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Air Quality and Greenhouse Gas Technical Report for the Trans Mountain Pipeline ULC Trans Mountain Expansion Project

Final Report

REP-NEB-TERA-00003

RWDI # 1202006
December, 2013

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EXECUTIVE SUMMARY

This air quality assessment addresses emissions of air contaminants and greenhouse gases from Trans Mountain assets including pipelines, pump stations and storage terminals, both during construction and operations. Emissions were estimated and predictive dispersion modelling was completed for operational emissions for three scenarios, namely, existing, application (Project) and cumulative. Several chemicals were modelled and these values were compared to applicable ambient air quality objectives. Although not explicitly part of the terrestrial assets, for technical completeness in the Westridge/Burnaby study area, emissions from tankers at berth, both fugitives and combustion related, were included in this assessment for combined effects.

The objectives of the air quality assessment were to:

- identify the assessment indicators and measurement endpoints for air quality and greenhouse gas (GHG);
- establish the spatial boundaries for air quality and GHG indicators, comprising the geographic bounds within which potential air quality effects and GHG emissions are predicted and assessed;
- characterize existing (baseline) conditions to gain an understanding of existing air quality along the pipeline corridor and to provide context for the predicted air quality effects;
- characterize existing GHG emissions to provide context to estimate the Project contribution;
- predict residual effects of the Project on air quality and GHG emissions;
- predict cumulative effects of the Project on air quality in addition to baseline conditions and other reasonably foreseeable developments; and,
- provide mitigation recommendations for minimizing the air quality effects from the Project.

This report describes the methods of the air quality and GHG assessment, and provides general air quality mitigation recommendations for the construction and operation phases of the Project. This air quality technical report supports the ESA, and was completed in accordance with the *NEB Filing Manual* (2013). Requirements under the *Canadian Environmental Assessment Act* (CEAA) (2012) have also been considered. The air quality assessment was conducted as per the Alberta Environment and Sustainable Resource Development (AESRD) *Air Quality Model Guideline* (2013a) and the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (British Columbia Ministry of Environment [BC MOE] 2008).

In addition to the dispersion modelling guidelines, ambient air quality criteria were developed by environmental and health authorities. These criteria are based on scientific studies that consider the influence of various air contaminants on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. These criteria were used to provide context for existing conditions and predicted changes to ambient concentrations of air contaminants due to the Project.

Consultation

Trans Mountain and its consultants have conducted a number of consultative activities to inform Aboriginal communities, landowners, government agencies, stakeholders and the general public about the approach to assessing potential environmental effects of the Project and to seek input throughout the Project planning process. This section summarizes consultation and engagement activities that have focused on identifying and assessing Project effects on air quality and GHG.

While Environment Canada is the lead reviewer for the air quality and GHG portion of the ESA, a number of other regulatory authorities are stakeholders and may provide comments on the ESA. These include BC MOE, Metro Vancouver, the Fraser Valley Regional District (FVRD) and Port Metro Vancouver (PMV). Consultation meetings were held with these regulatory authorities in November 2012.

Activities that occur during the construction and operations phases have the potential to affect air quality and GHG. Therefore, Project interactions with air quality and GHG during these phases were assessed.

The Project will result in the following air emissions:

- criteria air contaminants (CACs), a group of commonly found contaminants typically formed from combustion for which there are ambient air quality criteria, including particulate matter (PM), Carbon Monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2);
- volatile organic compounds (VOCs)[1], a group of organic compounds with sufficiently high vapour pressures under ambient conditions to evaporate from the liquid form of the compound and enter the surrounding air, and participate in atmospheric photochemical reactions;
- hydrogen sulphide (H_2S) and mercaptans; and,
- GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) as well as overall climate change.

The air quality and GHG assessment comprises three assessments:

- The assessment of existing conditions includes all projects in the region at the start of the Project. For the purpose of this assessment, existing conditions include current operations of the Trans Mountain Pipeline, all projects currently underway at the facilities, and all existing natural and anthropogenic (i.e., human-caused) sources;

[1] For the purposes of this assessment, total VOC is defined as total hydrocarbon, or total organic compound (TOC), minus methane and ethane, which have negligible photochemical reactivity.

- The Project effects assessment includes all proposed design changes associated with the Trans Mountain Expansion Project assets and reflects the effects of the Project alone; and,
- The cumulative effects assessment includes existing conditions, the Project and all reasonably foreseeable projects.

Meteorological conditions along the pipeline corridor are described based on climate normal data from Environment Canada meteorological stations. Climate normals are compiled at the completion of each decade and represent average climatic conditions over the last 30 years of meteorological data.

Ambient air quality data for CACs, BTEX, TRS and ozone were collected from the Clean Air Strategic Alliance, BC MOE, Metro Vancouver and Environment Canada's National Air Pollution Surveillance Program. The pipeline corridor was divided into 11 areas for the purpose of characterizing ambient concentrations along the corridor and a number of stations were selected to represent each area. .

Emissions

National, provincial and local air emission inventories were reviewed to establish existing emissions of CACs and VOCs in the Air Quality LSAs and RSAs. An emission inventory is an account of total air emissions from all pollution sources within a defined area. Emission inventories typically separate total air emissions into three categories: point, area and mobile. Point sources represent industrial facilities that operate under air discharge permits. Area sources represent smaller, more broadly distributed light industrial, commercial, institutional, residential and naturally occurring sources that do not require air discharge permits. Mobile sources include on-road vehicles, non-road equipment, railways, aircraft and marine vessels.

