125,244**	**118,077**	**124,736**	**1,468,057**
2019/20 Patronage	136,766	129,011	121,416	120,662	128,440	128,282	136,985	131,102	90,746	9,919	42,577	73,597	**1,249,503**
2020/21 Patronage	100,951	98,102	72,143	73,385	71,464	69,096	68,550	60,717	62,613	65,928	66,863	79,251	**889,063**
2021/22 Patronage	95,248												

Figure 8: 2020/21 patronage vs 2018/19

[31] Figure 8 evidences the relative lack of post-COVID patronage recovery in Queenstown when compared to Dunedin; 2020/21 patronage shows a decrease of 39.4% when compared to 2018/19

[32] Noting that July and August in 2020/21 financial year were periods where fares were not charged, the data with these months removed shows a decrease in patronage of 43.8%:

Queenstown	July	August	September	October	November	December	January	February	March	April	May	June	Totals
2018/19 Patronage			**103,974**	**111,657**	**125,600**	**118,997**	**136,055**	**129,439**	**134,084**	**125,244**	**118,077**	**124,736**	**1,227,863**
2019/20 Patronage			121,416	120,662	128,440	128,282	136,985	131,102	90,746	9,919	42,577	73,597	**983,726**
2020/21 Patronage			72,143	73,385	71,464	69,096	68,550	60,717	62,613	65,928	66,863	79,251	**690,010**
2021/22 Patronage													

Figure 9: 2020/21 patronage vs 2018/19, September to June

[33] The most recent 2 months of data, for June and July 2021, do however show an upwards trend, with June being 36% lower than 2018/19 and July 22% lower.

Queenstown Public Transport

June 2021

Queenstown patronage and revenue continues to be low with the lack of tourists in the area. Revenue is up compared to June 2020 where we weren't charging fares, and patronage up by 8% compared to June 2020.

