Attachment A

REPORT

# Pitt Meadows Preliminary Air Quality and Human Health Risk Assessment of Railway-source Diesel Emissions

*City of Pitt Meadows*

Prepared for:
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**Envirochem Project No.: 21162**

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# EXECUTIVE SUMMARY

As a result of CP’s expressed desire to expand railway operations and operational capacity in the area, the City of Pitt Meadows retained Envirochem Services Inc. (Envirochem) to conduct an air quality and preliminary Human Health Risk Assessment (HHRA) to estimate the potential impacts of air emissions related to projected rail operation increases and proposed rail infrastructure and operational growth within the city’s boundary.

The rail changes considered in this study largely focuses on predicted increases in mainline rail traffic and associated rail layout changes before 2030, and the proposed CP Logistics Park: Vancouver (LPV) project. Various scenarios (Scenario 1 - current operations, Scenario 2 - predicted 2030 operations, and Scenario 3 – predicted 2030 operations including the proposed LPV project) were evaluated to assess the air quality impacts and associated potential health risks with the current and potential future rail operations within the city.

The methodology for this assessment can be broken into three main stages: emissions inventory calculations to predict the emissions related to current and future rail operations in Pitt Meadows, air quality dispersion modelling to predict the dispersion of emissions and ground level air contaminant concentrations around the rail operations, and preliminary human health risk assessment to assess the health risks of predicted worst-case contaminant concentrations.

This study predicted exceedances of the acceptable health risk thresholds (for non-carcinogenic and carcinogenic health effects) for some of the individual air contaminants due to exposure to the model predicted concentrations associated with diesel emissions in each of the three scenarios evaluated, including under existing conditions. Based on these results, potential human health risks related to diesel emissions from the existing and proposed rail-related operations need further consideration.

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# GLOSSARY OF TERMS

| Acronym | Definition |
| --- | --- |
| **AAQOs** | Ambient Air Quality Objectives |
| **CAAQs** | Canadian Ambient Air Quality Standards |
| **CACs** | Criteria Air Contaminants |
| **COPCs** | Contaminants of Potential Concern |
| **CP** | Canadian Pacific Railway |
| **DB** | Dynamic Breaking |
| **DE** | Diesel Emissions |
| **DPM** | Diesel Particulate Matter |
| **HAPs** | Hazardous Air Pollutants |
| **HHRA** | Human Health Risk Assessment |
| **HQ** | Hazard Quotient |
| **ILCR** | Incremental Lifetime Cancer Risks |
| **IUR** | Inhalation Unit Risk |
| **LPV** | CP Logistics Park: Vancouver |
| **MOVES** | Motor Vehicle Emissions Simulator (US EPA Model) |
| **MPOI** | Maximum Point of Impingement |
| **RAC** | Railway Association of Canada |
| **ROPCs** | Receptors of Potential Concern |
| **TC** | Tolerable Concentration |
| **TDCA** | Time-adjusted average daily air concentration |
| **TLACA** | Time-adjusted lifetime air concentration |
| **TRV** | Toxicity Reference Value |
| **US EPA** | United States Environmental Protection Agency |
| **VFPA** | Vancouver Fraser Port Authority |
| **VIF** | Vancouver Intermodal Facility |
| **VKT** | Vehicle Kilometers Travelled |
| **VOCs** | Volatile Organic Compounds |
| **WCE** | West Coast Express |

# 1.0 INTRODUCTION

## 1.1 Overview of Project

The City of Pitt Meadows retained Envirochem Services Inc. (Envirochem) to conduct a preliminary air quality Human Health Risk Assessment (HHRA) of the current and future predicted air emissions from rail operations within the city's boundary.

Canadian Pacific Railway (CP) operations within the city currently consist of the CP Vancouver Intermodal Facility (VIF) and a 5.3 km long rail corridor with two mainline tracks. Approximately 28 freight trains use the corridor each day and additional processing of the trains occurs in the VIF. This rail activity supports a considerable amount of goods that move to and from the Port of Vancouver.

Port growth is expected in future years and that growth will lead to additional freight trains travelling along the mainline on a daily basis. CP has indicated that they are planning to extend their existing lead track from the east end of the VIF as well as adding a new rail siding alongside the VIF. It is understood that the future lead track extension and new siding will accommodate activities currently happening on the north mainline. Additionally, the CP Logistics Park: Vancouver (LPV) is at a proposal stage as a separate project in an area adjacent to the VIF.

This preliminary HHRA study includes air emissions from current locomotive operations within the city's boundary as well as two future operation scenarios; 2030 predicted locomotive operations without the LPV, and 2030 predicted locomotive operations with the addition of the proposed LPV as well as emissions related to heavy trucking associated with the proposed LPV operations. Current air quality in the area has also been reviewed and compared to applicable air quality standards and objectives. The main aspect of this study looks at human health concerns associated with diesel combustion emissions (DE) from rail activities. Many air contaminants are emitted from diesel engines and are evaluated in this study.

It should be noted that detailed CP rail operational data was not provided by CP to the project team or City staff. Hence, to identify the maximum potential health impacts and locations where they may occur, the operating scenarios and their related air emissions modelling were based on estimated worst-case activity levels (based on understanding of rail operations in Pitt Meadows and available research on comparable railyard operations, such as those identified in risk assessments of the major rail yards in California [1]).

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[1] California Air Resources Board - *Railyard Health Risk Assessments*

## 1.2 Evaluated Scenarios

The following scenarios were evaluated in this study. Details of these scenarios are expanded upon further in **Sections 4.3, 4.4**, and **4.5.**

- **Scenario 1** – Current rail operations in the City of Pitt Meadows including freight and passenger rail traffic on the two mainline tracks through the city as well as operations of diesel locomotives at the CP Vancouver Intermodal Facility (VIF). On average, 28 freight trains use the corridor each day, along with 10 West Coast Express (WCE) passenger trains (5 westbound in the morning, 5 eastbound in the evening).
- **Scenario 2** – Future (2030) rail operations based on a predicted increase in rail traffic to 59 freight trains using the corridor per day, plus current operations occurring on the north mainline track moving to the extension of the lead track from the east end of the VIF, and a new rail siding alongside the VIF.
- **Scenario 3** – Future (2030) rail operations as evaluated in Scenario 2 with the addition of predicted locomotive operations at the proposed CP Logistics Park: Vancouver (LPV) located to the south of the VIF and mainline at the west end of Pitt Meadows. In addition to evaluation of locomotive emissions, the proposed LPV is predicted to have significant heavy truck operations and emissions from these heavy trucks were also considered.

## 1.3 Limitations

Estimating air emissions from rail operations can be challenging for a number of reasons. Many variables influence emissions of air contaminants from diesel locomotives including, but not limited to: the model and age of the locomotive, track grade and curvature, train speed, train scheduling etc. Limited data on these variables, especially on a local level, is a common limitation across all rail emissions studies and therefore assumptions need to be made to predict air emissions.

Two main factors that influence the calculated air emissions and dispersion modelling used in this study are activity levels, and characterization of emission sources.

With regards to rail activity levels, it should be noted that information provided by CP regarding the operations within the VIF and anticipated operations at the proposed LPV was limited in detail. Therefore, through consultation with the City of Pitt Meadows, the project proceeded with activity level estimates based on the limited information provided and available information on activity levels at similar size rail facilities. Where ranges of potential activity values were considered, values on the upper end of the range were selected to avoid underestimating emissions (i.e., a conservative approach was taken).

With regards to the characterization of emission sources, due to limitations of the available data, identifying the exact locomotives and variables influencing their emission rates (e.g., throttle settings or emission control features) were not feasible. This is a common limitation across studies of rail emissions. In this study, rail emission sources were characterized using similar methodology to other studies of similar facilities as described in **Section 4.0**. Emission factors (i.e., representative values identifying the amount of a pollutant released by an activity, for example, the amount of particulate matter emitted per litre of diesel used) were identified from the Railway Association of Canada (RAC) annual report [2], as applied by the Vancouver Fraser Port Authority (VFPA) for their 5-year regional emission inventories. RAC emission factors are categorized by locomotives used for freight line haul, yard switching, and passenger transport as the locomotives used for these activities differ, but emission factors are averaged across the makeup of the national fleet of rail locomotives in terms of specific models and the age of locomotives. The makeup of the locomotive fleet may be slightly different on a local level resulting in higher or lower emission rates. RAC emission rates used for all scenarios in this study are based on the most recent year available (2018). Please note that emission rates may decrease ahead of the 2030 scenarios modelled, as a percentage of older locomotives may be retired from the fleet and replaced with new locomotives with improved emission controls. Emissions from new and rebuilt locomotives are required to meet the emission standards set out by the Canadian Locomotive Emissions Regulations enforced by Transport Canada.

Truck emissions associated with the proposed LPV were based on anticipated truck volumes/activities provided by CP and were estimated using the US EPA Motor Vehicle Emission Simulator, also known as MOVES [3]. Variables influencing emissions related to truck movements/activity include but are not limited to: travel speeds, travel distances, idling times, road grade, area of assessment, vehicle age, and climatic conditions. Limited data on some of these variables, especially on a local level, is a common limitation in studies without an in-depth traffic assessment and therefore assumptions need to be made to predict air emissions. Where specific information was not available in certain model input areas (e.g., vehicle age distribution), either default model settings or conservative estimates were assumed. Similar to rail estimates, please note that trucking emissions may decrease ahead of the 2030 scenario depending on potential emission improvements/implementation of other fuel-based transport options (e.g., electric trucks, biofuels, etc.).

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[2] Railway Association of Canada – *Locomotive Emissions Monitoring Report 2018*
[3] U.S. Environmental Protection Agency – *MOVES3 Model*

# 2.0 BACKGROUND

This section provides the background information used in the air quality assessment of the railway emissions including air emission contaminants, emission sources, modelling scenarios, relevant ambient air quality objectives and methodology for the assessment.

## 2.1 Air Emission Contaminants

The following air contaminants are considered in this air quality assessment:

- Diesel particulate matter (DPM),
- Fine particulate matter ($PM_{2.5}$),
- Nitrogen Oxide ($NO_2$),
- Sulphur Oxide ($SO_2$),
- Carbon Monoxide (CO), and
- Hydrocarbons (HC) [4].

In addition to the air contaminants assessed in the air quality assessment, additional Hazardous Air Pollutants (HAPs) are assessed in the preliminary HHRA through scaling of the predicted DPM and total hydrocarbon concentrations into individual components of these contaminant groups, using speciation profiles for locomotive and heavy truck emissions (approach described in **Sections 4.1**, and **4.2**, respectively). The full list of Contaminants of Potential Concern (COPCs) assessed in the preliminary HHRA are presented in **Table 6-1**.

While ozone is an air contaminant that is regularly of interest and has air quality objectives and standards at various levels, it was not the focus of this study as predicting ozone concentrations is reliant on more complex modelling that considers chemical transformation in the atmosphere on a regional scale and requires more detailed information on all emissions in an airshed (rather than focusing on one source such as rail operations).

## 2.2 Air Emission Sources

As noted in **Section 1.2**, three scenarios were considered for this assessment:

- Scenario 1: Current rail operations,
- Scenario 2: Predicted rail operations in 2030, and
- Scenario 3: Predicted rail operations in 2030 with the addition of the proposed LPV.

Emission sources considered in this study include freight and passenger rail traffic and idling on the mainline tracks through the city. On-site freight movement/switching/idling activities at the VIF and LPV (for current and future scenarios as applicable) are also included in emission estimates. For Scenario 3, project related trucking emissions associated with the LPV were also modelled. Additional details for emission estimates and the air dispersion modelling study conducted as a part of this assessment are provided in **Sections 4** and **5,** respectively.

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[4] *Total hydrocarbon emissions and predicted concentrations are included for speciation into individual HAPs in the preliminary HHRA only, and are not evaluated as a whole.*

## 2.3 Relevant Ambient Air Quality Objectives (AAQOs)

Ambient Air Quality Objectives (AAQOs) are set at federal, provincial, and regional levels. These are targets that define the acceptable outdoor concentration of key air contaminants, informed by human and environmental health considerations. Metro Vancouver has delegated authority under the *BC Environmental Management Act* to manage air quality within the region. Metro Vancouver uses a variety of approaches to manage air contaminants in the region, including AAQOs. Metro Vancouver uses AAQOs to:

- Assess regional and local air quality,
- Support the development of air quality management plans and regulations, and
- Guide air management and decisions, including when to issue permits and air quality advisories.

Metro Vancouver AAQOs are in line with (or in some cases more stringent than) the federal Canadian Ambient Air Quality Standards (CAAQS) and the provincial British Columbia Ambient Air Quality Objectives. The relevant Metro Vancouver AAQOs have been presented in **Table 2-1**. The CAAQS are planned to decrease in 2025 for $NO_2$ and $SO_2$ and these lower objectives are also presented. Metro Vancouver's 2025 objectives are expected to be at least as stringent as the federal CAAQS. AAQOs are presented in units of micrograms per cubic metre of air (µg/m$^3$).

It should be noted that ambient air quality objectives are not based solely on health effects; therefore, further health-based thresholds and objectives for other parameters are considered in the preliminary HHRA aspect of this study.

**Table 2-1: Relevant Metro Vancouver Ambient Air Quality Objectives**

| Air Contaminant | Averaging Period | Metro Vancouver Objectives [a] *(µg/m$^3$)* |
|---|---|---|
| **Carbon Monoxide (CO)** | 1-hour<br>8-hour [b] | 14,900<br>5,700 |
| **Fine Particulate Matter ($PM_{2.5}$)** | 24-hour [b]<br>Annual | 25<br>8 (6) [d] |
| **Nitrogen Dioxide ($NO_2$)** | 1-hour [c]<br>Annual | 113 (CAAQS 2025 - 79) [e]<br>32 (CAAQS 2025 - 23) [e] |
| **Sulphur Dioxide ($SO_2$)** | 1-hour<br>Annual | 183 (CAAQS 2025 - 173) [e]<br>13 (CAAQS 2025 - 11) [e] |

(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) *Objectives based on rolling average.*
(c) *Achievement based on annual 98th percentile of the daily maximum 1-hour concentration, averaged over three consecutive years.*
(d) *Metro Vancouver's annual $PM_{2.5}$ planning goal of 6 µg/m$^3$ is a longer-term aspirational target to support continuous improvement.*
(e) *The 2025 Canadian Ambient Air Quality Standards (CAAQS) are presented as context for how Metro Vancouver's AAQO's may decrease for $NO_2$ and $SO_2$ in 2025.*

## 2.4 Methodology for Assessment

The methodology for this assessment can be broken into three main stages:

1. Emissions inventory calculations to predict the emissions associated with each scenario,
2. Air dispersion modelling to predict the dispersion of the calculated emissions in the areas surrounding the rail operations, and predict ground level air contaminant concentrations, and
3. Preliminary human health risk assessment to evaluate the health risks associated with the worst-case predictions of air contaminant concentrations.

Methodology for each of these project stages is described below. Prior to these steps of this assessment, a review of background air quality in the project area was conducted and is described in **Section 3**. The focus of this study was to assess the impact of rail operations in Pitt Meadows; therefore, the emissions from railway operations only were considered for evaluation without the addition of background concentrations. The preliminary HHRA methodology used in this study is described in **Section 6.0.**

### Emissions Inventory

Emissions associated with rail operations in each of the three scenarios identified were calculated using a combination of activity estimates and published emission factors (e.g., mass of pollutant emitted per litre of diesel consumed in g/L). Where specific operational information/details were not available or provided, conservatively high activity level estimates were used to ensure emission projections were not underestimated. Through the emissions inventory calculations, the expected emission rates were calculated for use in the air dispersion modelling. Average emission rates were calculated based on typical daily activity levels for evaluation of air contaminants where 24-hour or annual AAQOs and health thresholds exist, and worst-case maximum hourly emission rates were calculated based on estimated maximum hourly activity levels for evaluation of air contaminants where 1-hour AAQOs and acute health thresholds exist.

The emissions inventory methodology is described in more detail in **Section 4.0.**

### Air Quality Dispersion Modelling

Air quality dispersion modelling was then conducted to predict the dispersion of the emissions calculated in the emission inventory, and predict ground level concentrations of the various air contaminants of interest. Modelling was performed using the CALPUFF air dispersion modelling system and followed the British Columbia Air Quality Dispersion Modelling Guideline 2021 (BC AQDMG) [5]. The BC AQDMG provides key guidance on a variety of topics including: model selection, application of models for regulatory purposes in BC, and best modelling practices. The CALPUFF modelling system consists of two main model packages including CALMET, a diagnostic 3-dimensional meteorological model, and CALPUFF, an air quality dispersion model.

The air dispersion modelling methodology is described in more detail in **Section 5.1.**

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[5] British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *British Columbia Air Quality Dispersion Modelling Guideline.*

### Preliminary Human Health Risk Assessment

From the results of the dispersion model, a preliminary HHRA was then completed to provide context to the potential health effects/impacts of project related emissions. An HHRA is a scientific process that estimates the potential toxicological human health risks from exposure to chemical contaminants in environmental media. An HHRA determines if contaminant(s) with potential health effects are present, if human receptor(s) are present, and if there are exposure pathways from the contaminant(s) to the human receptor(s), which could result in risks to health. The methodology for conducting this HHRA follows guidance published by Health Canada outlining the best practices and approaches to HHRAs [6]. This study is referred to as a *preliminary* human health risk assessment as it assesses exposures that are based on estimated emissions and model predictions of air contaminant concentrations and is an appropriate level of assessment for the scope of this study. This study also assesses worst-case exposures only with regards to acute health effects (note that model predicted annual average exposures are used for assessment of chronic health risks).

A summary of the inputs and components included in the HHRA is summarized in **Figure 2-1**.

The preliminary human health risk assessment methodology is described in more detail in **Section 6.05.1.**

[6] Health Canada, 2016 – *Human Health Risk Assessment for Diesel Exhaust*, and Health Canada, 2021 - *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0*

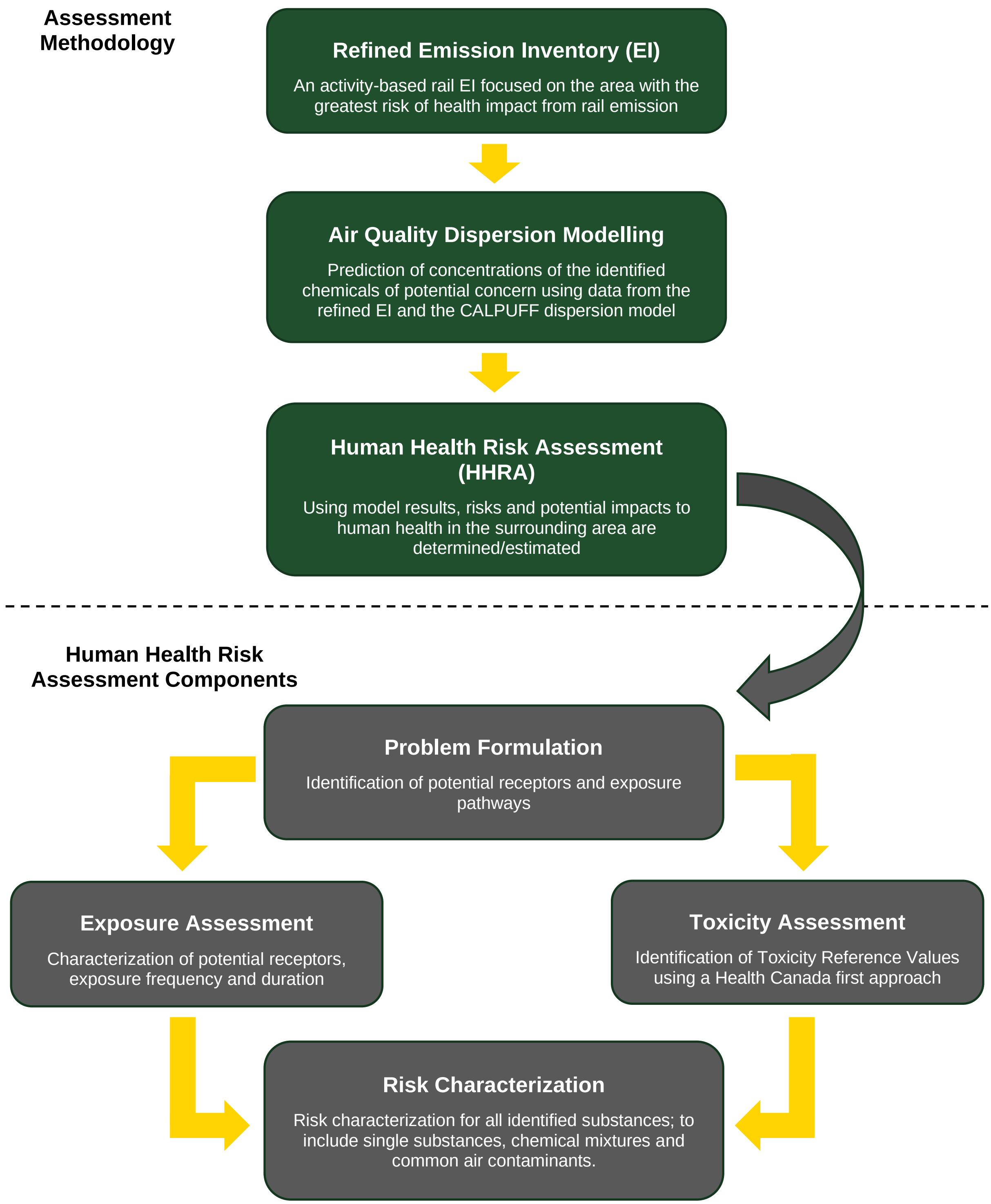



**Figure 2-1: Flow Chart of the Development of the Human Health Risk Assessment**

# 3.0 BASELINE AIR QUALITY REVIEW

Existing air quality in the area is affected by many emission sources including: vehicles and roads, construction projects, natural sources, industrial sources and rail activity (the focus of this study). Metro Vancouver operates an extensive network of ambient air quality monitoring stations that measure criteria air contaminants (CACs). **Figure 3-1** shows Metro Vancouver meteorological and ambient air quality monitoring stations, including the T20 station which is operated in Pitt Meadows.

To evaluate the existing ambient air quality in the area, historical hourly air quality data from the Pitt Meadows station was obtained from Metro Vancouver for the most recent four-years and compiled to achieve the relevant time-based averaging period to be compared with the related ambient air quality objectives.

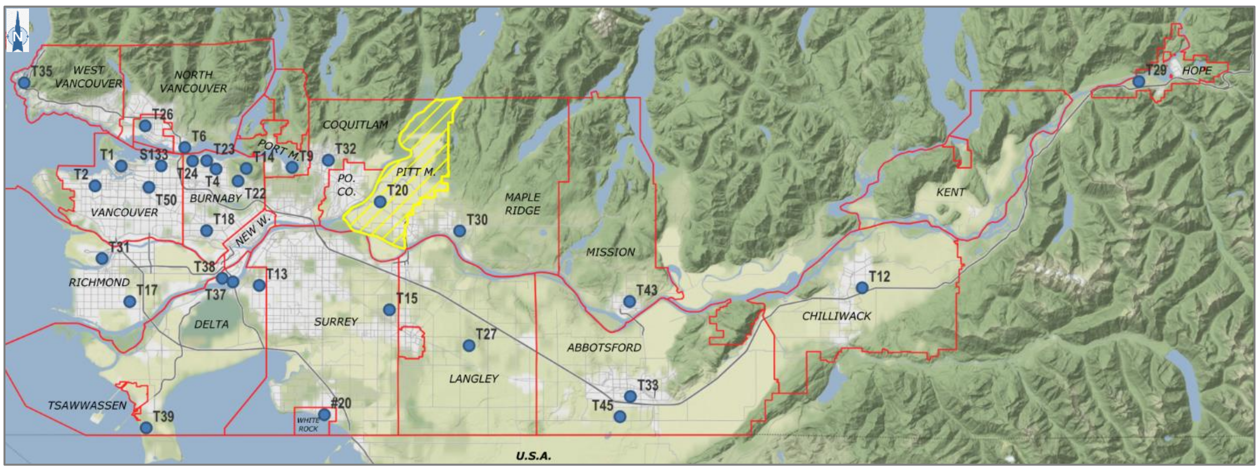



**Figure 3-1. Metro Vancouver Air Quality Monitoring Station Network**

*Blue circles indicate the locations of Metro Vancouver air quality monitoring stations. Red outlines indicate municipal boundaries within the region with the City of Pitt Meadows highlighted in yellow.*

*Map tiles by Stamen Design, under CC BY 3.0. Base map data by OpenStreetMap, under OdbL.*

## 3.1 Pitt Meadows Air Quality Monitoring Station

The Metro Vancouver Pitt Meadows air quality monitoring station (T20) is operated on Old Dewdney Trunk Road. This location is approximately 700 m to the north of the CP VIF boundary, and 1 km from the rail mainline. The surrounding area to the north and east of the station is primarily agricultural land. South of the station is Lougheed Highway (~600 m), and the urban areas of Pitt Meadows. The Pitt River is to the west of the station, with the CP Coquitlam rail yard and Coquitlam urban areas on the west side of the river.

To add context to the air quality measured at the monitoring station, wind patterns using the hourly data at the monitoring station were evaluated and show that wind patterns in the area are dominated by winds flowing out of the valley between Coquitlam Mountain and Golden Ears and containing Pitt Lake, as seen in annual wind roses presented in **Table 3-1** and an overall wind rose from 2017-2020 in **Figure 3-2**. Wind patterns are very similar between the years analyzed.

***<u>How to read a wind rose</u>***

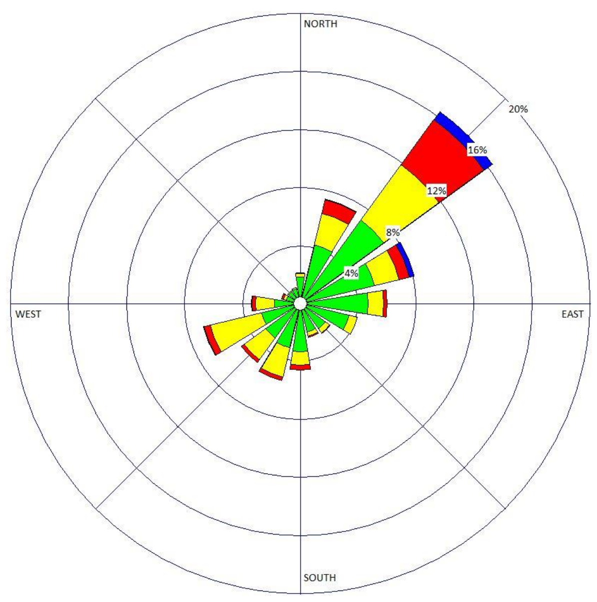
*Wind rose diagrams are used to show the general wind direction and speed patterns at a location for a period of time. The circular format of the wind rose shows the direction the winds blew from and the length of each "spoke" around the circle shows how often the wind blew from that direction. For example, the wind rose for 2017 in* ***Table 3-1*** *below shows that during this particular period (2017) the wind blew from the northeast approximately 16% of the time, and from the east approximately 6% of the time, etc.*

*The different colors of each spoke provide details on the wind speed, in metres/second (1 m/s = 3.6 km/h), of the wind from each direction. Using the 2017 example, the longest spoke shows the wind blew from the northeast at speeds between 0.50 - 2.10 m/s (green) about 7% of the time, 2.10 - 3.60 m/s (yellow) about 5% of the time, 3.60 – 5.70 m/s about 3.5% of the time and 5.70 - 8.80 m/s (dark blue) about 0.5% of the time.*

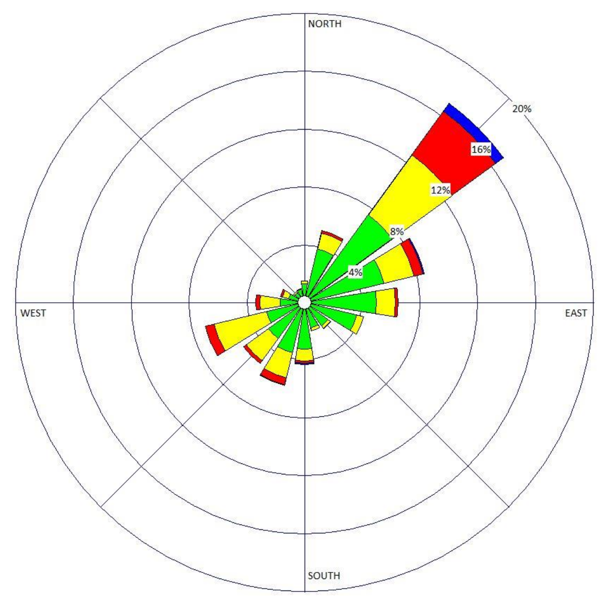
**Table 3-1: Wind Rose Showing Wind Patterns Measured at the Pitt Meadows Air Quality Monitoring Station (2017, 2018, 2019, and 2020)**

*Direction shown as 'wind blowing from'.*

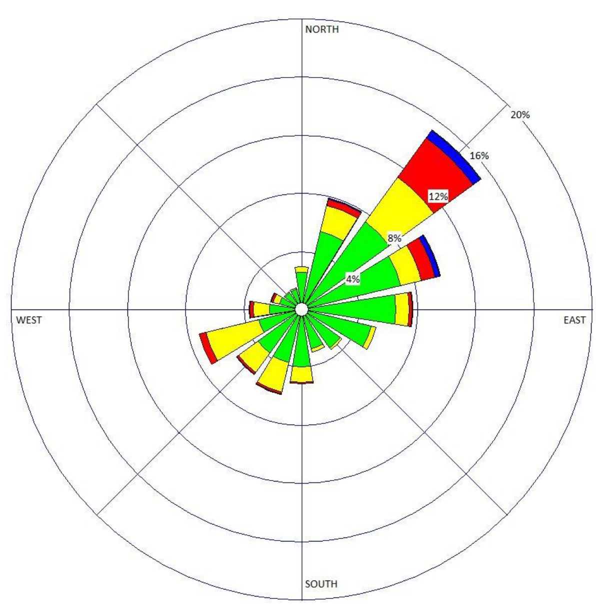
**2017**



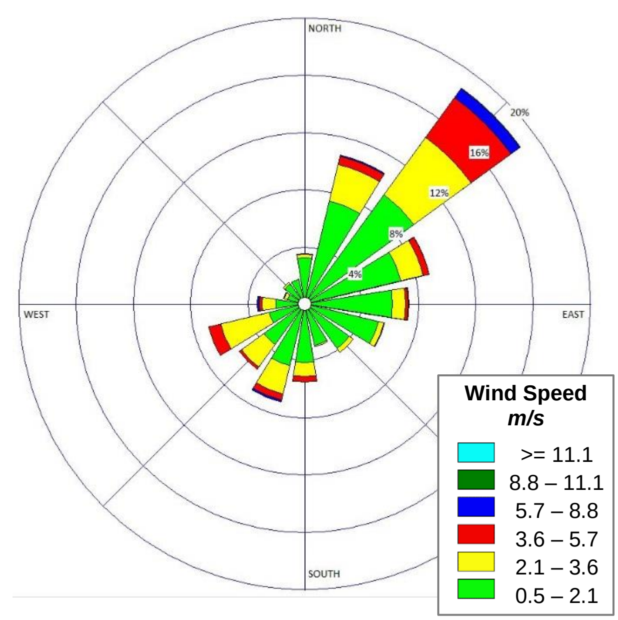

**2018**




**2019**




**2020**



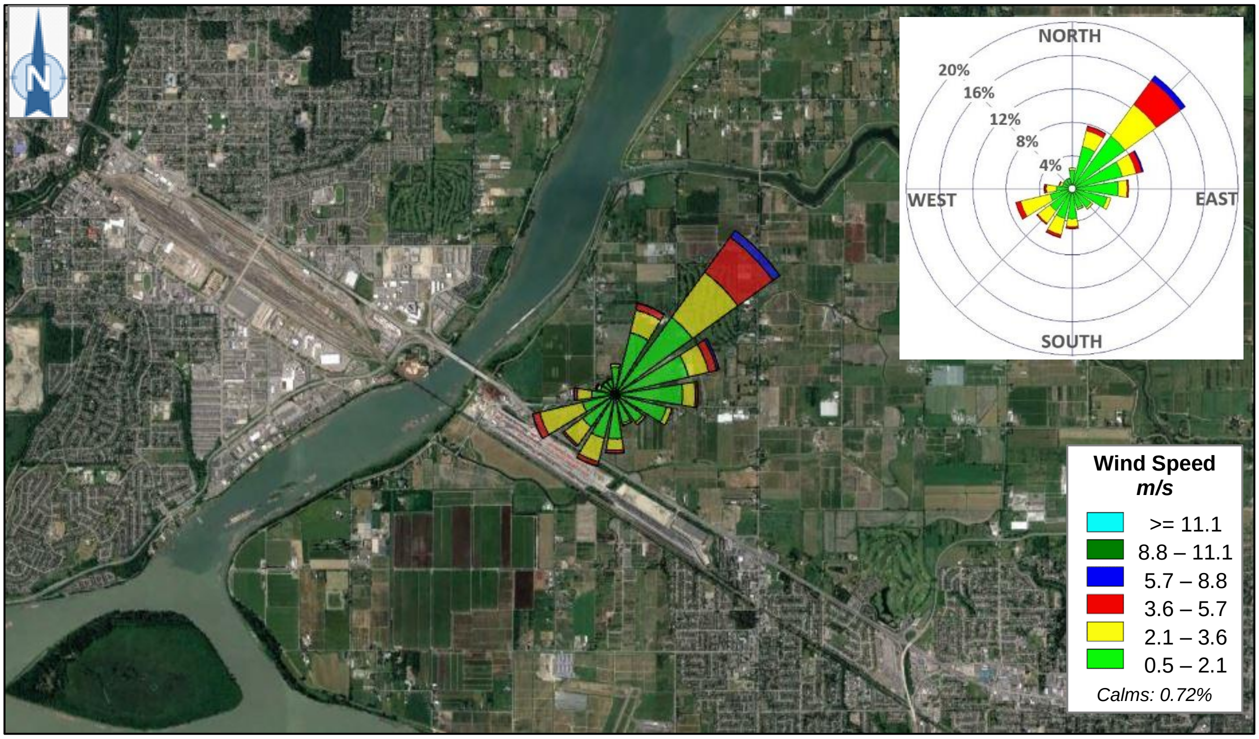



**Figure 3-2: Wind Rose Showing Wind Patterns Measured at the Pitt Meadows Air Quality Monitoring Station (2017-2020 Inclusive)**

*Direction shown as 'wind blowing from'.*

$PM_{2.5}$ and $NO_2$ hourly monitoring data were compared to the wind directions at the time of measurement from 2017 to 2020 and are presented in **Table 3-2**. At times where wind directions are from the south, higher concentrations of $PM_{2.5}$ and $NO_2$ appear to be measured more frequently compared to when wind direction is from the north.

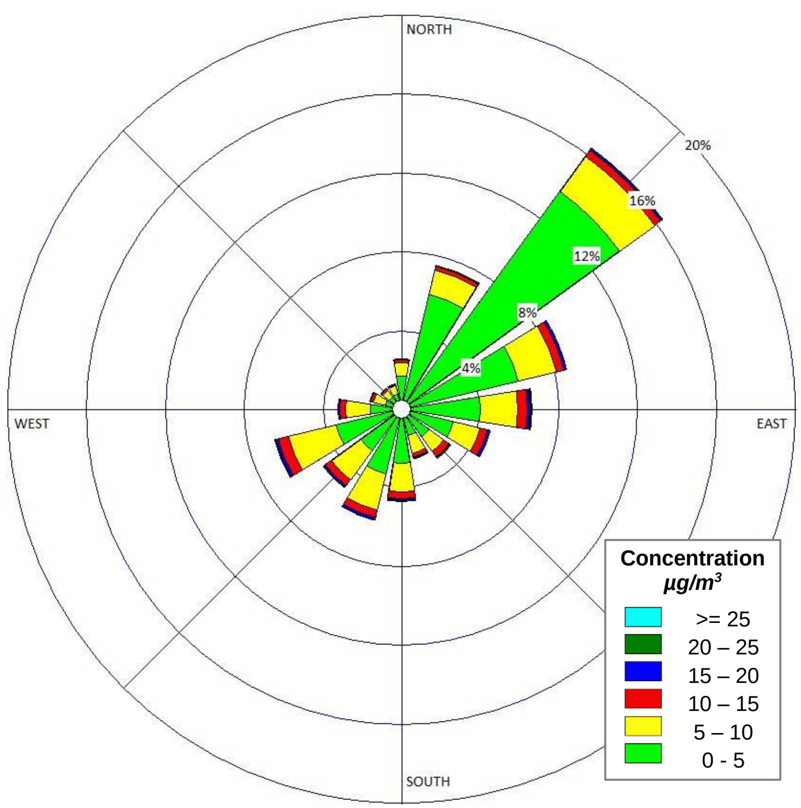
***How to read a pollution rose***

*Pollution rose diagrams are used to show the general wind direction and contaminant concentration patterns for a substance at a location for a period of time. The circular format of the pollution rose shows the direction the winds blew from and the length of each "spoke" around the circle shows how often the wind blew from that direction.*

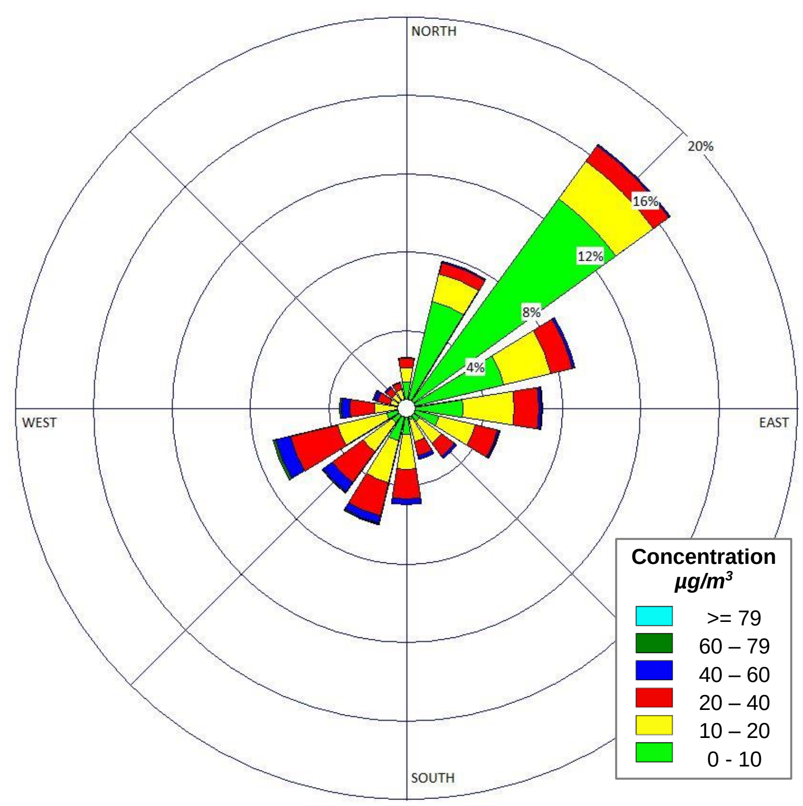
*The different colors of each spoke provide details on the typical concentration readings for the contaminant examined, in micrograms/cubic metres, at times the wind was blowing from each direction.*

**Table 3-2: Pollution Roses Showing Comparison of Measured $PM_{2.5}$ and $NO_2$ Concentrations and Wind Direction at the Pitt Meadows Air Quality Monitoring Station**

**Fine Particulate Matter ($PM_{2.5}$)**




**Nitrogen Dioxide ($NO_2$)**




(a) *Direction shown as 'wind blowing from'*

(b) *$PM_{2.5}$ data excludes dates where Metro Vancouver Air Quality Advisories were in place due to wildfire smoke.*

## 3.2 Calculated Background Air Quality

For this study, appropriate time-based averages of the historical monitoring data from T20 station (Pitt Meadows) were calculated based on the British Columbia Air Quality Dispersion Modelling Guideline [7]. As carbon monoxide is assessed in the air quality aspect of this study and as background data for CO is not recorded at station T20 (Pitt Meadows), data from the closest station with available CO data was assessed (the Metro Vancouver T30 Maple Ridge air quality monitoring station).

Annual averages of hourly data are calculated for each of the four years and for short-term periods (i.e., maximum 1-hour and 24-hour values) the applicable percentile of each time-based averages of the data were calculated based on the BC AQDMG. The BC AQDMG recommends using 98$^{th}$ percentiles to establish background values for short-term averaging periods (i.e., 1-hour and 24-hour) for most contaminants to be used in dispersion modelling studies (please note 99$^{th}$ is recommended for $SO_2$). 98$^{th}$ percentiles are a common statistical approach to provide context on the high values observed in a dataset by calculating the maximum value or measurement which includes 98% of the data (i.e., only 2% of the data is above this value). It should be also noted that as per the BC AQDMG, the 1-hour $NO_2$ background data for the dispersion modelling purposes is calculated differently and is based on the 98$^{th}$ percentile of the daily maximum 1-hour values rather than all hourly data.

In recent years, wildfire smoke events have impacted the Metro Vancouver area, leading to episodes of elevated $PM_{2.5}$ concentrations. Therefore, in addition to evaluating all $PM_{2.5}$ data, $PM_{2.5}$ concentrations from dates not impacted by wildfire smoke were also reviewed. To do this, $PM_{2.5}$ data from the dates where Metro Vancouver air quality advisories were in place were removed from consideration to exclude the impact of these high concentrations on the calculation of background averages.

The calculated background air quality data are presented in **Table 3-3**. The background air quality data can be also compared to each of the relevant Metro Vancouver ambient air quality objectives as applicable to have a general understanding of the current air quality in the region. In addition to the applicable background air quality data, other measures such as average, median, and the 98$^{th}$ percentile of the data are presented in this table for further statistical information on the general air quality in the region.

It should be noted that although the review of background air quality data is included here, model predicted air contaminant concentrations based on the emission estimates only were evaluated, without the addition of background concentrations, in order to assess the impact of rail operations in Pitt Meadows.

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[7] British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *British Columbia Air Quality Dispersion Modelling Guideline.*

**Table 3-3: Background Air Quality Concentrations for T20 Pitt Meadows Air Quality Monitoring Station (2017-2020)**

| Air Contaminant | Averaging Period | Ambient Air Quality Objective *(µg/m³)* | Measure | Year(s) of Analysis Monitoring Data | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2017 | 2018 | 2019 | 2020 | 2017-2020 |
| $PM_{2.5}$ *All Data* | 24-hour Rolling Average | 25 | Maximum *(24-hour Rolling Average)* | 63.0 | 115.3 | 24.2 | 153.9 | 153.9 |
| | | | 98th Percentile *(of 24-hour Rolling Averages)* | 38.8 | 31.2 | 13.2 | 52.6 | 25.3 |
| | Annual | 8 (6) | Average | 6.1 | 6.8 | 5.2 | 6.2 | 6.1 |
| | | | Median | 3.8 | 4.5 | 4.4 | 3.5 | 4.0 |
| $PM_{2.5}$ *With Wildfire Smoke Events Excluded* (a) | 24-hour Rolling Average | 25 | Maximum *(24-hour Rolling Average)* | 18.3 | 28.0 | 24.2 | 18.5 | 28.0 |
| | | | 98th Percentile *(of 24-hour Rolling Averages)* | 14.4 | 13.9 | 13.2 | 11.3 | 13.5 |
| | Annual | 8 (6) | Average | 4.7 | 5.4 | 5.2 | 4.3 | 4.9 |
| | | | Median | 3.6 | 4.3 | 4.4 | 3.4 | 3.9 |
| $NO_2$ | 1-hour | 113 (2025 CAAQS of 79) | Maximum | 92.2 | 84.9 | 93.9 | 86.3 | 93.9 |
| | | | 98th Percentile *(All Data)* | 58.0 | 49.3 | 51.6 | 44.2 | 51.4 |
| | | | 98th Percentile of Daily 1-hour Maximums (b) | 76.1 | 71.2 | 79.8 | 63.3 | 73.9 |
| | Annual | 32 (2025 CAAQS of 23) | Average | 18.1 | 16.5 | 16.2 | 13.2 | 16.0 |
| | | | Median | 14.7 | 13.6 | 13.4 | 10.1 | 12.8 |
| $SO_2$ | 1-hour | 183 (2025 CAAQs of 173) | Maximum | 30.3 | 14.1 | 18.6 | 13.6 | 30.3 |
| | | | 99th Percentile | 6.7 | 5.3 | 5.9 | 3.7 | 5.9 |
| | Annual | 13 (2025 CAAQs of 11) | Average | 1.1 | 0.9 | 1.0 | 0.7 | 0.9 |
| | | | Median | 0.5 | 0.5 | 0.5 | 0.0 | 0.5 |
| CO (c) | 1-hour | 14,900 | Maximum | 1,921 | 1,735 | 1,432 | 2,247 | 2,247 |
| | | | 98th Percentile | 769 | 652 | 571 | 843 | 675 |
| | 8-hour Rolling Average | 5,700 | Maximum | 1,195 | 1,351 | 852 | 2,140 | 2,140 |
| | | | 98th Percentile | 700 | 568 | 504 | 867 | 603 |

*(a) Data from dates during Metro Vancouver air quality advisories for wildfire smoke was removed from consideration in the analysis of monitored $PM_{2.5}$ concentrations.*

*(b) The 98th percentile of 1-hour daily maximums is presented for $NO_2$ as this is the exceedance criteria for the Metro Vancouver AAQO.*

*(c) CO not recorded at T20 Pitt Meadows air quality monitoring station. Hence, data for CO was obtained from the next closest air quality monitoring station - Metro Vancouver T30 Maple Ridge.*

## 3.3 Comparison of Background Concentrations to Metro Vancouver Ambient Air Quality Objectives

For each of the four years analyzed, none of the calculated annual average background concentrations exceeded the existing annual Metro Vancouver AAQO's as seen in **Table 3-3**. In the case of $PM_{2.5}$, the annual averages were each below the current objective of 8 µg/m$^3$ but in all years except 2019 they were above the long-term planning goal of 6 µg/m$^3$. When $PM_{2.5}$ calculations were performed for the dates where wildfire smoke was not impacting the airshed (data from dates where Metro Vancouver air quality advisories were in place were removed), the annual averages were each below the long-term planning goal of 6 µg/m$^3$.

For the short-term Metro Vancouver ambient air quality objectives (i.e., 24 hour rolling averages and 1 hour average), the frequency of exceedance was calculated and is presented in **Table 3-4**. Aside from periods with wildfire smoke impacts, the analysis indicates the regional air quality measured at the Metro Vancouver monitoring station is generally within the Metro Vancouver AAQOs.

In most cases Metro Vancouver's AAQOs "…are not to be exceeded, meaning the objective is achieved if 100% of the validated measurements are at or below the objective level". It should be noted that the $NO_2$ objective is evaluated differently and is based on the annual 98$^{th}$ percentile of the daily maximum 1-hour objectives averaged over three consecutive years.

**Table 3-4: Background Air Quality Comparison to Short-Term Metro Vancouver Ambient Air Quality Objectives**

| Air Contaminant | Averaging Period | Objective µg/m³ | Measure | Year(s) of Analysis | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2017 | 2018 | 2019 | 2020 | 2017-2020 |
| **$PM_{2.5}$** *All Data* | 24-hour Rolling Average | 25 | Number of Exceedances | 272 | 218 | 0 | 198 | 688 |
| | | | Percentage of Exceedances (a) | 3.11% | 2.49% | 0 % | 2.25% | 1.96% |
| **$PM_{2.5}$** *With Wildfire Smoke Events Excluded* (b) | 24-hour Rolling Average | 25 | Number of Exceedances | 0 | 13 | 0 | 0 | 13 |
| | | | Percentage of Exceedances | 0 % | 0.15% | 0 % | 0 % | 0.04% |
| **$NO_2$** | 1-hour | Current Objective: 113 | Number of Exceedances(c) | 0 | 0 | 0 | 0 | 0 |
| | | | Percentage of Exceedances (c) | 0 % | 0 % | 0 % | 0 % | 0 % |
| | | 2025 CAAQs: 79 | Number of Exceedances (c) | 8 | 4 | 16 | 1 | 29 |
| | | | Percentage of Exceedances (c) | 0.09% | 0.05% | 0.18% | 0.01% | 0.08% |
| **$SO_2$** | 1-hour | Current Objective: 183 | Number of Exceedances | 0 | 0 | 0 | 0 | 0 |
| | | | Percentage of Exceedances | 0 % | 0 % | 0 % | 0 % | 0 % |
| | | 2025 CAAQs: 173 | Number of Exceedances | 0 | 0 | 0 | 0 | 0 |
| | | | Percentage of Exceedances | 0 % | 0 % | 0 % | 0 % | 0 % |
| **CO (d)** | 1-hour | 14,900 | Number of Exceedances | 0 | 0 | 0 | 0 | 0 |
| | | | Percentage of Exceedances | 0 % | 0 % | 0 % | 0 % | 0 % |
| | 8-hour Rolling Average | 5,700 | Number of Exceedances | 0 | 0 | 0 | 0 | 0 |
| | | | Percentage of Exceedances | 0 % | 0 % | 0 % | 0 % | 0 % |

*(a) Percentage of hours exceeding is based on a count of available data (e.g. wildfire removed $PM_{2.5}$ is calculated as the number of 24 hour rolling averages above the objective divided by the total hours of remaining data after advisory dates were removed).*

*(b) Data from dates during Metro Vancouver air quality advisories for wildfire smoke was removed from consideration in the analysis of monitored $PM_{2.5}$ concentrations.*

*(c) The Metro Vancouver AAQO for 1-hour average $NO_2$ concentrations is assessed based on the 98$^{th}$ percentile over three consecutive years of the daily maximum 1-hour average values. This allows for up to 2% of the daily maximum values to be higher than the objective level before the objective is deemed to be exceeded.*

*(d) CO not recorded at T20 Pitt Meadows air quality monitoring station. Hence, data for CO was obtained from the next closest air quality monitoring station - Metro Vancouver T30 Maple Ridge.*

## 3.4 Preliminary Air Quality Monitoring Data

Preliminary air quality monitoring was conducted at a residence along the mainline approximately 500 m east of the Harris Road rail crossing between October and November, 2021 to explore the current air quality concentrations present in areas of Pitt Meadows closer to the rail operations. A continuous $PM_{2.5}$ monitoring instrument was installed in the garden of the residence which backs onto the rail line to measure ambient $PM_{2.5}$ concentrations along the rail line. Measured one-hour average concentrations are presented in **Figure 3-3** below. **Figure 3-4** presents the 24-hour rolling average concentration (which corresponds with the Metro Vancouver short-term AAQO) measured by the temporarily installed $PM_{2.5}$ monitoring instrument and comparison to the $PM_{2.5}$ concentrations measured at the Metro Vancouver T20 Pitt Meadows air quality monitoring station over the same time period.

