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2021 Lower Fraser Valley Air Quality Monitoring Report

SERVICES AND SOLUTIONS FOR A LIVABLE REGION

This report was prepared by the staff of the Air Quality and Climate Action Services Division of the Metro Vancouver Regional District ("Metro Vancouver"). The project was managed by Geoff Doerksen with a project team that included Ken Reid, and Kyle Howe.

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Summary

This annual report summarizes the air quality monitoring data collected by the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2021 and describes the air quality monitoring activities and programs conducted during the year. The focus is to report on the state of ambient (outdoor) air quality in the LFV.

LFV Air Quality Monitoring Network

Metro Vancouver operates a comprehensive network with stations in Metro Vancouver, as well as stations in the Fraser Valley Regional District (FVRD) in partnership with the FVRD. The LFV Air Quality Monitoring Network includes air quality monitoring stations located from Horseshoe Bay in West Vancouver to Hope. A map of the network is provided in Section C.

Air quality and weather data is collected automatically and on a continuous basis, transmitted to Metro Vancouver's Head Office in Burnaby, and stored in an electronic database. The data is then used to communicate air pollutant information to the public, such as through air quality health index (AQHI) values and on airmap.ca.

Air quality monitoring stations are located throughout the LFV to provide an understanding of the air quality levels that residents are exposed to most of the time. This report shows how these levels have varied throughout the region and how these levels have changed over time. Trends in air quality measured by the Air Quality Monitoring Network are used to evaluate the effectiveness of pollutant emission reduction actions undertaken as part of Metro Vancouver's *Clean Air Plan* (Metro Vancouver, 2021).

Specialized Air Quality Monitoring

In addition to the monitoring network stations, Metro Vancouver deploys portable air quality stations and instruments to conduct specialized monitoring studies. Specialized studies can target suspected problem areas at the local, neighbourhood or community level. In 2021, Metro Vancouver's mobile air monitoring unit (MAMU) concluded an air quality monitoring study at Musqueam's Indian Reserve No. 2 lands in Vancouver. The monitoring provides information on air quality in the Musqueam community and supports Metro Vancouver's Iona Island Wastewater Treatment Plant Biosolids Dewatering Facility project.

Pollutants Monitored

Pollutants are emitted to the air from a variety of human activities and natural phenomena. Once airborne, the resulting pollutant concentrations are dependent on several factors, including the weather, topography and chemical reactions in the atmosphere. Common air contaminants, including ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter, are widely monitored throughout the network. Particulate matter is composed of very small particles that remain suspended in the air. They are further distinguished by their size, which is measured in units of a millionth of a metre (or micrometre).
Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored at stations throughout the LFV.
Other pollutants less widely monitored in the network include black carbon (BC), ultrafine particles (UFP), ammonia (NH_3), volatile organic compounds (VOC), and total reduced sulphur compounds (TRS).

Air Quality Health Index (AQHI)

Developed by Environment and Climate Change Canada and Health Canada, the Air Quality Health Index (AQHI) communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change. The AQHI is calculated every hour using monitoring data from stations in the LFV.
Current AQHI levels in the LFV as well as the AQHI forecasts and additional information about the AQHI are available at:

- airmap.ca; and
- env.gov.bc.ca/epd/bcairquality/readings/aqhi-table.xml

Air Quality Objectives and Standards

Several pollutant-specific air quality objectives and standards are used as benchmarks to characterize air quality. They include Metro Vancouver and provincial ambient air quality objectives and the federal Canadian Ambient Air Quality Standards (CAAQS) for ozone, particulate matter, sulphur dioxide, and nitrogen dioxide.

The federal Canadian Ambient Air Quality Standards have been established as objectives under the Canadian Environmental Protection Act. In 2015, Metro Vancouver adopted a 1-hour interim ambient air quality objective for SO_2 of 75 parts per billion (ppb). After establishment of the federal SO_2 CAAQS, Metro Vancouver's SO_2 objectives were revised in 2017, with a more stringent 1-hour objective of 70 ppb not to be exceeded and an annual objective of 5 ppb.

In 2019, Metro Vancouver aligned its objectives for CO, NO_2, and O_3 with federal and provincial standards. Metro Vancouver adopted a 1-hour and annual ambient air quality objective for NO_2 that is the same as the federal 2020 CAAQS. Similarly, the 8-hour O_3 objective was made the same as the 2020 CAAQS. The 1-hour and 8-hour CO objectives were set to 13,000 ppb and 5,000 ppb respectively, to match the more stringent Provincial objectives.

Priority Pollutants

Research indicates that adverse health effects can occur at the air contaminant concentrations measured in the LFV. Health experts have identified exposure to ozone, particulate matter, and nitrogen dioxide as being associated with the most serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. $PM_{2.5}$ particles are small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Nitrogen dioxide can have adverse effects on human health and the environment. It can cause adverse effects on respiratory systems of humans, cause damage to vegetation, and contribute to the formation of ozone. Long-term exposure to these pollutants can aggravate existing health conditions and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail, and non-road engines. These particles ("diesel PM") are carcinogenic and are believed to contribute significantly to the health effects described above. Instrumentation operated at some air quality monitoring stations in the LFV can be used to estimate the proportion of particles that originate from diesel engines.

Research presents evidence of harmful effects of air pollution on health, including mortality, at levels below current objectives and standards for many pollutants including fine particulate matter, nitrogen dioxide, and ground-level ozone. These findings suggest there may be no safe levels of exposure to air pollution and there are important public health benefits from continued reduction of air contaminants.

Air Quality Advisories

In 2021, air quality advisories were issued during four separate periods for a total of ten days in the summer. In June, a four-day advisory was issued for ground-level ozone during a record-breaking heat wave with a fine particulate matter advisory added on the fourth day. In July a one-day ozone advisory was issued due to hot and sunny weather. In August, a two-day fine particulate matter advisory was issued due to smoke from wildfires burning in BC and Washington state, and a three-day particulate matter and ozone advisory was issued due to smoke, local emissions, and hot and sunny weather.

In the last ten years, the number of days when air quality advisories were in place ranged from zero to as many as 22 days annually. Periods of degraded air quality can occur in the LFV for several reasons, such as summertime smog during hot weather or smoke from forest fires. Air quality advisories are issued to the public when air quality has deteriorated or is predicted to deteriorate within the LFV.

Wildfires and Climate Change

In recent years, wildfires in the Pacific Northwest have increased in severity, frequency, duration, and spatial extent. Wildfires can produce considerable amounts of smoke that can be transported great distances. Both 2017 and 2018 had significant wildfire seasons with 2018 experiencing one of the worst in British Columbia's history, with the largest area burned. Overall fire activity in 2019 and 2020 were both well below the 10-year provincial average. However, in

2020 the region was severely impacted by wildfire smoke due to active wildfire seasons in Washington, Oregon, and California. In 2021 an active wildfire season in BC resulted in wildfire smoke impacts to the region.

Climate projections indicate the region will experience hotter, drier summers and wetter, warmer winters. A warming climate is likely to increase the frequency and duration of wildfires and associated smoke impacts, while also increasing in-region ground-level ozone formation through the intensity and duration of summer heat waves.

Metro Vancouver's *Clean Air Plan* considers the increasing impacts of wildfire activity in the strategies and actions it outlines to reduce health risks for Metro Vancouver residents (Metro Vancouver, 2021). Metro Vancouver's *Climate 2050* Roadmaps also identify actions to help the region adapt to climate-related impacts on regional air quality (Metro Vancouver, 2024).

Regional Long-Term Trends

Long-term *regional* trends in air quality are the trends observed within the LFV as a whole. They are determined by averaging measurements from several stations distributed throughout the LFV.

Figures S1 to S4 show the average concentrations and the short-term peak concentrations of four common air contaminants for the last two decades. Average concentrations represent the ambient concentrations that the region experiences most of the time. Short-term peak concentrations show the relatively infrequent higher concentrations experienced for short periods (on the scale of one hour to one day). Specific locations may have experienced trends that differ slightly from the regional picture.

Improvements have been made over the last two decades for most air pollutants, including nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). Both short-term peak and average concentrations have declined since the mid-nineties for all these pollutants with the exception of $PM_{2.5}$ which has been influenced in recent years by wildfire smoke. This improvement is a result of actions by Metro Vancouver and others to reduce emissions across a variety of sectors, despite population growth in the region over this period. For example, stricter vehicle emission standards and the AirCare program (1992 – 2014) are largely responsible for lower NO_2 and CO levels.

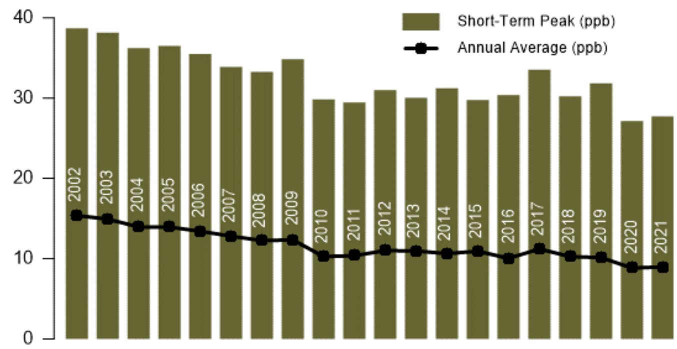


Figure S1: Nitrogen dioxide (NO_2) trend

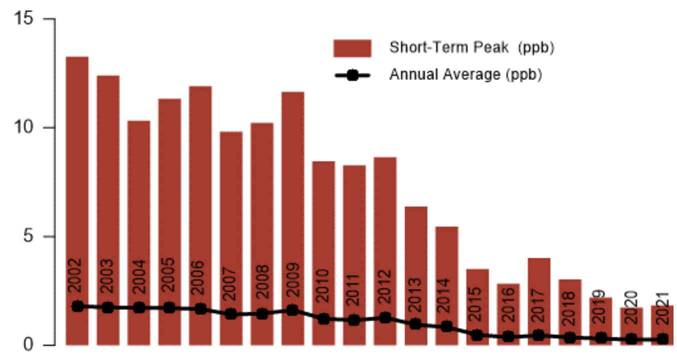


Figure S2: Sulphur dioxide (SO_2) trend

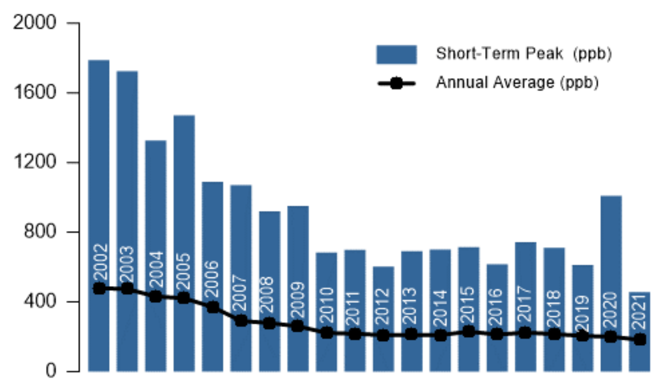


Figure S3: Carbon monoxide (CO) trend

Requirements for reduced sulphur content in marine, on-road and off-road fuels, and reduced emissions from the petroleum refining and cement industries have led to the considerable improvements in SO_2 levels. Emission reductions from light duty and heavy duty vehicles, wood products sectors, and petroleum refining have contributed to the decline in $PM_{2.5}$ levels.

The regional $PM_{2.5}$ trends are illustrated in Figure S4. Wildfire effects are evident in 2017, 2018, and 2020.

Fine particulate matter monitoring technology was upgraded in 2013 to continuous particulate monitors that met the US Environmental Protection Agency $PM_{2.5}$ Federal Equivalent Method (FEM). The FEM monitors have the ability to measure a portion of particulate matter not previously measured.

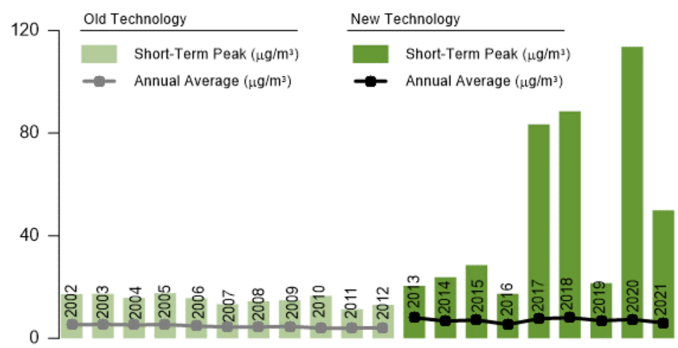


Figure S4: Fine particulate matter ($PM_{2.5}$) trend

For ozone, the same improvements seen for other pollutants have not been observed. In contrast, average regional ozone levels (Figure S5) have shown a slight increasing trend. Research suggests that background ozone concentrations (i.e., ozone from out of region) are rising and are one reason for the observed increase in average levels.

Regionally averaged short-term peak ozone trends are also shown in Figure S5. Short-term peak ozone levels have been mainly unchanged during the last two decades, despite large reductions in emissions of pollutants that contribute to ozone formation.

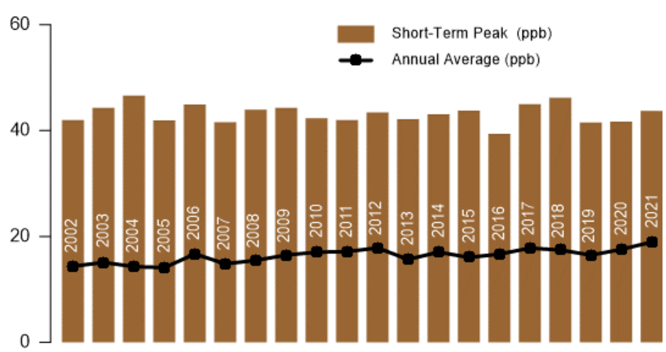


Figure S5: Ozone (O_3) trend

Strategic policy direction for ozone management in the LFV is provided in the Regional Ground-Level Ozone Strategy based on local scientific research (Metro Vancouver, 2014). This research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

Visual Air Quality

Visual air quality (sometimes referred to as visibility or haze) can become degraded in the LFV, causing local views to become partially or fully obscured. Haze may have different characteristics depending on the underlying cause. In parts of Metro Vancouver, especially more urbanized areas to the west, haze can have a brownish appearance due to nitrogen dioxide from transportation emissions. Further east in the LFV, impaired visual air quality can be more associated with a white haze caused by small particles ($PM_{2.5}$) in the air that scatter light.

Monitoring is conducted to assess how and by how much visual air quality has become impaired. Measurements of $PM_{2.5}$, particle constituents (for example, particulate nitrate, particulate sulphate, elemental carbon, and organic carbon), nitrogen dioxide, and other air contaminants, as well as light scattering, provide important data for visual air quality management activities. Automated digital cameras record views along specific lines-of-sight in several locations in the LFV.

By examining photographs alongside data from monitoring equipment, visual air quality impairment can be related to pollutant concentrations and relevant emissions sources. These activities, which are conducted through a multi-agency collaboration (BC Visibility Coordinating Committee), inform the development of policy options for improving visual air quality.

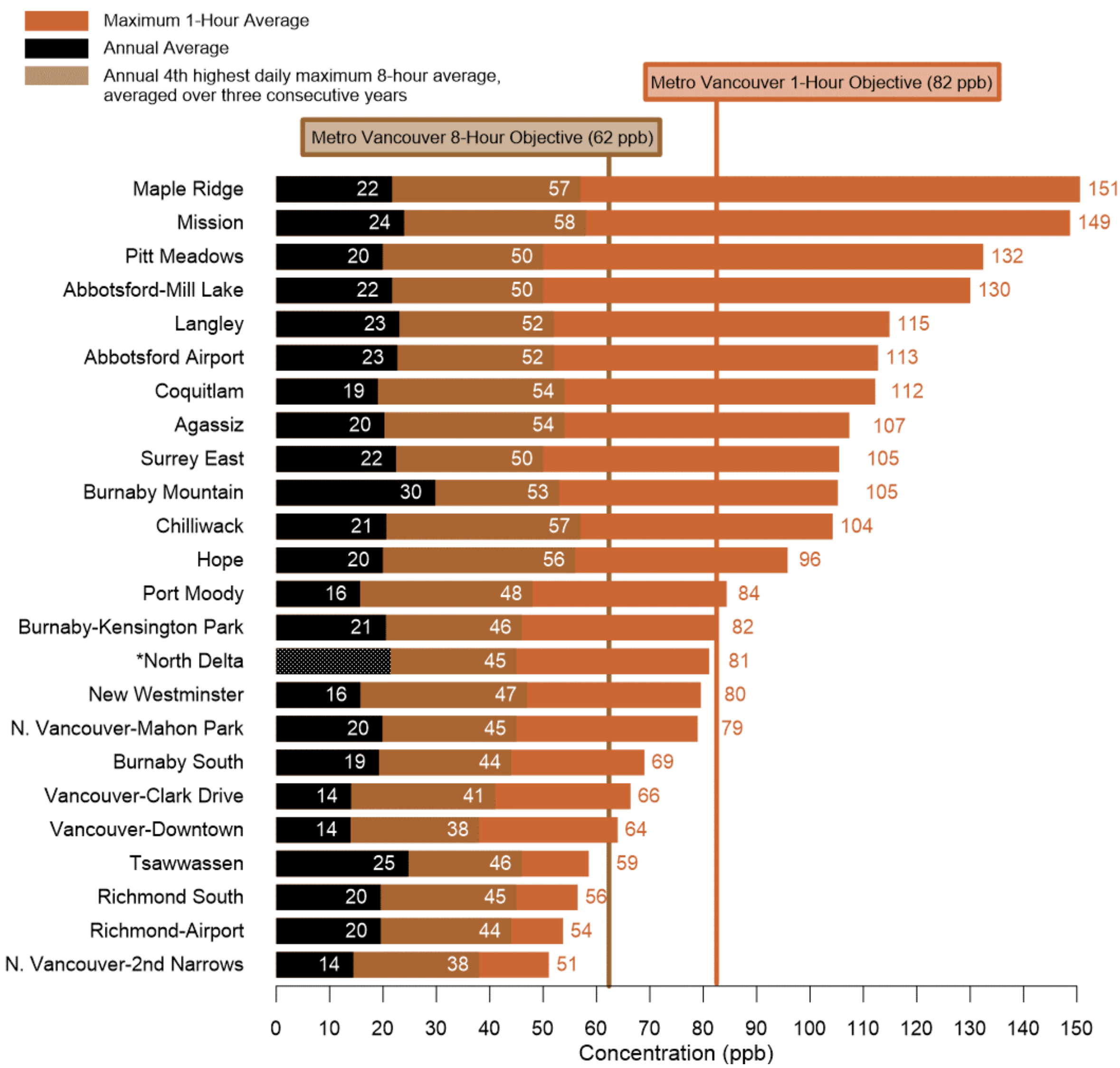
Ground-Level Ozone – 2021

Monitoring results for all ozone monitoring stations in 2021 are shown in Figure S6. The data show that peak ozone levels, as measured by the maximum 1-hour average and Metro Vancouver's 8-hour objective value, generally occurred in the eastern parts of Metro Vancouver and in the FVRD during sunny, hot weather.

In 2021, Metro Vancouver's 8-hour objective was met at all monitoring stations. The 1-hour Metro Vancouver objective was exceeded at numerous stations during a record-breaking heat wave in late June resulting in high ozone levels not measured in the region since the 1980s. Exceedances of the objective were experienced at more than half the monitoring stations on June 26 to 29.

Exceedances were also measured during hot and sunny weather on July 30 and August 13 at a few stations. Air quality advisories were in effect for eight days (June 26 to 30, July 30, and August 13) due to elevated levels of ground-level ozone.

> Ground-level ozone is a secondary pollutant formed in the air from other contaminants such as nitrogen oxides (NO_X) and volatile organic compounds (VOC). The highest concentrations of ozone occur during hot sunny weather and can be enhanced by wildfire smoke.
>
> NO_X emissions are dominated by transportation sources, while VOC are emitted from natural sources (e.g., trees), cars, light trucks, and solvents found in industrial, commercial, and consumer products.



*Data completeness criteria was not met at this station. The average has been calculated with all available data.

Figure S6: Ground-level ozone (O_3), 2021

Fine Particulate Matter ($PM_{2.5}$) – 2021

Results for all $PM_{2.5}$ monitoring stations in 2021 are shown in Figure S7. All stations were below (i.e., better than) the Metro Vancouver annual objective of 8 µg/m³. Metro Vancouver's 24-hour $PM_{2.5}$ objective was exceeded at four stations between June 28 and 30 due to a buildup of local emissions and secondary formation of $PM_{2.5}$ during a record-breaking heat wave. A one day $PM_{2.5}$ advisory was issued during the heat wave.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective also occurred on July 31 to August 3 at four stations. A two-day $PM_{2.5}$ advisory was issued due to wildfire smoke from fires burning in BC and Washington state. Exceedances occurred at all monitoring stations from August 12 to 15 due to wildfire smoke from fires burning in BC and Washington state, with a $PM_{2.5}$ advisory issued for three days.

All stations were at or below the Canadian Ambient Air Quality Standard (CAAQS) with the exception of Mission. The $PM_{2.5}$ 24-hour CAAQS value is calculated by taking the annual 98th percentile daily average concentrations, averaged over three consecutive years.

Fine particulate matter ($PM_{2.5}$) emissions are typically dominated by residential wood burning, non-road engines and equipment, and industrial sources. However, impacts of smoke from wildfires outside the region are becoming more apparent.

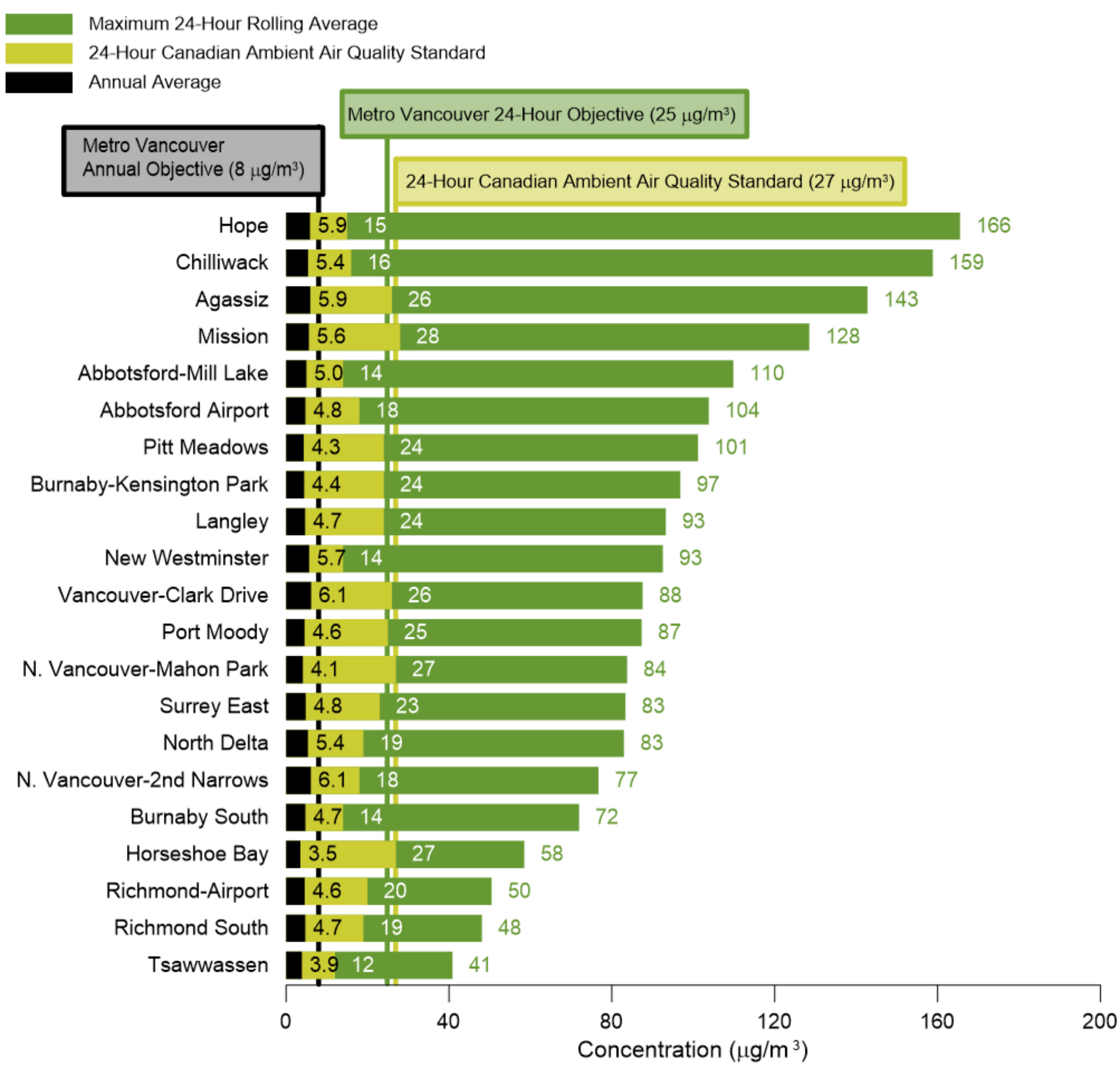
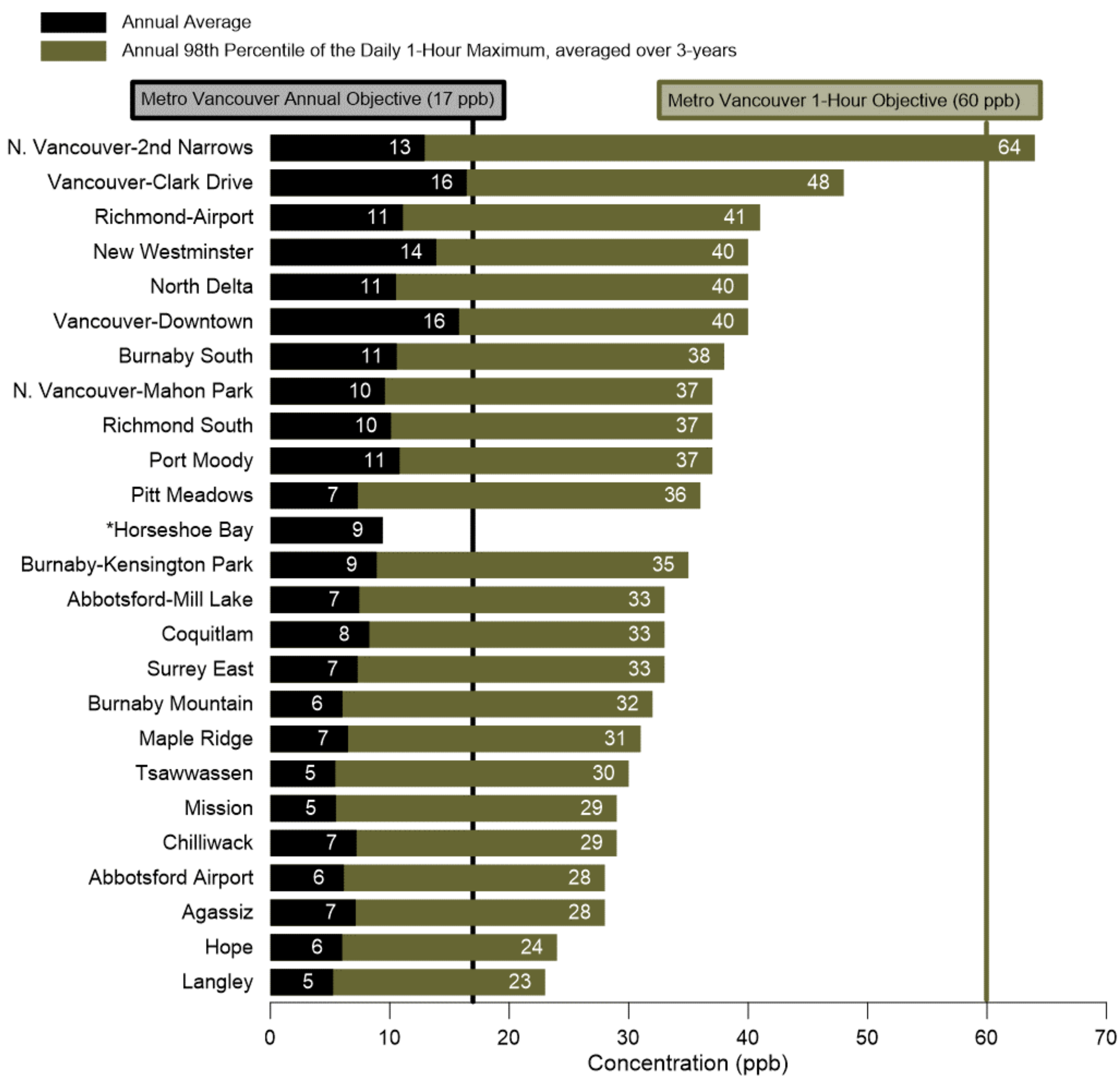


Figure S7: Fine particulate matter ($PM_{2.5}$), 2021

Nitrogen Dioxide – 2021

Results for nitrogen dioxide (NO_2) monitoring in 2021 are shown in Figure S8. All stations measured nitrogen dioxide levels that were below Metro Vancouver's 1-hour objective with the exception of North Vancouver-Second Narrows, which was influenced by local construction activity in 2021. The 1-hour objective value is calculated by taking the annual 98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years. The annual objective was met at all monitoring stations.

As nitrogen dioxide emissions are dominated by transportation sources, the highest average nitrogen dioxide concentrations are measured in the more densely-trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.



*Nitrogen dioxide measurements were added to Horseshoe Bay in 2021. There is insufficient data to calculate the three year 1-hour metric.

Figure S8: Nitrogen dioxide (NO_2), 2021

Sulphur Dioxide – 2021

Monitoring results for sulphur dioxide (SO_2) monitoring stations are shown in Figure S9. Sulphur dioxide levels were below Metro Vancouver's 1-hour objective and annual objective at all stations in 2021.

Sulphur dioxide levels were at or below the Metro Vancouver's 1-hour objective at all stations in 2021 with the exception of Burnaby-Capitol Hill that exceeded for two hours. Average levels remained low and below the annual objective in 2021, which can be attributed in part to stricter marine fuel requirements that came into effect at the beginning of 2015.

Sulphur dioxide is formed primarily by the combustion of fossil fuels containing sulphur. Within the LFV the major sources of SO_2 are an oil refinery (37%), marine vessels (16%), a waste- to-energy facility (1%) and two cement plants (12%). The geographical distribution of sulphur dioxide emissions is influenced mainly by the refinery in Burnaby and ocean-going vessels in the marine areas of Burrard Inlet, although in recent years, marine emissions have been reduced substantially. The highest sulphur dioxide levels are typically measured near the Burrard Inlet area. Away from the Burrard Inlet area, sulphur dioxide levels are considerably lower.

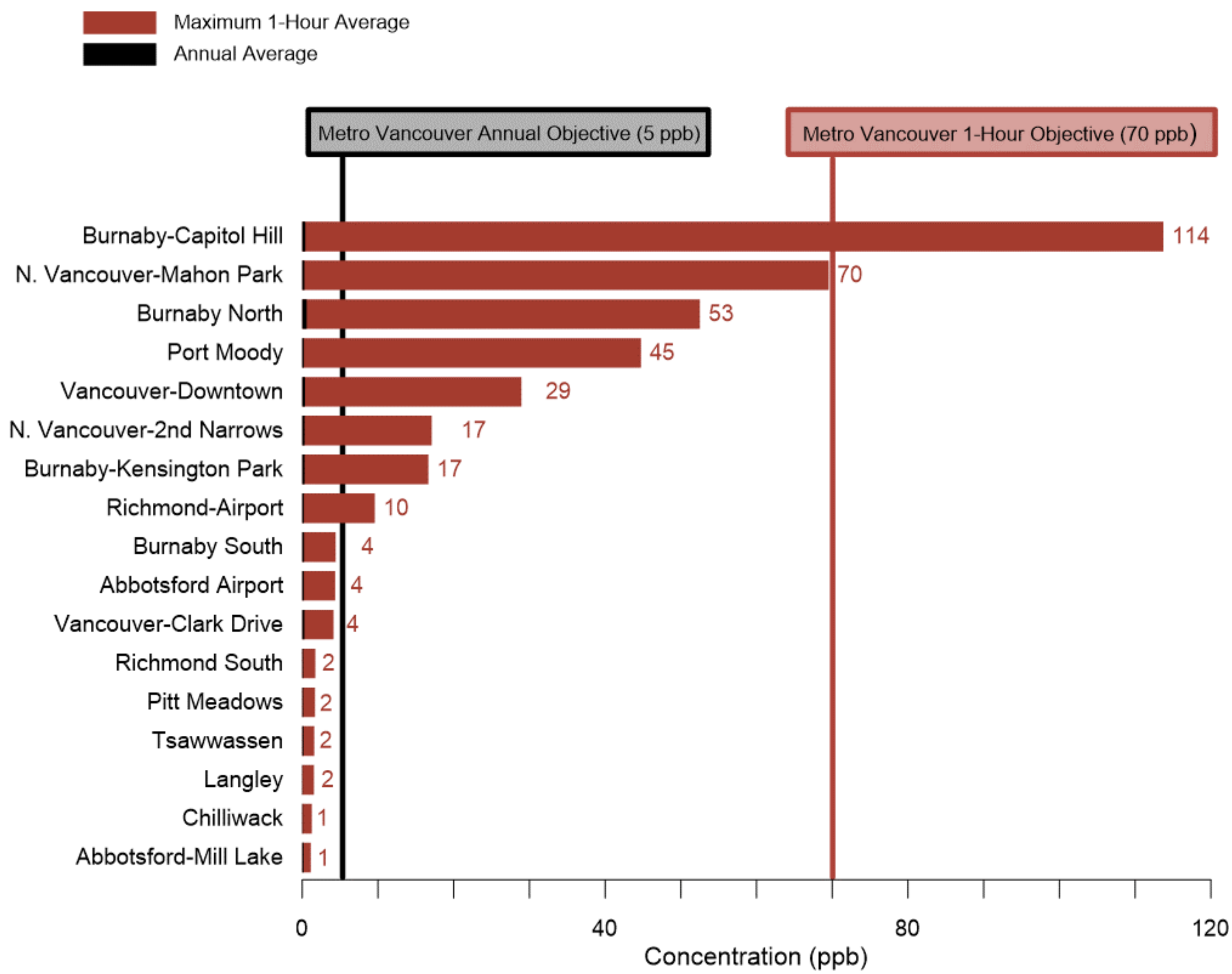
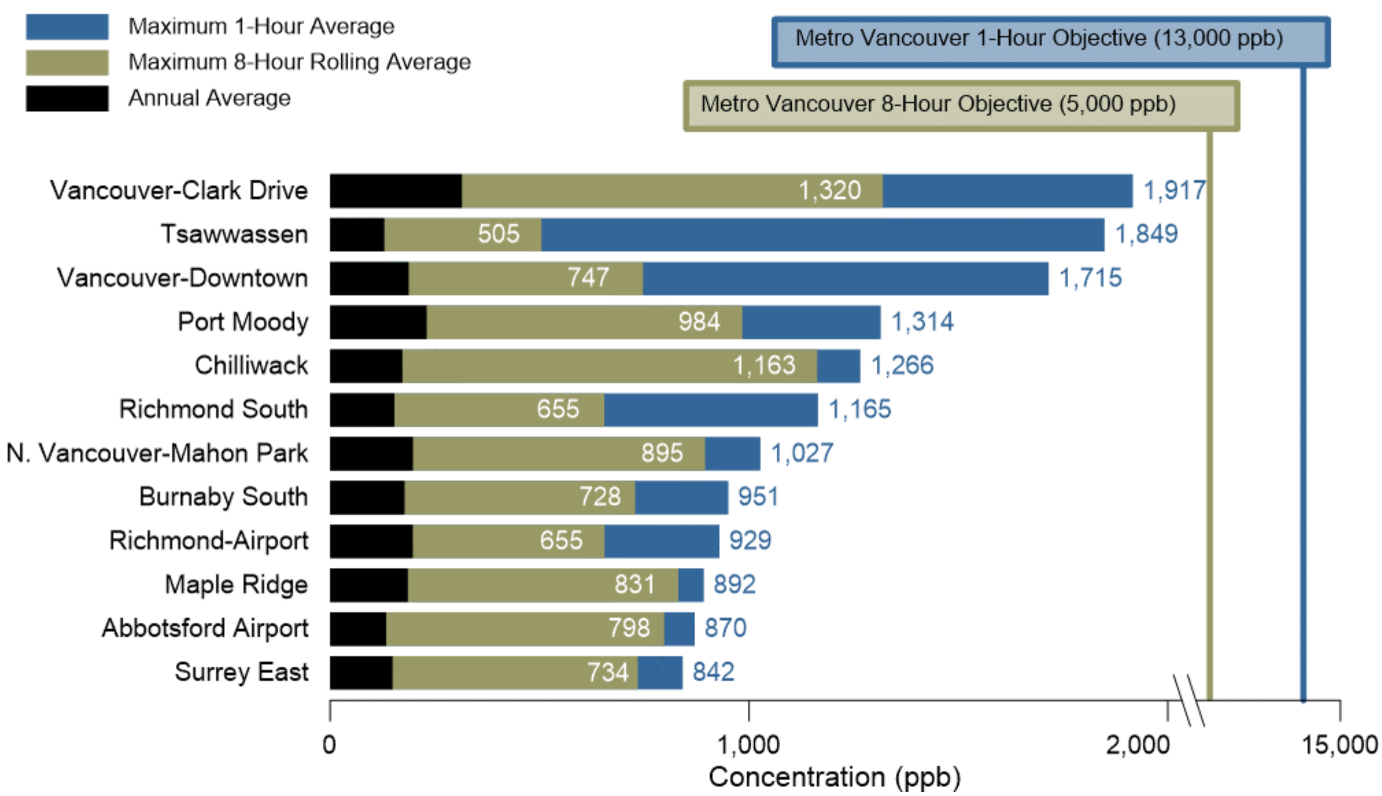


Figure S9: Sulphur dioxide (SO_2), 2021

Carbon Monoxide – 2021

Carbon monoxide (CO) monitoring results for 2021 are shown in Figure S10. Carbon monoxide levels were all well below the relevant Metro Vancouver air quality objectives at all stations throughout the LFV. The principal source of carbon monoxide continues to be emissions from motor vehicles.

Higher concentrations typically occur close to major roads during peak traffic periods. Like nitrogen dioxide, the highest average carbon monoxide concentrations are measured in the more densely trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the suburban and rural parts of Metro Vancouver and the FVRD.



Note: The scale is broken in the x-axis between 2,000 and 4,000 ppb. The highest concentrations measured are five times less than the objective.

Figure S10: Carbon monoxide (CO), 2021

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List of Acronyms

AQHI	Air Quality Health Index
BC	Black Carbon
BC ENV	British Columbia Ministry of Environment and Climate Change Strategy
BCVCC	BC Visibility Coordinating Committee
CCME	Canadian Council of Ministers of the Environment
CAAQS	Canadian Ambient Air Quality Standards
CO	Carbon Monoxide
FEM	Federal Equivalent Method
FVRD	Fraser Valley Regional District
LFV	Lower Fraser Valley
MAMU	Mobile Air Monitoring Unit
NAPS	National Air Pollution Surveillance
NO_X	Nitrogen oxides
NO_2	Nitrogen dioxide
NO	Nitric oxide
NH_3	Ammonia
O_3	Ozone
PM	Particulate matter
PM_{10}	Inhalable particulate matter (particles smaller than 10 micrometres in diameter)
$PM_{2.5}$	Fine particulate matter (particles smaller than 2.5 micrometres in diameter)
PNW	Pacific Northwest
SO_X	Sulphur oxides
SO_2	Sulphur dioxide
THC	Total hydrocarbons
TRS	Total reduced sulphur compounds
UFP	Ultrafine particles
VOC	Volatile organic compounds

Section A – Introduction

This report summarizes data collected from air quality stations in the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2021 and describes the air quality monitoring activities and programs conducted during the year. The focus is to report on the state of ambient (outdoor) air quality in the LFV.

Metro Vancouver maintains one of the most comprehensive air quality networks in North America serving a large population with air quality stations located from Horseshoe Bay in West Vancouver to Hope. Pollutants monitored by the network include both gases and particulate matter. Common air contaminants include ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter. These are all widely monitored throughout the network.

Particulate matter consists of very small solid and liquid material suspended in the air. This air pollutant is characterized by size and measured in units of a millionth of a metre, or micrometre (µm). Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored throughout the LFV.

Other pollutants monitored by the network include ammonia, volatile organic compounds (VOC), black carbon, ultrafine particles (UFP), and odourous total reduced sulphur compounds (TRS). Additional information Metro Vancouver collects to help monitor air quality conditions includes weather (meteorological) data and images recording visual air quality conditions (visibility).

Priority Pollutants

Research indicates that adverse health effects can occur at air quality levels commonly measured in the LFV. Health experts have identified exposure to ozone and particulate matter as being associated with serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. Fine particulate ($PM_{2.5}$) is small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Long-term exposure to these pollutants can aggravate existing heart and lung diseases and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail, and non-road engines. These particles ("diesel PM") are carcinogenic and are believed to contribute significantly to the health effects described above. Instrumentation installed in some air quality monitoring stations in the LFV can be used to estimate the proportion of particles that originate from diesel engines.