Fare Revenue June 2021
$137,366
▲ Up vs June 2020
▼ -44% vs June 2019

2020/21 Fare Revenue financial year to date
$1,109,655
▼ -52% vs 2019/2020 YTD

Patronage June 2021
79,251
▲ 8% vs June 2020
▼ -36% vs June 2019

2020/21 Patronage financial year to date
889,063
▼ -29% vs 2019/2020 YTD

Concession Type June 2021

Adult Card	82%
Adult Cash	6%
Child Card	10%
Child Cash	0.2%
SuperGold	2%

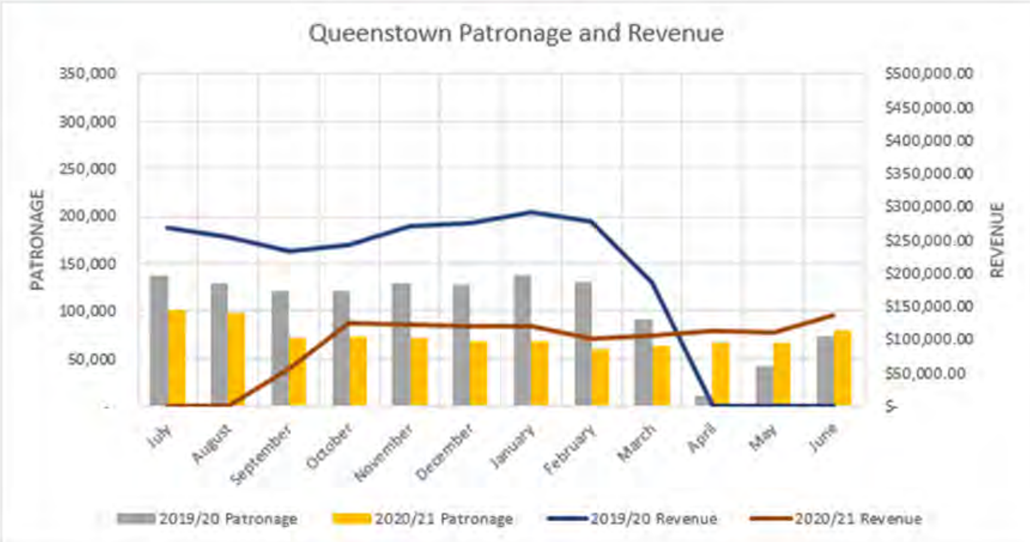
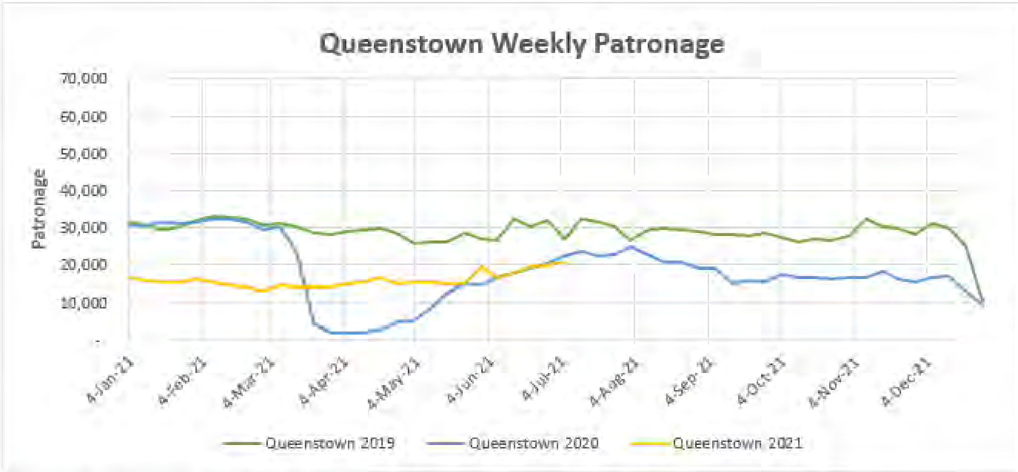


Figure 10: Queenstown Patronage and Revenue, FY 2020/21



The weekly patronage graph above shows us the full calendar year view of patronage per week.

Unit 6	Unit 7
• Fernhill – Remarkables Park • Jacks Point – Frankton Hub • Lake Hayes - Queenstown	• Arthurs Point – Arrowtown • Kelvin Heights – Frankton Flats