As anticipated, concentrations of $PM_{2.5}$ (an air contaminant emitted by diesel combustion and other sources) were generally higher during this period at the temporary near-rail monitoring location than those reported by the Metro Vancouver T20 air quality monitoring station location, which is located further from specific $PM_{2.5}$ emission sources and where winds often blow from the northeast where fewer emission sources are located (as seen in **Figure 3-2**).

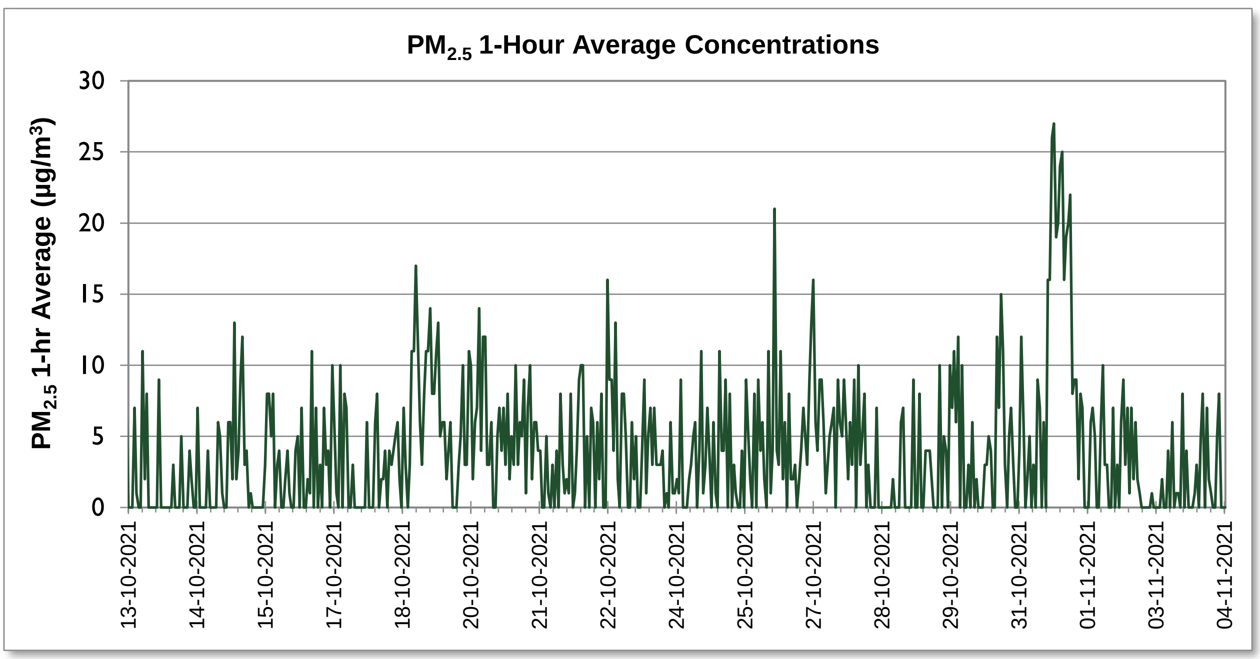


**Figure 3-3: $PM_{2.5}$ 1-hour Average Concentrations Measured by the Temporarily Installed $PM_{2.5}$ Instrument**

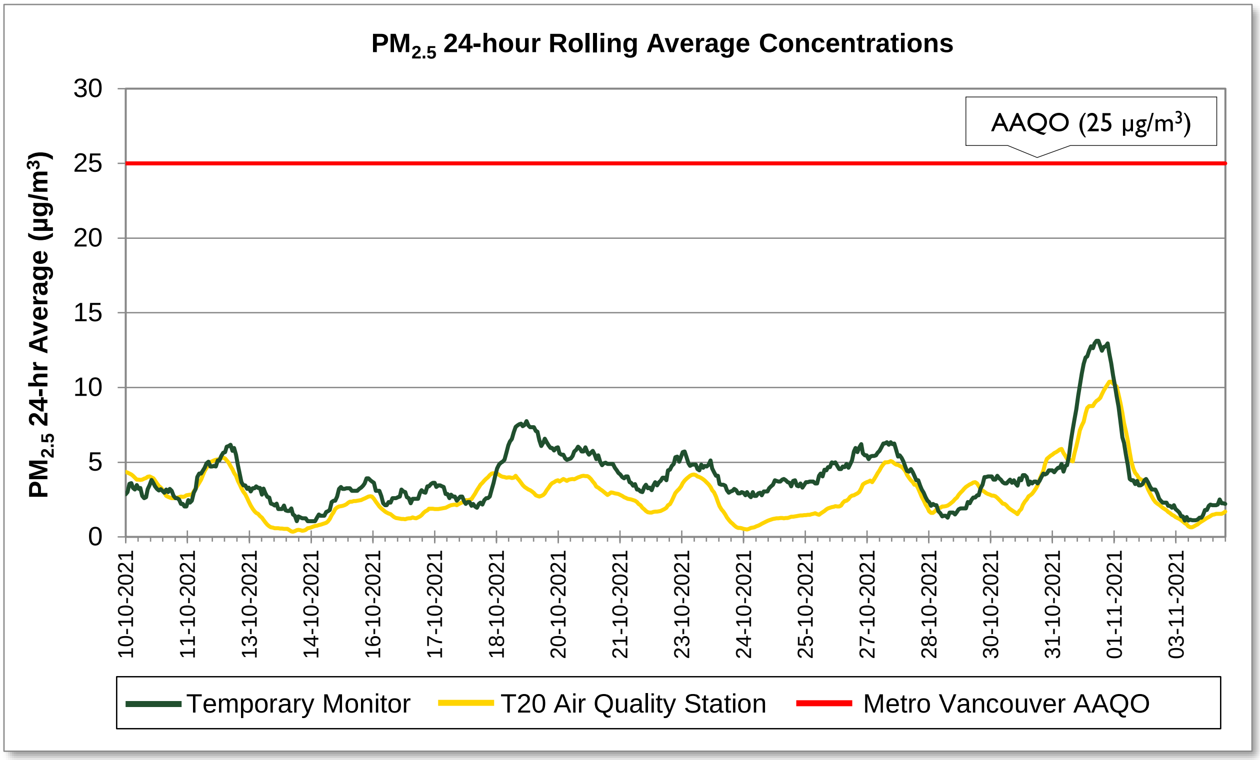


**Figure 3-4: $PM_{2.5}$ 24-hour Rolling Average Concentrations Measured by the Temporarily Installed $PM_{2.5}$ Instrument and at the Metro Vancouver T20 Air Quality Monitoring Station**

*Note: Data from the T20 station is presented as raw data and has not been passed through Metro Vancouver's data validation procedures which are conducted on an annual basis.*

# 4.0 EMISSIONS INVENTORY

Emissions considered in this study include locomotive emissions in all scenarios and truck-related emissions to/from the proposed LPV in Scenario 3. The methods used to estimate locomotive emissions and truck emissions are described in **Sections 4.1** and **4.2**, respectively. Emission estimates and details for each of the three scenarios are included in **Sections 4.3**, **4.4**, and **4.5** respectively.

## 4.1 Locomotive Emissions

The activity-based rail emissions inventories for the three scenarios and their various components (i.e., mainline, VIF, and proposed Logistics Park) are presented in **Table 4-3**, **Table 4-4**, and **Table 4-5** below. As noted in **Section 2.4** above, where specific information/details were not available or provided, conservatively high activity level estimates were established based on available information to ensure emission projections were not underestimated.

Diesel-electric locomotives operate with their engines in one of eight specific throttle positions known as notches, or with their engine idling. Annual and maximum hourly fuel consumption for the activities considered in each scenario (e.g., mainline travel, switching activities, idling, etc.) was therefore calculated based on fuel consumption rates for representative trains by notch setting utilization (i.e., the amount of time spent in each throttle position). A summary of the fuel consumption rates for the line-haul/passenger/switch locomotives used for this study is shown in **Table 4-1** below.

**Table 4-1: Fuel Consumption for Line Haul/Passenger, and Switcher Locomotives**

| Locomotive Type | Model | Fuel Consumption by Throttle Notch Position *(L/hour)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Idle | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | DB [(a)] |
| Line Haul/Passenger [8] | GE AC4400 | 11.4 | 45.4 | 102.2 | 204.4 | 299.1 | 397.5 | 530.0 | 647.3 | 794.9 | 44.4 |
| Switcher Locomotives [9] | SD40-2 | 20.8 | 34.4 | 94.3 | 156.7 | 216.5 | 299.0 | 410.7 | 549.6 | 634.8 | 79.5 |
| | GP38 | 17.4 | 26.5 | 60.6 | 118.9 | 177.2 | 241.5 | 314.6 | 389.1 | 463.3 | 56.8 |

[(a)] *DB = Dynamic Braking*

The locomotive engines assumed in this study were based on typical models expected in CP's fleet and switching yards. The GE AC4400 (a relatively high-powered locomotive typically used for line-haul operations) was used to model line-haul locomotives. The GE AC4400 was also used to model the typically lower powered passenger trains travelling/idling on the mainline, again, to ensure emissions

[8] U.S. EPA, 1998 – *Locomotive Emissions Standards, Regulatory Supporting Document*
[9] Railserve Leaf – *Utilizing Genset Technology in Locomotive Power at Intermodal Railyard Operations*

rates were not under-estimated. Switchers in the switching yards for the VIF and proposed Logistics Park were represented by SD40-2 and GP38 locomotive engine models based on available information.

The duty cycle (i.e., time spent in each throttle notch setting) and the associated fuel consumption rates for each activity considered in the study were based on a combination of available information, literature values, and estimates on the upper range of expected values. For line-haul trains, an average of operation in notches 4 and 5 were used to estimate train movements on the mainline. Notch 5 was used to estimate passenger train movements (based on communication with Translink - West Coast Express). The distribution of typical times spent in each notch position for switching activities were based on locomotive duty cycle data from the Railway Association of Canada (RAC) Locomotive Emissions Monitoring Program [10].

Once the annual and maximum hourly fuel consumption values for each activity were estimated based on activity times and the rates above, emission totals/rates were then calculated using fuel-based emission factors from the RAC Locomotive Emissions Monitoring Report [11]. These emission factors are based on active locomotive fleets for line-haul locomotives, yard switching locomotives, and passenger locomotives across Canada. Fuel-based emission factors from the most recent fleetwide study available (2018) were used and are summarized in **Table 4-2** for reference. The fuel-based emission factors used are consistent with those employed by the Vancouver Fraser Port Authority (VFPA) in their 5-year emission inventories for rail operation. It should be noted that these emission rates may decrease ahead of the 2030 scenarios modelled, as a percentage of older locomotives may be retired from the fleet and are rebuilt or replaced with new locomotives with improved emission controls. Emissions from new or rebuilt locomotives are required to meet the emission standards set out by the Canadian Locomotive Emissions Regulations.

**Table 4-2: Railway Association of Canada Fuel-Based Emission Factors**

| Locomotive Type | Emission Factor *(g/L)* | | | | |
|---|---|---|---|---|---|
| | Nitrogen Oxides (NOx) | Particulate Matter (PM) [(a)] | Carbon Monoxide (CO) | Hydrocarbons (HC) | Sulphur Dioxide ($SO_2$) |
| Freight: Line-Haul | 34.56 | 0.78 | 7.02 | 1.54 | 0.02 |
| Total Yard Switching | 56.67 | 1.18 | 7.35 | 3.33 | 0.02 |
| Total Passenger | 54.37 | 1.11 | 7.03 | 2.1 | 0.02 |

(a) *Based on correspondence with RAC, the PM emission factor here refers to $PM_{10}$ (particulate matter with a diameter of less than 10 microns). For the purposes of this study, it was assumed that PM, $PM_{10}$, $PM_{2.5}$ and DPM are equivalent from diesel locomotive combustion.*

[10] Railway Association of Canada – *Locomotive Emissions Monitoring Program 2008*
[11] Railway Association of Canada – *Locomotive Emissions Monitoring Report 2018*

Using the emission factors above and speciation profiles for locomotive emissions (i.e., the ratios of specific contaminants found in diesel emissions to total particulate matter or total hydrocarbons) recommended by port emission inventory guidance [12], additional hazardous air pollutants (HAPs) emissions from locomotive engines were estimated. Speciation profiles were applied to scale the identified base pollutant concentrations (i.e., PM or HC) to yield individual HAP emission rates (e.g., nickel emission rate was predicted by multiplying the PM emission rate by the nickel to PM ratio). To avoid underestimating emissions, the maximum speciation value found for each HAP across the locomotive engine types considered in the guidance (i.e., line haul, passenger, yard) was used.

## 4.2 Heavy Truck Emissions

Heavy truck emissions associated with the LPV in Scenario 3 were estimated using a combination of transportation model emission rates, established emission factors, and activity estimates. The scope of items considered in truck emission estimates include emissions from truck exhaust (from travelling/idling), emissions from brake/tire wear, and emissions from re-entrainment of road dust. The activity-based truck emissions inventories for Scenario 3 and the various components are presented in **Table 4-7**.

Emissions associated with truck exhaust and tire/brake wear were estimated using emission factors extracted from the US EPA Motor Vehicle Emission Simulator, also known as MOVES [13]. Emissions estimation in MOVES is dependent on several factors including travel speeds, area of assessment, vehicle age, and climatic conditions. Emission factors from combination short haul trucks were used as a basis for the emission calculations. Travel speeds were conservatively estimated to be below road/on-site speed limits to avoid underestimating emissions and account for the slower speeds typically associated with fully loaded heavy vehicles, road traffic, and controlled intersections. Where specific information was not available in certain input areas (e.g., vehicle age distribution) default model settings were used. Emission factors obtained from the EPA's MOVES model were then multiplied by activity estimates (e.g., total kilometers travelled, idling times, etc.) to yield total yearly emissions and emission rates.

As with locomotive engines, hazardous air pollutants (HAPs) from truck engine emissions were also estimated. HAPs from truck engine emissions were estimated using MOVES.

Road dust emissions associated with trucking activity from the LPV were estimated in accordance with the US EPA's Compilation of Air Pollutant Emission Factors known as AP-42. Specifically, equations/details from AP42 Section 13.2.1 – Paved Roads were used in road dust emission calculations [14]. Road dust kicked up from vehicle travel (i.e., re-entrainment) contributes to airborne particulate matter concentrations.

As noted above, heavy truck emissions were considered as an additional source for LPV operations only (Scenario 3) to account for anticipated increases in traffic-related emissions due to the project.

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[12] U.S. Environmental Protection Agency, 2020 - *Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions*
[13] U.S. Environmental Protection Agency – *MOVES3 Model*
[14] U.S. Environmental Protection Agency, 2011 – *AP-42 13.2.1 Paved Roads.*

## 4.3 Scenario 1 – Current Operations

The components included in Scenario 1 are reflective of current operations as a baseline for comparison with the future scenarios considered (i.e., Scenario 2 and 3).

Components included in Scenario 1 include emissions from the mainline from freight travel, emissions from the mainline from WCE passenger trains, idling emissions at the Pitt Meadows WCE station, and activities at the VIF rail yard.

Based on current traffic data, 28 freight trains were modelled to be travelling on the mainline each day. An additional 10 passenger trains per day were modelled to account for WCE traffic on the mainline.

Travel on the mainline was modelled including a buffer of 1 km either side of the City of Pitt Meadows boundary and was broken into three main sections of track (west, alongside, and east of the VIF) totaling 7.3 km. Travel times for each of the three sections of track were determined using section distances and maximum travel speed information provided by CP (speeds for eastbound travel is 25 mph over the Pitt River bridge and 60 mph when clear of bridge, speeds for westbound travel is maximum of 45 mph, slowing to 25 mph at the bridge). Since only maximum travel speeds were available, a 0.75 factor was applied to conservatively estimate the amount of time needed to cross each section of track. Four line-haul locomotives were assumed for each freight train travelling on the mainline and one locomotive per train was assumed for each passenger train travelling on the mainline. Based on correspondence with TransLink, 1.5 minutes at the WCE station was used to model locomotive idling time in addition to the modelled moving activity. A reduced speed was assumed for passenger train travel on the modelled mainline segment east of the VIF to account for additional time needed for slowing down and speeding up of trains from the stations.

Locomotive rail activity at the VIF was estimated based on provided daily traffic information:

- 2 trains departing eastbound per day,
- 2 trains terminating westbound per day,
- 1 shuttle train both arriving and departing to Deltaport.

Based on activity times from similar sized facilities/operations, switching times are typically 30-60 minutes for arrival trains and 45-90 minutes for departing trains/train make-ups. Since exact switching times at the VIF were not provided, the high end of the ranges noted above were used to model switching activities at the VIF (i.e., 60 minutes for arrival trains, and 90 minutes for departing trains/train make-ups). Four switch locomotives were assumed to be operational at the VIF as seen in studies of other similar sized rail facilities.

Using the activity estimates above, maximum 1-hour emission rates were determined. These emission rates reflect the expected worst-case scenarios associated with each activity (to avoid under-estimating emissions). A maximum of three freight trains and two passenger trains were expected in 1-hour. Maximum 1-hour emissions in the switching yard assumes all four switcher locomotives operating at the same time for the full hour.

Idling of a pair of locomotives was modelled on the north mainline track under the Bonson Road pedestrian bridge between two schools as a worst-case location scenario. Idling near the Bonson Road pedestrian bridge was assumed to occur for 30 minutes (based on on-site observations of train building during a departing train from the VIF) for both eastbound trains leaving the VIF facility per day for a total of one hour per day.

Additionally, idling emissions for two trains a day were also modelled on the existing north mainline track, again under the Bonson Road pedestrian bridge as a worst-case location scenario, to account for trains waiting for the Pitt River rail bridge to close (i.e., when the bridge is drawn up/not crossable due to vessel movements on the Pitt River). Idling was estimated to occur for 20 minutes for each bridge event. Idling trains waiting for the rail bridge to close were assumed to have four locomotives per train, consistent with line-haul trains noted in the sections above.

Maximum 1-hour emission rates for the locomotive idling activity associated with train building assumed two locomotives (at the front of a train) idling under the Bonson Road pedestrian bridge for the full hour. Maximum 1-hour emission rates for the mainline train idling waiting for the Pitt River rail bridge assumed all four locomotives on the train idling for the full duration of time estimated to wait for the bridge (20 minutes). As it is not possible for two trains to be idling on the same section of the north mainline in Scenario 1, the higher of these two calculated maximum hourly emission rates (lead track idling departing the VIF) were used to model maximum 1-hour rates for locomotive idling at this location.

A summary table including the estimated activity times/operational details included in this scenario and emission totals and rates are provided in **Table 4-3**.

**Table 4-3: Scenario 1 Emissions Inventory Summary**

| Scenario Details | | | | | | | | Annual | | | | | | | | Maximum 1-hour | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Emissions (Tonnes/yr) | | | | | | | Emissions (g/s) | | | | |
| Scenario Component | Activity | Modelled Sections | Length (m) | Number of Locomotives | Speed (km/h) | Minutes per Delivery/ Activity | Number of Deliveries per Day | Number of Deliveries per Year | Total Hours per Year | Calculated Fuel Consumption (L/yr) | CO | NOx | HC | DPM | SOx | Max 1-hour Deliveries/ Scenarios | Calculated Fuel Consumption in Maximum Hour (L/hr) | CO | NOx | HC | DPM | SOx |
| Freight Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 4 | 30.2 | 2.32 | 28 | 10220 | 395 | 549,656 | 3.86 | 19.00 | 0.85 | 0.43 | 0.01 | Max of 3 trains in one hour | 161.3 | 0.31 | 1.55 | 0.07 | 0.03 | 8.96E-04 [(a)] |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 495 | 689,739 | 4.84 | 23.84 | 1.06 | 0.54 | 0.01 | | 202.5 | 0.39 | 1.94 | 0.09 | 0.04 | 1.12E-03 |
| | | Mainline 3: East of VIF | 2,954 | | 63.4 | 2.8 | | | 476 | 663,677 | 4.66 | 22.94 | 1.02 | 0.52 | 0.01 | | 194.8 | 0.38 | 1.87 | 0.08 | 0.04 | 1.08E-03 |
| | VIF Departing Train Idling | LTI: Idling on mainline under Bonson Road Pedestrian Bridge | - | 2 | - | 30 | 2 | 730 | 365 | 8,293 | 0.06 | 0.29 | 0.01 | 0.01 | 1.66E-04 | 2 Locomotives in the front, idling for full hour | 22.7 | 0.04 | 0.22 | 9.72E-03 | 4.92E-03 | 1.26E-04 |
| | Idling waiting for the Pitt River rail bridge to close | SI: Idling on mainline under Bonson Road Pedestrian Bridge | - | 4 | - | 20 | 2 | 730 | 243 | 11,057 | 0.08 | 0.38 | 0.02 | 0.01 | 2.21E-04 | 4 Locomotives idling for 20 minutes | 15.1 [(b)] | - [(b)] | - [(b)] | - [(b)] | - [(b)] | - [(b)] |
| West Coast Express Passenger Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 1 | 30.2 | 2.32 | 10 | 3650 | 141 | 56,011 | 0.39 | 3.05 | 0.12 | 0.06 | 1.12E-03 | Max of 2 trains in an hour | 30.7 | 0.06 | 0.46 | 0.02 | 9.46E-03 | 1.71E-04 |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 177 | 70,286 | 0.49 | 3.82 | 0.15 | 0.08 | 1.41E-03 | | 38.5 | 0.08 | 0.58 | 0.02 | 0.01 | 2.14E-04 |
| | | Mainline 3: East of VIF | 2,954 | | 31.7 | 5.59 | | | 340 | 135,260 | 0.95 | 7.35 | 0.28 | 0.15 | 2.71E-03 | | 74.1 | 0.14 | 1.12 | 0.04 | 0.02 | 4.12E-04 |
| | Idling | At WCE Station | - | | - | 1.5 | | | 91 | 1,037 | 7.29E-03 | 5.64E-02 | 2.18E-03 | 1.15E-03 | 2.07E-05 | | 0.568 | 1.11E-03 | 8.58E-03 | 3.31E-04 | 1.75E-04 | 3.16E-06 |
| VIF | Moving freight/ switching/ idling | VIF | - | 4 | - | 90 | 3 Departing | 1095 | 1643 | 223,333 | 1.64 | 12.66 | 0.74 | 0.26 | 4.47E-03 | Max operation of 4 locomotives at once | 136 | 0.28 | 2.14 | 0.13 | 0.04 | 7.55E-04 |
| | | | | | - | 60 | 3 Arriving | 1095 | 1095 | 148,888 | 1.09 | 8.44 | 0.50 | 0.18 | 2.98E-03 | | | | | | | |

*(a) Written in scientific notation. For example: 8.96E-04 = 8.96 x $10^{-4}$ = 0.00896*

*(b) Idling of trains departing the VIF eastbound, and idling waiting for the Pitt River rail bridge were modelled in the same location on the north mainline under the Bonson Road Pedestrian Bridge in Scenario 1. The higher of the two calculated maximum hourly emission rates (lead track idling departing the VIF) were used to model maximum 1-hour rates for this location as two trains cannot both be idling on the same section of mainline.*

## 4.4 Scenario 2 – Future (2030) Predicted Operations

Scenario 2 builds on Scenario 1 and reflects the predicted increases in mainline traffic by 2030 (59 freight trains compared to the 28 trains in Scenario 1). VIF operations and West Coast Express emissions are modelled with the same activity levels and assumptions as it is anticipated the operational activities modeled in Scenario 1 sufficiently captures the expected operational capacity of the VIF and expected WCE operations.

Freight train idling emissions were assumed to be the same as Scenario 1, however in different locations. The estimated idling of two trains a day to account for trains waiting for the Pitt River rail bridge to close (i.e., when the bridge is drawn up/not crossable due to vessel movements on the Pitt River) were assumed to be moved from the north mainline track (Scenario 1 modelled under the Bonson Road pedestrian bridge) to a new siding alongside the VIF and closer to the river. Similar to mainline idling in Scenario 1, idling at the new siding in Scenario 2 was estimated to occur for 20 minutes for each bridge event. Idling trains waiting for the rail bridge to close were assumed to have four locomotives per train, consistent with line-haul trains noted in the sections above. Maximum 1-hour emission rates at the new siding assume all four locomotives on the train idling for the full duration of time estimated to close the bridge (20 minutes).

The locomotive idling during each eastbound train departure from the VIF will move from the north mainline track to the extended lead track from the east end of the VIF. These emissions were still modelled under the Bonson Road pedestrian bridge between two schools as a worst-case location scenario. This idling activity was assumed to occur for 30 minutes (based on on-site observations of train building during a departing train from the VIF) for both eastbound trains leaving the VIF facility per day for a total of one hour per day. Maximum 1-hour emission rates assume two locomotives (at the front of the train) idling for the full hour.

A summary table including the estimated activity times/operational details included in this scenario and emission totals/rates are provided in **Table 4-4**.

### Table 4-4: Scenario 2 Emissions Inventory Summary

| Scenario Details | | | | | | | | Annual | | | | | | | | Maximum 1-hour | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Emissions (Tonnes/yr) | | | | | | | Emissions (g/s) | | | | |
| Scenario Component | Activity | Modelled Sections | Length (m) | Number of Locomotives | Speed (km/h) | Minutes per Delivery/ Activity | Number of Deliveries per Day | Number of Deliveries per Year | Total Hours per Year | Calculated Fuel Consumption (L/yr) | CO | NOx | HC | DPM | SOx | Max 1-hour Deliveries/ Scenarios | Calculated Fuel Consumption in Maximum Hour (L/hr) | CO | NOx | HC | DPM | SOx |
| Freight Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 4 | 30.2 | 2.32 | 59 | 21535 | 831 | 1,158,205 | 8.13 | 40.03 | 1.78 | 0.90 | 0.02 | Max of 7 deliveries in an hour | 376.5 | 0.73 | 3.61 | 0.16 | 0.08 | 2.09E-03 (a) |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 1043 | 1,453,378 | 10.20 | 50.23 | 2.24 | 1.13 | 0.03 | | 472.4 | 0.92 | 4.54 | 0.20 | 0.10 | 2.62E-03 |
| | | Mainline 3: East of VIF | 2,954 | | 63.4 | 2.8 | | | 1004 | 1,398,462 | 9.82 | 48.33 | 2.15 | 1.09 | 0.03 | | 454.6 | 0.89 | 4.36 | 0.19 | 0.10 | 2.53E-03 |
| | VIF departing train idling | LTI: Idling on extended VIF east lead track under Bonson Road Pedestrian Bridge | - | 2 | - | 30 | 2 | 730 | 365 | 8,293 | 0.06 | 0.29 | 0.01 | 0.01 | 1.66E-04 | 2 Locomotives idling for the full hour | 22.7 | 0.04 | 0.22 | 9.72E-03 | 4.92E-03 | 1.26E-04 |
| | Idling waiting for the Pitt River rail bridge to close | SI: Idling on new siding alongside VIF | - | 4 | - | 20 | 2 | 730 | 243 | 11,057 | 0.08 | 0.38 | 0.02 | 0.01 | 2.21E-04 | 4 Locomotives idling for 20 minutes | 15.1 | 0.03 | 0.15 | 6.48E-03 | 3.28E-03 | 8.41E-05 |
| West Coast Express Passenger Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 1 | 30.2 | 2.32 | 10 | 3650 | 141 | 56,011 | 0.39 | 3.05 | 0.12 | 0.06 | 1.12E-03 | Max of 2 deliveries in an hour | 30.7 | 0.06 | 0.46 | 0.02 | 9.46E-03 | 1.71E-04 |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 177 | 70,286 | 0.49 | 3.82 | 0.15 | 0.08 | 1.41E-03 | | 38.5 | 0.08 | 0.58 | 0.02 | 0.01 | 2.14E-04 |
| | | Mainline 3: East of VIF | 2,954 | | 31.7 | 5.59 | | | 340 | 135,260 | 0.95 | 7.35 | 0.28 | 0.15 | 2.71E-03 | | 74.1 | 0.14 | 1.12 | 0.04 | 0.02 | 4.12E-04 |
| | Idling | At WCE Station | - | | - | 1.5 | | | 91 | 1,037 | 7.29E-03 | 5.64E-02 | 2.18E-03 | 1.15E-03 | 2.07E-05 | | 0.568 | 1.11E-03 | 8.58E-03 | 3.31E-04 | 1.75E-04 | 3.16E-06 |
| VIF | Moving freight/ switching/ idling | VIF | - | 4 | - | 90 | 3 Departing | 1095 | 1643 | 223,333 | 1.64 | 12.66 | 0.74 | 0.26 | 4.47E-03 | Max operation of 4 locomotives at once | 136 | 0.28 | 2.14 | 0.13 | 0.04 | 7.55E-04 |
| | | | | | - | 60 | 3 Arriving | 1095 | 1095 | 148,888 | 1.09 | 8.44 | 0.50 | 0.18 | 2.98E-03 | | | | | | | |

*(a) Written in scientific notation. For example: 2.09E-03 = $2.09 \times 10^{-3}$ = 0.00209*

## 4.5 Scenario 3 – Future (2030) Predicted Operations with Inclusion of Proposed CP Logistics Park: Vancouver

As noted in Section 1.2 above, Scenario 3 includes future rail operations with inclusion of activities associated with the proposed LPV. Since the proposed project is predicted to have significant heavy truck operations, trucking emissions were estimated in addition to rail emission estimates. Activity details referenced below that inform the emissions estimates were based on the most up to date information on the proposed LPV plans made available at the time of writing [15].

### 4.5.1 Locomotives

Locomotive emission estimates in Scenario 3 builds on Scenario 2 and includes rail activity at the proposed CP LPV to be located south of VIF operations. As with Scenario 2, Scenario 3 also includes expected mainline traffic in 2030 (59 trains on the mainline). Emissions from VIF operations, West Coast Express, and the freight train idling are modelled with the same activity levels and assumptions.

The proposed LPV is proposed to consist of operations for the transloading of agricultural products, automobiles, and liquid products in three distinct areas of the LPV. Additional activities modelled in Scenario 3 include idling emissions from the agricultural hub/rail loop, and rail switching activities associated with the automobile and liquid products subsites. Idling on the LPV entry and loop track just north of Highland Park Elementary was also included as a worst-case scenario.

Agricultural products are proposed to arrive to the LPV in 147-car, 8,500-ft unit trains. Once arrived on-site, unit trains for agricultural products are intended to move as a solid train (no switching required) through the proposed rail loop in a clockwise direction. Agricultural cars will be bottom unloaded into a conveyor in an unloading pit. Based on provided descriptions, one unit train can be unloaded every 24 hours, with an average of one train unloaded every three days. Trains were assumed to be idling during unloading operations. As with the other mainline freight trains considered in this study, fuel consumption rates from GE4400AC locomotives were used with an assumed four locomotives per train. Maximum 1-hour emission rates at the rail loop assume all four locomotives on the train idling for the full hour.

Automobile and liquid products are proposed to arrive at the LPV via mixed-product trains and directed to the receiving staging yard. Switcher locomotives are intended to move loaded railcars from the receiving staging yard to commodity specific locations on-site. Empty/unloaded railcars from the automobile/liquid subsites will then be sorted in destination specific blocks for departure. It was assumed approximately two mixed-product trains will be arriving and departing the LPV each day.

Activity times for switching activities at the LPV were assumed to be consistent with the activity times assumed at the VIF (i.e., 60 minutes for arrival trains, and 90 minutes for departing trains/train make-ups). Four switch locomotives were also assumed to be operational at the LPV. Maximum 1-hour emissions in the switching yard assumes all four switcher locomotives operating at the same time for the full hour.

To consider the additional entry and loop track associated with the LPV facility, idling of a pair of locomotives is modelled on the proposed entry and loop track just north of Highland Park Elementary as a

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[15] Canadian Pacific, 2021 – *Environmental Effects Evaluation CP Logistics Park: Vancouver*

worst-case location close to sensitive receptors. Idling near the school was assumed to occur for 30 minutes during the departure of two trains per day from the LPV facility, similar to the assumption used for the VIF (based on on-site observation of a departing train). Maximum 1-hour emission rates near Highland Park Elementary assumes two locomotives (at the front of the train) idling for the full hour.

A summary table including the estimated activity times/operational details included for rail in this scenario and emission totals and rates are provided in **Table 4-5**.

**Table 4-5: Scenario 3 Emissions Inventory Summary (Locomotives Only)**

| Scenario Details | | | | | | | | Annual | | | | | | | | Maximum 1-hour | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Emissions *(Tonnes/yr)* | | | | | | | Emissions *(g/s)* | | | | |
| Scenario Component | Activity | Modelled Sections | Length *(m)* | Number of Locomotives | Speed *(km/h)* | Minutes per Delivery/ Activity | Number of Deliveries per Day | Number of Deliveries per Year | Total Hours per Year | Calculated Fuel Consumption *(L/yr)* | CO | NOx | HC | DPM | SOx | Max 1-hour Deliveries/ Scenarios | Calculated Fuel Consumption in Maximum Hour *(L/hr)* | CO | NOx | HC | DPM | SOx |
| Freight Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 4 | 30.2 | 2.32 | 59 | 21535 | 831 | 1,158,205 | 8.13 | 40.03 | 1.78 | 0.90 | 0.02 | Max of 7 deliveries in an hour | 376.5 | 0.73 | 3.61 | 0.16 | 0.08 | 2.09 E-03 (a) |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 1043 | 1,453,378 | 10.20 | 50.23 | 2.24 | 1.13 | 0.03 | | 472.4 | 0.92 | 4.54 | 0.20 | 0.10 | 2.62 E-03 |
| | | Mainline 3: East of VIF | 2,954 | | 63.4 | 2.8 | | | 1004 | 1,398,462 | 9.82 | 48.33 | 2.15 | 1.09 | 0.03 | | 454.6 | 0.89 | 4.36 | 0.19 | 0.10 | 2.53 E-03 |
| | VIF departing train idling | LTI: Idling on extended VIF lead track under Bonson Road Pedestrian Bridge | - | 2 | - | 30 | 2 | 730 | 365 | 8,293 | 0.06 | 0.29 | 0.01 | 0.01 | 1.66E-04 | 2 Locomotives idling for the full hour | 22.7 | 0.04 | 0.22 | 9.72E-03 | 4.92E-03 | 1.26 E-04 |
| | Idling waiting for the Pitt River rail bridge to close | SI: Idling on new siding alongside VIF | - | 4 | - | 20 | 2 | 730 | 243 | 11,057 | 0.08 | 0.38 | 0.02 | 0.01 | 2.21E-04 | 4 Locomotives idling for 20 minutes | 15.1 | 0.03 | 0.15 | 6.48E-03 | 3.28E-03 | 8.41 E-05 |
| West Coast Express Passenger Trains | Mainline Travel | Mainline-1: West of VIF | 1,165 | 1 | 30.2 | 2.32 | 10 | 3650 | 141 | 56,011 | 0.39 | 3.05 | 0.12 | 0.06 | 1.12E-03 | Max of 2 deliveries in an hour | 30.7 | 0.06 | 0.46 | 0.02 | 9.46E-03 | 1.71 E-04 |
| | | Mainline 2: Alongside VIF | 3,070 | | 63.4 | 2.91 | | | 177 | 70,286 | 0.49 | 3.82 | 0.15 | 0.08 | 1.41E-03 | | 38.5 | 0.08 | 0.58 | 0.02 | 0.01 | 2.14 E-04 |
| | | Mainline 3: East of VIF | 2,954 | | 31.7 | 5.59 | | | 340 | 135,260 | 0.95 | 7.35 | 0.28 | 0.15 | 2.71E-03 | | 74.1 | 0.14 | 1.12 | 0.04 | 0.02 | 4.12 E-04 |
| | Idling | At WCE Station | - | | - | 1.5 | | | 91 | 1,037 | 7.29E-03 | 5.64E-02 | 2.18E-03 | 1.15E-03 | 2.07E-05 | | 0.568 | 1.11E-03 | 8.58E-03 | 3.31E-04 | 1.75E-04 | 3.16 E-06 |
| VIF | Moving freight/switching/ idling | VIF | - | 4 | - | 90 | 3 Departing | 1095 | 1643 | 223,333 | 1.64 | 12.66 | 0.74 | 0.26 | 4.47E-03 | Max operation of 4 locomotives at once | 136 | 0.28 | 2.14 | 0.13 | 0.04 | 7.55 E-04 |
| | | | | | - | 60 | 3 Arriving | 1095 | 1095 | 148,888 | 1.09 | 8.44 | 0.50 | 0.18 | 2.98E-03 | | | | | | | |
| LPV | Agricultural Products Transloading | Idling along LPV rail loop for agricultural products | - | 4 | - | 1440 | 1/3 | 122 | 2920 | 132,685 | 0.93 | 4.59 | 0.20 | 0.10 | 2.65E-03 | Max idling is 4 locomotives | 45.4 | 0.09 | 0.44 | 0.02 | 9.85E-03 | 2.52 E-04 |
| | Moving freight/ switching/ idling | Automobiles & Liquids areas of proposed LPV | - | 4 | - | 90 | 2 Departing | 730 | 1095 | 148,888 | 1.09 | 8.44 | 0.50 | 0.18 | 2.98E-03 | Max operation of 4 locomotives at once | 136.0 | 0.28 | 2.14 | 0.13 | 0.04 | 7.55 E-04 |
| | | | | | - | 60 | 2 Arriving | 730 | 730 | 99,259 | 0.73 | 5.63 | 0.33 | 0.12 | 1.99E-03 | | | | | | | |
| | Idling on LPV lead track | LPLTI: Idling on proposed lead track just north of Highland Park Elementary | - | 2 | - | 30 | 2 | 730 | 365 | 8,293 | 0.06 | 0.29 | 0.01 | 0.01 | 1.66E-04 | 2 locomotives idling for the full hour | 22.7 | 0.04 | 0.22 | 9.72E-03 | 4.92E-03 | 1.26 E-04 |

*(a) Written in scientific notation. For example: 2.09E-03 = 2.09 x $10^{-3}$ = 0.00209*

### 4.5.2 Trucks

As part of Scenario 3, emissions from the high volume of trucking traffic associated with the proposed LPV were also considered and estimated. After the shipments of agricultural products, automobiles, and liquids are received via rail, they are proposed to be transferred to temporary storage before distribution. Liquid products and automobiles will be distributed to various locations throughout greater Vancouver by truck, while agricultural products will be moved by truck to CP's VIF facility for further distribution. As part of the construction of the LPV project, a new access road is proposed to provide access to the sites. Other proposed infrastructure associated with the project also includes two 3-leg, stop-controlled intersections to direct traffic to and from the sites as needed.

With consultation with the City of Pitt Meadows, estimated emissions associated from trucking movements and activity in Scenario 3 includes the following:

- On-site truck movements to/from product areas to LPV entrance,
- Off-site truck movements to/from LPV entrance to the VIF entrance (agricultural products),
- Off-site truck movements to/from LPV entrance to the intersection with Lougheed highway (automobile/liquid products),
- Truck idling at LPV at staging/loading areas (for agricultural, automobile, liquid products),
- Truck idling at stop-controlled intersections,
- Truck idling during rail crossing closures at the Kennedy Road at-grade crossing of the mainline.

The number of trucks coming to and from CP's LPV facility is approximately 374 trucks (round trip) per day on average and are based on expected commodity throughputs. Approximately 37 trucks (round trip) are expected to come to and from the LPV facility at peak hour. Using the distribution of trucks from daily averages, the maximum number of trucks anticipated for each product/commodity at peak hour were estimated.

The daily average truck traffic and expected trucks at peak hour are summarized and shown in **Table 4-6** for reference.

**Table 4-6: LPV Expected Daily Throughput and Project-Related Truck Traffic [16]**

| Product | Expected Commodity Throughput Per Day | Average Trucks Per Day | Estimated Trucks at Peak Hour |
|---|---|---|---|
| Agricultural Products | 4,900 tonnes/day | 186 | 18 |
| Automobiles | 360 vehicles/day | 45 | 5 |
| Liquid Products | 1,920,000 gallons/day | 143 | 14 |
| **Facility Total** | **-** | **374** | **37** |

[16] Canadian Pacific, 2021 – *Environmental Effects Evaluation CP Logistics Park: Vancouver*

Using expected number of trucks and approximate distances of travel for each truck (on-site and off-site), total vehicle kilometers travelled (VKT) values were calculated. Activity emission factors from MOVES and road dust emission factors from AP42 Section 13.2.1 [17] were applied to total VKT values to yield total emissions for truck movement.

Average truck idling times at the rail crossing were approximated based on anticipated crossing closure times in 2030 of up to 6 hours/day and up to 30 minutes/hour [18]. Average truck idling times at intersections near the LPV were assumed to be 2 minutes/truck. On-site idling times were based on an anti-idling policy limiting idling to 3 minutes unless essential [19]; an idling time of 6 minutes was applied per truck to account for multiple stops and starts on-site. A summary table including the estimated activity times/operational details included for trucks in this scenario and emission totals and rates are provided in **Table 4-7**.

[17] U.S. Environmental Protection Agency, 2011 – *AP-42 13.2.1 Paved Roads*
[18] Port of Vancouver. (n.d.). – *Port authority-led infrastructure and developments*
[19] Canadian Pacific, 2021 – *Environmental Effects Evaluation CP Logistics Park: Vancouver*

**Table 4-7: Scenario 3 Emissions Inventory Summary (Trucks Only)**

| Area | Spatial Description | Activity | Movement | | Annual | | | | | | | | Maximum-1-hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length (km) | Average Speed (km/h) | Number of Trucks/Day | Idling Minutes per Truck | Emissions (Tonnes/yr) | | | | | | Max Number of Trucks/Hr | Idling Minutes per Truck | Emissions (g/s) | | | | | |
| | | | | | | | CO | NOx | HC | DPM | SOx | $PM_{2.5}$ Brakes, Tires, and Road Dust | | | CO | NOx | HC | DPM | SOx | $PM_{2.5}$ Brakes Tires, and Road Dust |
| Road Travel | LPV to VIF entrance | Movement | 1.36 | 25 | 186 | - | 0.35 | 0.50 | 0.10 | 0.01 | 4.13E-04 | 9.19E-02 | 18 | - | 2.6E-02 | 3.7E-02 | 7.6E-03 | 7.0E-04 | 3.0E-05 | 7.6E-03(a) |
| | LPV to Highway | Movement | 2.2 | 30 | 188 | - | 0.48 | 0.71 | 0.14 | 0.01 | 6.30E-04 | 1.48E-01 | 19 | - | 3.7E-02 | 5.4E-02 | 1.1E-02 | 1.1E-03 | 4.8E-05 | 1.3E-02 |
| | Idling for KR crossing | Idling | - | - | 748 | 1.5 | 0.14 | 0.35 | 0.09 | 0.01 | 1.71E-04 | - | 74 | 2.5 | 1.8E-02 | 4.4E-02 | 1.1E-02 | 8.1E-04 | 2.1E-05 | - |
| LPV | Access Road | Movement | 0.52 | 15 | 374 | - | 0.36 | 0.53 | 0.13 | 0.01 | 3.71E-04 | 7.37E-02 | 37 | - | 2.7E-02 | 4.0E-02 | 9.5E-03 | 6.4E-04 | 2.8E-05 | 6.2E-03 |
| | | Idling | - | - | 374 | 2 | 0.10 | 0.23 | 0.06 | 4.32E-03 | 1.14E-04 | - | 37 | 2 | 7.2E-03 | 1.8E-02 | 4.6E-03 | 3.3E-04 | 8.6E-06 | - |
| | Automobile | Movement | 0.525 | 10 | 45 | - | 0.06 | 0.09 | 0.02 | 1.31E-03 | 5.68E-05 | 9.37E-03 | 5 | - | 4.7E-03 | 7.3E-03 | 1.9E-03 | 1.1E-04 | 4.8E-06 | 8.8E-04 |
| | | Idling | - | - | 45 | 6 | 0.03 | 0.08 | 0.02 | 1.56E-03 | 4.12E-05 | - | 5 | 6 | 2.9E-03 | 7.1E-03 | 1.8E-03 | 1.3E-04 | 3.5E-06 | - |
| | Agricultural | Movement | 1.7 | 10 | 186 | - | 0.75 | 1.16 | 0.30 | 0.02 | 7.60E-04 | 1.25E-01 | 18 | - | 5.5E-02 | 8.5E-02 | 2.2E-02 | 1.3E-03 | 5.6E-05 | 1.0E-02 |
| | | Idling | - | - | 186 | 6 | 0.14 | 0.35 | 0.09 | 0.01 | 1.70E-04 | - | 18 | 6 | 1.0E-02 | 2.6E-02 | 6.6E-03 | 4.7E-04 | 1.3E-05 | - |
| | Liquids | Movement | 1.2 | 10 | 143 | - | 0.41 | 0.63 | 0.16 | 0.01 | 4.13E-04 | 6.81E-02 | 14 | - | 3.0E-02 | 4.7E-02 | 1.2E-02 | 7.1E-04 | 3.1E-05 | 5.6E-03 |
| | | Idling | - | - | 143 | 6 | 0.11 | 0.27 | 0.07 | 4.95E-03 | 1.31E-04 | - | 14 | 6 | 8.1E-03 | 2.0E-02 | 5.2E-03 | 3.7E-04 | 9.7E-06 | - |

*(a) Written in scientific notation. For example: 7.6E-03 = 7.6 x $10^{-3}$ = 0.0076*

# 5.0 AIR QUALITY DISPERSION MODELLING

## 5.1 Methodology

Air dispersion modelling was performed to predict the dispersion of emissions from rail operations into surrounding areas and predict ground level air contaminant concentrations.

Modelling was performed using the CALPUFF air dispersion modelling system and followed the British Columbia Air Quality Dispersion Modelling Guideline 2021 [20]. The BC AQDMG provides key guidance on a variety of topics: model selection, application of models for regulatory purposes in BC, and best modelling practices. The CALPUFF modelling system consists of two main model packages including CALMET, a diagnostic 3-dimensional meteorological model, and CALPUFF, an air quality dispersion model.

Meteorological modelling was performed using CALMET for a 1-year period using a domain of 25 km x 25 km centred on Pitt Meadows. CALMET was ran in hybrid mode where both mesoscale meteorological model output data (i.e., output from a larger scale meteorological model to characterize the impact of regional meteorology) and local measured meteorological station data for the modelled year are used along with geophysical data (terrain elevations, land use and land cover etc.) to predict 3D wind fields. QA/QC checks of the model output data was conducted and is included in **Appendix C**. The meteorological modelled year was chosen as 2012 based on availability of high-resolution (1 km grid resolution) Weather Research and Forecasting (WRF) model output prognostic data and as this year has been found to be representative of typical conditions in the region.

CALPUFF is a multi-layer, multi-species, non-steady-state Lagrangian Gaussian air quality modelling system for regulatory use that can simulate the effects of varying meteorological conditions in time and space on pollutant transport. CALPUFF modelling was performed using similar parameters for rail emission sources and road trucks as used in other studies. Rail activities were modelled as a mixture of road sources to simulate the train movements along the mainline, volume sources to cover switching locomotives moving around the VIF and LPV, and point sources to simulate stationary idling locomotives. Emissions from heavy trucks were also modeled as road sources to simulate emissions along the assessed roads (Kennedy Road and LPV access road), and area sources for each activity area of the LPV.

A cartesian nested grid of receptors (i.e., points where air contaminant concentrations are calculated) of 50 m spacing within 1.5 km of the mainline and 500 m spacing for the reminder of the CALPUFF domain was defined within the study area, as shown in **Figure 5-1.** Sensitive receptors (e.g., schools, residences, care facilities, businesses) anticipated to be most impacted were identified and included in the model, as shown in **Figure 5-2**. It should be noted that the receptors height above ground level were set to 1.5 m (breathing height, which may be predicted to have a slightly higher ambient concentration than when the height of receptors is set to 0.0m), with some residential receptors in multi-storey buildings at increased heights.

[20] British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *British Columbia Air Quality Dispersion Modelling Guideline.*

Model results, for each of the three modeled scenarios were extracted for varying averaging periods corresponding with AAQOs and health thresholds by using the appropriate emission rates based on either the daily average, or predicted worst-case 1-hour activity estimates for each modelled emission source as described in **Section 4.0**.

Maximum 1-hour average concentrations of each contaminant were predicted for each source/model run at each receptor based on a full year of meteorological data (i.e., 8,784 simulated hours for 2012). The CALSUM post-processor was then used to sum the hourly predicted maximum concentrations at each receptor from each of the model runs for each scenario to obtain the total predicted maximum concentrations from all emission sources. Post-processing of the total hourly model results was then conducted by CALPOST, a statistical processing program, to determine required metrics for comparison with ambient air quality objectives over the relevant averaging periods.

The Ambient Ratio Method (ARM) was chosen to model nitrogen dioxide ($NO_2$) emissions based on the total emissions of nitrogen oxides (NOx) as recommended by the British Columbia Guidance for $NO_2$ Dispersion Modelling [21]. The ARM method utilizes representative hourly NOx and $NO_2$ monitoring data to characterize the NOx: $NO_2$ ratio based on the estimated ambient NOx concentration. The ARM2 method, a refinement of the original ARM, was used for urban sites as recommended by the British Columbia Guidance for $NO_2$ Dispersion Modelling.