Air Quality Trends

Improvements have been made in air quality over the last two decades for most pollutants, including nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and volatile organic compounds (VOC). Despite significant population growth in the region over the same time period, emission reductions across a variety of sectors have brought about these improvements. The population increased in Metro Vancouver and the FVRD by about 67% from 1991 to 2021, from approximately 1.8 million to 3.0 million residents.

The long-term regional trends for ground-level ozone show a different story. Long-term trends of peak ozone concentrations show levels currently lower than those experienced in the 1980s, but peak levels have been largely unchanged over the last fifteen to twenty years. Average concentrations of ground-level ozone however have increased over the same period.

Metro Vancouver and the Fraser Valley Regional District (FVRD) adopted the Regional Ground-Level Ozone Strategy (Metro Vancouver, 2014), which provides strategic policy direction for ozone management in the LFV based on local scientific research. Research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

Trends in air pollutants are discussed further by pollutant in Section D.

Air Quality Advisories

Metro Vancouver issues air quality advisories for the LFV airshed, including Metro Vancouver and the FVRD, to help protect public health during periods of degraded air quality. Periods of degraded air quality can occur in the LFV for several reasons, such as summertime smog during hot weather, smoke from forest fires and winter inversions preventing dispersion of emitted air contaminants. Metro Vancouver operates an air quality advisory program in cooperation with partner agencies, including the FVRD, Vancouver Coastal Health Authority, Fraser Health Authority, Environment and Climate Change Canada, and the BC Ministry of Environment and Climate Change Strategy.

Air quality advisories are issued to the public when air quality has deteriorated or is forecast to deteriorate significantly within the LFV. Typically, air quality advisories are issued when a pollutant exceeds or is predicted to exceed an air quality objective or standard at more than one monitoring location.

In the last ten years, the number of days on which air quality advisories were in place has ranged from zero to twenty-two days annually.

Shown in Figure 1 is the historical trend of the number of days the LFV was under an advisory.

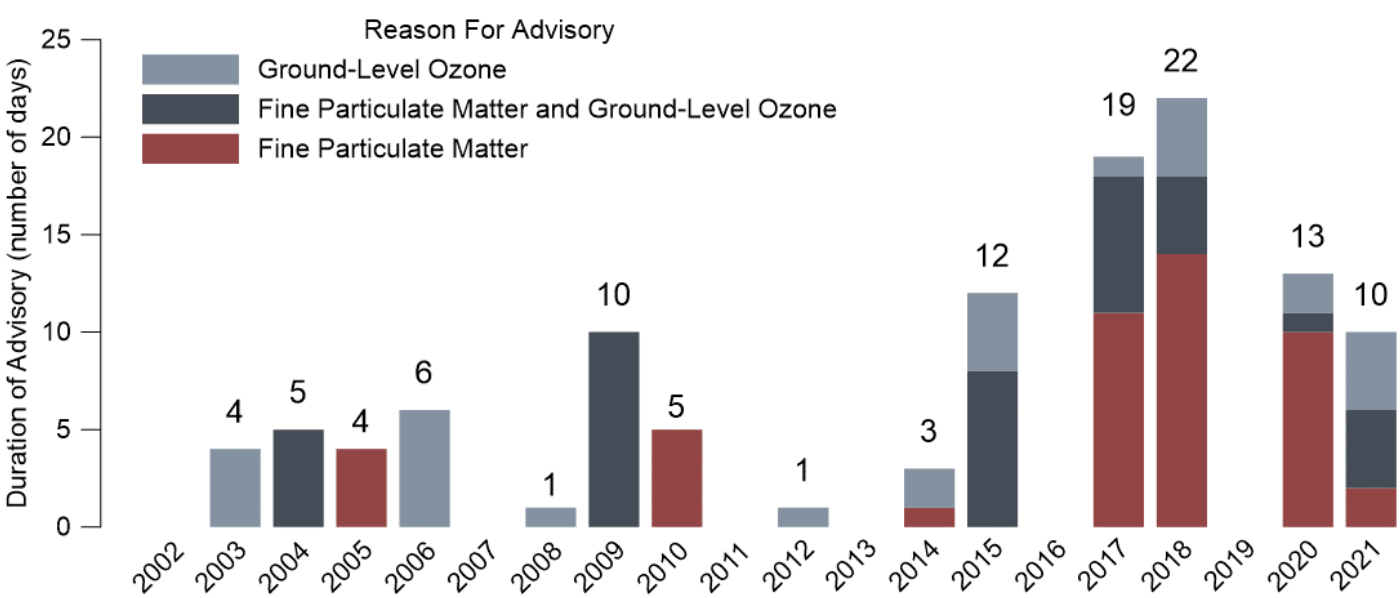
Air quality bulletins are used to advise the public of the occurrence of localized degraded air quality during cool weather months and actions that may be taken to reduce the emissions contributing to degraded air quality conditions.

In 2021, air quality advisories were issued during four separate periods for a total of ten days in the summer. A four-day advisory was issued on June 26 for ground-level ozone during a record-breaking heat wave. A fine particulate matter advisory was added on the fourth day due to the build up of local pollutants and secondary formation of particulate matter.

A one-day ozone advisory was issued on July 30 for eastern parts of Metro Vancouver and the Fraser Valley due to hot and sunny weather.

On August 1, a two-day fine particulate matter advisory was issued for the entire region due to smoke from wildfires burning in the interior of BC and Washington state.

The last advisory was issued on August 12 for three days for elevated levels of ozone in eastern parts of Metro Vancouver and the Fraser Valley due to smoke, local emissions, and hot and sunny weather.



Notes: Trigger levels for advisories have changed over the years; care must be taken when interpreting advisory trends.

Figure 1: Number of days of air quality advisories in the LFV

Wildfires and Climate Change

In recent years, wildfires in the Pacific Northwest (PNW) have increased in severity and become more widespread. Wildfires can produce considerable amounts of smoke that can be transported great distances. Both 2017 and 2018 were significant wildfire seasons, with 2018 being one of the worst in British Columbia's history, with the largest area burned. Overall fire activity in 2019 and 2020 were both well below the 10-year provincial average. However, in 2020 the region was impacted by wildfire smoke due to active wildfire seasons in Washington, Oregon, and California. In 2021 an active wildfire season in BC resulted in wildfire smoke impacts to the region. More information on wildfire smoke impacts are provided in Section I.

An analysis of area burned and annual climate data for the period 1919-2021 in BC showed that after nearly a century-long decline, wildfire activity has increased significantly since 2005 (Parisien et al, 2023). Examination of trends in wildfire behaviour that have had a direct impact on air quality in the region revealed that four of the most severe wildfire seasons of the last century occurred in the past 7 years (2017, 2018, 2021, and 2023). The increase in wildfire activity coincided with a rapid acceleration of climate-induced changes, including increasing temperatures and increasing moisture deficits across the province. Moisture deficits in the spring and summer have led to environmental changes, such as a lack of soil moisture, and increased biomass flammability. Other factors that affected the availability of forest fuels also contributed to this trend: past wildfires, insect outbreaks, and, land-use practices.

Climate projections indicate the region will experience hotter, drier summers and wetter, warmer winters. A warming climate is likely to increase the frequency and duration of wildfires and associated smoke impacts, while also increasing in-region ground-level ozone formation through the intensity and duration of summer heat waves.

Public awareness of air quality and health has also grown with the recent summer wildfire smoke impacts. The public has inquired about air quality, health effects, and steps that can be taken to reduce their own health risk during these events. Since late 2017, Metro Vancouver has been working with local health authorities, BC Centre for Disease Control, Health Canada, the BC Ministry of Environment and Climate Change Strategy (BC ENV), the FVRD, and experts from outside BC to develop communication materials for residents on wildfire smoke health impacts and interventions for reducing these impacts.

Metro Vancouver is also looking at further developing collaborations, such as working with member jurisdictions on provision of clean air shelters, to ensure that people will be better protected from the health impacts of wildfire smoke going forward.

Metro Vancouver's updated air quality management plan, the *Clean Air Plan*, considers the increasing impacts of wildfire activity when developing strategies and actions to reduce health risks for Metro Vancouver residents (Metro Vancouver, 2021). In parallel, Metro Vancouver's series of *Climate 2050* Roadmaps identify actions to help the region adapt to climate-related impacts on regional air quality (Metro Vancouver, 2024).

Visual Air Quality

Elevated levels of air contaminants can cause views to be partially or fully obscured by haze at times in the LFV. This is referred to as visual air quality impairment. Throughout the LFV, the contaminant with the greatest impact on visual air quality is $PM_{2.5}$. However, the appearance of haze can also be affected by the presence of a number of other air contaminants. In more urbanized areas in the west, haze may have a brownish colour. Nitrogen dioxide emissions from sources such as transportation contribute to this brown appearance. Further east in the LFV, a white haze can sometimes be observed as a result of small particles in the air ($PM_{2.5}$) scattering light. Secondary $PM_{2.5}$, such as that formed by reactions of NO_X and SO_2 with ammonia, as well as emitted (or primary) $PM_{2.5}$ contribute to this haze. Smoke, windblown dust, and soil particles, as well as moisture levels in the air can also affect visibility.

Analysis of the air contaminants present under different visual air quality conditions is being used to understand the factors contributing to visual air quality impairment in the LFV and to develop tools to evaluate visual air quality quantitatively. Data collected as part of the visual air quality monitoring program include measurements of nitrogen dioxide and $PM_{2.5}$, measurements of the constituents of particulate matter (for example particulate nitrate, particulate sulphate, elemental carbon, and organic carbon) and the optical (light scattering) characteristics of ambient air samples.

Automated digital cameras are used to record visual air quality conditions in several locations. Images from the cameras show views along specific lines-of-sight with recognizable topographical features at known distances. The images are archived for various uses, including:

- relating air contaminant measurements to visual range and visual air quality degradation under a variety of air quality and meteorological conditions;
- assessing public perceptions of the different visual air quality conditions found in the LFV; and
- developing visual air quality measurement metrics.

Images from each of the monitoring locations are shown on [www.clearairbc.ca.](www.clearairbc.ca)

The monitoring data and images collected provide important input to a collaborative multi-agency initiative to develop a visual air quality management strategy for the LFV. Visual air quality is further discussed in Section F.

Air Quality Measurements

The LFV Air Quality Monitoring Network primarily employs continuous monitors which provide data in real-time every minute of the day. The network also contains specialized air quality monitors that sample the air non-continuously. Non-continuous 24-hour (daily) samples are collected on filters and/or in canisters every sixth or twelfth day depending on the site. The sampling is scheduled in accordance with the National Air Pollution Surveillance (NAPS) program. After sample collection, filters, and canisters are analyzed in a federal laboratory to determine pollutant concentrations. Non-continuous samples of volatile organic compounds (VOC) are collected at several sites throughout the LFV. VOC refers to a group of organic chemicals. A large number of chemicals are included in this group but each individual chemical is generally present at relatively low concentrations in air compared to other common air contaminants.

Non-continuous particulate samples are collected at monitoring stations in the LFV where pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for several of these stations (Port Moody, Burnaby South, Abbotsford Airport, and Vancouver Clark-Drive).

Chemicals contained in $PM_{2.5}$ and VOC samples are identified and quantified at a federal laboratory. These data can then be used to help determine the emission sources contributing to the contaminants in the air. Non-continuous measurements are discussed in Section E.

Air Quality Health Index (AQHI)

The national health-based Air Quality Health Index (AQHI), developed by Environment Canada and Health Canada, has been in use since 2008. The AQHI communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change.

The AQHI is calculated every hour using monitoring data from stations in the LFV. Current AQHI levels in the LFV, AQHI forecasts, and additional information about the AQHI are available at:

- airmap.ca
- weather.gc.ca/airquality/pages
- www.env.gov.bc.ca/epd/bcairquality/readings/aqhi-table.xml

Section B – Air Quality Objectives and Standards

Several air quality objectives and standards are used as benchmarks to characterize air quality including the federal Canadian Ambient Air Quality Standards (CAAQS), and Metro Vancouver's ambient air quality objectives. Metro Vancouver's ambient air quality objectives are shown in Table 1. The objective or standard is achieved if the ambient concentration is at or lower than (i.e., better than) the objective.

The federal Canadian Ambient Air Quality Standards (CAAQS) have been established as objectives under Canadian Environmental Protection Act 1999, and replaced the Canada-Wide Standards for fine particulate matter and ground-level ozone. The CAAQS were implemented in 2015 for particulate matter (PM) and ozone (O_3). In 2020, the numerical value of the CAAQS became more stringent for $PM_{2.5}$ and O_3 and nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) were also added. These set specific limits for $PM_{2.5}$, O_3, NO_2, and SO_2 based on concentrations averaged over a three-year period with the exception of the annual metric, which are averaged over one year.

The CAAQS for $PM_{2.5}$ is a value that is calculated by taking an annual 98th percentile value using daily averages, averaged over three consecutive years. Achievement of the $PM_{2.5}$ CAAQS is attained when the CAAQS value is less than or equal to 27 µg/m^3.

The CAAQS for ozone is a value that is calculated by the 4th highest annual 8-hour daily maximum, averaged over three consecutive years. Achievement of the ozone CAAQS is attained when the CAAQS value is less than or equal to 62 ppb.

The NO_2 CAAQS include metrics for both 1-hour and annual averages. The 1-hour NO_2 CAAQS is a value that is calculated by taking an annual 98th percentile value using daily maximum 1-hour measurements, averaged over three consecutive years. Achievement of the 1-hour NO_2 CAAQS is attained when the CAAQS value is less than or equal to 60 ppb. The annual CAAQS for NO_2 is a value of 17 ppb that is compared to the average of all 1-hour concentrations collected within the year.

In 2005, as part of the Air Quality Management Plan, Metro Vancouver adopted health-based ambient air quality objectives for ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO).

In 2009 the provincial government established air quality objectives for $PM_{2.5}$. The province's annual objective is eight micrograms per cubic metre (µg/m^3) and annual planning goal is six micrograms per cubic metre for $PM_{2.5}$.

An objective or standard is achieved if the ambient concentration is at or lower than (i.e., better than) the objective.

Metro Vancouver aligned its annual objectives for $PM_{2.5}$ in the 2011 *Integrated Air Quality and Greenhouse Gas Management Plan*, as well as adopting a one-hour ozone objective of 82 parts per billion.

Metro Vancouver's 24-hour $PM_{2.5}$ objective of 25 µg/m^3 is numerically the same as the province, but compliance with Metro Vancouver's objective requires that there are no exceedances and is applied as a rolling average.

In 2015, Metro Vancouver adopted a 1-hour interim ambient air quality objective for SO_2 of 75 parts per billion (ppb) prior to establishment of the federal SO_2 CAAQS. After establishment of the federal SO_2 CAAQS, Metro Vancouver's SO_2 objectives were revised in November 2017, with a more stringent 1-hour objective of 70 ppb not to be exceeded and an annual objective of 5 ppb.

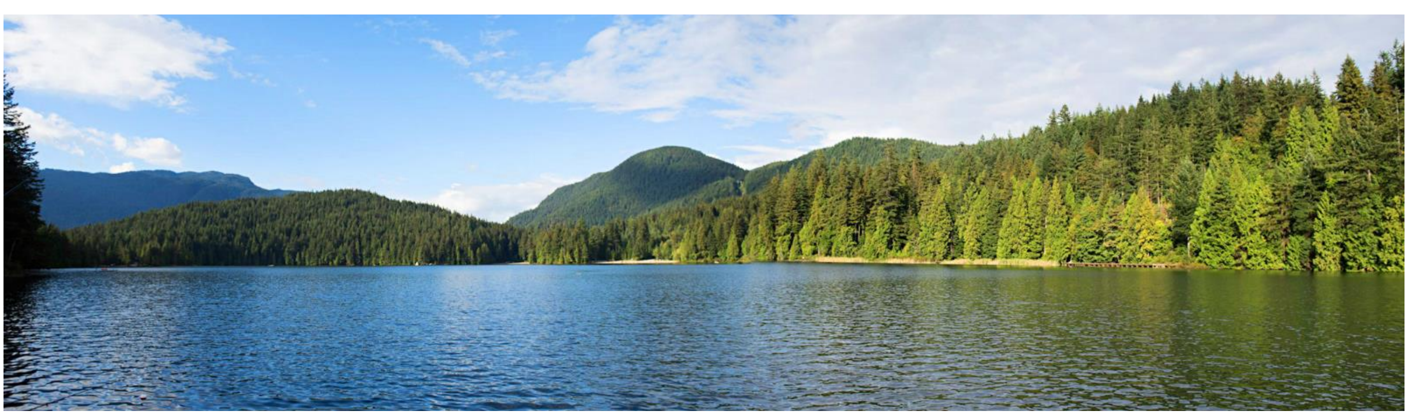
In 2019, Metro Vancouver aligned its objectives for CO, NO_2, and O_3 with federal and provincial standards. Metro Vancouver adopted a 1-hour and annual ambient air quality objective for NO_2 that is the same as the federal 2020 CAAQS. Similarly, the 8-hour O_3 objective was made the same as the 2020 CAAQS. The 1-hour and 8-hour CO objectives were set to 13,000 ppb and 5,000 ppb respectively, to match the more stringent Provincial objectives.

Several of Metro Vancouver's objectives are intended to be compared with *rolling averages*. A *rolling average* is an average that is calculated by averaging the concentrations from a number of previous consecutive hours. For example, a 24-hour rolling average is calculated by averaging the concentrations measured during the previous 24 hours. A 24-hour rolling average is calculated for each hour of the day.

Table 1: Metro Vancouver's ambient air quality objectives

Air Contaminant	Averaging Period	Ambient Air Quality Objective[a]	
		$\mu g/m^3$	ppb
Carbon monoxide (CO)	1-hour	14,900	13,000
	8-hour[b]	5,700	5,000
Nitrogen dioxide (NO_2)	1-hour[c]	113	60
	Annual	32	17
Sulphur dioxide (SO_2)	1-hour	183	70
	Annual	13	5
Ozone (O_3)	1-hour	161	82
	8-hour[d]	122	62
Inhalable particulate matter (PM_{10})	24-hour[b]	50	
	Annual	20	
Fine particulate matter ($PM_{2.5}$)	24-hour[b]	25	
	Annual	8 (6[e])	
Total reduced Sulphur (TRS)	1-hour (acceptable)	14	10
	1-hour (desirable)	7	5

[a] Except where noted, Metro Vancouver objectives are "not to be exceeded", meaning the objective is achieved if 100% of the validated measurements are at or below the objective level.
[b] Achievement based on rolling average.
[c] Achievement based on annual 98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years.
[d] Achievement based on annual 4th highest daily maximum 8-hour average concentration, averaged over three consecutive years.
[e] Metro Vancouver's annual $PM_{2.5}$ planning goal of 6 $\mu g/m^3$ is a longer term aspirational target to support continuous improvement.



Section C – Lower Fraser Valley Air Quality Monitoring Network

Metro Vancouver operates the LFV Air Quality Monitoring Network, which consists of air quality monitoring sites located between Horseshoe Bay in West Vancouver and Hope. The locations of the monitoring stations operated in 2021 are shown in Figure 2 while the pollutants and meteorology measured at each station are identified in Table 2.

Air quality monitoring sites are located in both Metro Vancouver and the FVRD. There are also a few stations in Metro Vancouver that provide only weather data. Air quality and weather data are collected automatically on a continuous basis, transmitted to Metro Vancouver's head office in Burnaby, and stored in a database. The data are then used to provide information to the public through the AQHI, Metro Vancouver's website, the BC air quality website, and reports.

Many pollutants measured are discussed in this report with a focus on common air contaminants: particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2,), and sulphur dioxide (SO_2). Comparisons of measured levels of these air contaminants with federal, provincial and Metro Vancouver air quality objectives and standards and an assessment of regional trends are provided in Section D. The locations of O_3, NO_2, and $PM_{2.5}$ monitoring in 2021 are shown in Figures 3 to 5.

Portable equipment was used to carry out short-term air quality monitoring studies (specialized studies) in 2021. The equipment employed in specialized studies includes Metro Vancouver's Mobile Air Monitoring Unit (MAMU), which is capable of monitoring gaseous and particulate pollutants using similar instrumentation as other monitoring stations in the network. Specialized studies and other monitoring activities undertaken are described in Sections G and H.

Real-time data from the LFV Air Quality Monitoring Network can be accessed on Metro Vancouver's website at: www.airmap.ca

Additional information on the LFV Air Quality Monitoring Network is available in the 2012 report "Station Information: Lower Fraser Valley Air Quality Monitoring Network". This report is available at: www.metrovancouver.org

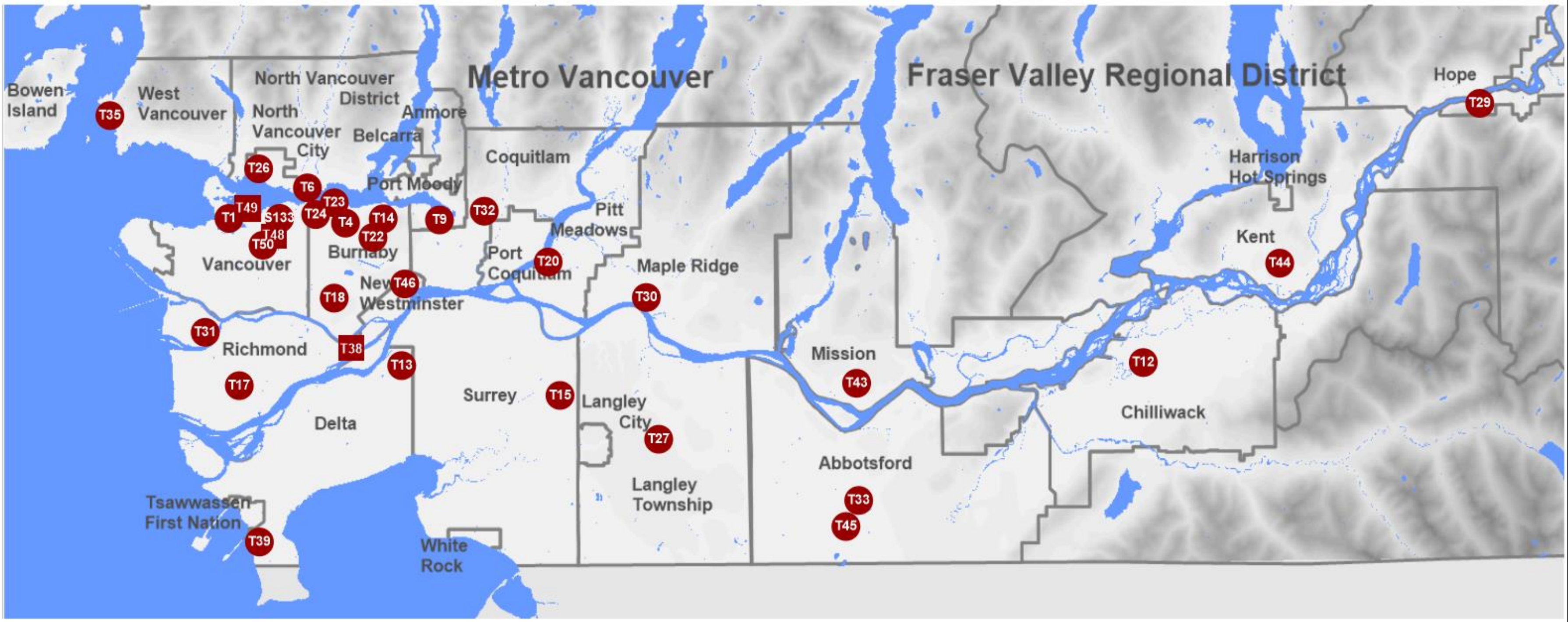
Data completeness for the year 2021 is shown in Table 3. In Table 3 the annual completeness is provided numerically while each quarter shown as green if completeness for that quarter is greater than or equal to 75%, red if below 75% and white if no data exists.

Network Changes

There are ongoing enhancements to stations and equipment that occur throughout the air quality monitoring network.

Changes to the network in 2021 include:

- Following recommendations made in a review of the monitoring network, CO monitoring was reduced throughout the network including removal at the Burnaby-Kensington Park, North Vancouver-Second Narrows, Langley, Hope, Coquitlam, and Horseshoe Bay stations during February and March. CO concentrations have never exceeded air quality objectives and the trend has been clearly decreasing over the years.
- A NOx analyzer was added to the Horseshoe Bay station in February.
- The daily zero/span check system was upgraded to a dilution calibrator, zero air generator and NO/CO blended span gas cylinder at the North Vancouver-Second Narrows, Maple Ridge, and Horseshoe Bay stations.
- The black carbon analyzers were upgraded from the model AE22 to AE33 aethalometers at the Chilliwack and Abbotsford-Airport stations in June.
- The atmospheric pressure sensors were upgraded from the 090D Met One to Vaisala PTM110 model at the Burnaby South and Richmond-Airport stations.



T1	Vancouver-Downtown	T18	Burnaby South	T31	Richmond-Airport	T46	New Westminster
T4	Burnaby-Kensington Park	T20	Pitt Meadows	T32	Coquitlam	T48	Vancouver-Templeton
T6	N. Vancouver-2nd Narrows	T22	Burnaby-Burmount	T33	Abbotsford-Mill Lake	T49	Vancouver-Portside
T9	Port Moody	T23	Burnaby-Capitol Hill	T35	Horseshoe Bay	T50	Vancouver-Clark Drive
T12	Chilliwack	T24	Burnaby North	T38	Annacis Island	S133	Vancouver-Pandora Park
T13	North Delta	T26	N. Vancouver-Mahon Park	T39	Tsawwassen		Continuous Station
T14	Burnaby Mountain	T27	Langley	T43	Mission		Meteorological Station Only
T15	Surrey East	T29	Hope	T44	Agassiz		
T17	Richmond South	T30	Maple Ridge	T45	Abbotsford Airport		

Figure 2: Lower Fraser Valley air quality monitoring network, 2021

Table 2: Air quality monitoring network, 2021

Stations		Air Quality Monitors														Meteorology					
		Continuous											Non-Continuous								
		Gases							Particulate Matter												
ID	Name	SO_2	TRS	NO_2	CO	O_3	THC	NH_3	PM_{10}	$PM_{2.5}$	BC	UFP	VOC	SP	D	Wind	T_{air}	SR	RH	BP	Precip
T1	Vancouver-Downtown	√		√	√	√															
T4	Burnaby-Kensington Park	√	√	√		√			√	√						√	√		√		
T6	N. Vancouver-2nd Narrows	√		√		√				√	√					√	√		√		√
T9	Port Moody	√	√	√	√	√			√	√	√		√		√	√	√	√	√		√
T12	Chilliwack	√		√	√	√		√	√	√	√		√			√	√	√	√	√	√
T13	North Delta			√		√				√						√	√		√		√
T14	Burnaby Mountain			√		√										√	√		√		√
T15	Surrey East			√	√	√				√						√	√		√		√
T17	Richmond South	√		√	√	√				√						√	√		√		√
T18	Burnaby South	√		√	√	√			√	√	√		√	√	√	√	√		√	√	√
T20	Pitt Meadows	√		√		√				√	√					√	√		√	√	√
T22	Burnaby-Burmount		√				√						√			√	√				
T23	Burnaby-Capitol Hill	√	√													√	√		√		
T24	Burnaby North	√	√				√		√				√			√	√	√	√		√
T26	N. Vancouver-Mahon Park	√		√	√	√				√						√	√		√	√	√
T27	Langley	√		√		√			√	√						√	√		√	√	√
T29	Hope			√		√			√	√						√	√		√		√
T30	Maple Ridge			√	√	√										√	√		√		√
T31	Richmond-Airport	√		√	√	√			√	√	√		√			√	√	√	√	√	√
T32	Coquitlam			√		√										√	√		√	√	√
T33	Abbotsford-Mill Lake	√		√		√		√	√	√						√	√		√		√
T35	Horseshoe Bay			√						√						√	√		√		√
T38	Annacis Island															√	√		√		√
T39	Tsawwassen	√		√	√	√				√						√	√		√		√
T43	Mission			√		√				√						√	√		√		√
T44	Agassiz			√		√		√		√						√	√		√		√
T45	Abbotsford Airport	√		√	√	√		√	√	√	√		√	√	√	√	√	√	√	√	√
T46	New Westminster			√		√				√						√					
T48	Vancouver-Templeton															√	√		√		
T49	Vancouver-Portside															√	√		√		√
T50	Vancouver-Clark Drive	√		√	√	√				√	√	√	√	√	√	√	√		√		
S133	Vancouver-Pandora	√																			
Total Monitoring Units		**18**	**5**	**25**	**12**	**24**	**2**	**4**	**10**	**21**	**8**	**1**	**8**	**3**	**4**	**30**	**29**	**5**	**28**	**8**	**24**

SO_2 = sulphur dioxide; TRS = total reduced sulphur; NO_2 = nitrogen dioxide; CO = carbon monoxide; O_3 = ozone; THC = total hydrocarbon; NH_3 = ammonia;

PM10 = inhalable particulate matter; $PM_{2.5}$ = fine particulate matter; UFP = ultrafine particulate; VOC = volatile organic compounds; SP = particulate speciation;

D = dichotomous particulate; BC = Black Carbon; Wind = wind speed and direction; T_{air} = air temperature; SR = incoming solar radiation; RH = relative humidity;

BP = barometric pressure; Precip = precipitation; √ = monitored at this location.

Table 3: Annual and quarterly data completeness, 2021

		Air Quality Monitors											Meteorology						
Stations		Gases							Particulate Matter										
ID	Name	SO_2	TRS	NO_2	CO	O_3	THC	NH_3	PM_{10}	$PM_{2.5}$	BC	UFP	Wind Spd	Wind Dir	Tair	SR	RH	BP	Precip
T01	Vancouver-Downtown	99		99	99	99													
T04	Burnaby-Kensington Park	99	99	100		98			36	98			100	100	100		100		
T06	N. Vancouver-2nd Narrows	98		99		99				93	97		72	72	72		72		75
T09	Port Moody	100	98	100	99	100			93	97	99		100	100	100	100	100		100
T12	Chilliwack	100		100	99	99		100	99	99	100		100	100	100	100	100	100	100
T13	North Delta			98		74				80			100	100	100		100		100
T14	Burnaby Mountain			100		100							100	100	99		99		99
T15	Surrey East			99	99	100				99			99	99	99		99		99
T17	Richmond South	100		100	98	99				99			100	100	100		100		12
T18	Burnaby South	100		99	98	100			93	98	100		100	100	100		100	100	100
T20	Pitt Meadows	99		100		99				98	100		100	100	100		100	100	100
T22	Burnaby-Burmount		95				99						99	99	99				
T23	Burnaby-Capitol Hill	100	96										100	100	100		100		
T24	Burnaby North	98	100				97		74				100	100	100	100	100		100
T26	N. Vancouver-Mahon Park	99		99	99	99				99			99	99	99		99	99	99
T27	Langley	99		99		99			97	99			100	98	100		100	100	100
T29	Hope			99		99			98	97			98	98	98		98		98
T30	Maple Ridge			100	100	100							100	100	100		100		100
T31	Richmond-Airport	100		100	100	99			99	99	100		100	100	100	100	100	100	99
T32	Coquitlam			100		99							100	100	100		100	100	100
T33	Abbotsford-Mill Lake	99		99		99		99	99	99			100	100	100		100		100
T35	Horseshoe Bay			84						86			99	99	99		99		99
T38	Annacis Island												100	100	100		100		100
T39	Tsawwassen	100		100	100	99				99			100	100	100		100		100
T43	Mission			100		99				99			100	100	100		100		100
T44	Agassiz			100		99		100		99			100	100	100		100		100
T45	Abbotsford Airport	99		99	100	99		99	95	99	100		100	100	100	100	100	100	100
T46	New Westminster			100		100				98			100	100					
T48	Vancouver-Templeton												100	100	100		100		
T49	Vancouver-Portside												100	100	100		100		100
T50	Vancouver-Clark Drive	98		98	98	98				99	97	70	100	100	100		100		
S133	Vancouver-Pandora Park																		

Note: Quarterly completeness ≥ 75% is shown in green, < 75% is shown in red, and no data is white, while annual completeness is shown numerically.

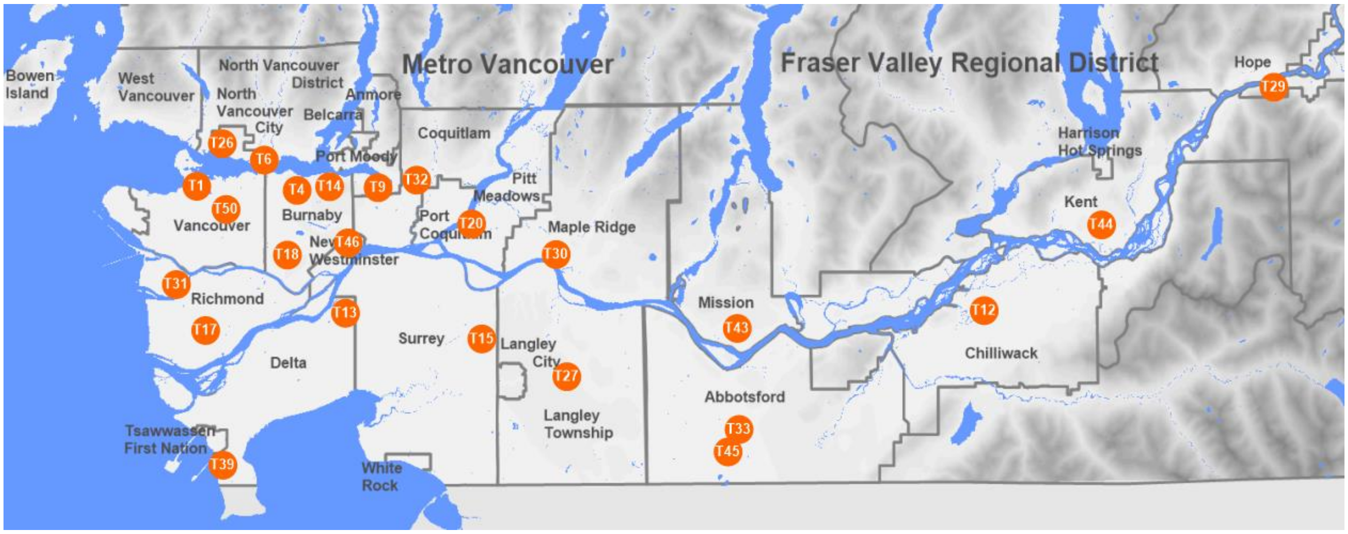


Figure 3: Ground-level ozone monitoring stations, 2021

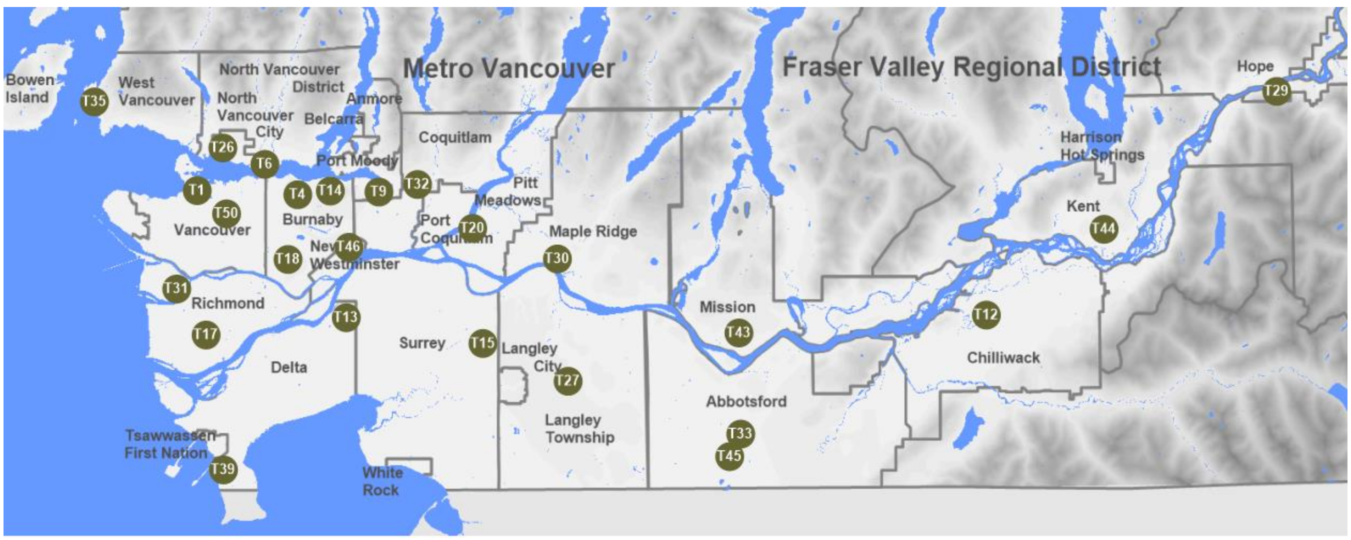


Figure 4: Nitrogen dioxide monitoring stations, 2021

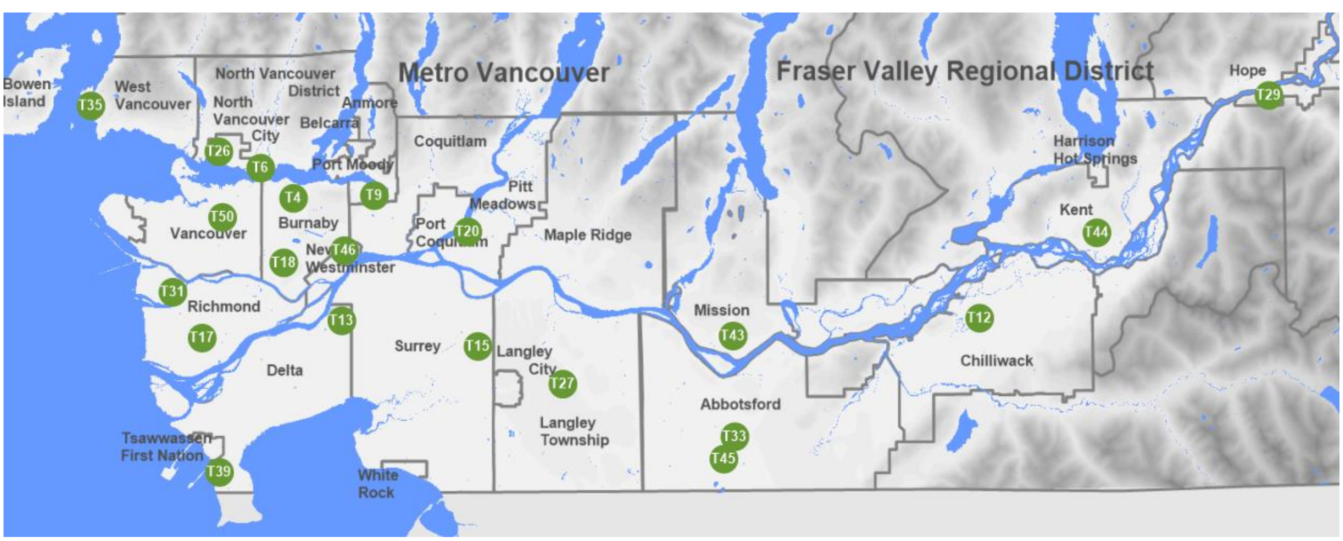


Figure 5: Fine particulate matter ($PM_{2.5}$) monitoring stations, 2021

Section D – Continuous Pollutant Measurements

Ozone (O_3)

Characteristics

Ozone (O_3) is a reactive form of oxygen. It is a major pollutant formed when NO_X and reactive volatile organic compounds (VOC) react chemically in the presence of heat and sunlight. Sunlight plays a significant role in O_3 production and as such, local maximum O_3 concentrations are usually experienced during the summer in the LFV.

Naturally occurring O_3 in the upper level of the atmosphere, known as the stratosphere, shields the surface from harmful ultraviolet radiation. However, at ground level, O_3 is a major environmental and health concern. Ozone is a significant oxidant and can irritate the eyes, nose, and throat as well as reduce lung function. High concentrations can also increase the susceptibility to respiratory disease and reduce crop yields.

Sources

Ozone is termed a secondary pollutant because it is not usually emitted directly into the air. Instead, it is formed from chemical reactions involving pollutants identified as precursors, including NO_X and reactive VOC. The levels of O_3 measured depend on the emissions of these precursor pollutants.

Nitrogen oxide (NO_X) emissions are dominated by transportation sources. About 60% of the emissions come from cars, trucks, ships, rail, and planes. Other sources include non-road engines, boilers, and building heating systems.

The main contributors to VOC emissions are chemical products use (industrial, commercial, and consumer products such as paints, varnishes and solvents), cannabis production, natural sources (trees and vegetation), cars and light trucks and non-road engines.

The formation of O_3 occurs readily during hot and sunny weather conditions with peak levels observed in the summer. Under these conditions, the highest levels generally occur downwind of major precursor emissions such as in eastern parts of Metro Vancouver and in the FVRD under specific wind conditions. The presence of wildfire smoke can also enhance ozone production.