Unit 6 Revenue June 2021

$108,706.52

▲ Up vs June 2020

Unit 6 Patronage

62,167

▲ 8% vs June 2020

Unit 7 Revenue June 2021

$28,660.00

▲ Up vs June 2020

Unit 7 Patronage

17,084

▲ 6% vs June 2020

Figure 11: Queenstown weekly patronage, Unit Revenue and Unit Patronage

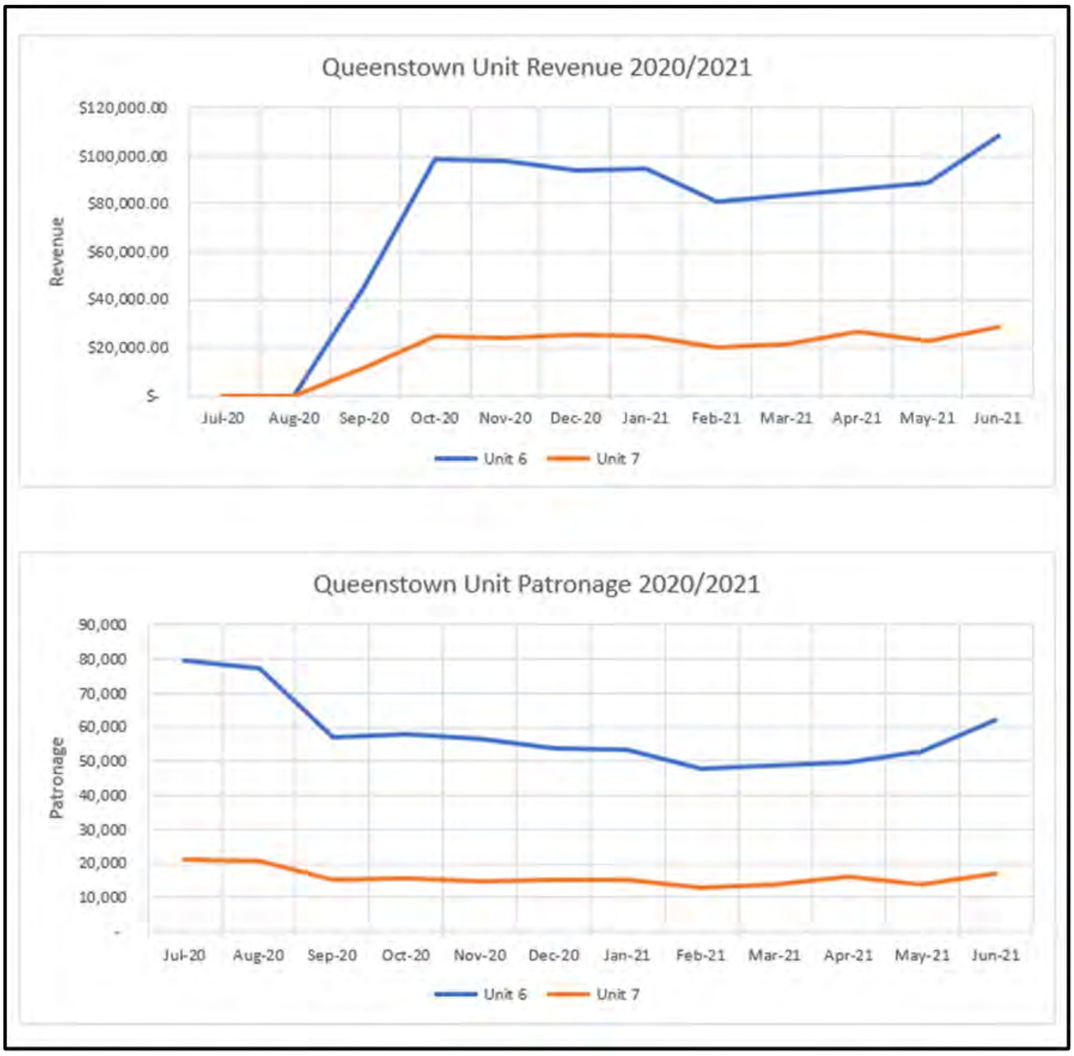


Figure 12: Queenstown Unit Revenue and Patronage

BEE CARD STATISTICS

[34] Over the weekend of 17 and 18 July 2021, Otago reached 50,488 registered Bee Card users.

[35] 100,424 cards have been issued in Otago, which equates to approximately two thirds of the combined population of Dunedin and Queenstown.

[36] At that time, the only other region in the Regional Integrated Ticketing System (RITS) consortium that has reached this number is Waikato, who have around 30 additional buses in comparison to Otago - and a higher population.

[37] Reaching 50,000 is a significant achievement for Council, noting that prior to the Bee Card launch the number of regular Go Card users was around 35,000.

CUSTOMER FEEDBACK AND COMPLAINTS

[38] The table and chart below capture feedback and complaints data, segregated by enquiry type, for November 2020 to July 2021.

[39] The table also provides for measurements against contractual (annual) KPI's, being:

- Less than 1 complaint per 1,000 trips regarding vehicle cleanliness and comfort;
- Less than 1 complaint per 3,000 trips regarding punctuality and driver behaviour
- Less than 1 complaint per 3,000 trips regarding incorrect fares

[40] These are highlighted in yellow in the table and are currently tracking well within target, noting that this method of data collation commenced in November 2020.

[41] Pre-COVID, the Otago network was reporting in excess of 4.1 million trips per annum. For the period November 2020 to July 2021 below, 2,571,749 trips were recorded. 852 of the enquiries below were complaints, equating to 0.033% of the trips taken for this period (or 0.33 complaints per 1,000 trips).

[42] Staff continue to follow up all complaints and take operational action where required.