[21] British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *Guidance for $NO_2$ Dispersion Modelling in British Columbia*

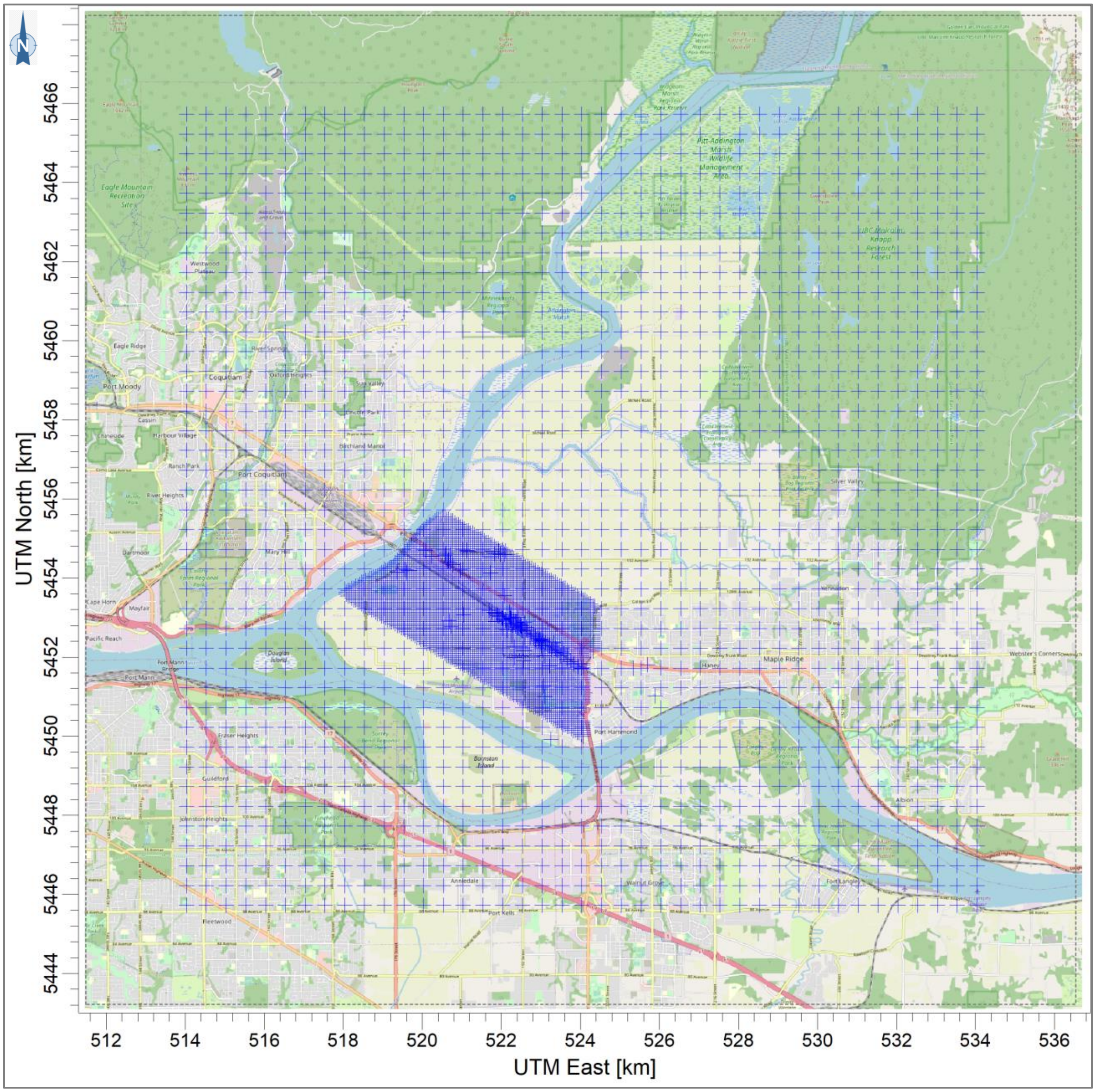



**Figure 5-1: Discrete Receptors used in CALPUFF**

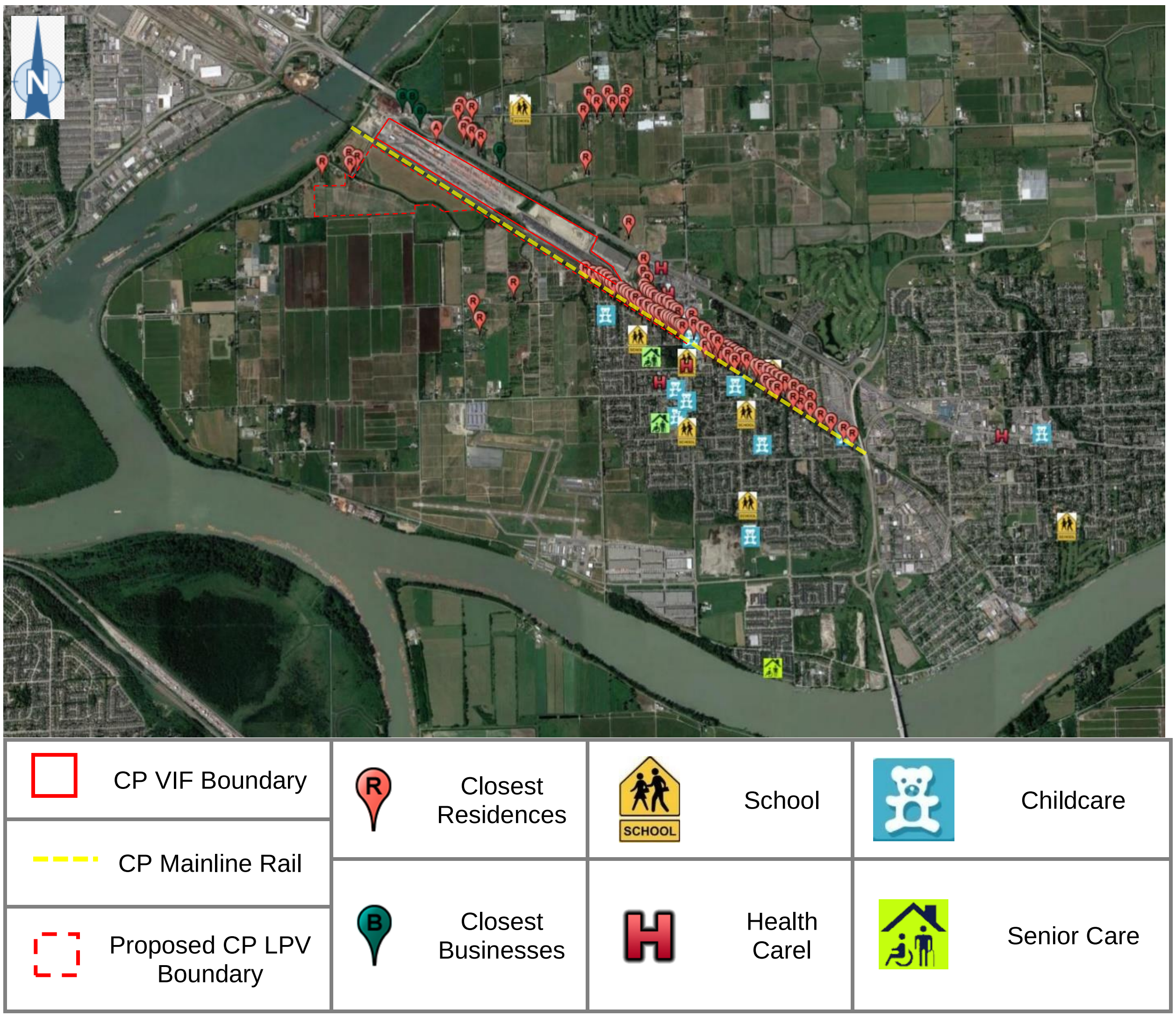



**Figure 5-2: Sensitive Receptors Used in CALPUFF**

## 5.2 Results

Model predicted worst-case ground level concentrations are presented in **Table 5-1** for each of the three scenarios for CO, $NO_2$, DPM, $PM_{2.5}$, $SO_2$ and total hydrocarbons. For the purposes of this study, it was assumed that particulate matter (PM), $PM_{2.5}$, and DPM emissions are equivalent from diesel combustion as the vast majority of particulate matter generated by diesel combustion is smaller than 2.5 microns (i.e., $PM_{2.5}$). As Scenarios 1 and 2 only consider diesel combustion emissions from locomotives, model predicted ground-level concentrations of DPM and $PM_{2.5}$ are therefore equivalent for these scenarios. In Scenario 3 the predicted $PM_{2.5}$ ground level concentrations include both the diesel combustion emissions from locomotives and trucks, as well as the non-diesel combustion emissions from the assessed truck activity in Scenario 3 (i.e., from brake wear, tire wear, and road dust re-entrainment), therefore predicted $PM_{2.5}$ concentrations are greater than DPM concentrations in Scenario 3.

It should be noted that for the purpose of this study, only railway operation emissions were considered for evaluation, without the addition of background concentrations in order to assess the impact of rail operations in Pitt Meadows. Model results are based on the estimated worst-case scenarios for locomotive and truck (only in Scenario 3 for proposed LPV trucking) emissions within the municipal boundary of the City of Pitt Meadows (plus 1 km buffer on each end of the mainline).

The model results are discussed for locations outside of the CP "fenceline", that is, where there is public access. For each air contaminant and assessed averaging period, the predicted worst-case concentration predicted at each receptor over the year of modelling was assessed. Results presented in **Table 5-1** are for the sensitive receptors identified to have the predicted worst-case concentration within each receptor category (i.e., concentration at the residence with the highest predicted concentration of all modelled residences, concentration at the school with the highest predicted concentration of all modelled schools etc.). Therefore, the result under each averaging period and for each scenario may not necessarily be at the same receptor (e.g., a different residence may be predicted to have the highest 1-hour average than the residence predicted to have the highest annual average).

No exceedances of Metro Vancouver AAQOs are predicted for the majority of air contaminants for all scenarios with the exception of the $NO_2$ 1-hour objective of 113 µg/m$^3$ (assessed as the 98$^{th}$ percentile of the 1-hour daily maximums) and annual objective of 32 µg/m$^3$. The distribution of exceedances is increased under the future scenarios presented (Scenarios 2 and 3). While it should be noted that the recommended methodology for modelling of $NO_2$ concentrations in BC is conservative, these exceedances are predicted without the addition of background $NO_2$ concentrations (i.e., impacts from other emission sources in the airshed).

For $PM_{2.5}$, the highest model predicted 24-hour rolling average $PM_{2.5}$ concentration (10.5 µg/m$^3$, close to the CP fence line in Scenario 3) in any of the three scenarios was less than 50% of the Metro Vancouver 24-hour ambient air quality objective of 25 µg/m$^3$. Annual average $PM_{2.5}$ concentrations were also below the Metro Vancouver long-term planning goal of 6 µg/m$^3$ in all three scenarios, with a maximum result of 3.6 µg/m$^3$ close to the CP fence line in Scenario 3. While there are no 1-hour ambient air quality objectives in BC nor in Metro Vancouver for comparison of predicted $PM_{2.5}$ concentrations under the worst-case maximum 1-hour scenarios, these results are presented for use in the preliminary HHRA aspect of this study.

When DPM concentrations are examined separately (i.e., PM from diesel combustion only), the highest 1-hour and 24-hour rolling average DPM concentrations were predicted as 50.9 and 6.4 µg/m$^3$, respectively, both for Scenario 3. While there is no specific ambient air quality objective for DPM and the **Table 5-2**

DPM results are only for comparison purposes, further health-based thresholds specific to DPM are evaluated in the preliminary HHRA aspect of this study.

Results for CO and $SO_2$ show predicted concentrations are well below AAQO's. AAQO's do not exist for total hydrocarbons; these results are presented for context only, as they are speciated into individual HAPs and evaluated in the preliminary HHRA aspect of this study.

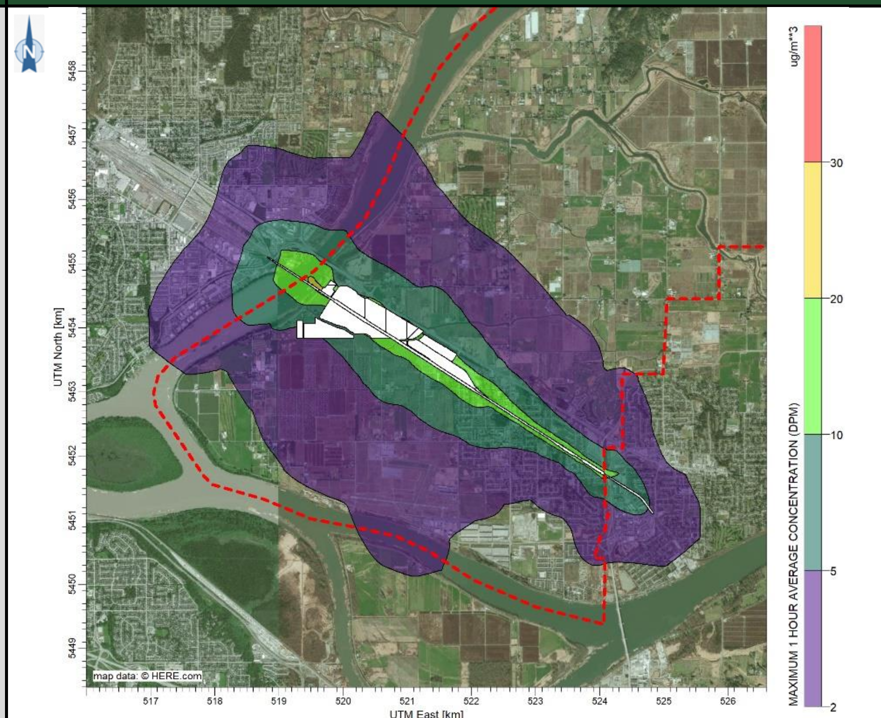
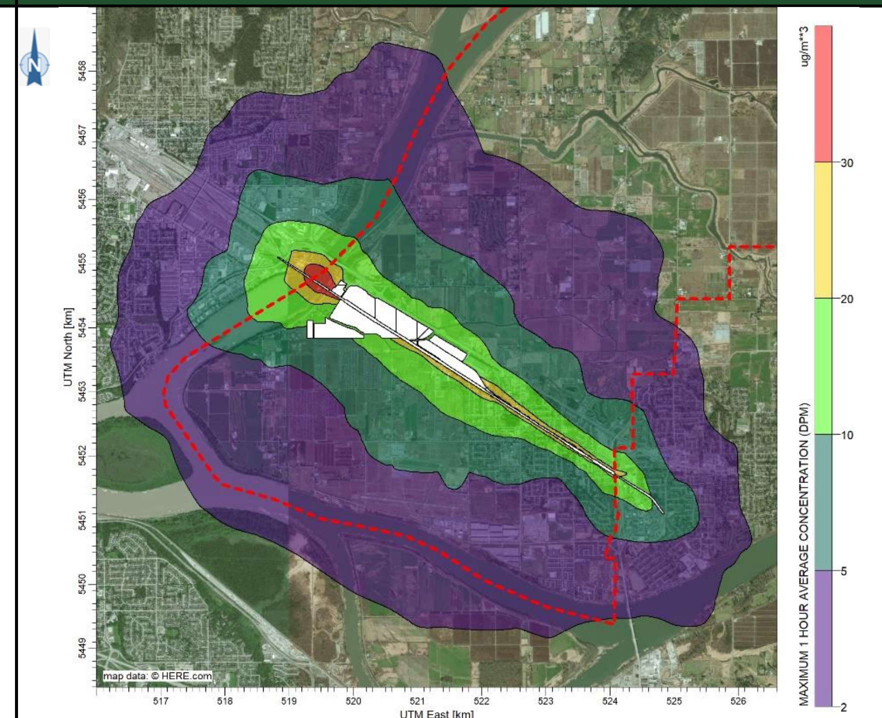
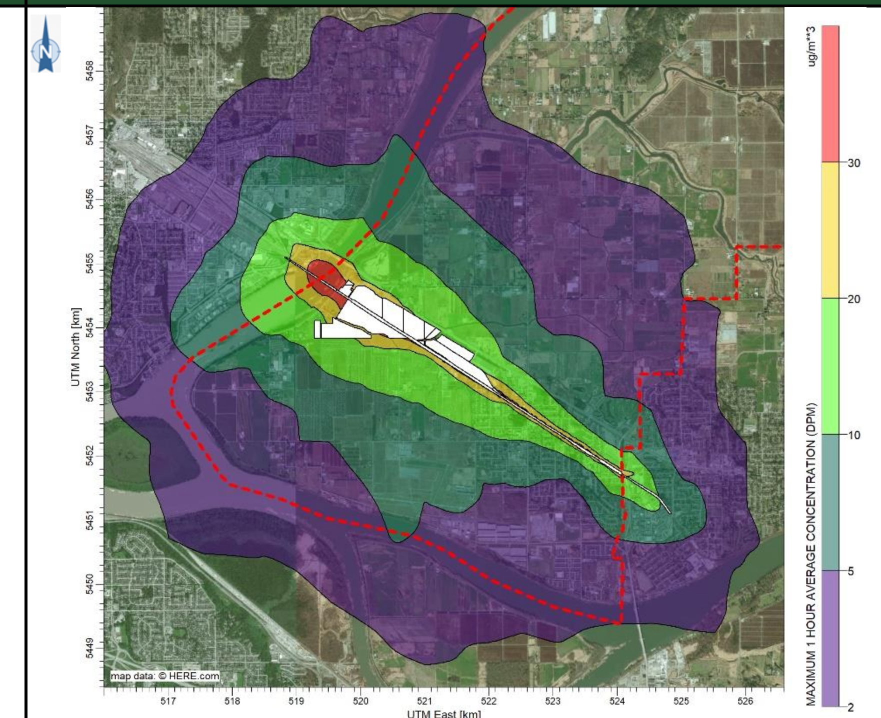
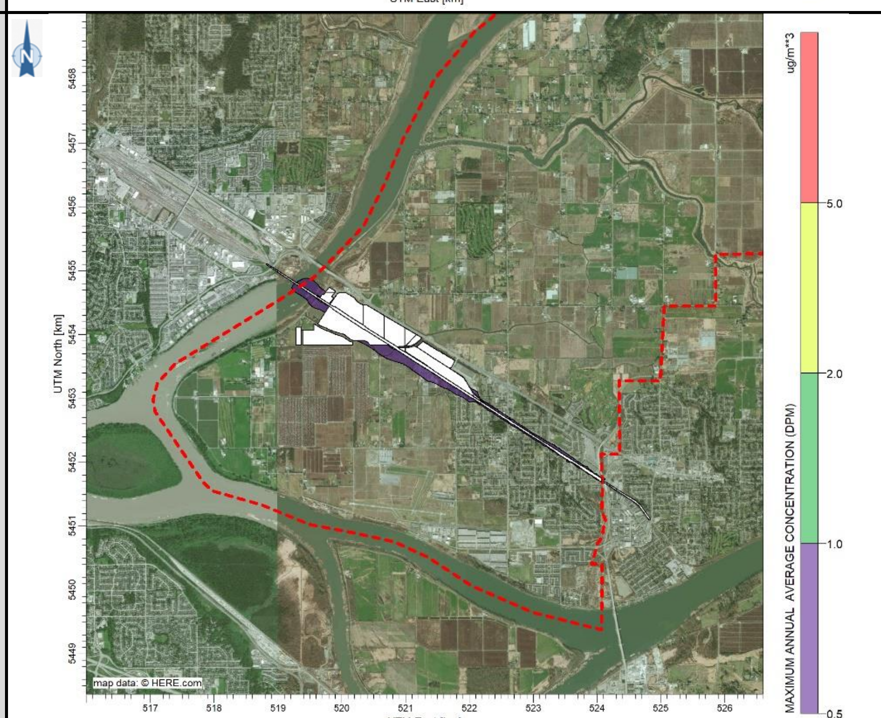
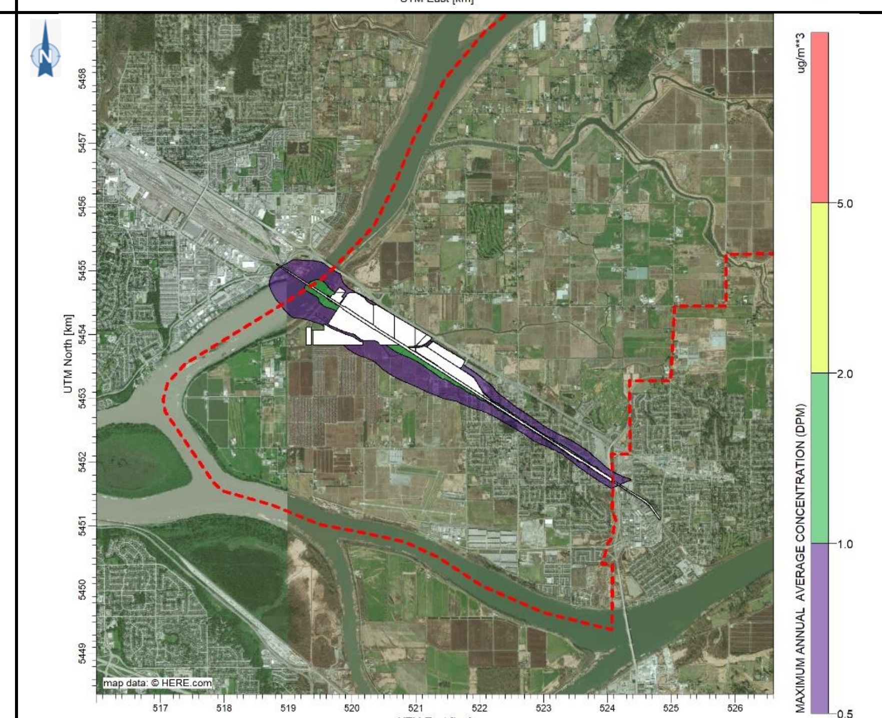
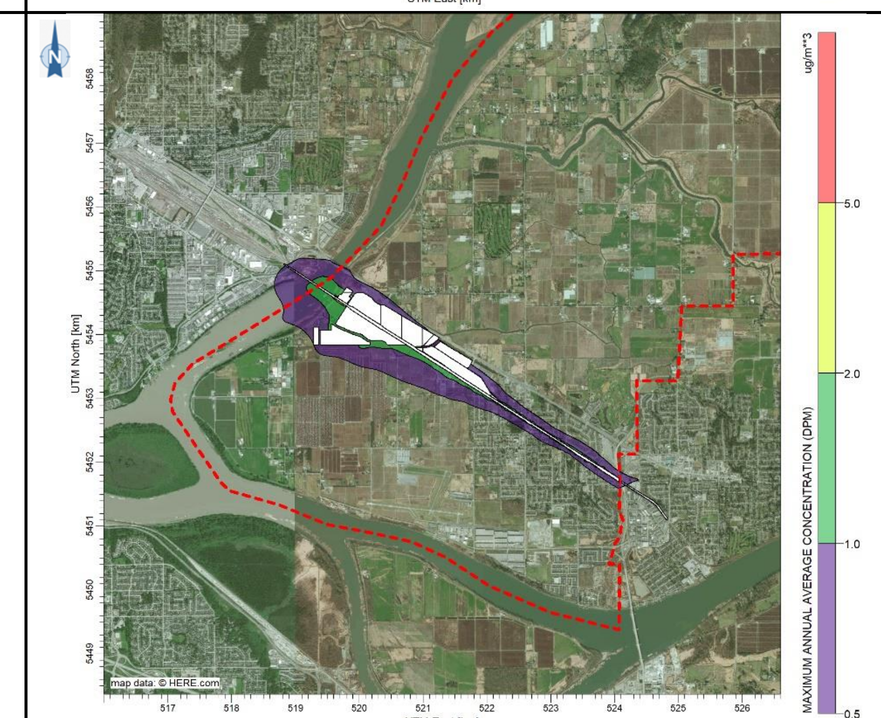
**Table 5-2**, **Table 5-3**, and **Table 5-4** present isopleth figures (i.e., bands of colour representing areas with similar concentration values) showing the model predicted worst-case short-term averages and the annual averages of DPM, $PM_{2.5}$, and $NO_2$ concentrations across the area surrounding the modelled rail operations. For the short-term averaging periods (1-hour, 24-hour, etc.), the figures show the worst result at each location over the full model year (i.e., this pattern could not be observed at a single point in time). **Table 5-5** also shows the distribution of frequency of exceedances (percentage of hours per year) of the 1-hour $NO_2$ objective for each emissions scenario (using the ARM2 $NO_X$ to $NO_2$ conversion method). Predicted concentrations were found to follow the mainline with higher results close to the current VIF rail yard and proposed LPV in Scenario 3.

**Table 5-1: Maximum Predicted Concentration in Each Receptor Category for Each Modelled Scenario**

| Contaminant | Averaging Period | | Metro Vancouver AAQO (μg/m³) | Maximum Predicted Ground Level Concentration for each Sensitive Receptors Category [(a)] (μg/m³) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Scenario 1: *Current Rail Operations* | | | | | | | Scenario 2: *Forecasted 2030 Operations* | | | | | | | Scenario 3: *Scenario 2 with the Addition of the LPV* | | | | | | |
| | | | | MPOI[(b)] | Business | Child Care | Health Care | Residence | School | Senior Care | MPOI[(a)] | Business | Child Care | Health Care | Residence | School | Senior Care | MPOI[(a)] | Business | Child Care | Health Care | Residence | School | Senior Care |
| CO | Max 1-Hour Average | | 14,900 | 189 | 67 | 116 | 82 | 133 | 66 | 56 | 392 | 117 | 220 | 143 | 256 | 127 | 101 | 451 | 190 | 227 | 154 | 260 | 130 | 105 |
| | Max 8-hour Rolling Average | | 5,700 | 38 | 18 | 26 | 16 | 30 | 16 | 12 | 73 | 29 | 51 | 31 | 60 | 32 | 23 | 300 | 149 | 151 | 93 | 176 | 96 | 68 |
| $NO_2$ | Max 1-hour Average | 100% Conversion | - | 1024 | 415 | 669 | 501 | 818 | 408 | 334 | 2042 | 669 | 1214 | 822 | 1397 | 693 | 569 | 2303 | 1024 | 1254 | 886 | 1415 | 710 | 595 |
| | | ARM2 | | 205 | 107 | 134 | 115 | 164 | 105 | 97 | 408 | 134 | 243 | 164 | 279 | 139 | 121 | 461 | 205 | 251 | 177 | 283 | 142 | 121 |
| | Annual 98th Percentile of 1-hour Daily Max | 100% Conversion | 113 (79) [(c)] | **827** | **387** | **528** | **341** | **704** | **317** | **247** | **1627** | **593** | **997** | **605** | **1194** | **600** | **457** | **1950** | **972** | **1003** | **612** | **1202** | **602** | **457** |
| | | ARM2 | | **165** | **103** | **118** | 97 | **141** | 95 | 90 | **325** | **121** | **199** | **121** | **239** | **121** | **113** | **390** | **194** | **201** | **122** | **240** | **121** | **113** |
| | Annual Average | 100% Conversion | 32 (23) [(c)] | **45.6** | 14.7 | 22.9 | 11.9 | **34.9** | 13.7 | 8.7 | **86.5** | 22.4 | **41.4** | 21.3 | **54.9** | **24.6** | 15.5 | **101.5** | **31.6** | **41.7** | 21.5 | **55.2** | **24.7** | 15.7 |
| | | ARM2 | | **32.7** | 12.6 | 19.2 | 10.6 | 27.0 | 12.2 | 7.8 | **45.6** | 17.2 | **29.1** | 17.1 | **35.7** | 19.7 | 13.4 | **50.3** | 20.7 | **29.3** | 17.3 | **35.8** | 19.7 | 13.5 |
| $PM_{2.5}$ | Max 1 Hour Average | | - | 22.8 | 9.0 | 14.7 | 10.9 | 17.8 | 8.9 | 7.3 | 45.4 | 14.6 | 26.3 | 17.8 | 30.2 | 15.0 | 12.4 | 65.1 | 33.5 | 27.4 | 19.7 | 41.6 | 15.8 | 13.3 |
| | Max 24-hour Rolling Average | | 25 | 2.8 | 1.4 | 1.9 | 1.1 | 2.4 | 1.2 | 0.7 | 5.3 | 2.2 | 3.5 | 2.0 | 4.3 | 2.1 | 1.3 | 10.5 | 5.3 | 3.5 | 2.1 | 7.3 | 2.1 | 1.3 |
| | Annual Average | | 8 (6) [(d)] | 1.0 | 0.3 | 0.5 | 0.3 | 0.8 | 0.3 | 0.2 | 1.9 | 0.5 | 0.9 | 0.5 | 1.2 | 0.5 | 0.3 | 3.6 | 1.1 | 0.9 | 0.5 | 2.1 | 0.5 | 0.3 |
| DPM | Max 1 Hour Average | | - | Same as $PM_{2.5}$ | | | | | | | Same as $PM_{2.5}$ | | | | | | | 50.9 | 22.4 | 27.1 | 19.2 | 30.5 | 15.3 | 12.9 |
| | Max 24-hour Rolling Average | | - | | | | | | | | | | | | | | | 6.4 | 3.4 | 3.5 | 2.0 | 4.6 | 2.1 | 1.3 |
| | Annual Average | | - | | | | | | | | | | | | | | | 2.2 | 0.7 | 0.9 | 0.5 | 1.2 | 0.5 | 0.3 |
| $SO_2$ | Max 1-Hour Average | | 183 (173) [(e)] | 0.54 | 0.19 | 0.33 | 0.23 | 0.38 | 0.19 | 0.16 | 1.10 | 0.33 | 0.62 | 0.41 | 0.73 | 0.36 | 0.29 | 1.21 | 0.47 | 0.64 | 0.43 | 0.73 | 0.37 | 0.30 |
| | Annual Average | | 13 (11) [(e)] | 0.024 | 0.007 | 0.012 | 0.006 | 0.016 | 0.007 | 0.004 | 0.047 | 0.011 | 0.023 | 0.012 | 0.029 | 0.013 | 0.008 | 0.054 | 0.016 | 0.023 | 0.012 | 0.029 | 0.014 | 0.009 |
| Hydrocarbon (HC) | Max 1-Hour Average | | - | 46.7 | 21.3 | 30.4 | 24.6 | 41.3 | 20.1 | 16.1 | 88.5 | 31.3 | 53.0 | 38.1 | 60.4 | 31.1 | 25.9 | 126.2 | 61.4 | 55.8 | 42.5 | 77.8 | 33.3 | 27.7 |
| | Max 24-hour Rolling Average | | - | 6.7 | 3.2 | 3.8 | 2.2 | 5.2 | 2.3 | 1.5 | 10.7 | 4.7 | 7.0 | 4.0 | 8.6 | 4.2 | 2.6 | 20.2 | 9.6 | 7.1 | 4.1 | 14.5 | 4.3 | 2.7 |
| | Annual Average | | - | 2.2 | 0.7 | 1.0 | 0.5 | 1.7 | 0.6 | 0.4 | 3.8 | 1.1 | 1.8 | 0.9 | 2.6 | 1.1 | 0.7 | 6.4 | 2.0 | 1.8 | 1.0 | 4.2 | 1.1 | 0.7 |

[a)] *Maximum concentration of contaminants for the sensitive receptors which were predicted to have the highest ground-level concentration among that receptor category are presented for each scenario and averaging period.*
[b)] *Maximum Point of Impingement outside of CP Owned Lands (i.e., at a publicly accessible location).*
[c)] *Metro Vancouver's $NO_2$ objectives are expected to decrease to a value equal to or less than 79 μg/m³ and 23 μg/m³ in 2025 for 1-hour and annual averaging periods respectively, in alignment with the 2025 CAAQS.*
[d)] *Annual objective of 6 μg/m³ is a longer-term aspirational target to support continuous improvement.*
[e)] *Metro Vancouver's $SO_2$ objectives are expected to decrease to a value equal to or less than 173 μg/m³ and 11 μg/m³ in 2025 for 1-hour and annual averaging periods respectively, in alignment with the 2025 CAAQS.*
[f)] ***Bold** = predicted value exceeds relevant ambient air quality objective.*

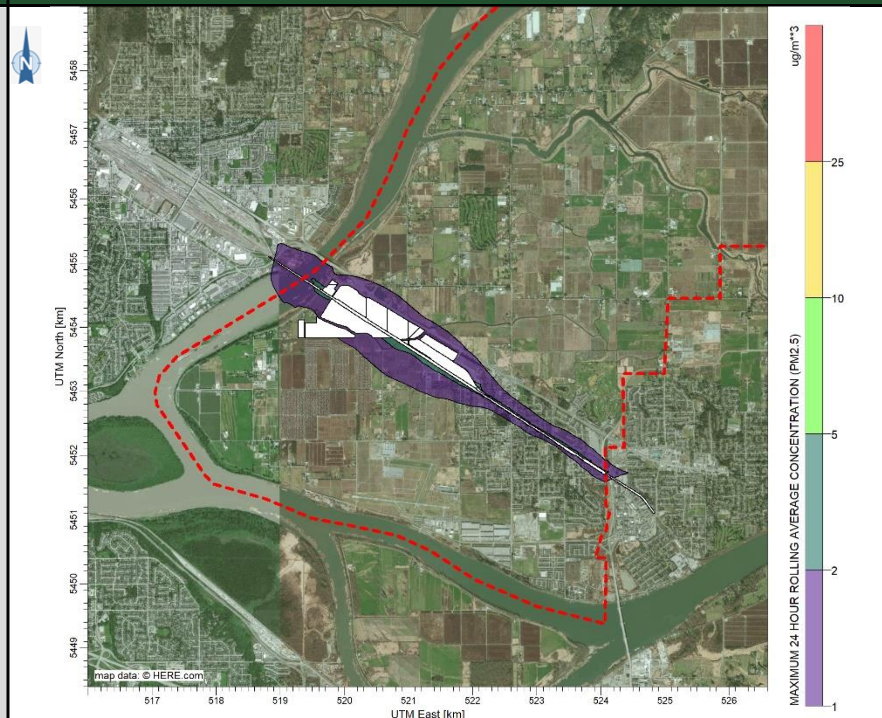
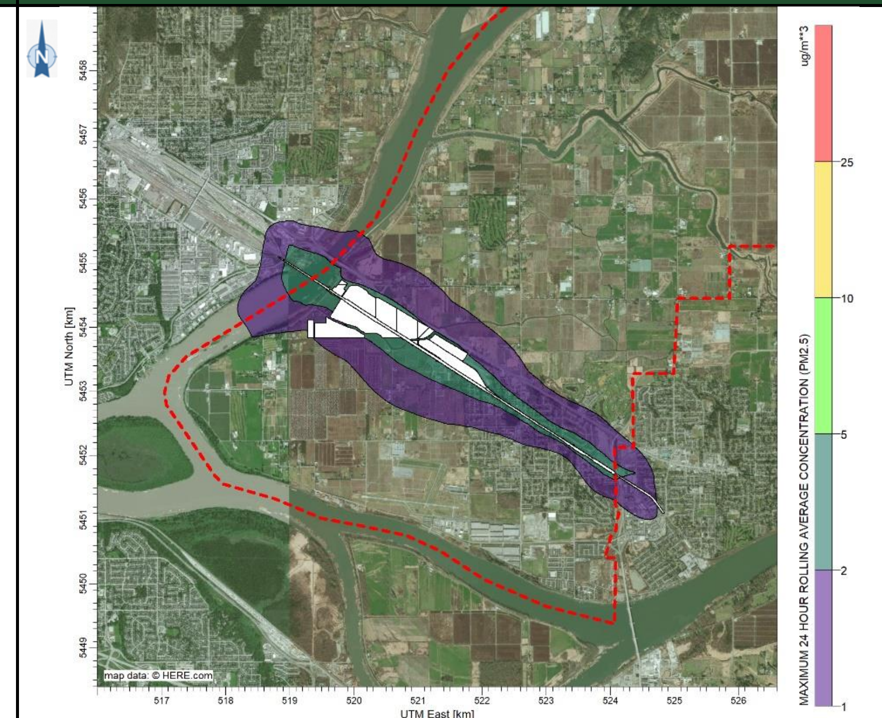
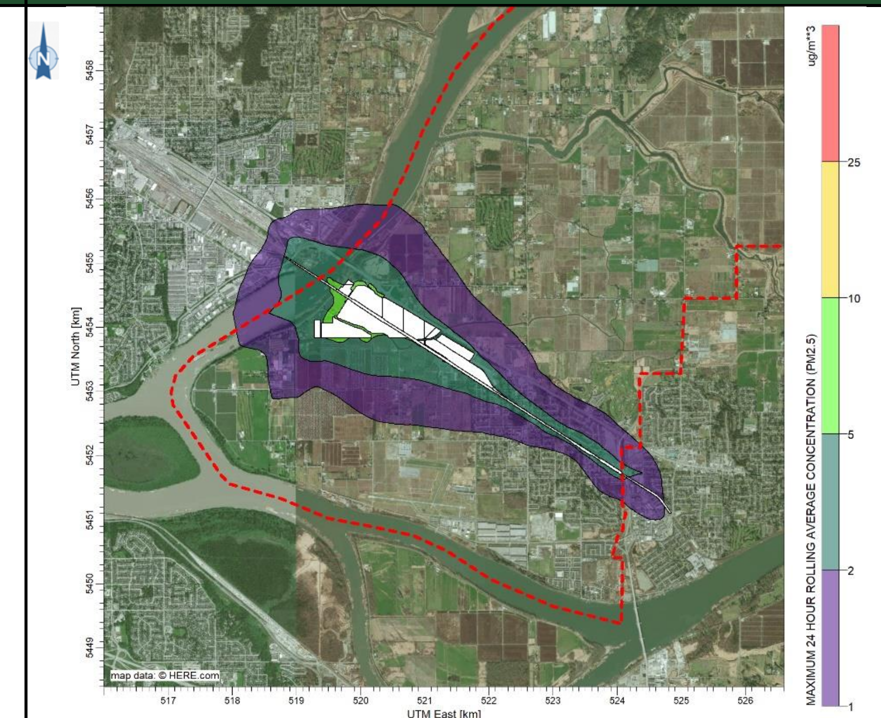
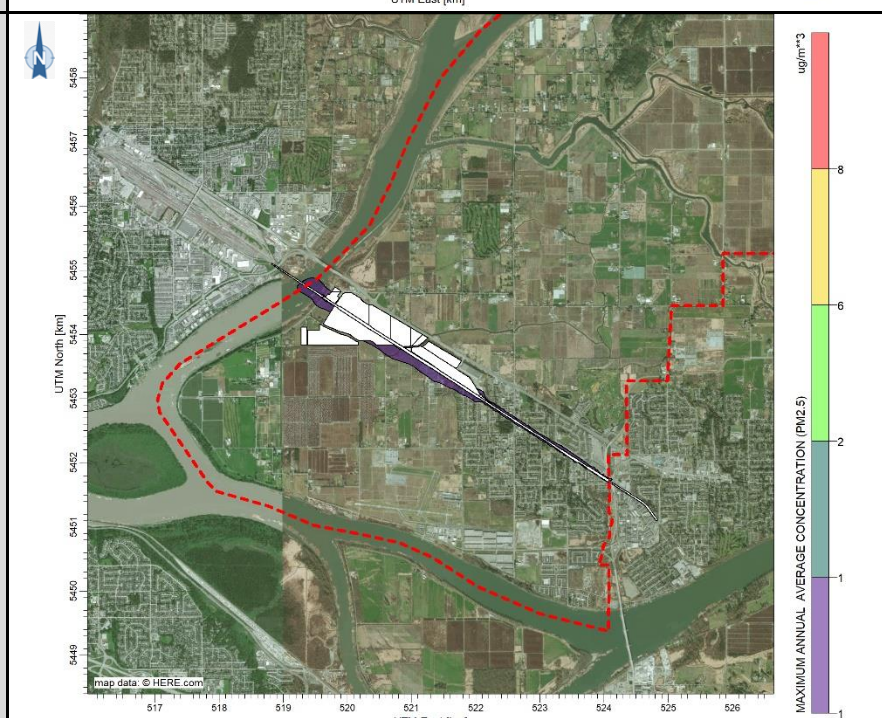
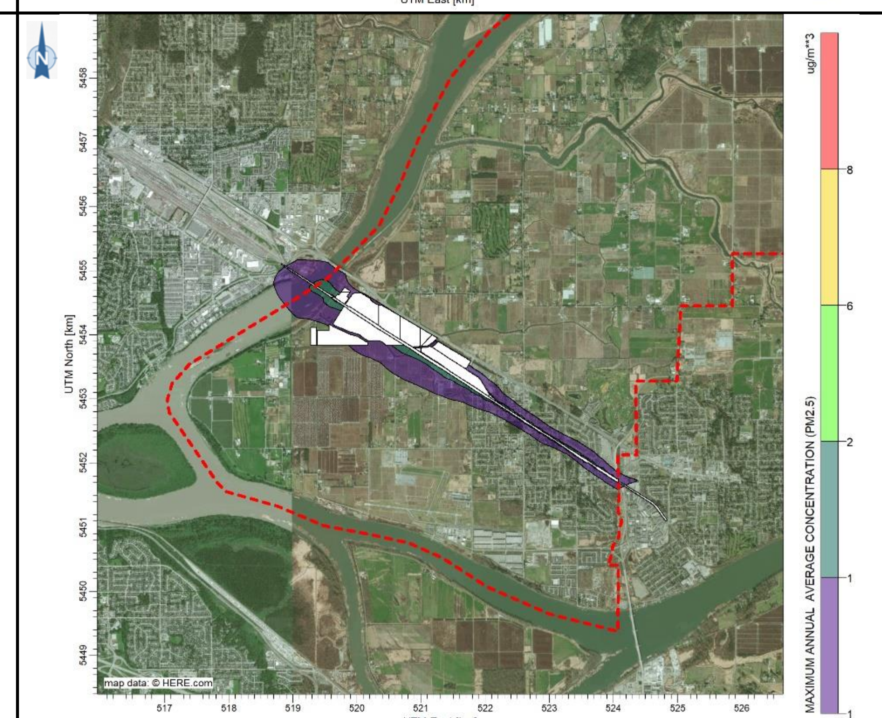
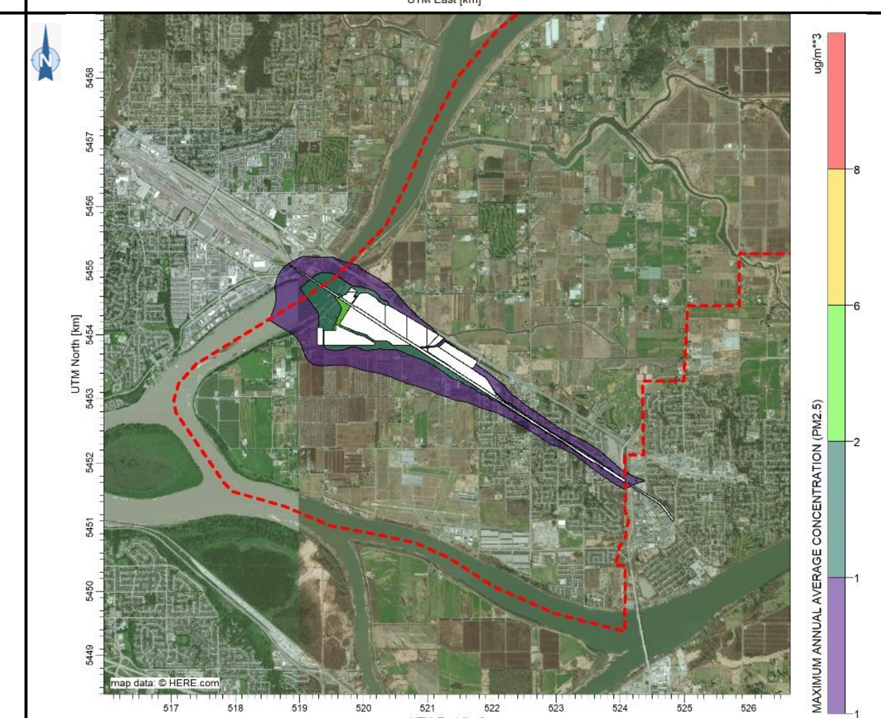
**Table 5-2: Dispersion Model Predicted Ground Level DPM Concentrations for Each Emissions Scenario**

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Maximum 1-hour Average** |  |  |  |
| **Annual Average** |  |  |  |

***NOTE**: Model predicted DPM concentrations shown here are based on emissions from rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*

*- - - - = The City of Pitt Meadows Boundary*

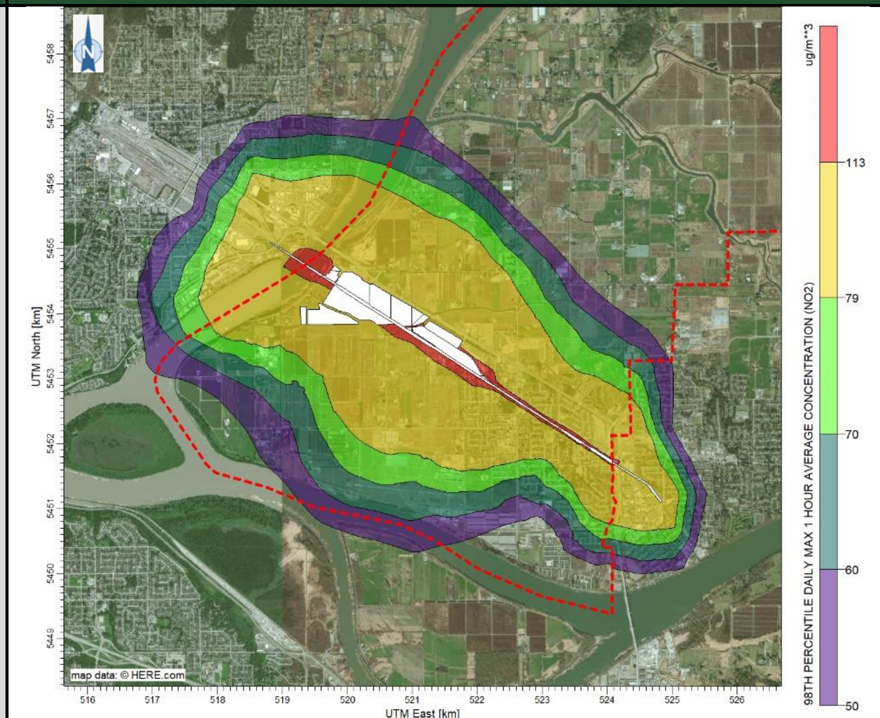
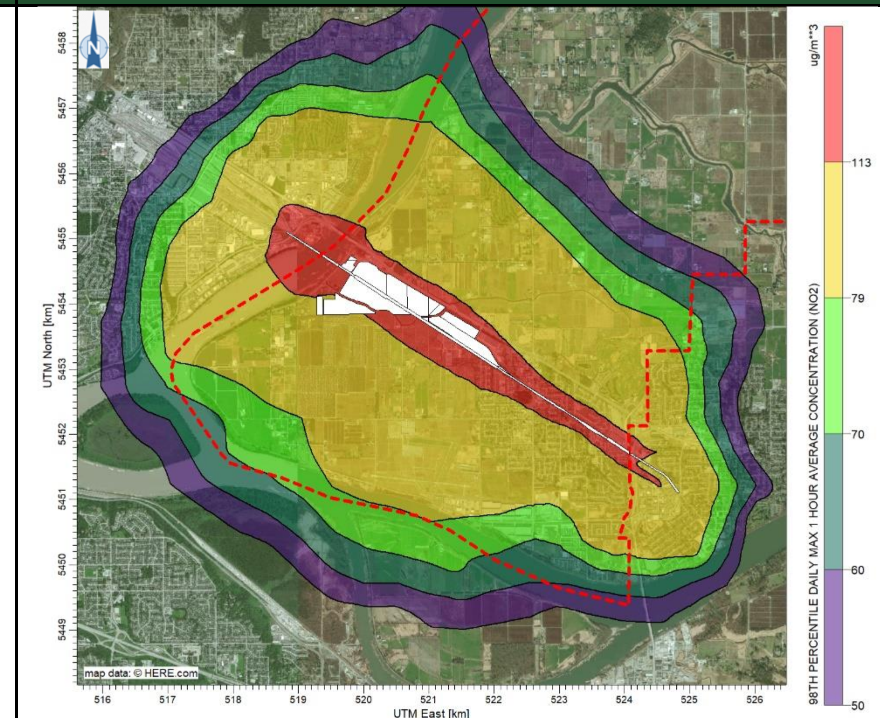
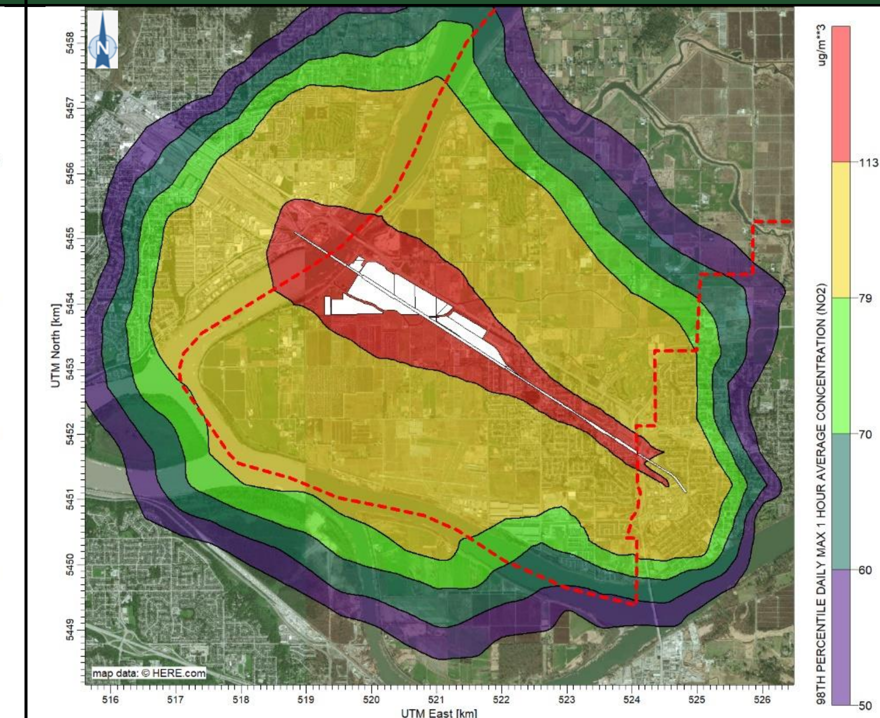
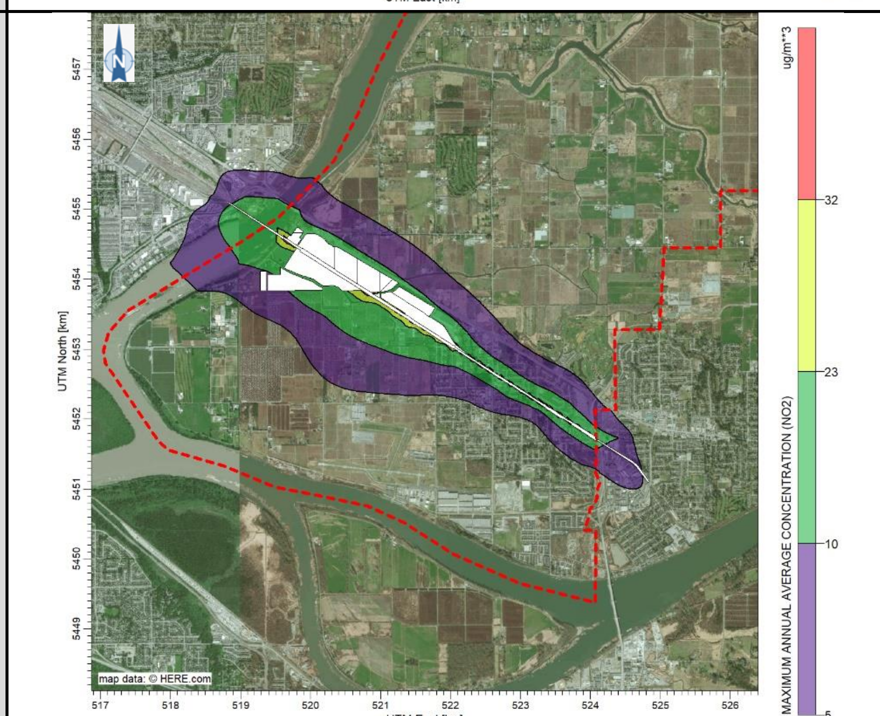
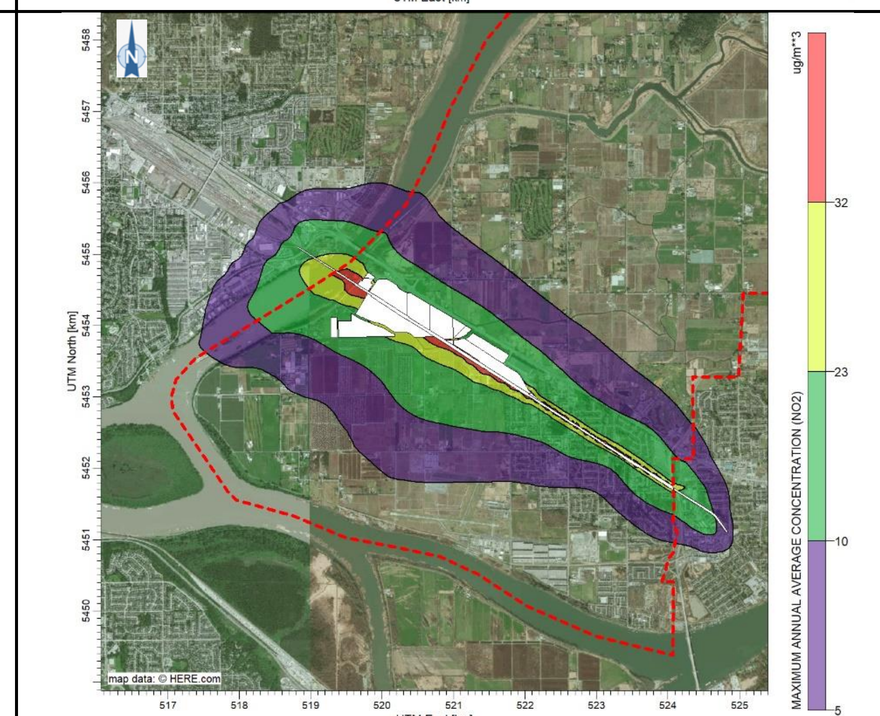
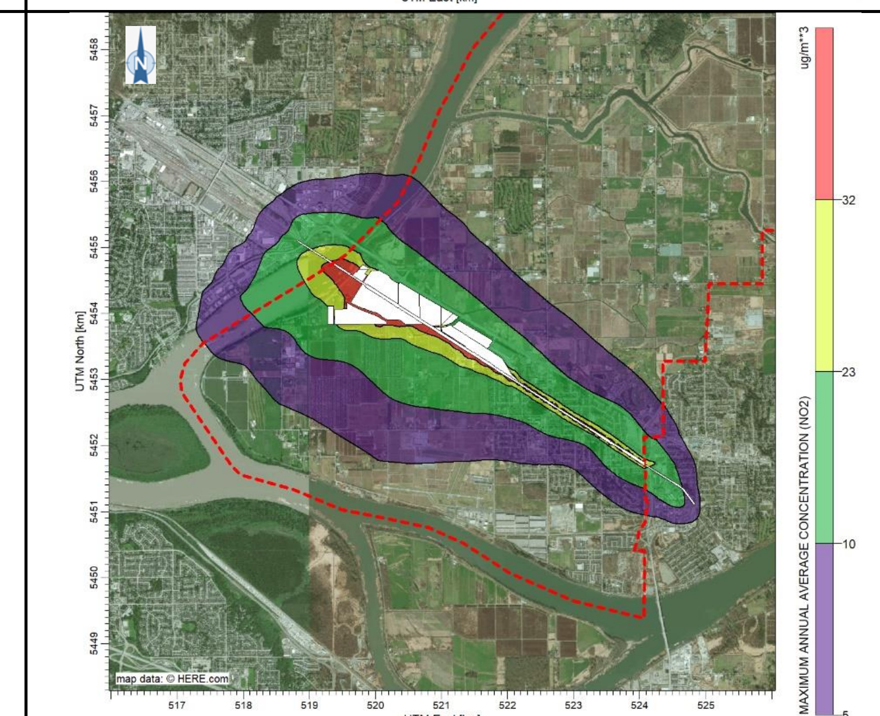
**Table 5-3: Dispersion Model Predicted Ground Level $PM_{2.5}$ Concentrations for Each Emissions Scenario**