Monitoring Results

Figures S6 (shown in the previous summary) and 6 illustrate the results of O_3 monitoring in 2021. Figure 6 represents a bubble plot, which shows three types of information: maximum 1-hour, Metro Vancouver's 8-hour objective value and annual average concentrations for each ozone monitoring station. In Figure 6 the bubble position on the x-axis denotes the maximum 1-hour average, the position on the y-axis denotes the 8-hour value and the size of the bubble is proportional to the annual average. The Metro Vancouver 1-hour and 8-hour objectives are also provided on the plot as lines and areas of exceedance are shaded grey. The stations plotted to the right of the 1-hour objective line (82 ppb) all exceeded the 1-hour objective while all stations below the 8-hour objective line (62 ppb) met the 8-hour objective. The same values are represented spatially in Figures 7 to 9.

A record-breaking heat wave in late June of 2021 resulted in high ozone levels not measured in the region since the 1980s.

In 2021, there were no exceedances of Metro Vancouver's 8-hour objective or the Canadian Ambient Air Quality Standard, which both have the same numerical value (62 ppb). Both Metro Vancouver's 8-hour objective and the Canadian Ambient Air Quality Standard are calculated as the annual 4th highest daily maximum 8-hour average concentration, averaged over three consecutive years.

Metro Vancouver's 1-hour objective was exceeded at numerous stations during a record-breaking heat wave in late June that resulted in high ozone levels not measured in the region since the 1980s. Exceedances of the 1-hour objective were experienced on June 26 to 29, coinciding with record-breaking temperatures reaching 42^{o}C in parts of Metro Vancouver and the Fraser Valley. During this four-day period more than half of the ozone monitoring stations exceeded the 1-hour objective. The highest 1-hour concentrations on June 26 were measured at Pitt Meadows (93 ppb), on June 27 at Coquitlam (112 ppb), on June 28 at Maple Ridge (151 ppb) and on June 29 at Hope (94 ppb).

The 1-hour objective was exceeded on July 30 at Chilliwack, Hope, Abbotsford-Mill Lake, Mission, and Agassiz with the highest concentration measured at Agassiz (107 ppb).

On August 13 the 1-hour objective was exceeded at Burnaby-Kensington Park, Burnaby Mountain, Maple Ridge, and Coquitlam. Exceedances in the western portion of Metro Vancouver (i.e., Burnaby-Kensington Park) are not common and it is likely that ozone was enhanced on August 13 due to wildfire smoke that was prevalent throughout the region.

Air quality advisories were in effect for eight days (June 26 to 29, July 30, and August 12 to 14) due to elevated levels of ground-level ozone.

The Burnaby Mountain station measured the highest average ozone level, which is typical given the station's high elevation on the top of Burnaby Mountain.

The highest short-term concentrations occur in the eastern parts of Metro Vancouver and in the FVRD (Figures 8 and 9). The lowest annual O_3 averages (Figure 7) occur in highly urbanized areas due to O_3 scavenging. Ozone scavenging occurs in locations where higher levels of NO_x are found (e.g., urban areas or near busy roadways). In these areas, emissions containing NO_x, react quickly with O_3 to form NO_2 (nitrogen dioxide) and O_2 (oxygen) thus decreasing O_3 concentrations.

Figure 10 shows the seasonal trend of O_3 with the monthly average provided with highest 1-hour concentration from each month. In both figures, concentrations from selected stations are shown alongside the range of concentrations measured at all stations (shown as a grey band). The seasonal variation evident in Figure 10 is typical of historical ozone trends in the LFV with higher values in spring and summer, and lower values during fall and winter. Since O_3 is produced by photochemical reactions, there is greater production in spring and summer with the presence of sunlight and land- and sea-breeze wind patterns. Spring exhibits the highest average O_3 concentrations (Figure 10 left) while the highest short-term hourly concentrations (Figure 10 right) occur in the summer.

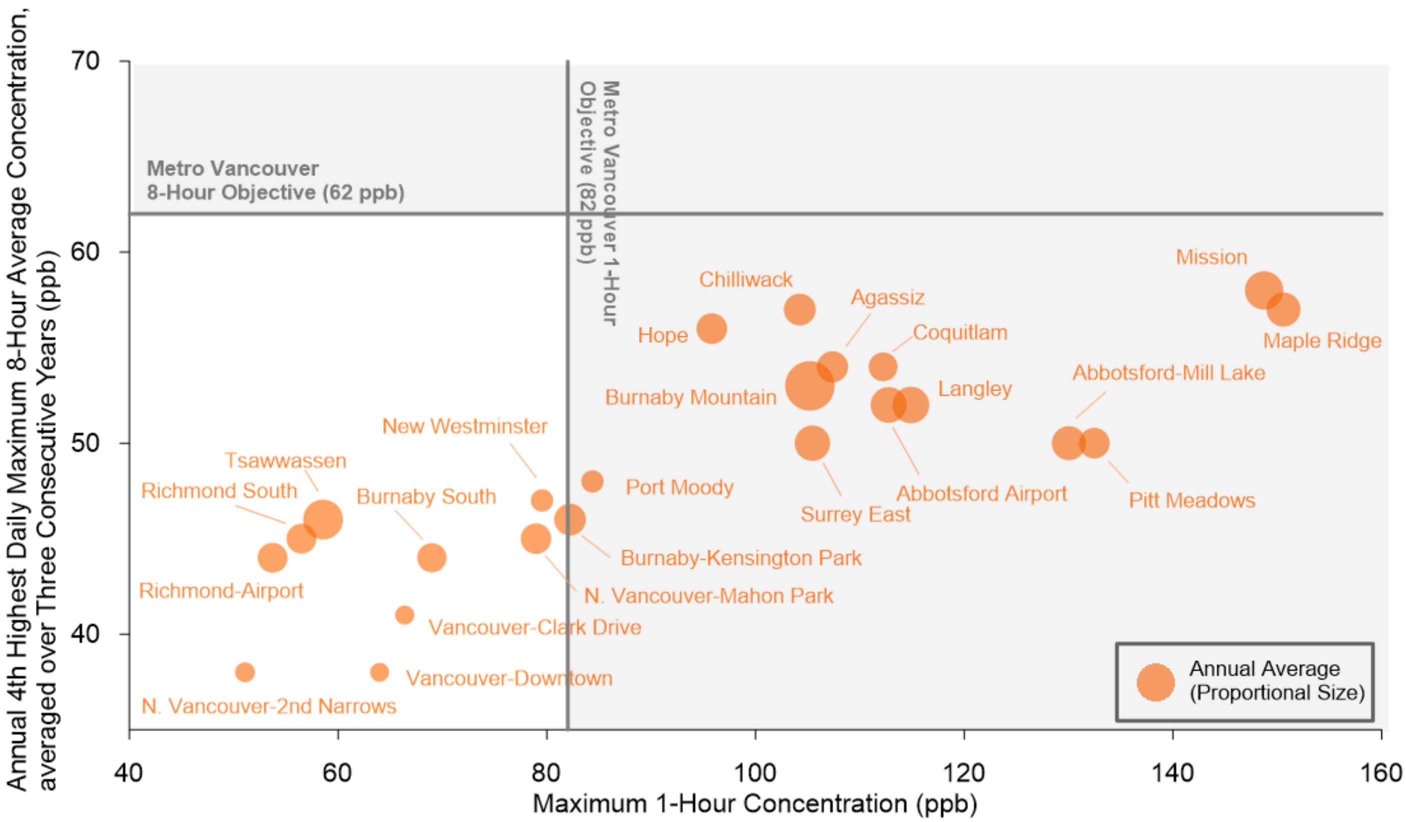
Figure 11 illustrates the long-term annual average O_3 trend in the LFV. The annual average trend is given in the left plot with the short-term peak trend given in right plot for the last two decades. Annual average O_3 levels have shown an upward trend in the last several decades. Research indicates that background ozone concentrations are rising and is one factor for observed increases in average levels.

A trend in short-term peak O_3 concentrations (Figure 11 right) is less apparent. Yearly differences are likely related to variability in meteorology, however there doesn't appear to be a trend in peak concentrations. Peak ozone levels have been mostly unchanged during the last fifteen to twenty years, despite significant reductions in ozone precursor pollutants over the same time period.

Metro Vancouver and the Fraser Valley Regional District adopted the Regional Ground-Level Ozone Strategy (Metro Vancouver, 2014) which provides strategic policy direction for ozone management in the LFV based on local scientific research. Research indicates that a spatial understanding of the ratio of concentrations of nitrogen oxides (NO_X) and volatile organic compounds (VOC), two precursor pollutants that react to form ozone, is key to determining which precursors to reduce in order to maintain and improve air quality in our region.

The values in Tables 4 and 5 represent the frequency distribution (or count) of how many hourly and 8-hour rolling average measurements were in the specified ranges, respectively. The frequency distributions in these tables show how often various O_3 levels are reached. It can be seen that stations located in the eastern parts of Metro Vancouver and in the FVRD measured the greatest frequency of high O_3 concentrations.

A series of diurnal plots are shown in Figure 12 for each O_3 monitoring station. The plots demonstrate the differences between weekdays and weekends along with differences between summer and winter. In the summer, O_3 concentrations are low through the night and begin increasing near sunrise with the highest (peak) concentration occurring in the afternoon. Examining the timing of the peak shows in general the stations in the west peak first while the stations in the east peak a few hours later with Hope typically experiencing the latest peak in the day. Noon is marked on the figure as a black vertical line for reference. On very hot sunny days, typically during a summertime episode, the O_3 peak occurs later in the day. Winter shows a similar trend of an afternoon peak although it is greatly attenuated compared with the summer.



Note: Stations contained within the grey area denote an exceedance of an objective

Figure 6: Ground-level ozone monitoring, 2021

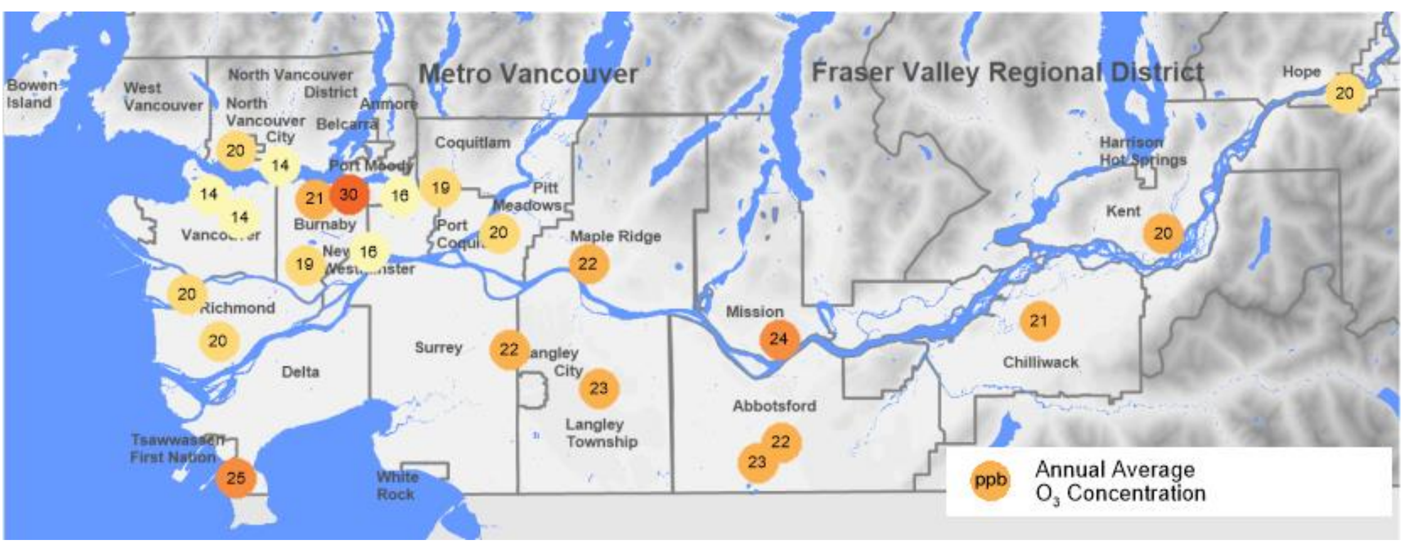


Figure 7: Annual average ozone in the LFV, 2021

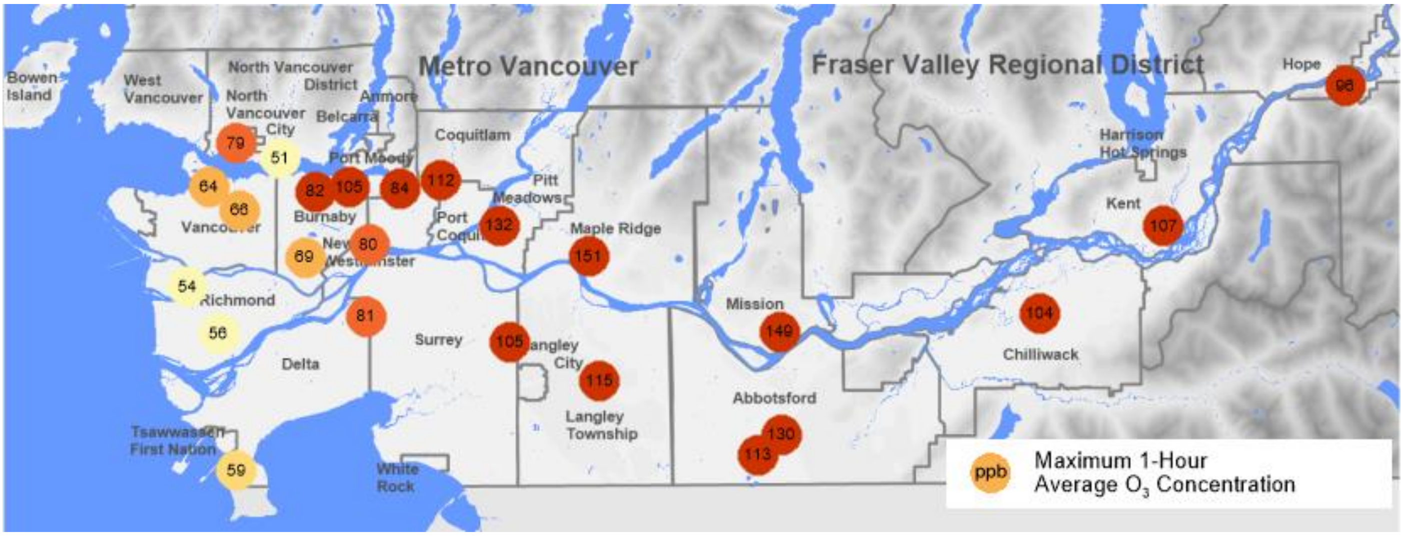


Figure 8: Short-term peak (1-hour) ozone in the LFV, 2021

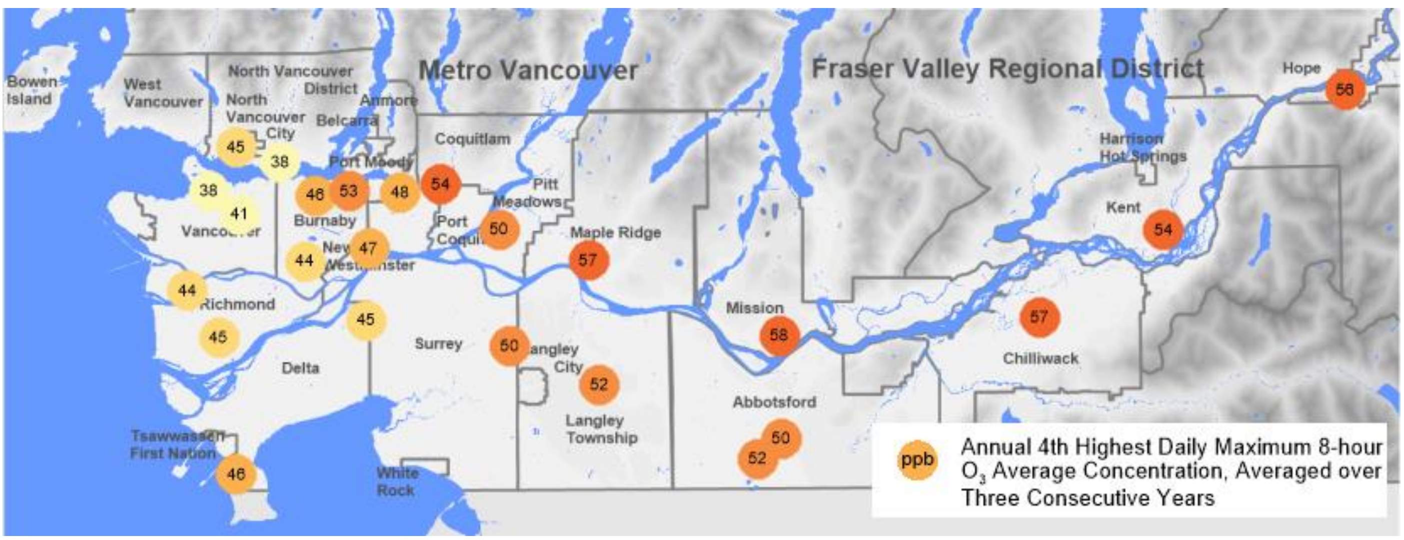


Figure 9: Short-term peak (8-hour) ozone in the LFV, 2021

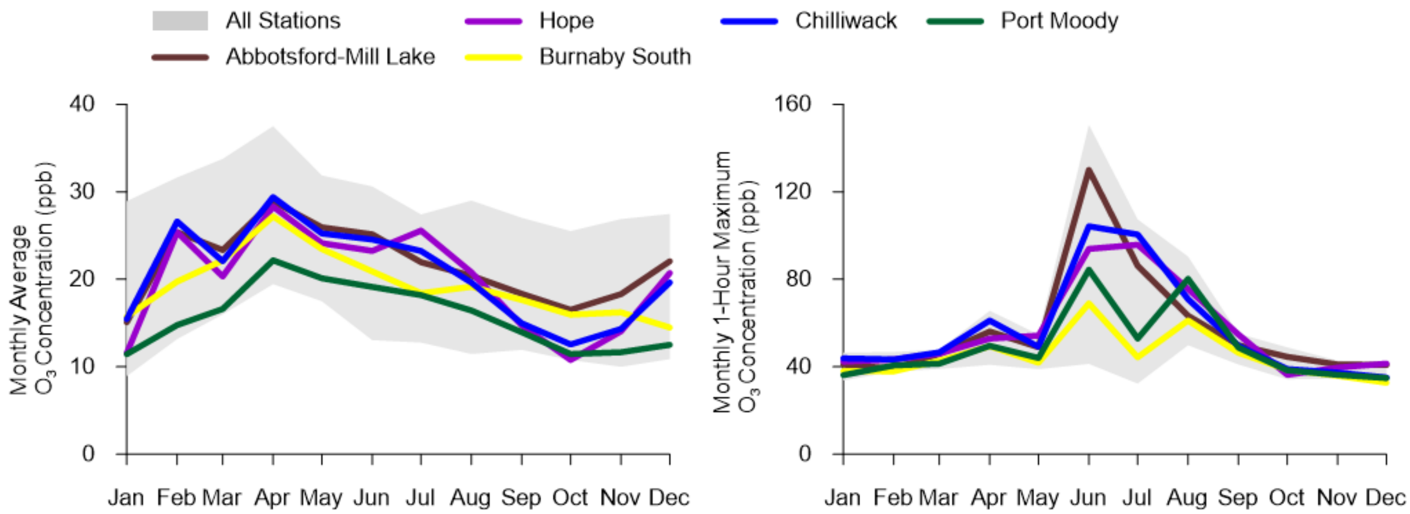


Figure 10: Monthly average (left) and short term peak (right) ozone, 2021

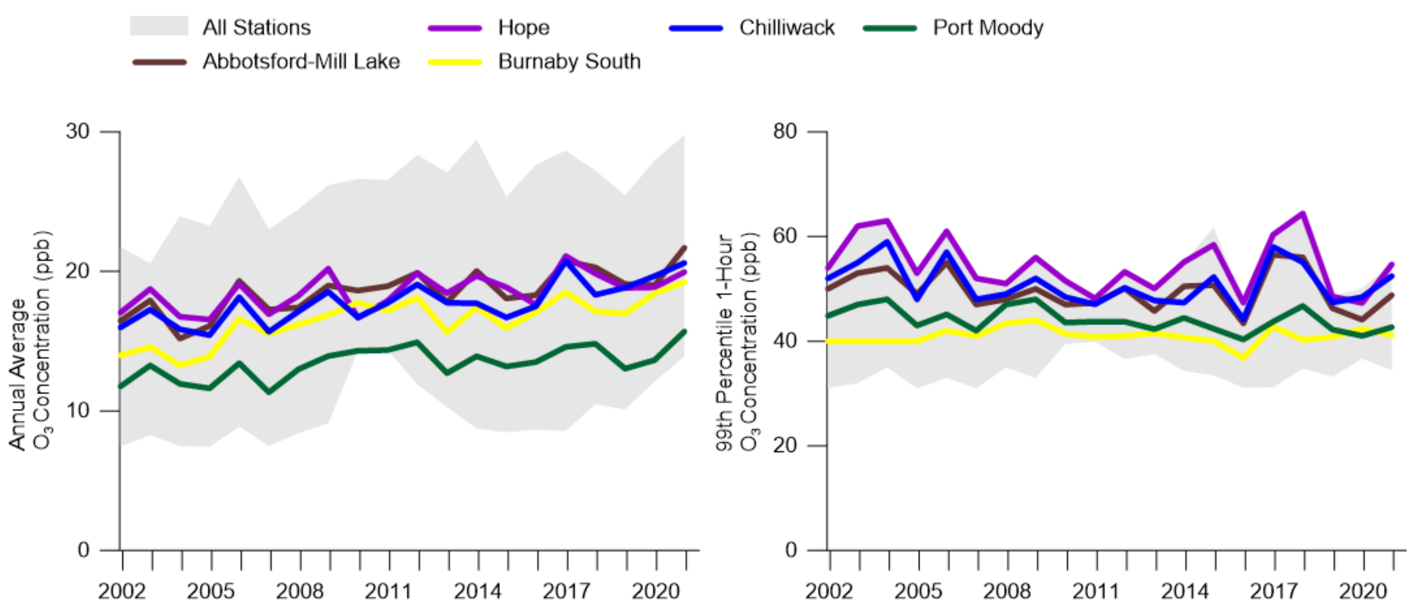


Figure 11: Annual (left) and short term peak (right) ozone trend, 2002 to 2021

Table 4: Frequency distribution of hourly ozone, 2021

O3 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to <8	3240	1289	2434	2818	1758	848	70	1003	2063	1368	1952	1473	1110	2126	1327	1852	1875	1292	584	805	1848	1236	3103	3192
8 to <16	2030	1899	2589	1876	1650	1280	419	1603	1387	1997	1387	1776	1372	1624	1700	1526	1873	1669	1187	1431	1668	1427	1689	1908
16 to <24	1676	1995	2254	1734	1730	1545	1707	2127	1711	2425	1727	2181	1963	1430	1946	1925	1932	1924	2148	2115	1839	1862	1520	1684
24 to <32	1197	2011	1151	1490	1757	1597	2928	2099	1760	2005	2125	2012	2131	1680	1969	1879	1707	1865	2386	2172	1526	2032	1269	1180
32 to <40	511	1096	205	651	1242	987	2713	1464	1356	823	1145	971	1626	1263	1298	1249	888	1474	1935	1507	1359	1694	805	545
40 to <48	40	258	11	108	375	162	697	311	346	101	238	216	386	355	359	240	254	323	439	434	327	357	249	79
48 to <56	4	34	1	20	83	16	147	72	20	14	45	30	77	95	69	16	70	80	19	107	83	67	46	7
56 to <64	5	5		7	34	4	21	14	1	3	19	2	17	39	26		23	10	1	38	30	12	21	1
64 to <72		3		5	12	2	6	5		1	9		1	15	10		7	4		19	12	3	2	1
72 to <80		1		2	3		4				1	4	3	7	11		4	2		5	5	5	1	
80 to <88		1		4	3	1	3	1			2			5	3		7	3		4	3	3		
88 to <96					2		2	3			3		4	5	1		2			5	1	1		
96 to <104					1			2			1				1			1		1	1	1		
104 to <112					1		1	2			1		1				2	1			2			
112 to <120											1		1		1		1			1		1		
120 to <128																								
128 to <136											1				1			2						
136 to <144															1					1				
>=144															1					1				
Missing	54	168	115	43	107	2317	42	48	113	23	102	95	68	116	34	71	101	110	61	114	56	59	46	162
Data Completeness	99%	98%	99%	100%	99%	74%	100%	100%	99%	100%	99%	99%	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	100%	98%

Table 5: Frequency distribution of 8-hour rolling average ozone, 2021

O3 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to <6	1980	570	1341	1770	860	348	7	475	1263	610	1127	701	500	1245	558	1065	1004	576	186	288	941	492	2021	2065
6 to <12	2150	1294	2216	1652	1389	808	79	890	1102	1349	1162	1304	906	1403	1201	1191	1435	1130	653	818	1328	1114	1700	1857
12 to <18	1857	1634	2227	1767	1611	1237	471	1650	1557	1886	1397	1641	1334	1386	1605	1616	1637	1619	1243	1388	1658	1309	1541	1865
18 to <24	1423	1861	1816	1615	1478	1328	1422	1784	1517	2160	1574	1968	1780	1221	1746	1639	1787	1699	1855	1913	1596	1743	1359	1442
24 to <30	855	1757	841	1196	1390	1415	2356	1786	1408	1766	1832	1748	1760	1407	1635	1605	1475	1511	1931	1800	1319	1671	1070	919
30 to <36	352	1023	205	571	1156	1014	2700	1447	1209	758	1146	968	1589	1214	1270	1083	877	1456	1892	1504	1106	1626	669	355
36 to <42	90	393	7	111	558	234	1268	537	513	176	340	270	642	490	545	426	291	496	805	665	551	607	288	114
42 to <48	7	50		26	123	42	268	107	80	25	57	45	105	161	93	50	73	105	131	145	129	111	54	7
48 to <54		14		10	56	5	111	21	2		18	6	38	44	37		27	20		63	43	25	22	
54 to <60		4		9	12		22	6			7	3	4	21	17		14	6		28	10	4		
60 to <66				3	10		6	3			8		3	15	10		12	2		12	8	4		
66 to <72					5		4	4			2		3	4	5		4	3		4	3	3		
72 to <78					1		3	3			2			4	3		3	2		4	4	3		
78 to <84					4			3			1		3	5	1		2	2		1	2	2		
84 to <90											3		2		1			1		2	2			
90 to <96															1			1		4				
>=96															4			1						
Missing	46	160	107	30	107	2329	43	44	109	30	84	106	91	140	28	85	119	130	64	121	60	46	36	136
Data Completeness	100%	98%	99%	100%	99%	73%	100%	100%	99%	100%	99%	99%	99%	98%	100%	99%	99%	99%	99%	99%	99%	100%	100%	98%

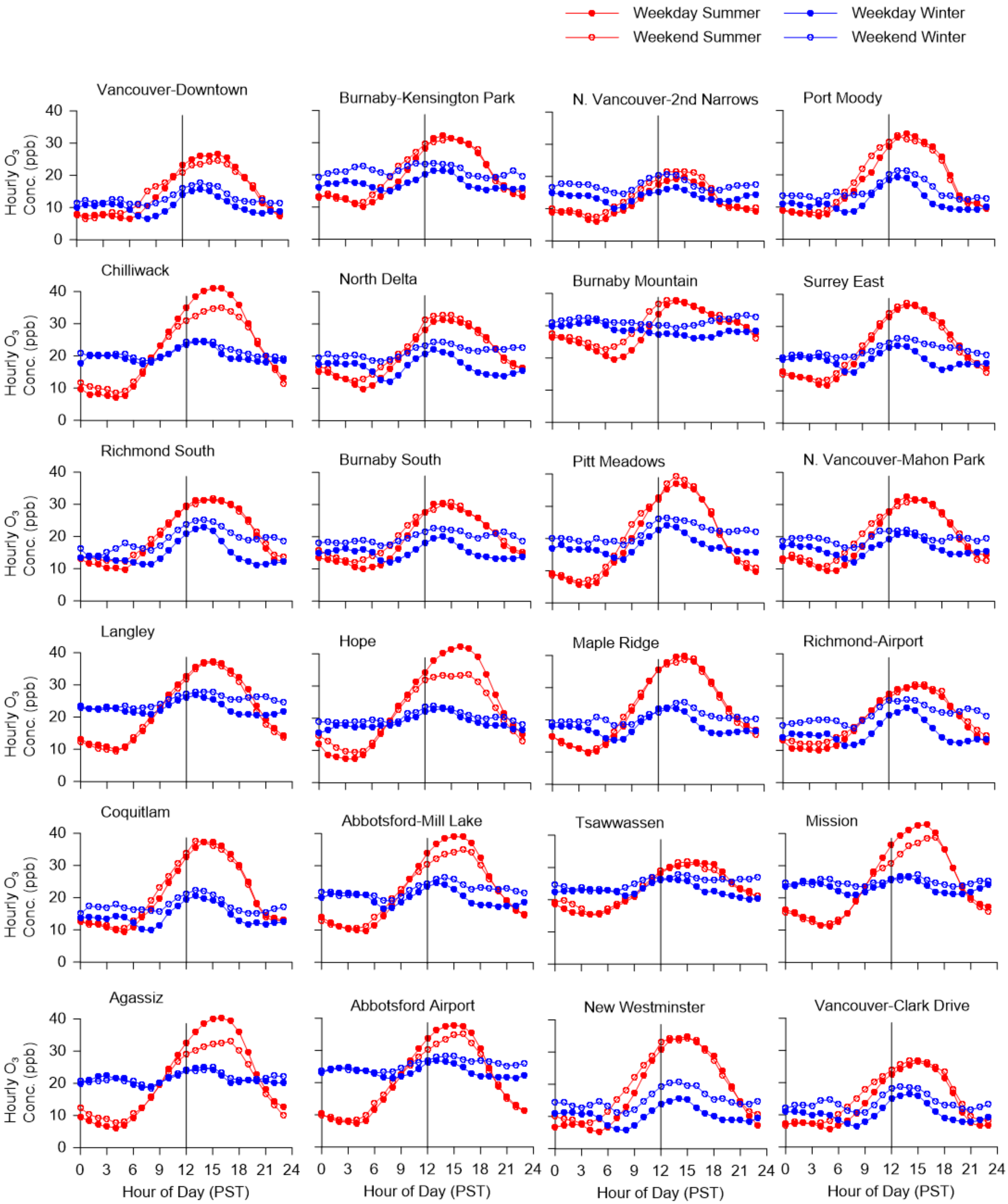


Figure 12: Diurnal trends ozone, 2021

Fine Particulate ($PM_{2.5}$)

Characteristics

The term '$PM_{2.5}$' has been given to airborne particles with a diameter of 2.5 micrometres (μm) or less, also known as fine particulate matter. Given the very small size of these particles, they can penetrate into the finer structures of the lungs. Exposure to fine particulate ($PM_{2.5}$) can lead to both chronic and acute human health impacts, aggravate pulmonary or cardiovascular disease, increase symptoms in asthmatics and increase mortality. Fine particulate matter is considered by health experts to be an air pollutant of serious concern because of these health effects.

Fine particulate is also effective at scattering and absorbing visible light. In this role $PM_{2.5}$ contributes to regional haze and impaired visual air quality.

Sources

Emissions of $PM_{2.5}$ are dominated by residential wood burning at 32% of the total, 15% from non-road engines and equipment, and 19% from industrial sources (Metro Vancouver, 2018). In addition to local sources, $PM_{2.5}$ can be transported long distances from sources such as wildfires in other parts of western Canada, the US or more distant.

Scientific investigations in the LFV indicate that a proportion of ambient $PM_{2.5}$ is also formed by reactions of NO_X and SO_2 with ammonia in the air (mainly from agricultural sources in the LFV). Fine particulate produced in this manner is called secondary $PM_{2.5}$ and accounts for a percentage of $PM_{2.5}$ in summer. Therefore, emissions of precursor gases of secondary $PM_{2.5}$ are also important sources in the region.

Monitoring Results

The $PM_{2.5}$ annual average, maximum 24-hour rolling average, and Canadian Ambient Air Quality Standard values are shown in Figures S7 and 13 for 2021. The same values are shown spatially in Figures 14, 15, and 16, respectively.

All stations were below the $PM_{2.5}$ CAAQS with the exception of Mission. CAAQS values for 2021 ranged from 12 to 28 $\mu g/m^3$. The $PM_{2.5}$ CAAQS is a value that is calculated by taking an annual 98th percentile value using daily averages, averaged over three consecutive years. All stations were below the Metro Vancouver annual objective of 8 $\mu g/m^3$ and all but two stations exceeded the planning goal of 6 $\mu g/m^3$. Metro Vancouver's planning goal is a longer term aspirational target to support continuous improvement.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2021 due to wildfire smoke from fires burning in BC and Washington and secondary $PM_{2.5}$ formation during a record-breaking heat wave.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were widespread in 2021. The region was impacted by a record breaking heat wave in June and wildfire smoke in late July into August from fires burning in BC and Washington.

Metro Vancouver's 24-hour $PM_{2.5}$ objective was exceeded at four stations (North Vancouver-Second Narrows, New Westminster, Abbotsford-Mill Lake, and Mission) between June 28 to 30 during a record-breaking heat wave due to a buildup of local emissions and secondary formation of $PM_{2.5}$. During the heat wave a ground-level ozone advisory was in place and a fine particulate matter advisory was added on June 29 for a single day due to elevated levels of $PM_{2.5}$. The maximum 24-hour average occurred at New Westminster with a concentration of 31.1 $\mu g/m^3$.

Exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective were measured on July 31 to August 3 at four stations in the eastern Fraser Valley (Chilliwack, Hope, Agassiz, and Mission) due to wildfire smoke from fires burning in BC and Washington state. The maximum 24-hour average occurred at Hope with a concentration of 63.9 $\mu g/m^3$. A two-day $PM_{2.5}$ air quality advisory was issued on August 1, coinciding with widespread smoke.
Smoke returned August 12 to 15 with exceedances measured at all monitoring stations. The maximum 24-hour average concentration of 165.5 $\mu g/m^3$ occurred at Hope. Exceedances were due to wildfire smoke from fires burning mainly in BC and Washington state. A $PM_{2.5}$ air quality advisory was issued on August 12 for three days.
The impacts of wildfire smoke and climate change are discussed further in Section I.

Table 6 gives the frequency distribution of $PM_{2.5}$ concentrations for the year. In 2021, Chilliwack, Hope, and Agassiz experienced the highest frequency of elevated $PM_{2.5}$ concentrations, a result of wildfire smoke.

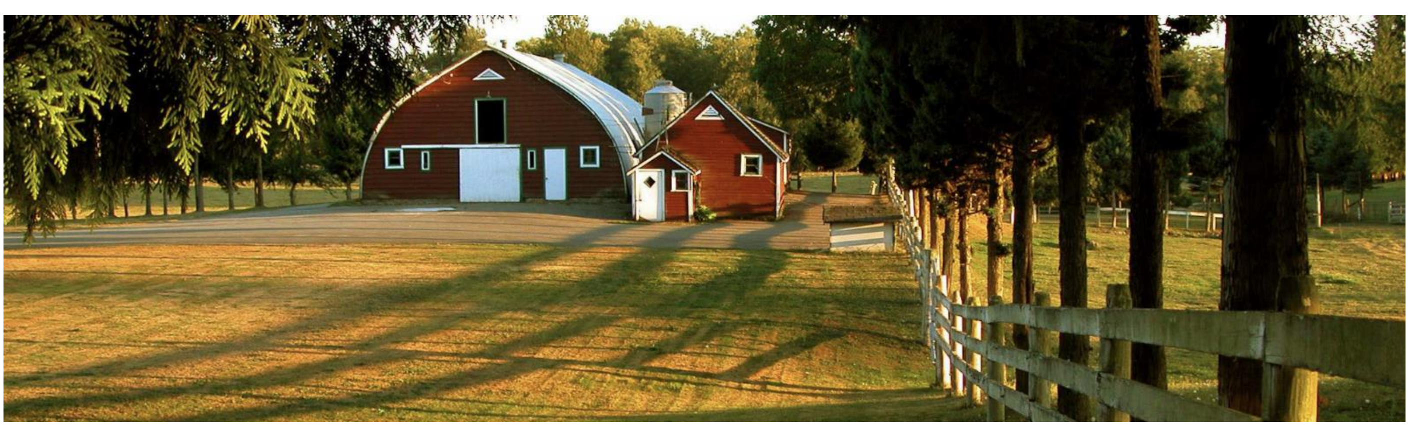
Seasonally, $PM_{2.5}$ levels are typically higher in the summer with the highest values typically experienced during the dry summer months (Figure 17), due to smoke from wildfire activity and the formation of secondary $PM_{2.5}$. The influence of wildfire smoke is evident in both the monthly average and 24-hour maximum rolling average concentrations in August.

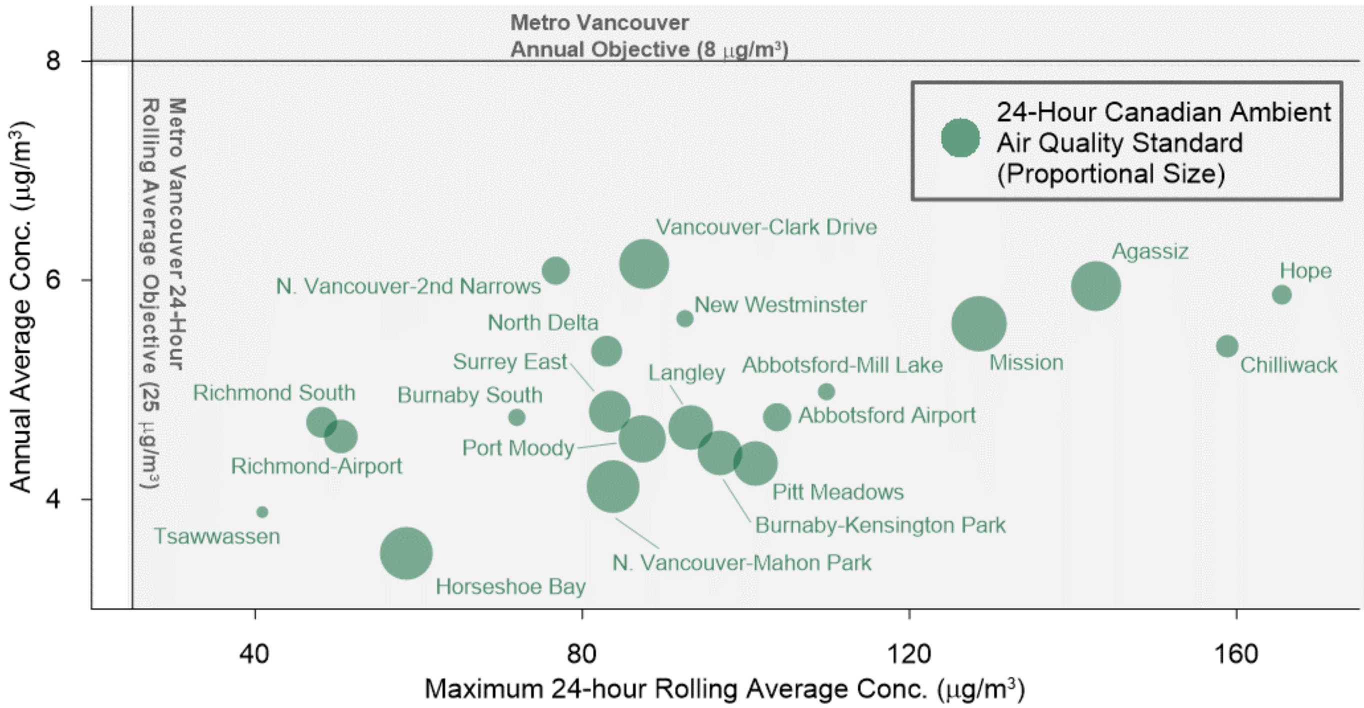
Figure 18 illustrates the long-term $PM_{2.5}$ trends in the LFV with annual average and peak concentrations shown respectively. Monitoring technology was upgraded in 2013 to continuous particulate monitors that met the U.S. Environmental Protection Agency $PM_{2.5}$ Federal Equivalent Method (FEM). The FEM monitors have the ability to measure a portion of particulate matter not previously measured. The short-term peak concentrations reflect the highest levels that occur, represented by the 99^{th} percentile of the 24-hour rolling average for each year. Given that it will take several years to establish a long-term record of $PM_{2.5}$ with the FEM monitor, both the older monitor data (TEOM) and FEM data are shown together.

In Figure 18 the TEOM data is shown as solid lines with a grey band displaying the range of values from all TEOM stations, while the FEM data is shown as dotted lines with an orange band showing the range from all FEM stations. It is evident that the FEM monitor measures higher $PM_{2.5}$ concentrations compared to the TEOM monitor. Long-term average trends of the TEOM data show that 2015 was not appreciably different than previous years. However, the FEM data shows a step increase compared with the TEOM, which is a result of the FEM monitor's ability to measure some particles not previously measured by the TEOM monitor.