Detail	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21				
Total Escalated enquiries	128	75	150	248	234	100	135	111	136						
Queenstown	35	17	35	47	38	30	30	30	43						
Dunedin	93	58	115	201	186	72	105	78	87						
Unspecified	-	-	-	-	9	-	-	3	6						
Enquiries split by category															
General	12	11	35	51	56	7	4	21	31						
Request	13	1	13	12	12	11	2	11	20						
Praise (Compliment)	2	0	4	8	9	2	3	1	6						
Lost Property	1	0	23	42	38	-	-	-	1						
Unspecified	-	-	-	-	4	-	-	-							
Total enquiries (excl. complaints)	28	12	75	113	119	20	9	33	58						
Total Complaints	100	63	75	135	115	82	126	78	78						
Complaints breakdown:												Total	% trips	Rate per 1,000	Rate per 3,000
Complaints related to the Bus Hub	2	1	1	2	0	-	-	-				6	0.023%	0.002333043	0.006999128
Complaint about cost	1	1	0	5	2	-	-	1				10	0.039%	0.003888404	0.011665213
Complaints about drivers	39	28	39	43	55	41	46	38	51			380	1.478%	0.147759365	0.443278096
Complaint about passenger behaviour	1	0	0	5	3	2	5	1				17	0.066%	0.006610287	0.019830862
Complaints about routes and times	17	8	29	24	3	3	5	1	8			98	0.381%	0.038106363	0.114319088
Complaints about ticketing	4	0	5	4	2	8	2	2	10			37	0.144%	0.014387096	0.043161288
Complaints about on-street infrastructure	10	2	6	14	1	7	9	5	9			63	0.245%	0.024496947	0.073490842
Complaints about timeliness	23	20	14	62	40	15	27	24	32			257	0.999%	0.099931992	0.299795975
Complaints about timetables/schedules	11	2	7	5	0	10	5	1	7			48	0.187%	0.018664341	0.055993023
Complaint about on-bus wi-fi	1	0	1	0	0	1	-	-	1			4	0.016%	0.001555362	0.004666085
Complaints related to other unclassified issues	18	13	34	18	5	7	2	-	14			111	0.432%	0.043161288	0.129483865
Complaints about cleanliness/condition of bus	-	-	-	6	2	2	3	2				15	0.058%	0.005832607	0.01749782
Complaints about transfers	-	-	-	4	0	-	-	-				4	0.016%	0.001555362	0.004666085
Complaints about information/comms	-	-	-	10	2	5	17	1	2			37	0.144%	0.014387096	0.043161288
Complaints related to app/website	-	-	-	4	0	1	5	2	2			14	0.054%	0.005443766	0.016331298