<table>
<tr><th></th><th>Scenario 1 – Current Operations</th><th>Scenario 2 – Future 2030 Operations</th><th>Scenario 3 – Future 2030 Operations Including the LPV</th></tr>
<tr><td>Maximum 24-hour Rolling Average</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Annual Average</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
</table>

***NOTE**: Model predicted $PM_{2.5}$ concentrations shown here are based on emissions from rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*

*– – – – = The City of Pitt Meadows Boundary*

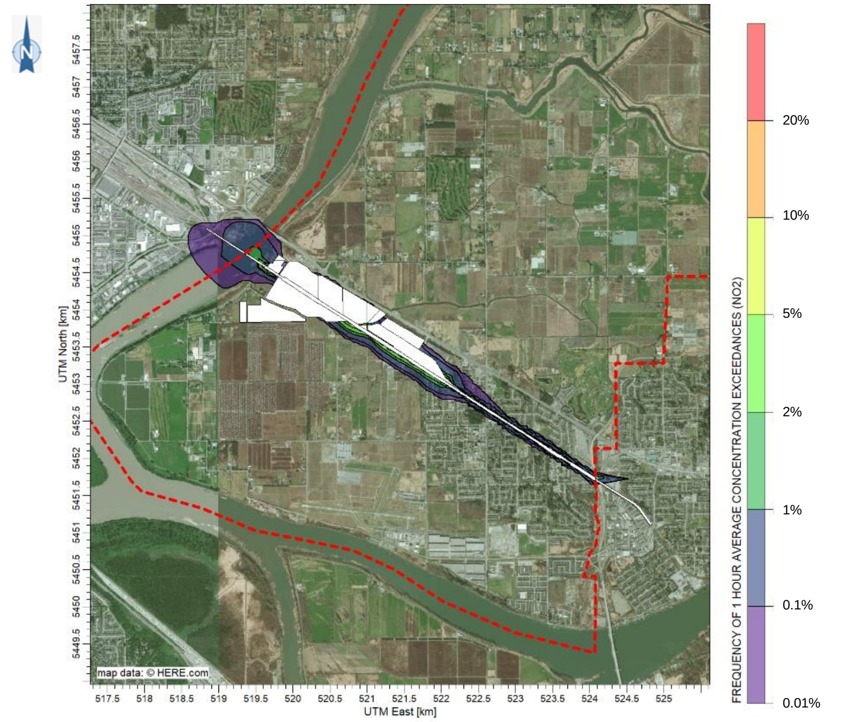
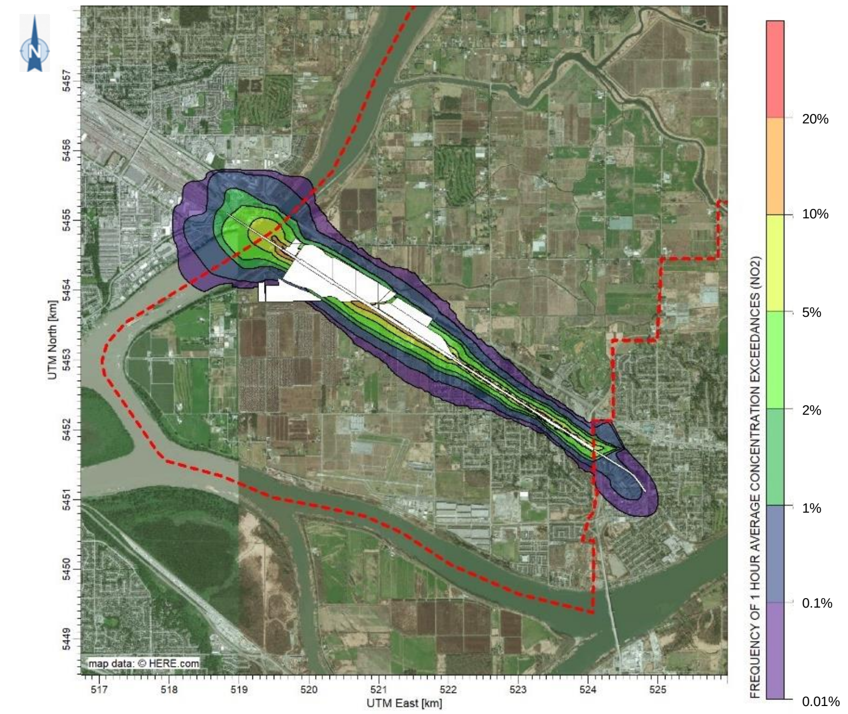
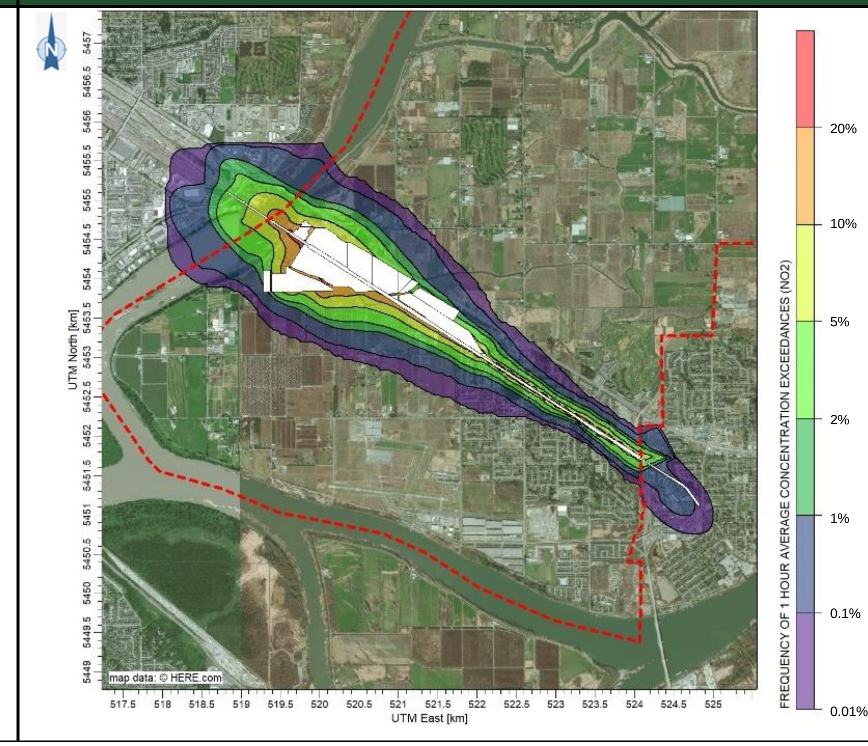
**Table 5-4: Dispersion Model Predicted Ground Level $NO_2$ Concentrations for Each Emissions Scenario (Using ARM2 $NO_2$ Conversion Method)**

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **98th Percentile Daily Max 1-Hour Average** |   |   |   |
| **Annual Average** |   |   |   |

***NOTE**: Model predicted $NO_2$ concentrations shown here are based on emissions from rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*

*– – – – = The City of Pitt Meadows Boundary*

**Table 5-5: Dispersion Model Predicted Frequency of Exceedance (Percentage of Hours per Year) of the 1-hour $NO_2$ Objective for Each Emissions Scenario (Using ARM2 $NO_2$ Conversion Method)**

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Frequency of Exceedance of 1-hour $NO_2$ Objective**<br>*(Percentage of Hours of the Year)* |  |  |  |

***NOTE 1**: Exceedance of 1-hour $NO_2$ Ambient Air Quality Objective would be determined based on the 98th percentile of daily maximum 1-hour values.*
***NOTE 2**: Model predicted $NO_2$ concentrations shown here are based on emissions from rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*
– – – – = *The City of Pitt Meadows Boundary*

# 6.0 PRELIMINARY HUMAN HEALTH RISK ASSESSMENT

## 6.1 Risk Assessment Approach

The potential for human health risks exist due to the presence of chemical constituents in environmental media is predicated on the co-existence of three components: 1) chemicals must be present at hazardous levels, 2) receptors (people) must be present, and 3) exposure pathways must exist between the chemicals and receptors. In the absence of any one of the three components, human health risks do not exist. The presence of all three elements indicates a potential for risks but does not indicate the magnitude of risk. A risk assessment is conducted to determine if these three essential elements of risk are present, and whether the magnitude of risk is acceptable or unacceptable.

The risk assessment framework applied for the project is consistent with provincial and federal guidance and consists of four steps:

1) Problem Formulation;
2) Exposure Assessment;
3) Effects Assessment; and
4) Risk Characterization.

In Problem Formulation, a conceptual exposure model is developed which identifies the contaminants of potential concern, the human receptors of potential concern, and potentially complete exposure pathways between the contaminants and receptors. In Exposure Assessment, the frequency, magnitude and duration of contaminant exposure is estimated for each receptor. In Effects Assessment, the adverse effects that exposures to the contaminants could cause are identified, and toxicity reference values (TRVs) are selected. During the Risk Characterization step, the results of the Exposure and Effects Assessments are integrated and interpreted into descriptions of human health risk.

The guidance documents used in the human health risk assessment were:

- Protocol 1 for Contaminated Sites - Detailed Risk Assessment, Version 3.0. ENV, May 13, 2021.
- Human Health Risk Assessment for Diesel Exhaust. Health Canada, March 2016.
- Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0. Health Canada, March 2021.
- Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0. Health Canada, March 2021.

## 6.2 Problem Formulation

### 6.2.1 Conceptual Exposure Model

The three scenarios for which dispersion modelling was conducted and that the HHRA considers are as follows. It should be noted that the emissions modelling in this study includes worst-case activity levels (based on current understanding of rail operations in Pitt Meadows) to identify the maximum potential health impacts. Comparison of the results for each scenario is reasonable with the understanding that background concentrations from other emissions sources in the region will also impact potential risks identified below.

- **Scenario 1:** Current rail operations,
- **Scenario 2:** Forecasted 2030 rail operations,
- **Scenario 3:** Forecasted 2030 rail operations with the addition of the proposed CP Logistics Park: Vancouver

#### Contaminants of Potential Concern

The contaminants of potential concern (COPCs) associated with diesel emissions for which dispersion modelling was conducted include CO, $NO_2$, $PM_{2.5}$, DPM, $SO_2$ and hydrocarbons. Model predicted concentrations of DPM and total hydrocarbons were then speciated (i.e., concentrations of their individual chemical components were identified) using speciation factors specific to locomotive and truck emissions from the US EPA to also evaluate the health impacts of additional COPCs, including specific volatile organic compounds (VOCs), metals, polycyclic aromatic hydrocarbons (PAHs), and dioxins/furans. The full list of COPCs evaluated is presented in **Table 6-1**.

**Table 6-1: Evaluated Contaminants of Potential Concern**

| COPC | Class |
|---|---|
| Diesel Particulate Matter (DPM) | - |
| Fine Particulate Matter ($PM_{2.5}$) | Criteria Air Contaminant |
| Nitrogen Dioxide ($NO_2$) | Criteria Air Contaminant |
| Sulphur Dioxide ($SO_2$) | Criteria Air Contaminant |
| Carbon Monoxide ($NO_2$) | Criteria Air Contaminant |
| 1,2,3,4,6,7,8-Heptachlorodibenzofuran | Dioxin/Furan |
| 1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin | Dioxin/Furan |
| 1,2,3,4,7,8-Hexachlorodibenzofuran | Dioxin/Furan |
| 1,2,3,6,7,8-Hexachlorodibenzofuran | Dioxin/Furan |
| 1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin | Dioxin/Furan |
| 1,2,3,7,8,9-Hexachlorodibenzofuran | Dioxin/Furan |
| 1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin | Dioxin/Furan |
| 1,2,3,7,8-Pentachlorodibenzofuran | Dioxin/Furan |
| 2,3,4,7,8-Pentachlorodibenzofuran | Dioxin/Furan |
| 2,3,7,8-Tetrachlorodibenzofuran | Dioxin/Furan |

| COPC | Class |
|---|---|
| 2,3,7,8-Tetrachlorodibenzo-p-Dioxin | Dioxin/Furan |
| Octachlorodibenzofuran | Dioxin/Furan |
| Octachlorodibenzo-p-Dioxin | Dioxin/Furan |
| Arsenic | Metal |
| Chromium (VI) | Metal |
| Manganese | Metal |
| Mercury | Metal |
| Nickel | Metal |
| Anthracene | PAH |
| Benz[a]Anthracene | PAH |
| Benzo[a]Pyrene | PAH |
| Benzo[b]Fluoranthene | PAH |
| Benzo[g,h,i,]Perylene | PAH |
| Benzo[k]Fluoranthene | PAH |
| Chrysene | PAH |
| Dibenzo[a,h]Anthracene | PAH |
| Fluoranthene | PAH |
| Fluorene | PAH |
| Indeno[1,2,3-c,d]Pyrene | PAH |
| Phenanthrene | PAH |
| Pyrene | PAH |
| Acenaphthene | PAH/VOC |
| Acenaphthylene | PAH/VOC |
| Naphthalene | PAH/VOC |
| 1,3-Butadiene | VOC |
| 2,2,4-Trimethylpentane | VOC |
| Acetaldehyde | VOC |
| Acrolein | VOC |
| Benzene | VOC |
| Ethylbenzene | VOC |
| Formaldehyde | VOC |
| Hexane | VOC |
| Propionaldehyde | VOC |
| Toluene | VOC |
| Xylenes (Mixed Isomers) | VOC |

### Receptors of Potential Concern

The human receptors of potential concern (ROPCs) with respect to exposures to diesel emissions from rail activities are members of the general public that live, work and recreate within the City of Pitt Meadows and the region in general. In particular, dispersion modelling predicted COPC concentrations for the following locations within the study area to which people could be exposed: Businesses, Child Care Facilities, Health Care Facilities, Residences, Schools, Senior Care Facilities, and the Maximum Point of Impingement (MPOI). The ROPCs for the preliminary HHRA are people that spend time at these locations. The location with the highest predicted concentration within each category was assessed (e.g., the school with the highest predicted concentration of the school locations included in the model).

### Exposure Pathways

Inhalation of COPCs attached to airborne particles and/or in the vapour phase is expected to be the primary exposure pathway of concern with respect to human exposure and health effects and therefore is the focus of the preliminary HHRA. Exposure to diesel emission related COPCs via other exposure pathways (e.g., ingestion of settled dust, dermal contact with settled dust, ingestion of food grown in contaminated soils, etc.) is possible but expected to be a less important contributor to exposure and risk.

A conceptual exposure model is presented in **Appendix A**.

## 6.3 Exposure Assessment

### Exposure Estimation

The following equation from Health Canada [22] was used to estimate human exposures to COPCs for which inhalation pathway-specific air concentration-based TRVs were available:

$$\mathrm{TDC}_A \text{ or } \mathrm{TLAC}_A = \frac{\mathrm{C}_A \times \mathrm{RAF}_{\mathrm{Inh}} \times \mathrm{D}_1 \times \mathrm{D}_2 \times \mathrm{D}_3 \times \mathrm{D}_4}{\mathrm{LE}}$$

Where:

- $TDC_A$ = time-adjusted average daily air concentration (µg/m$^3$) – to assess non-cancer risk
- $TLAC_A$ = time-adjusted lifetime average air concentration (µg/m$^3$) – to assess cancer risk
- $C_A$ = concentration of COPC in air (µg/m$^3$)
- $RAF_{Inh}$ = relative absorption factor for inhalation (unitless)
- $D_1$ = hours per day exposed/24 hours
- $D_2$ = days per week exposed/7 days
- $D_3$ = weeks per year exposed/52 weeks
- $D_4$ = number of years exposed (used in exposure estimation for cancer risk only)
- LE = life expectancy (year; used in exposure estimation for cancer risk only)

For non-carcinogenic COPCs for which only an oral dose-based TRV was available, the following equation from Health Canada was used to estimate exposure:

$$\mathrm{Dose} = \frac{\mathrm{C}_A \times \mathrm{IR}_A \times \mathrm{RAF}_{\mathrm{Inh}} \times \mathrm{D}_1 \times \mathrm{D}_2 \times \mathrm{D}_3}{\mathrm{BW}}$$

Where:

- Dose = Daily dose of COPC (mg/kgBW-day)
- $C_A$ = concentration of COPC in air (µg/m$^3$)
- $IR_A$ = air intake rate (m$^3$/day)
- $RAF_{Inh}$ = relative absorption factor for inhalation (unitless)
- $D_1$ = hours per day exposed/24 hours
- $D_2$ = days per week exposed/7 days
- $D_3$ = weeks per year exposed/52 weeks
- BW = body weight (kgBW)

The input parameters used in the exposure estimation equations are defined below.

[22] Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0.*

### Predicted Exposure Concentrations

Maximum predicted 1-hour (all COPCs except $PM_{2.5}$), 8-hour (carbon monoxide) and 24-hr ($PM_{2.5}$ [23]) average concentrations at each location and scenario were assumed to represent the concentration of each respective contaminant in air ($C_A$) for the purposes of estimating short term exposures (see **Table 5-1**). To estimate chronic COPC exposures, predicted annual average concentrations at each location and scenario were assumed to represent the $C_A$ term (see **Table 5-1**). As described previously in this report, for the additional Hazardous Air Pollutants (HAPs) that are not included in **Table 5-1**, concentrations were calculated through scaling of the predicted DPM and total hydrocarbon concentrations into concentrations of the individual components of these contaminant groups, using speciation profiles for locomotive and heavy truck emissions from the US EPA (approach described in **Sections 4.1**, and **4.2**, respectively).

### COPC Absorption

A relative inhalation absorption factor ($RAF_{Inh}$) of one (1) was assumed when estimating COPC exposure, per Health Canada guidance [24].

### Receptor Characteristics

The duration and frequency ($D_1$, $D_2$, $D_3$, $D_4$) that ROPCs were assumed to be exposed to each COPC and assumed ROPC life expectancies were based on preliminary human health risk assessment guidance from Health Canada [25] and are presented below in **Table 6-2**. The exposure time, frequency, duration and life expectancy terms were not employed when estimating acute COPC exposures.

**Table 6-2: Assumed Exposure Duration and Frequency**

| Location | Hours Per Day Exposed | Days Per Week Exposed | Weeks Per Year Exposed | Years Exposed | Life Expectancy *(Years)* | Air Intake Rate [(c)] *($m^3/d$)* | Body Weight [(c)] *(kg)* |
|---|---|---|---|---|---|---|---|
| **MPOI [(a)]** | 2 | 7 | 52 | 80 | 80 | 8.3 | 16.5 |
| **Business** | 10 | 5 | 48 | 35 | 80 | 8.3 | 16.5 |
| **Child Care** | 10 | 5 | 48 | 35 | 80 | 8.3 | 16.5 |
| **Health Care [(b)]** | 10 | 5 | 48 | 35 | 80 | 8.3 | 16.5 |
| **Residence** | 24 | 7 | 52 | 80 | 80 | 8.3 | 16.5 |
| **School** | 10 | 5 | 48 | 35 | 80 | 8.3 | 16.5 |
| **Senior Care** | 24 | 7 | 52 | 35 | 80 | 16.6 | 70.7 |

*(a) Maximum predicted model result at an outdoor space near the rail operations*
*(b) Business hours assumed for the health care facilities as those within the study area are clinics without overnight care.*
*(c) Conservatively the air intake rate and body weights for most receptors were assigned based on a toddler, with the exception of senior care where it was assumed only adults would be present.*

[23] Model predicted 24-hour rolling average $PM_{2.5}$ concentrations were used to assess the acute health risks of $PM_{2.5}$ exposure due to the format of the reference value used (i.e., the CAAQS 24-hour rolling average for $PM_{2.5}$).
[24] Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0.*
[25] Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0.*

## 6.4 Toxicity Assessment

### Carcinogenicity

The potential for each COPC to cause cancer was evaluated in accordance with BC ENV Protocol 30 [26]. The following COPCs were determined to be carcinogenic by this approach:

- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- 1,3-Butadiene
- Chromium VI
- Chrysene
- Diesel Particulate Matter
- Dibenz(a,h)anthracene
- Formaldehyde
- 2,3,4,7,8-Pentachlorodibenzofuran
- 2,3,7,8-Tetrachlorodibenzo-p-Dioxin

For these substances, cancer risks and non-cancer health risks were estimated. For the remaining substances, only non-cancer health risks were estimated.

### Toxicity Reference Values

The following sources were consulted to identify applicable TRVs for use in the HHRA, as recommended by the BC ENV [27]:

Tier 1:

- Health Canada, Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs). Version 3.0. March 2021.
- United States Environmental Protection Agency - Integrated Risk Information System.
- World Health Organization - International Programme on Chemical Safety.

Tier 2:

- United States Agency for Toxic Substances and Disease Registry - Toxic Substances Portal.
- Oak Ridge National Laboratory - Risk Assessment Information System.
- Netherlands National Institute of Public Health and the Environment – Re-evaluation of Human Toxicological Maximum Permissible Risk Levels
- California Environmental Protection Agency - Toxic Criteria Database
- United States Environmental Protection Agency - Regional Screening Levels (2015)
- European Chemicals Agency - Registered Substances
- Other Canadian provinces or US state agencies

[26] British Columbia Ministry of Environment & Climate Change Strategy, 2017 – *Protocol 30 for Contaminated Sites – Classifying Substances as Carcinogenic, Version 1.0.*
[27] British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *Protocol 1 for Contaminated Sites - Detailed Risk Assessment, Version 3.0.*

Within Tier 1, Canadian TRVs were prioritized over international TRVs. TRVs were selected from Tier 2 sources only when applicable values from a Tier 1 source were unavailable. The TRVs used in the HHRA are presented below in **Table 6-3**. The regional air quality objectives and federal standards identified in **Section 2.3** are not purely health-based and therefore were only used for substances where TRVs are not available. In the case of the CAAQS used for $NO_2$ and $SO_2$, the 2025 standards have been used as these standards will be in place ahead of the future scenarios evaluated in this study.

A toxicity profile for select COPCs that were predicted to show elevated risk is provided in **Appendix B**.

**Table 6-3: Toxicity Reference Values**

| COPC | Inhalation Reference Concentration – Acute *(µg/m³)* | Inhalation Reference Concentration – Chronic *(µg/m³)* | Oral Tolerable Daily Intake *(mg/kgBW-day)* | Critical Non-Cancer Effect | Inhalation Unit Risk *(µg/m³)⁻¹* | Tumor Sites |
|---|---|---|---|---|---|---|
| **Diesel Particulate Matter (DPM)** | 10 (a) | 5 (a),(d) | - (m) | Respiratory Cardiovascular | 0.0003 (c) | Respiratory |
| **Fine Particulate Matter ($PM_{2.5}$)** | 27 (h) | 8.8 (h) | - | Respiratory Cardiovascular | NA (l) | NA |
| **Nitrogen Dioxide ($NO_2$)** | 79 (h) | 22.6 (h) | - | Respiratory | NA | NA |
| **Sulphur Dioxide ($SO_2$)** | 26 (e) | 10.5 (h) | - | Respiratory | NA | NA |
| **Carbon Monoxide (CO)** | 14,900 (i)<br>5,700 (j) | VNA (k) | - | Respiratory | NA | NA |
| **1,2,3,4,6,7,8-Heptachlorodibenzofuran** | VNA (k) | VNA (k) | 2.3E-9 TEQ (b) | Development | NA | NA |
| **1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,4,7,8-Hexachlorodibenzofuran** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,6,7,8-Hexachlorodibenzofuran** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,7,8,9-Hexachlorodibenzofuran** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin** | VNA (k) | VNA (k) | | | NA | NA |
| **1,2,3,7,8-Pentachlorodibenzofuran** | VNA (k) | VNA (k) | | | NA | NA |
| **2,3,4,7,8-Pentachlorodibenzofuran** | VNA (k) | VNA (k) | | | 11.4 (n) | Multiple |
| **2,3,7,8-Tetrachlorodibenzofuran** | VNA (k) | VNA (k) | | | NA | NA |

| COPC | Inhalation Reference Concentration – Acute *($\mu g/m^3$)* | Inhalation Reference Concentration – Chronic *($\mu g/m^3$)* | Oral Tolerable Daily Intake *(mg/kgBW-day)* | Critical Non-Cancer Effect | Inhalation Unit Risk *($\mu g/m^3)^{-1}$* | Tumor Sites |
|---|---|---|---|---|---|---|
| **2,3,7,8-Tetrachlorodibenzo-p-Dioxin** | VNA [k] | VNA [k] | | | 38 [n] | Multiple |
| **Octachlorodibenzofuran** | VNA [k] | VNA [k] | | | NA | NA |
| **Octachlorodibenzo-p-Dioxin** | VNA [k] | VNA [k] | | | NA | NA |
| **Arsenic** | 0.2 [c] | 0.015 [c] | - | Reproduction<br>Development<br>Neurologic<br>Cardiovascular | 0.0064 [b] | Respiratory |
| **Chromium (VI)** | 0.3 [e] | 0.1 [b] | - | Respiratory | 0.076 [b] | Respiratory |
| **Manganese** | VNA [k] | 0.05 [d] | - | Neurobehavior | NA | NA |
| **Mercury** | 0.6 [c] | 0.3 [d] | - | Reproduction<br>Development<br>Neurologic | NA | NA |
| **Nickel** | 0.2 [c] | 0.018 [b] | - | Immunity<br>Respiratory<br>Hematologic | NA | NA |
| **Anthracene** | VNA [k] | 10 [b],[f] | - | Respiratory | NA | NA |
| **Benz[a]Anthracene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.00006 [b] | GI<br>Respiratory |
| **Benzo[a]Pyrene** | VNA [k] | 0.002 [b] | - | Development | 0.0006 [b] | GI<br>Respiratory |
| **Benzo[b]Fluoranthene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.00006 [b] | GI<br>Respiratory |
| **Benzo[g,h,i,]Perylene** | VNA [k] | 0.002 [b],[g] | - | Development | | NA |
| **Benzo[k]Fluoranthene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.00006 [b] | GI<br>Respiratory |
| **Chrysene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.000006 [b] | GI<br>Respiratory |
| **Dibenzo[a,h]Anthracene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.0006 [b] | GI<br>Respiratory |
| **Fluoranthene** | VNA [k] | 0.002 [b],[g] | - | Development | NA | NA |
| **Fluorene** | VNA [k] | 10 [b],[f] | - | Respiratory | NA | NA |
| **Indeno[1,2,3-c,d]Pyrene** | VNA [k] | 0.002 [b],[g] | - | Development | 0.00006 [b] | GI<br>Respiratory |
| **Phenanthrene** | VNA [k] | 10 [b],[f] | - | Respiratory | NA | NA |
| **Pyrene** | VNA [k] | 0.002 [b],[g] | - | Development | NA | NA |
| **Acenaphthene** | VNA [k] | 10 [b],[f] | - | Respiratory | NA | NA |

| COPC | Inhalation Reference Concentration – Acute *(µg/m³)* | Inhalation Reference Concentration – Chronic *(µg/m³)* | Oral Tolerable Daily Intake *(mg/kgBW-day)* | Critical Non-Cancer Effect | Inhalation Unit Risk *(µg/m³)⁻¹* | Tumor Sites |
|---|---|---|---|---|---|---|
| **Acenaphthylene** | VNA [(k)] | 10 [(b),(f)] | - | Respiratory | NA | NA |
| **Naphthalene** | VNA [(k)] | 10 [(b)] | - | Respiratory | NA | NA |
| **1,3-Butadiene** | 660 [(c)] | 2 [(d)] | - | Development Reproduction | 0.00003 [(d)] | Hematologic |
| **2,2,4-Trimethylpentane** | VNA [(k)] | VNA [(k)] | - | NA | NA | NA |
| **Acetaldehyde** | 470 [(c)] | 9 [(d)] | - | Respiratory Eyes Neurologic | NA | NA |
| **Acrolein** | 2.5 [(c)] | 0.02 [(d)] | - | Respiratory Eyes | NA | NA |
| **Benzene** | 21 [(e)] | 30 [(d)] | - | Reproduction Development Immunity Hematologic | 0.000016 [(b)] | Hematologic |
| **Ethylbenzene** | 15,973 [(e)] | 2000 [(b)] | - | Liver Endocrine | NA | |
| **Formaldehyde** | 49 [(e)] | 9 [(c)] | - | Respiratory Eyes | 0.000013 [(d)] | Respiratory |
| **Hexane** | VNA [(k)] | 700 [(b)] | - | Neurologic | NA | NA |
| **Propionaldehyde** | VNA [(k)] | 8 [(d)] | - | Respiratory Neurologic | NA | NA |
| **Toluene** | 5,000 [(c)] | 2,300 [(b)] | - | Neurologic | NA | NA |
| **Xylenes (Mixed Isomers)** | 8,684 [(e)] | 100 [(b)] | - | Neurologic | NA | NA |

*(a) Health Canada [28]*
*(b) Health Canada [29].*
*(c) California Office of Environmental Health Hazard Assessment (CalEPA)*
*(d) United States Environmental Protection Agency Integrated Risk Information System*
*(e) Agency for Toxic Substances and Disease Registry (ATSDR)*
*(f) TRV for naphthalene used, based on structure-activity relationship (low molecular weight PAH)*
*(g) TRV for benzo(a)pyrene used, based on structure-activity relationship (high molecular weight PAH)*
*(h) CCME Canadian Ambient Air Quality Standards*
*(i) Metro Vancouver Ambient Air Quality Objectives (Averaging Time = 1 hour)*
*(j) Metro Vancouver Ambient Air Quality Objectives (Averaging Time = 8 hour)*
*(k) VNA: TRV not available*
*(l) NA: not applicable*
*(m) -: dose-based TRV not used since inhalation reference concentration available*
*(n) World Health Organization*

[28] Health Canada, 2016 – *Human Health Risk Assessment for Diesel Exhaust*
[29] Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0.*

## 6.5 Preliminary Risk Estimates (Worst-Case by Receptor Category)

The health risks for each human receptor were estimated based on worst-case air dispersion modelling presented in **Section 5.2**, exposure assumptions presented in **Section 6.3** and TRVs presented in **Section 6.4**. Since CP's rail operations are federally regulated, federal risk guidelines were used to interpret the acceptability of the estimated risks.

Health risks are assessed with respect to acute (i.e., due to short-term exposures to air contaminants) and chronic (i.e., due to long term exposures to air contaminants) non-cancer health risks in **Section 6.5.1**, as well as the incremental lifetime cancer risk associated with long-term exposure to each of the assessed COPCs in **Section 6.5.3**. Acute health risks for each of the COPCs are assessed based on the model predicted worst-case maximum 1-hour concentrations (i.e., based on the estimated emissions for the worst-case maximum 1-hour activity levels of the rail operations described in **Section 4.0** and hourly meteorological data), while chronic non-cancer health risks and incremental lifetime cancer risks are assessed based on the model predicted annual average air concentrations of each COPC (i.e., based on the average of the model predicted air contaminant concentrations predicted for each hour of the model year due to estimated emissions from the typical activity levels of the rail operations described in **Section 4.0**). Therefore, while any model predicted exceedances of the threshold of acceptability used in this study for acute health risks would show potential risk, model predictions of chronic non-cancer health risks or cancer risks exceeding acceptable risk thresholds would show potential risk with greater certainty.

### 6.5.1 Non-Cancer Health Risks – Methodology

Non-cancer health risks were estimated for each receptor location and scenario by the formulas below. Non-cancer health risks are calculated as hazard quotients (HQ) which refer to the ratio of the estimated exposure concentration/dose over the threshold reference value (e.g., a HQ of 1 identifies that the assessed value is equal to the TRV, while a HQ of 0.33 identifies that the assessed value is equal to one third of the TRV).

$$\mathrm{HQ} = \frac{\mathrm{TDC}_A}{\mathrm{RFC}}$$

Or

$$\mathrm{HQ} = \frac{Daily\ Dose}{\mathrm{TDI}}$$

Where:

- HQ = Hazard Quotient,
- $TDC_A$ = Time-adjusted average daily air concentration (µg/m$^3$),
- Daily Dose = Time-adjusted daily average oral dose (mg/kgBW-day),
- RFC = Inhalation reference concentration (µg/m$^3$),
- TDI = Oral Tolerable Daily Intake (mg/kgBW-day)

The default threshold of acceptability for non-cancer health risks in a preliminary quantitative human health risk assessment conducted for federally-regulated sites, according to Health Canada [30], is a HQ of 0.2. This threshold of acceptability is applicable when all pathways of exposure to a chemical, including background exposures unrelated to a particular site, have not been quantified. Health Canada guidance allows for the use of HQ acceptability thresholds other than 0.2 with rationale.

This preliminary HHRA does not fully account for background exposures to COPCs and focusses on inhalation exposures only. The media to which people could theoretically be exposed to the COPCs include air (inhalation), soil/settled dust (ingestion/dermal contact), water (ingestion/dermal contact), food (ingestion), and consumer products (dermal contact). It is highly unlikely that people would be exposed to COPCs through consumption or contact with water or consumer products. If the tolerable daily intake of COPCs is apportioned equally to the three remaining media (i.e. air, soil/settled dust and food), an allowable HQ of 0.33 from exposure to each medium can be derived. Accordingly, an HQ of 0.33 was used as the threshold of acceptability for the air inhalation risk estimates presented below. This is expected to be conservative since air exposures to COPCs are likely to be much higher and hazardous than exposures to soil/settled dust and food.

Non-cancer hazard quotients for each scenario and location (the receptors with the maximum predicted ground level concentrations in each receptor category) are presented below in **Table 6-4** to **Table 6-6**. (calculated HQs are presented only for COPCs where predicted HQs were greater than 0.2 at any receptor). A toxicity profile for COPC's with elevated risk estimates is provided in **Appendix B.**

**Example Calculation – Non-Cancer Hazard Quotient**

- Scenario: 1
- Receptor: Business
- Exposure Type: Chronic
- COPC: Diesel Particulate Matter (DPM)

$$\mathrm{HQ} = \frac{\mathrm{TDC}_A}{\mathrm{RFC}}$$

$$\mathrm{HQ} = \frac{0.32\ \mu g/m^3 \times 10\ \text{hours}/24\ \text{hours} \times 5\ \text{days}/7\ \text{days} \times 48\ \text{weeks}/52\ \text{weeks}}{5\ \mu g/m^3}$$

$$\mathrm{HQ} = 0.018$$

It should be noted that in the absence of available TRVs from health agencies, the Canadian Ambient Air Quality Standards (CAAQS) were used as reference concentrations for $PM_{2.5}$, $NO_2$ and $SO_2$ (chronic) (as outlined in **Table 6-3** above). These standards may not be purely based on health protection but rather

[30] Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0.*

represent objectives to encourage air quality improvement across the country. As the relationship between health outcomes and exposure to concentrations of both $PM_{2.5}$ and $NO_2$ has not been determined to have a concentration threshold below which health outcomes are not observed; if the hazard quotients calculated for these contaminants are found to be below the threshold of acceptability used in this study (i.e., less than 0.33), this does not warrant that there are no health risks associated with exposure to the predicted concentrations of these air contaminants. This matter is discussed further in **Section 6.7.**

### 6.5.2 Non-Cancer Health Risks – Results

#### Scenario 1: Current Operations

Under current conditions for Scenario 1, a potential for adverse non-cancer health effects due to acute inhalation exposures was indicated for:

- DPM, and $NO_2$ at the maximum receptor within all receptor categories,
- $PM_{2.5}$ at the MPOI and maximum residence, child care, and health care receptors, and
- Nickel at the MPOI and maximum residence.

A potential for adverse non-cancer health effects due to chronic inhalation exposures was indicated for:

- Nitrogen dioxide and acrolein for residences and senior care facilities.

**Table 6-4** presents the maximum calculated hazard quotients under Scenario 1 for each receptor category for all substances where a HQ greater than 0.2 was calculated.

**Table 6-4: Hazard Quotients for Scenario 1: Current Operations**

| COPC | Hazard Quotient Term | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | MPOI | Business | Child Care | Health Care | Residence | School | Senior Care |
| $PM_{2.5}$ | Acute HQs | **0.84** | 0.33 | **0.54** | **0.40** | **0.66** | 0.33 | 0.27 |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| DPM | Acute HQs | **2.3** | **0.90** | **1.5** | **1.1** | **1.8** | **0.89** | **0.73** |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| $NO_2$ | Acute HQs | **2.6** | **1.3** | **1.7** | **1.5** | **2.1** | **1.3** | **1.2** |
| | Chronic HQs | *<0.2* | *<0.2* | 0.23 | *<0.2* | **1.2** | *<0.2* | **0.35** |
| Nickel | Acute HQs | **0.46** | *<0.2* | 0.30 | 0.22 | **0.36** | *<0.2* | *<0.2* |
| | Chronic HQs | <0.2 | *<0.2* | <0.2 | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| Acrolein | Acute HQs | 0.30 | *<0.2* | <0.2 | *<0.2* | 0.26 | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | 0.21 | *<0.2* | **1.3** | *<0.2* | 0.30 |
| Arsenic [(c)] | Acute HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| Formaldehyde [(c)] | Acute HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |

*(a) MPOI – maximum point of impingement*
*(b) **Bold** – exceeds threshold of acceptable risk (0.33)*
*(c) Arsenic and Formaldehyde are presented here for comparison as HQs exceed 0.2 at some receptors in Scenarios 2 and 3.*

### Scenario 2: Forecasted 2030 Rail Operations

Under Scenario 2, a potential for adverse non-cancer health effects due to acute inhalation exposures was indicated for:

- $PM_{2.5}$, DPM, and $NO_2$, at the maximum receptor within all receptor categories,
- Nickel for the MPOI and maximum residence, child care, and health care receptors,
- Acrolein for the MPOI and maximum residence and child care receptors, and
- Formaldehyde at the MPOI only.

A potential for adverse non-cancer health effects due to chronic inhalation exposures was indicated for:

- $NO_2$ at the maximum residence, child care and senior care receptors, and
- Acrolein at the maximum residence, child care and senior care receptors.

When comparing the estimated HQs at each of the sensitive receptors between Scenario 2 and Scenario 1, the estimated inhalation HQs for acute DPM (chosen as a proxy) exposure were between 46% and 91% higher, while the estimated HQs for chronic DPM exposure were between 55% and 89% higher. It should be noted that when comparing predicted HQs between each scenario, an increased HQ of “X”% means that the predicted concentration of the air contaminant increased by “X”%, but this does not necessarily infer that there is “X”% more risk associated with exposure to the higher air contaminant concentration as the relationships between the contaminant concentration and health outcomes may not be linear. However, it does imply that greater risk is associated with the exposure to the higher predicted air contaminant concentration.

**Table 6-5** presents the maximum calculated hazard quotients under Scenario 2 for each receptor category for all substances where a HQ greater than 0.2 was calculated.

**Table 6-5: Hazard Quotients for Scenario 2: Forecasted 2030 Operations**

| COPC | Hazard Quotient Term | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | MPOI | Business | Child Care | Health Care | Residence | School | Senior Care |
| $PM_{2.5}$ | Acute HQs | **1.7** | **0.54** | **0.97** | **0.66** | **1.1** | **0.55** | **0.46** |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| DPM | Acute HQs | **4.5** | **1.5** | **2.6** | **1.8** | **3.0** | **1.5** | **1.2** |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | 0.25 | *<0.2* | *<0.2* |
| $NO_2$ | Acute HQs | **5.2** | **1.7** | **3.1** | **2.1** | **3.5** | **1.8** | **1.5** |
| | Chronic HQs | *<0.2* | 0.21 | **0.35** | 0.21 | **1.6** | 0.24 | **0.59** |
| Nickel | Acute HQs | **0.92** | 0.30 | **0.53** | **0.36** | **0.61** | 0.30 | 0.25 |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | 0.28 | *<0.2* | *<0.2* |
| Acrolein | Acute HQs | **0.57** | *<0.2* | **0.34** | 0.24 | **0.39** | *<0.2* | *<0.2* |
| | Chronic HQs | 0.26 | 0.24 | **0.40** | 0.21 | **2.1** | 0.23 | **0.55** |
| Arsenic | Acute HQs | 0.24 | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| Formaldehyde | Acute HQs | **0.40** | *<0.2* | 0.24 | *<0.2* | 0.27 | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |

(a) *MPOI – maximum point of impingement*
(b) ***Bold*** *– exceeds threshold of acceptable risk (0.33)*

### Scenario 3: Forecasted 2030 Rail Operations Including Proposed LPV

Under Scenario 3, a potential for adverse non-cancer health effects due to acute inhalation exposures was indicated for:

- $PM_{2.5}$, DPM, and $NO_2$, at the maximum receptor within all receptor categories,
- Nickel for the maximum receptor in all categories except school and senior care,
- Acrolein for the MPOI, and maximum residence and child care receptors, and
- Formaldehyde at the MPOI only.

A potential for adverse non-cancer health effects due to chronic inhalation exposures is indicated for:

- $NO_2$ for the MPOI and at the maximum residence, child care, and senior care receptors, and
- Acrolein for the MPOI and at the maximum residence, child care, and senior care receptors.

The estimated inhalation HQs for acute DPM (chosen as a proxy) exposure at each of the sensitive receptors were up to 79% higher in Scenario 3 (forecasted 2030 rail operations including the proposed LPV) than in Scenario 2 (forecasted 2030 operations without the proposed LPV) while the estimated inhalation HQs for chronic DPM exposure were up to 95% higher. The percentage increase in predicted HQ between scenarios is influenced by the location of the sensitive receptor relative to the proposed LPV operations.

When comparing the estimated HQs at each of the sensitive receptors between Scenario 3 (forecasted 2030 rail operations including the proposed LPV) and Scenario 1 (current rail operations), the estimated inhalation HQs for acute DPM exposure were between 61% and 225% higher, while the estimated inhalation HQs for chronic DPM exposure were between 62% and 243% higher.

As described above, it should be noted that when comparing predicted HQs between each scenario, an increased HQ of “X”% means that the predicted concentration of the air contaminant increased by “X”%, but this does not necessarily infer that there is “X”% more risk associated with exposure to the higher air contaminant concentration as the relationships between the contaminant concentration and health outcomes may not be linear. However, it does imply that greater risk is associated with the exposure to the higher predicted air contaminant concentration.

**Table 6-6** presents the maximum calculated hazard quotients under Scenario 3 for each receptor category for all substances where a HQ greater than 0.2 was calculated.

**Table 6-6: Hazard Quotients for Scenario 3: Forecasted 2030 Operations Including the Proposed LPV**

| COPC | Hazard Quotient Term | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | MPOI | Business | Child Care | Health Care | Residence | School | Senior Care |
| $PM_{2.5}$ | Acute HQs | **2.4** | **1.2** | **1.0** | **0.73** | **1.5** | **0.59** | **0.49** |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | 0.24 | *<0.2* | *<0.2* |
| DPM | Acute HQs | **5.1** | **2.2** | **2.7** | **1.9** | **3.1** | **1.5** | **1.3** |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | 0.25 | *<0.2* | *<0.2* |
| $NO_2$ | Acute HQs | **5.8** | **2.5** | **3.2** | **2.2** | **3.6** | **1.8** | **1.5** |
| | Chronic HQs | *<0.2* | 0.24 | **0.36** | 0.21 | **1.6** | 0.24 | **0.60** |
| Nickel | Acute HQs | **1.0** | **0.43** | **0.55** | **0.39** | **0.62** | 0.31 | 0.26 |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | 0.28 | *<0.2* | *<0.2* |
| Acrolein | Acute HQs | **0.65** | 0.33 | **0.35** | 0.27 | **0.41** | 0.21 | *<0.2* |
| | Chronic HQs | 0.30 | 0.33 | **0.40** | 0.21 | **2.1** | 0.24 | **0.56** |
| Arsenic | Acute HQs | 0.27 | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |
| Formaldehyde | Acute HQs | **0.46** | 0.23 | 0.25 | *<0.2* | 0.29 | *<0.2* | *<0.2* |
| | Chronic HQs | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* | *<0.2* |

*(a) MPOI – maximum point of impingement*
*(b) **Bold** – exceeds threshold of acceptable risk (0.33)*

### 6.5.3 Cancer Risks - Methodology

The incremental lifetime cancer risks posed by exposure to the carcinogenic COPCs were estimated for each location and scenario by the following formula:

$$\mathrm{ILCR} = \mathrm{TLAC_A} \times \mathrm{IUR}$$

Where:

- ILCR = Incremental Lifetime Cancer Risks
- $TLAC_A$ = Time-adjusted lifetime air concentration (µg/m$^3$)
- IUR = Inhalation unit risk (µg/m$^3$)$^{-1}$

**Example Calculation – Incremental Lifetime Cancer Risk**

- Scenario: 1
- Receptor: Business
- COPC: Diesel Particulate Matter (DPM)

ILCR = 0.32 µg/m$^3$ x 10 hours/24 hours x 5 days/7 days x 48 weeks/52 weeks x 35 years/80 years x 3E-04 (µg/m$^3$)$^{-1}$

# Extra Cancer Cases/100,000 = 1.2 in 100,000

Health Canada's guideline of acceptability for incremental lifetime cancer risk is 1 additional cancer case in 100,000 people exposed. (i.e., ILCR = 1E-05). ILCRs for each scenario and location are presented in **Table 6-7** to **Table 6-9** for DPM, the only carcinogenic COPC for which ILCRs exceeded the guideline of acceptability.

### 6.5.4 Cancer Risks - Results

#### Scenario 1: Current Operations

ILCRs estimated for all carcinogenic COPCs and receptor types under Scenario 1 predicted an unacceptable cancer risk for DPM only. The threshold of acceptable risk (1 additional cancer case per 100,000 people exposed) was exceeded at the maximum receptor in all receptor categories.

**Table 6-7: Incremental Lifetime Cancer Risks from Exposure to Predicted DPM Concentrations– Scenario 1: Current Operations**

| | MPOI | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | Business | Child Care | Health Care | Residence | School | Senior Care |
| **ILCR** | **2.5E-05** | **1.2E-05** | **1.8E-05** | **3.4E-05** | **2.3E-04** | **1.1E-05** | **2.5E-05** |
| **# Extra Cancer Cases/100,000** | **2.5** | **1.2** | **1.8** | **3.4** | **23** | **1.1** | **2.5** |

*(a) MPOI – maximum point of impingement*
*(b) **Bold** – exceeds threshold of acceptable risk (1 in 100,000)*

#### Scenario 2: Forecasted 2030 Rail Operations

ILCRs estimated for all carcinogenic COPCs and receptor types under Scenario 2 predicted an unacceptable cancer risk for DPM only. The threshold of acceptable risk was exceeded at the maximum receptor in all receptor categories. Estimated ILCRs were between 55% and 89% higher under Scenario 2 compared to Scenario 1.