The differences in peak trends from year to year are driven by meteorological variability and wildfire activities. The long-term peak trend shows that 2017, 2018 and 2020, three very active wildfire years, measured much higher peak concentrations compared with other years.

A series of diurnal plots are shown in Figure 19 for each $PM_{2.5}$ monitoring station. Typically, the summer exhibits little diurnal variation while the winter displayed higher $PM_{2.5}$ concentrations in the evenings compared with the daytime. The evenings in winter were likely elevated due to reduced atmospheric mixing depths coupled with regional and local emission sources.





Note: Stations contained within the grey area denote an exceedance of an objective

Figure 13: Fine particulate ($PM_{2.5}$), 2021

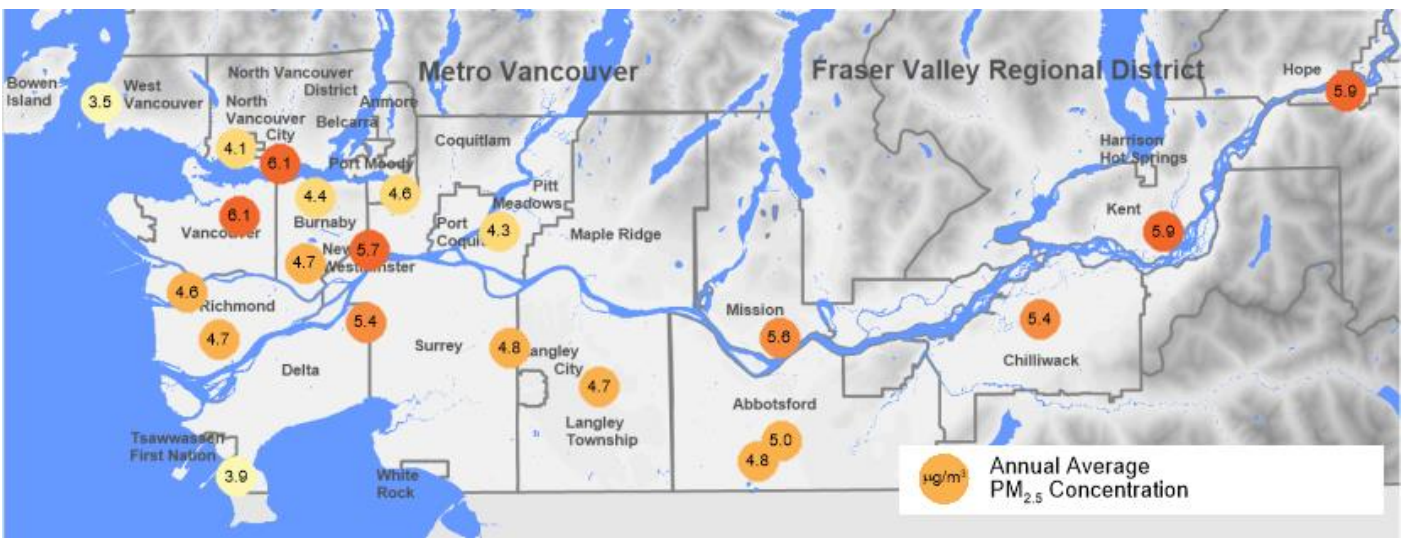


Figure 14: Annual average fine particulate ($PM_{2.5}$) in the LFV, 2021

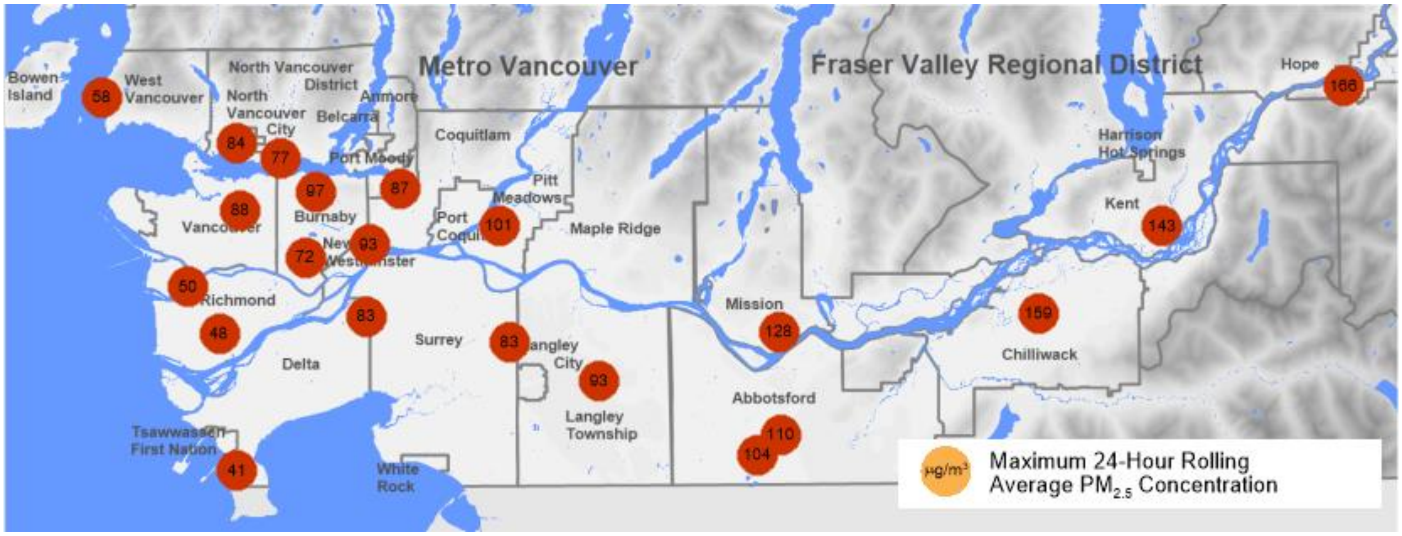


Figure 15: Short-term peak fine particulate ($PM_{2.5}$) in the LFV, 2021

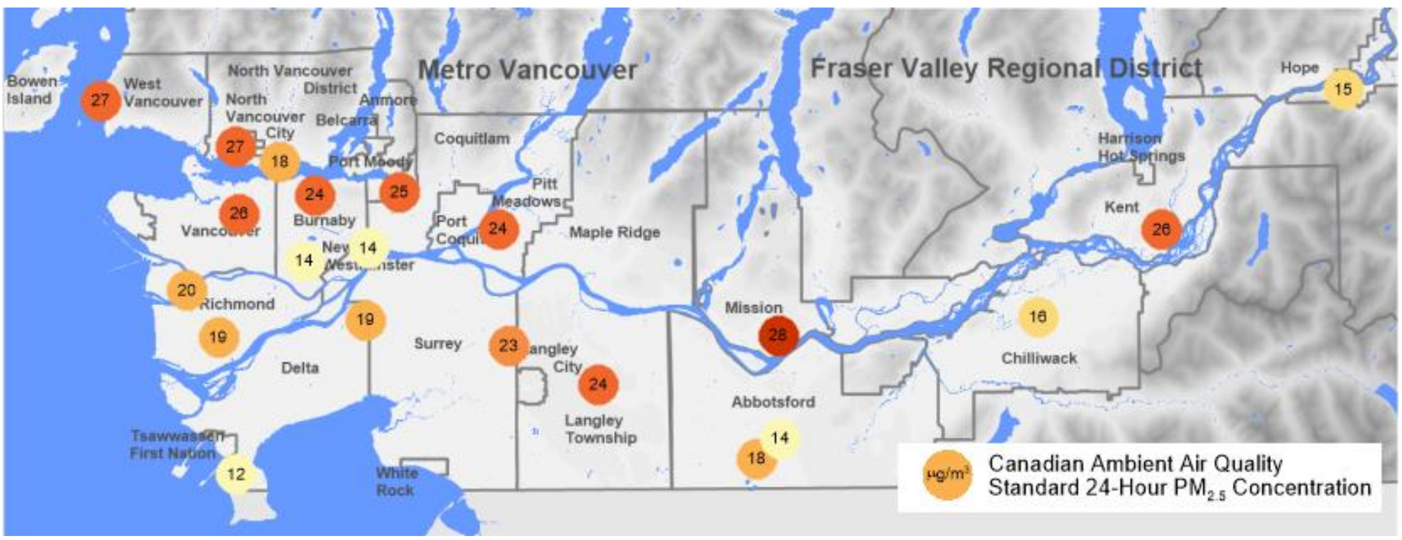


Figure 16: Canadian Ambient Air Quality Standard value for fine particulate ($PM_{2.5}$), 2021

Table 6: Frequency distribution of 24-hour rolling average fine particulate ($PM_{2.5}$), 2021

$PM_{2.5}$ Conc. ($\mu g/m^3$)	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Horseshoe Bay	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to <10	8335	7531	8257	8227	6769	8371	8382	8150	8336	8502	8330	8040	8449	8401	7254	8498	8029	8210	8291	8317	8120
10 to <20	160	476	151	349	130	236	194	335	188	149	295	251	204	206	109	135	508	321	300	195	547
20 to <30	29	74	26	33	30	9	11	27	13	8	38	17	5	35	13	4	62	37	30	22	20
30 to <40	3	6	6	6	6	6	5	5	5	7	6	21	6	7	6	8	6	19	7	9	6
40 to <50	2	7	5	5	4	5	17	5	5	5	5	21	15	9	7	13	6	21	13	6	5
50 to <60	2	5	6	5	5	5		4	4	4	6	21	3	13	13		6	3	12	5	3
60 to <70	4	7	4	3	5	4		9	5	6	8	11		5			4	5	5	5	6
70 to <80	8	10	8	4	8	7		6	5	8	5	3		5			4	3	4	5	6
80 to <90	6		7	4	7	8			6	5	6	4		5			4	5	8	7	8
90 to <100	7			3					6		6	3		7			8	4	7	3	
100 to <110				3					3			4		10			6	4	4		
110 to <120				4								2					6	9			
120 to <130				5								5					13	12			
130 to <140				8								6						8			
140 to <150				7								6						5			
150 to <160				12								8									
>=160											11										
Missing	204	644	290	82	1796	109	151	219	184	66	55	326	78	57	1358	102	98	94	79	186	39
Data Completeness	98%	93%	97%	99%	80%	99%	98%	98%	98%	99%	99%	96%	99%	99%	85%	99%	99%	99%	99%	98%	100%

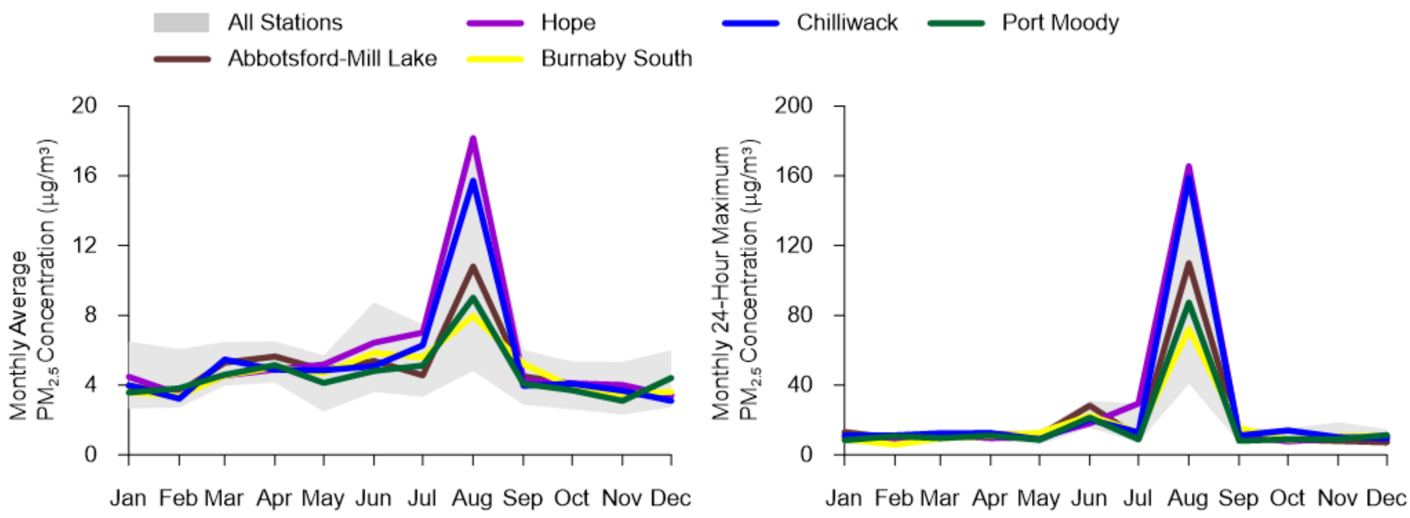


Figure 17: Monthly average (left) and short term peak (right) fine particulate ($PM_{2.5}$), 2021

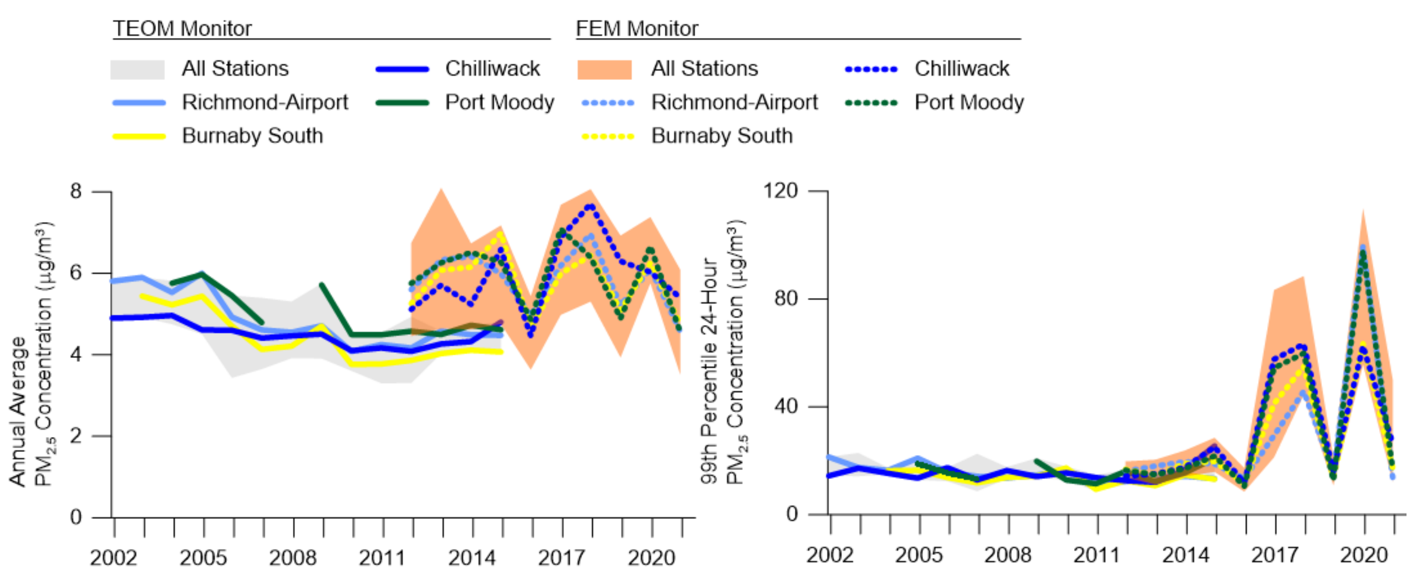


Figure 18: Annual (left) and short term peak (right) fine particulate ($PM_{2.5}$) trend, 2002 to 2021

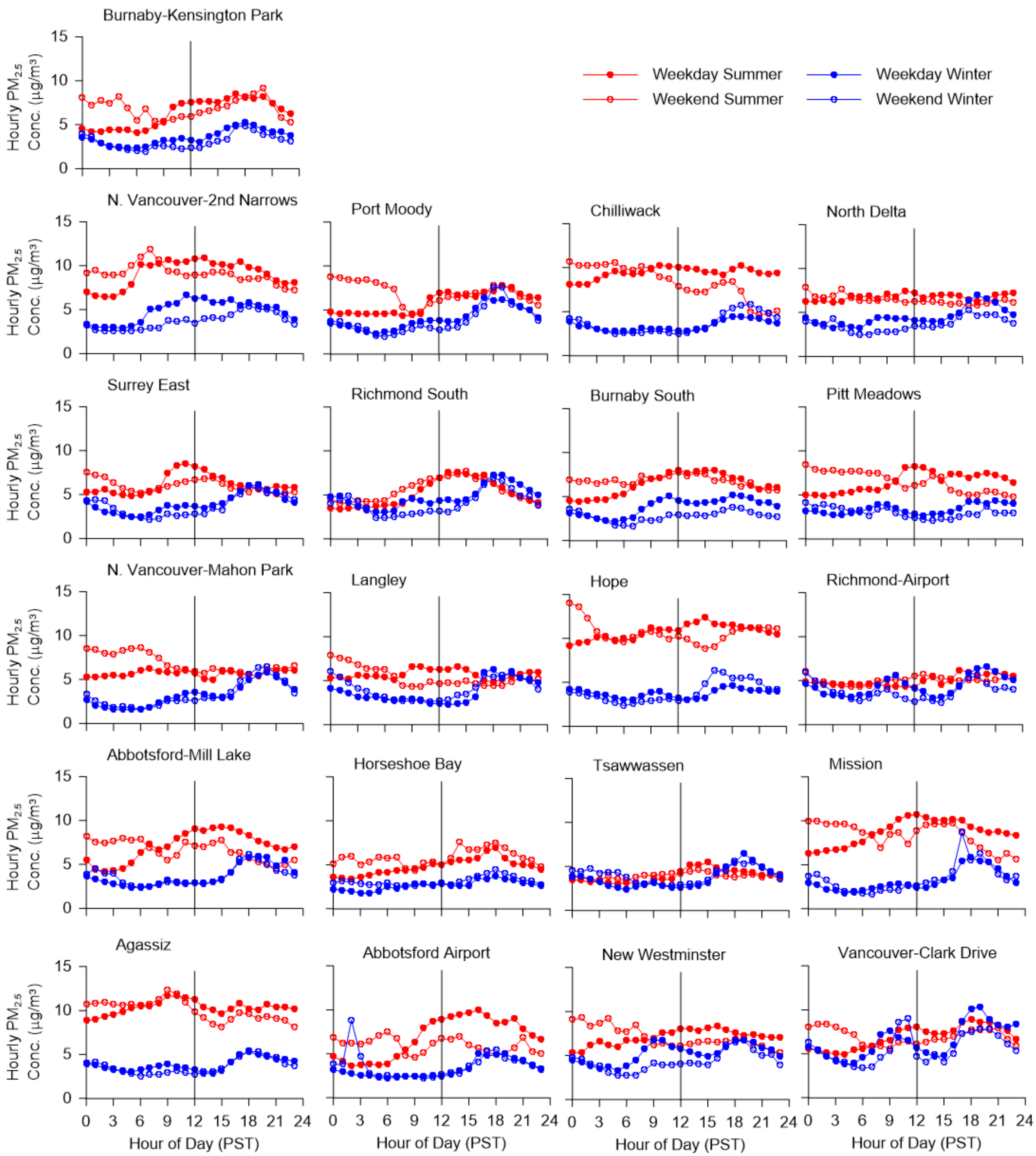


Figure 19: Diurnal trends fine particulate ($PM_{2.5}$), 2021

Nitrogen Dioxide (NO_2)

Characteristics

Of all the different oxides of nitrogen (NO_X), nitric oxide (NO), and nitrogen dioxide (NO_2) are of most concern in ambient air quality. Both are produced by the high temperature combustion of fossil fuels, and are collectively referred to as NO_X. Nitric oxide generally predominates in combustion emissions but rapidly undergoes chemical reactions in the atmosphere to produce NO_2.

Nitrogen dioxide is a reddish-brown gas with a pungent, irritating odour. It has been implicated in acute and chronic respiratory disease and in the creation of acid rain. It also plays a major role in ozone formation, and as a precursor to secondary particulate formation ($PM_{2.5}$), both of which can affect visual air quality in the region.

Sources

Common NO_X sources include boilers, building heating systems and internal combustion engines. In the LFV, transportation sources account for approximately 77% of NO_X emissions, with stationary and area sources contributing the remainder.

Monitoring Results

Figures S8 and 20 shows NO_2 monitoring levels in 2021, while Figures 21 and 22 shows the same values spatially. All 1-hour NO_2 concentrations were below Metro Vancouver's objective at all stations with the exception of North Vancouver-Second Narrows due to local construction activity. Figure 20 shows the annual average, 1-hour maximum and Metro Vancouver's 1-hour objective value. Metro Vancouver's 1-hour NO_2 objective level is the same as the 1-hour NO_2 Canadian Ambient Air Quality Standard which is calculated by taking an annual 98th percentile value using daily maximum 1-hour measurements, averaged over three consecutive years.

Average levels for the year were below Metro Vancouver's annual objective at all sites. Emissions affecting NO_2 concentrations are dominated by transportation sources, which is indicated by the locations of the highest concentrations. The highest concentrations are measured in more densely trafficked areas near busy roads. Lower concentrations were observed where traffic influences were less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.

The majority of nitrogen oxides are from transportation sources such as cars, trucks, rail, planes, and ships. These sources play a large role in ozone formation in the summer, which can lead to an air quality advisory.

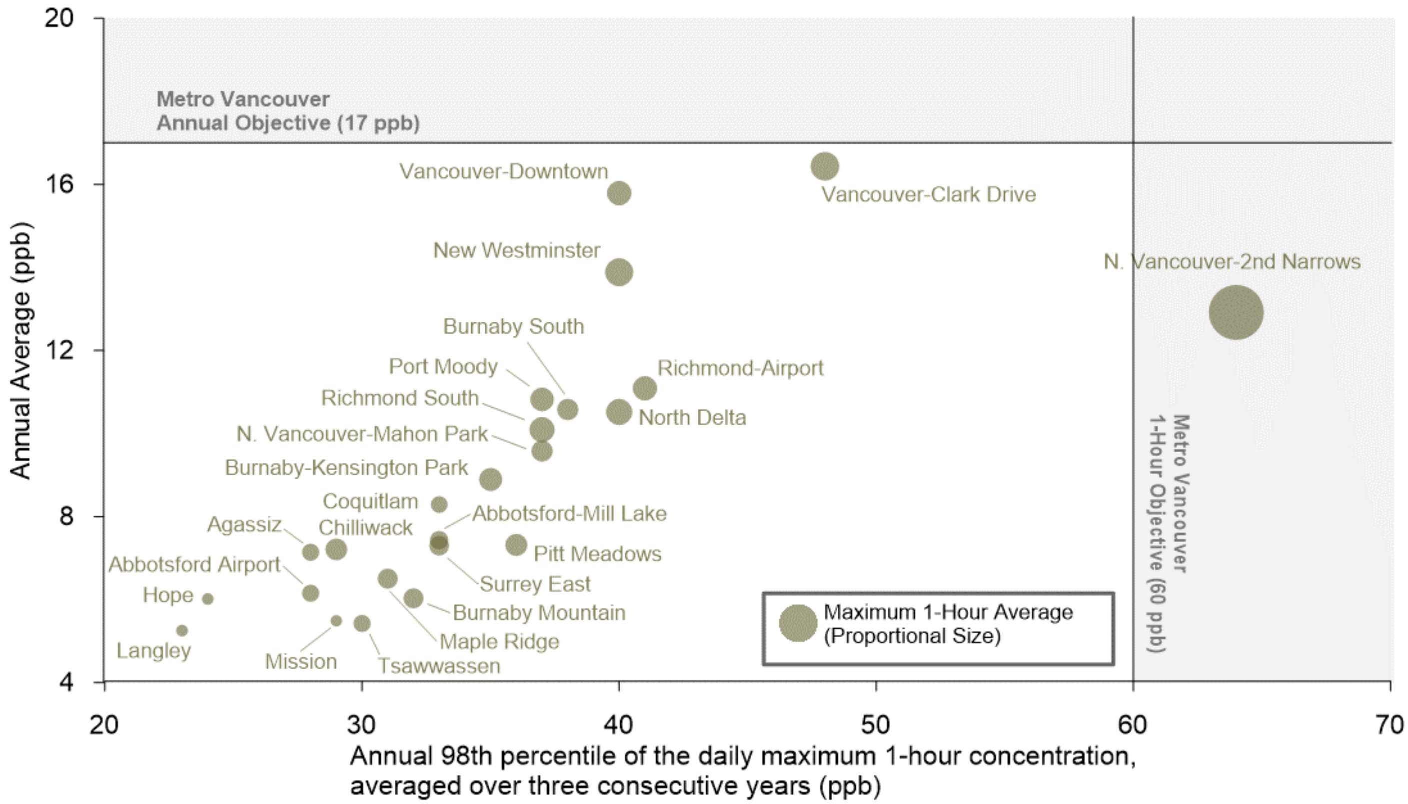
The seasonal trend for NO_2 in 2021 is shown by monthly averages and the monthly maximum 1-hour concentrations in Figure 23. On average, NO_2 concentrations were higher in the winter and lower in the summer. This seasonal trend is typical of the region and is the result of lower atmospheric mixing heights in winter along with increased residential, commercial and industrial heating that uses fossil natural gas.

The long-term NO_2 trends are shown in Figure 24. The annual average and short-term peak trends are provided in Figure 24 for the last two decades.

The trend for average and peak (99th percentile of 1-hour) concentrations continued to decline for most stations, showing constant improvement in NO_2 levels since the mid 1990's. Long-term changes in air quality can be attributed to changes in emissions while the yearly variation is likely attributable to meteorological variability. The improvements in the long-term trends shown here are largely due to improved vehicle emission standards and the AirCare program, which was operated in BC from 1992 to 2014.

The frequency distribution of hourly concentrations measured in 2021 is given in Table 7. The North Vancouver-Second Narrows station experienced the greatest frequency of elevated NO_2 concentrations, due to construction activities that were present near the monitoring station.

A series of diurnal plots are shown in Figure 25 for each station that monitors NO_2. The plots demonstrate the differences between weekdays and weekends along with differences between summer and winter. Most stations exhibit higher concentrations on weekdays compared with weekends and show a peak in the morning along with a peak in the afternoon. Higher concentrations correspond relatively well with traffic volume patterns.



Note: Stations contained within the grey area denote an exceedance of an objective

Figure 20: Nitrogen dioxide monitoring, 2021

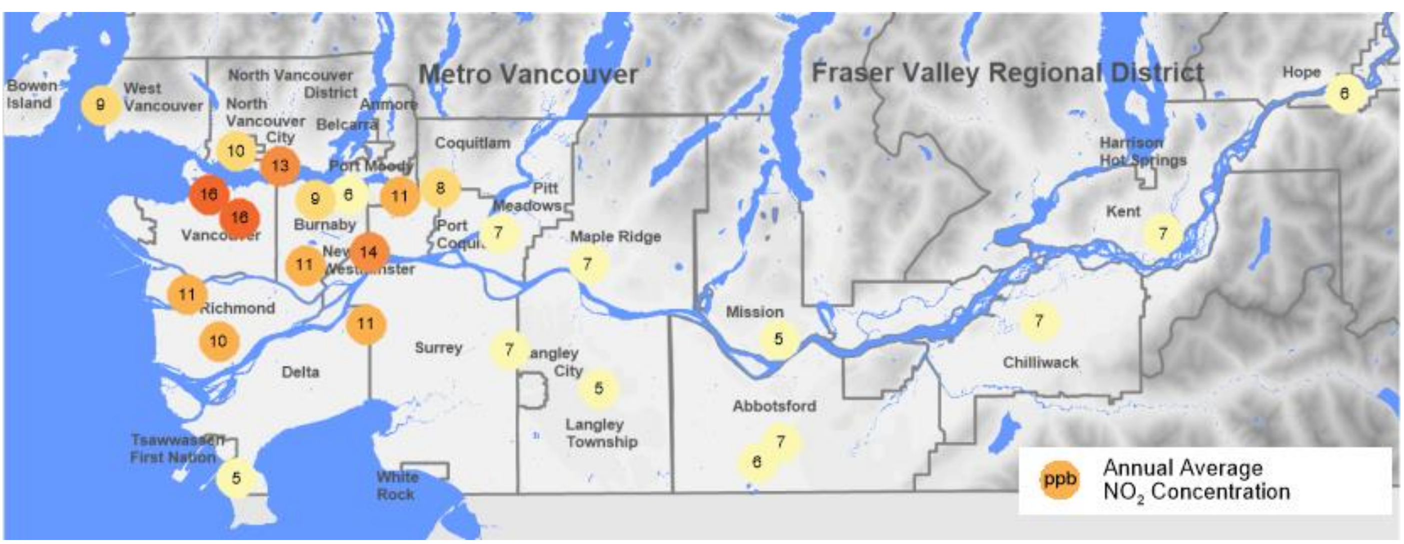


Figure 21: Annual average nitrogen dioxide in the LFV, 2021

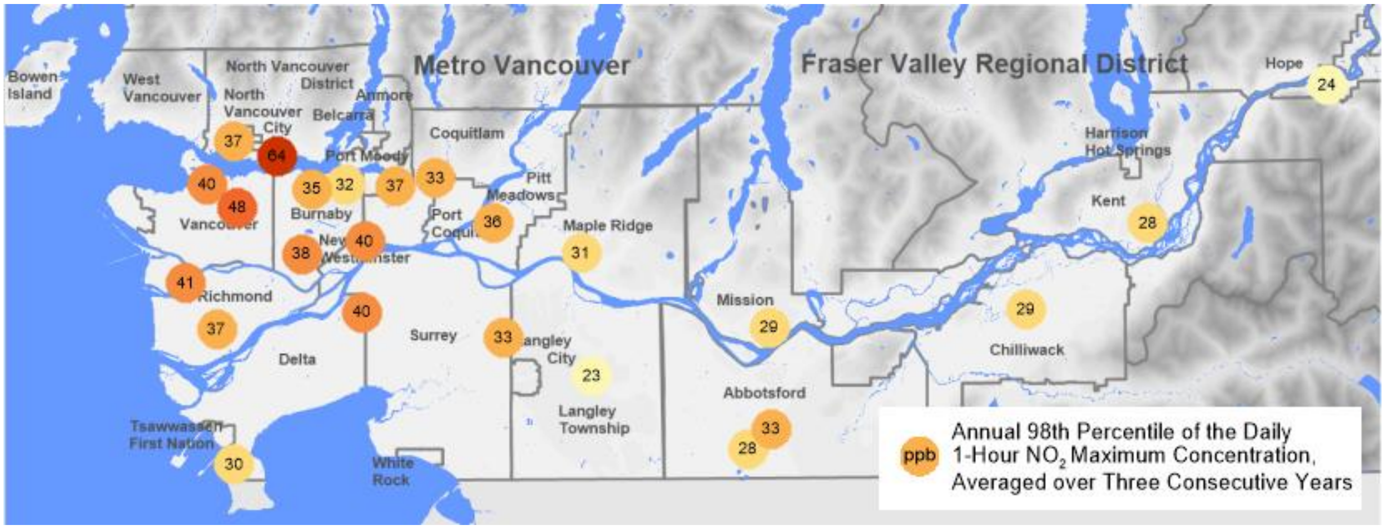


Figure 22: Short-term peak nitrogen dioxide in the LFV, 2021

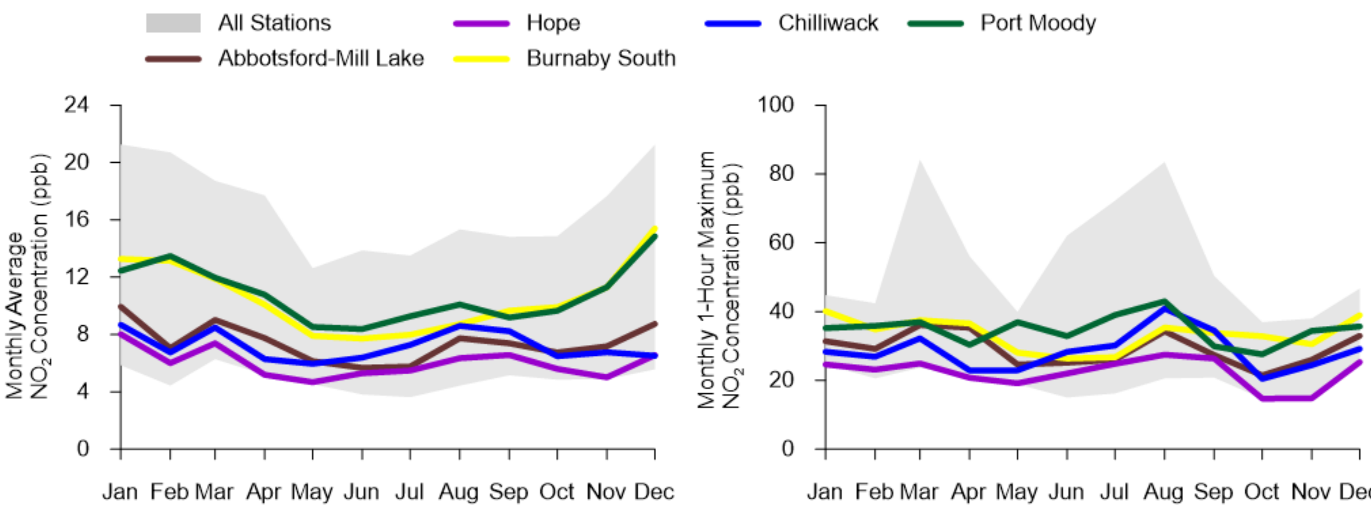


Figure 23: Monthly average (left) and short term peak (right) nitrogen dioxide, 2021

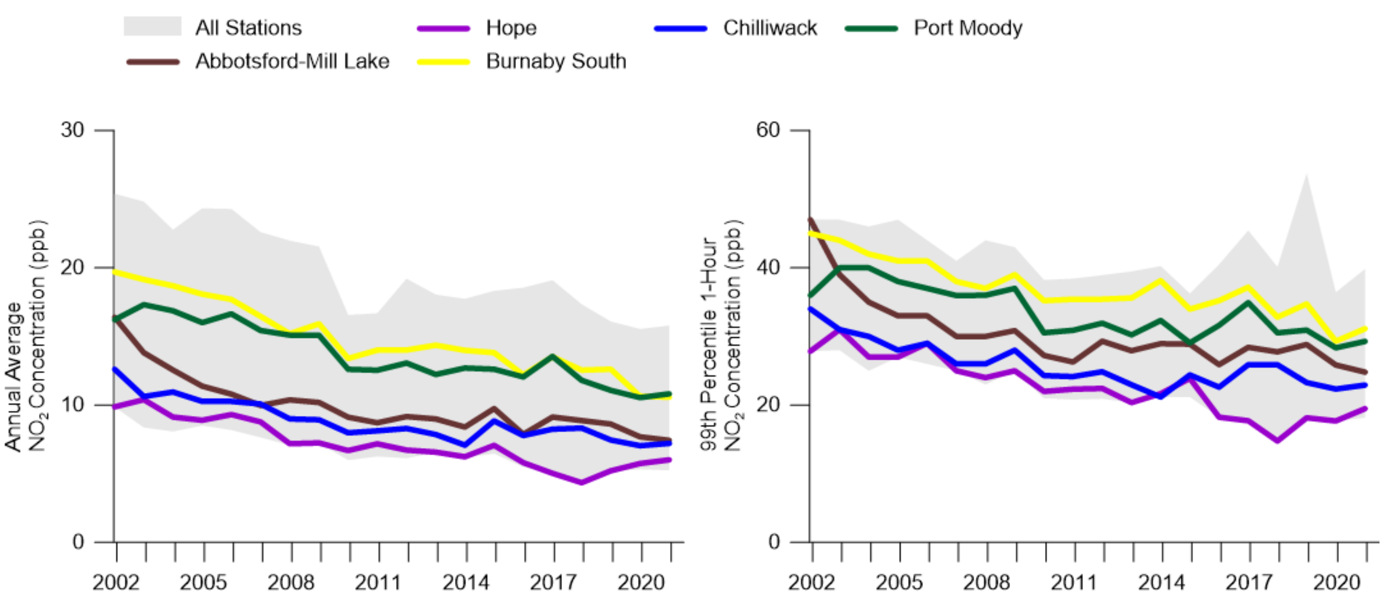


Figure 24: Annual (left) and short term peak (right) nitrogen dioxide trend, 2002 to 2021

Table 7: Frequency distribution of hourly nitrogen dioxide, 2021

NO2 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Horseshoe Bay	Tsawwassen	Mission	Agassiz	Abbotsford Airport	New Westminster	Vancouver-Clark Drive
0 to <5	448	2382	1021	1582	3731	2438	4349	3835	3200	1788	3831	2478	5232	4470	4274	2618	2978	3711	2593	5503	5217	3996	4715	830	827
5 to <10	1899	3514	2854	2982	2906	2591	3089	2770	1880	3058	2585	2950	2426	2721	2779	2232	3147	2769	1902	1916	2289	2545	2281	2206	1517
10 to <15	1882	1643	2098	2109	1320	1555	895	1233	1366	1925	1349	1649	730	1084	1024	1381	1480	1267	1396	718	809	1333	1124	2135	1637
15 to <20	1867	691	1256	1285	544	925	270	540	1036	1030	553	892	198	288	457	1070	710	611	792	386	302	610	461	1679	1749
20 to <25	1501	300	635	491	170	586	82	230	729	502	261	447	44	68	155	698	284	214	368	164	83	191	104	1180	1379
25 to <30	783	121	384	195	29	301	28	75	365	247	109	199	6	5	28	428	106	65	150	45	13	46	18	514	851
30 to <35	255	47	202	57	11	149	6	18	114	83	26	58			3	225	18	14	64	10		8	5	135	412
35 to <40	60	13	100	13	3	53	6	2	24	31	3	23			2	70		4	36					28	165
40 to <45	12	1	45	2	1	9			2	1	1	1				3			18					3	56
45 to <50			20			1			1										8					2	8
50 to <55			5																3						
55 to <60			5																1						
60 to <65			4																						
65 to <70			1																						
70 to <75			2																						
75 to <80			1																						
>=80			2																						
Missing	53	48	124	44	45	152	35	57	43	95	42	63	124	124	38	35	37	105	1429	18	47	31	52	48	159
Data Completeness	99%	100%	99%	100%	100%	98%	100%	99%	100%	99%	100%	99%	99%	99%	100%	100%	100%	99%	84%	100%	100%	100%	99%	100%	98%

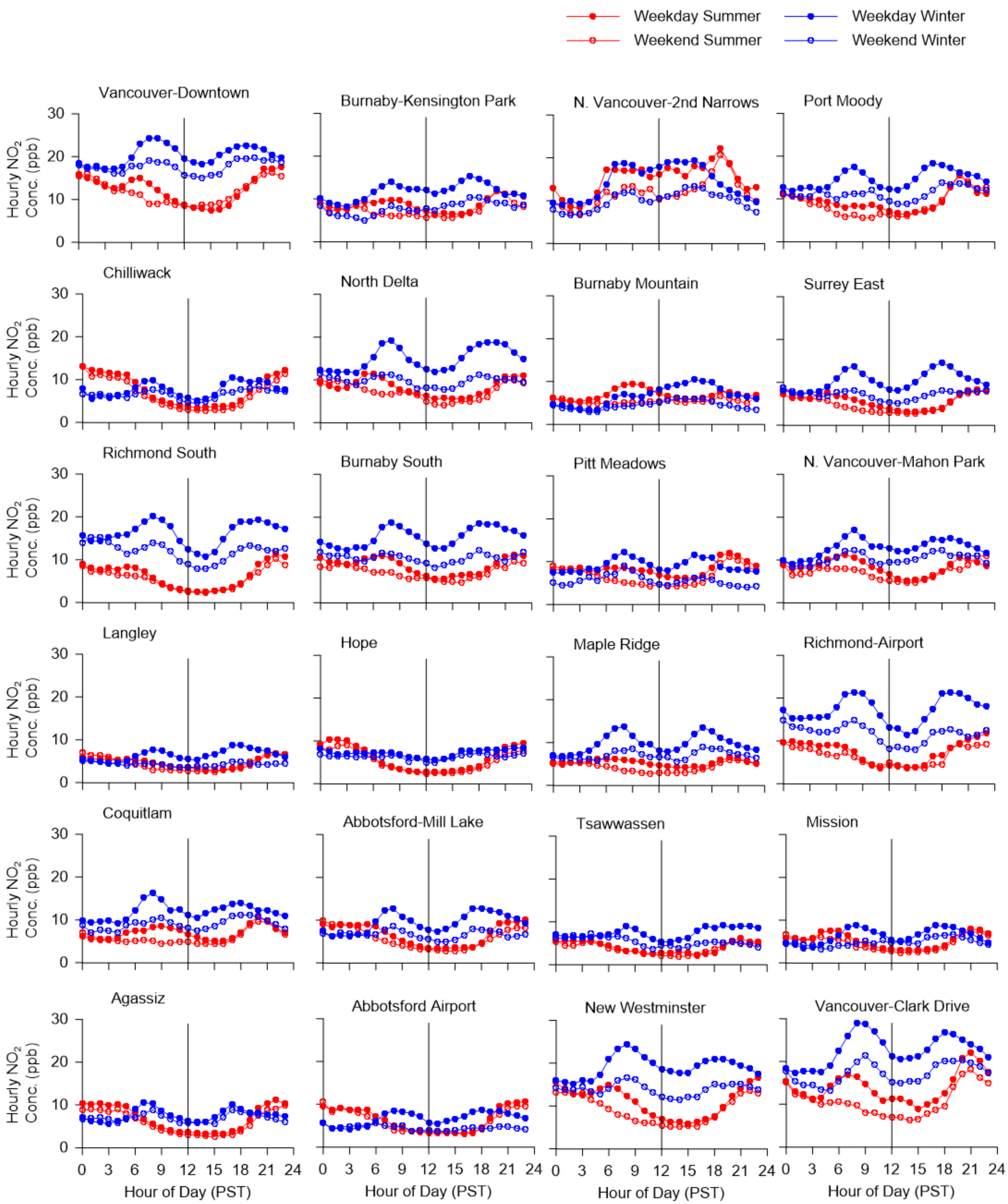


Figure 25: Diurnal trends nitrogen dioxide, 2021

Sulphur Dioxide (SO_2)

Characteristics

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour. It reacts in the air to form acidic substances such as sulphuric acid and sulphate particles.