Figure 13: Customer Feedback, November 2020-July 2021

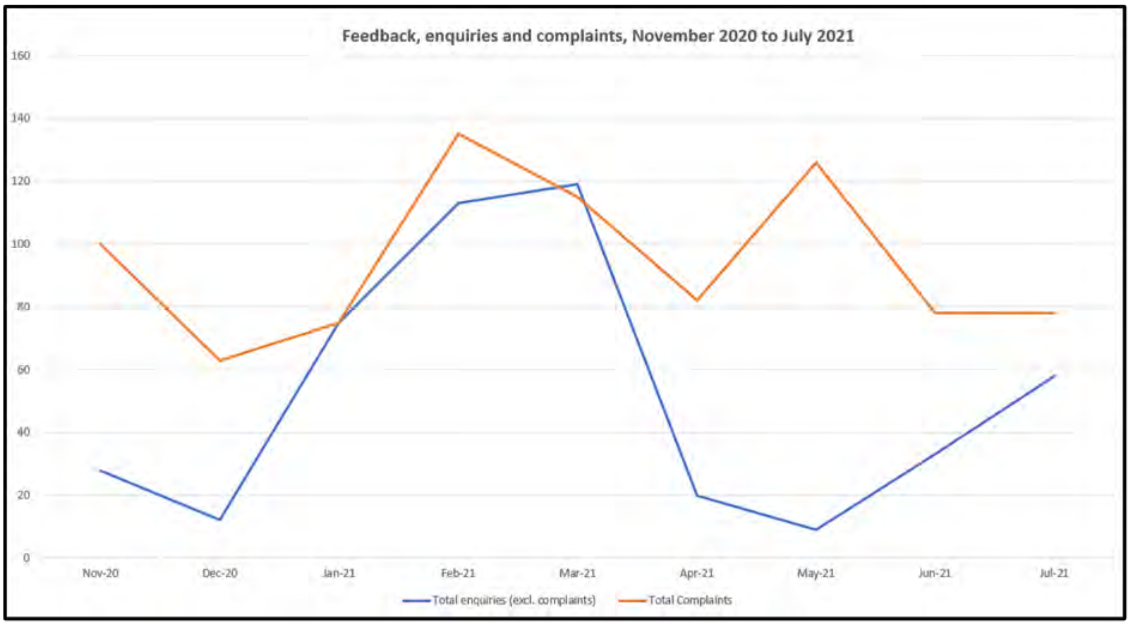


Figure 14: Customer feedback, charted, November 2020 - July 2021

REALTIME INFORMATION

[43] The report to the June 2021 meeting of the Data and Information Committee[3] noted the introduction of a new mobile-friendly realtime tracking system, utilising the Transit app and the existing Trackabus system.

[3] *Queenstown and Dunedin Q3 FY21 Patronage Report*, Report No. PPT2110, Prepared for Data and Information Committee, 9 June 2021.

Figure 15: The Transit app, showing live tracking of the number 8 St Clair Service

[44] The app has been very well received and has had significant uptake in a short period of time. Figures 16 and 17 show app usage for the period May/June/July 2021 for Dunedin and Queenstown, detailing tens of thousands of views across the period.

[45] The most popular route, Route 8, St Clair-Normanby, shows 75,261 views for this period. 'Views' refers to opening the app and using it to view services or buses nearest to the user. 'Clicks' refers to the specific action of 'clicking' on a route and using the additional functionality within the app to plan routes, set reminders, etc.

Line	Views	Clicks
8 St Clair - City - Normanby	75,261	9,016
3 Ross Creek - City - Ocean Grove	56,722	6,038
11 Shiel Hill - Opoho	53,620	5,324
10 Opoho - Shiel Hill	53,284	4,432
63 Balaclava - City - Logan Park	52,062	6,258
19 Waverley - City - Belleknowes	46,783	5,436
50 St Clair Park - City - Helensburgh	46,335	4,777
5 Pine Hill - City - Calton Hill	45,909	2,660
6 Calton Hill - City - Pine Hill	43,751	2,141
15 Ridge Runner Northbound	42,615	2,226
33 Corstorphine - City - Wakari	41,283	3,505
44 St Kilda - City - Halfway Bush	40,262	2,857
55 St Kilda - City - Brockville	40,142	2,537
18 Peninsula - City	36,895	2,916
14 Port Chalmers - City	34,285	3,910
77 Mosgiel - City	32,445	5,224
38 University - City - Concord	30,794	1,550
37 Concord - City - University	28,209	1,397
61 City to Kenmure	26,551	1,346
1 Palmerston - City	11,266	763
70 Brighton - Abbotsford - Green Island	8,149	470
80 Mosgiel East Circuit	4,456	100
81 Mosgiel West Circuit	3,786	61
40 MacAndrew Intermediate to Lookout Point via	1,035	39

Figure 16: Transit App usage, May – July 2021, Dunedin

Line		Views	Clicks
1	Fernhill to Remarkables Shopping Centre	34,499	6,732
2	Arthurs Point to Arrowtown	32,874	3,537
5	Queenstown to Lake Hayes Direct	30,854	2,758
3	Kelvin Heights to Frankton Flats	25,885	1,082
4	Frankton Hub to Jacks Point	15,515	546

Figure 17: Transit App usage, May – July 2021, Queenstown

[46] The back end of the RTI system delivers operational benefits, principally in terms of contract management and network reliability. Staff are utilising this to aid with contract/operator management and network reliability.