**Table 6-8: Incremental Lifetime Cancer Risks from Exposure to Predicted DPM Concentrations – Scenario 2: Forecasted 2030 Operations**

| | MPOI | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | Business | Child Care | Health Care | Residence | School | Senior Care |
| **ILCR** | **4.7E-05** | **1.8E-05** | **3.3E-05** | **6.2E-05** | **3.7E-04** | **1.9E-05** | **4.5E-05** |
| **# Extra Cancer Cases/100,000** | **4.7** | **1.8** | **3.3** | **6.2** | **37** | **1.9** | **4.5** |

*(a) MPOI – maximum point of impingement*
*(b) **Bold** – exceeds threshold of acceptable risk (1 in 100,000)*

### Scenario 3: Forecasted 2030 Rail Operations Including Proposed LPV

ILCRs estimated for DPM at the maximum receptor in each category under Scenario 3 exceeded 1E-05 (1 in 100,000) indicating an unacceptable risk. The threshold of acceptable risk was not approached for any of the other carcinogenic COPCs assessed at any receptor.

When comparing the predicted ILCRs due to exposure to predicted DPM concentrations at each of the sensitive receptors between Scenario 3 (forecasted 2030 rail operations including the proposed LPV) and Scenario 2 (forecasted 2030 operations without the proposed LPV), predicted ILCRs were up to 95% higher in Scenario 3.

When comparing the predicted ILCRs due to exposure to predicted DPM concentrations at each of the sensitive receptors between Scenario 3 (forecasted 2030 rail operations including the proposed LPV) and Scenario 1 (current rail operations), the estimated ILCRs were between 62% and 243% higher. The percentage increase in predicted ILCRs between scenarios is influenced by the location of the sensitive receptor relative to the proposed LPV operations.

**Table 6-9: Incremental Lifetime Cancer Risks from Exposure to Predicted DPM Concentrations - Scenario 3: Forecasted 2030 Operations Including the Proposed LPV**

| | MPOI | Sensitive Receptor with Maximum Predicted Ground Level Concentration in each Category | | | | | |
|---|---|---|---|---|---|---|---|
| | | Business | Child Care | Health Care | Residence | School | Senior Care |
| **ILCR** | **5.5E-05** | **2.5E-05** | **3.3E-05** | **6.3E-05** | **3.7E-04** | **1.9E-05** | **4.5E-05** |
| **# Extra Cancer Cases/100,000** | **5.5** | **2.5** | **3.3** | **6.3** | **37** | **1.9** | **4.5** |

*(a) MPOI – maximum point of impingement*
*(b) **Bold** – exceeds threshold of acceptable risk (1 in 100,000)*

## 6.6 Preliminary Risk Estimates (Spatial Extents)

In order to provide context to the preliminary worst-case risk estimates calculated for each receptor category in **Section 6.5**, for those COPCs where preliminary risk estimates found a potential for adverse effect, the distribution of these results beyond the worst-case receptors in each category was reviewed.

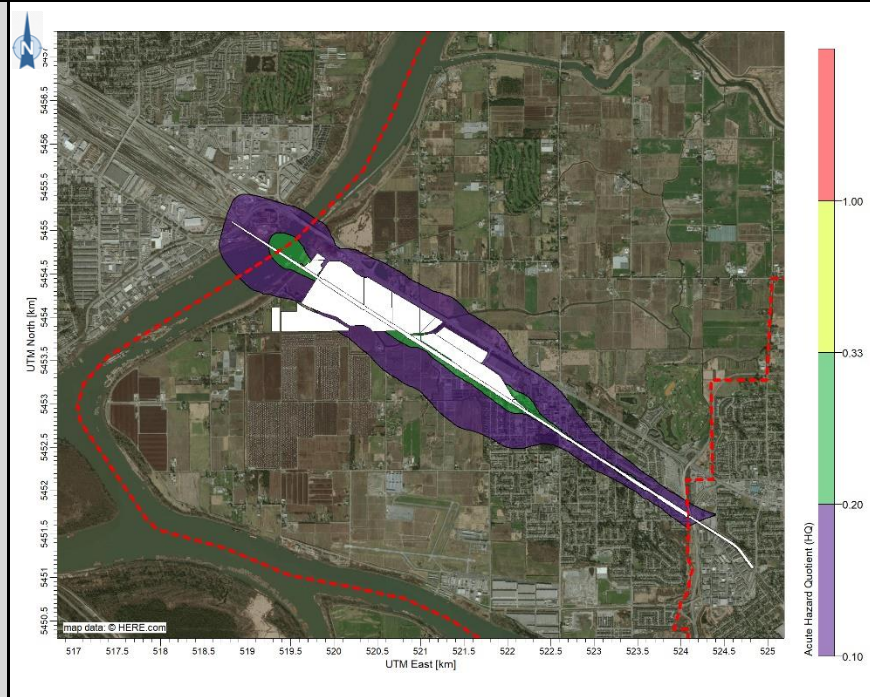
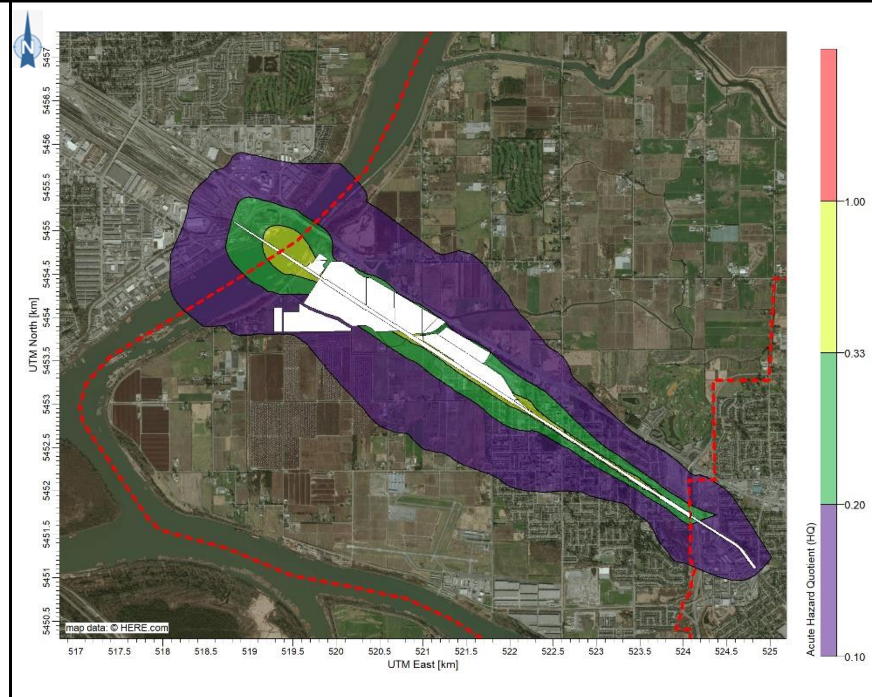
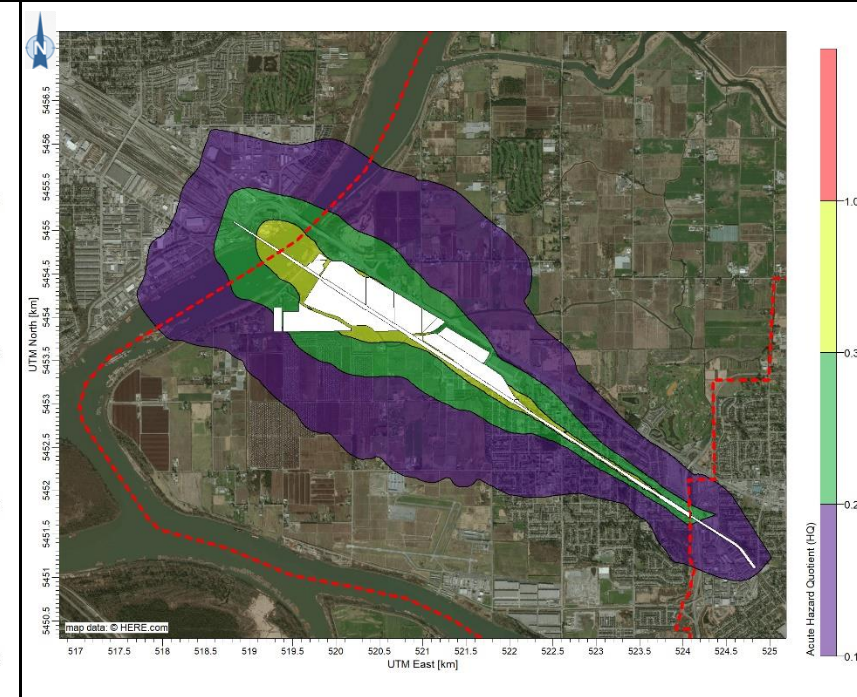
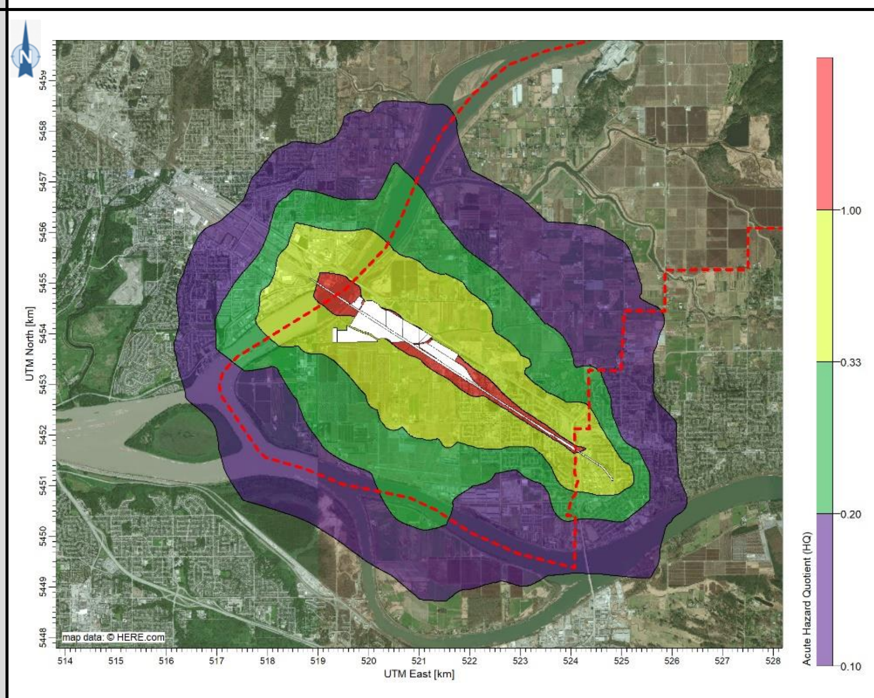
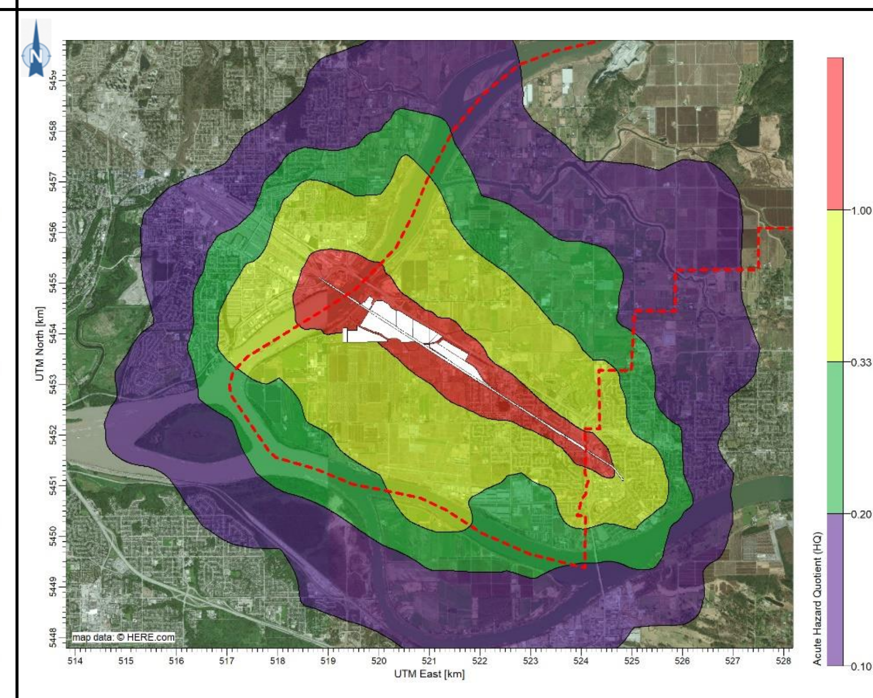
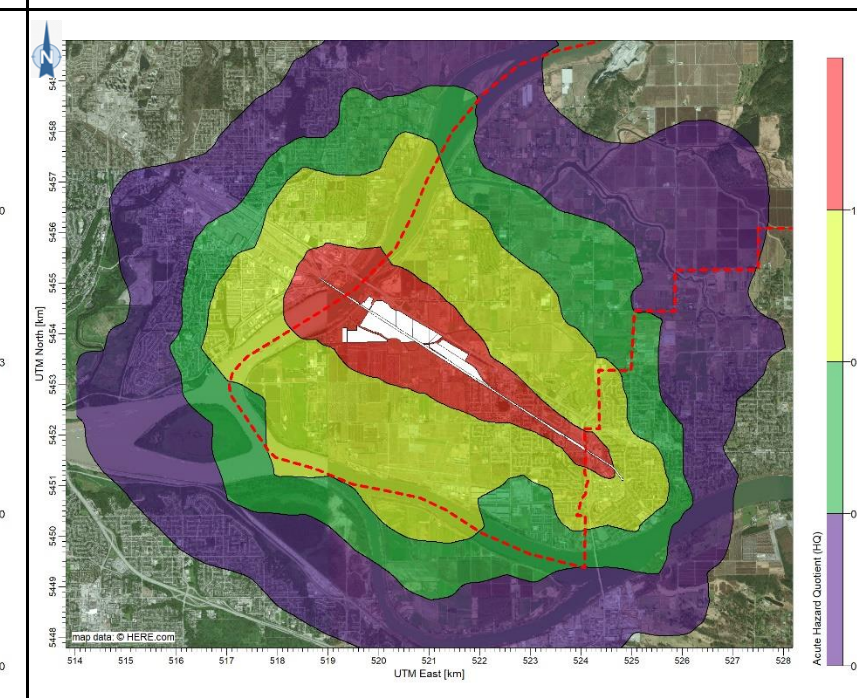
**Table 6-10** presents the maximum hazard quotients predicted at each receptor over the modelling year for acute inhalation exposures in the areas surrounding the rail operations. It should be noted that the acute health risk hazard quotients presented here are the model predicted worst-case risk based on emissions from estimated maximum 1-hour rail operations and show the maximum air contaminant concentration predicted at each receptor over the full model year (i.e., it is not possible for these risks to be observed at one time, for example if individual hours were examined, at a time where the wind blows from west to east, elevated air contaminant concentrations would be expected to the east of the modelled emission sources, with reduced air contaminant concentrations predicted to the west). Red areas on the figures presented indicate areas where the maximum predicted hazard quotient exceeds 1, with yellow areas indicating areas that exceed the threshold of acceptability of 0.33 used in this study. It should be noted that in the absence of toxicity reference values for $PM_{2.5}$ and $NO_2$, the Canadian Ambient Air Quality Standards for these substances were used to assess risk due to exposure to the predicted concentrations of these substances in this study. Given the non-threshold nature of the relationship between these air contaminants and health outcomes (i.e., no safe level of exposure to these air contaminants have been found where health outcomes are not observed), if the hazard quotients calculated for these contaminants are found to be below the threshold of acceptability used in this study (i.e., less than 0.33), this may not warrant that there are no health risks associated with exposure to the predicted concentrations of these air contaminants. Therefore, health risks may still be observed in the areas outside of these contours for these air contaminants ($PM_{2.5}$ and $NO_2$).

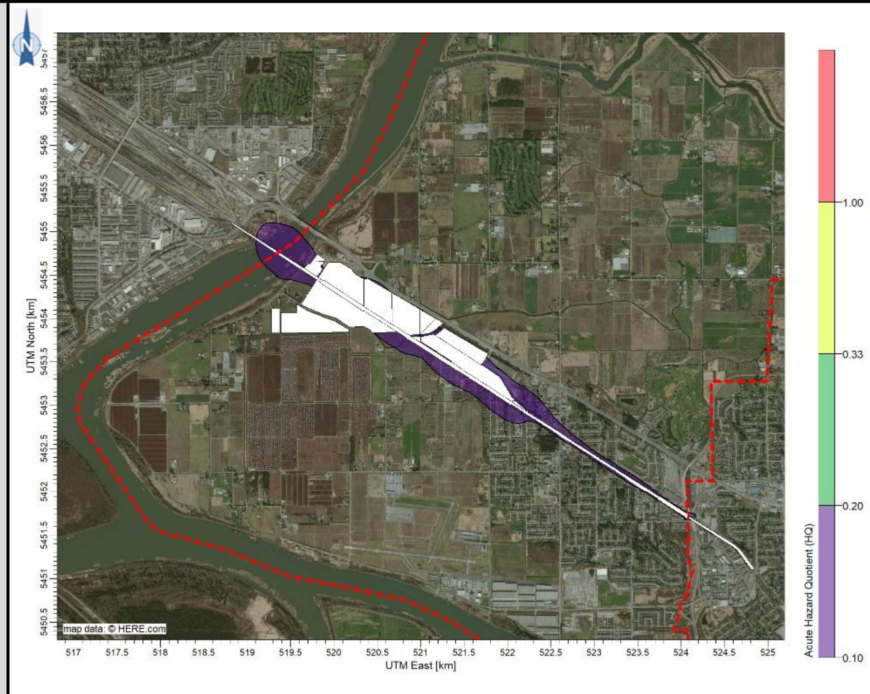
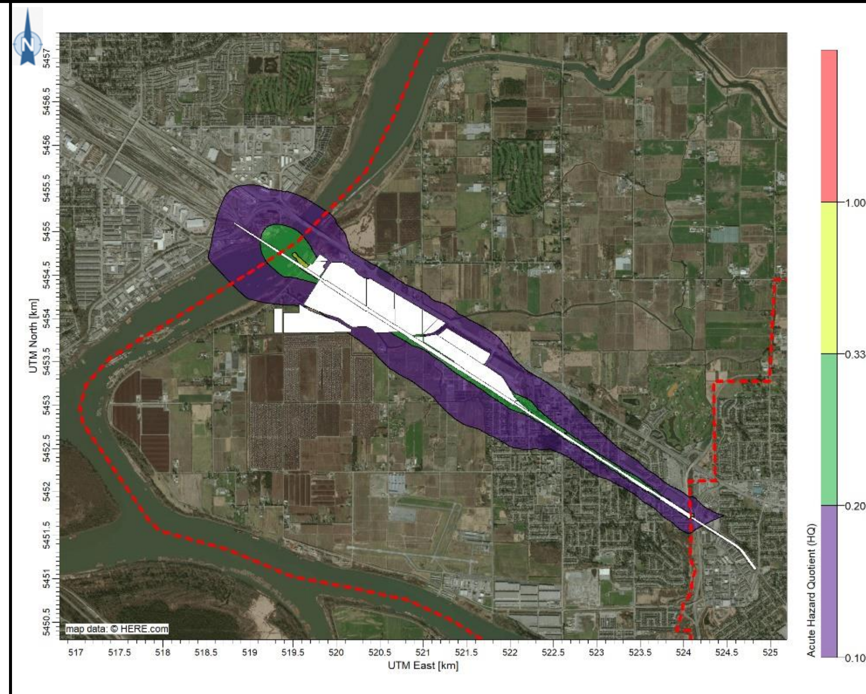
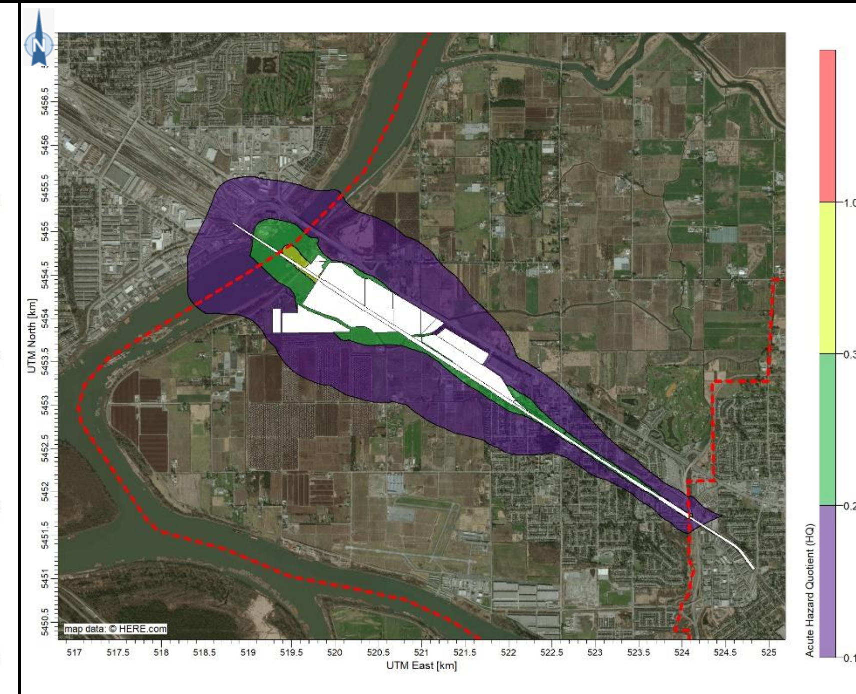
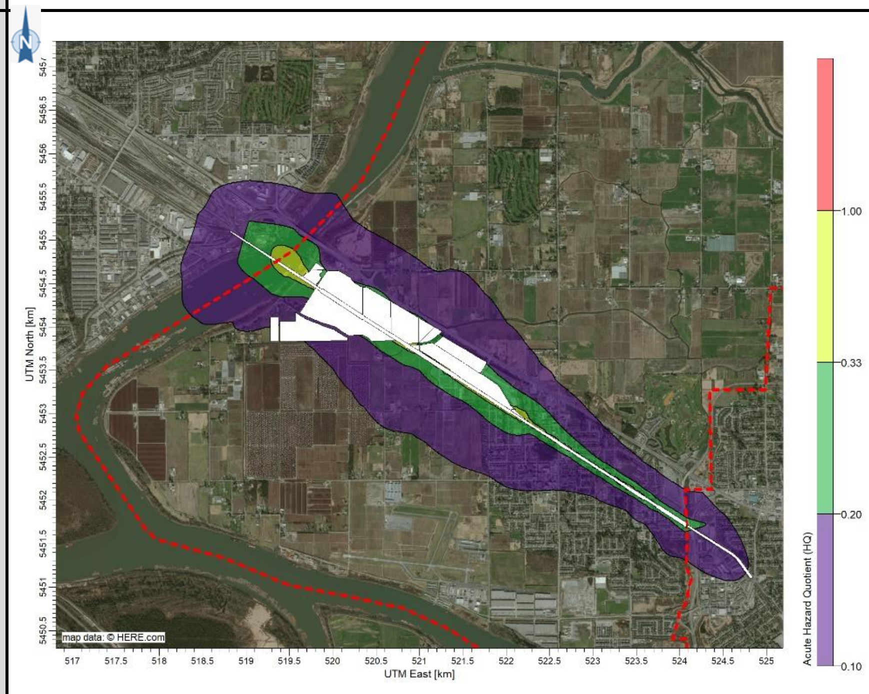
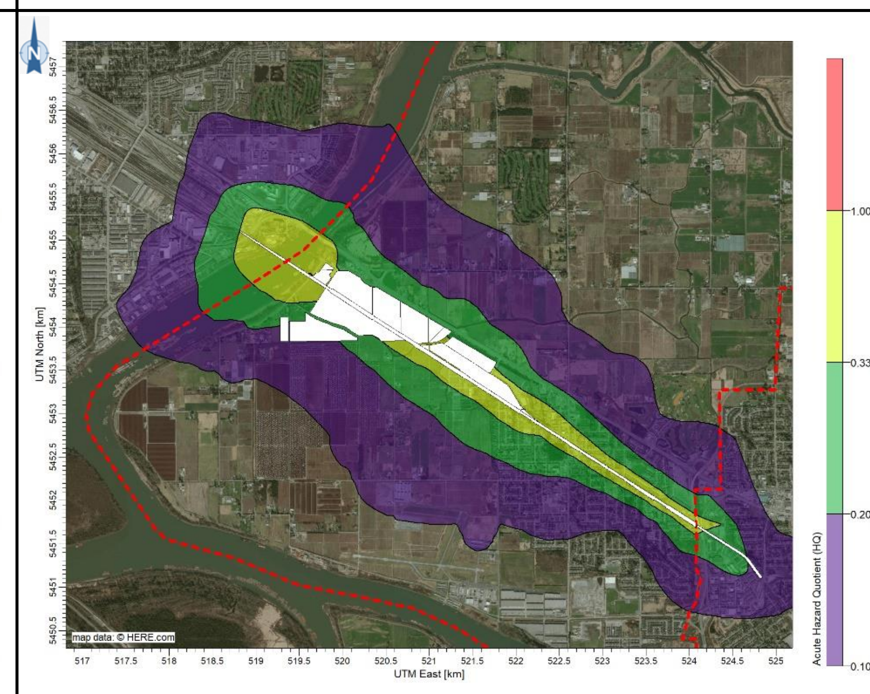
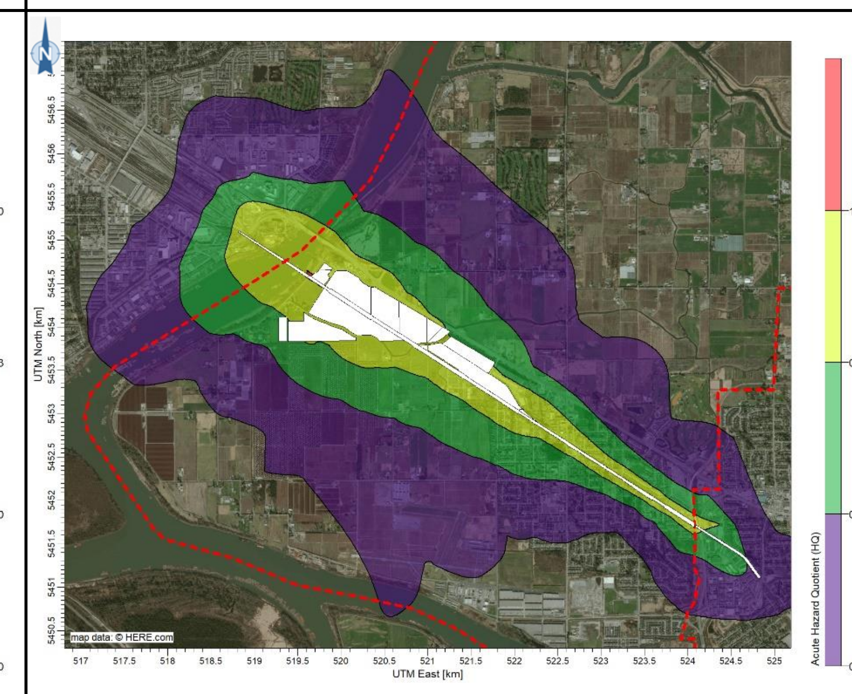
**Table 6-11** presents the distribution of non-cancer chronic health risks (based on model predicted annual average air contaminant concentrations) in the areas surrounding the rail operations if a residential exposure time is assumed (i.e., 24 hours a day, 7 days a week, 365 days per year), for exposure to $NO_2$ and acrolein. Similar to the acute hazard quotient figures, red areas on these figures indicate areas where the maximum predicted hazard quotient exceeds 1, with yellow areas indicating areas that exceed the threshold of acceptability of 0.33 used in this study. As described above, the same details regarding the non-threshold nature of health outcomes associated with $PM_{2.5}$ and $NO_2$ exposure also affect chronic health effects, therefore, health risks may still be observed in the areas outside of these contours for these air contaminants.

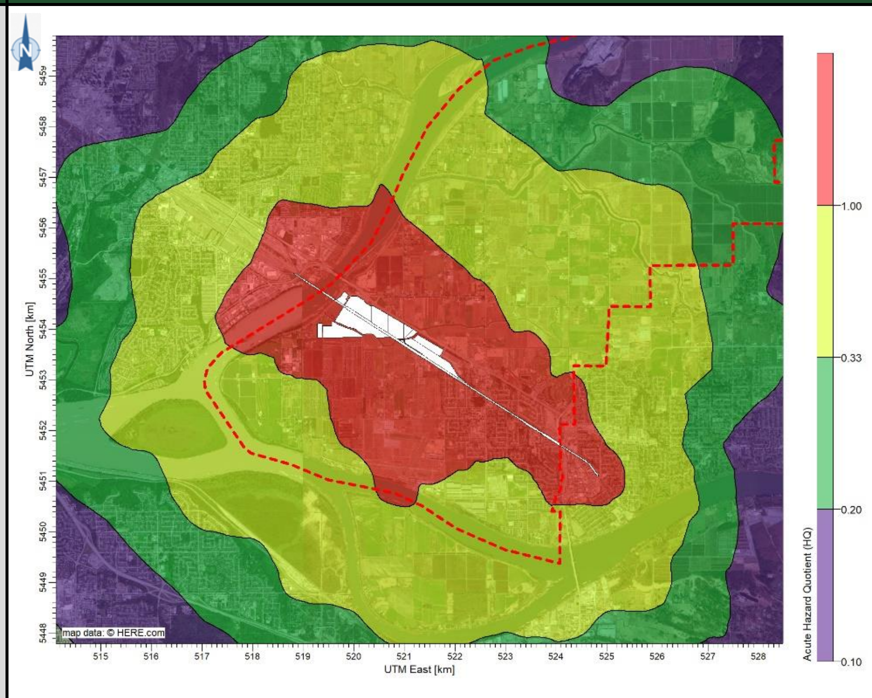
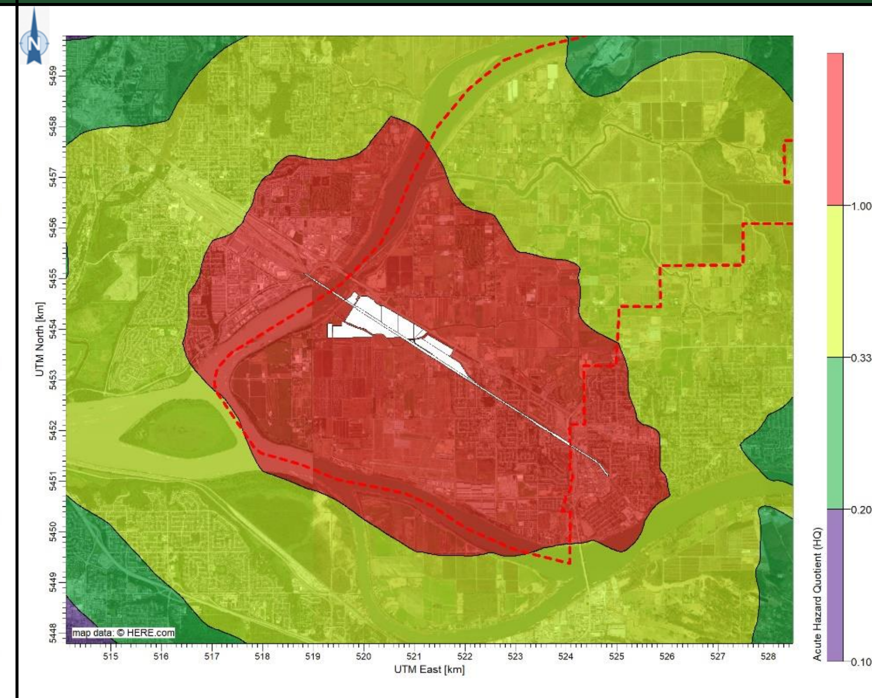
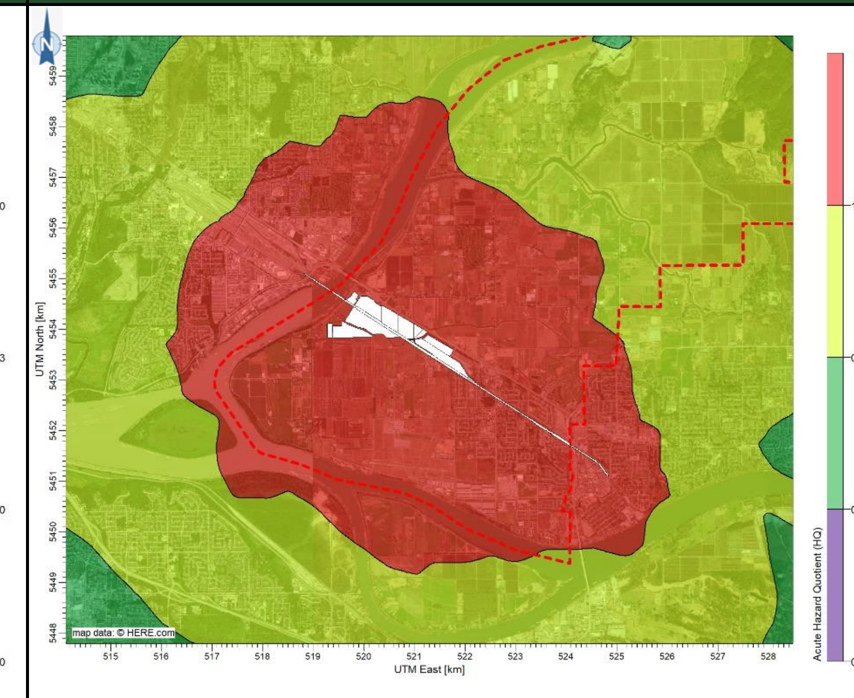
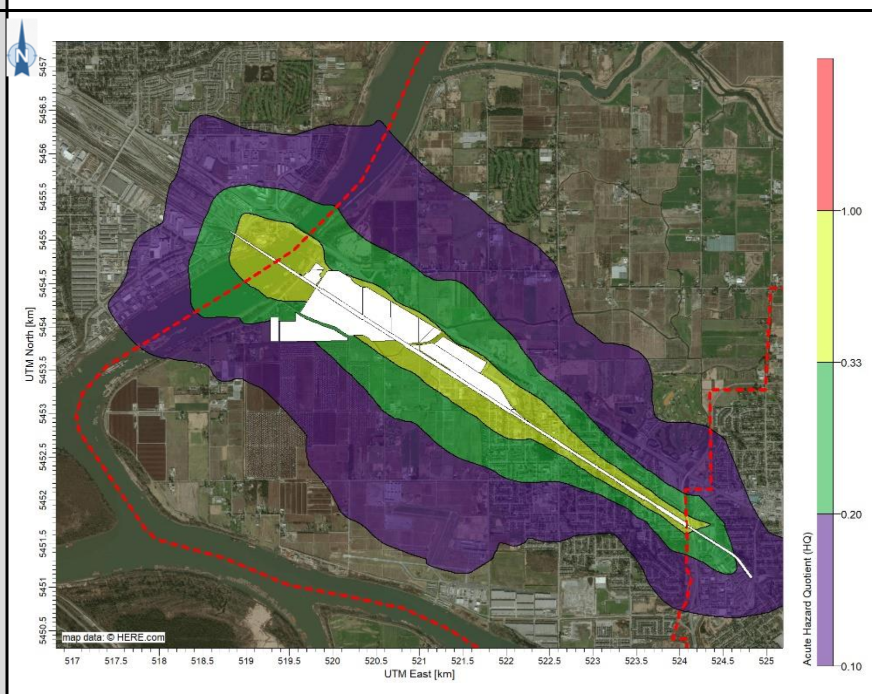
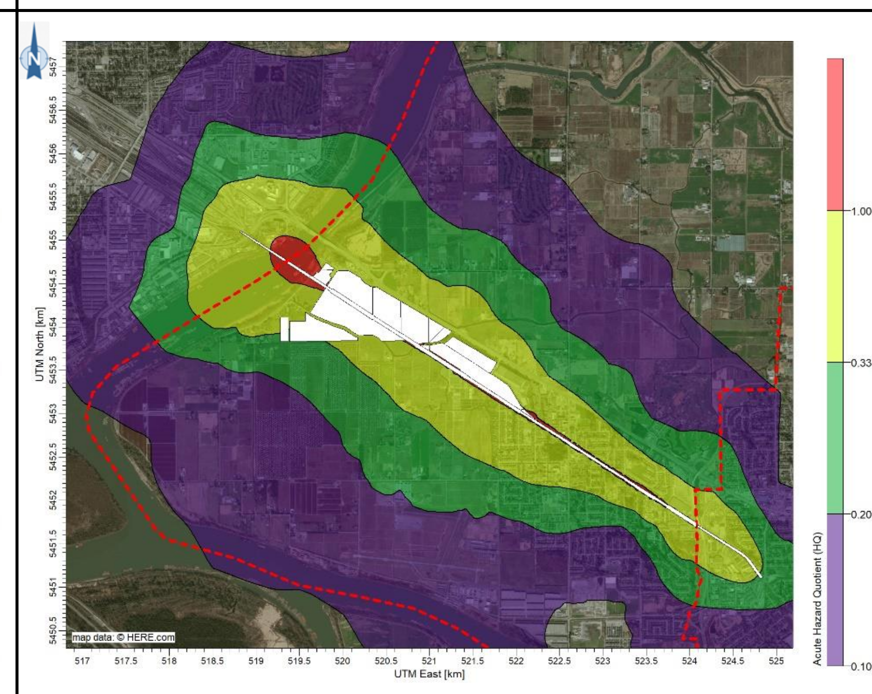
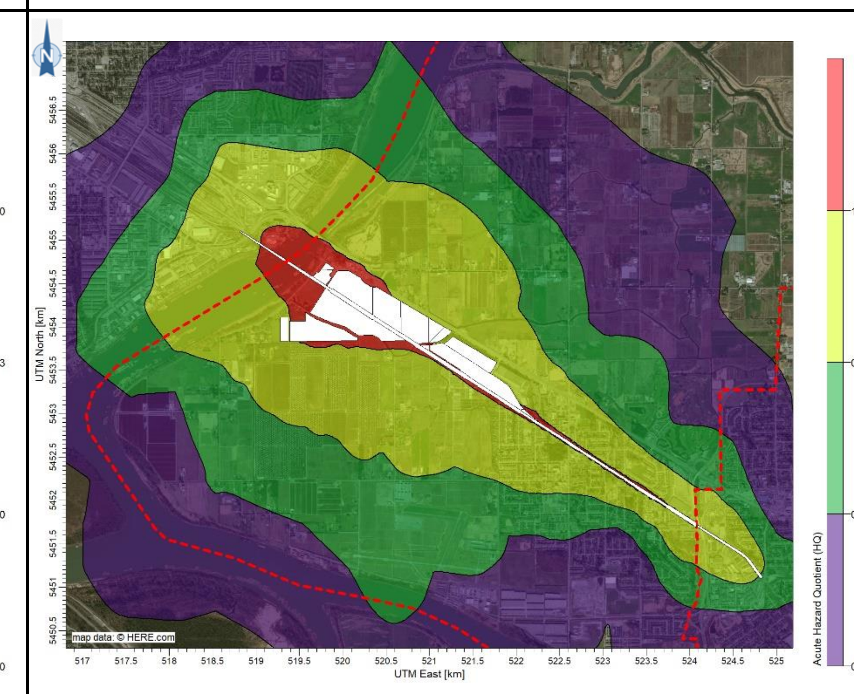
**Table 6-12** presents the incremental lifetime cancer risks from exposure to model predicted annual average DPM concentrations in the areas surrounding the rail operations if a residential exposure time is assumed (i.e., 24 hours a day, 7 days a week, 365 days per year). The contours on these figures depict the number of additional cancer cases that may occur per 100,000 people exposed to the annual average contaminant concentration predicted at each location. These cancer risks are expressed on a population average basis, it should be noted that an individual's cancer risk is based on many individual factors.

As noted in earlier sections, these results are based on the exposure to emissions from rail operations only. Comparison of the results for each scenario is reasonable with the understanding that background concentrations from other emissions sources in the region will also impact the potential risks identified.

**Table 6-10: Spatial Extents of Acute Health Risk Estimates Due to Maximum Model Predicted Inhalation Exposure to: Acrolein, DPM, Formaldehyde, Nickel, $NO_2$, and $PM_{2.5}$, for Each Emissions Scenario**

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**Acrolein** |   |   |   |
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**DPM** |   |   |   |

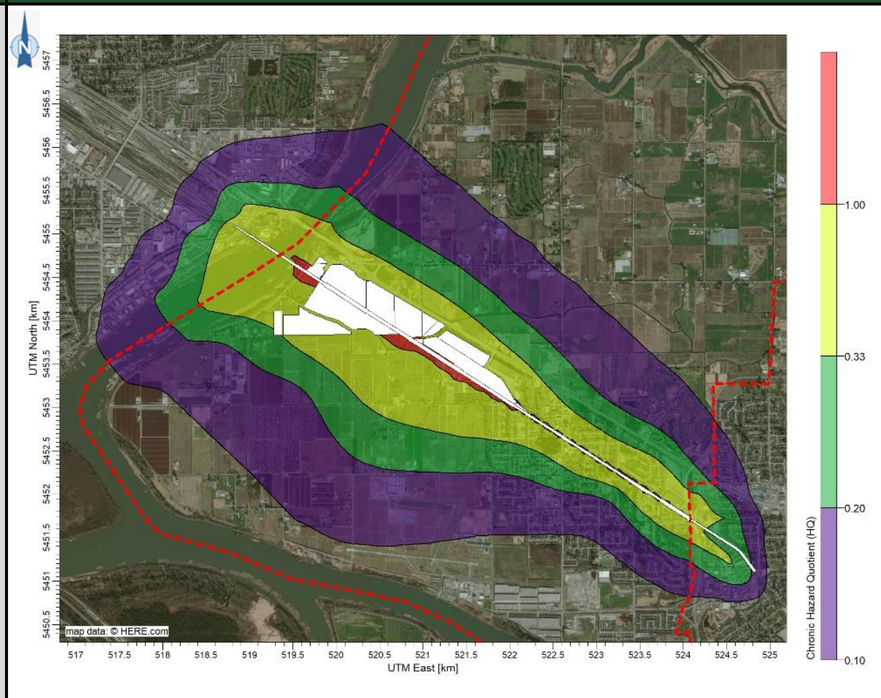
| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**Formaldehyde** |  |  |  |
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**Nickel** |  |  |  |

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**$NO_2$** |  |  |  |
| **Acute Health Risks:**<br><br>**Hazard Quotient for Maximum Predicted Exposure to:**<br><br>**$PM_{2.5}$** |  |  |  |

***NOTE**: Model predicted acute health risk hazard quotients shown here are the model predicted worst-case risks based on estimated emissions from maximum expected 1-hour rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary, and show the maximum air contaminant concentration predicted at each receptor over the full model year (i.e., it is not possible for these risks to be observed at any one time). White areas show CP lands and the rail right of way where there is no public access.*

*– – – – = The City of Pitt Meadows Boundary*

**Table 6-11: Spatial Extents of Chronic Non-Cancer Health Risk Estimates Due to Model Predicted Inhalation Exposure to $NO_2$ and Acrolein for Each Emissions Scenario**

<table>
<tr><th></th><th>Scenario 1 – Current Operations</th><th>Scenario 2 – Future 2030 Operations</th><th>Scenario 3 – Future 2030 Operations Including the LPV</th></tr>
<tr><td>Chronic Non-Cancer Health Risks:<br><br>Hazard Quotient for Predicted Exposure to:<br><br>$NO_2$<br><br>Assumes residential full-time presence.</td>
<td>
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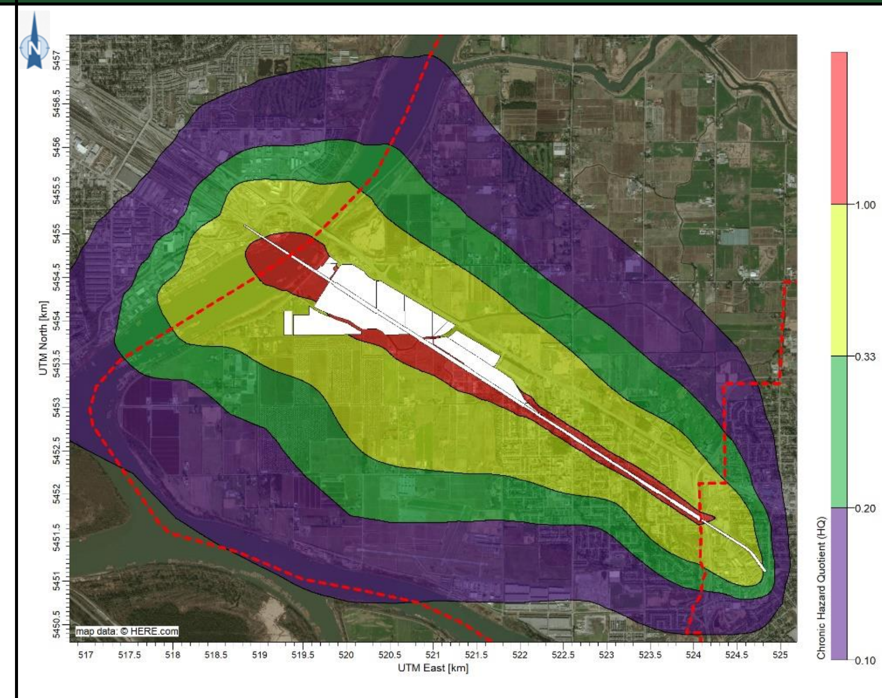
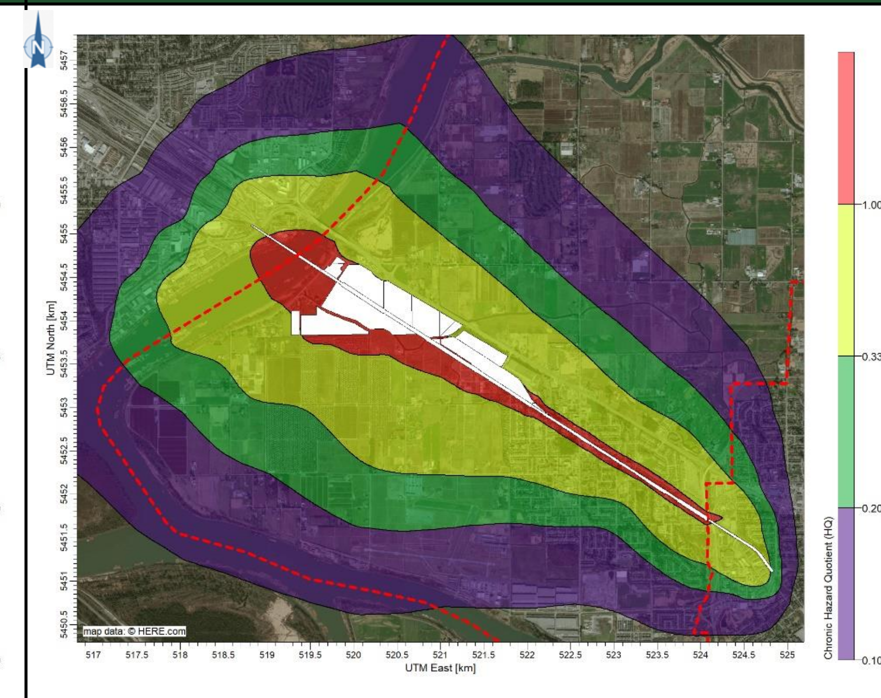
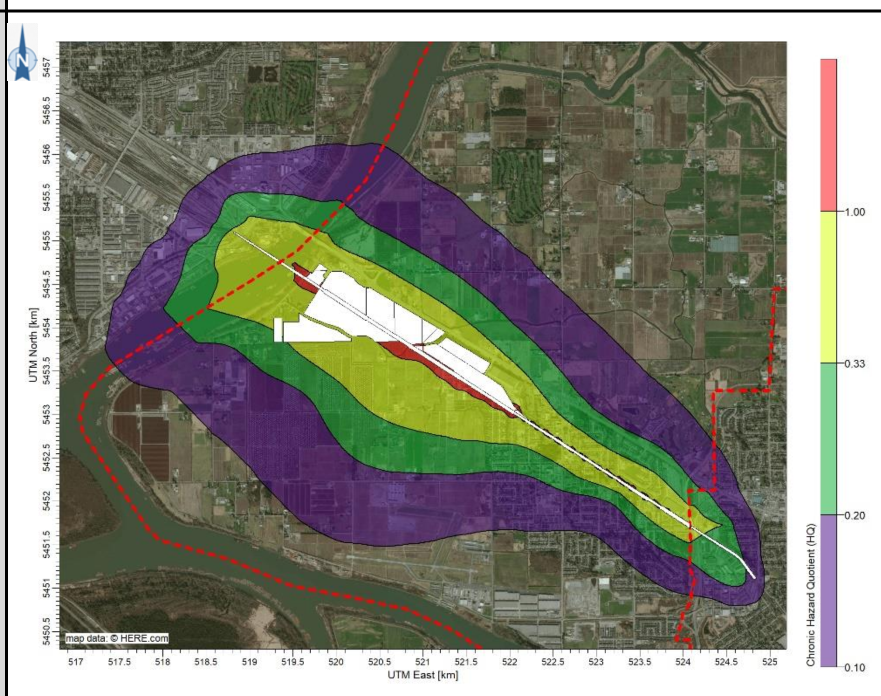
<td>
</td>
<td>
</td></tr>
<tr><td>Chronic Non-Cancer Health Risks:<br><br>Hazard Quotient for Predicted Exposure to:<br><br>Acrolein<br><br>Assumes residential full-time presence.</td>
<td>
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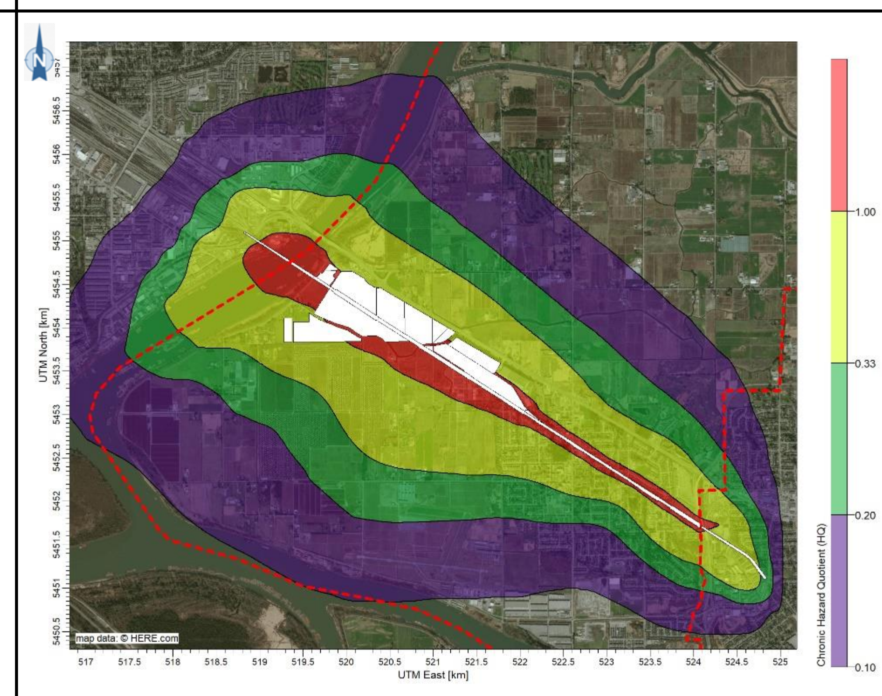
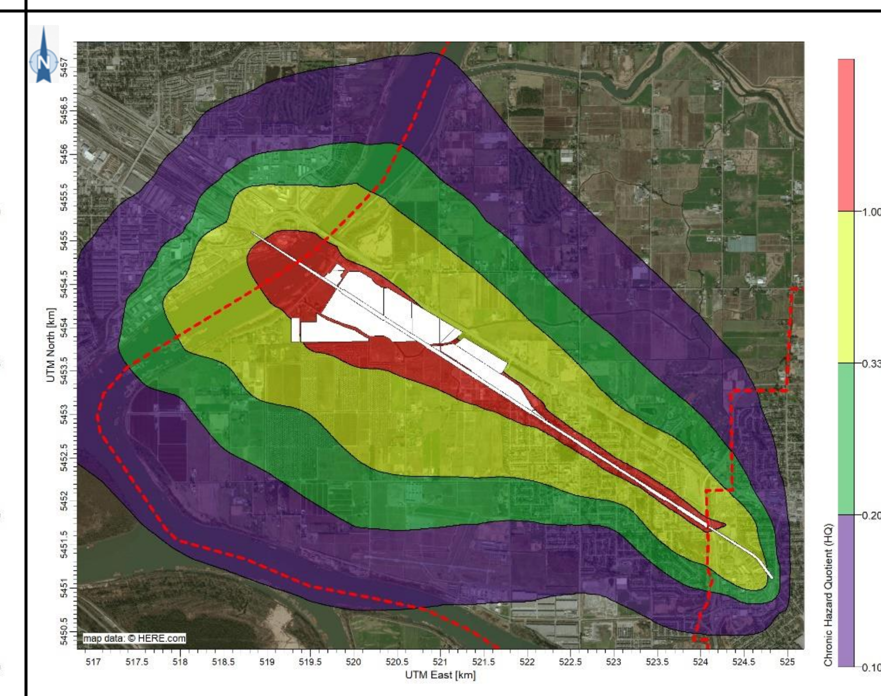
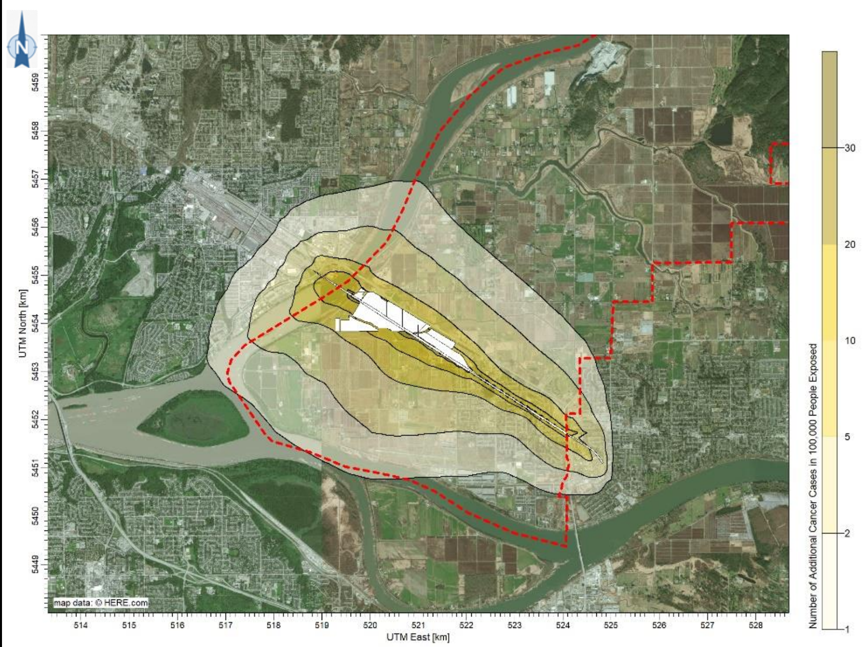
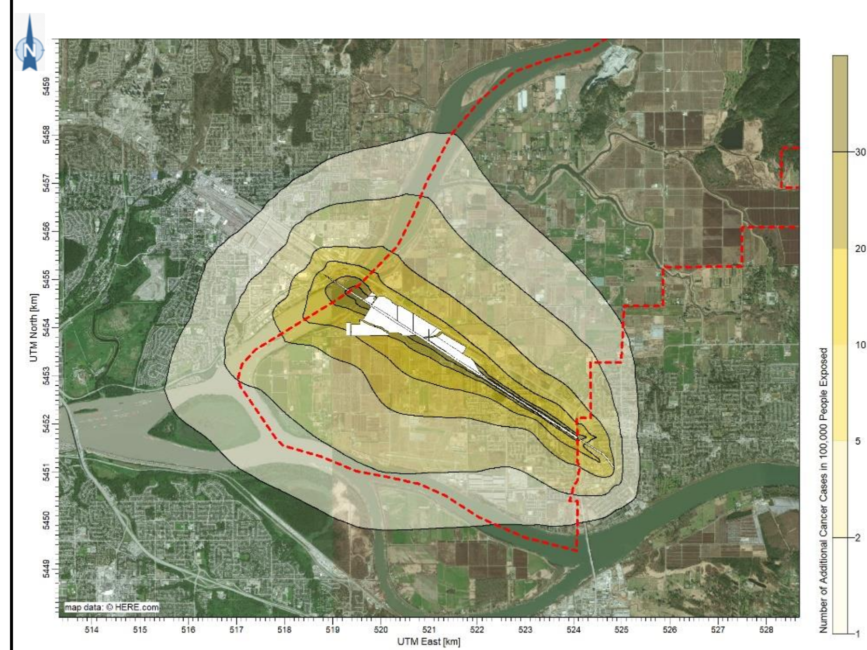
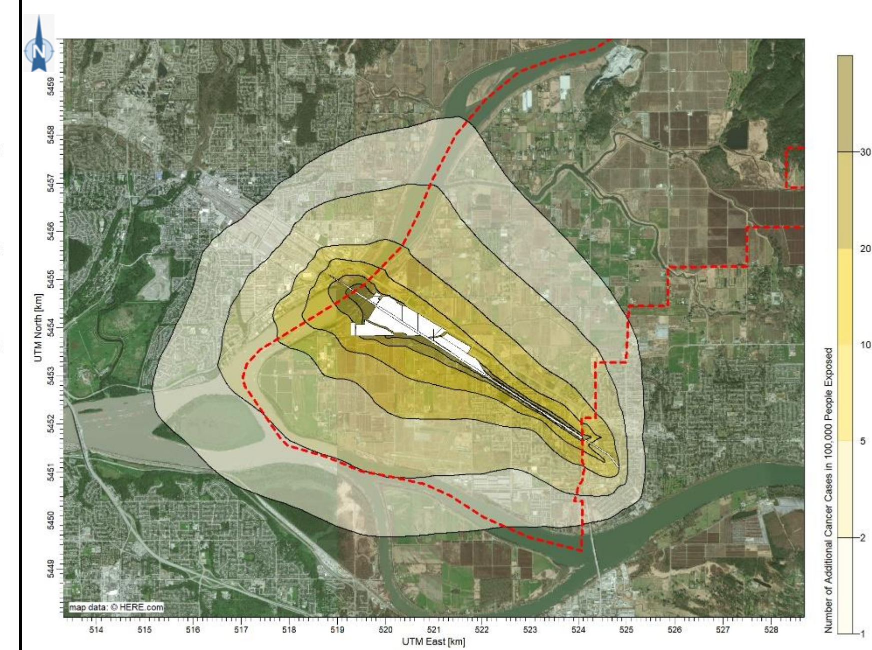
<td>
</td>
<td>
</td></tr>
</table>