Brief exposure to high concentrations of SO_2 and its by-products can irritate the upper respiratory tract and aggravate existing cardiac and respiratory disease in humans. Long-term exposure may increase the risk of developing chronic respiratory disease.

The environmental effects of SO_2 and its reactive products have been studied for many years. These compounds can cause damage to vegetation and buildings, they play a role in the formation of acid rain and they may affect the natural balance of waterways and soils. Sulphur oxides (SO_X) including SO_2 can also combine with other air contaminants to form the fine particulates ($PM_{2.5}$) that are thought to be one of the contributing factors in the degradation of visual air quality in the region.

Sources

Sulphur dioxide is emitted when fossil fuels containing sulphur are burned. The largest source of SO_2 emissions in the region an oil refinery, marine vessels, a waste to energy facility and two cement plants. The geographical distribution of sulphur dioxide emissions is influenced mainly by a petroleum refinery in Burnaby and ocean-going vessels in the marine areas of Burrard Inlet, although in recent years, marine emissions have been reduced substantially.

Local SO_2 emissions are low relative to other cities of similar size because fossil natural gas and electricity, rather than coal or oil, is used in almost all residential, commercial and industrial heating in the region.

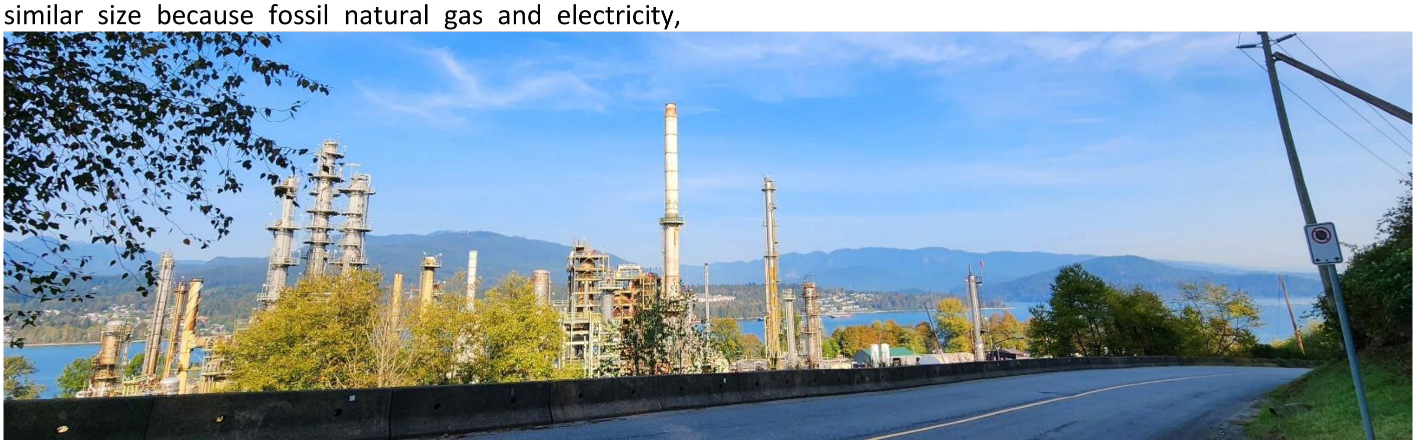
Monitoring Results

Sulphur dioxide levels measured in 2021 are shown in Figures S9 and 26. Figure 26 displays the maximum 1-hour and annual average concentrations for each SO_2 monitoring location. The same values are represented spatially in Figures 27 and 28.

Average sulphur dioxide levels have improved significantly in recent years due to stricter requirements for lower sulphur content marine fuels.

Sulphur dioxide levels were below Metro Vancouver's 1-hour objective at all stations in 2021 with the exception of Burnaby-Capitol Hill. The objective was exceeded for two hours at Burnaby-Capitol Hill on December 28 in the early morning. The highest concentrations correlate with times when winds where blowing from the oil refinery in Burnaby. The annual average SO_2 levels were below Metro Vancouver's annual objective and less than 1 ppb at all stations. Average levels remained low in 2021 compared with previous years and can be attributed to stricter marine fuel requirements that came into effect at the beginning of 2015.

The highest levels of SO_2 are typically measured in the northwest (Figures 27 and 28), particularly close to the dominant sources of SO_2 emissions (i.e., the petroleum refinery, marine vessels, and port areas) in the Burrard Inlet area.



There is little or no discernible seasonal trend in SO_2 concentrations throughout the year (Figure 29). The stations nearest to Burrard Inlet generally experienced the highest average concentrations through most of the year while the highest 1-hour measurements were recorded at Burnaby- Capitol Hill in December.

The long-term SO_2 trends in the LFV are shown in Figure 30. Average sulphur dioxide levels have improved significantly in recent years due to stricter requirements for lower sulphur content marine fuels. Overall, the yearly variation can be attributed in part to meteorological variability while the major long-term changes in air quality are mainly a result of changes in emissions.

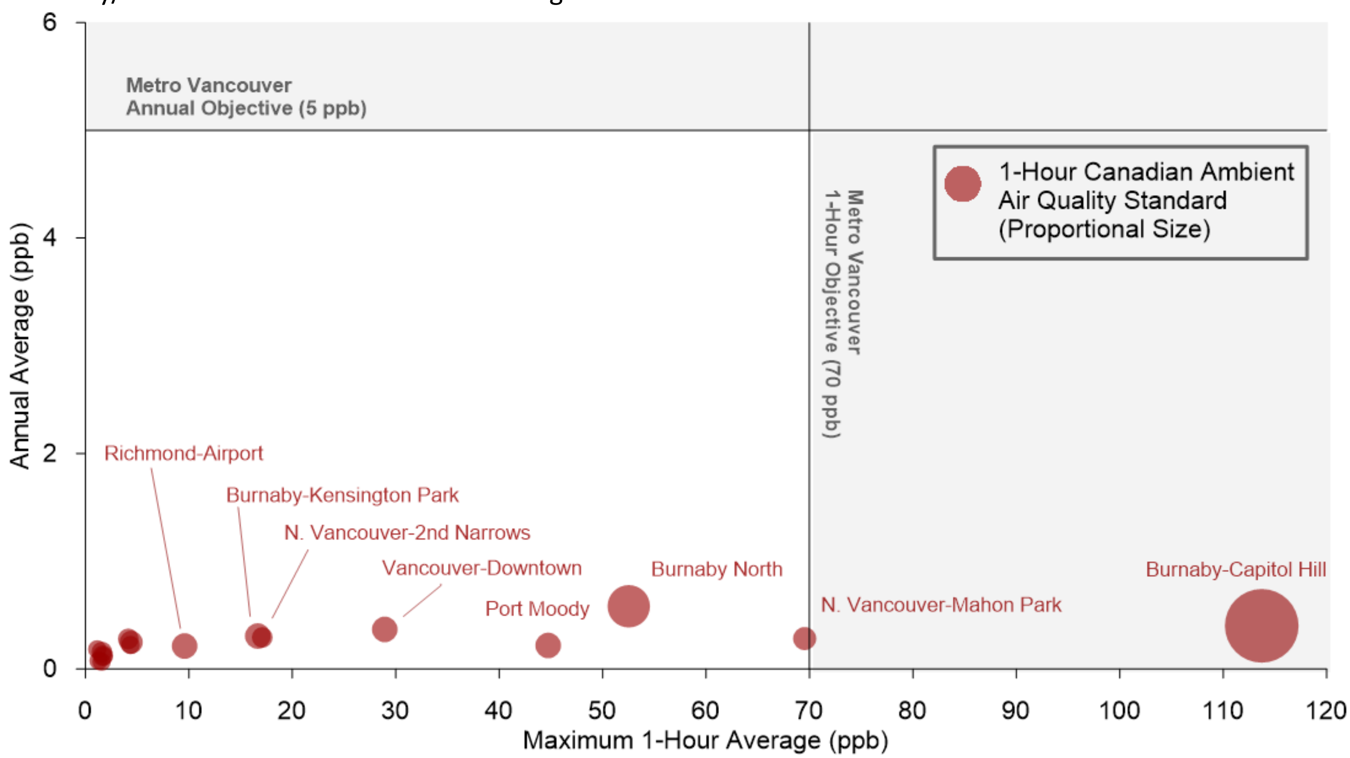
Long-term trends provide information to help assess the impact of emission reduction efforts, policy changes, and technology advances. For example, emissions of SO_2 declined during the early 1990s due to reduced sulphur content in on-road fuels and reduced emissions from oil refining and cement industries. In recent years, measurements of both the annual short-term peak (99th percentile of the 1-hour values) and the annual average are markedly lower than they were in the 1990s.

A series of diurnal plots are shown in Figure 31 for each SO_2 monitoring station. The diurnal plots illustrate the weekday/weekend differences along with summer/winter differences. Stations located away from Burrard Inlet show little diurnal variation while stations located near the inlet show trends indicative of nearby emission sources.

The diurnal patterns of SO_2 measured near Burrard Inlet in the summer are mainly influenced by wind flow and marine and oil refinery emissions. Port Moody experiences higher concentrations during the middle of the day in summer when winds are blowing from marine areas and the oil refinery toward the station.

Stations historically influenced by marine vessel emissions such as North Vancouver-2nd Narrows attenuated levels compared with previous years. The Burnaby-Capitol Hill and Burnaby North stations show diurnal variation with sporadic peak SO_2 concentrations during the morning and evening periods when mixing layer depth is reduced and dispersion is limited. Measurements of SO_2 at these stations are influenced by their proximity to the oil refinery.

The values in Table 8 represent the frequency distribution (or count) of how many hourly average measurements were in the specified ranges, respectively. It is evident that stations located near the Burrard Inlet area experience a greater occurrence of higher concentrations compared with areas away from the Inlet.



Note: For clarity, some stations have not been labelled due to several stations clustered together

Figure 26: Sulphur dioxide monitoring, 2021

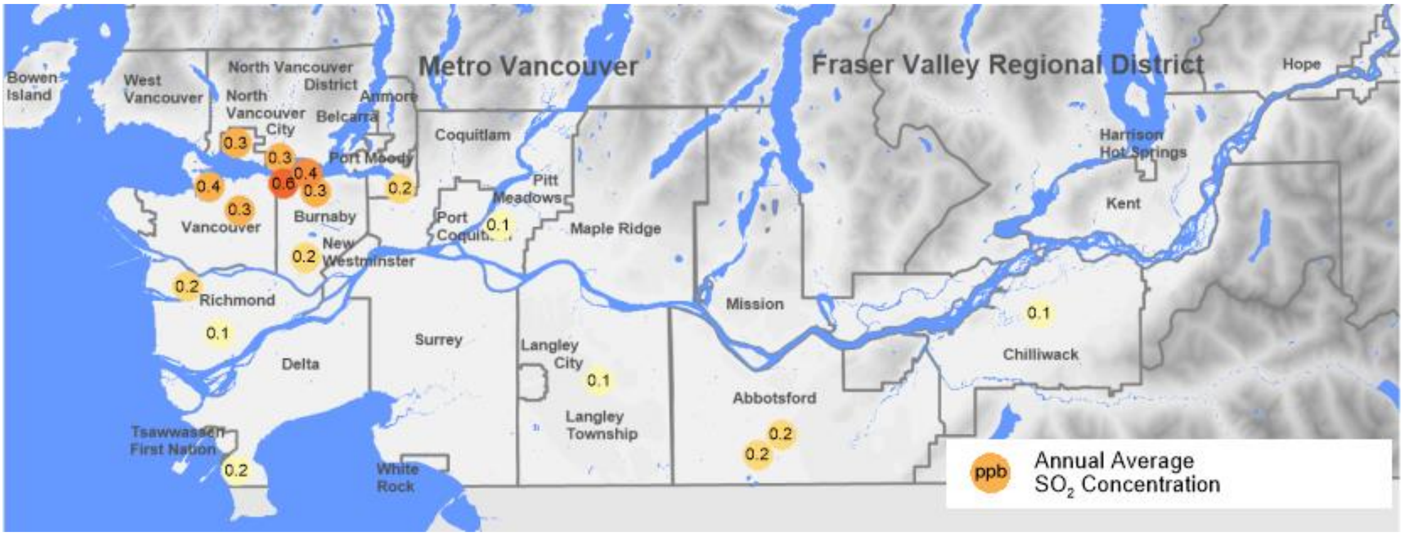


Figure 27: Annual average sulphur dioxide in the LFV, 2021

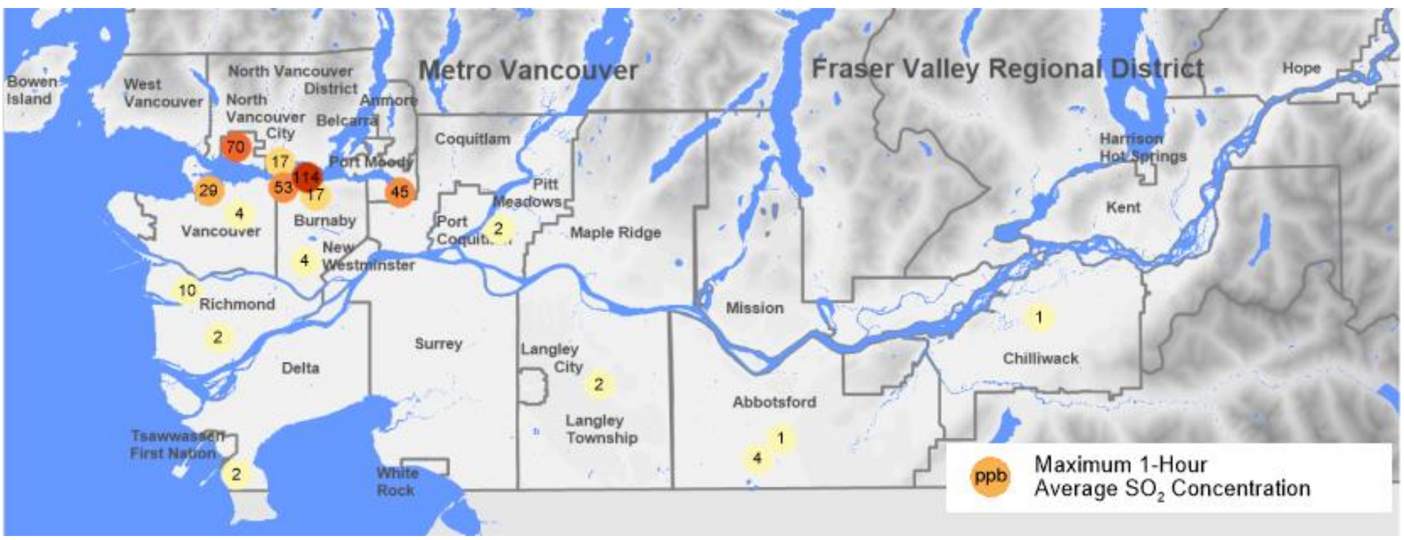


Figure 28: Short-term peak sulphur dioxide in the LFV, 2021

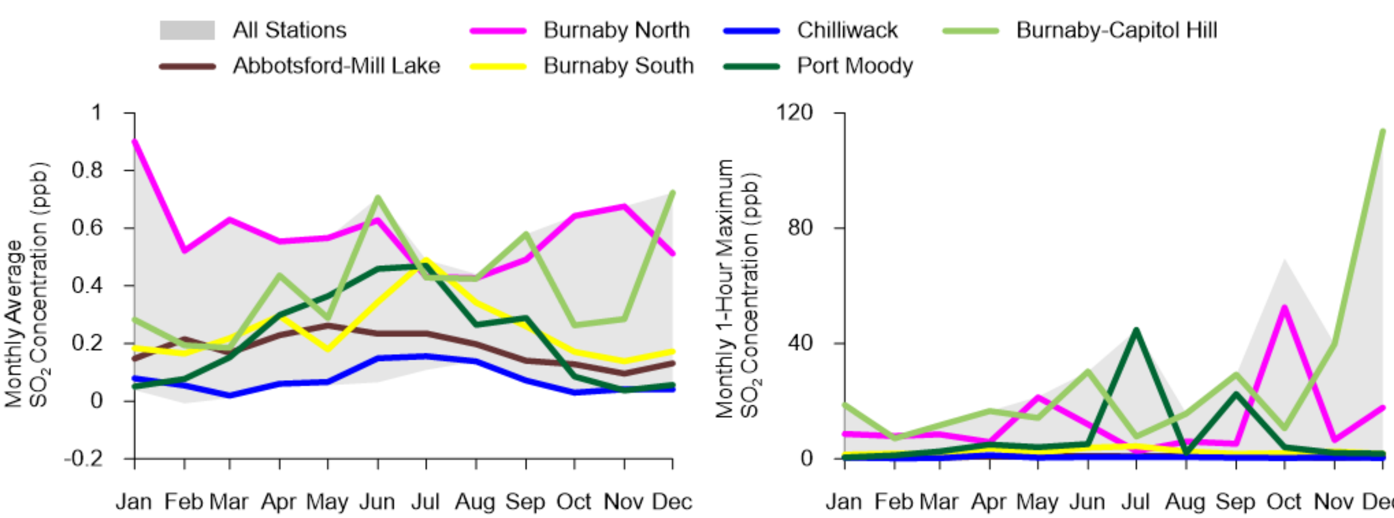


Figure 29: Monthly average (left) and short-term peak (right) sulphur dioxide, 2021

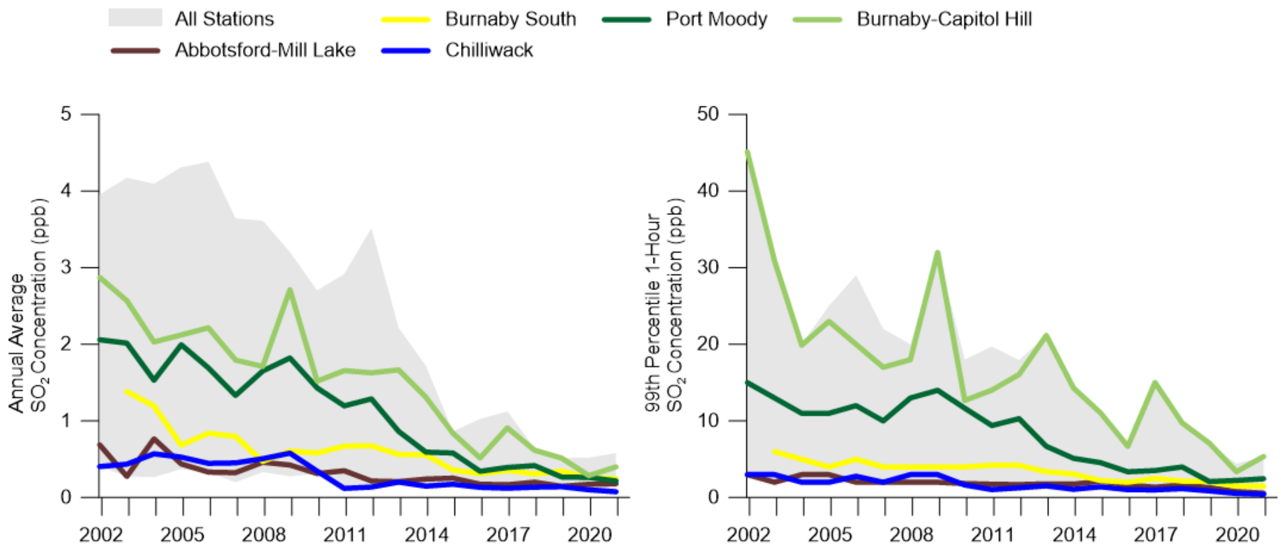


Figure 30: Annual (left) and short-term peak (right) sulphur dioxide trend, 2002 to 2021

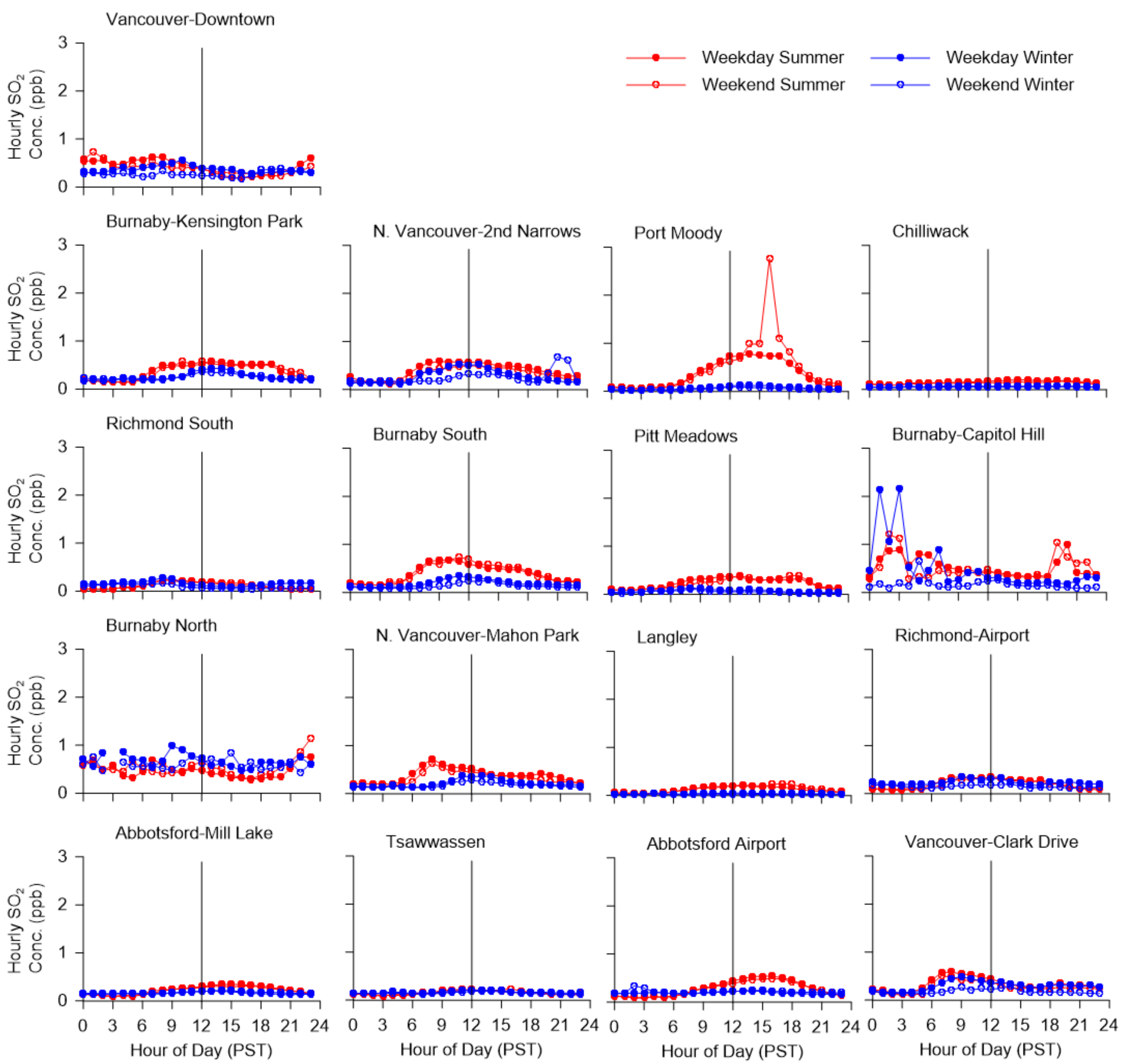


Figure 31: Diurnal trends sulphur dioxide, 2021

Table 8: Frequency distribution of hourly sulphur dioxide, 2021

SO2 Conc. (ppb)	Vancouver-Downtown	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Richmond-Airport	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport	Vancouver-Clark Drive
0 to <6	8406	8514	8486	7012	7747	7960	8428	7545	8350	8373	8551	6870	8366	8568	8556	8481	8138
6 to <12	5	1	2	4					47	25	1		5				
12 to <18		1	2	1					12	3	2						
18 to <24	3			1					7	3							
24 to <30	1								4	1	1						
30 to <36									1	1							
36 to <42									1								
42 to <48				1					1		1						
48 to <54										1							
54 to <60																	
60 to <66																	
66 to <72											1						
72 to <78																	
78 to <84																	
84 to <90																	
90 to <96																	
96 to <102																	
102 to <108																	
>=108									2								
Missing	66	85	139	41	43	40	22	79	17	136	73	59	26	94	22	105	178
Data Completeness	99%	99%	98%	99%	99%	100%	100%	99%	100%	98%	99%	99%	100%	99%	100%	99%	98%

Carbon Monoxide (CO)

Characteristics

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. It has a strong affinity for haemoglobin and thus reduces the ability of blood to transport oxygen. Long-term exposure to low concentrations may cause adverse effects in people suffering from cardiovascular disease.

Sources

Carbon monoxide is a commonly occurring air pollutant that is measured at levels well below air quality objectives. The principal sources are non-road engines and motor vehicles. In the LFV, over 91% comes from mobile sources, which include cars, trucks, buses, planes, trains, ships, and non-road engines. Other sources contributing to measured CO levels are building heating, commercial and industrial operations, and smoke from wildfires.

Monitoring Results

Figures S10 and 32 illustrate the results of CO monitoring in 2021 for stations with sufficient data completeness. Figure 32 displays the maximum 1-hour and 8-hour average as well as the annual average for each CO monitoring location. The same results are represented on maps in Figures 33, 34, and 35.

Measured carbon monoxide levels were well below Metro Vancouver's objectives at all stations throughout the LFV. Typically, the highest concentrations occur in the west where highly urbanized areas experience large volumes of traffic.

Average levels remained low throughout the LFV with the lowest readings recorded at stations away from heavily trafficked areas.

With the majority of CO released from cars, trucks, buses, and non-road engines, significant improvements have occurred in the last two decades due to improved vehicle emission standards and vehicle emissions testing.

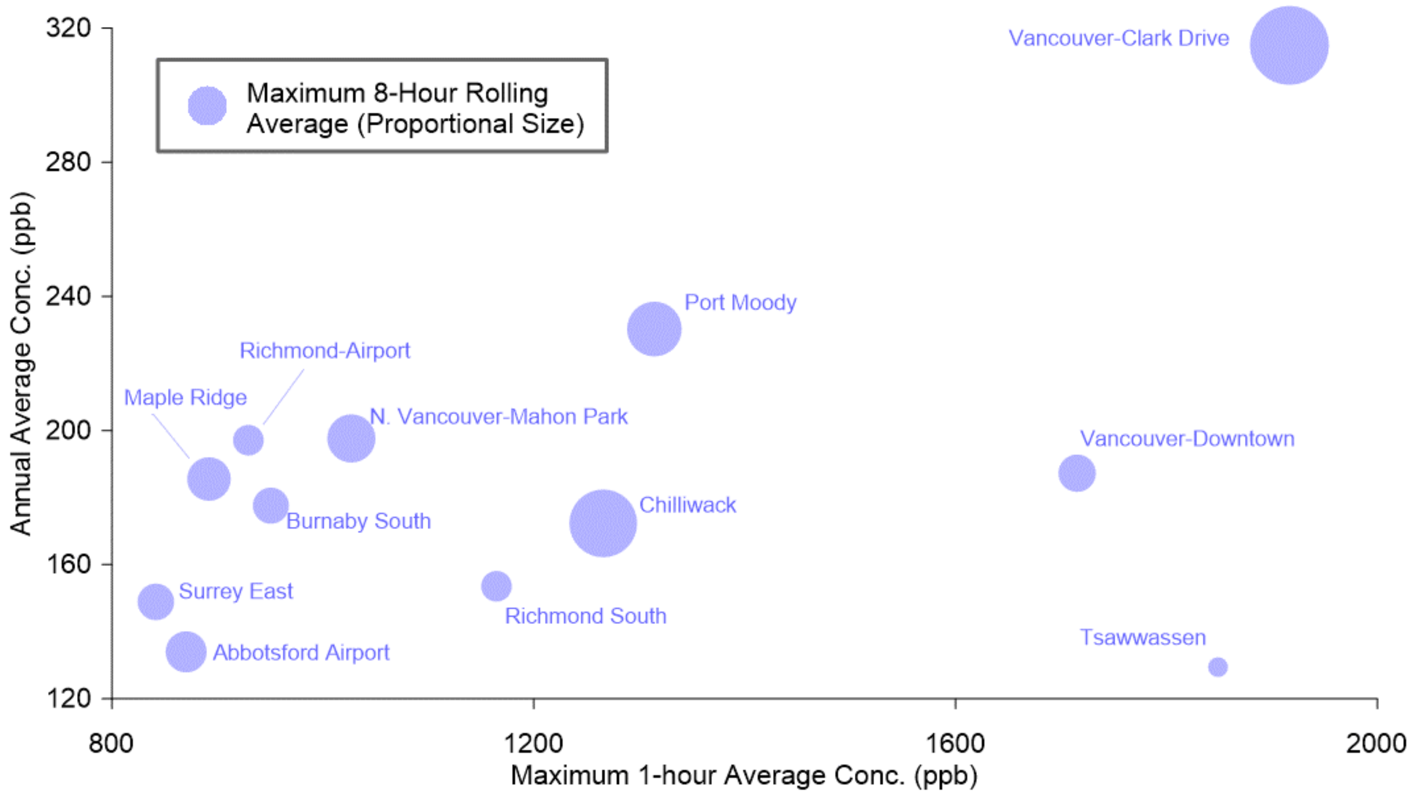
The seasonal trends for CO in 2021 are plotted as monthly average and maximum 1-hour concentrations in Figure 36. Typically average CO concentrations are higher in the winter compared with the summer, however the influence of wildfire smoke in August is evident in the monthly 1-hour maximum (right).

Figure 37 illustrates the long-term average and peak CO trends in the LFV. Some year-to-year variation is evident in the peak trends, however long-term changes in air quality are mainly attributed to changes in emissions, and wildfire smoke in recent years. Improvements in both the average and the short-term peak concentrations (99^{th} percentile of the 1-hour values) appear to be leveling off in recent years.

In the LFV average levels have decreased dramatically since the early nineties. Declining CO concentrations are largely due to improved vehicle emission standards and the AirCare program, which was operated in BC from 1992 to 2014.

A series of diurnal plots are shown in Figure 38 for each station that monitors CO. Most stations exhibit higher winter concentrations on weekdays compared with weekends, with many stations showing a large peak in the morning that corresponds relatively well with morning traffic patterns.

Stations that appear to be strongly influenced by CO emission sources such as traffic include Vancouver-Clark Drive where a well-defined peak is evident in the mornings on weekdays during the winter.



Notes: Air contaminant levels shown here are well below (i.e., better than) air quality objectives

Figure 32: Carbon monoxide monitoring, 2021

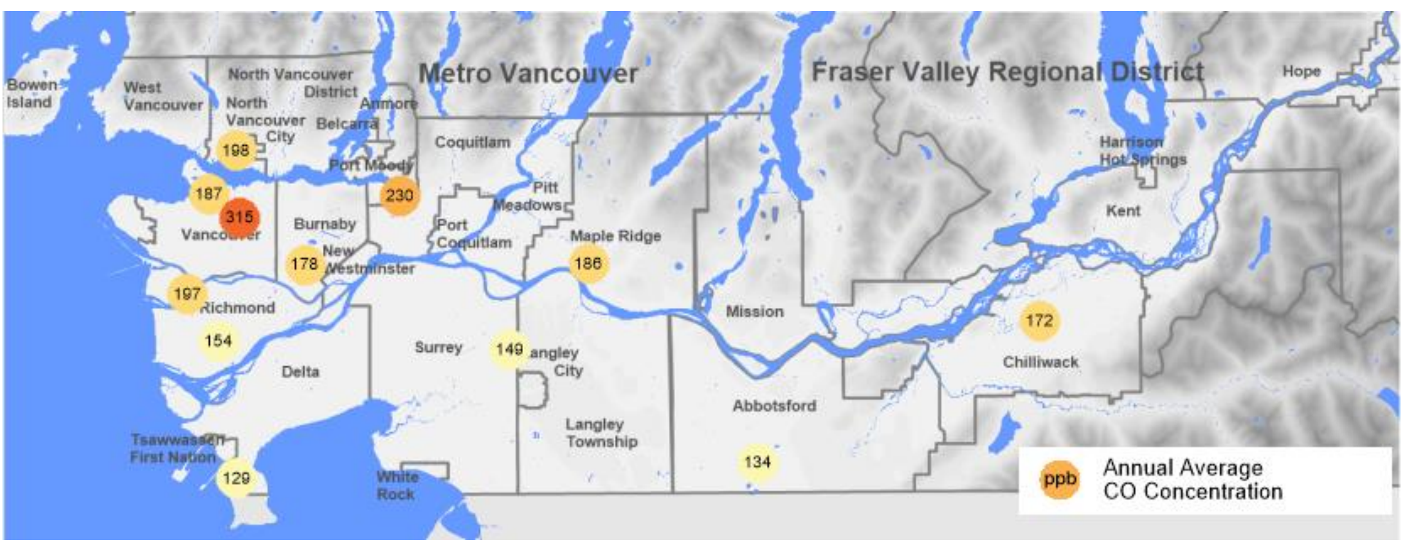


Figure 33: Annual average carbon monoxide in the LFV, 2021

Figure 34: Short-term peak (1-hour) carbon monoxide in the LFV, 2021

Figure 35: Short-term peak (8-hour) carbon monoxide in the LFV, 2021

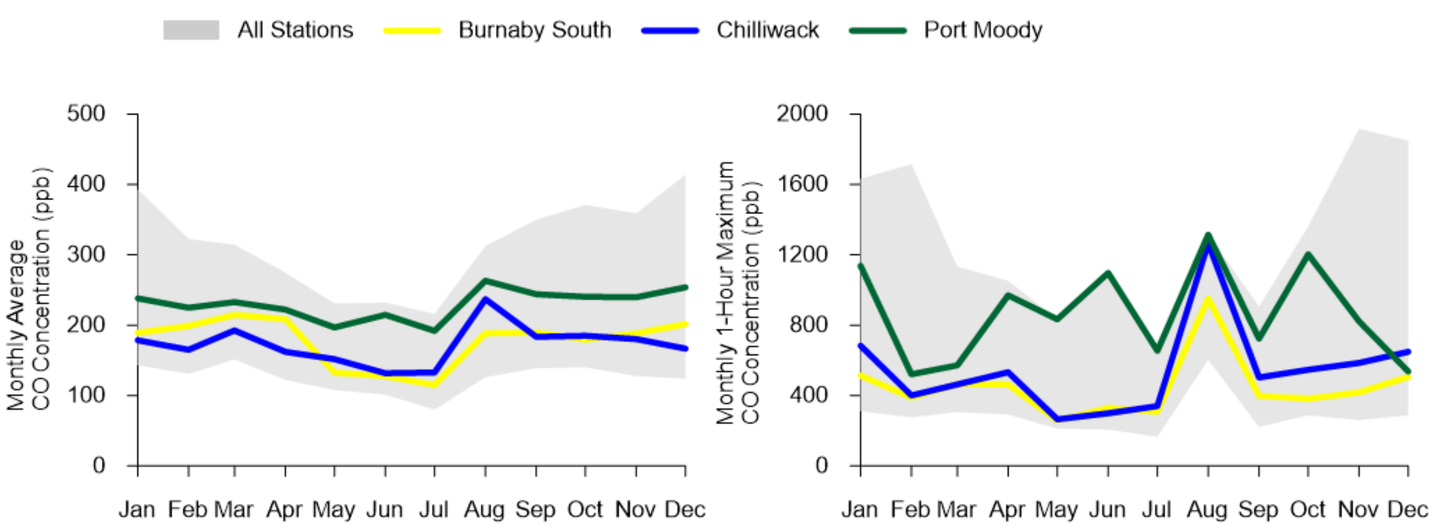


Figure 36: Monthly average (left) and short term peak (right) carbon monoxide, 2021

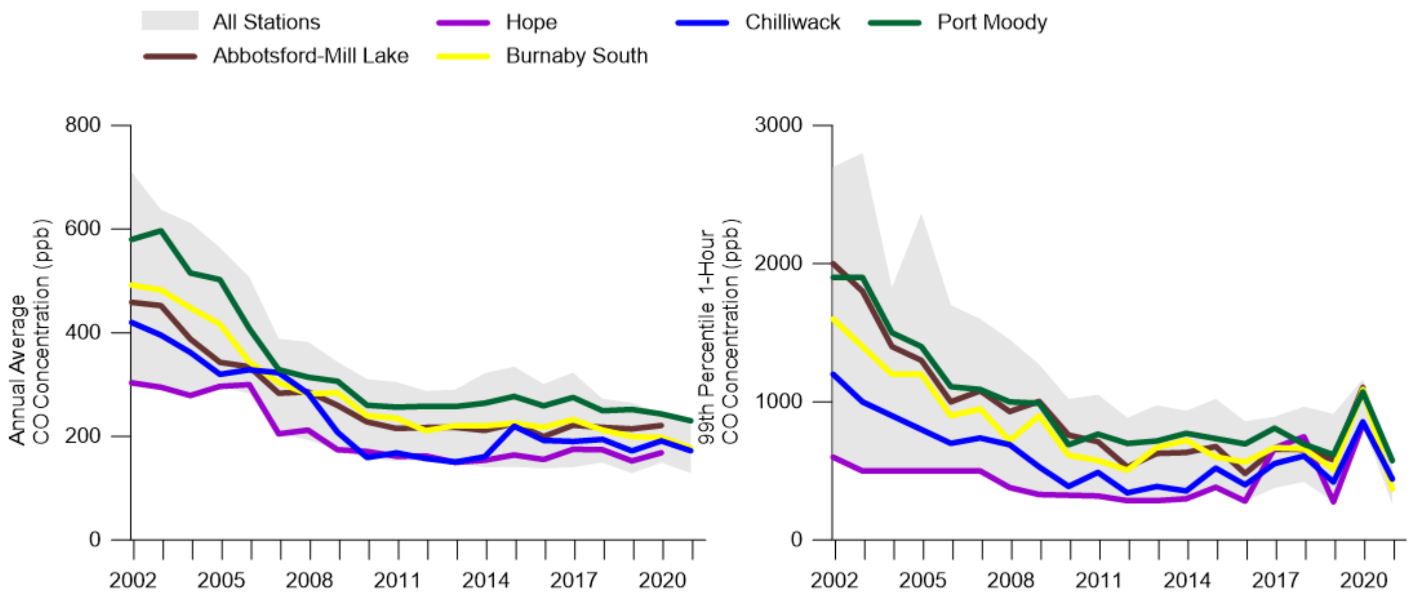


Figure 37: Annual (left) and short term peak (right) carbon monoxide trend, 2002 to 2021

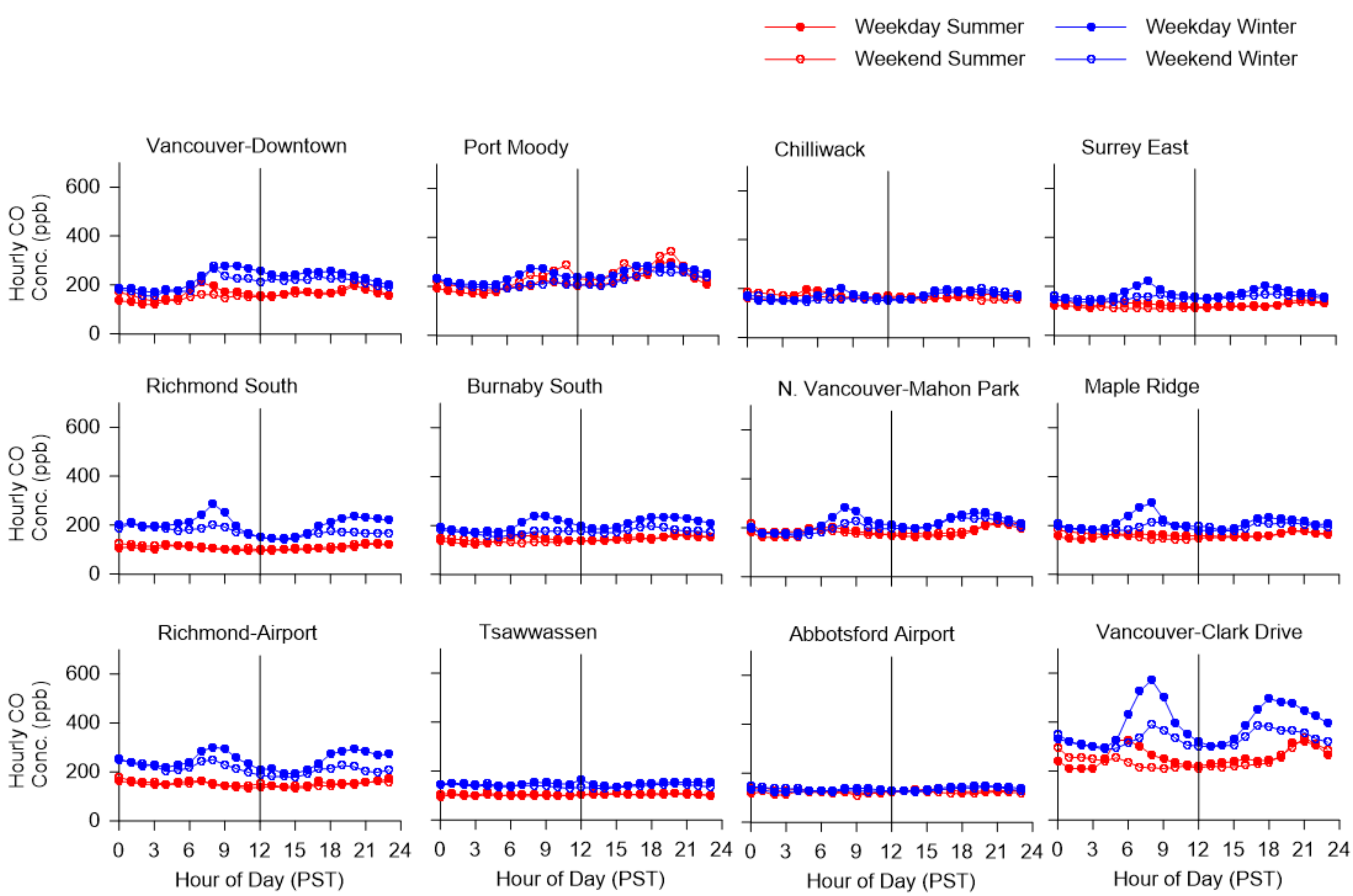


Figure 38: Diurnal trends carbon monoxide, 2021

Inhalable Particulate (PM_{10})

Characteristics

The term 'PM_{10}' refers to airborne particles with a diameter of 10 micrometres (μm) or less. These particles are also known as inhalable particulate matter which, given their small size, can be inhaled and deposited in the lungs. Given the larger size, PM_{10} also includes $PM_{2.5}$ (see the Fine Particulate $PM_{2.5}$ section).