[47] Staff are working on the system 'back end' to derive more valuable data to help improve punctuality and monitor KPI's.

CUSTOMER SATISFACTION SURVEY

[48] The Waka Kotahi NZ Transport Agency (WKNZTA)/ORC customer satisfaction surveys for Queenstown and Dunedin have been completed.

[49] The survey is mandated by WKNZTA to take place biennially; however, Council has conducted the survey annually since 2013, with the exception of 2020 (due to COVID).

[50] WKNZTA state that for customer satisfaction survey results to be comparable across different operators, modes and regions, the questions, sampling methods and rating scales must be the same. The Transport Agency has developed a list of common questions that form the public transport customer satisfaction survey. This set of questions allows for national statistics to be developed for the purpose of accountability reporting to government and to allow benchmarking between approved organisations and between operators. WKNZTA sets out the question wording, the required rating scale and sampling method and provides guidelines for carrying out surveys (https://www.nzta.govt.nz/assets/resources/procurement-manual/docs/appendix-k-measuring.pdf).

[51] A randomised sample of trips is taken using an approved Excel formula, including peak/off-peak, evening and weekend services. 'Onboard sampling' is the WKNZTA approved methodology for ORC surveys, meaning selecting users onboard in-service buses.

[52] Temporary staff travel on selected trips and select every third person entering the bus (excluding those younger than 15 years). Surveys are completed on iPads that are controlled by survey staff use and the results are collated in a surveying tool before collation/analysis by transport staff.

[53] The Queenstown survey was completed May 2021, with all surveyed factors in the 80-100% range except for one, 'information about services and delays', at 70%. This measure is expected to improve over time due to the introduction of the Transit app.

[54] The 2020-21 Annual Plan, 'Measures and Targets – Transport' (Transport section, page 35) states "Public satisfaction – at least 85% of bus users surveyed annually for each network are satisfied with the overall standard of service". The overall result for the Queenstown network is 96%, which exceeds the target by 11%. This is lower than 2019 but higher than 2018.