***NOTE**: Model predicted chronic non-cancer health risk hazard quotients shown here are based on model predicted annual average air contaminant concentrations based on estimated emissions from typical expected levels of rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*

*– – – – = The City of Pitt Meadows Boundary*

**Table 6-12: Spatial Extents of Incremental Lifetime Cancer Risks Posed by Model Predicted Exposure to DPM for Each Emissions Scenario**

| | Scenario 1 – Current Operations | Scenario 2 – Future 2030 Operations | Scenario 3 – Future 2030 Operations Including the LPV |
|---|---|---|---|
| **Incremental Lifetime Cancer Risk Posed by Predicted Exposure to:**<br><br>**DPM**<br><br>***Assumes residential full-time presence.*** |  |  |  |

***NOTE****: Model predicted incremental lifetime cancer risk due to exposure to model predicted annual average DPM concentrations shown here are based on estimated emissions from typical expected levels of rail activities within the City of Pitt Meadows municipal boundary (shown as a red dashed line) with the addition of a 1km buffer on the mainlines to the east and west of the city boundary. White areas show CP lands and the rail right of way where there is no public access.*

*– – – – = The City of Pitt Meadows Boundary*

## 6.7 Uncertainty Analysis

Uncertainties in the risk estimates presented above relate to the modelling of air concentrations associated with emissions from the rail operations, estimating chemical exposures for the various receptor types and locations, and the toxicity reference values used.

### Air Quality Dispersion Modelling

As air quality dispersion modelling predicts theoretical air contaminant concentrations based on many variables there is inherent uncertainty involved. The air quality dispersion model conducted in this study followed industry best practices including following the British Columbia Air Quality Dispersion Modelling Guidelines and took steps to reduce uncertainty. Some specific uncertainties are described below.

As described in **Section 1.3**, there are limitations which introduce uncertainty into the accuracy of the predicted air contaminant concentrations by the emission inventory and air quality dispersion model, including aspects such as a lack of detailed information being made available on the rail activities within the region. Where detailed information was not available, assumptions on activity times etc. were made based on the information available and activity levels at similar size rail facilities. Where ranges of potential activity values were considered, values on the upper end of the range were selected to avoid underestimating emissions (i.e., a conservative approach was taken) and to capture the potential maximum air quality concentrations for review in the preliminary HHRA.

Emissions modelled in this study are based on the most recent available emission rate data for locomotives and trucks which are presented based on the makeup of the national fleets of these vehicles. The makeup of the local fleets may be slighter different which could result in higher or lower emission rates than those reported for national fleets. Emission rates used are also based on the data for the most recent year available, actual average emission rates from the locomotives and truck exhausts in operation in the future 2030 scenarios may decrease as older vehicles are retired from the fleets and are replaced with newer or rebuilt models with improved emission controls or the use of alternative energy sources with lower emissions. Therefore, the predicted air contaminant concentrations in the future scenarios are expected to be conservative.

Nitrogen oxides (NOx) undergo chemical transformation and conversion in the atmosphere, primarily between nitrogen monoxide (NO), and nitrogen dioxide ($NO_2$). Emission rates are typically reported for total $NO_X$ while nitrogen dioxide ($NO_2$) specifically is the main focus from an air quality and health risk perspective. In this study the ARM method is used for the estimation of nitrogen dioxide ($NO_2$) concentrations based on emissions of total nitrogen oxides as recommended by the 2021 BC ENV guidance for nitrogen dioxide modelling [31]. There is uncertainty in the prediction of $NO_2$ concentrations as the influence of other air contaminants in the airshed and NOx emissions from other sources will affect the chemical transformations and the ambient concentrations of $NO_2$ that are actually experienced.

[31] BC Ministry of Environment & Climate Change Strategy, 2021 - *Guidance For $NO_2$ Dispersion Modelling In British Columbia*

### Exposure Estimation

Un-amortized model-predicted maximum 1-hour average air concentrations at the various receptor locations were assumed to represent acute exposures. Model-predicted annual average air concentrations at the various receptor locations amortized using Health Canada guidance were assumed to represent chronic exposures. The degree to which the exposure estimates reflect actual potential exposures is uncertain, however the estimates are expected to be conservative.

### Toxicity Reference Values

With few exceptions the TRVs used in the HHRA were effects-based thresholds and cancer potency factors obtained from recognized Canadian and international health agencies and are expected to contribute to reliable and conservative risk estimates.

In the absence of available TRVs from health agencies, TRVs used to assess $PM_{2.5}$, nitrogen dioxide and sulphur dioxide (chronic) were Canadian Ambient Air Quality Standards (CAAQS) which may not be purely based on health protection but rather represent objectives to encourage air quality improvement across the country. For $PM_{2.5}$ and nitrogen dioxide, there is no threshold concentration below which adverse health effects are not possible. Therefore, the TRVs applied for these substances likely do not represent effects thresholds [32]. However, Hazard Quotients for one or both of these substances were elevated indicating a need for risk mitigation at all receptor types rendering uncertainty in the TRVs unimportant. For sulphur dioxide, the chronic inhalation RfC applied was the CAAQS. However, the uncertainty in this TRV is not likely important given that its use led to Hazard Quotients 90 times less than the threshold of acceptability.

Similarly, the acute inhalation RfCs applied for carbon monoxide were 14,900 and 5,700 $\mu g/m^3$ for 1- and 8-hour exposures, which were Metro Vancouver ambient air quality objectives. These values appear to be sufficiently protective given that the California Environmental Protection Agency recommends a health-based acute TRV of 23,000 $\mu g/m^3$ for carbon monoxide.

Based on the foregoing, overall uncertainty in the risk estimates is considered to be moderate with an expectation that they are conservative for all COPCs except $PM_{2.5}$ and nitrogen dioxide. Where the hazard quotients for the $PM_{2.5}$ and nitrogen dioxide concentrations predicted in this study were found to be below the threshold of acceptability used (i.e., HQs of less than 0.33), this does not warrant that no health risks would be associated with exposure to the predicted concentrations of these air contaminants.

[32] For this reason, other approaches such as Health Canada's Air Quality Benefits Assessment Tool (AQBAT) are often applied to evaluate the potential impacts of these parameters. Such modelling was beyond the scope of this Preliminary Quantitative Human Health Risk Assessment.

# 7.0 CONCLUSION

This study assesses the air quality and potential health risks of emissions associated with the current and future rail operations within the City of Pitt Meadows boundary, through completion of an emissions inventory, air quality dispersion modelling, and preliminary human health risk assessment. Scenarios evaluating both current rail operations and future operations (based on 2030 with and without the inclusion of the proposed CP Logistics Park: Vancouver) were evaluated. It should be noted that the emissions modelling in this study includes estimated worst-case activity levels (based on current understanding of rail operations in Pitt Meadows), to identify the maximum potential health risks and locations where they may occur.

This study predicted exceedances of the acceptable health risk thresholds (for non-carcinogenic and carcinogenic health effects) for some of the individual air contaminants due to exposure to the model predicted concentrations associated with diesel emissions in each of the three scenarios evaluated, including under existing conditions. The health risks were predicted to increase in the future scenarios based on 2030 rail operations without (Scenario 2), and with (Scenario 3) the proposed CP: Logistics Park Vancouver.

The risks predicted for acute health effects (i.e., health effects due to short-term exposures to air contaminants) were typically higher than risks predicted for chronic non-carcinogenic health effects (i.e., non-cancer health effects due to long-term exposures to air contaminants). While model predicted exceedances of the threshold for acceptability for acute health risks shows potential risk, the assessment of acute health risks in this preliminary HHRA were based on exposure to the model predicted worst-case maximum 1-hour air contaminant concentrations based on the estimated air emissions associated with worst-case maximum 1-hour activity levels of the rail operations, and therefore this potential risk represents an upper bound of the acute health risks predicted to occur. The model predicted exceedances of the threshold for acceptability for chronic non-cancer health risks (based on model predicted concentrations of nitrogen dioxide and acrolein), and particularly for incremental lifetime cancer risks associated with exposure to predicted concentrations of DPM, show a potential for risk with greater certainty as these predicted chronic health risks were based on the annual average of model predicted air contaminant concentrations and emissions associated with typical activity levels for the rail operations. Based on these results, potential human health risks related to diesel emissions from the existing and proposed rail-related operations (with or without the proposed LPV) need further consideration.

# 8.0 REFERENCES

British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *British Columbia Air Quality Dispersion Modelling Guideline*

British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *Guidance for $NO_2$ Dispersion Modelling in British Columbia*

British Columbia Ministry of Environment & Climate Change Strategy, 2017 – *Protocol 30 for Contaminated Sites – Classifying Substances as Carcinogenic, Version 1.0.*

British Columbia Ministry of Environment & Climate Change Strategy, 2021 – *Protocol 1 for Contaminated Sites - Detailed Risk Assessment, Version 3.0.*

California Air Resources Board, 2008 – *Railyard Health Risk Assessments and Mitigation Measures*

Canadian Pacific, 2021 – *Environmental Effects Evaluation CP Logistics Park: Vancouver*

Health Canada, 2016 – *Human Health Risk Assessment for Diesel Exhaust*

Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0.*

Health Canada, 2021 – *Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0.*

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U.S. Environmental Protection Agency, 2011 – *AP-42 13.2.1 Paved Roads.*

U.S. Environmental Protection Agency, 2020 – *Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions*

U.S. Environmental Protection Agency – *MOVES3 Model*

U.S. EPA, 1998 – *Locomotive Emissions Standards, Regulatory Supporting Document*

# 9.0 LIMITATIONS

This report is intended and prepared for the City of Pitt Meadows. This report is not for the benefit of any third party and may not be distributed to, disclosed in any form to, used by, or relied upon by any third party without the prior written consent of Envirochem Services Inc. (Envirochem). Any other third-party recipient of this report or user of any content contained herein uses this report and its contents at its sole risk, and by acceptance or use releases Envirochem, its affiliates, officers, employees and subcontractors from any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the report or reliance upon any of its content.

This report involves matters that could be precisely determined at the time of research. Calculations generally depend on conservative judgements and uncertainties that increase as we forecast further into the future. Much of the information available was based on estimates and assumptions made available by CP and third parties. Accordingly, this report does not guarantee a specific result; instead, it is a means of assessing the relative human health impacts of current and planned future projects on the surrounding areas and communities.

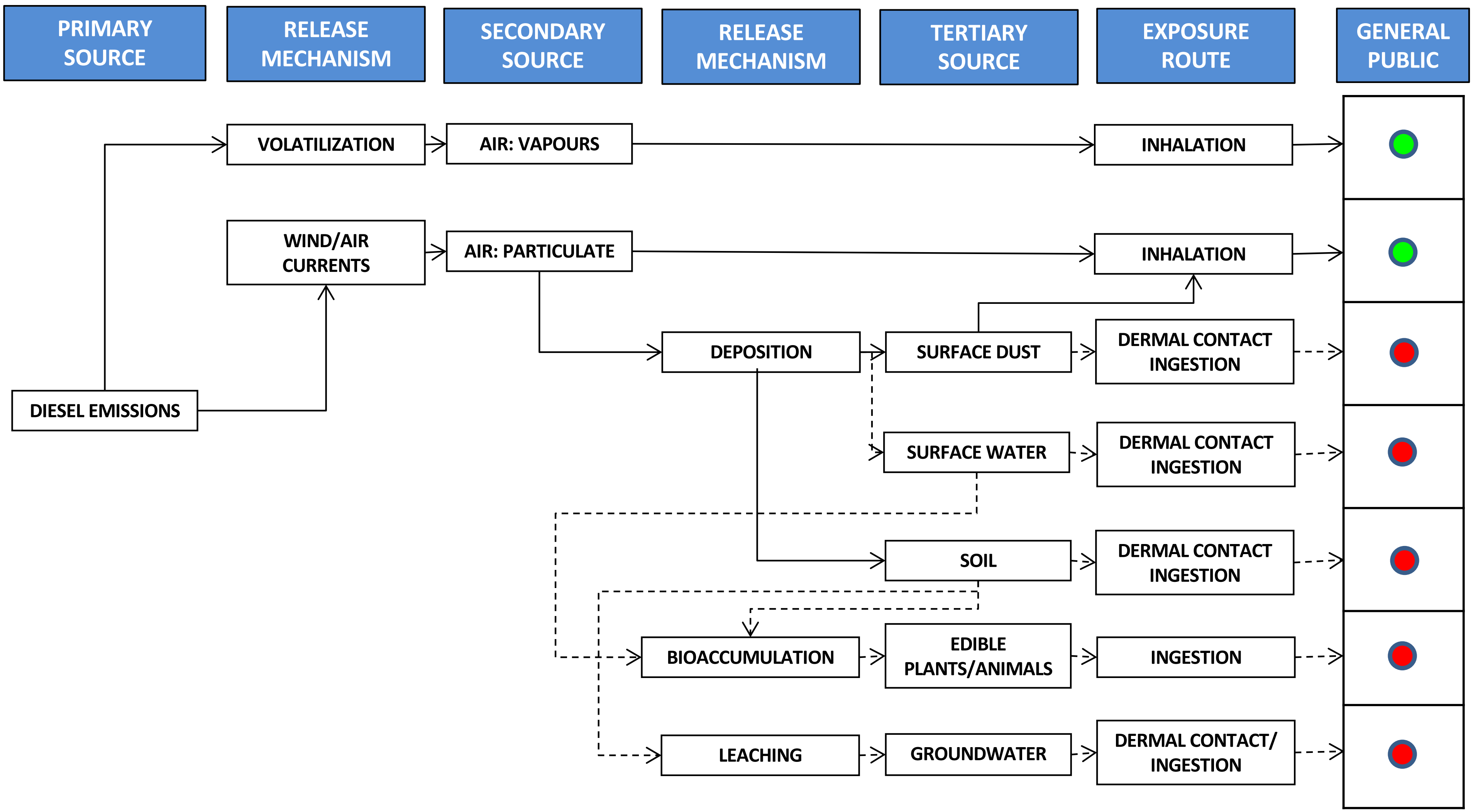
Envirochem reserves the right (but will be under no obligation) to review all calculations referred to in this report and, if considered necessary, to revise them in light of new facts, trends, or changing conditions that become apparent to us after the report is published.

Envirochem based many of its findings on provided information and reviews of available files. Envirochem takes no responsibility for the accuracy of provided information. This report was prepared for City of Pitt Meadow's uses only and Envirochem accepts no responsibility for its use by other parties. Envirochem's total liability does not extend beyond the value of the current preliminary HHRA and report preparation contract.

# APPENDIX A:

# HHRA CONCEPTUAL EXPOSURE MODEL

# Figure 1 – Conceptual Exposure Model




EXPOSURE PATHWAY OPERABLE

EXPOSURE PATHWAY LIKELY INOPERABLE/INSIGNIFICANT

EXPOSURE PATHWAY POTENTIALLY COMPLETE

EXPOSURE PATHWAY INCOMPLETE OR INSIGNIFICANT

# APPENDIX B:

# TOXICITY PROFILES FOR CONTAMINANTS OF POTENTIAL CONCERN

## Diesel Particulate Matter (DPM)

Emissions from diesel vehicles may originate from several sources, such as combustion (i.e. exhaust), mechanical wear (e.g. tires, brakes) and fugitive releases. Exhaust emissions are generally the dominant source of emissions. The composition of the exhaust emission mixture is dependent on several factors, such as fuel characteristics and additives, lubricants, engine and vehicle technologies, emission control devices and environmental conditions. Diesel PM generally consists of fine particulate matter ($PM_{2.5}$) and ultrafine particulate matter (UFP), which are released directly or formed secondarily via gaseous precursors in exhaust and evaporative emissions.

Exposure to diesel exhaust has been shown to be associated with lung cancer (causal relationship), bladder cancer (suggestive of a causal relationship), respiratory effects (causal relationship), cardiovascular effects (likely a causal relationship), immunological effects (likely a causal relationship), reproductive and developmental effects (suggestive of a causal relationship) and central nervous system effects (suggestive of a causal relationship).

Obtained from: Human Health Risk Assessment for Diesel Exhaust, Health Canada. 2016

## Nitrogen Dioxide

Nitrogen dioxide (NO2) belongs to the oxides of nitrogen group of compounds (NOx) that are formed primarily through the burning of fossil fuels. While transportation sources represent over half of all emissions, energy production and industrial processes also emit significant amounts of NOx, mainly as Nitric Oxide (NO) and Nitrogen Dioxide (NO2). NO2 at higher concentrations has a strong, harsh odour and can typically be seen over large cities as a brownish haze. Once formed, NO2 can combine with water molecules in the air to form compounds like nitric acid and nitrous acid. Ultimately, these compounds fall to earth through precipitation (such as rain, snow and fog) where they contribute to the acidification and eutrophication of ecosystems.

Short-term exposure to NO2 can elicit a range of adverse respiratory effects including decreased lung function, increased respiratory symptoms, and airway inflammation, and cause aggravation of respiratory diseases, particularly asthma and chronic obstructive pulmonary disease. Longterm exposure to NO2 may contribute to allergic responses, asthma development and may increase susceptibility to respiratory infections. Inhalation of NO2 has also been linked to effects on the cardiovascular system, and some reproductive effects.

Obtained from: https://ccme.ca/en/air-quality-report

## Fine Particulate Matter ($PM_{2.5}$)

Particulate matter (PM), a major component of smog, consists of airborne particles in solid or liquid form. PM may be classified as primary or secondary, depending on the process that led to its formation. Primary PM is emitted directly into the atmosphere from a source, such as a smokestack or exhaust pipe, or from wind-blown soils or vehicle traffic on a dirt road. Secondary PM is formed in the atmosphere through a series of chemical and physical reactions involving gases such as sulphur oxides (SOx) and nitrogen oxides (NOx). PM exists in various sizes and the particles of most concern for human health are those with a diameter of less than 2.5 micrometres (referred to as $PM_{2.5}$).

Exposures to fine particulate matter ($PM_{2.5}$) can negatively impact the heart and lungs, and can lead to health issues like asthma attacks, chronic bronchitis, and heart attacks. Exposure to $PM_{2.5}$ is also linked to increased emergency room visits and hospitalization due to respiratory and cardiovascular problems, as well as increased risk of premature mortality. Children and those with pre-existing cardiovascular and respiratory disease have greater sensitivity to effects.

Obtained from: https://ccme.ca/en/air-quality-report

# ACROLEIN

## CAS # 107-02-8

Division of Toxicology and Environmental Medicine ToxFAQs™ August 2007

**This fact sheet answers the most frequently asked health questions (FAQs) about acrolein. For more information, call the ATSDR Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.**

**HIGHLIGHTS: Exposure to acrolein occurs mostly from breathing it in air. Cigarette smoke and automobile exhaust contain acrolein. Acrolein causes burning of the nose and throat and can damage the lungs. Acrolein has been found in at least 32 of the 1,684 National Priority List sites identified by the Environmental Protection Agency (EPA).**

### What is acrolein?

Acrolein is a colorless or yellow liquid with a disagreeable odor. It dissolves in water very easily and quickly changes to a vapor when heated. It also burns easily. Small amounts of acrolein can be formed and can enter the air when trees, tobacco, other plants, gasoline, and oil are burned.

Acrolein is used as a pesticide to control algae, weeds, bacteria, and mollusks. It is also used to make other chemicals.

### What happens to acrolein when it enters the environment?

❏ Acrolein may be found in soil, water, or air.
❏ It breaks down fairly rapidly in the air (about half will disappear within 1 day) by reacting with other chemicals and sunlight.
❏ Acrolein evaporates rapidly from soil and water.

### How might I be exposed to acrolein?

❏ Smoking tobacco or breathing air containing tobacco smoke or automobile exhaust.
❏ Working in or living near industries where acrolein is manufactured or used to make other chemicals.
❏ Inhaling vapors from overheated cooking oil or grease.

### How can acrolein affect my health?

There is very little information about how exposure to acrolein affects people's health. The information we have indicates that breathing large amounts damages the lungs and could cause death. Breathing lower amounts may cause eye watering and burning of the nose and throat and a decreased breathing rate; these effects usually disappear after exposure stops.

Animal studies show that breathing acrolein causes irritation to the nasal cavity, lowered breathing rate, and damage to the lining of the lungs.

We do not know if eating food or drinking water containing acrolein affects your health. However, animals that swallowed acrolein had stomach irritation, vomiting, stomach ulcers and bleeding.

### How likely is acrolein to cause cancer?

The Department of Health and Human Services (DHHS) has not classified acrolein as to its carcinogenicity. The International Agency for Research on Cancer (IARC) has determined that acrolein is not classifiable as to carcinogenicity in humans. The EPA has stated that the potential carcinogenicity of acrolein cannot be determined based on an inadequate database.

### How can acrolein affect children?

In general, children are not likely to be affected by acrolein more than adults. However, children who are sensitive to irritants in the air (such as children with asthma) may be more sensitive to lung irritation from acrolein.

In animal studies, ingestion of very large amounts of acrolein during pregnancy caused reduced birth weights and skeletal deformities in newborns. However, the levels causing these effects were often fatal to the mother.

### How can families reduce the risks of exposure to acrolein?

You can reduce your family's exposure to acrolein by reducing their exposure to tobacco smoke, smoke from burning wood products or cooking oils and grease, and exhaust from diesel or gasoline vehicles.

### Is there a medical test to determine whether I've been exposed to acrolein?

There are tests to detect acrolein or breakdown products of acrolein in blood or urine; however, these tests are not available in a doctor's office because they require special equipment. These tests also cannot be used to determine if you were exposed to acrolein because acrolein can be produced by the breakdown of other chemicals in the body.

### Has the federal government made recommendations to protect human health?

The Food and Drug Administration (FDA) has determined that the amount of acrolein used to prepare modified food starch must not be more than 0.6%.

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.1 parts of acrolein per million parts of workplace air (0.1 ppm) for 8 hour shifts and 40 hour work weeks.

The EPA has restricted the use of all pesticides containing acrolein.

### References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Acrolein (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

**Where can I get more information?** For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-800-232-4636, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

# Arsenic - ToxFAQs™

**CAS # 7440-38-2**

This fact sheet answers the most frequently asked health questions (FAQs) about arsenic. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

**HIGHLIGHTS: Exposure to higher than average levels of arsenic occur mostly in the workplace, near hazardous waste sites, or in areas with high natural levels. At high levels, inorganic arsenic can cause death. Exposure to lower levels for a long time can cause a discoloration of the skin and the appearance of small corns or warts. Arsenic has been found in at least 1,149 of the 1,684 National Priority List (NPL) sites identified by the Environmental Protection Agency (EPA).**

## What is arsenic?

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds.

Inorganic arsenic compounds are mainly used to preserve wood. Copper chromated arsenate (CCA) is used to make "pressure-treated" lumber. CCA is no longer used in the U.S. for residential uses; it is still used in industrial applications. Organic arsenic compounds are used as pesticides, primarily on cotton fields and orchards.

## What happens to arsenic when it enters the environment?

- Arsenic occurs naturally in soil and minerals and may enter the air, water, and land from wind-blown dust and may get into water from runoff and leaching.
- Arsenic cannot be destroyed in the environment. It can only change its form.
- Rain and snow remove arsenic dust particles from the air.
- Many common arsenic compounds can dissolve in water. Most of the arsenic in water will ultimately end up in soil or sediment.
- Fish and shellfish can accumulate arsenic; most of this arsenic is in an organic form called arsenobetaine that is much less harmful.

## How might I be exposed to arsenic?

- Ingesting small amounts present in your food and water or breathing air containing arsenic.
- Breathing sawdust or burning smoke from wood treated with arsenic.
- Living in areas with unusually high natural levels of arsenic in rock.
- Working in a job that involves arsenic production or use, such as copper or lead smelting, wood treating, or pesticide application.

## How can arsenic affect my health?

Breathing high levels of inorganic arsenic can give you a sore throat or irritated lungs.

Ingesting very high levels of arsenic can result in death. Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of "pins and needles" in hands and feet.

Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso.

Skin contact with inorganic arsenic may cause redness and swelling.

Almost nothing is known regarding health effects of organic arsenic compounds in humans. Studies in animals show that some simple organic arsenic compounds are less toxic than inorganic forms. Ingestion of methyl and dimethyl compounds can cause diarrhea and damage to the kidneys.

## How likely is arsenic to cause cancer?

Several studies have shown that ingestion of inorganic arsenic can increase the risk of skin cancer and cancer in the liver, bladder, and lungs. Inhalation of inorganic arsenic can cause increased risk of lung cancer. The Department of Health and Human Services (DHHS) and the EPA have determined that inorganic arsenic is a known human carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic arsenic is carcinogenic to humans.

## How can arsenic affect children?

There is some evidence that long-term exposure to arsenic in children may result in lower IQ scores. There is also some evidence that exposure to arsenic in the womb and early childhood may increase mortality in young adults.

There is some evidence that inhaled or ingested arsenic can injure pregnant women or their unborn babies, although the studies are not definitive. Studies in animals show that large doses of arsenic that cause illness in pregnant females, can also cause low birth weight, fetal malformations, and even fetal death. Arsenic can cross the placenta and has been found in fetal tissues. Arsenic is found at low levels in breast milk.

## How can families reduce the risks of exposure to arsenic?

- If you use arsenic-treated wood in home projects, you should wear dust masks, gloves, and protective clothing to decrease exposure to sawdust.
- If you live in an area with high levels of arsenic in water or soil, you should use cleaner sources of water and limit contact with soil.
- If you work in a job that may expose you to arsenic, be aware that you may carry arsenic home on your clothing, skin, hair, or tools. Be sure to shower and change clothes before going home.

## Is there a medical test to determine whether I've been exposed to arsenic?

There are tests available to measure arsenic in your blood, urine, hair, and fingernails. The urine test is the most reliable test for arsenic exposure within the last few days. Tests on hair and fingernails can measure exposure to high levels of arsenic over the past 6-12 months. These tests can determine if you have been exposed to above-average levels of arsenic. They cannot predict whether the arsenic levels in your body will affect your health.

## Has the federal government made recommendations to protect human health?

The EPA has set limits on the amount of arsenic that industrial sources can release to the environment and has restricted or cancelled many of the uses of arsenic in pesticides. EPA has set a limit of 0.01 parts per million (ppm) for arsenic in drinking water.

The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) of 10 micrograms of arsenic per cubic meter of workplace air (10 $\mu g/m^3$) for 8 hour shifts and 40 hour work weeks.

## References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic (Update). Atlanta, GA: U.S. Department of Health and Human Services. Public Health Service.

## Where can I get more information?

**For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.**

**Phone: 1-800-232-4636**

**ToxFAQs™ Internet address via WWW is http://www.atsdr.cdc.gov/toxfaqs/index.asp.**

**ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.**

# Formaldehyde - ToxFAQs™

**CAS # 50-00-0**

This fact sheet answers the most frequently asked health questions (FAQs) about formaldehyde. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important that you understand this information because this substance may cause harm to you if you are exposed to it. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

**HIGHLIGHTS: Everyone is exposed to small amounts of formaldehyde in air and some foods and products. Formaldehyde can cause irritation of the eyes, nose, and throat and neurological effects. Formaldehyde has been found in at least 29 of the 1,669 National Priorities List sites identified by the Environmental Protection Agency (EPA).**

## What is formaldehyde?

At room temperature, formaldehyde is a colorless, flammable gas that has a distinct, pungent smell. Small amounts of formaldehyde are naturally produced by plants, animals, and humans.

It is used in the production of fertilizer, paper, plywood, and urea-formaldehyde resins. It is also used as a preservative in some foods and in many house-hold products, such as antiseptics, medicines, and cosmetics.

## What happens to formaldehyde when it enters the environment?

- Once formaldehyde is in the air, it is quickly broken down, usually within hours.
- Formaldehyde dissolves easily but does not last a long time in water.
- Formaldehyde evaporates from shallow soils.
- Formaldehyde does not build up in plants and animals.

## How might I be exposed to formaldehyde?

- The primary way you can be exposed to formaldehyde is by breathing air containing it.
- Releases of formaldehyde into the air occur from industries using or manufacturing formaldehyde, wood products (such as particle-board, plywood, and furniture), automobile exhaust, cigarette smoke, paints and varnishes, and carpets and permanent press fabrics.
- Indoor air contains higher levels of formaldehyde than outdoor air. Levels of formaldehyde measured in indoor air range from 0.02–4 parts per million (ppm). Formaldehyde levels in outdoor air range from 0.0002 to 0.006 ppm in rural and suburban areas and 0.001 to 0.02 ppm in urban areas.
- Breathing contaminated workplace air. The highest potential exposure occurs in the formaldehyde-based resins industry.

## How can formaldehyde affect my health?

Nasal and eye irritation, neurological effects, and increased risk of asthma and/or allergy have been observed in humans breathing 0.1 to 0.5 ppm. Eczema and changes in lung function have been observed at 0.6 to 1.9 ppm.

Decreased body weight, gastrointestinal ulcers, liver and kidney damage were observed in animals orally exposed to 50–100 milligrams/kilogram/day (mg/kg/day) formaldehyde.

## How likely is formaldehyde to cause cancer?

The Department of Health and Human Services (HHS) determined in 2011 that formaldehyde is a known human carcinogen based on sufficient human and animal inhalation studies.

## How can formaldehyde affect children?

A small number of studies have looked at the health effects of formaldehyde in children. It is very likely that breathing formaldehyde will result in nose and eye irritation. We do not know if the irritation would occur at lower concentrations in children than in adults.

# Formaldehyde

**CAS # 50-00-0**

There is some evidence of asthma or asthma-like symptoms for children exposed to formaldehyde in homes.

Animal studies have suggested that formaldehyde will not cause birth defects in humans.

## How can families reduce the risk of exposure to formaldehyde?

- Formaldehyde is usually found in the air, and levels are usually higher indoors than outdoors. Opening windows and using fans to bring fresh air indoors are the easiest ways to lower levels in the house. Not smoking and not using unvented heaters indoors can lower the formaldehyde levels.
- Formaldehyde is given off from a number of products used in the home. Removing formaldehyde sources in the home can reduce exposure. Providing fresh air, sealing unfinished manufactured wood surfaces, and washing new permanent press clothing before wearing can help lower exposure.

## Is there a medical test to show whether I've been exposed to formaldehyde?

Formaldehyde cannot be reliably measured in blood, urine, or body tissues following exposure. Formaldehyde is produced in the body and would be present as a normal constituent in body tissues and fluids.

## Has the federal government made recommendations to protect human health?

The US EPA has determined that exposure to formaldehyde in drinking water at concentrations of 10 milligrams/liter (mg/L) for 1 day or 5 mg/L for 10 days is not expected to cause any adverse effects in children.

The US EPA has also determined that a lifetime exposure to 1 mg/L of formaldehyde in drinking water is not expected to cause any adverse health effects.

The Occupational Health and Safety Administration (OSHA) has limited workers' exposure to an average of 0.75 ppm for an 8-hour workday, 40-hour workweek.

The U.S. Department of Housing and Urban Development (HUD) has set standards for formaldehyde emissions in manufactured housing of less than 0.2 ppm for plywood and 0.3 ppm for particle board. The HUD standards are designed to provide an ambient air level of 0.4 ppm or less in manufactured housing.

## References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Formaldehyde. Addendum to the Profile for Formaldehyde. 2010. Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

## Where can I get more information?

**For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.**

**Phone: 1-800-232-4636.**

**ToxFAQs™ on the web: www.atsdr.cdc.gov/toxFAQs.**

**ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.**

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# NICKEL

## CAS # 7440-02-0

**Division of Toxicology ToxFAQs™** **August 2005**

**This fact sheet answers the most frequently asked health questions (FAQs) about nickel. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.**

**HIGHLIGHTS: Nickel is a naturally occurring element. Pure nickel is a hard, silvery-white metal used to make stainless steel and other metal alloys. Skin effects are the most common effects in people who are sensitive to nickel. Workers who breathed very large amounts of nickel compounds developed chronic bronchitis and lung and nasal sinus cancers. Nickel has been found in at least 882 of the 1,662 National Priority List sites identified by the Environmental Protection Agency (EPA).**

### What is nickel?

Nickel is a very abundant natural element. Pure nickel is a hard, silvery-white metal. Nickel can be combined with other metals, such as iron, copper, chromium, and zinc, to form alloys. These alloys are used to make coins, jewelry, and items such as valves and heat exchangers. Most nickel is used to make stainless steel.

Nickel can combine with other elements such as chlorine, sulfur, and oxygen to form nickel compounds. Many nickel compounds dissolve fairly easy in water and have a green color. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions. Nickel is found in all soil and is emitted from volcanoes. Nickel is also found in meteorites and on the ocean floor. Nickel and its compounds have no characteristic odor or taste.

### What happens to nickel when it enters the environment?

- Nickel is released into the atmosphere by industries that make or use nickel, nickel alloys, or nickel compounds. It is also released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators.
- In the air, it attaches to small particles of dust that settle to the ground or are taken out of the air in rain or snow; this usually takes many days.
- Nickel released in industrial waste water ends up in soil or sediment where it strongly attaches to particles containing iron or manganese.
- Nickel does not appear to accumulate in fish or in other animals used as food.

### How might I be exposed to nickel?

- By eating food containing nickel, which is the major source of exposure for most people.
- By skin contact with soil, bath or shower water, or metals containing nickel, as well as by handling coins or touching jewelry containing nickel.
- By drinking water that contains small amounts of nickel.
- By breathing air or smoking tobacco containing nickel.
- Higher exposure may occur if you work in industries that process or use nickel.

### How can nickel affect my health?

The most common harmful health effect of nickel in humans is an allergic reaction. Approximately 10-20% of the population is sensitive to nickel. People can become sensitive to nickel when jewelry or other things containing it are in direct contact with the skin for a long time. Once a person is sensitized to nickel, further contact with the metal may produce a reaction. The most common reaction is a skin rash at the site of contact. The skin rash may also occur at a site away from the site of contact. Less frequently, some people who are sensitive to nickel have asthma attacks following exposure to nickel. Some sensitized people react when they consume food or water containing nickel or breathe dust containing it.

People working in nickel refineries or nickel-processing plants have experienced chronic bronchitis and reduced lung function. These persons breathed amounts of nickel much higher than levels found normally in the environment. Workers who drank water containing high amounts of nickel had stomach ache and suffered adverse effects to their blood and kidneys.

Damage to the lung and nasal cavity has been observed in rats and mice breathing nickel compounds. Eating or drinking large amounts of nickel has caused lung disease in dogs and rats and has affected the stomach, blood, liver, kidneys, and immune system in rats and mice, as well as their reproduction and development.

## How likely is nickel to cause cancer?

Cancers of the lung and nasal sinus have resulted when workers breathed dust containing high levels of nickel compounds while working in nickel refineries or nickel processing plants. The Department of Health and Human Services (DHHS) has determined that nickel metal may reasonably be anticipated to be a carcinogen and that nickel compounds are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans. The EPA has determined that nickel refinery dust and nickel subsulfide are human carcinogens.

## How can nickel affect children?

It is likely that the health effects seen in children exposed to nickel will be similar to those seen in adults. We do not know whether children differ from adults in their susceptibility to nickel. Human studies that examined whether nickel can harm the fetus are inconclusive. Animal studies have found increases in newborn deaths and decreased newborn weight after ingesting very high amounts of nickel. Nickel can be transferred from the mother to an infant in breast milk and can cross the placenta.

## How can families reduce the risks of exposure to nickel?

❏ Avoiding jewelry containing nickel will eliminate risks of exposure to this source of the metal.

❏ Exposures of the general population from other sources, such as foods and drinking water, are almost always too low to be of concern.

## Is there a medical test to determine whether I've been exposed to nickel?

There are tests available to measure nickel in your blood, feces, and urine. More nickel was measured in the urine of workers who were exposed to nickel compounds that dissolve easily in water than in the urine of workers exposed to nickel compounds that are hard to dissolve. This means that it is easier to tell if you have been exposed to soluble nickel compounds than less-soluble compounds. The nickel measurements do not accurately predict potential health effects from exposure to nickel.

## Has the federal government made recommendations to protect human health?

The EPA recommends that drinking water should contain no more than 0.1 milligrams of nickel per liter of water (0.1 mg/L). To protect workers, the Occupational Safety and Health Administration (OSHA) has set a limit of 1 mg of nickel per cubic meter of air (1 mg/m$^3$) for metallic nickel and nickel compounds in workplace air during an 8-hour workday, 40-hour workweek.

## References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Nickel (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

**Where can I get more information?** For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

# APPENDIX C:

# CALMET MODEL EVALUATION

# APPENDIX C: CONTENTS



# APPENDIX C: TABLES



# APPENDIX C: FIGURES

# C. CALMET MODEL EVALUATION

To generate a high-quality and appropriate three-dimensional diagnostic meteorological field by CALMET to resolve the terrain forcing effects and meteorological conditions in the area under study, the following conditions were used:

- Initializing CALMET using WRF prognostic met data with 1 km grid resolution;
- Using a finer 200 m horizontal grid resolution within the CALMET domain to encompass the main topographical features in the modelling domain;
- Supplementing the local observational met station data in the whole domain; and,
- Using high-resolution terrain elevation data, land cover and land use characterization information.

The CALMET model was assessed by reviewing various model outputs and, where possible, comparing to actual meteorological observations. These outputs include: temperature, surface wind roses for various monitoring locations, CALMET derived stabilities and mixing heights and domain wind vector plots under various stability and flow regimes, and precipitation. Evaluation of the following CALMET outputs verified the quality of the input data and the proper CALMET model configuration and implementation for this project.

## C.1 Temperature

A comparison of observed and CALMET-derived temperatures at the closest stations: T20 (Pitt Meadows) and T30 (Maple Ridge) are respectively presented in **Figure C-1** and **Figure C-2**. The figures include a box-whisker plot which shows the minimum and maximum temperatures, the $25^{th}$ and $75^{th}$ percentiles and the median temperature. The frequency distribution of temperatures is also shown. This comparison indicates that the CALMET-derived temperatures are very similar to the observed temperatures, which indicates the model is performing as expected and properly ingested the input observations. The CALMET-derived temperatures extracted from the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station) are also compared to observation temperatures at the closest station (T20 – Pitt Meadows) in **Figure C-3**.

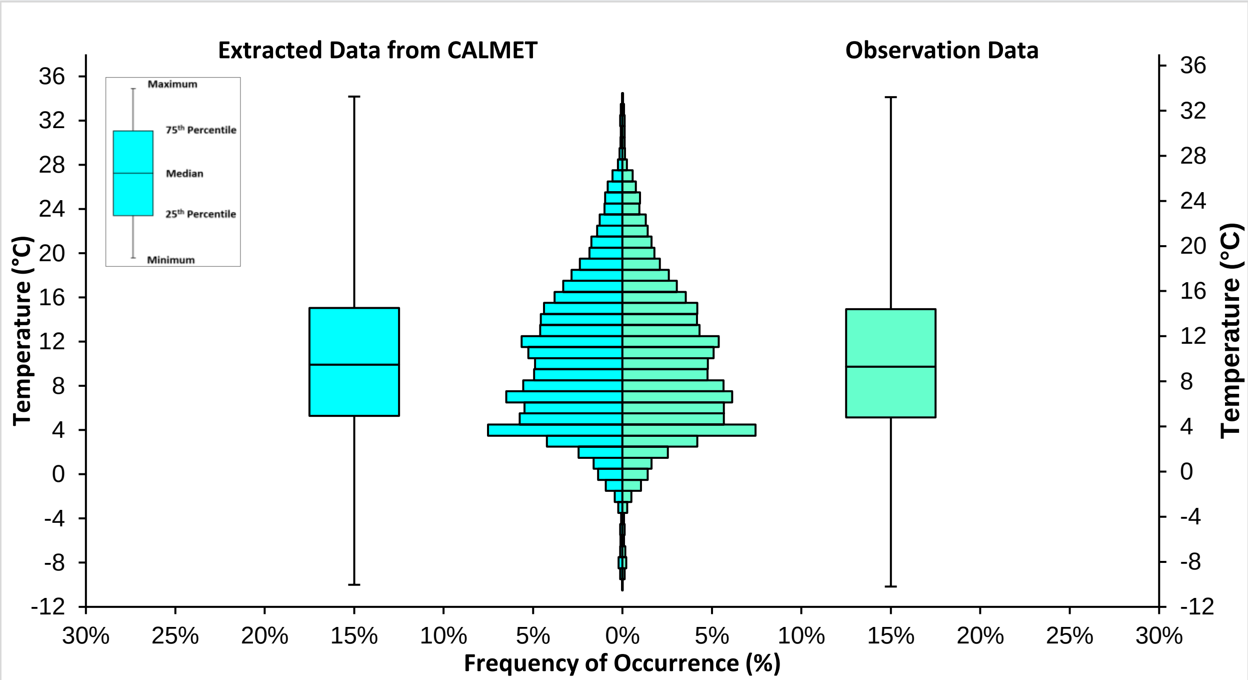



**Figure C-1: Comparison of CALMET-derived and observed temperatures at T20 – Pitt Meadows**

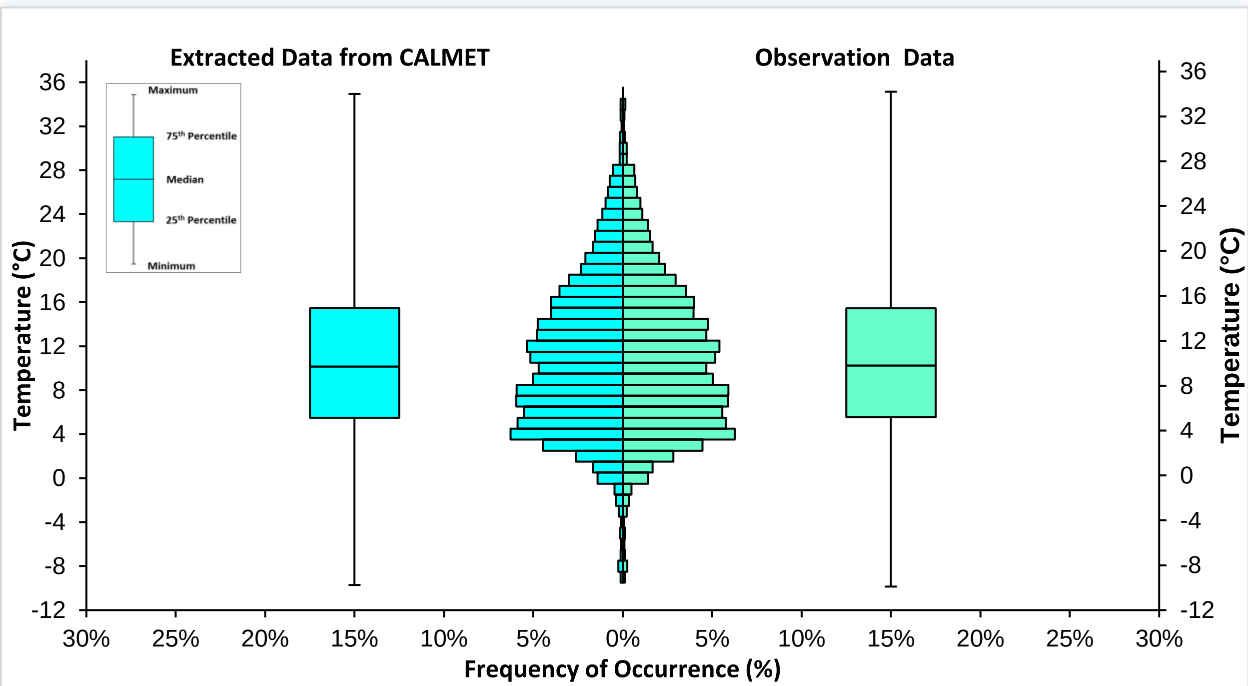



**Figure C-2: Comparison of CALMET-derived and observed temperatures at T30 – Maple Ridge**

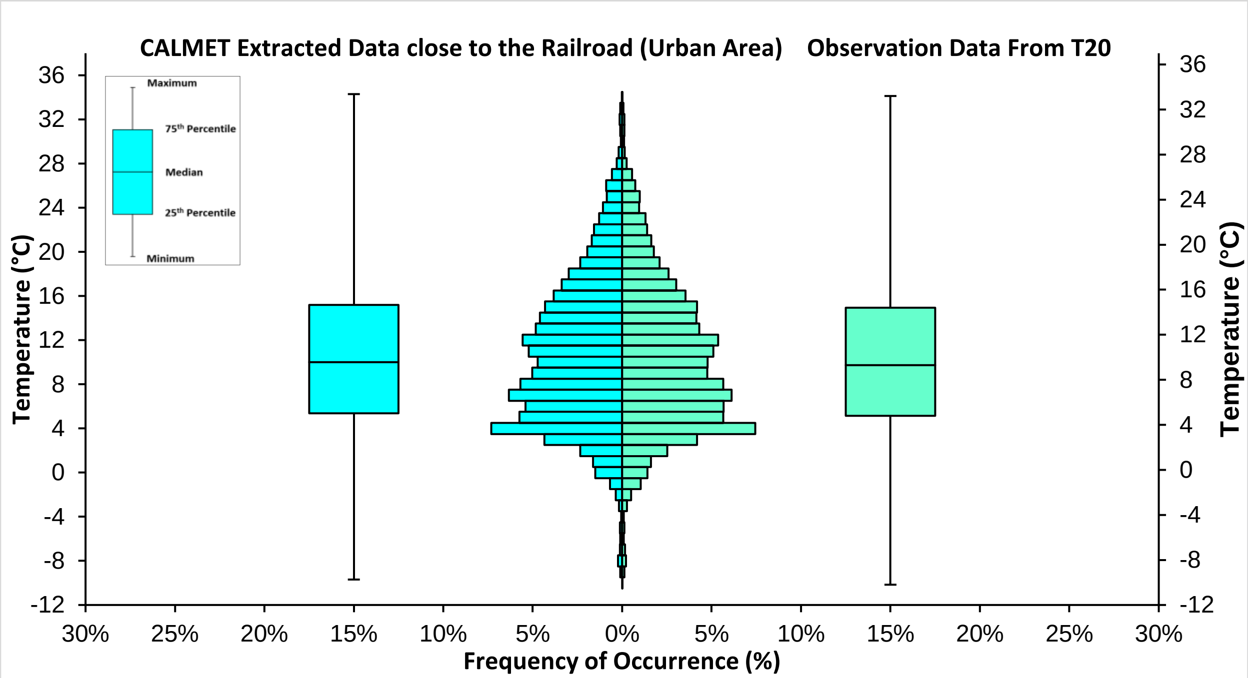



**Figure C-3: Comparison of CALMET-derived temperatures at the centre of the model domain (close to Pitt Meadows West Coast Express station) and observed temperatures at the closest monitoring station: T20– Pitt Meadows**

**Figure C-4** shows CALMET-derived monthly and diurnal variations of temperature at the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station). As expected, the highest temperature occurred during August afternoons. **Figure C-5** shows the monthly average CALMET derived temperatures at stations T20, and T30, compared with the observed monthly average temperatures at these stations. In addition, **Figure C-6** shows the diurnal variations of the CALMET derived temperatures compared to the observed temperatures at stations T20 and T30.