Exposure to PM_{10} can lead to both chronic and acute human health impacts, particularly pulmonary function. Inhalable particulate can aggravate existing pulmonary and cardiovascular disease, increase symptoms in asthmatics and increase mortality. High PM_{10} levels can also increase corrosion and soiling of materials, and may damage vegetation. The smaller particles also contribute to degraded visual air quality.

Sources

Inhalable particulate is emitted from a variety of sources with the largest contribution from construction and demolition activities (23%) followed by residential wood burning (21%). Other major contributors to PM_{10} are industrial sources, and non-road engines and equipment. There are also natural sources of PM_{10} such as wind-blown soil, wildfires, ocean spray, and volcanic activity.

Monitoring Results

Figures 39 and 40 illustrates the PM_{10} monitoring in 2021, while Figures 41 and 42 shows the same values spatially. Annual averages ranged from 8 to 14 $\mu g/m^3$, which are all below Metro Vancouver's annual PM_{10} objective.

Widespread exceedances of Metro Vancouver's 24-hour PM_{10} objective were experienced in 2021. The Metro Vancouver 24-hour objective was exceeded on August 1, 2 and 3 at Hope, August 3 at Abbotsford-Airport, August 12 at Chilliwack, Abbotsford-Mill Lake, Hope and Abbotsford-Airport, August 13 and 14 at all PM_{10} monitoring stations, August 15 at about half the stations and September 3 at Abbotsford-Airport. Exceedances in August were due to wildfire smoke from fires burning mainly in BC and Washington state.

Improvements in PM_{10} concentrations have occurred in the last two decades, however exceedances were measured in 2021 due to wildfire smoke.

Table 9 gives the frequency distribution of PM_{10} concentrations for the year. It can be seen that Abbotsford-Airport, Chilliwack, and Hope experienced the greatest frequency of elevated PM_{10} concentrations.

The seasonal trend of monthly average PM_{10} was similar to previous wildfire years, with the highest concentrations occurring during hot and dry periods of the summer (Figure 43). The highest average and peak level concentrations were experienced in the month of August. These trends were a result of wildfire smoke impacts to the region.

The long-term PM_{10} trends (2002 to 2021) are shown in Figure 44 with the annual average trend provided on the left and the short-term peak trend is on the right. The annual average PM_{10} trend shows a general improvement in the last 20 years. The peak trend, represented by the 99th percentile of the 24-hour rolling average shows a trend of degradation in the most recent years where widespread wildfire impacts have been experienced in 2015, 2017, 2018, 2020, and 2021. The 2005 peak was the result of a large fire in Burns Bog in Delta.

A series of diurnal plots are shown in Figure 45 for each PM_{10} monitoring station. The plots show the differences between weekdays and weekends along with differences between summer and winter.

Historically most stations exhibit higher concentrations on weekdays than weekends, likely the result of greater traffic volumes (road dust) and work related activities (outdoor burning, agricultural activities, industrial processes, etc.).

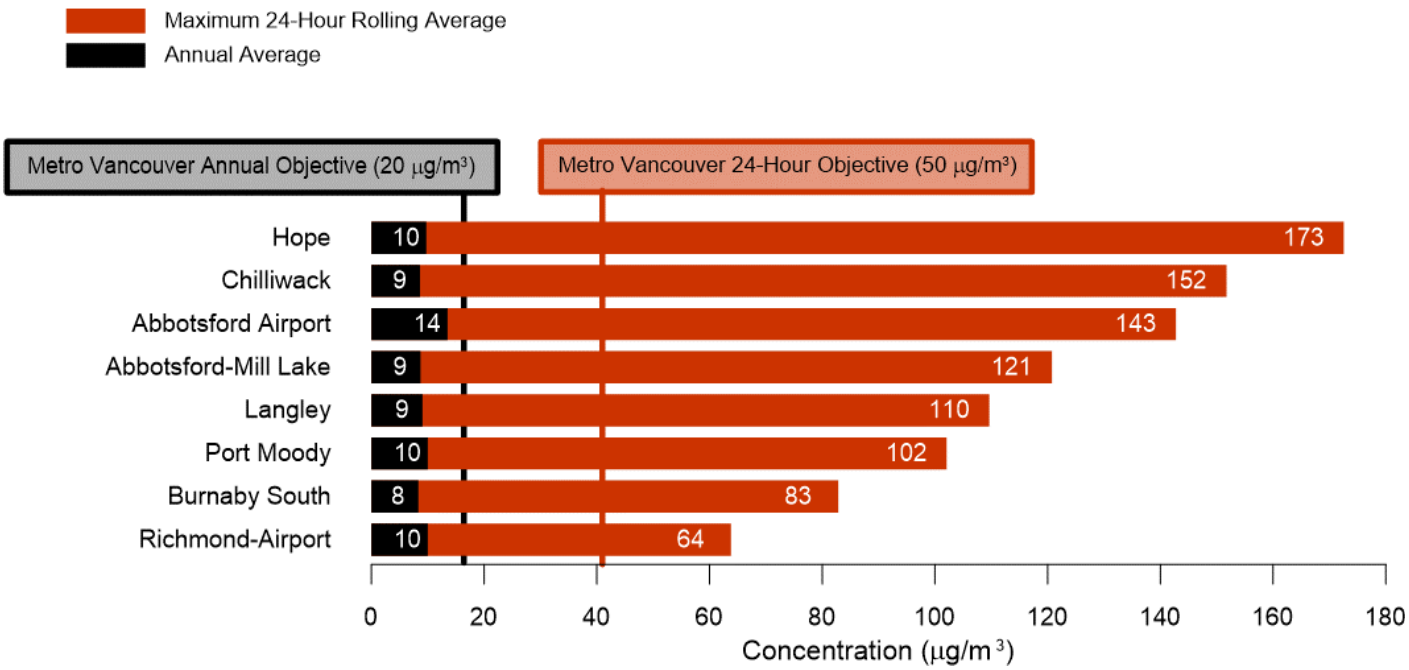
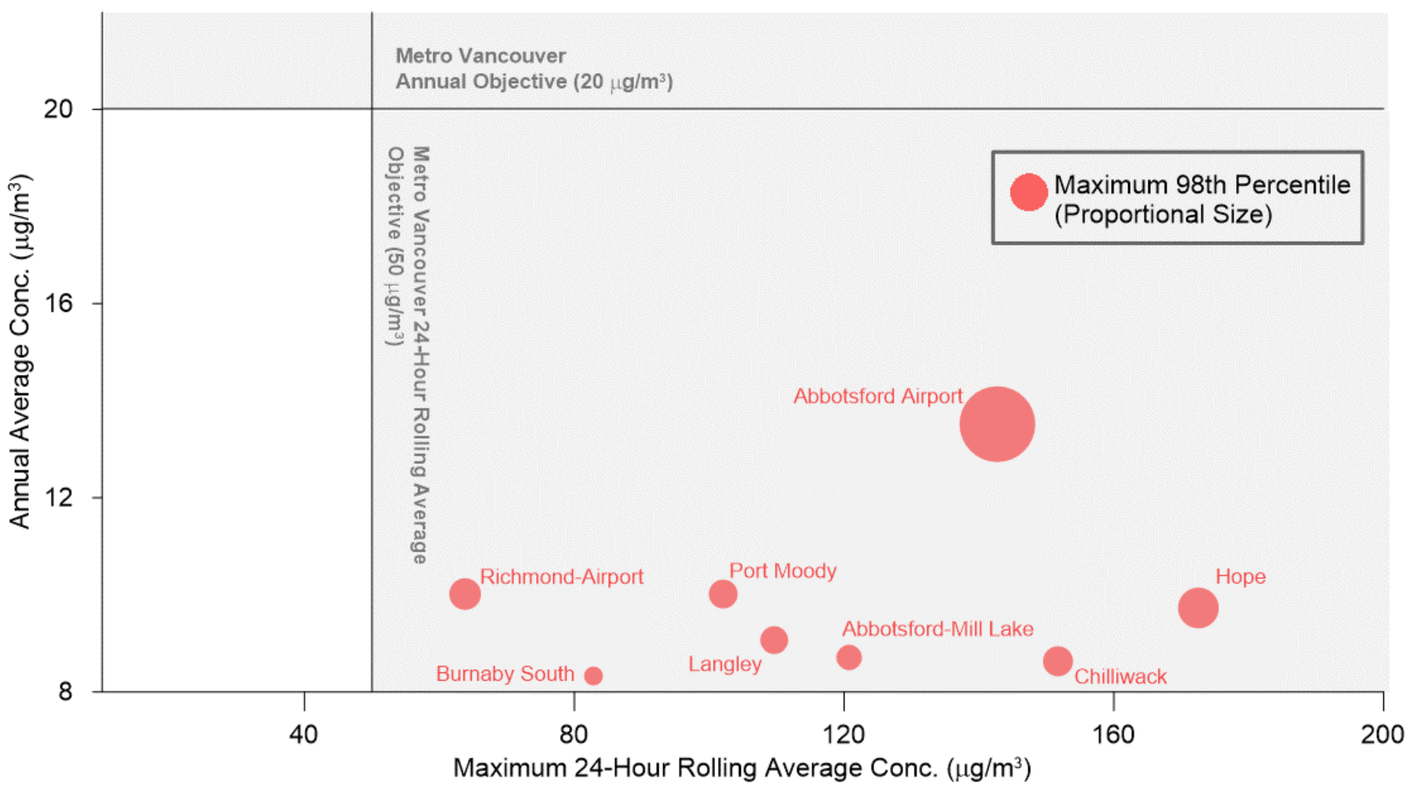


Figure 39: Inhalable particulate (PM_{10}) monitoring, 2021



Note: Stations contained within the grey area denote an exceedance of an objective

Figure 40: Inhalable particulate (PM_{10}) monitoring, 2021

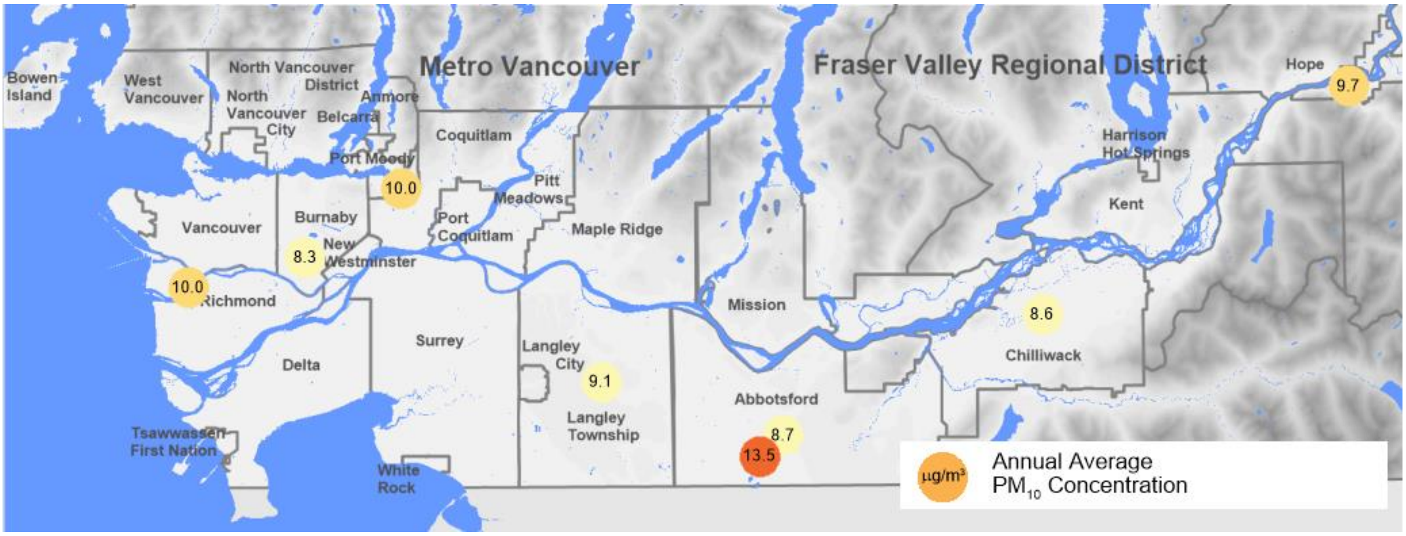


Figure 41: Annual average inhalable particulate (PM_{10}) in the LFV, 2021

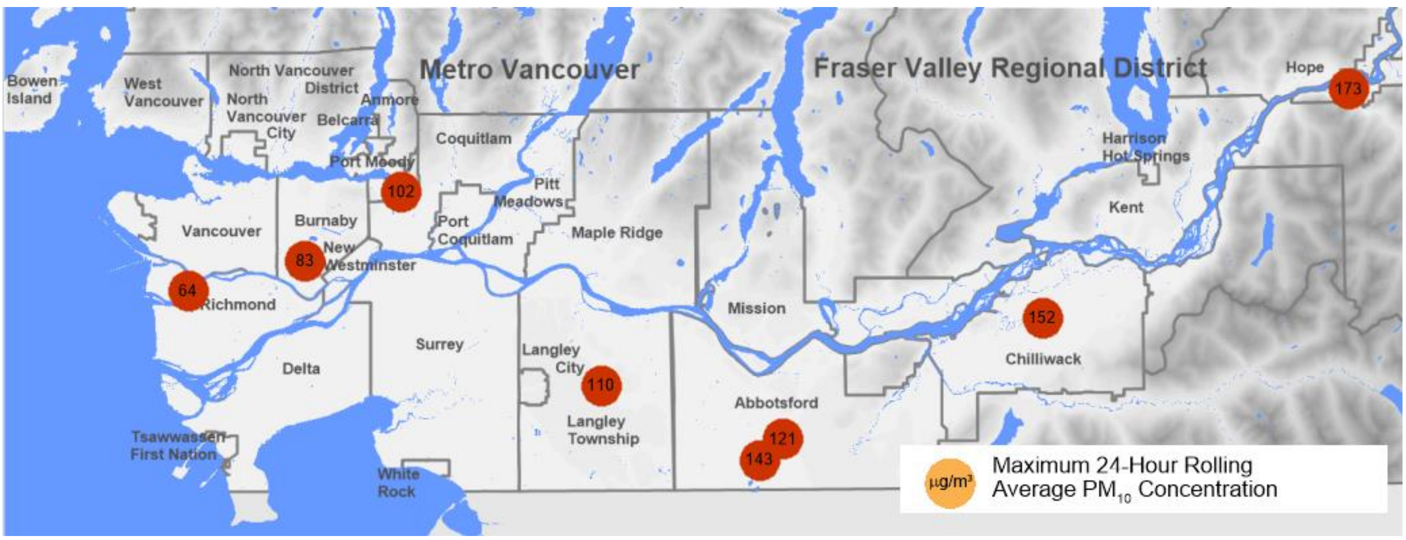


Figure 42: Short-term peak inhalable particulate (PM_{10}) in the LFV, 2021

Table 9: Frequency distribution of 24-hour rolling average inhalable particulate (PM_{10}), 2021

PM_{10} Conc. ($\mu g/m^3$)	Burnaby-Kensington Park	Port Moody	Chilliwack	Burnaby South	Burnaby North	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Abbotsford Airport
0 to <12	2642	5842	7589	7245	3890	7030	6964	6597	7457	4765
12 to <24	542	2206	1020	781	2367	1293	1327	1995	1163	2657
24 to <36		40	67	42	210	88	116	65	40	721
36 to <48		6	7	6	7	12	25	7	9	64
48 to <60		7	6	6	5	7	26	11	8	13
60 to <72		5	4	6	5	6	21	10	10	5
72 to <84		7	5	14	5	8	5		11	6
84 to <96		7	4		4	5	4		5	4
96 to <108		7	4		6	9	3		10	14
108 to <120			5		9	4	5		9	14
120 to <132			8		2		4		2	10
132 to <144			11				5			9
144 to <156			13				9			
156 to <168							9			
>=168							11			
Missing Data	5576	633	17	660	2250	298	226	75	36	478
Completeness	36%	93%	100%	93%	74%	97%	97%	99%	100%	95%

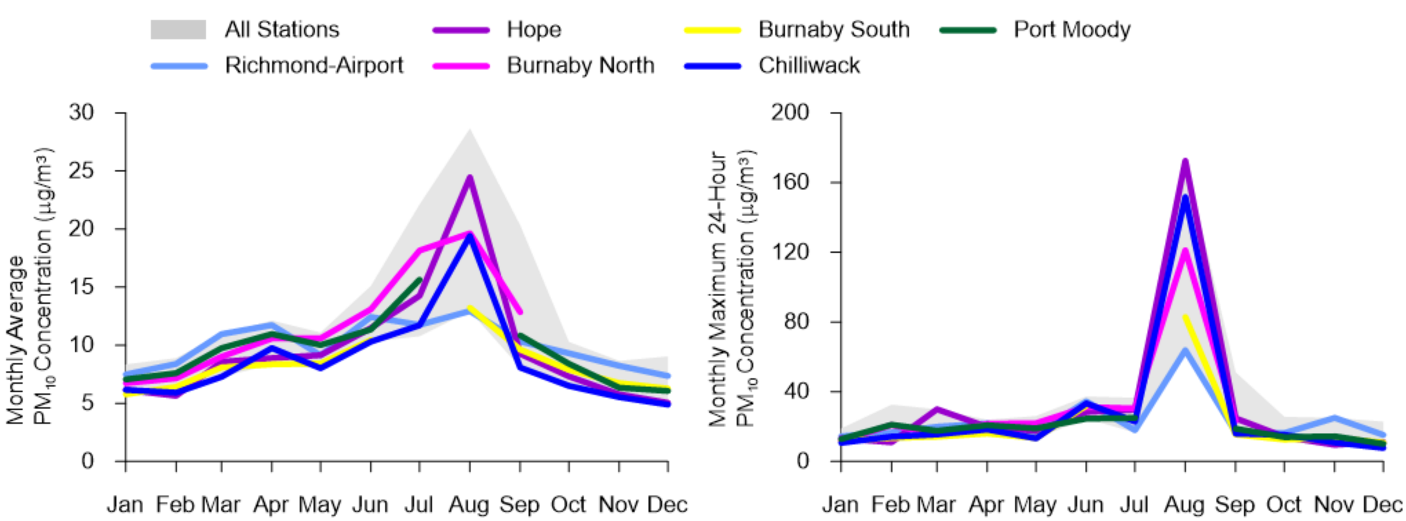


Figure 43: Monthly average (left) and short term peak (right) inhalable particulate (PM_{10}), 2021

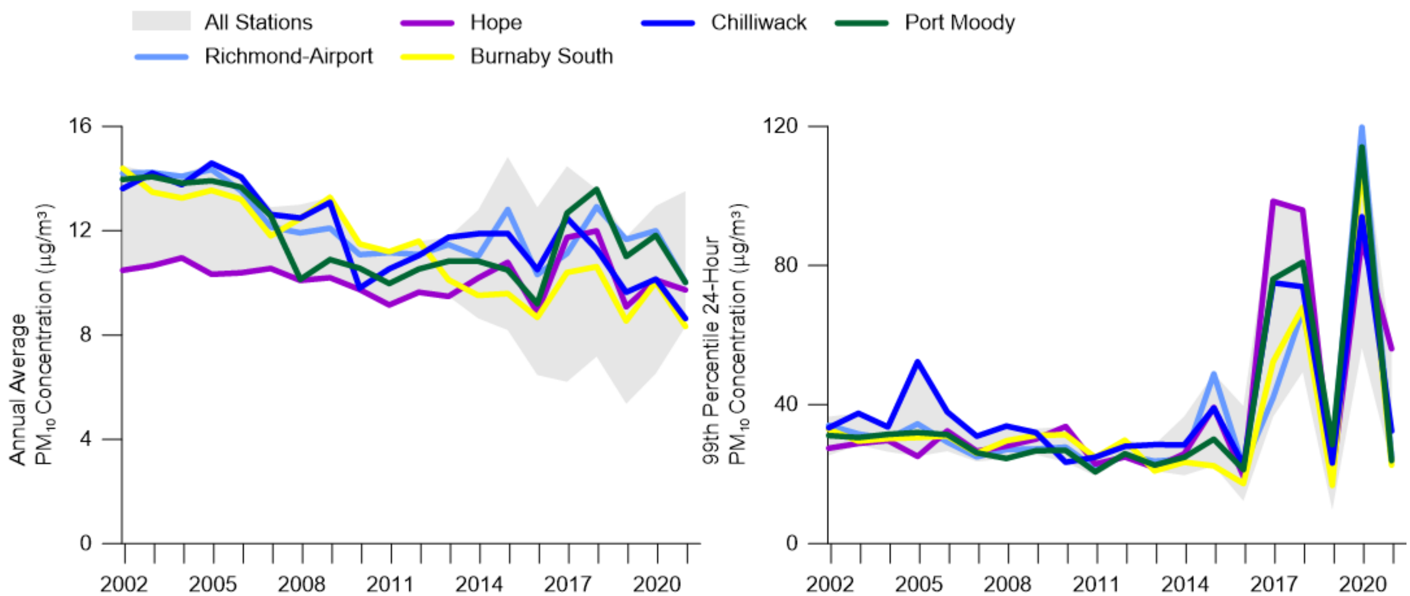


Figure 44: Annual average (left) and short term peak (right) inhalable particulate (PM_{10}) trend, 2002 to 2021

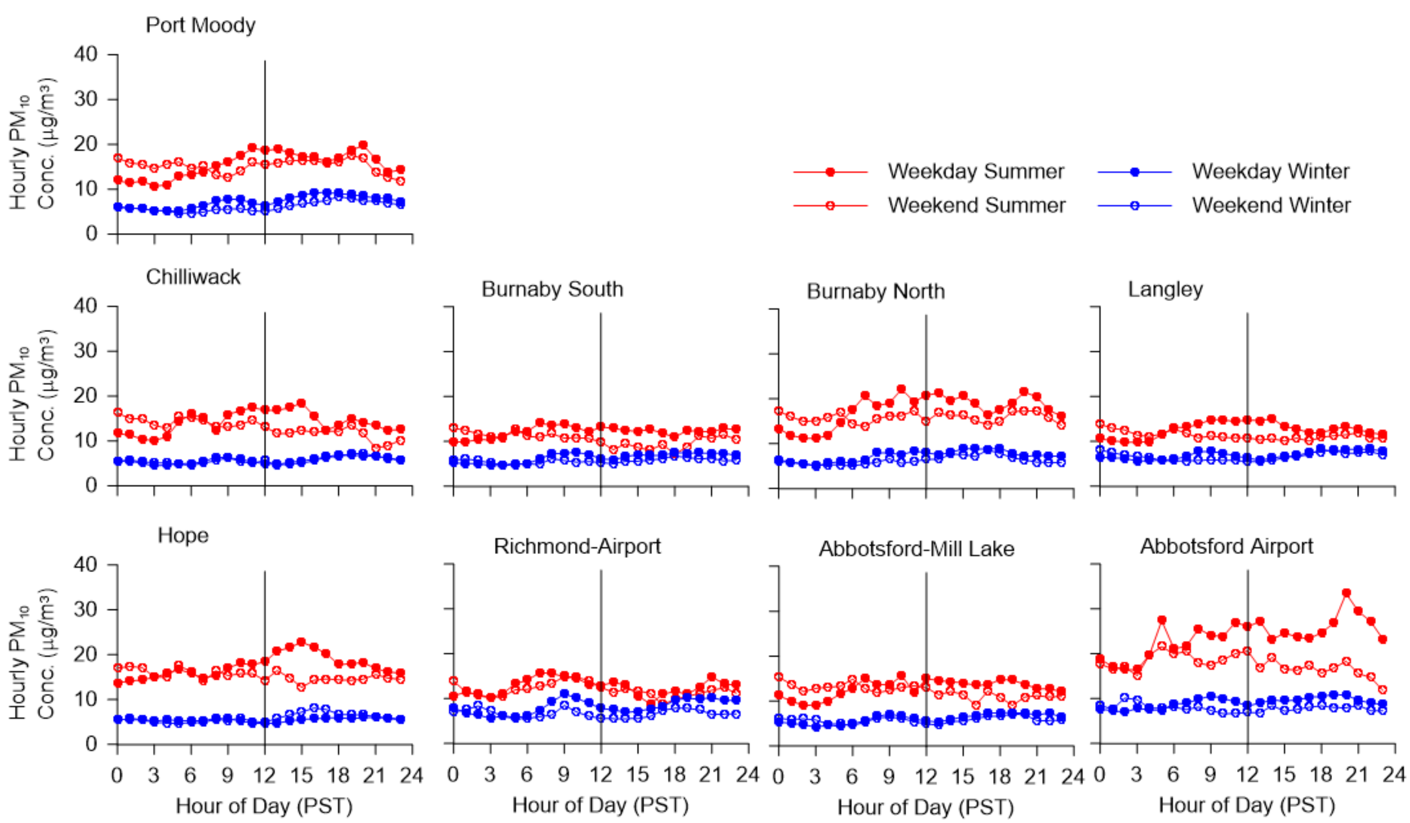


Figure 45: Diurnal trends inhalable particulate (PM_{10}), 2021

Black Carbon (BC)

Characteristics

Black carbon (BC) is carbonaceous material formed by the incomplete combustion of fossil fuels, biofuels, and biomass, and is emitted directly in the form of fine particles ($PM_{2.5}$). Locally, approximately 12% of $PM_{2.5}$ is BC. BC is a major component of “soot”, a complex light-absorbing mixture that also contains some organic carbon.

The terms black carbon and soot are sometimes used interchangeably. Although BC has a very short residence time in the atmosphere (about a week), it is a strong absorber of solar radiation and can absorb much more energy than carbon dioxide (CO_2). As a result, BC is considered a “short-lived climate forcer”. Black carbon contributes to the adverse impacts on human health, ecosystems, and visibility associated with fine particulate matter ($PM_{2.5}$).

Sources

Mobile sources are the largest contributors of BC emissions in the LFV, emitting over 80% of the BC emissions in the region. Non-road engines (primarily diesel fuelled), heavy duty vehicles, rail, and marine vessels are significant sources of BC emissions. Other significant sources in the region are biomass burning activities, including agricultural burning, open and prescribed burning, wildfires and residential heating.

Monitoring Results

Figures 46 and 47 illustrates the results of continuous BC monitoring for 2021. Figure 46 displays the value of the maximum 1-hour and 24-hour average as well as the annual average for each station with the same information shown in a bubble plot in Figure 47.

There are no provincial, federal or Metro Vancouver objectives for black carbon. The highest 1-hour average BC concentration occurred at North Vancouver-Second Narrows.

In Figure 48 the seasonal trends for BC shows average values higher in June and August with the highest peak level occurring in June.

Black carbon is generally greater on weekdays compared with weekends, shown in Figure 49. This trend is especially evident at the Vancouver-Clark Drive station where greater amounts of BC are measured in the winter and on weekdays compared with weekends.

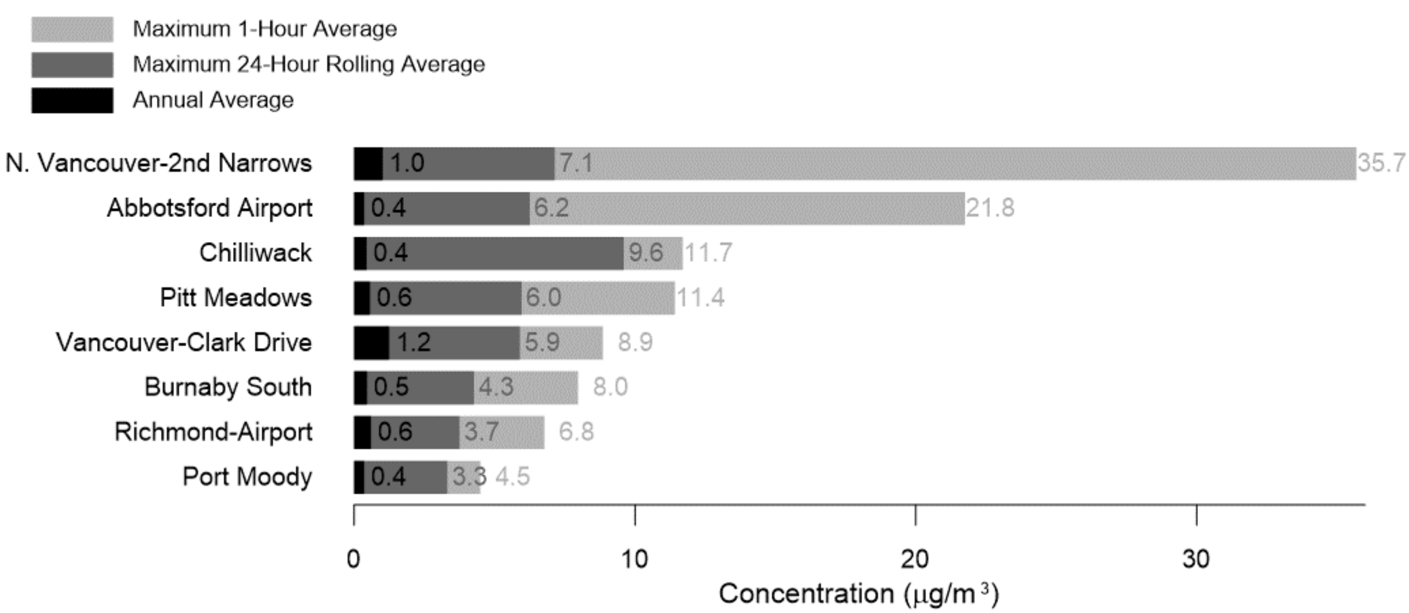


Figure 46: Black carbon monitoring, 2021

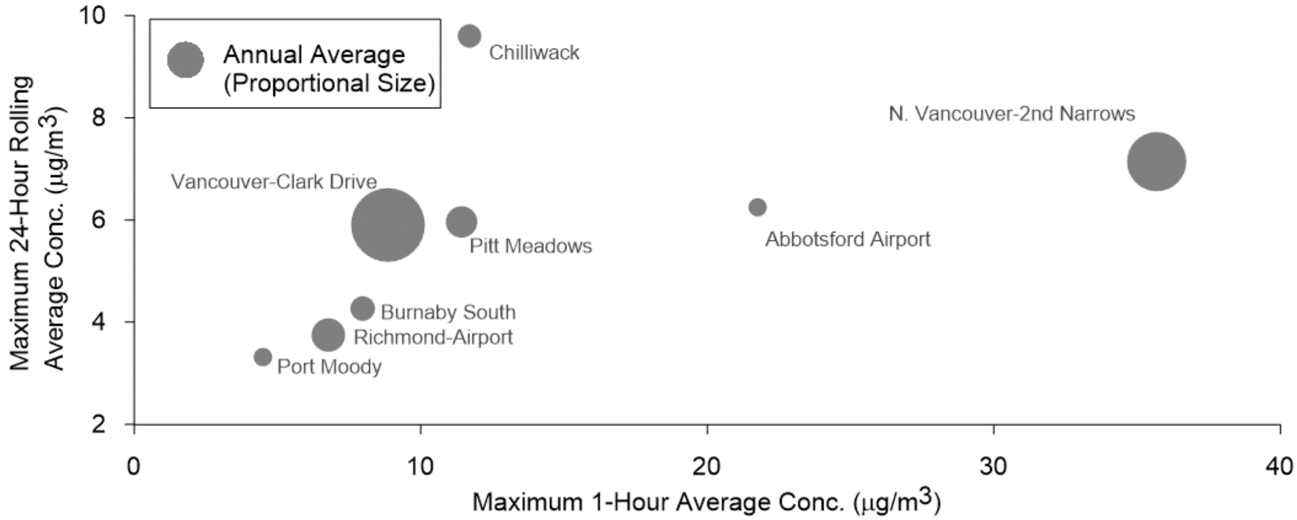


Figure 47: Black carbon monitoring, 2021

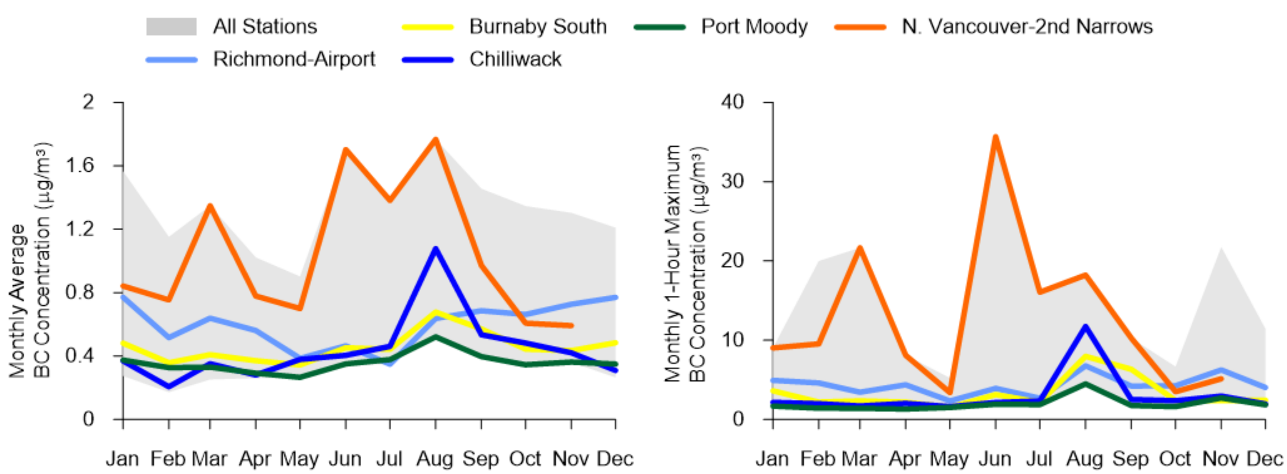


Figure 48: Monthly average (left) and short term peak (right) black carbon, 2021

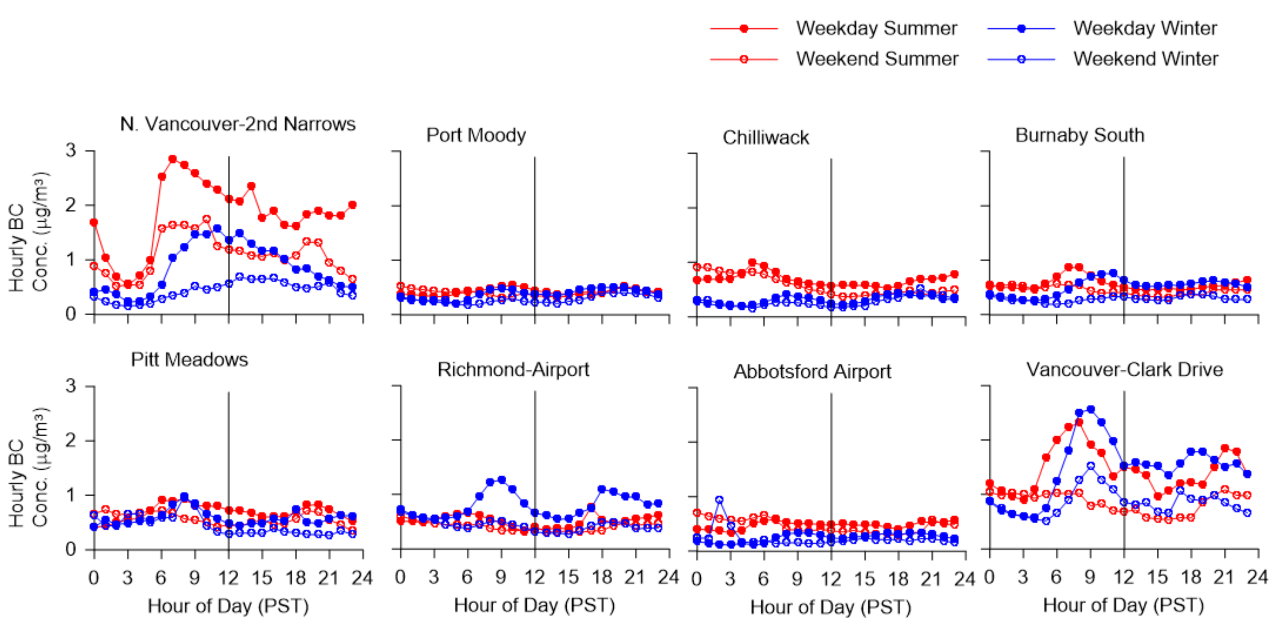


Figure 49: Diurnal trends black carbon, 2021

Ultrafine Particles (UFP)

Characteristics

Ultrafine particles (UFP) consist of a combination of suspended solids and liquid droplets having aerodynamic diameters less than 0.1 microns (100 nanometers). These particles are measured based on their numbers (units of 10^3 #/cm^3) in the atmosphere rather than fine particulate matter that is measured based on its mass ($\mu g/m^3$).

Ultrafine particles are relatively short-lived, as compared to longer-lived $PM_{2.5}$ particles, which may persist in the atmosphere for up to several weeks. The short lifetime for UFP results from their very high number concentrations upon emission. Levels may peak near strong UFP sources such as busy freeways. These exceptionally concentrated UFP rapidly agglomerate (stick together) with each other and with larger particles (e.g. $PM_{2.5}$) to yield particles with diameters larger than 0.1 microns. Agglomeration, dispersion, and advection are the dominant atmospheric processes determining the UFP spatial distribution. Deposition (settling onto surfaces) plays a minor role in the UFP spatial distribution because gravity does not have a strong influence on UFP. Typically, the UFP level decreases exponentially to reduced levels within 500 metres of a strong source.

Sources

There are several sources of UFP, including manufacturing, combustion sources, and nucleation events. It is generally recognized that smaller particles are more harmful to human health. Unlike larger particles, UFP can penetrate pulmonary tissue, enter the bloodstream, and circulate throughout the body. Thereby, UFP can damage a number of internal systems that may be inaccessible to larger particles.

Monitoring Results

Ultrafine particle monitoring has not been conducted in the region prior to a near-road air quality monitoring study. The results from the near-road monitoring study are the first collected in the Metro Vancouver region due to availability of new monitoring technology and interest in these particles from a health perspective (Metro Vancouver, 2020).

Figure 50 illustrates the results of continuous UFP monitoring for 2021. The figure displays the value of the maximum 1-hour and annual average for the single UFP station. There are currently no federal, provincial or regional air quality objectives for UFP.