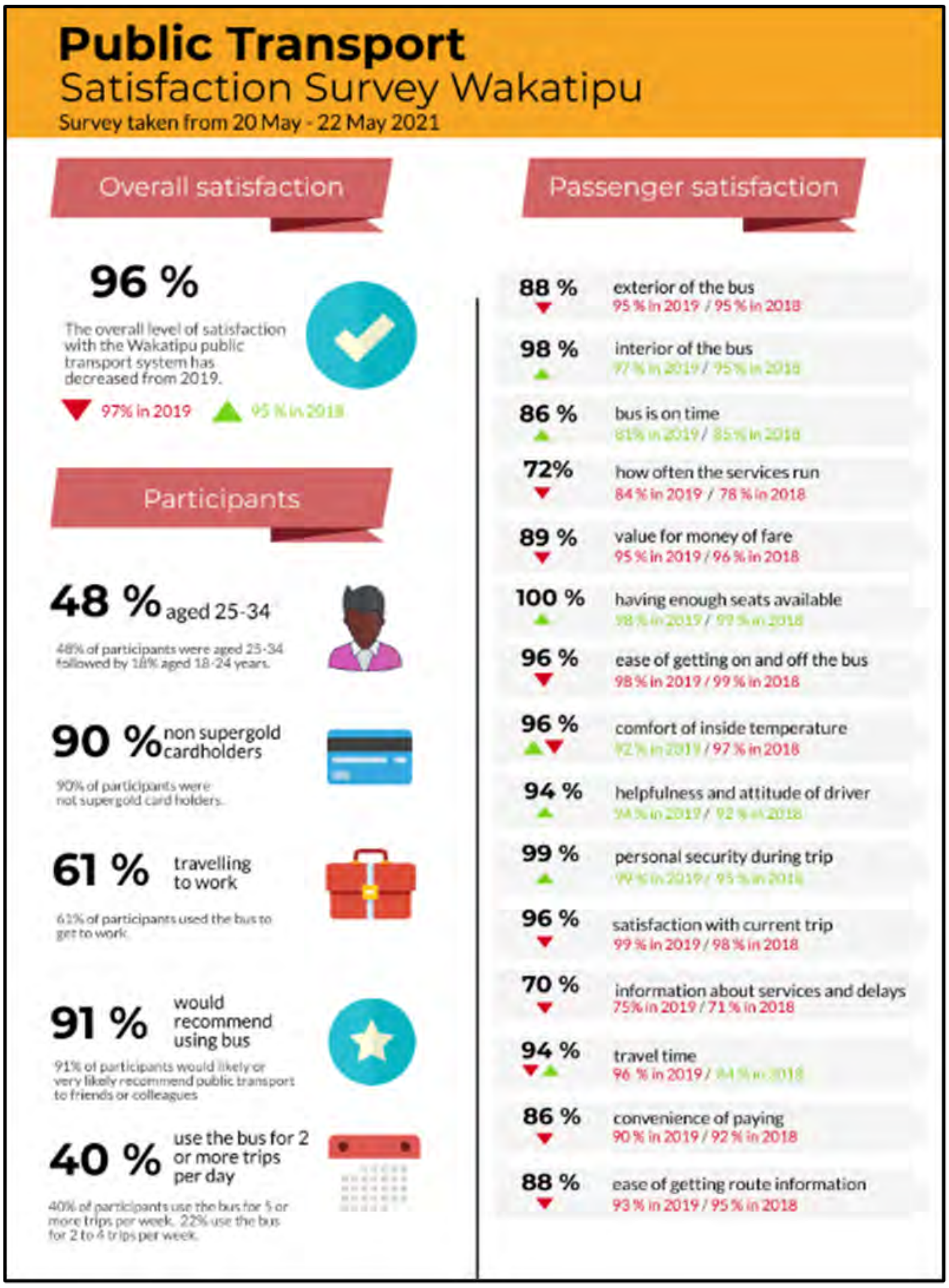


Figure 18: Queenstown Satisfaction Survey Results, 2020/21

[55] Survey points of interest include:

- Bus is on time: an increase of people satisfied from 2019 and 2018;
- Value for money of fare: this decreased from 2019 and 2018;
- Helpfulness and attitude of driver: this increased from 2019 and 2018;

- Personal security: an increase from both years.
- Convenience of paying: This has decreased.

[56] 'The convenience of payment' measure is a surprising decrease, given the introduction of the Bee Card; anecdotal feedback from the surveyors was passenger expectation of a Paywave-style system.

[57] The Dunedin survey was completed at the start of July 2021, with all surveyed factors in the 80-97% range.

[58] The 2020-21 Annual Plan, 'Measures and Targets – Transport' (Transport section, page 35) states "Public satisfaction – at least 85% of bus users surveyed annually for each network are satisfied with the overall standard of service". The overall result for the Dunedin network is 94%, which exceeds the target by 9%. This is higher than both 2019 and 2018.

[59] Survey points of interest include:

- Bus is on time: an increase of people satisfied from 2019 and 2018;
- Value for money of fare: this increased from 2019 and 2018, noting that the survey was taken during the $2 fare trial, whereas previous surveys were conducted in a multi-zone fare environment; This is likely an indication of the popularity of the flat fare trial.
- Helpfulness and attitude of driver: this increased from 2019 but is lower than 2018;
- Service frequency is down from both previous surveys. This could be a result of increased patronage, particularly on Mosgiel routes and peak afternoon services, where duplicate services have been operating in order to provide sufficient capacity for high demand that is filling scheduled services at these times.

Figure 19: Dunedin Satisfaction Survey Results, 2020/21

TOTAL MOBILITY

[60] Figure 21, below, shows 2020/21 patronage, whereby 'Trips' includes 'Hoist' trips. 'Hoist' refers to those customers that require a hoist-equipped vehicle to travel for which suppliers receive a separate reimbursement.