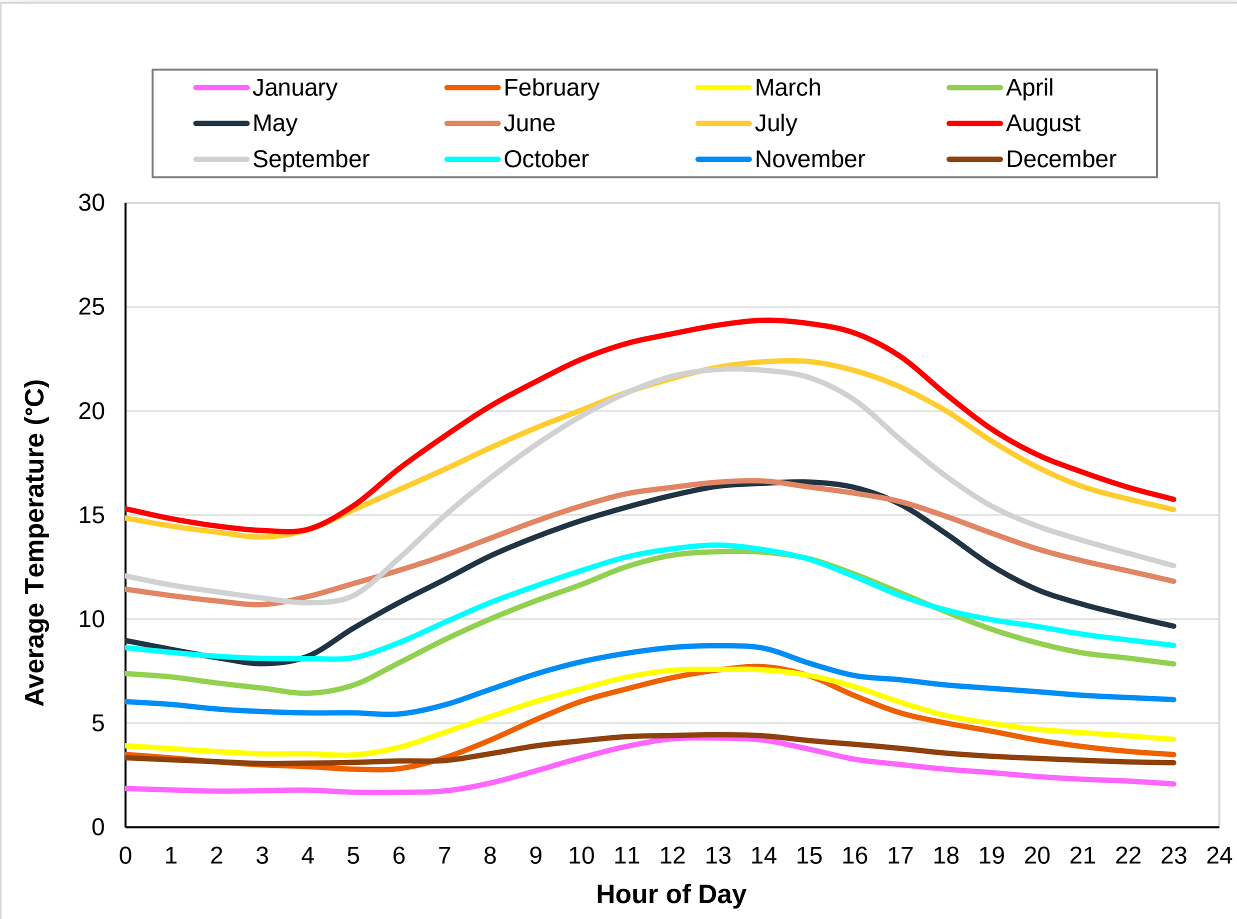



**Figure C-4: Average of CALMET-derived diurnal temperatures by month at the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station)**

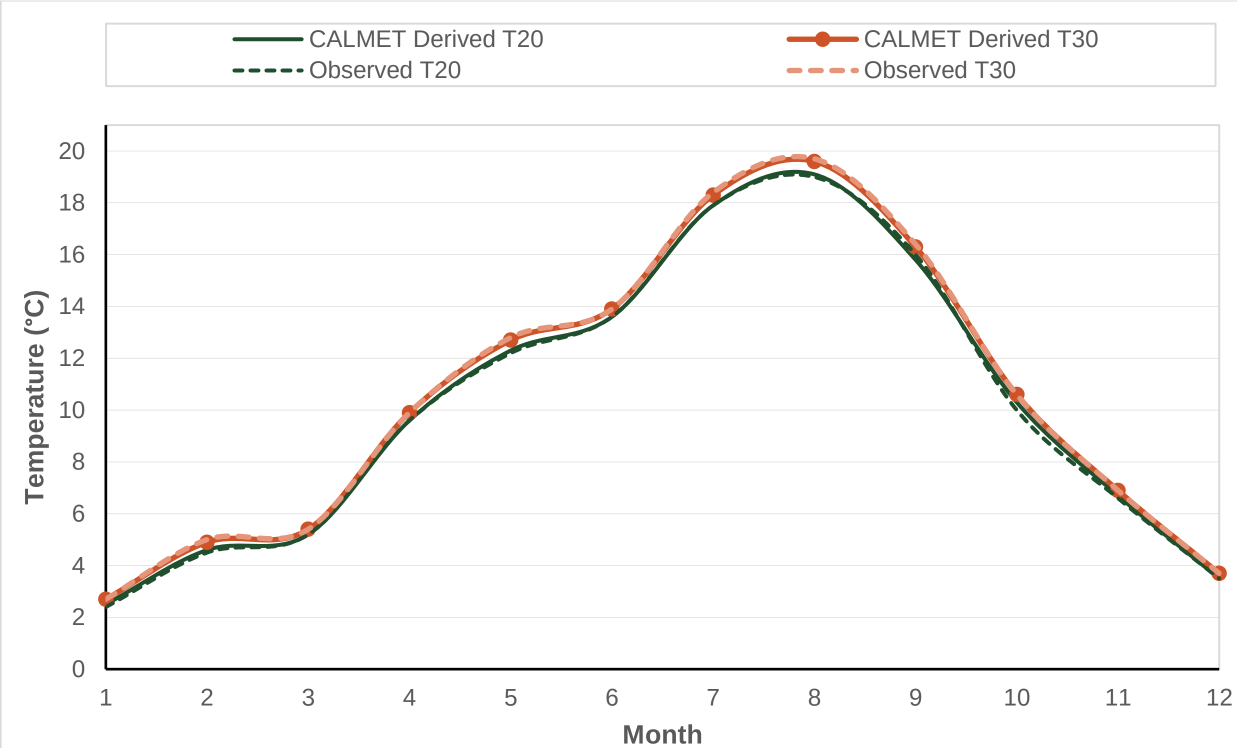



**Figure C-5: Comparison of CALMET-derived temperatures with observed temperatures by month at Stations T20 and T30**

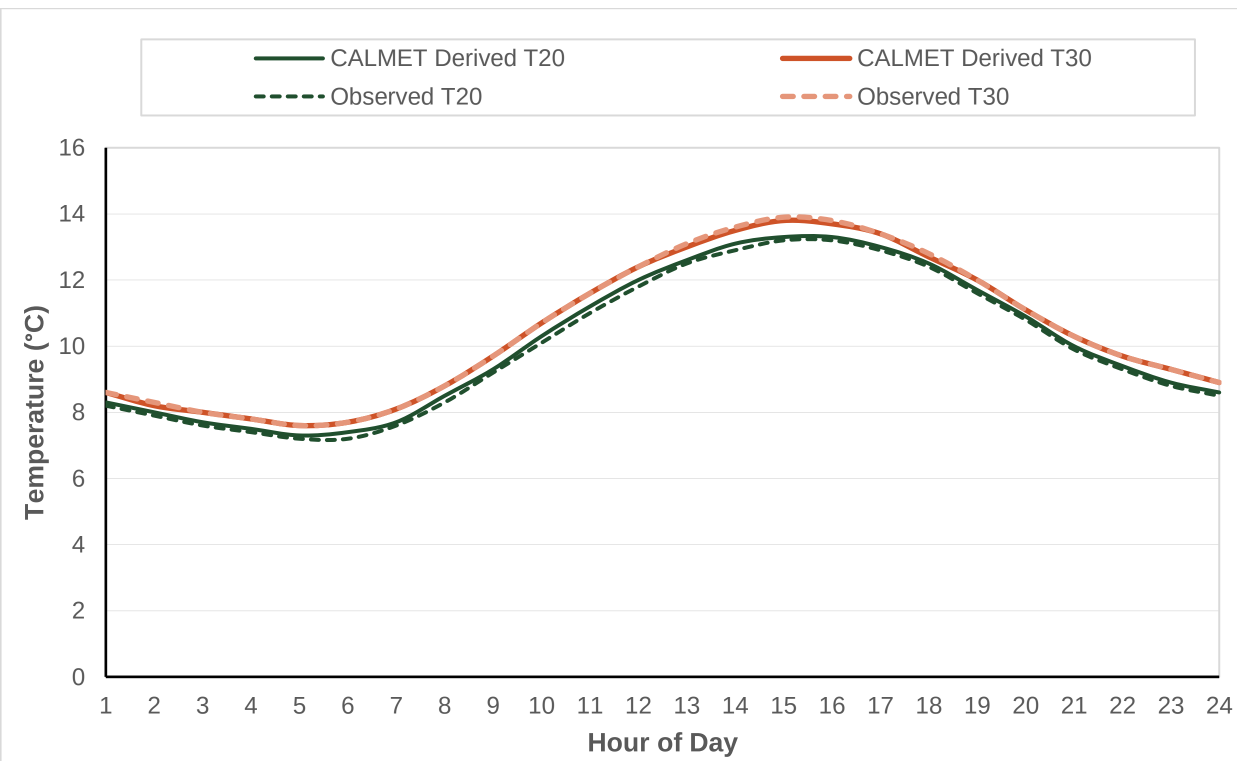



**Figure C-6: Comparison of CALMET-derived temperatures with observed temperatures by hour of day at Stations T20 and T30**

## C.2 Surface Wind Speed and Direction

The dispersion and transport of atmospheric emissions are driven primarily by the wind. A wind rose is often used to illustrate the frequency of wind direction and the magnitude of wind velocity. The lengths of the bars on the wind rose indicate the frequency of occurrence of the various speed of winds, while the direction from which the wind blows is shown by the orientation of the bar in each direction. The observed and CALMET model derived winds (at the first layer, 10m) at: T20 (Pitt Meadows) and T30 (Maple Ridge) stations for 2012 are presented in **Table C-1**. In addition, **Table C-2** and **Table C-3** present the observed and CALMET derived winds at Station T20 and T30 by season. The seasons are separated as identified based on the CALMET surface characteristics seasons. The observed and CALMET model derived surface wind roses are very similar at all selected stations over the modelling period, and during each season at the example station locations.

CALMET-derived and observed wind speeds have also been compared for a 24-hour period at Stations T20 and T30 during which unstable conditions were observed (summer time), shown in **Figure C-7**, and during which stable conditions were observed (winter time), shown in **Figure C-8**. During both 24-hour periods, CALMET-derived and observed wind speeds were similar at both stations, which indicates the model is performing as expected and properly ingested the input observations.

**Table C-1: Observed and CALMET model derived wind roses at Stations T20 and T30**

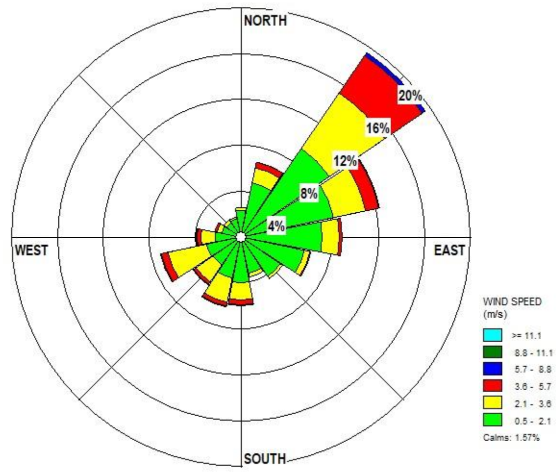
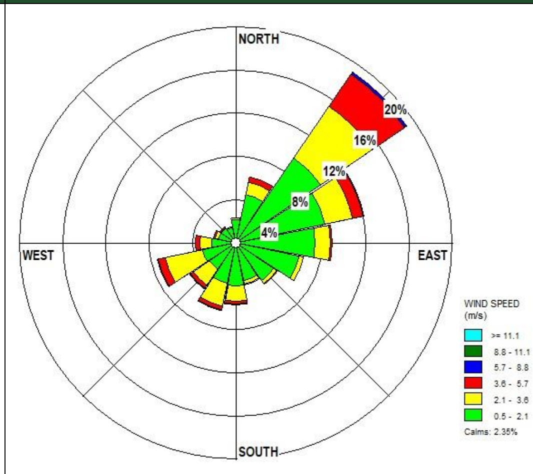
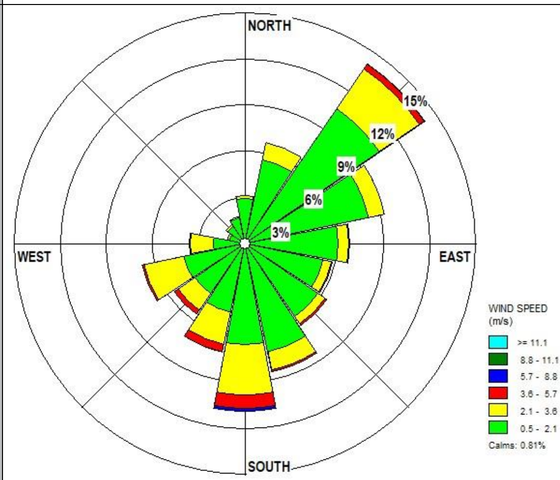
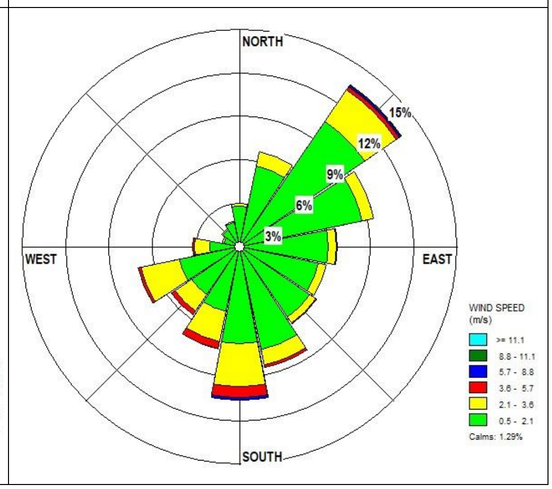
| Station | Observed Wind Data | CALMET Model Derived Wind Data |
|---|---|---|
| **T20**<br>(Pitt Meadows) |  |  |
| **T30**<br>(Maple Ridge) |  |  |

**Table C-2: Observed and CALMET model derived seasonal wind roses at Station T20**

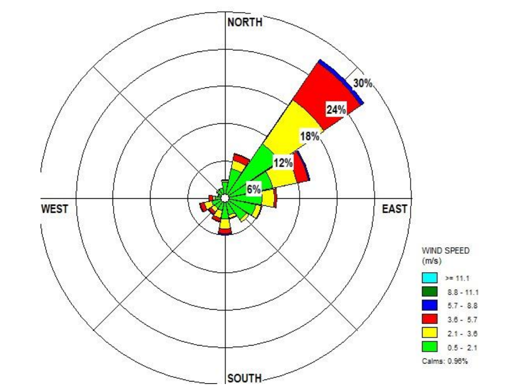
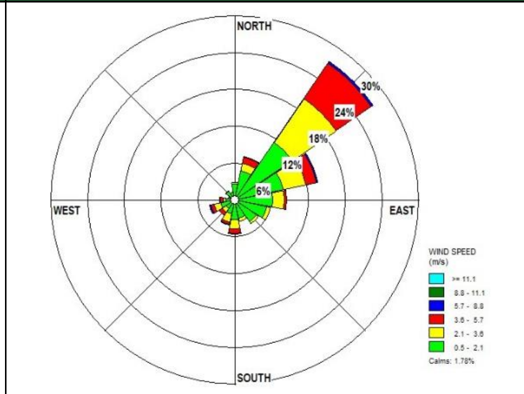
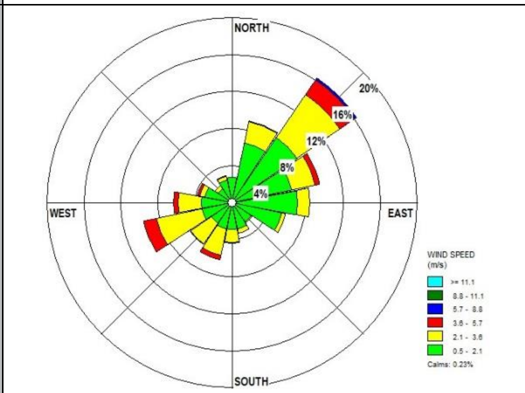
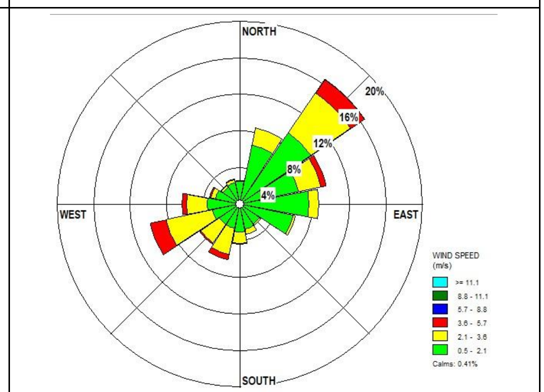
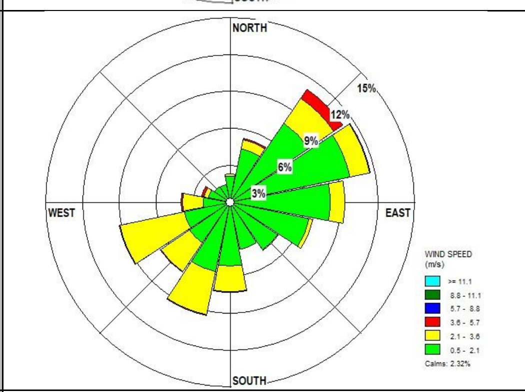
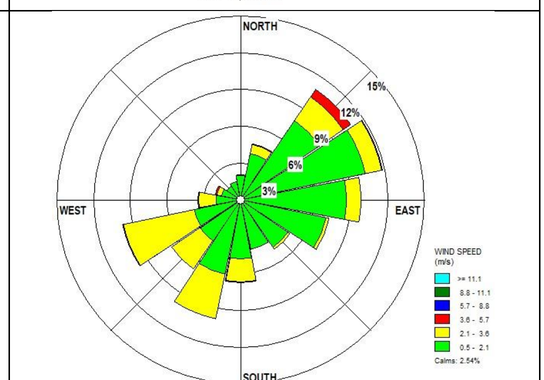
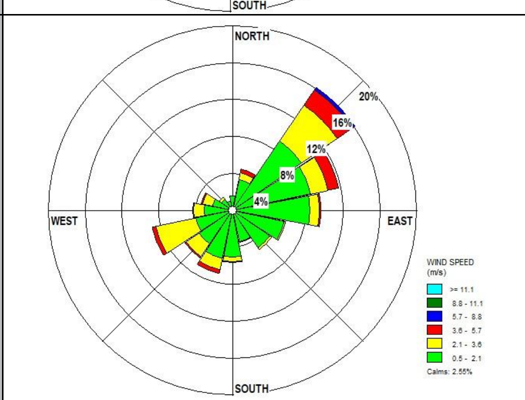
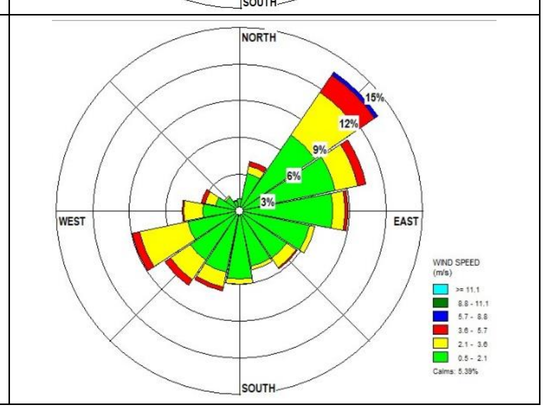
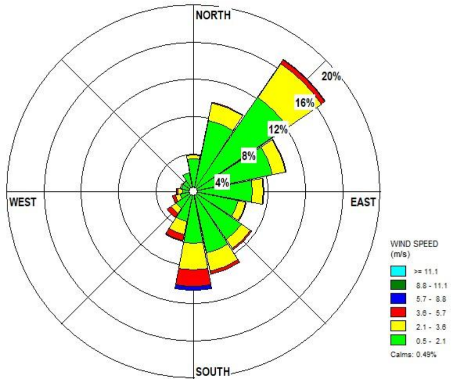
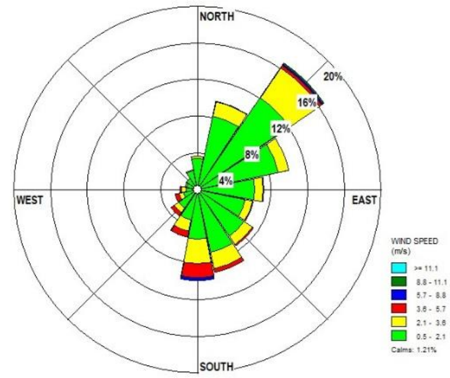
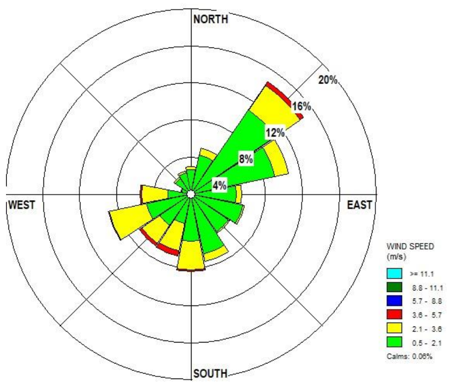
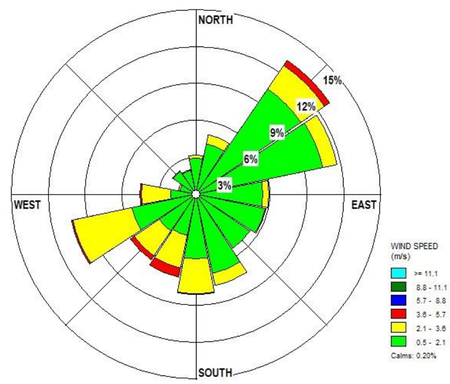
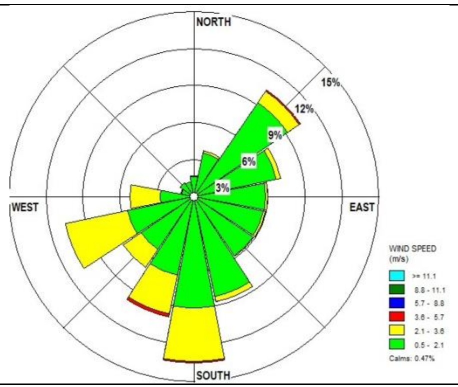
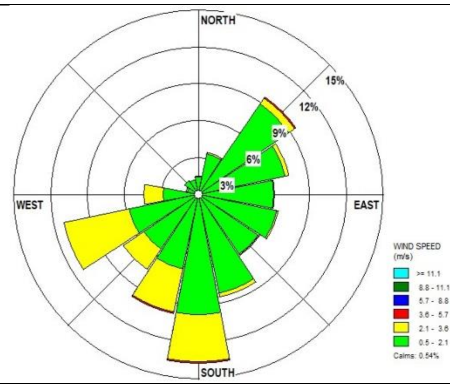
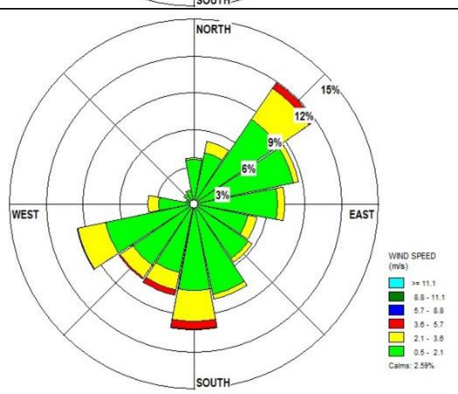
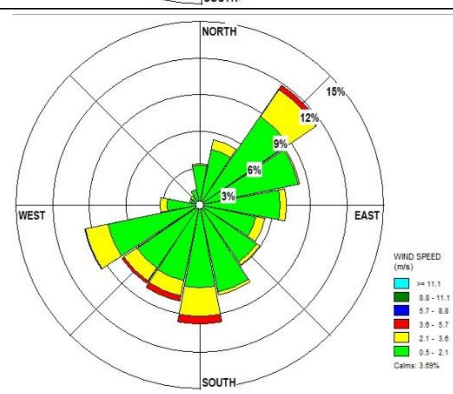
| Season | Observed Wind Data | CALMET Model Derived Wind Data |
|---|---|---|
| **Winter**<br>*(January, February, March, & November, December)* |  |  |
| **Spring**<br>*(April, May))* |  |  |
| **Summer**<br>*(June, July, August)* |  |  |
| **Autumn**<br>*(September, October)* |  |  |

**Table C-3: Observed and CALMET model derived seasonal wind roses at Station T30**

| Season | Observed Wind Data | CALMET Model Derived Wind Data |
|---|---|---|
| **Winter**<br>*(January, February, March, & November, December)* |  |  |
| **Spring**<br>*(April, May))* |  |  |
| **Summer**<br>*(June, July, August)* |  |  |
| **Autumn**<br>*(September, October)* |  |  |

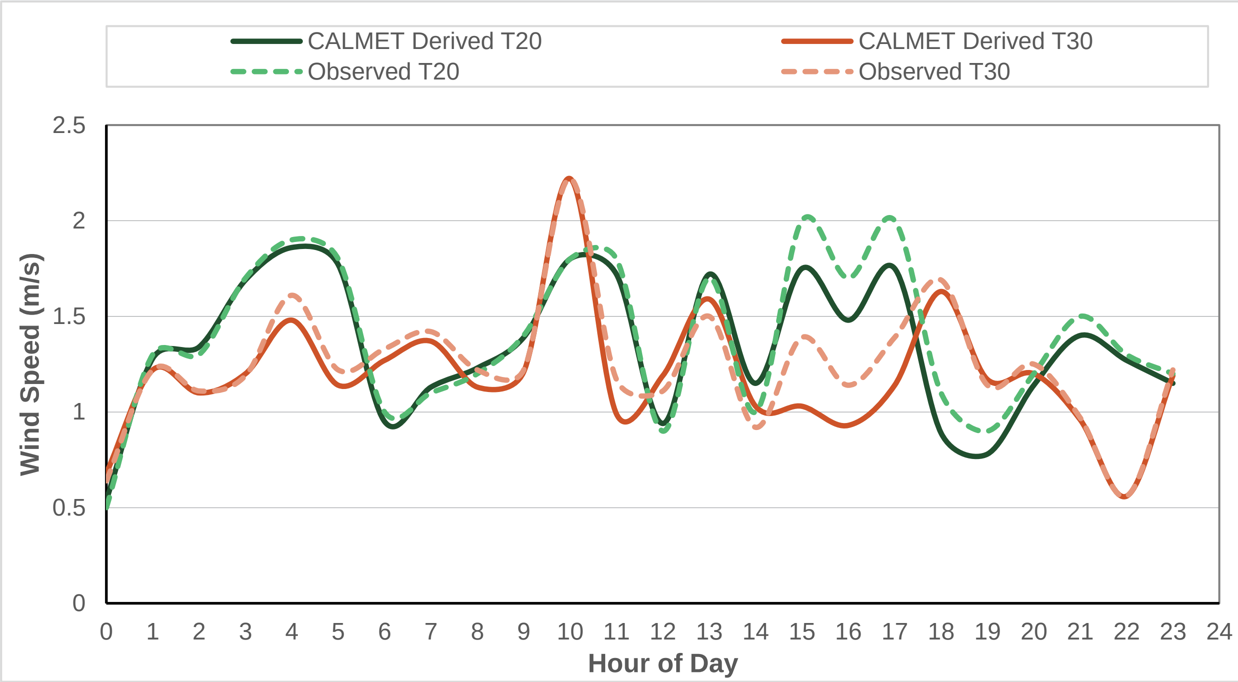



**Figure C-7: CALMET-Derived and Observed Wind Speeds for July 20th, 2012 at Stations T20 and T30**

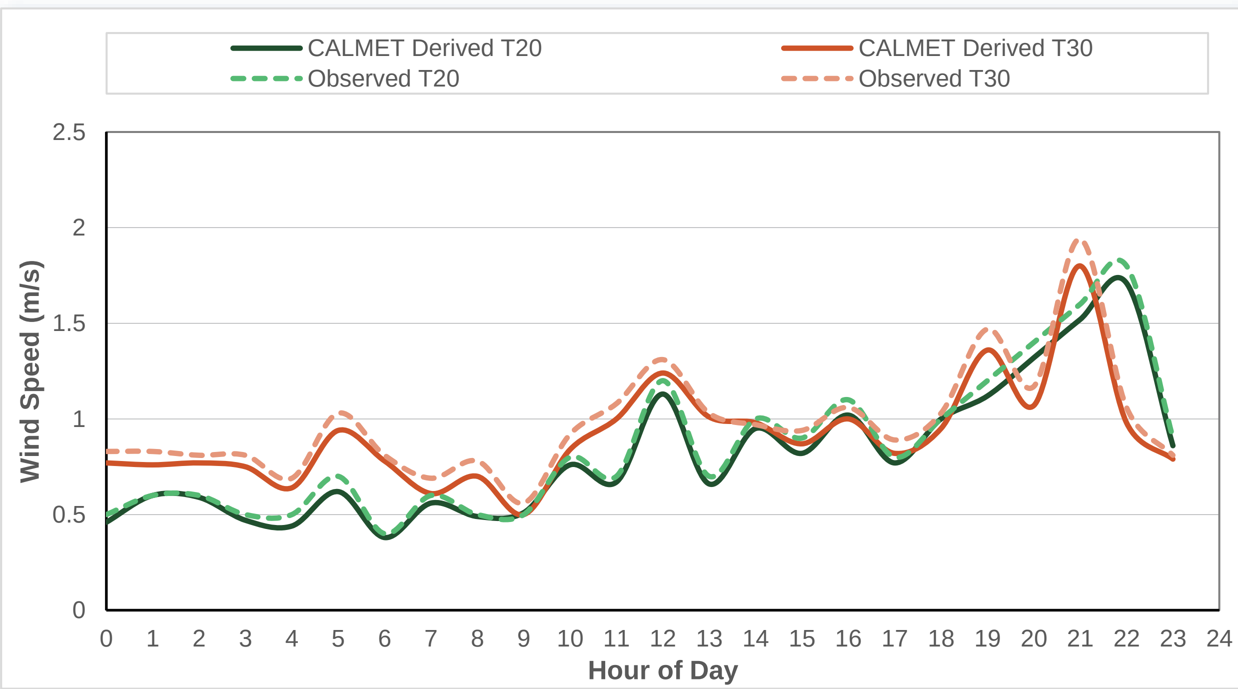



**Figure C-8: CALMET-Derived and Observed Wind Speeds for January 13th, 2012 at Stations T20 and T30**

## C.3 Pasquill-Gifford Stability Class (P-G Classes)

Atmospheric stability can be viewed as a measure of the atmosphere's capability to disperse emissions. The amount of turbulence plays an important role in the dilution of a plume as it is transported by the wind. Turbulence can be generated by either thermal or mechanical mechanisms. Surface heating or cooling by radiation contributes to the generation or suppression of thermal turbulence, while high wind speeds contribute to the generation of mechanical turbulence.

The Pasquill-Gifford (P-G) stability classification scheme is summarized in **Table C-4**.

**Table C-4: Atmospheric stability class category description**

| Atmospheric Stability Class | Category | Description |
|---|---|---|
| **A** | Very Unstable | Low wind, clear skies, hot daytime conditions |
| **B** | Unstable | Clear skies, daytime conditions |
| **C** | Moderately Unstable | Moderate wind, slightly overcast daytime conditions |
| **D** | Neutral | High winds or cloudy days and nights |
| **E** | Stable | Moderate wind, slightly overcast night-time conditions |
| **F** | Very Stable | Low winds, clear skies, cold night-time conditions |

The frequency distributions of occurrence for each stability class for the modelling period as predicted by CALMET at the project location, T20 (Pitt Meadows) and T30 (Maple Ridge) stations are presented in **Figure C-9**. For both locations, the results indicate the most typical condition is neutral stability class "D". The second highest frequency is stability class "F", indicative of highly stable conditions, which is conducive to moderate to low dispersion due to a lack of mechanical mixing.

In addition, **Figure C-10** shows the monthly frequency distribution of the P-G atmospheric stability classes for the modelling period from the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station).

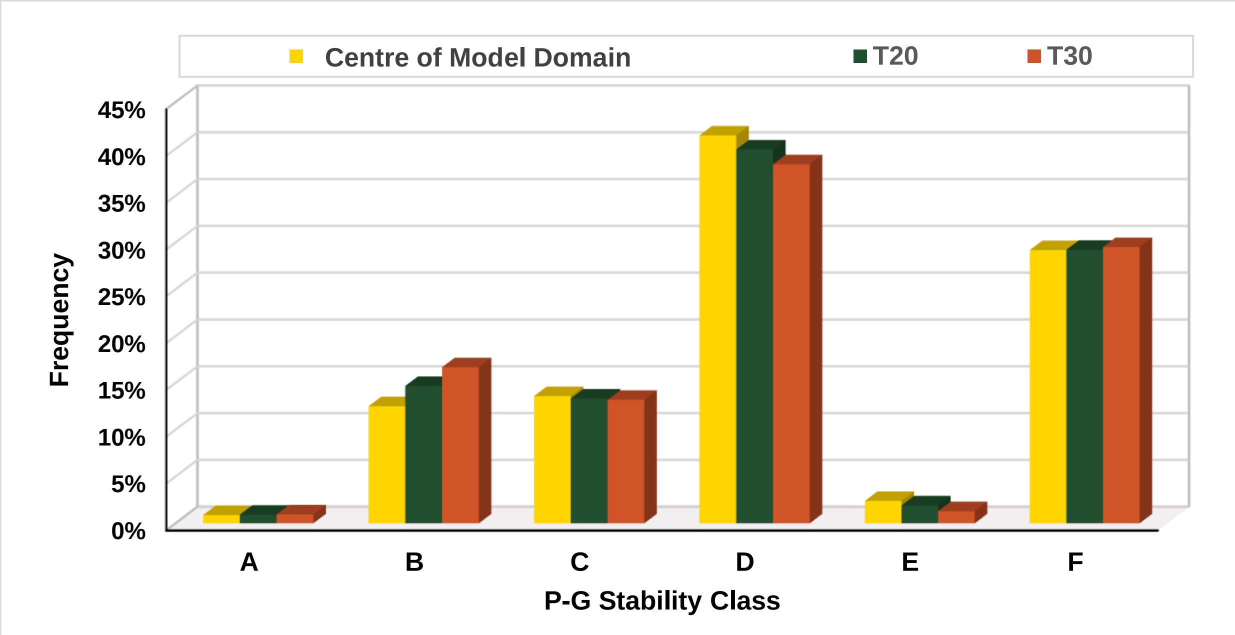



**Figure C-9: Frequency Distribution of CALMET Stability Classes at the selected locations**

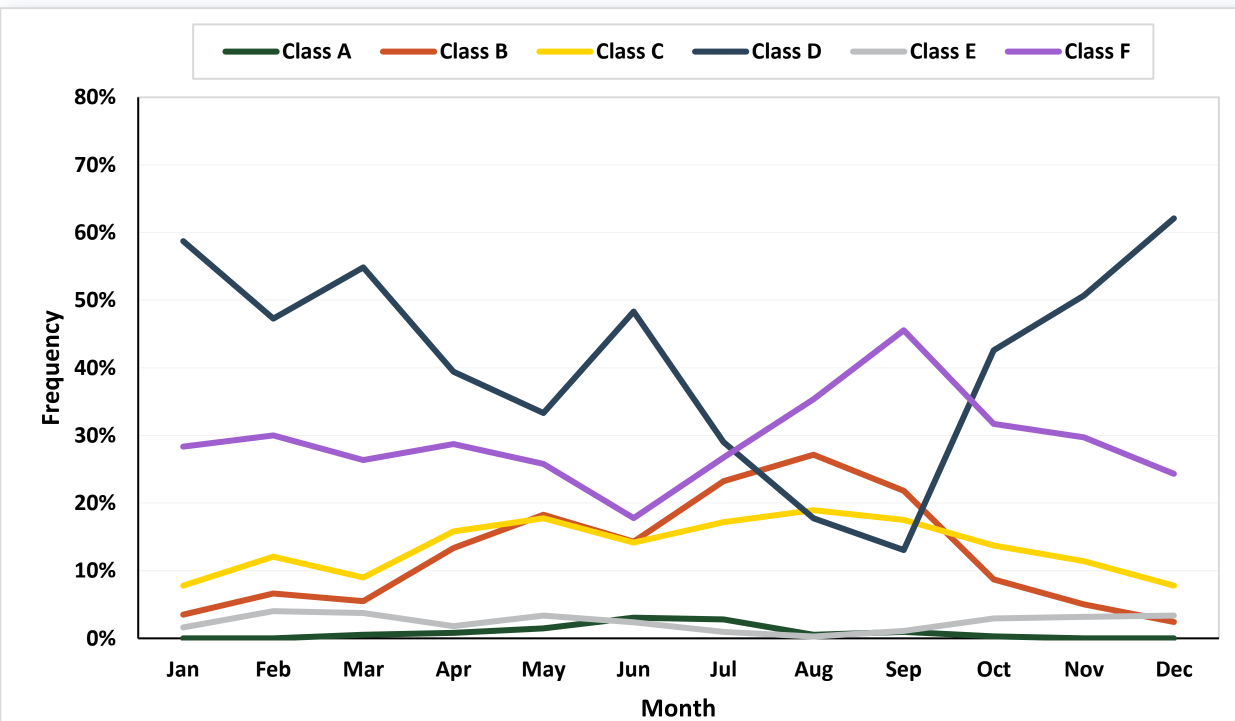



**Figure C-10: Monthly variation of P-G stability classes at centre of model domain**

## C.4 Mixing Height

Mixing height is a measure of the depth of the atmosphere through which mixing of emissions can occur. Mixing heights often exhibit a strong diurnal and seasonal variation: they are lower during the night and higher during the day. Seasonally, mixing heights are typically lower in the winter and higher in the late spring and early summer.

CALMET calculates an hourly convective mixing height for each grid cell from hourly surface heat fluxes and vertical temperature profiles from upper-air data. Mechanical mixing heights are calculated using an empirical relationship that is a function of friction velocity. To incorporate advective effects, mixing height fields are smoothed by incorporating values from upwind grid cells. The higher of the two mixing heights (convective or mechanical) in a given hour is used. A more detailed description of this method is given in the CALMET User's Manual Version 5.0 (Earth Tech 2000).

The frequency of diurnal mixing heights derived by CALMET near railroad in urban area and T20 and T30 stations for the assessment period are shown in **Figure C-11**, **Figure C-12**, and **Figure C-13.** Mixing heights are typically lower at night than during the day.

The median daytime and nighttime mixing height at different locations are summarized in **Table C-5**.

**Table C-5: Median daytime and nighttime mixing height at different locations**

| Location | Median Daytime Mixing Height (m) | Median Nighttime Mixing Height (m) |
|---|---|---|
| **Centre of Model Domain** | 598.8 | 55.8 |
| **T20** | 503.3 | 51.2 |
| **T30** | 587.4 | 67.2 |

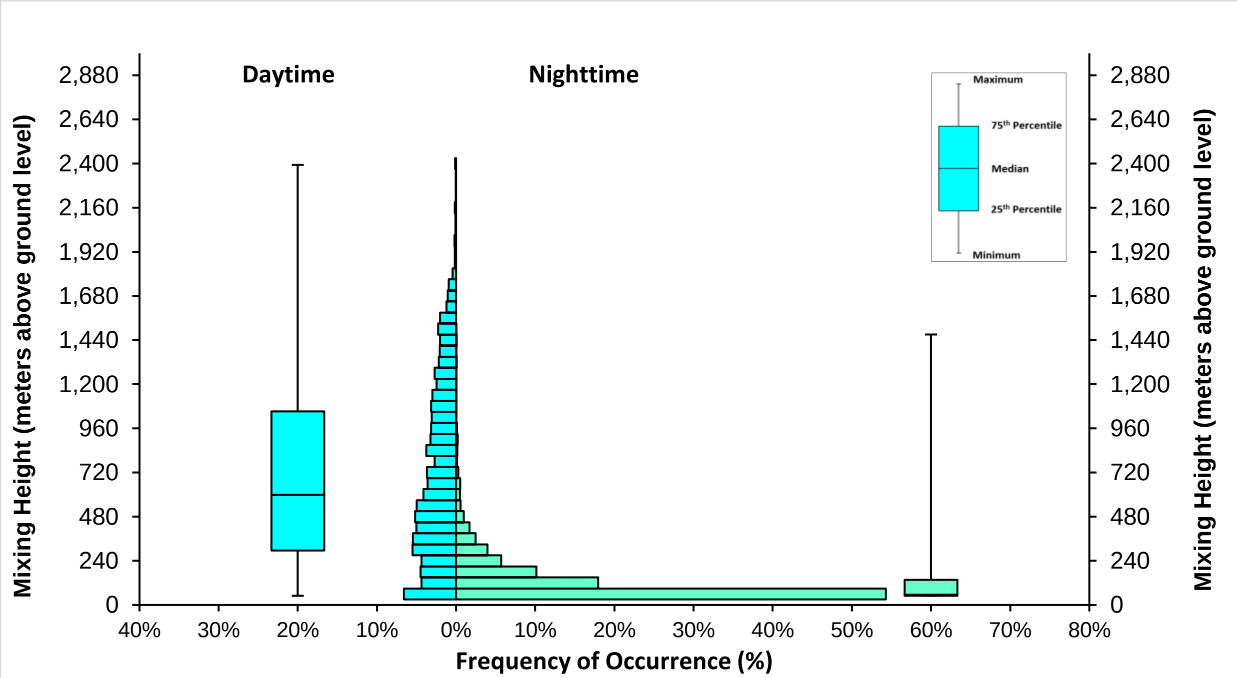



**Figure C-11: CALMET-derived mixing heights at the centre of the model domain**

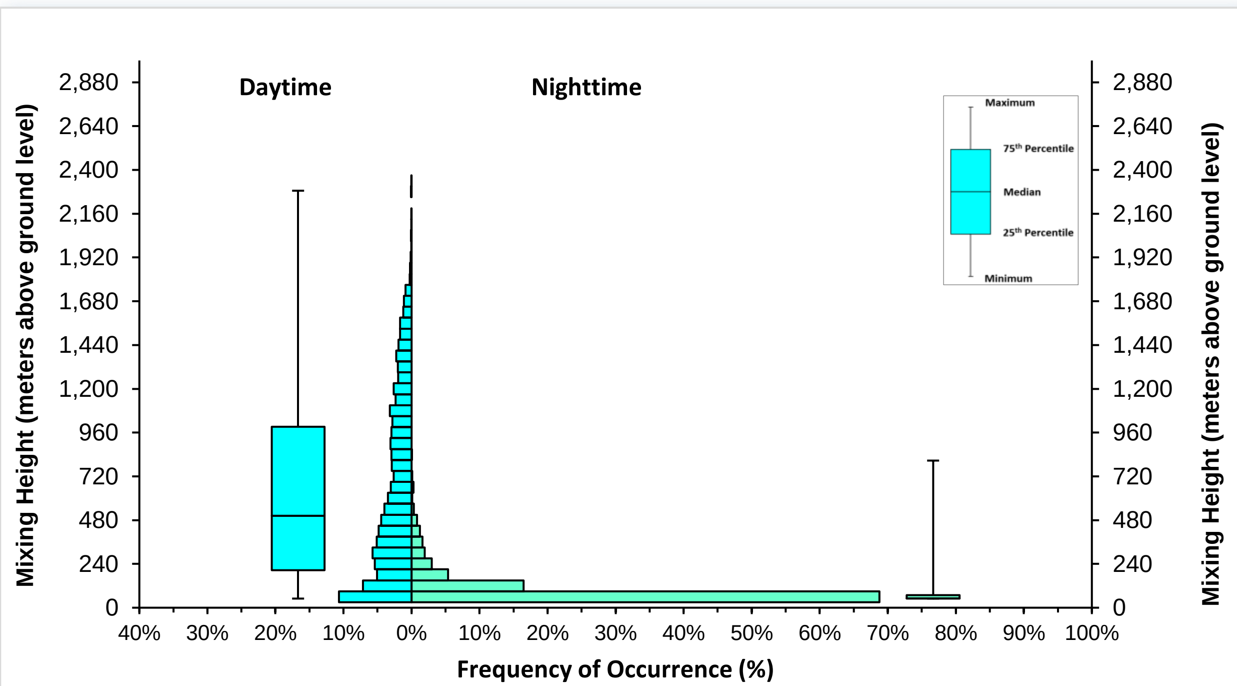



**Figure C-12: CALMET-derived mixing heights for T20 – Pitt Meadows**

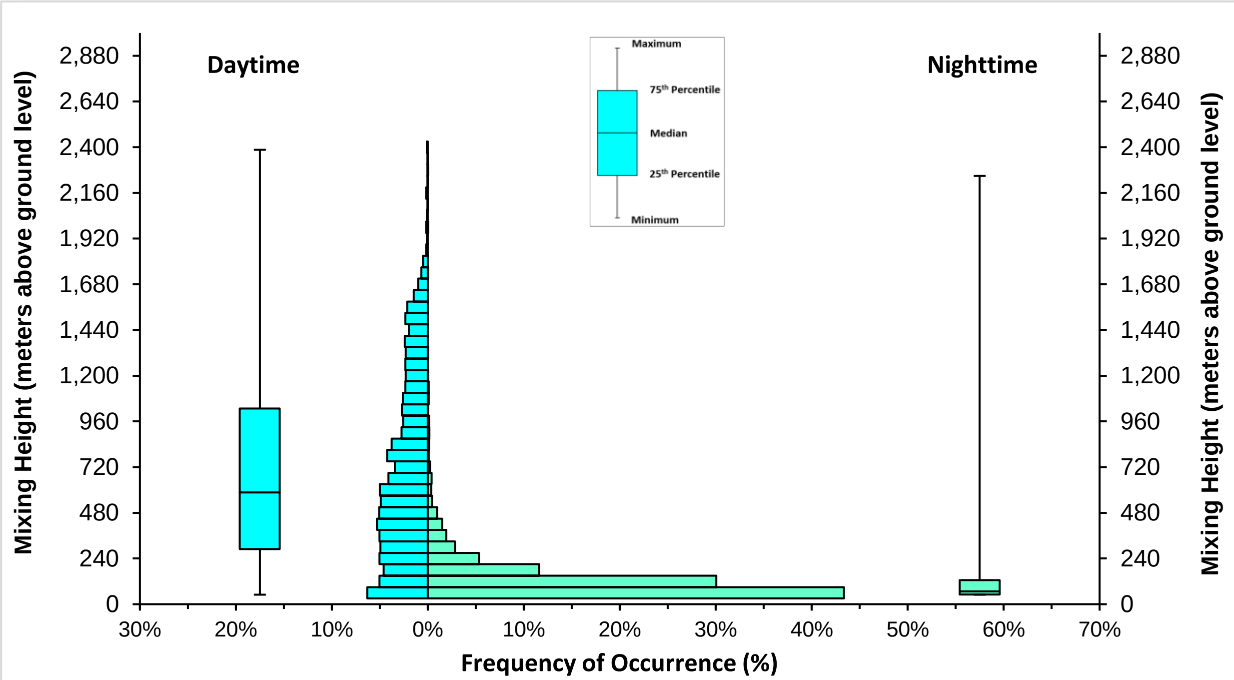



**Figure C-13: CALMET-derived mixing heights for T30 – Maple Ridge**

Diurnal variation of the median mixing height predicted by CALMET at the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station) is illustrated in **Figure C-14**. It can be seen that an increase in the mixing height begins during the morning hours due to the onset of vertical mixing following sunrise and that maximum mixing heights occur in the mid to late afternoon due to the dissipation of ground-based temperature inversions and the growth of convective mixing layer. Also, daytime mixing heights may be suppressed during stable winter conditions due to weak solar insolation, high reflectivity of probable snow-covered surfaces, low wind speeds and synoptic subsidence.