In Figure 51 the seasonal trend is provided for UFP, however due to data completeness a trend is unclear. Past years have shown average values higher in the winter months with lowest peak and averages summer.

Ultrafine particles are generally greater on weekdays compared with weekends, shown in Figure 52. The winter weekday trend is the most prominent with a peak count of ultrafine particles in the morning corresponding with traffic.

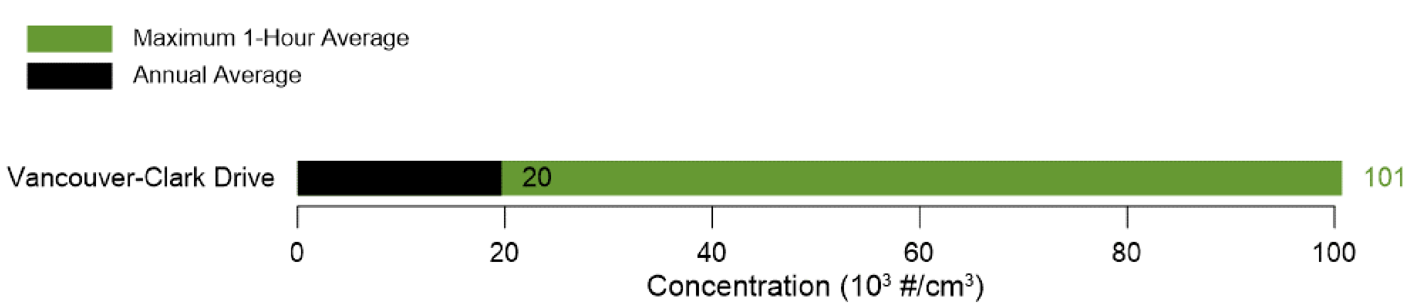


Figure 50: Ultrafine particle monitoring, 2021

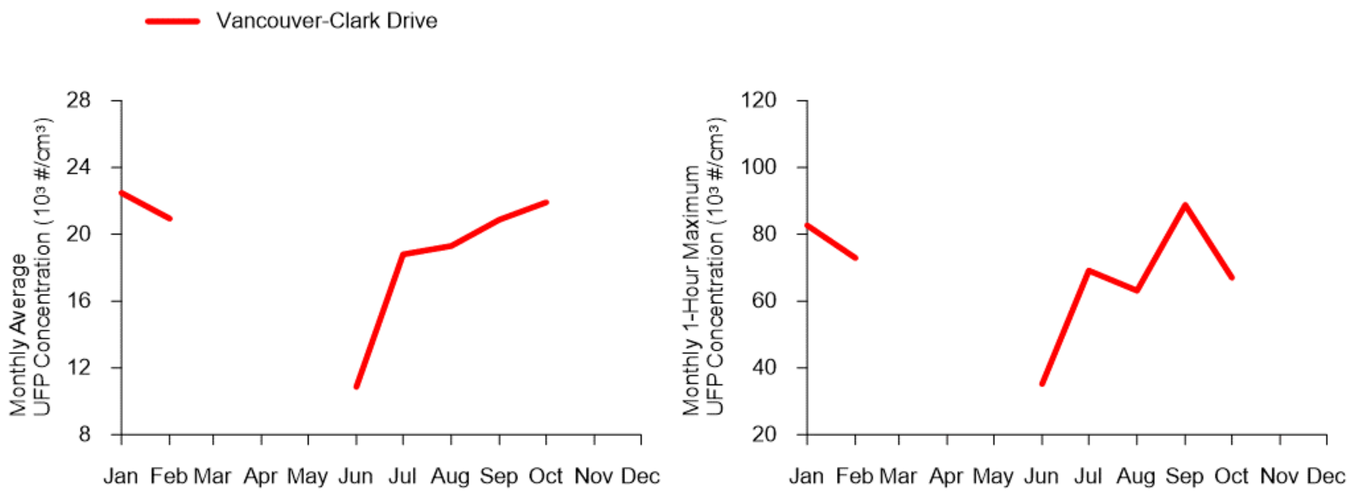


Figure 51: Monthly average (left) and short-term peak (right) ultrafine particles, 2021

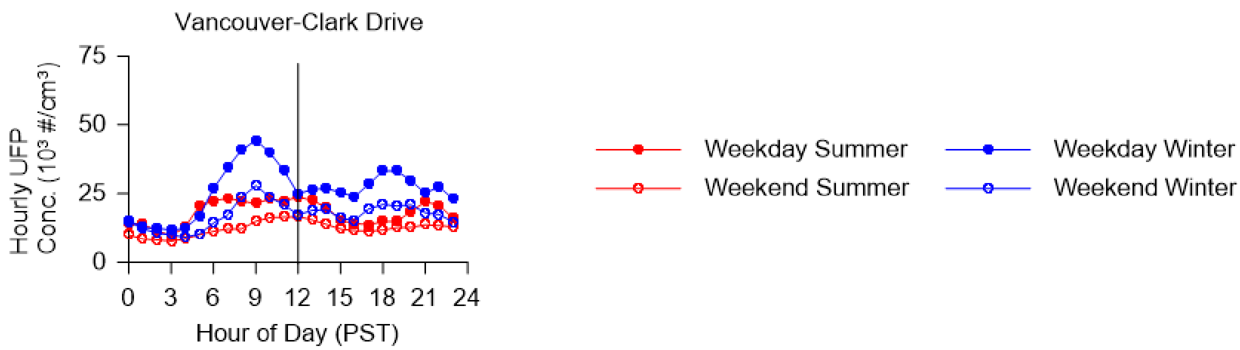


Figure 52: Diurnal trends ultrafine particles, 2021

Total Reduced Sulphur (TRS)

Characteristics

Total reduced sulphur (TRS) compounds are a group of sulphurous compounds that occur naturally in swamps, bogs, and marshes. They are also created by industrial sources such as pulp and paper mills, petroleum refineries, and composting facilities. These compounds have offensive odours similar to rotten eggs or rotten cabbage, and at high concentrations can cause eye irritation and nausea in some people.

Sources

Most public complaints regarding these odours are associated with composting facilities and with the petroleum refining and distribution industry located along Burrard Inlet. A few periodic inquiries also occur as a result of natural emissions from such locations as Burns Bog in Delta.

Monitoring Results

Figure 53 illustrates the TRS measurements in 2021. Average levels continued to be near or below detectable limits. Peak levels during 2021, indicated by the maximum 1-hour concentration, exceeded the Desirable Objective for a total of thirteen hours and the Acceptable Objective for three hours at Port Moody. The occurrences of elevated TRS are of short duration and generally during the night or early morning. The exceedances occurred in January, October, November, and December.

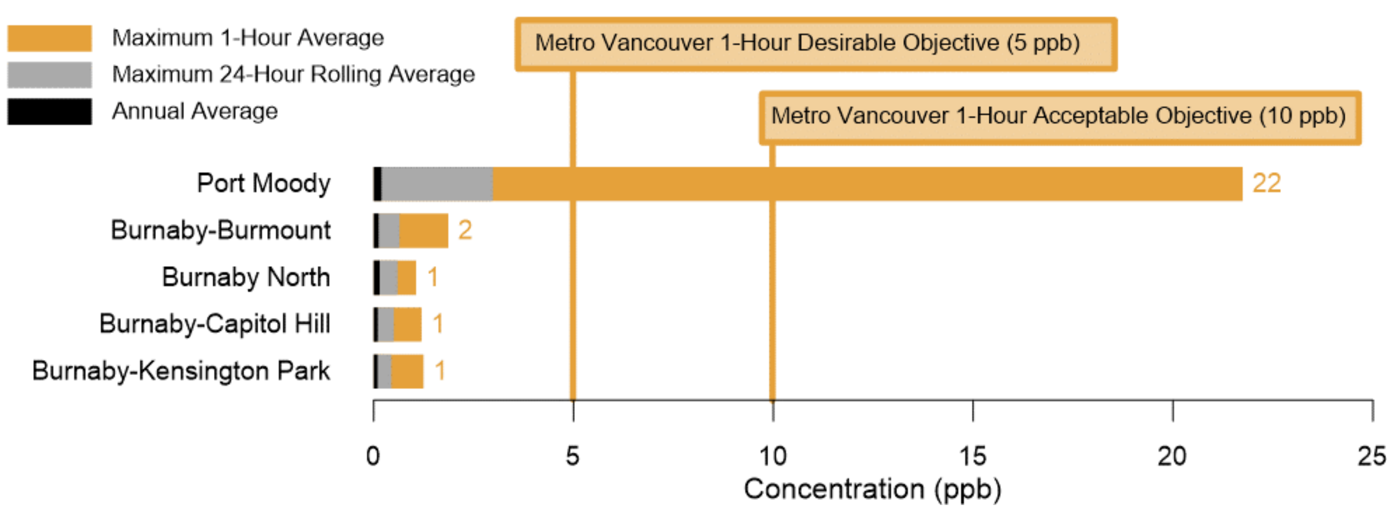


Figure 53: Total reduced sulphur monitoring, 2021

Ammonia (NH_3)

Characteristics

Ammonia (NH_3) can contribute to the formation of fine particles when chemical reactions occur between ammonia and other gases in the atmosphere including sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). The resulting ammonium nitrate and ammonium sulphate particles are efficient at scattering light and can impair visual air quality with a white haze.

Sources

The largest contribution to ammonia in the LFV comes from the agriculture sector. The majority of ammonia emissions come from cattle, pig, and poultry housing, land spreading and storage of manure, and fertilizer application.

Monitoring Results

Continuous measurements of ammonia were made at four sites in the monitoring network in 2021. The 2021 data are presented in Figure 54, shown as the maximum 1-hour average, maximum 24-hour rolling average and annual average ammonia concentrations. There are no applicable objectives for ammonia.

Continuous measurements of ammonia began in 2005. Due to the relatively short period for which data are available, no clear long-term trend in ammonia is evident.

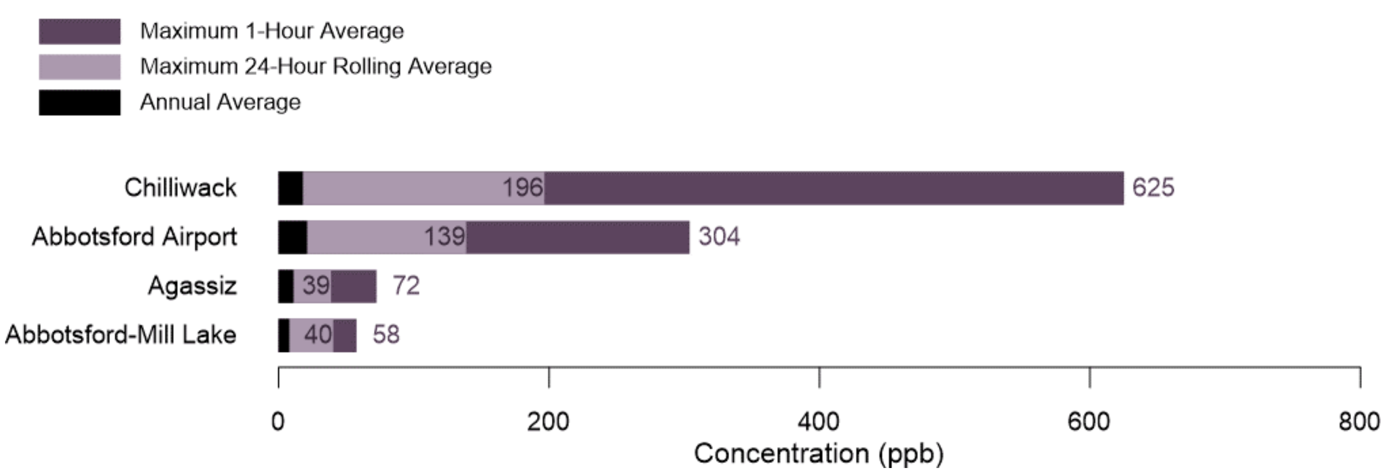


Figure 54: Ammonia monitoring, 2021

Section E – Non-Continuous Pollutant Measurements

Non-continuous samples are collected in accordance with the National Air Pollution Surveillance (NAPS) program. After collection, samples are transported to and analyzed in a federal laboratory in Ottawa to determine pollutant concentrations.

Analysis results of non-continuous (integrated) sampling from the federal laboratory can take considerable time. Therefore, analysis of non-continuous results will be conducted when available and appended to this report.

Particulate Sampling

Non-continuous 24-hour (daily) $PM_{2.5}$ and PM_{10} samples are collected on filters every sixth day depending on the site. Non-continuous particulate samples are collected at a few monitoring stations in the LFV and pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for some of these stations (Port Moody, Burnaby South, Abbotsford Airport, and Vancouver-Clark Drive).

Using specialized PM speciation instrumentation, additional detailed information about the chemical composition of $PM_{2.5}$ is obtained from a subset of stations in the network (Burnaby South, Abbotsford Airport, and Vancouver-Clark Drive) as a result of analyses carried out by the federal NAPS program. From the 24-hour samples collected at these sites, the various compounds that form $PM_{2.5}$ are identified.

Volatile Organic Compounds (VOC)

Volatile Organic Compounds (VOC) refers to a combination of organic chemicals. A large number of chemicals are included in this group but each individual compound is generally present at relatively low concentrations in air compared to other common air contaminants. The gaseous VOC present in the air can originate from direct emissions and from volatilization (*i.e.* changing into the gas phase) of substances in the liquid or solid phase.

Locally, some VOC can be pollutants found in urban smog and are precursors of other contaminants present in smog such as ozone and fine particulates. Some materials in this class (*e.g.* carbon tetrachloride) can contribute to depletion of the stratospheric ozone layer and may contribute to climate change. Other VOC (*e.g.* benzene) can pose a human health risk.

Sources of VOC in Metro Vancouver include, but are not limited to emissions from the combustion of fossil fuels, industrial and residential solvents and paints, vegetation, agricultural activities and cannabis production, petroleum refineries, fuel-refilling facilities, the burning of wood and other vegetative materials, and large industrial facilities.

Under the Canadian Environmental Protection Act some VOC are included in the Toxic Substances List.
Emissions of some VOC are managed under permits and industry-specific regulations within Metro Vancouver.

Non-continuous 24-hour (daily) sampling of VOC is conducted every sixth or twelfth day on a national schedule at several sites in the LFV. In cooperation with the federal National Air Pollution Surveillance (NAPS) program, canister sampling of VOC has been conducted in the LFV since 1988. Canisters sent to the federal laboratory are analyzed for up to 105 VOC. These data can then be used to help determine the emission sources contributing to contaminants in the air.

In addition to the canister sampling, continuous measurements of total hydrocarbons (THC) are made at the Burnaby North and Burnaby-Burmount stations (results not shown). Both of these are adjacent to petroleum industry facilities.

Network history and collaboration with the federal government on non-continuous sampling are provided in Section H.

Section F – Visual Air Quality Monitoring

Characteristics

When light between an object and the eye of an observer is scattered and/or absorbed by particles and gases in the air, views can look hazy or even be fully obscured. The term visual air quality refers to the impacts air contaminants have on our ability to see through the atmosphere, affecting the appearance of views including the distance at which the elements of a scene can be clearly seen. It does not refer to the direct effects of clouds, fog, rain or mist on a view.

Visual air quality studies conducted in the LFV have concluded that the major contributor to visual air quality impairment in the LFV is $PM_{2.5}$ and have shown that visual air quality degradation occurs at relatively low air contaminant concentrations, below Metro Vancouver's ambient air quality objectives for $PM_{2.5}$. However, the effects of visual air quality impairment can have different characteristics in different locations within the airshed due to the air contaminants present.

For example, in more urbanized areas of the western LFV, nitrogen dioxide emitted when fuels are burned contributes to the yellow-brown discolouration of the view. Further east in the LFV, visual air quality impairment usually occurs as white haze due to the presence of $PM_{2.5}$. Sources of particulate matter contributing to visual air quality impairment include anthropogenic activities as well as natural sources such as windblown dust, soil, sea salt, and smoke.

Monitoring Program

To assess visual air quality in the LFV, Metro Vancouver, FVRD, BC Ministry of Environment and Climate Change Strategy (BC ENV), and Environment and Climate Change Canada (ECCC) jointly established a visual air quality monitoring network and reporting metrics. Continuous measurements of light scattering and the species responsible for light absorption are complemented by particulate speciation sampling, meteorological measurements and images of views along specific lines-of-sight. Images are captured at 10- or 30-minute intervals along specific lines-of-sight with recognizable topographical features at defined distances. Measurements of views or both views and air contaminants are typically made at the monitoring locations identified in Figure 55.

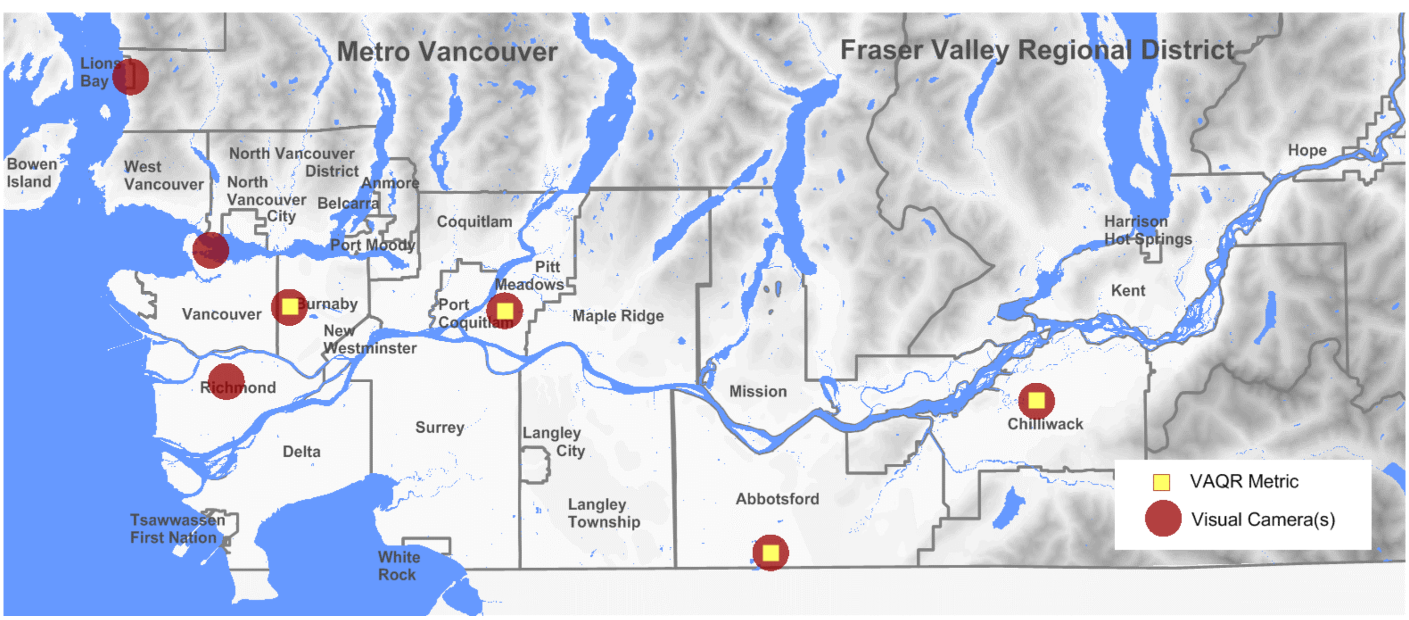


Figure 55: Visual air quality monitoring locations in the LFV, 2021

Light scattering measurements are made using nephelometers for visual air quality analysis at some of the locations. Aethalometers and nitrogen dioxide analyzers are also located at these sites and are used to characterize light absorption. Analysis of monitoring data to reconstruct light extinction has indicated that scattering by particles generally has the most influence on visual air quality in the LFV. Modelling work has determined that the highest contributions to extinction, and consequently visual air quality degradation, in the LFV on the most impaired visual air quality days are generally from particulate nitrate and organic matter. However, observations have shown that intense wildfire smoke can also cause severe impairment. The extent of the influence of other species, such as particulate sulphate, on visual air quality degradation is dependent on meteorological conditions.

Visual Air Quality Pilot Project

A visual air quality pilot project was established in the LFV by the BC Visibility Coordinating Committee (BCVCC). The BCVCC was established in 2006 and is a collaborative venture between Metro Vancouver, FVRD, ECCC, Health Canada, and BC ENV. An objective of the pilot project is to determine the actions necessary to protect and improve visual air quality in the LFV.

Key components of the pilot project include:

- The establishment and ongoing operation of a visual air quality monitoring network;
- The development of a visual air quality reporting tool and recommendations for a visual air quality goal;
- The identification of the causes and impacts of impaired visual air quality in the LFV;
- An improvement of our understanding of the economic drivers for visual air quality management; and
- The creation of a strategy to engage and inform stakeholders and members of the public about visual air quality issues.

Visual Air Quality Rating

The visual air quality rating (VAQR), with descriptors of excellent, good, fair, poor or very poor, is the reporting metric developed by the BCVCC, to enhance outreach about visual air quality in the LFV and to provide mechanisms to track changes in visual air quality. The VAQR was launched in 2015 and was reported at sites shown in Figure 55.

The VAQR reflects residents' perceptions of visual air quality conditions. Historical images from visual air quality monitoring network cameras were used to survey residents in Metro Vancouver and FVRD to relate perceived visual air quality to measured air contaminant concentrations and the estimated resulting optical characteristics of the atmosphere along the lines-of-sight to the views. Example visual air quality ratings and associated images at the Chilliwack site are shown in Figure 56.

Images from the visual air quality monitoring cameras can be viewed at: http://www.clearairbc.ca/community.

Figure 56: Example images and visual air quality ratings at the Chilliwack site

Section G – Meteorological Measurements

Purpose

An understanding of meteorology is integral to understanding and forecasting air quality and visual air quality patterns. The state of the atmosphere determines pollutant dispersion and the resultant ground-level concentration. Meteorology is observed at LFV air quality monitoring network stations for several purposes:

- To allow for a characterization of meteorological patterns throughout the LFV.
- To assist with the linkage between pollutant emission sources and ambient concentrations.
- To provide data to be used as input in dispersion modelling.
- To provide real-time data to numerous agencies including Environment Canada, which are used for weather and air quality forecasting in the region.

It should be noted that the LFV network's primary purpose is for the collection of air quality measurements and secondary purpose is for meteorological observation. Attempts have been made to site meteorological instruments to provide representative observation, however due to restrictions at some stations, not all instruments are sited to capture spatially representative measurements.

Monitoring Program

Various meteorological parameters are observed as part of the LFV air quality monitoring network (see Section C Table 2).

Meteorological parameters observed in the network include:

- wind speed and direction
- air temperature
- relative humidity
- precipitation
- barometric pressure
- incoming solar radiation
- net radiation

Wind speed and direction observations allow for the characterization of pollutant transport and dispersion and are used to understand the relationships between pollutant sources and measurements at air quality monitoring stations.

Air temperature and incoming solar radiation measurements can be used to determine the potential for ozone formation during the summer. Ozone concentrations are dependent on sunshine to cause photochemical reactions among air pollutants. Higher air temperatures are necessary for these reactions to occur.

Humidity is important in the formation and growth of visibility reducing particles, and its measurement is a key to understanding the many factors responsible for visual air quality degradation.

Precipitation can remove particles from the atmosphere and may help explain differences in air quality from one part of the region to another. In addition, precipitation data are used by Metro Vancouver's Wastewater Collection and Watershed Management functions.

Meteorological Observations

Figure 57 shows the annual precipitation totals for 2021 at Lower Fraser Valley air quality monitoring network stations. The greatest precipitation was observed near the local mountains. Historical 30-year climate normals (1981-2010) obtained from Environment Canada are also shown in Figure 57 for several stations. Figure 58 displays the seasonal variation as observed by the LFV air quality network stations (shown as a gray band). Historical 30-year climate normals (1981-2010) obtained from Environment Canada are also shown in Figure 58 for Vancouver International Airport, Port Moody, and Chilliwack.

Compared to climate normals, monthly precipitation in 2021 was drier in March, April, May, June, July, and August and was wetter in September, October, and November. A series of atmospheric river events in November caused catastrophic flooding and landslides, and cut key transportation links to the region (further described in Section I).

Figure 59 illustrates the seasonal variation of air temperatures observed throughout the monitoring network stations. The hourly maximum and minimum, daily maximum and minimum, and average temperatures are given with the range in values shown as bands. Also shown in Figure 59 are the 30-year climate normals (1981-2010) for Environment Canada's Vancouver International Airport and Agassiz stations.

The data observed in 2021 indicate that average temperatures recorded in January, June, July, and August were warmer than normal. The highest hourly air temperatures were measured in June when a record breaking heat wave impacted the Pacific Northwest. Section I provides additional description of the June heat wave event. February and December were cooler than the 30-year average. During these months, lower averages and daily minimums were experienced compared with the climate normals. The lowest air temperatures were measured in December.

Table 10 provides the average temperature along with the lowest and highest hourly air temperatures observed throughout the year. Air temperatures are milder near the water and exhibit a greater range inland. The highest hourly temperature in 2021 was 42.1°C observed at Chilliwack.

Table 11 gives the frequency distribution of hourly air temperature for the year. Stations located inland, such as those in eastern parts of Metro Vancouver and the FVRD exhibit the greatest frequency of both very low and high air temperatures.

Wind patterns vary between stations as shown by the frequency distributions in Figure 60. The distributions are shown as a "wind rose", which is a bar chart in a polar format. The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 60 shows observed annual wind roses for selected stations including (in order of west to east): Horseshoe Bay, Richmond-Airport, Burnaby North, Pitt Meadows, Abbotsford Airport, Chilliwack, and Hope. The patterns shown during 2021 reflect the predominant winds in those areas. Richmond exhibits a predominant easterly wind with a smaller component from the west, and very little wind from either the north or south. Horseshoe Bay shows wind patterns aligned with Howe Sound with a strong north-south component.

2021 was a year of extreme weather with an unprecedented heat wave in June and atmospheric river events resulting in landsides and regional flooding in November.

Burnaby North shows several northerly wind components along with a predominant east-north east component. This wind pattern is reflective of the North Shore mountain wind flows and drainage flow from Indian Arm. Pitt Meadows shows a somewhat similar pattern with predominant directions from the valleys of Pitt Lake and Alouette Lake. Abbotsford, Chilliwack and Hope experience similar wind flow patterns, with strong east-west components driven by the channelling of winds in the narrower portion of the Fraser Valley.

Figures 61 to 64 show wind roses for winter, summer, spring and fall, respectively. The contrast between winter and summer can be seen in Figures 61 and 62 with winds predominantly from the east in winter switching to southwest in summer. The more westerly flow seen in the summer is the development of a daytime sea breeze during anti-cyclonic (high pressure) weather.

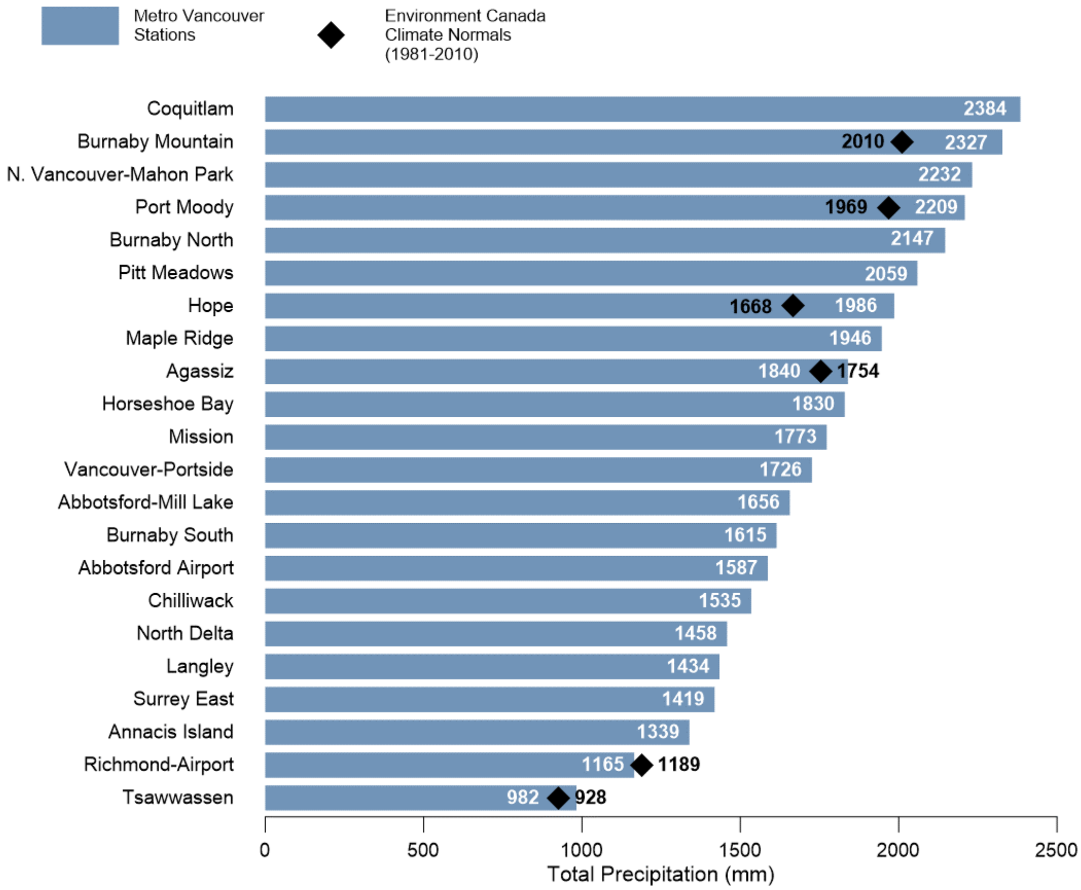
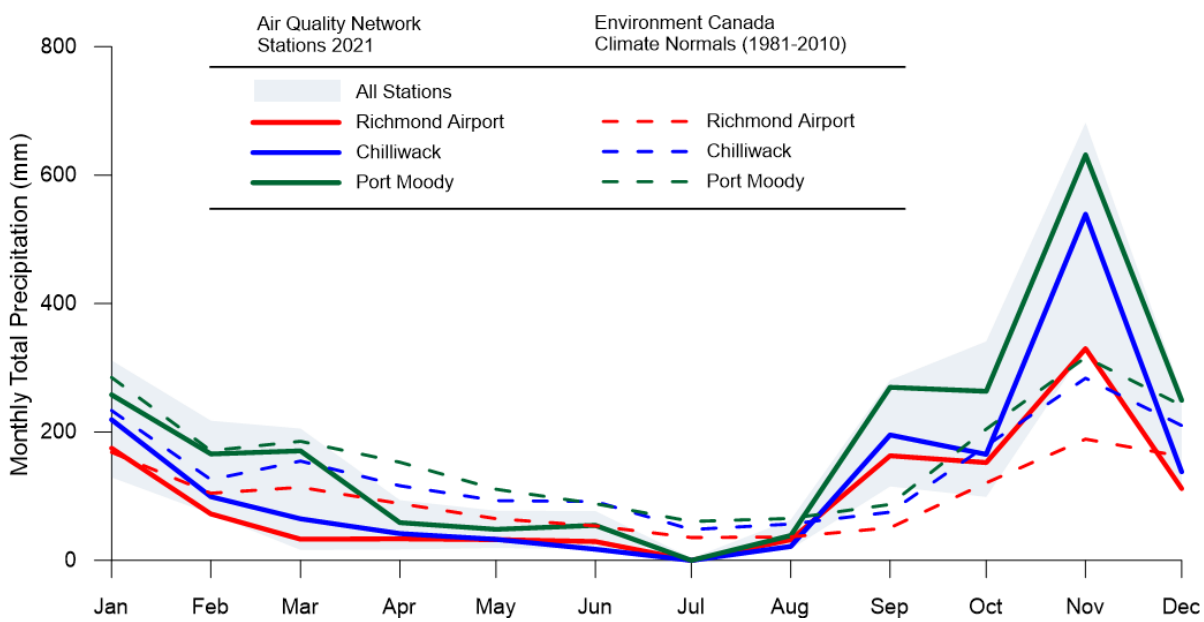
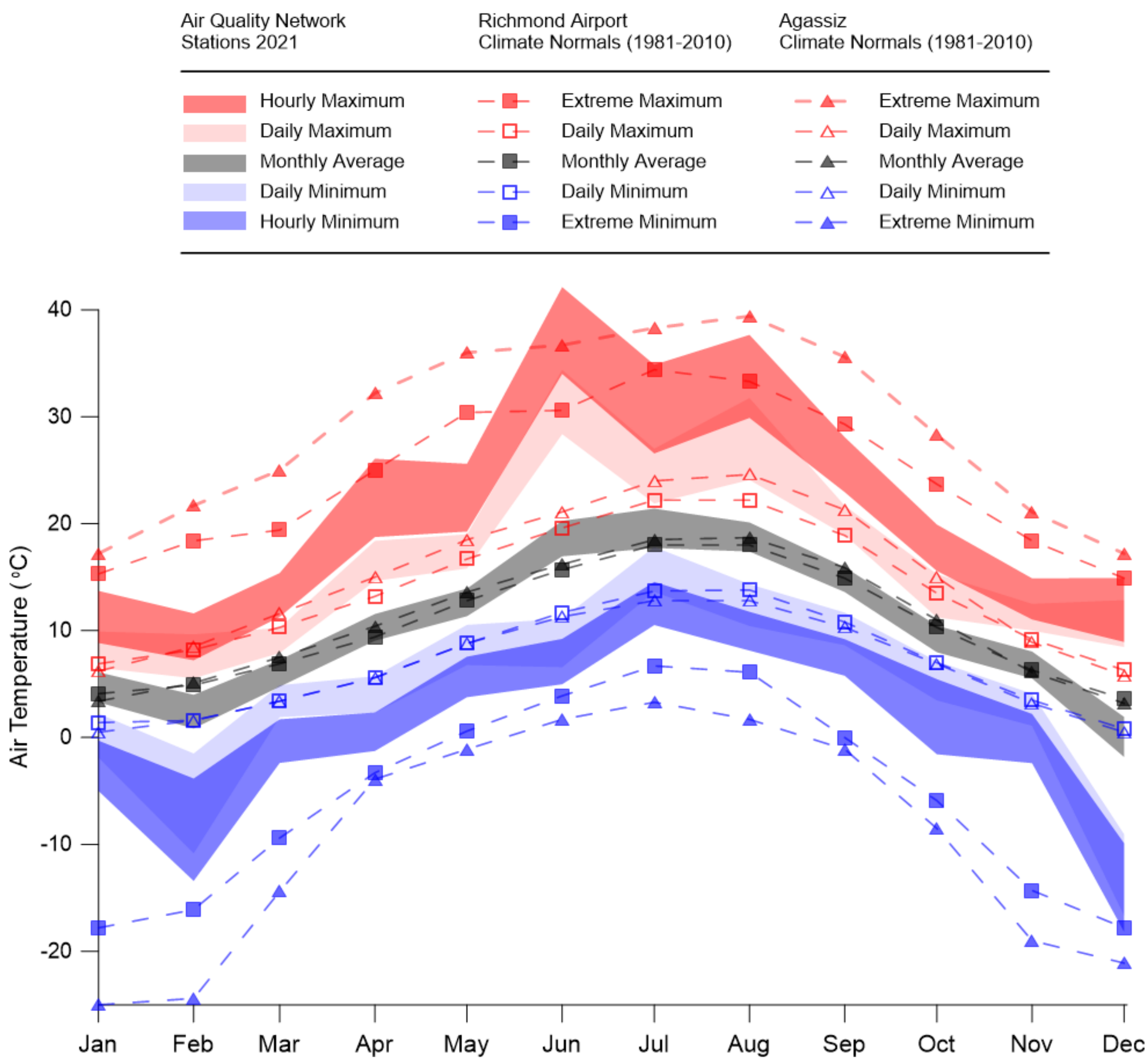


Figure 57: Annual precipitation totals in the LFV, 2021



Note: The range of values observed at LFV air quality network stations are shown as a blue band and Environment Canada climate normals are shown as dotted lines.