[61] For 2020/21, the mean monthly number of 'Trips' was just over 9,100 per month and of those, on average 1,290 required hoist transport.

[62] 85% of trips take place in Dunedin and Mosgiel, followed by 12% in Oamaru. The balance are travellers in Queenstown (2%) and Wanaka (1%).

[63] Comparing 2020/21 to 2019/20, there was an increase of 18.5% in trips, and a 31.4% increase in hoist trips:

- 2019/20: 100,797 trips of which 12,854 had hoist use
- 2020/21: 119,436 trips of which 16891 had hoist use

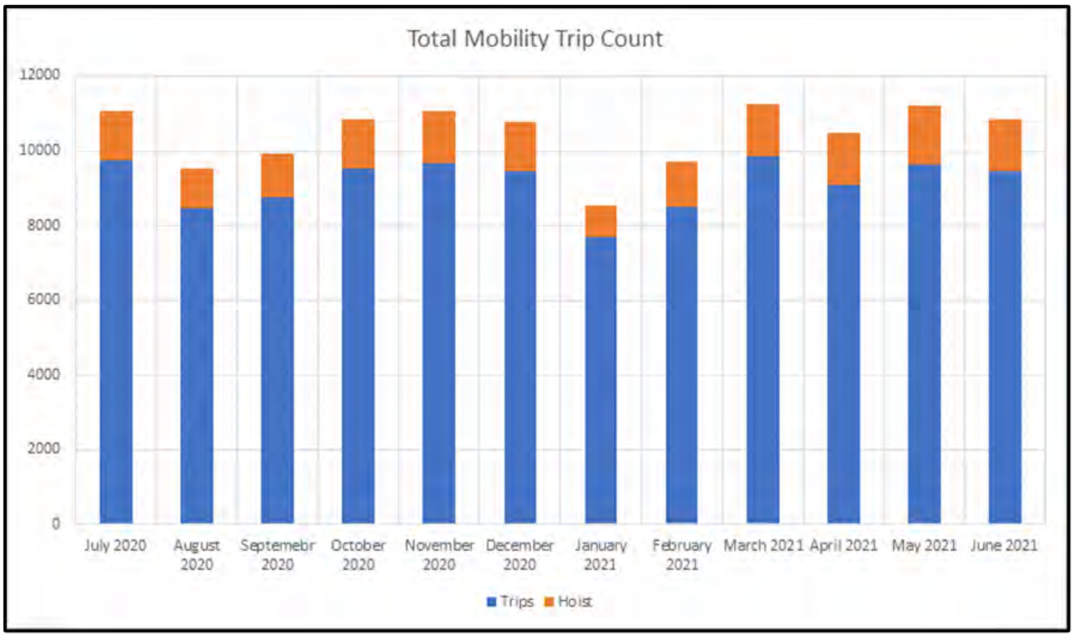


Figure 20: Total Mobility patronage

CONSIDERATIONS

Strategic Framework and Policy Considerations

[64] Not applicable.

Financial Considerations

[65] It is not known how long the current COVID-19 outbreak will be ongoing, thus it is unknown how great the effect on patronage and revenue will be.

Significance and Engagement

[66] Not applicable.

Legislative and Risk Considerations

[67] Not applicable.

Climate Change Considerations

[68] Continued focus on increasing the uptake of public transport in Otago will contribute to reductions in greenhouse gas levels / CO_2 output; noting that a single fully-occupied bus is the equivalent of approximately 50 single-occupancy passenger vehicles.

Communications Considerations

[69] Not applicable.

NEXT STEPS

[70] The next steps are to:

- Continue to work with bus contractors to address customer feedback and work to identify trends in that feedback with the ultimate objective to grow (Dunedin) and recover patronage in Queenstown;
- Continue to collaborate with local and central government partners on public transport matters;
- Provide an update to the next Data and Information Committee on the effects of the most recent COVID-19 outbreak on patronage and revenue for Dunedin and Queenstown.

ATTACHMENTS

Nil