**Figure C-15** shows the average of mixing heights versus Pasquill-Gifford stability class predicted by CALMET at T20 (Pitt Meadows) and T30 (Maple Ridge) stations. Overall, the highest mixing heights are associated with unstable conditions (Classes A, B and C), while the lowest mixing heights are associated with stable conditions (Classes E and F).

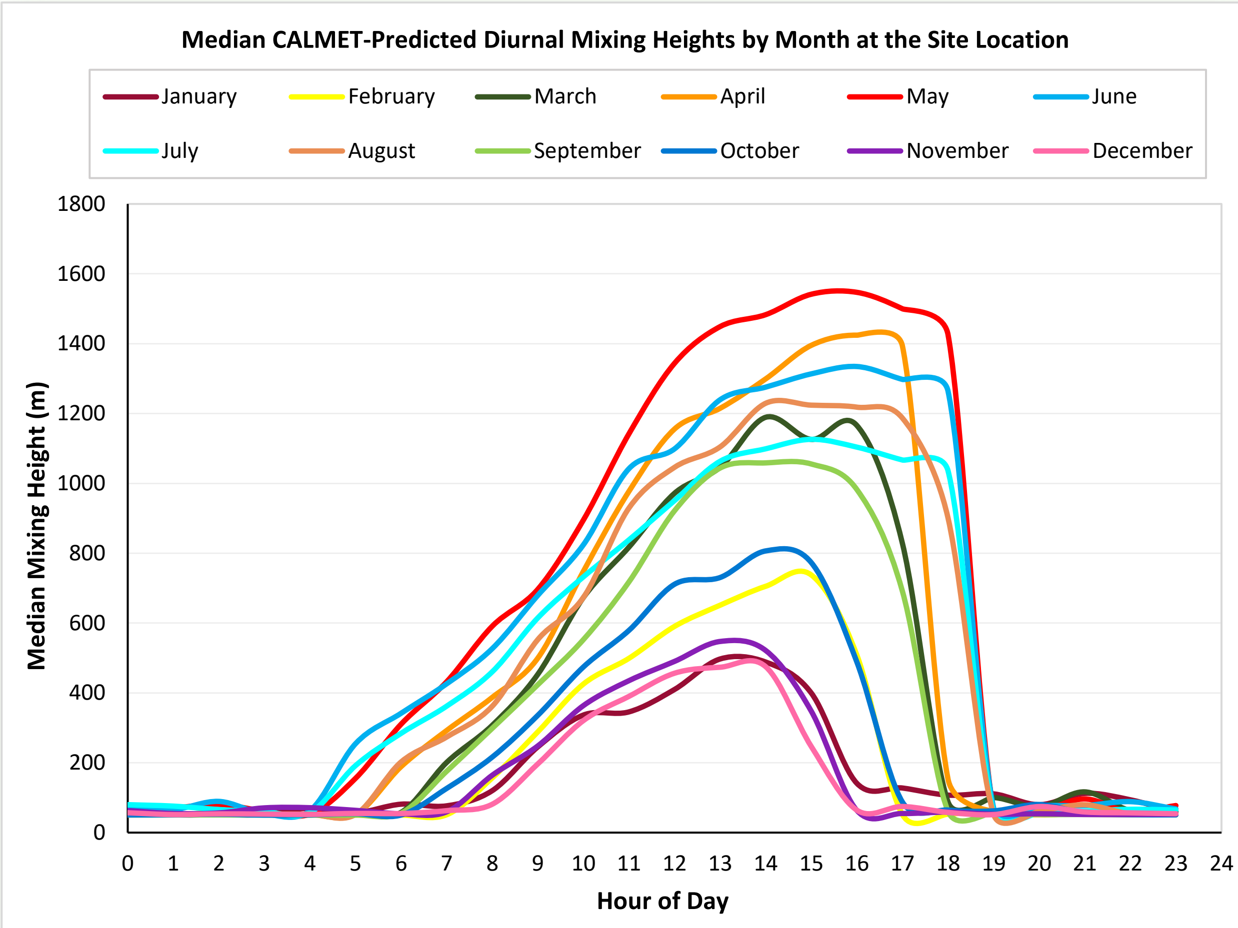



**Figure C-14: Median CALMET-derived diurnal mixing heights by month at the centre of the model domain (along the rail line at the Pitt Meadows West Coast Express station)**

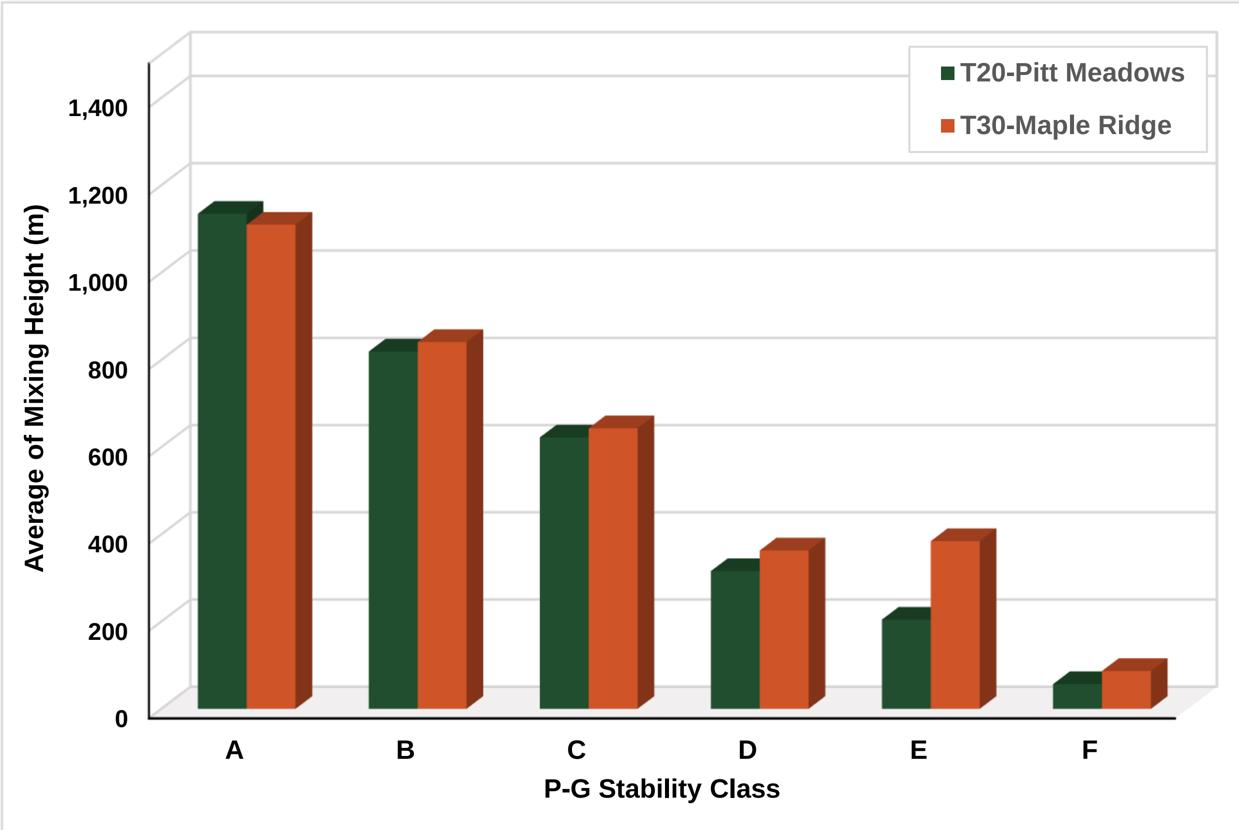
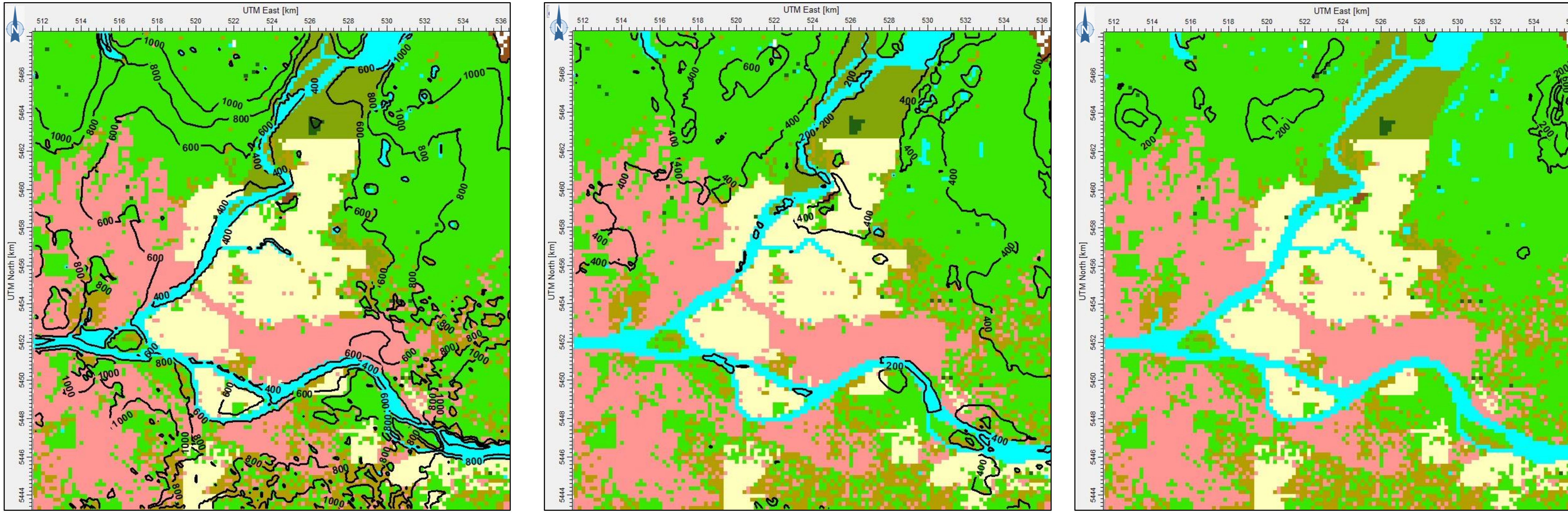



**Figure C-15: Average of CALMET-derived mixing heights versus Pasquill-Gifford stability class at selected stations for 2012**

The spatial distribution of mixing heights under example unstable, neutral, and stable conditions is shown in **Figure C-16**. Spatial changes in mixing height align with changes in the land use. Mixing height tends to be lowest over water and increases with distance more quickly in areas where surface roughness is greater (i.e., where surface elements are larger) especially in unstable conditions.

Time series of CALMET-derived mixing heights at stations T20, and T30 over the 24-hour period of a summer day (unstable condition during the day) and winter day (stable condition early in the morning) during light winds and clear sky conditions are presented in **Figure C-17** and **Figure C-18**.




**Unstable**

**July 20th, 2012 at 12:00 pm**

**Neutral**

**March 18th, 2012 at 10:00 am**

**Stable**

**January 13th, 2012 at 12:00 am**

**Figure C-16: CALMET predicted mixing heights (200 m contour lines) overlaid on top of land cover characterization during unstable, neutral, and stable atmospheric conditions**

| Land Use Codes | | | | |
|---|---|---|---|---|
| | 10 Urban | 30 Rangeland | 50 Water | 61 Forested Wetlands |
| | 20 Agricultural | 40 Forest Land | 55 Ocean | 62 Nonforested Wetlands |

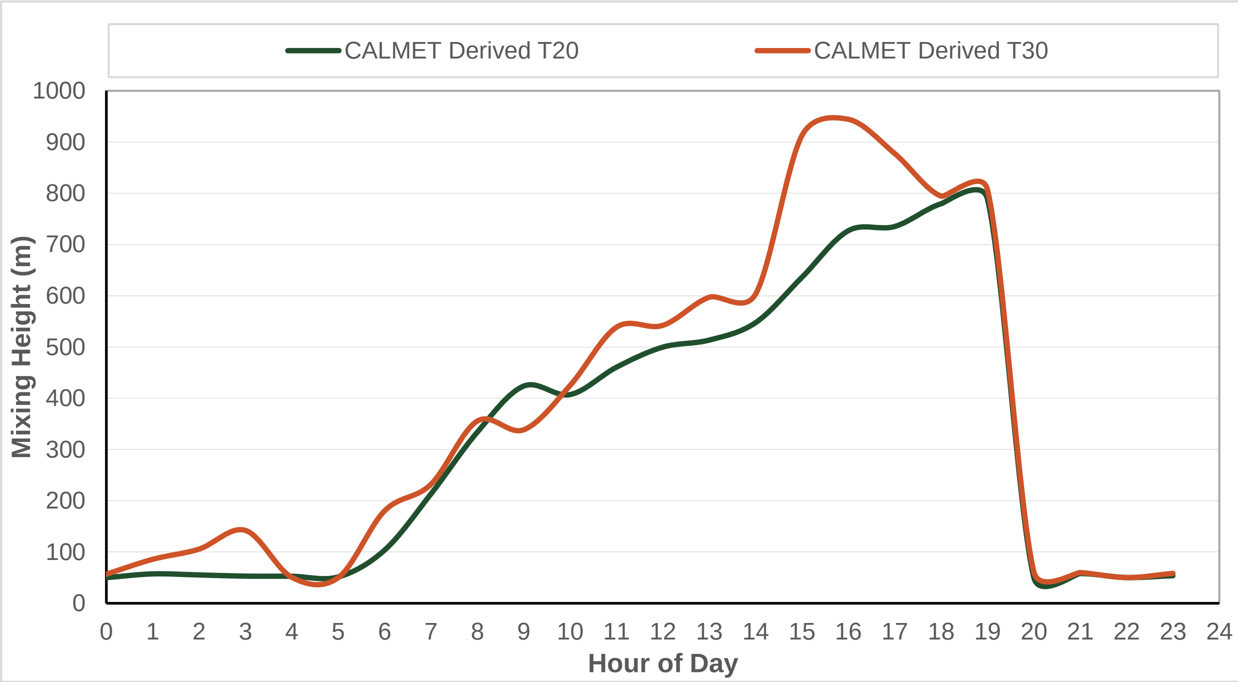



**Figure C-17: CALMET-derived mixing heights for July 20th, 2012 at T20 and T30 stations**

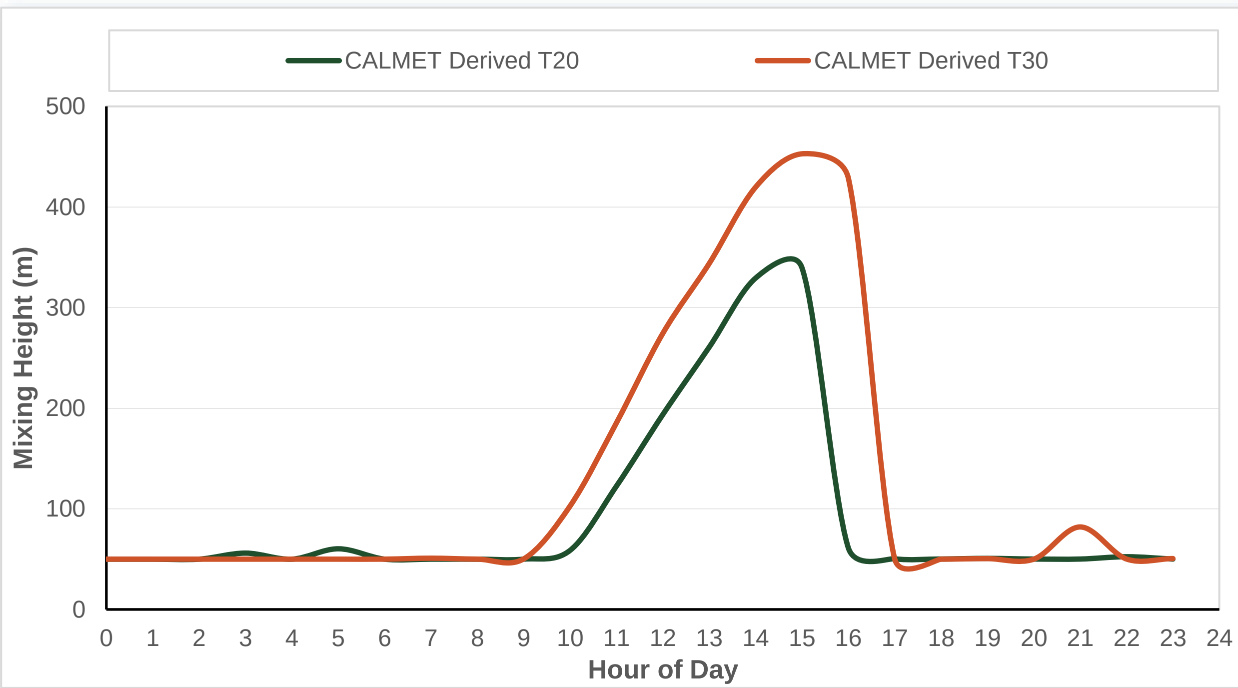
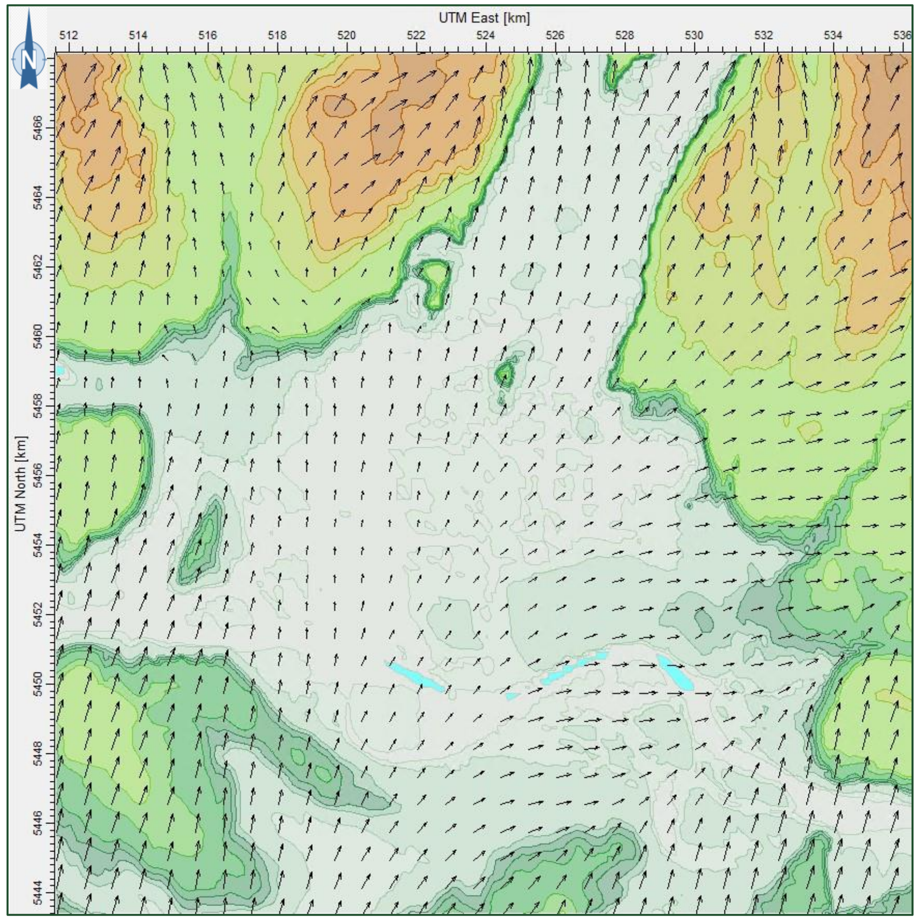



**Figure C-18: CALMET-derived mixing heights for January 13th, 2012 at T20 and T30 stations**

## C.5 Wind Fields

A common approach used to evaluate a meteorological model's ability to replicate wind flow patterns is through the use of wind field plots. Wind fields plots representing unstable, neutral, and stable conditions for the study area are illustrated in **Figure C-19**, **Figure C-20**, and **Figure C-21** for the surface layer, mid-layer and upper layer, respectively to provide an overview of how CALMET performed under different conditions. In general, CALMET-derived wind fields follow the expected terrain flows under various stability and flow regimes, flowing up slope during unstable, daytime conditions and down slope during stable, night-time conditions. Under neutral conditions, the characteristic high wind speeds result in less noticeable terrain effects and wind fields are fairly uniform across the model domain.

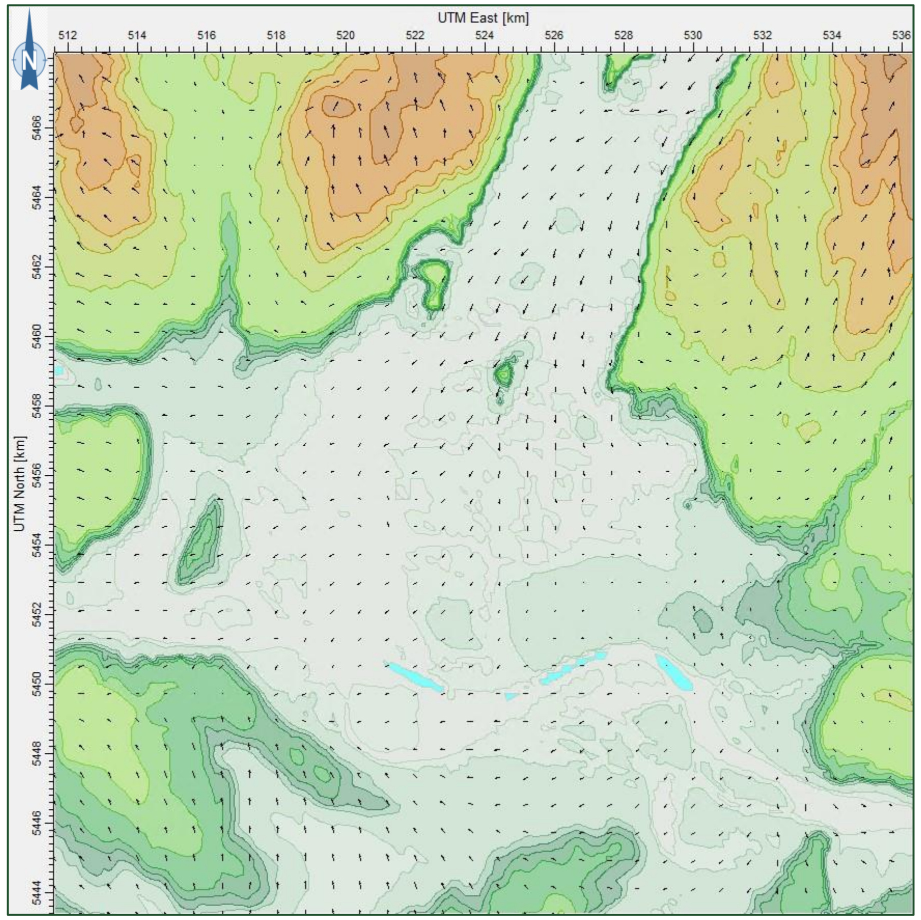
Surface level wind fields show that the model does well in capturing wind flows in the area. In addition, the effects of the elevated areas are well observed in the surface wind fields. Also, upper-level winds are uniform as would be expected for winds in the upper atmosphere that travel approximately parallel with pressure gradients.




**Unstable**

**July 20th, 2012 at 12:00 pm**

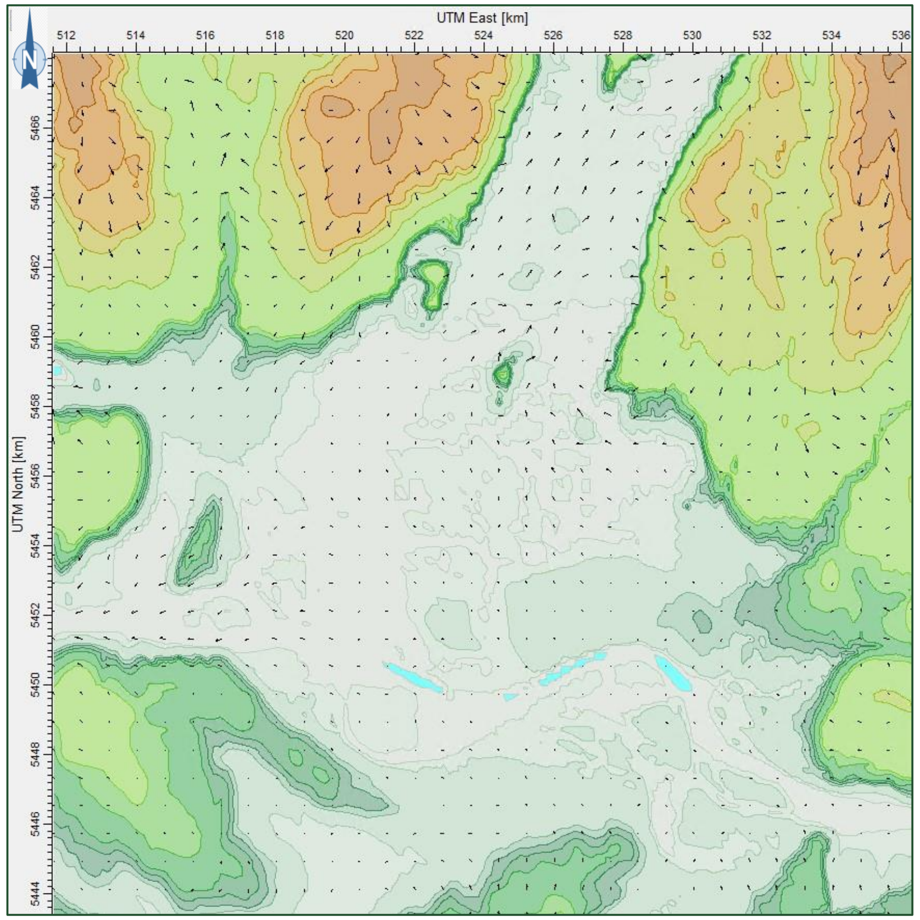
Arrow lengths show relative wind speed from 1.4 to 7.0 m/s.




**Neutral**

**March 18th, 2012 at 10:00 am**

Arrow lengths show relative wind speed from 0 to 3.8 m/s.




**Stable**

**January 13th, 2012 at 12.:00 am**

Arrow lengths show relative wind speed from 0 to 4.3 m/s.

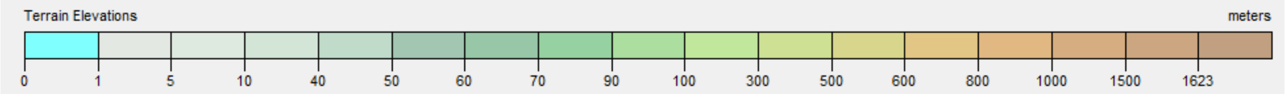
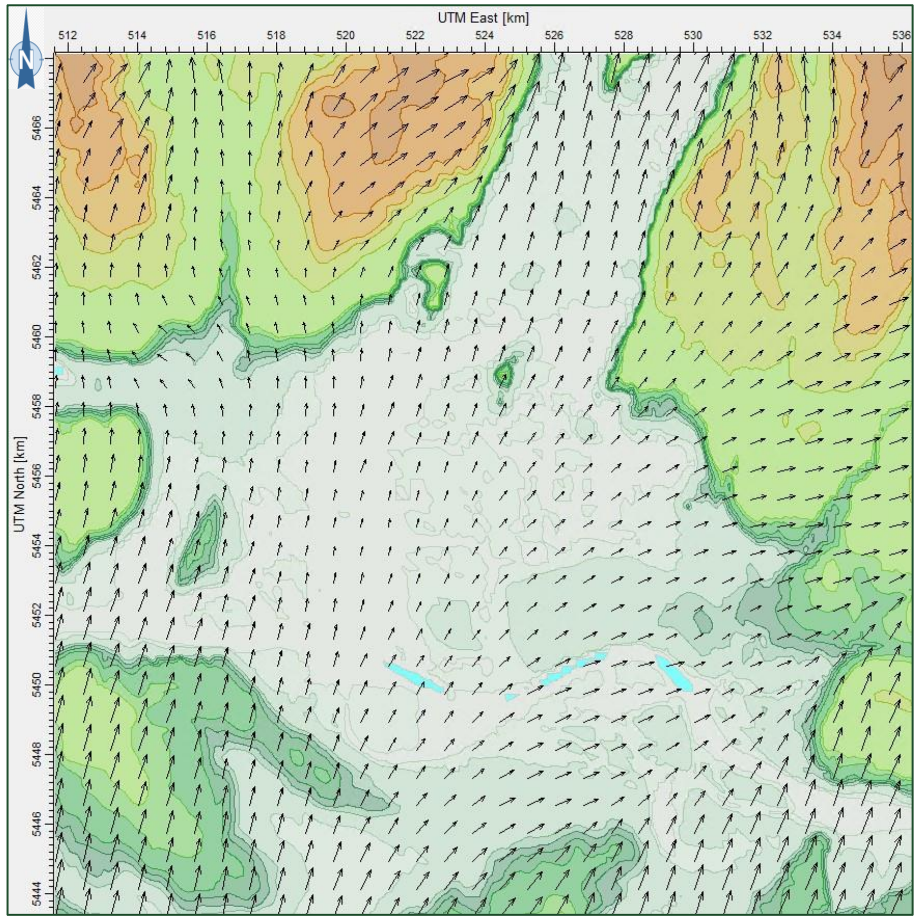


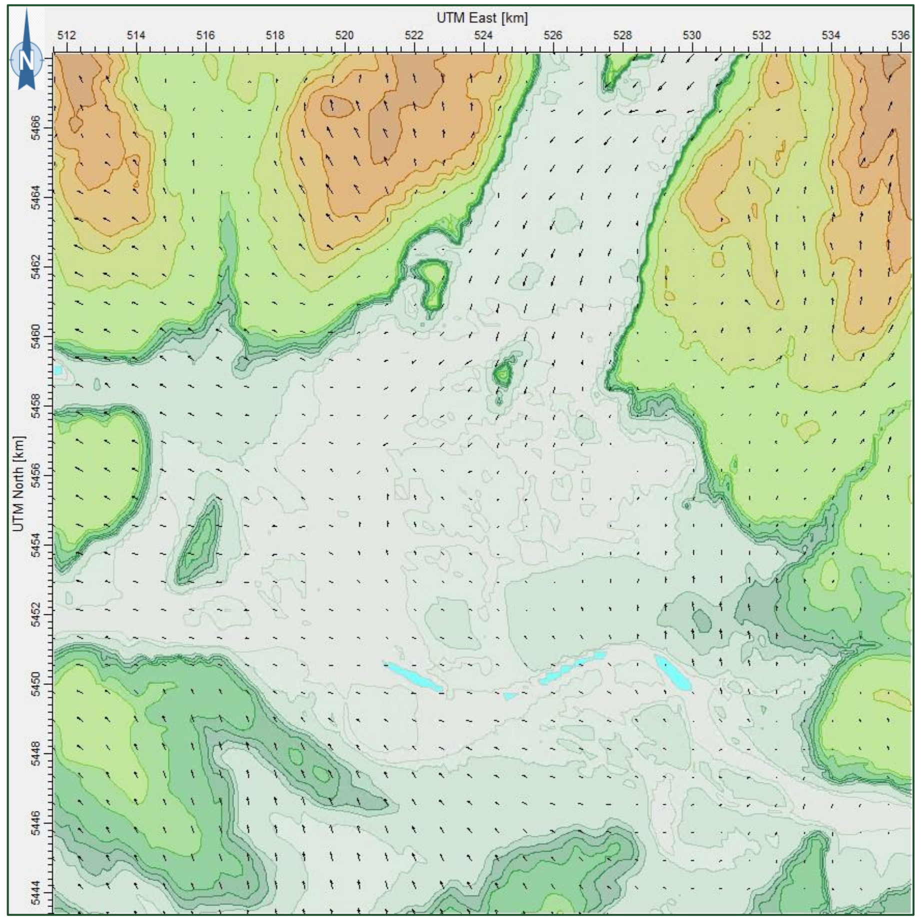

**Figure C-19: CALMET predicted wind fields at 10 m (surface layer) above ground level overlaid on top of the terrain elevation data during unstable, neutral, and stable atmospheric conditions**




**Unstable**

**July 20th, 2012 at 12:00 pm**

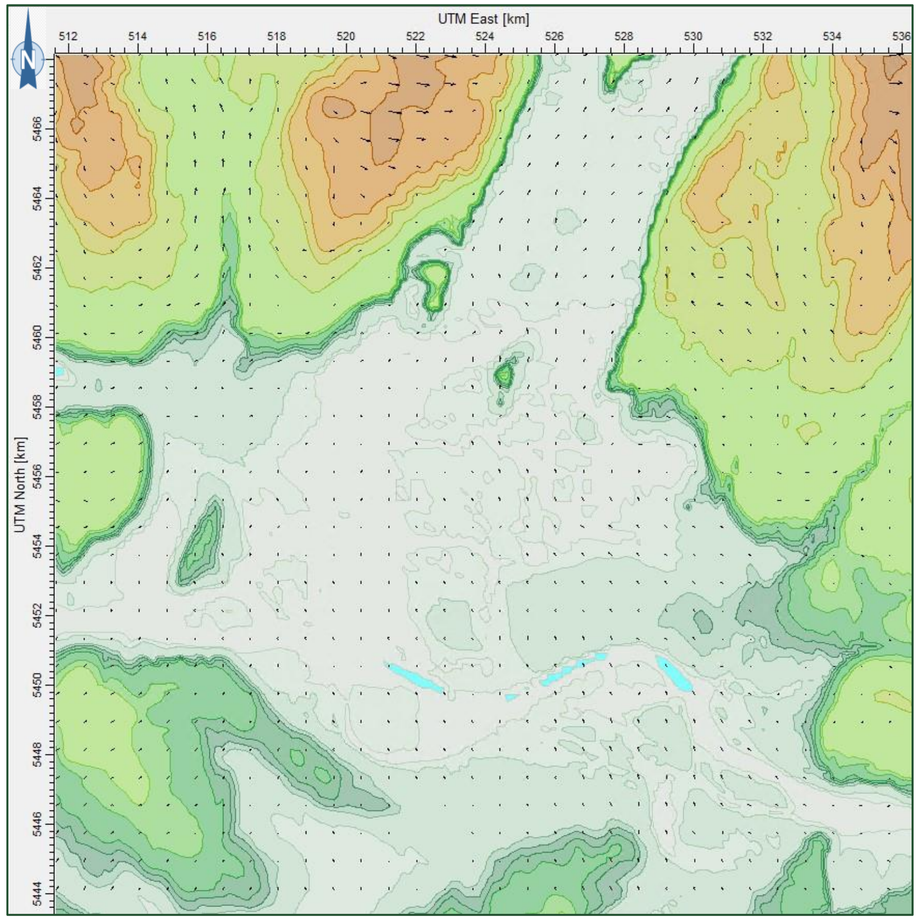
Arrow lengths show relative wind speed from 2.3 to 9.0 m/s




**Neutral**

**March 18th, 2012 at 10:00 am**

Arrow lengths show relative wind speed from 0 to 3.6 m/s

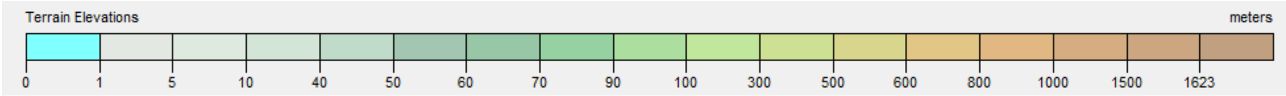


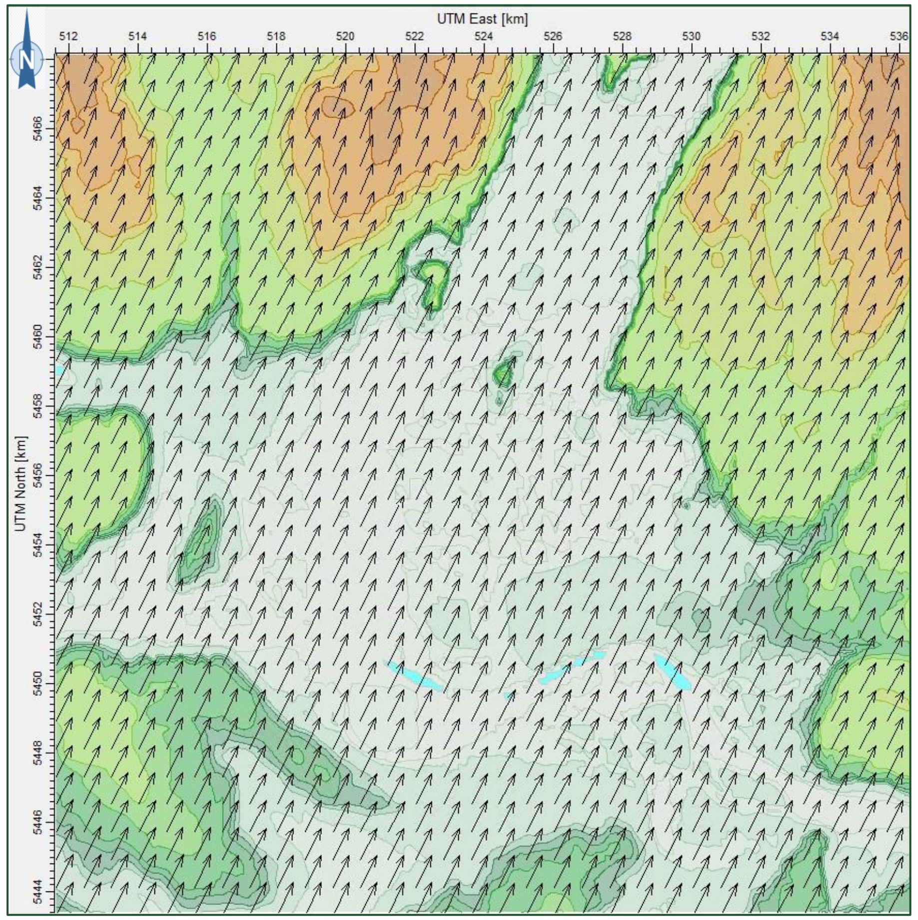

**Stable**

**January 13th, 2012 at 12:00 am**

Arrow lengths show relative wind speed from 0 to 5.3 m/s

**Figure C-20: CALMET predicted wind fields at 170 m above ground level (mid layer) overlaid on top of the terrain elevation data during unstable, neutral, and stable atmospheric conditions**

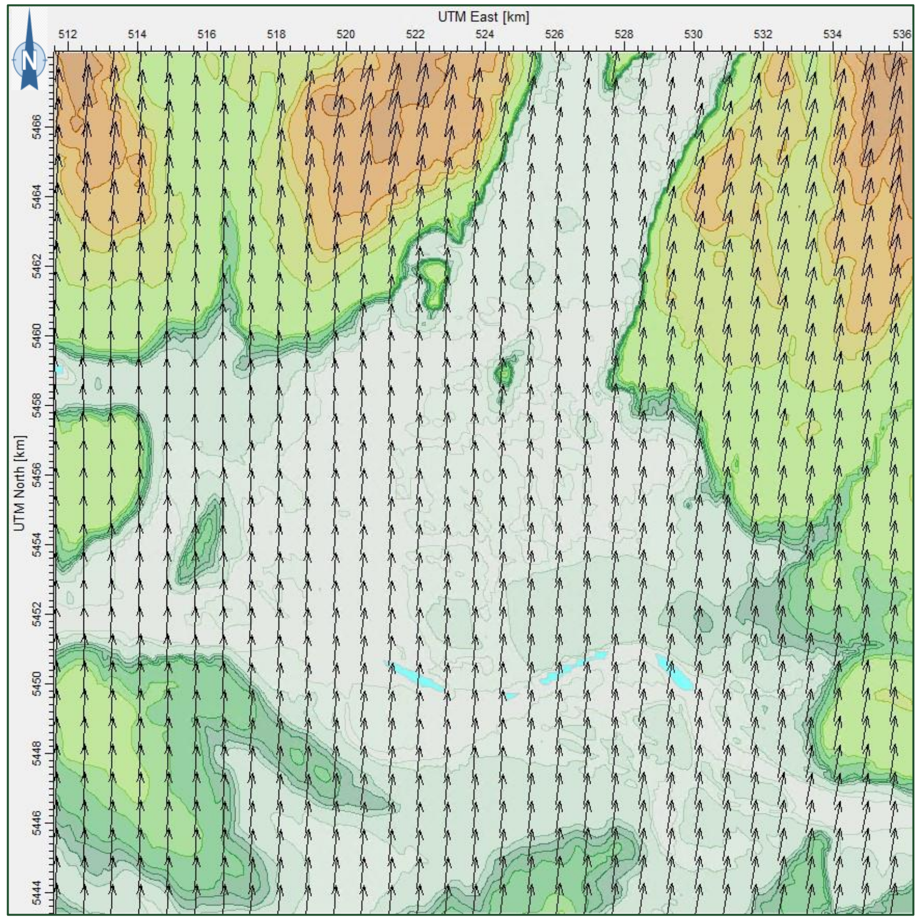





**Unstable**

**July 20th, 2012 at 12:00 pm**

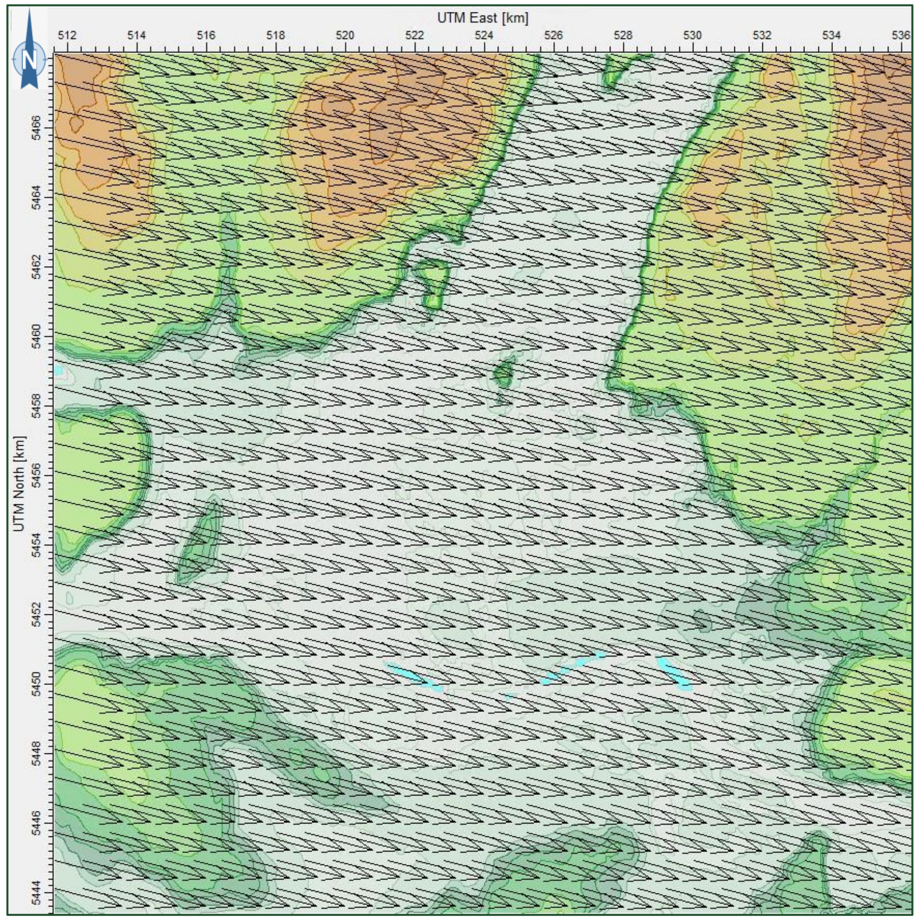
Arrow lengths show relative wind speed from 8 to 9.9 m/s




**Neutral**

**March 18th, 2012 at 10:00 am**

Arrow lengths show relative wind speed from 7.5 to 14.7 m/s




**Stable**

**January 13th, 2012 at 12:00 am**

Arrow lengths show relative wind speed from 18.4 to 27.1 m/s

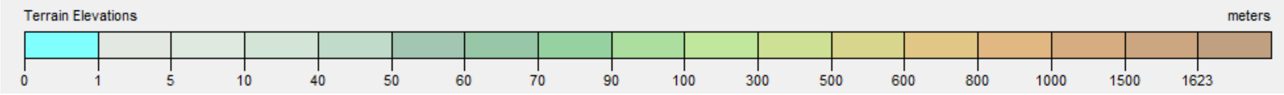



**Figure C-21: CALMET predicted wind fields at 3500 m above ground level (upper layer) overlaid on top of the terrain elevation data during unstable, neutral, and stable atmospheric conditions**

## C.6 Precipitation

As mentioned, based on Metro Vancouver guidance, precipitation data from a single station was used for the entire domain: Pitt Meadows (T20) station.

CALMET-derived precipitation patterns and the observed precipitation from T20 (Pitt Meadows) station (as CALMET Input for Entire Domain) and T30 (Maple Ridge) for the same period are compared in **Figure C-22**. The greatest average monthly precipitation occurred in October and the lowest amount of precipitation occurred in August and September. The predicted values appear representative of precipitation in the Metro Vancouver area.

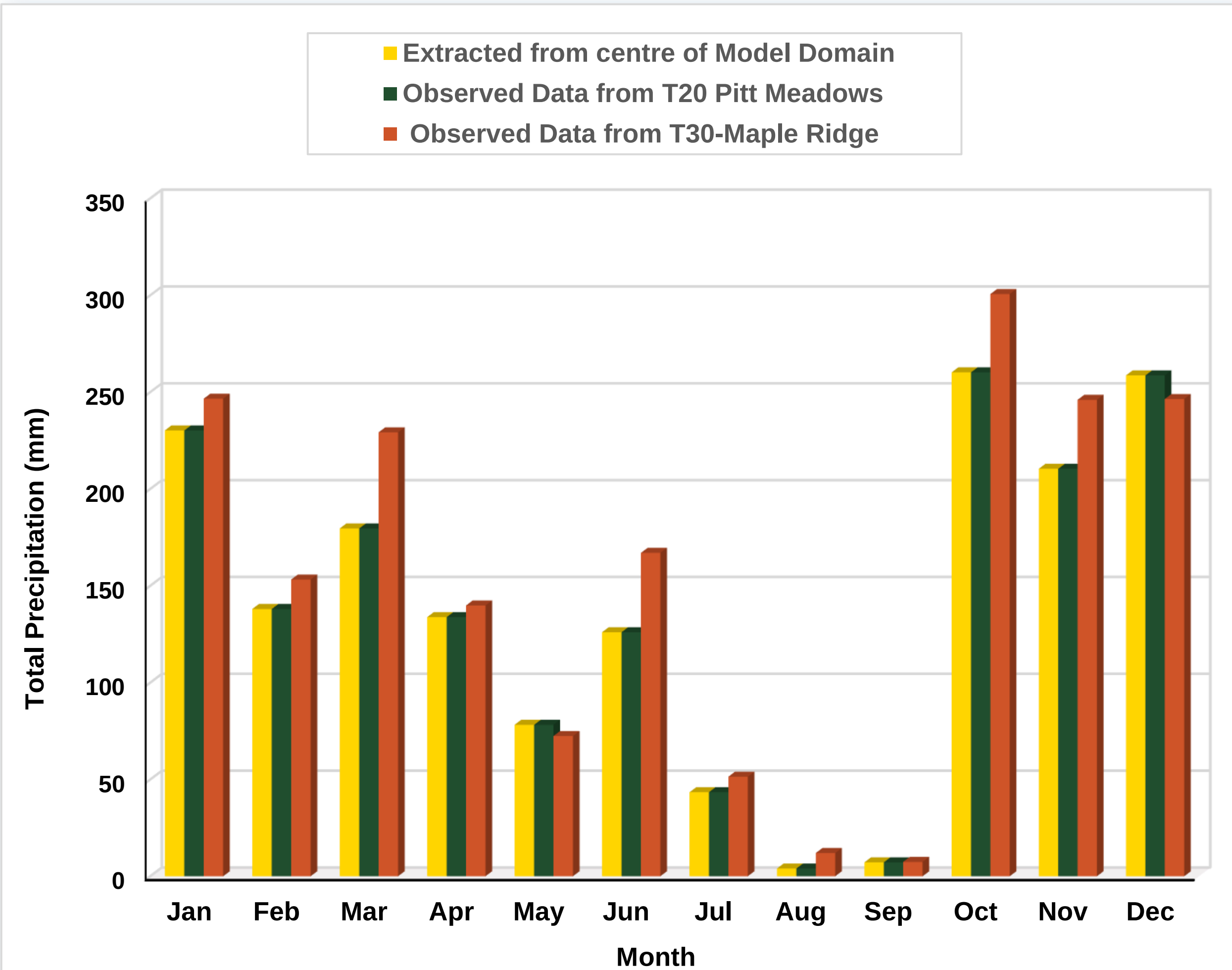



**Figure C-22: Average monthly distribution of CALMET-derived and station observed precipitation**