Figure 58: Total monthly precipitation in the LFV, 2021



Note: LFV air quality network stations are shown as colour bands and Environment Canada 30-year climate normals are shown as dotted lines

Figure 59: Monthly air temperatures in the LFV, 2021

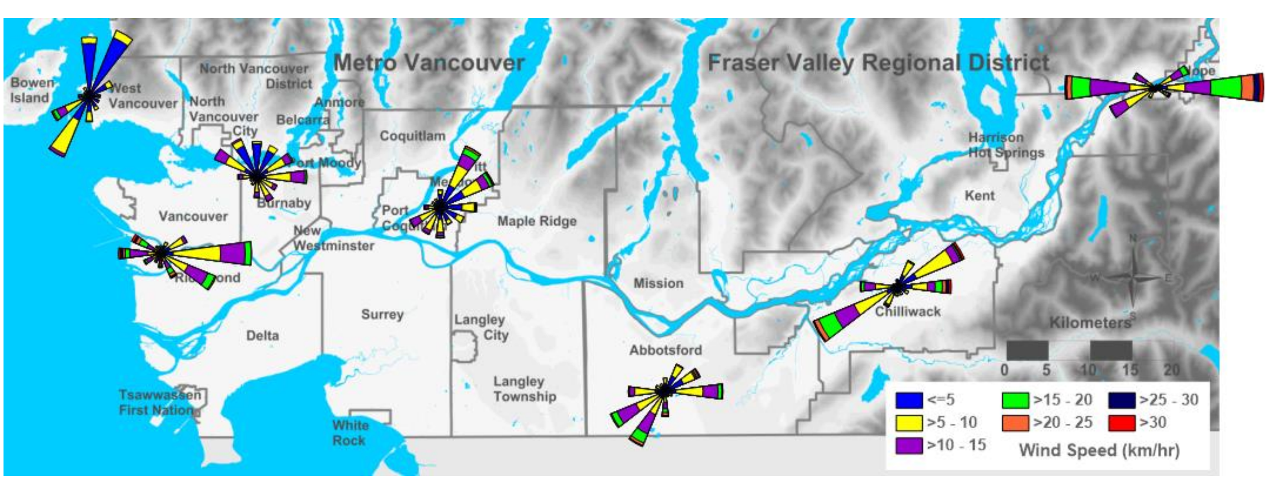


Figure 60: Selected annual wind roses throughout the LFV, 2021

Table 10: Air temperature in LFV, 2021

Station	Hourly Maximum (ºC)	Hourly Minimum (ºC)	Annual Average (ºC)
Chilliwack	42.1	-16.5	11.0
Maple Ridge	41.8	-14.8	10.6
Abbotsford Airport	41.5	-16.3	10.5
Agassiz	41.5	-16.8	11.2
Abbotsford-Mill Lake	41.3	-15.2	10.7
Pitt Meadows	40.7	-14.4	10.5
Mission	40.6	-16.4	10.6
Coquitlam	40.4	-13.6	10.8
Surrey East	40.3	-14.2	10.8
Burnaby-Burmount	40.2	-13.3	11.6
Langley	40.2	-14.7	10.2
Hope	40.2	-18.2	10.3
Burnaby South	39.8	-13.5	10.8
North Delta	38.9	-14.6	10.1
Burnaby-Kensington Park	38.5	-13.1	10.8
Burnaby Mountain	37.5	-14.1	9.1
Annacis Island	37.4	-13.5	10.8
Burnaby-Capitol Hill	37.3	-14.8	9.4
Vancouver-Clark Drive	37.2	-12.1	11.3
Burnaby North	36.7	-12.7	10.9
Burnaby North	36.7	-12.8	10.8
Vancouver-Templeton	36.4	-13.1	10.8
Port Moody	36.0	-14.3	10.3
N. Vancouver-Mahon Park	35.8	-12.7	10.8
Vancouver-Portside	35.2	-11.8	11.2
Horseshoe Bay	35.1	-9.9	10.2
Richmond South	35.0	-13.7	10.3
Richmond-Airport	34.3	-13.0	10.9

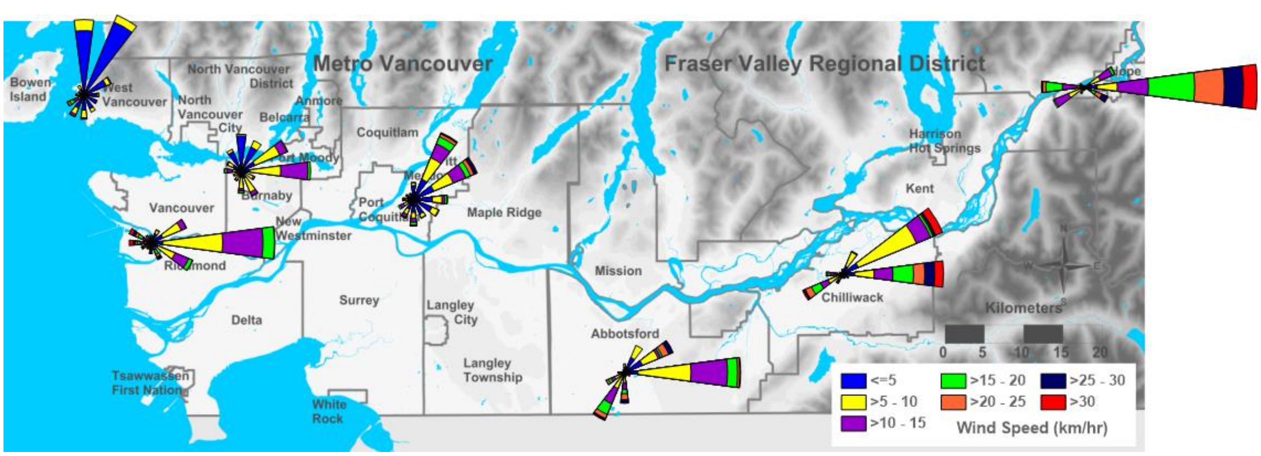


Figure 61: Winter (Jan, Feb, Dec) representative wind roses throughout the LFV, 2021

Table 11: Frequency distribution of hourly air temperature, 2021

Air Temp (deg C)	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Burmount	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Horseshoe Bay	Annacis Island	Tsawwassen	Mission	Agassiz	Abbotsford Airport	Vancouver-Templeton	Vancouver-Portside	Vancouver-Clark Drive
-18 to <-15	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	3	0	0	0	6	16	8	0	0	0
-15 to <-12	7	0	15	35	17	19	17	10	8	22	6	10	5	4	31	48	19	8	8	28	0	9	2	39	39	39	7	0	3
-12 to <-9	26	17	36	52	45	38	35	40	24	39	25	34	26	28	35	86	35	27	32	43	14	33	46	33	43	39	30	20	23
-9 to <-6	42	46	77	101	60	81	66	60	51	57	43	74	37	46	82	104	69	46	74	75	44	63	51	81	97	84	48	37	48
-6 to <-3	92	82	87	105	121	145	106	103	100	87	85	108	86	82	114	127	107	84	70	125	93	64	104	131	100	122	93	80	84
-3 to <0	193	151	336	228	257	333	207	289	183	330	168	336	194	216	286	242	286	198	246	199	228	193	212	227	200	210	216	145	206
0 to <3	703	379	873	741	764	1140	635	638	601	781	486	1099	631	631	733	920	762	441	797	644	710	532	514	814	718	647	654	422	535
3 to <6	1382	800	1106	1296	1545	1576	1305	1280	1382	1291	1211	1620	1337	1317	1344	1367	1308	1133	1192	1358	1544	1114	1444	1191	1171	1367	1266	1292	1194
6 to <9	1504	1056	1532	1283	1383	1330	1449	1571	1532	1414	1553	1317	1574	1512	1439	1094	1418	1740	1506	1374	1461	1800	1739	1437	1361	1412	1582	1722	1610
9 to <12	1325	707	1315	1226	1316	1098	1306	1368	1353	1279	1325	1149	1330	1380	1348	1162	1267	1404	1295	1259	1234	1455	1449	1187	1295	1278	1321	1335	1376
12 to <15	1045	665	1017	1012	1039	905	1140	1153	1073	1061	1123	960	1111	1082	1163	913	1078	1254	1056	1201	1114	1151	1314	1145	995	1243	1089	1150	1048
15 to <18	880	819	898	906	861	852	912	993	975	887	939	789	905	936	847	842	865	1075	894	921	1038	1049	939	935	957	906	957	1025	968
18 to <21	716	744	675	651	622	570	648	657	728	592	739	593	728	719	554	612	584	685	680	632	734	674	558	632	691	598	727	803	762
21 to <24	420	449	411	468	381	298	427	352	387	405	484	355	427	453	373	439	437	405	418	430	301	369	247	425	461	410	474	489	465
24 to <27	263	273	264	296	189	126	242	136	191	258	278	167	235	191	218	305	261	166	289	248	116	155	80	250	280	225	185	155	286
27 to <30	93	74	67	186	80	57	91	46	68	129	128	65	66	50	83	174	137	36	105	116	33	47	39	124	201	96	54	55	83
30 to <33	34	33	32	67	28	40	32	23	38	43	50	32	33	35	32	54	46	31	40	32	20	24	18	48	75	33	39	24	40
33 to <36	18	7	18	27	18	14	17	11	16	21	24	10	15	19	13	25	18	3	21	16	12	20	1	17	26	12	15	5	23
36 to <39	12	0	0	13	15	15	15	0	15	12	11	9	6	0	17	19	17	0	13	17	0	7	0	19	18	19	2	0	6
>=39	0	0	0	15	0	0	7	0	4	8	10	0	0	0	8	6	11	0	5	8	0	0	0	8	11	8	0	0	0
Missing	5	2458	1	44	19	123	103	30	31	44	72	33	14	59	40	183	35	24	19	31	64	1	3	11	5	4	1	1	0
Data Completeness (%)	100%	72%	100%	100%	100%	99%	99%	100%	100%	100%	99%	100%	100%	99%	100%	98%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	100%	100%

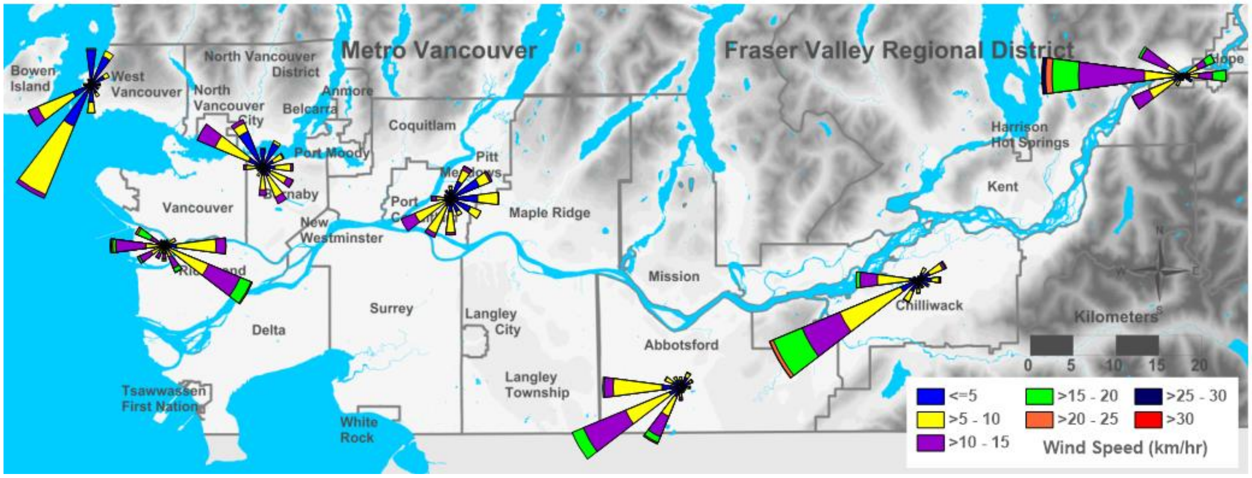


Figure 62: Summer (Jun, Jul, Aug) representative wind roses throughout the LFV, 2021

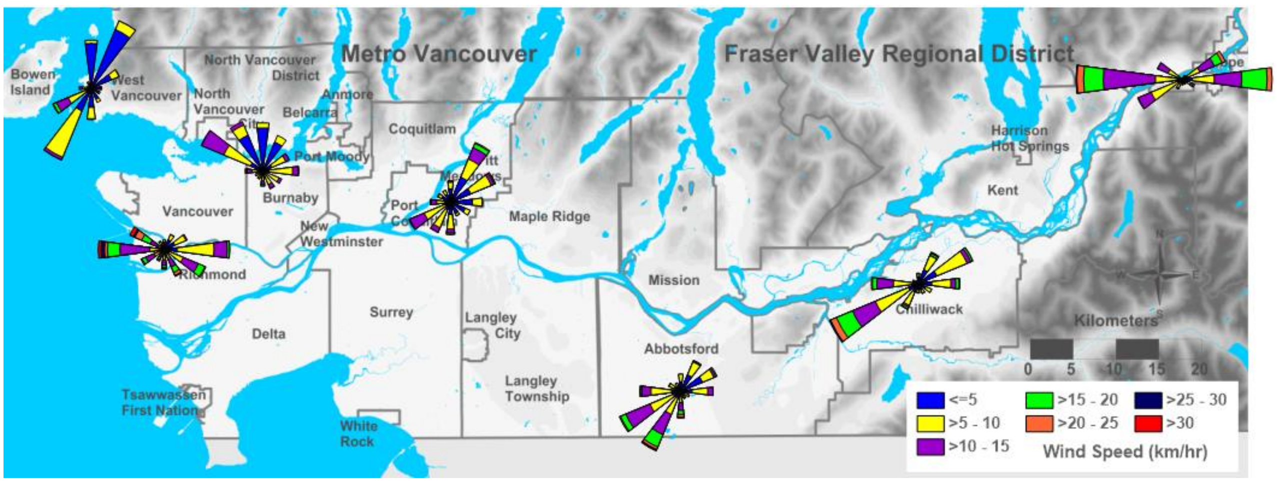


Figure 63: Spring (Mar, Apr, May) representative wind roses throughout the LFV, 2021

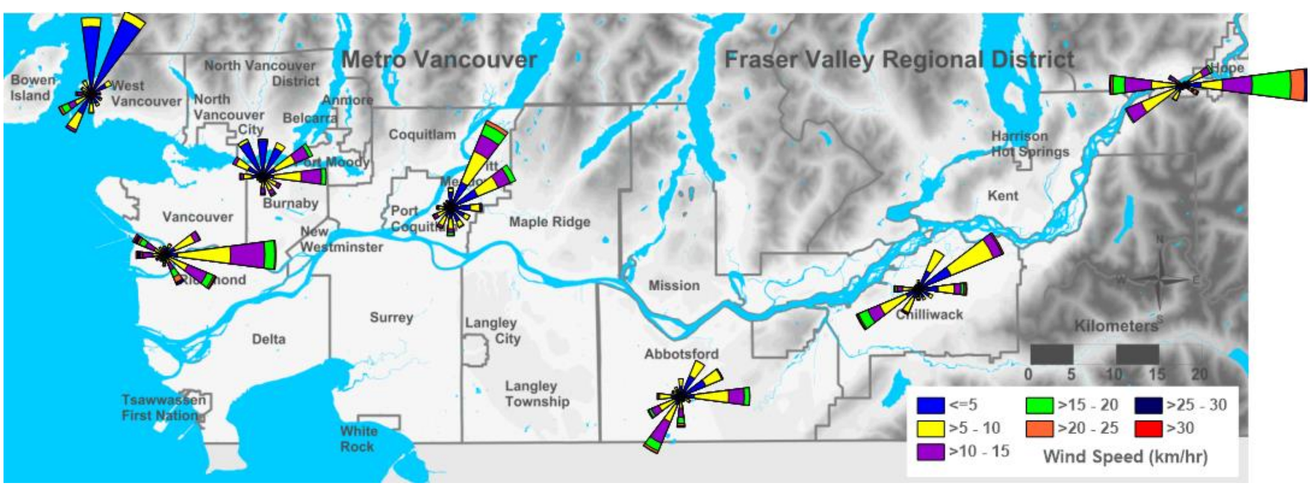


Figure 64: Fall (Sep, Oct, Nov) representative wind roses throughout the LFV, 2021

Section H – Monitoring Network Operations

Network History

Air monitoring in the region began in 1949, when the City of Vancouver established a dustfall monitoring network. Monitoring for total suspended particulate was added in later years. Following the Pollution Control Act (1967), provincial air quality programs initiated monitoring of dustfall and total suspended particulate in other areas of the region.

In 1972, provincial and municipal air quality responsibilities were transferred to Metro Vancouver, including operation of air quality monitoring programs. In 1998, a Memorandum of Understanding established cooperative management of the monitoring network by both Metro Vancouver and the Fraser Valley Regional District.

Continuous monitoring of gaseous pollutants began in 1972 under the auspices of the federal National Air Pollution Surveillance (NAPS) program. Several new stations were established to measure SO_2, O_3, CO, NO_X, and VOC. Over the years, stations and equipment have been added or removed in response to changing air quality management priorities. Mobile Air Monitoring Units and portable instruments provide added flexibility to carry out measurements at many locations. Some monitoring is part of co-operative programs with industry and other governments.

Specialized Monitoring Initiatives

Specialized air quality monitoring studies complement the monitoring network. The studies typically allow for characterization of air quality at finer spatial scales, such as at the neighbourhood scale, and allow investigation of air quality problems on the local scale. The regional monitoring network may not be ideally suited to address local scale issues and therefore performing specialized local air quality studies is an important component to characterizing air quality in the LFV.

A Mobile Air Monitoring Unit (MAMU) that is capable of monitoring particulate and gaseous pollutants along with meteorology is utilized throughout the region to conduct specialized air quality studies. In addition to MAMU, Metro Vancouver utilizes small mobile units along with several portable air quality monitors.

In April 2021, Metro Vancouver's mobile air monitoring unit (MAMU) concluded a year-long air quality monitoring study at Musqueam's Indian Reserve No. 2 lands in Vancouver. In cooperation with Musqueam's public works department, MAMU was located beside the Musqueam Cultural Pavilion, near the shore of the north arm of the Fraser River. The monitoring will provide information on air quality in the Musqueam community and support Metro Vancouver's Iona Island Wastewater Treatment Plant Biosolids Dewatering Facility project.

Monitoring Network Partners

Several partners contribute to the on-going management and operation of the Lower Fraser Valley Air Quality Monitoring Network. The government partners include:

- Fraser Valley Regional District
- Environment and Climate Change Canada
- BC Ministry of Environment and Climate Change Strategy

Motor Vehicle Inspection Facility in Vancouver, ca. 1948 (Courtesy of City of Vancouver Archives)

Other monitoring network partnerships:

- The Vancouver International Airport Authority provides partial funding for the Vancouver International Airport station (T31).
- Parkland Refining (BC) Ltd. provides funding for the Burnaby North (T24) and Capitol Hill (T23) stations.
- Trans Mountain Pipeline LP provides funding for the Burnaby-Burmount (T22) station.
- Port of Vancouver provides funding for the Tsawwassen (T39) station in Delta.

Metro Vancouver continues to operate and maintain the monitoring stations and equipment, and to collect real-time data from the regional monitoring network on behalf of all partners.

Federal Government

Metro Vancouver co-operates with the federal government by providing field services for three major nation-wide sampling programs under the National Air Pollution Surveillance (NAPS) program of Environment Canada.

- Canister sampling of VOC has been conducted in the LFV since 1988. The federal government supplies equipment and Metro Vancouver staff provide field exchange of canisters, calibration, and routine maintenance. Sample canisters are sent to the federal laboratory in Ottawa, for analysis of up to 105 VOC.

- A second program involves dichotomous particulate sampling at three sites where two size fractions: 10 to 2.5 μm (coarse), and under 2.5 μm (fine) are collected every sixth day for detailed chemical analysis in Ottawa.

- A $PM_{2.5}$ speciation sampling program, initiated in 2003, includes sampling at the Vancouver-Clark Drive, Burnaby South, and Abbotsford Airport stations where samples are taken every sixth day and sent to Ottawa to be analyzed for various particulate species.

Quality Assurance and Control

Air quality monitoring data is regularly reviewed and validated. Technicians perform regular inspections and routine maintenance of the monitoring equipment and stations. In addition, technicians perform major repairs to any instrument in the network, as required. Through the data acquisition system, technicians can check on instruments remotely prior to site visits. This system also allows for calibration of the instruments either automatically or upon demand.
Continuous air quality monitors are subject to performance audits and multi-point calibration every four to six months. In addition, all other instruments in the network are subjected to annual and/or biannual calibrations. All reference materials and quality control procedures meet or exceed Environment Canada and/or US Environmental Protection Agency requirements. Metro Vancouver coordinates quality assurance procedures and activities with both the provincial and federal government.

Database

Data from continuous air quality analyzers are transmitted to Metro Vancouver's central database using internet and cellular links. Hourly averages for each monitor are calculated from the one-minute data and stored in the database. For a measurement to be considered valid, at least 75% of the relevant data must be available. Calibration data and instrument diagnostics are also retained by the data acquisition system.

Section I – Wildfires, Air Quality Events and Climate Change

In recent years, wildfire activity has increased in frequency and severity due to the impacts of climate change. Wildfires produce considerable amounts of smoke that can be transported great distances. Wildfire smoke is a complex mixture of many gases and small particles. The mixture can change quickly depending on the weather, the fuel, the temperature of the fire, and how far the smoke has travelled. Of all the pollutants in wildfire smoke, fine particulate matter ($PM_{2.5}$) poses the greatest risk to human health.

Locally, wildfire smoke can result in two differing outcomes for ground-level ozone production. Wildfire smoke can either enhance or inhibit ozone production, depending on the amount of smoke present. The mixture of chemical contaminants in wildfire smoke includes ozone precursors, which can enhance ozone production. A study indicated that a wildfire smoke event in 2012 was responsible for an enhancement of 8-hour ozone concentrations at coastal BC sites by as much as 10 ppb (Teakles et al., 2017). Conversely, if wildfire smoke becomes dense enough, the smoke can block solar radiation, decrease air temperatures, and inhibit ozone formation. Both of these effects are experienced in the LFV.

Climate projections indicate the region will experience hotter, drier summers and wetter, warmer winters. A warming climate is likely to increase the frequency, severity and duration of wildfires and associated smoke impacts, while also increasing in-region ground level ozone formation through the intensity and duration of summer heat waves.

A study of the extreme 2017 wildfire season in British Columbia, found that human-induced climate change contributed greatly to the extreme warm temperatures, high wildfire risk, and large burned areas (Kirchmeier-Young et al., 2019). The authors concluded that as the climate continues to warm, it can be expected that extreme wildfire seasons like 2017 in BC will become more likely in the future.

Public awareness of air quality and health has also grown with the recent summer wildfire smoke impacts. Since 2017, Metro Vancouver has been working with local health authorities, BC Centre for Disease Control, Health Canada, BC ENV, FVRD and experts from outside BC to develop communication resources for residents on wildfire smoke health impacts and how they can protect themselves.

Metro Vancouver is also exploring opportunities to collaborate with member jurisdictions and other partners on programs and policies to help protect residents from the impacts of extreme heat and smoke.

Metro Vancouver's *Clean Air Plan* considers the increasing impacts of wildfire activity in the strategies and actions outlined (Metro Vancouver, 2021). Metro Vancouver's *Climate 2050* Roadmaps also identify actions that will help the region adapt to climate-related impacts on regional air quality (Metro Vancouver, 2024).

2021 Wildfires

Historically, episodes of degraded air quality due to smoke from wildfires outside the region have been infrequent. Since 2015, however, wildfire smoke impacts have increased significantly. In 2015, eight air quality advisory days occurred due to wildfire smoke. There were no air quality advisories in 2016 or 2019, while 2017, 2018 and 2020 experienced significant and lengthy smoke-related air quality impacts due to wildfires burning throughout the Pacific Northwest, including BC and the US. There were 19 advisory days in 2017, 22 advisory days in 2018, 13 advisory days in 2020, and 10 advisory days in 2021.

In 2018, the total number of fires in British Columbia were nearly twice as many as 2017. In 2018, the total area burned was over three times greater than the 10-year average with 13,543 km^2 burned (Table 12). The 2018 wildfire season was one of the worst in British Columbia's history, with the largest area burned. This led to the most air quality advisory days that the region has experienced in a single year.

In both 2019 and 2020, the total number of fires and area burned was well below the 10-year average in BC. However, in 2020 Washington, Oregon and California had active wildfire seasons. In 2021, the total area burned in BC was over two times greater than the 10-year average with 8,693 km^2 burned and more total fires than the 10-year average (Table 12).

In 2021, BC had an active wildfire season with an above average total number of fires and area burned, with nearly two times the size of the 10-year average area burned. On August 1 wildfire smoke from the BC interior and Washington contributed to elevated PM2.5 concentrations and hazy skies throughout the region. Exceedances of the 24-hour PM2.5 objective occurred in the eastern Fraser Valley with other parts of the region experiencing intermittently elevated PM2.5, but remaining better than the objective. An advisory was issued for Metro Vancouver and parts of the FVRD, remaining in place until August 3 when smoke cleared with onshore winds.

Table 12. Total fires and area burned in British Columbia.

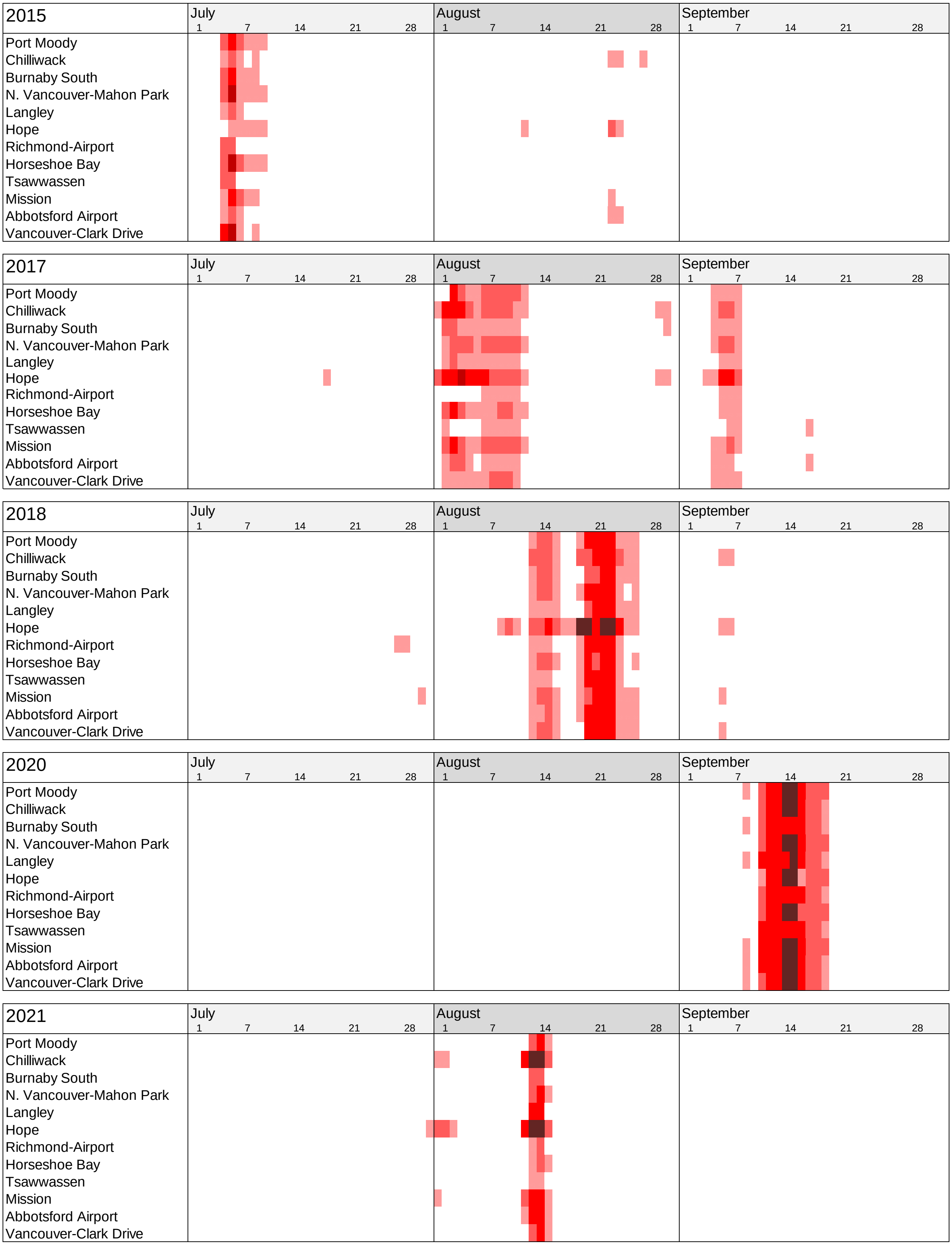
Year	Total Fires	Area Burned (km^2)
2015	1,858	2,806
2016	1,050	1,004
2017	1,353	12,161
2018	2,117	13,543
2019	825	211
2020	670	145
2021	1,647	8,693
10-year average	***1,451***	***4,346***

An air quality advisory was issued for both PM2.5 and ozone when smoke returned August 12 from wildfires burning in BC and Washington, with the highest concentrations confined to the Fraser Valley. On August 13 outflow winds continued to bring smoke to the region, pushing west through the Fraser Valley into Metro Vancouver with high concentrations of fine particulate matter. With heat warnings also in place, PM2.5 exceedances were widespread and at times the AQHI was at the highest risk level (10+) throughout the region. The advisory was cancelled August 15 due to a change in the weather with cooler and wetter weather moderating wildfire activity and smoke production.

An analysis of area burned and annual climate data for the period 1919 to 2021 in BC showed that after nearly a century-long decline, wildfire activity has increased significantly since 2005 (Parisien et al, 2023). Examination of trends in wildfire behaviour that have had a direct impact on air quality in the region, revealed that four of the most severe wildfire seasons of the last century occurred in the past seven years (2017, 2018, 2021 and 2023). The increase in wildfire activity coincided with a rapid acceleration of climate-induced changes, including increasing temperatures and increasing moisture deficits across the province. Moisture deficits in the spring and summer have led to environmental changes, such as a lack of soil moisture, and increased biomass flammability. Other factors that affected the availability of forest fuels also contributed to this trend: past wildfires, insect outbreaks, and land-use practices.

The combined effects of climate-induced changes and altered wildfire fuels is causing more frequent years of intense and prolonged wildfire activity (Parisien et al, 2023). The study estimated that the average length of wildfire season has increased by 26.7 days and the onset of fire activity occurs 27.1 days earlier compared to the early 1900s. With current climate trends, it is expected that more, faster-spreading, larger, and longer-burning wildfires will occur across BC in future years. Even under the best climate projection scenarios, there is little indication that the increasing trend will stabilize in the near future.

Figure 65 shows summertime exceedances of the $PM_{2.5}$ objective due to elevated $PM_{2.5}$ in five wildfire years: 2015, 2017, 2018, 2020, and 2021. The colour corresponds to the maximum $PM_{2.5}$ 24-hour rolling average with dark red signifying concentrations greater than 150 µg/m^3.



Note: Shades of red denote exceedance days with light red representing a maximum 24-hour rolling average concentrations greater than 25 μg/m³ and dark red greater than 150 μg/m³.

Figure 65: Comparison of exceedance days in five wildfire influenced years: 2015, 2017, 2018, 2020 and 2021

June 2021 Heat Wave

In late June 2021, a heat wave of unprecedented magnitude impacted the Pacific Northwest (PNW) region of Canada and the United States. Temperature records were shattered, with all-time high records broken in BC, Washington, and Oregon. Many locations broke all-time maximum temperature records by more than 5°C, and the Canadian national temperature record was broken by 4.6°C, with a new record temperature of 49.6°C in Lytton, BC on June 29. An out-of-control wildfire swept through the village of Lytton the following day, burning approximately 90% of the village structures. The new record temperature was reportedly the hottest worldwide temperature recorded north of 45° latitude, and hotter than any recorded temperature in Europe or South America (White et al., 2023).

The heat wave occurred from June 25 to July 2, 2021 with the hottest days occurring locally on June 27 and 28. In the Lower Fraser Valley, temperatures reached 42°C in Chilliwack, Agassiz, and Maple Ridge, 41°C in Abbotsford and West Vancouver, and 40°C in Burnaby, Surrey, Langley, Pitt Meadows, and Mission. Slightly cooler temperatures were measured near the coast. Overnight temperatures on June 28 were above 25°C at all monitoring stations in the region, 30°C in Burnaby, and 31°C in Mission and Agassiz.

The impacts of the event were catastrophic, including hundreds of attributable deaths across the PNW, mass mortalities of marine life, reduced crop and fruit yields, river flooding from rapid snow and glacier melt, and a substantial increase in wildfires (White et al., 2023).

Between June 25 and July 2, an estimated 740 excess deaths in the province of BC were attributed to the heat wave (Henderson et al., 2021), while the BC Coroner attributed 619 deaths to the heat event. Most people died in their homes, likely due to dangerously high indoor temperatures in a region where most households do not have air conditioning or other passive ways to shed excess heat (Henderson et al., 2022). Including deaths in other regions such as Alberta, Washington, and Oregon a total estimate of at least 868 deaths were attributed to this heat wave (White et al., 2023).

While the heat wave was predicted well in advance, weather forecasters were challenged with accurately forecasting daily high temperatures, given the forecast was outside the range of temperatures previously experienced in this region. The June 2021 event was truly exceptional with no precedent in the observational record and was among the most extreme weather events ever recorded globally (Thompson et al., 2022).

From an air quality perspective, the heat wave resulted in ground-level ozone concentrations not measured in the region since the 1980s, since high temperature is a key factor that leads to formation of ozone. The first air quality advisory of the year was initiated on June 26, for ground-level ozone in the eastern portions of Metro Vancouver and the central Fraser Valley. On June 28, nine stations exceeded the 1-hour and 8-hour ambient air quality objectives for ozone, including a 1-hour average of 151 parts per billion (ppb) at the Maple Ridge station (the 1-hour objective is 82 ppb). The last time the region experienced ozone concentrations of that magnitude was in 1988.

On June 29 the advisory was extended to also include the eastern Fraser Valley, and $PM_{2.5}$ was added to the advisory for the entire region due to a buildup of local emissions and formation of secondary $PM_{2.5}$. While wildfire activity was a growing concern across the province, the region was not yet impacted by wildfire smoke during this advisory. The advisory was cancelled on June 30 as cooler, clean marine air flowed into the region.

Research shows that climate change significantly influenced the June 2021 heat wave. The June 2021 heat wave was among the most extreme events ever recorded globally (Thompson et al., 2022). While heat extremes are a natural part of our climate system, they are getting hotter and longer in duration because of human-induced climate change.

According to Philip et al. (2022), such a severe heat wave would have been extremely unlikely without human-caused climate change. Their study showed climate change made the heat wave 1.2 to 2.8°C hotter. In a future with 2°C of global warming, an event of this magnitude would occur every 5 to 10 years instead of being a rare 1 in 1000-year event. Other researchers have found that global warming has caused about a 0.8°C to 1°C increase in heat wave temperatures worldwide and that future warming could lead to about a 5°C increase in heat wave temperatures by the end of the 21st century (Bercos-Hickey et al., 2022).

A striking feature of the heat wave was that it exceeded some climate projections for Metro Vancouver (Metro

Vancouver, 2016), including the 2050 projection for number of days annually with overnight temperatures above 20 degrees (tropical nights) and the highest 1-in-20 year return period temperature for 2080.

Metro Vancouver's climate projections have predicted two tropical nights on average by the year 2050. In 2021, the heat wave resulted in exceedances of the climate projection of number of tropical nights (Figure 66). The 2021 heat wave resulted in five tropical nights in Vancouver and North Vancouver, and four nights at over half of Metro Vancouver's monitoring stations.

The June heat wave was so extreme that it resulted in measured temperatures in the region that exceeded climate projections for the hottest temperature projected for 2080. Metro Vancouver's climate projections project the highest 1-in-20 year return period temperature of 39°C by 2050 and 41°C by 2080. A temperature of 42°C was observed in Maple Ridge on June 27, 2021, the highest temperature measured in Metro Vancouver during the heat wave. Figure 67 shows the daily maximum temperature for the past 20 years compared with climate projections.

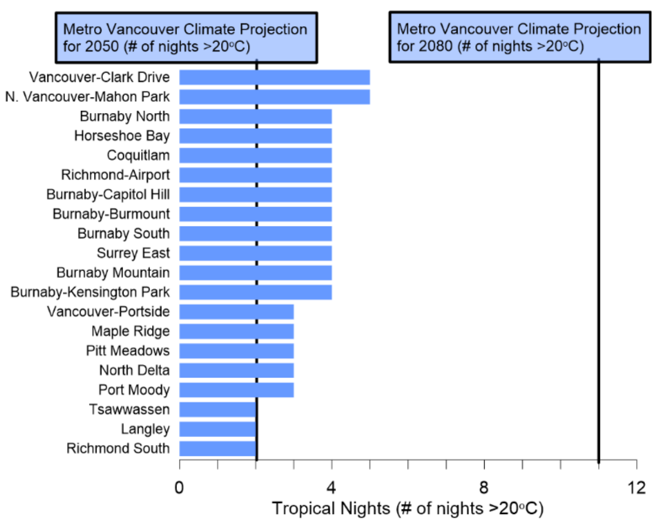


Figure 66: Number of tropical nights observed in 2021 compared with Metro Vancouver's climate projections

Climate projections for the region indicate extreme heat waves will become more common even if global greenhouse gas emissions are reduced by 45% by 2030 and reach net zero by 2050. A warming climate will further increase the frequency, intensity, and duration of heat extremes with the potential for temperatures to reach dangerous levels for human health and agriculture (Bercos-Hickey et al., 2022).

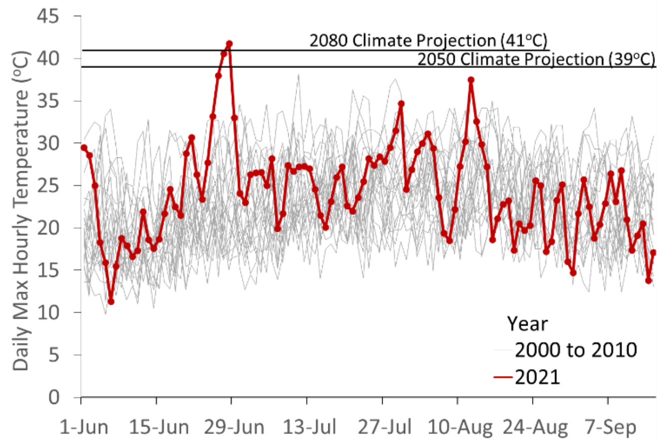


Figure 67: Daily maximum temperatures by year at Maple Ridge compared with Metro Vancouver's climate projections

November 2021 Flooding

An atmospheric river was associated with two days of heavy precipitation in southwestern BC, beginning November 14, 2021. As a result, floods and landslides led to the loss of life, cut the Lower Fraser Valley region off from the rest of Canada by road and rail, and was one of the costliest natural disasters in BC history (Gillett et al., 2022).

The storm had devastating impacts due to a number of factors: the rate and amount of precipitation received over a two-day period, the westerly direction from which the storm came, the already high streamflow from preceding precipitation events, snowmelt due to warm temperatures, and wildfire scars left on the landscape from an active summer fire season (Gillett et al., 2022). The rainfall broke dozens of all-time rainfall records, with some communities seeing nearly a month's worth of rain over a 48-hour period.

Gillett et al. (2022) showed that the amount of precipitation that fell during the two days was approximately a 1 in 50 to 1 in 100-year event. While the peak streamflow return periods varied across the region, some were found to exceed 1 in 100-year events in several basins.

In terms of impacts, the event caused a number of landslides in the region, trapping motorists at both ends of the region and causing as many as five deaths. Floodwaters, landslides, wash-outs, and bridge collapses caused by the event closed all the highways, pipelines and rail lines connecting Vancouver and southwestern BC with the rest of Canada for several days, with some highways closed for weeks after the event (Gillett et at., 2022).

The province declared a state of emergency on November 17, 2021, stating that the storm was the worst weather to hit the area in a century. Nearly 20,000 people had to evacuate their homes and communities faced intense shortages of basic items as stores were unable to restock due to supply chain disruptions.

Entire regions of the Fraser Valley were overcome by floodwater and evacuation orders were issued in several communities including Abbotsford, Princeton, and Merritt. The Sumas Prairie area of Abbotsford was flooded after a dike on the Nooksack River overflowed its banks and breached its dikes, resulting in flooding to over 1,000 homes and hundreds of thousands of farm animal deaths.

Climate projections indicate that annual precipitation will increase, with greater increases in the fall and winter. Annual precipitation is predicted to increase 5% by 2050 and 11% by 2080. The largest increase in rainfall is expected in the fall, increasing 11% by 2050 and 20% by 2080. Conversely, September is projected to get drier over time, extending the dry season into the fall. Summer, already our region's driest season, is expected to experience a precipitation decline of 19% by 2050 and 29% by 2080 (Metro Vancouver, 2016).

References

Bercos-Hickey, E., O'Brien, T. A., Wehner, M. F., Zhang, L., Patricola, C. M., Huang, H., and Risser, M. D. 2022. Anthropogenic contributions to the 2021 Pacific Northwest heatwave. *Geophysical Research Letters*, 49(23).

Kirchmeier-Young, M. C., Gillett, N. P., Zwiers, F. W., Cannon, A. J., and Anslow, F. S. 2019. Attribution of the Influence of Human-Induced Climate Change on an Extreme Fire Season. *Earth's Future, 7*(1): 2-10.

Gillett, N.P., Cannon A.J., Malinina, E., Schnorbus, M., Anslow, F., Sun, Q., Kirchmeier-Young, M., Zwiers, F., Seiler, C., Zhang, X., Flato, G., Wan, H., Li, G., and Castellan, A. 2022. Human influence on the 2021 British Columbia floods. *Weather and Climate Extremes*, 36.

Henderson, S.B., McLean, K.E., Lee, M. J., and Kosatsky, T. 2021. Extreme heat events are public health emergencies. *BC Med. J.*, 63.

Henderson, S.B., McLean, K.E., Lee, M.J., and Kosatsky, T. 2022. Analysis of community deaths during the catastrophic 2021 heat dome: Early evidence to inform the public health response during subsequent events in greater Vancouver, Canada. *Environ. Epidemiol,* 6.

Loikith, P. C., and D. A. Kalashnikov. 2023. Meteorological Analysis of the Pacific Northwest June 2021 Heatwave. *Monthly Weather Review*, 151: 1303–1319.

Metro Vancouver, 2014. Regional Ground-Level Ozone Strategy. Burnaby, British Columbia. https://metrovancouver.org/services/air-quality-climate-action/Documents/regional-ground-level-ozone-strategy-2014.pdf

Metro Vancouver, 2016. Climate Projections for Metro Vancouver. Burnaby, British Columbia https://metrovancouver.org/services/air-quality-climate-action/Documents/climate-projections-for-metro-vancouver-2016.pdf

Metro Vancouver, 2018. 2015 Lower Fraser Valley Air Emissions Inventory and Forecast, Final Report and Summarized Results. Burnaby, British Columbia. https://metrovancouver.org/services/air-quality-climate-action/Documents/lower-fraser-valley-air-emissions-inventory-forecast-2015.pdf

Metro Vancouver, 2020. Metro Vancouver Near-Road Air Quality Monitoring Study. Burnaby, British Columbia. https://metrovancouver.org/services/air-quality-climate-action/Documents/near-road-air-quality-monitoring-study-technical-report-2015-2017.pdf

Metro Vancouver, 2021. *Clean Air Plan*. Burnaby, British Columbia. https://metrovancouver.org/services/air-quality-climate-action/Documents/clean-air-plan-2021.pdf

Metro Vancouver, 2024. *Climate 2050* Roadmaps. Burnaby, British Columbia. https://metrovancouver.org/services/air-quality-climate-action/climate-2050/regional-priorities

Philip, S. Y., Kew, S. F., van Oldenborgh, G. J., Anslow, F. S., Seneviratne, S. I., Vautard, R., Coumou, D., Ebi, K. L., Arrighi, J., Singh, R., van Aalst, M., Pereira Marghidan, C., Wehner, M., Yang, W., Li, S., Schumacher, D. L., Hauser, M., Bonnet, R., Luu, L. N., Lehner, F., Gillett, N., Tradowsky, J. S., Vecchi, G. A., Rodell, C., Stull, R. B., Howard, R., and Otto, F. E. L. 2022. Rapid attribution analysis of the extraordinary heat wave on the Pacific coast of the US and Canada in June 2021. *Earth Syst. Dynam*., 13: 1689–1713.

Parisien, M. A., Barber, Q. E., Bourbonnais, M. L., Daniels, L. D., Flannigan, M. D., Gray, R. W., Hoffman, K. M., Jain, P., Stephens, S. L., Taylor, S. W., Whitman, E. 2023. Abrupt, climate-induced increase in wildfires in British Columbia since the mid-2000s. *Commun. Earth Environ.*, 4 (309)

Teakles, A. D., So, R., Ainslie, B., Nissen, R., Schiller, C., Vingarzan, R., McKendry, I., Macdonald, A. M., Jaffe, D. A., Bertram, A. K., Strawbridge, K. B., Leaitch, W. R., Hanna, S., Toom, D., Baik, J., and Huang, L. 2017. Impacts of the July 2012 Siberian fire plume on air quality in the Pacific Northwest. *Atmos. Chem. Phys.*, 17: 2593–2611.

Thompson, V., Kennedy-Asser, A.T., Vosper, E., Eunice Lo, Y.T., Huntingford, Cl, Andrews, O., Collins, M., Hegerl, G.C., and Mitchell, D. 2022. The 2021 western North America heat wave among the most extreme events ever recorded globally. *Science Advances*, 8(18).

White, R. H., Anderson, S., Booth, J. F., Braich, G., Draeger, C., Fei, C., Harley, C. D. G., Henderson, S. B., Jakob, M., Lau, C. A., Mareshet Admasu, L., Narinesingh, V., Rodell, C., Roocroft, E., Weinberger, K. R., and West, G. 2023. The unprecedented Pacific Northwest heatwave of June 2021. *Nature communications*, 14, 727.