Emissions from pipeline construction activities were estimated where information was available. All pipeline construction emissions will be intermittent and limited in duration. Since the construction schedule is subject to change, construction related emissions were not estimated on an annual basis. Instead, these emissions are estimated at overall totals. Construction related emissions are mainly caused by operation of construction equipment. Burning of brush will also result in CAC and VOC emissions, but these emission happen sporadically and are not estimated here.

Emissions of CACs and TOCs associated with the Project operation phase were estimated for the following equipment or activity:

- diesel generators and fire water pumps;
- line heaters;
- storage tanks;
- loading of marine vessels at Westridge Marine Terminal; and,

- pump stations.

Dispersion Modelling

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the Air Quality RSAs due to existing and projected future emissions from the Trans Mountain terminals. CALMET is a meteorological model that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport within CALPUFF. CALPUFF is a multi-layer, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition.

The CALMET/CALPUFF modelling approach, and corresponding assumptions and methodology were summarized in a detailed model plan for the four storage terminals in BC. This model plan was reviewed and updated based on input from Metro Vancouver and the BC MOE and approved in October, 2013.

Existing Conditions

Edmonton Terminal

The predicted 9th highest 1-hour benzene concentration exceeds the AAAQO near the Suncor facility (NPRI ID 6566). Concentrations of 1-hour benzene, including background, are predicted to exceed the objective less than 1% of the time. The ambient 1-hour benzene background is 12.9 µg/m^3, almost half of the AAAQO. Approximately 74% of the predicted concentrations without background are contributed from Suncor Edmonton Terminal. In comparison to Suncor's contribution, KMC sources contributed about 2% of the concentration prior to background

The maximum predicted annual benzene concentration exceeds the AAAQO only when ambient background is included. The ambient background is 1.3 µg/m^3, almost half of the AAAQO. Exceedances of annual benzene, including background, are predicted to occur in each of the five years modelled. High concentrations were also found to be near other industrial sources modelled. The nearby Suncor facility contributes approximately 84% of the predicted annual benzene concentrations. By comparison, KMC sources contributed less than 0.1% of the concentration prior to background.

The predicted 9th highest 1-hour xylenes concentration, including background, is less than 60% of the AAAQO.

The maximum predicted 24-hour xylenes concentration exceeds the AAAQO near the Shell Sherwood Terminal (NPRI ID 6660). Concentrations of 24-hour xylenes, including background, are predicted to exceed the objective less than 1% of the time in a very small area near the Shell facility The area of exceedance was predicted at one receptor in the Edmonton RSA, about 2 km from Edmonton Terminal. Approximately 87% of the maximum predicted concentration without background is contributed from Shell Sherwood Terminal. By comparison, KMC sources contributed less than 0.1% of the concentration.

The predicted 9th highest 1-hour H_2S concentrations with and without background are under the AAAQO.

The maximum predicted 24-hour H_2S concentrations with and without background both exceed the AAAQO. The ambient background is 1.4 µg/m³, over a third of the objective. Concentrations of 24-hour H_2S, including background, are predicted to exceed the objective 2% of the time. Approximately 95% of the maximum predicted concentration without background is contributed from the Suncor Refinery. By comparison, KMC sources contributed less than 0.1% of the concentration prior to background.

All predicted concentrations for ethylbenzene, toluene and total mercaptans are well below their respective AAAQO.

Kamloops and Sumas Terminals

No exceedances were predicted to occur.

Burnaby and Westridge Marine Terminals

The maximum predicted 24-hour $PM_{2.5}$ concentrations with and without background both exceed the Metro Vancouver objective. The ambient background is 12.5 µg/m³, half of the Metro Vancouver objective. Concentrations of 24-hour $PM_{2.5}$, with background, occur up to 10% of the time. The largest contributor to predicted $PM_{2.5}$ concentrations is the existing VCU at Westridge Marine Terminal, from which all soot was conservatively assumed to be $PM_{2.5}$. The maximum predicted annual $PM_{2.5}$ concentration with background was approximately half of the Metro Vancouver objective.

The maximum predicted 1-hour NO_2 concentrations with and without NO_X background exceed the Metro Vancouver objective. Concentrations of 1-hour NO_2, with NO_X background, were predicted to exceed the objective less than 1% of the time. All exceedances are in small areas near the Chevron Refinery, and over water, where there are no residences. The maximum predicted 24-hour and annual NO_2 concentrations were less than half of the relevant objectives.

Application Case

With a few exceptions, the predicted concentrations for the terminals in the Application Case are similar to the existing conditions. All Project related concentrations were less than their applicable ambient air quality objectives.

Cumulative Case

The results from the Cumulative case are generally the same as the Application Case except for some marine traffic related emissions at Westridge Marine Terminal that are expected to grow up to year 2030.

Pump Stations

Screening modelling was conducted to provide a first-order estimate of existing air quality effects from the pump stations along the proposed pipeline corridor: Gainford, Wolf, Edson, Hinton, Rearguard, Blue River, Blackpool, Black Pines, Kingsvale and Sumas. A screening model assessment was conducted using the US EPA AERSCREEN model to predict maximum short-term (1-hour) concentrations based on the estimated fugitive hydrocarbon emission rates for the three representative pump stations. Edson, Gainford and Wolf pump stations were selected to represent large, medium and small pump stations in terms of emission rates, respectively. The ambient air quality objectives selected for comparison represent the most stringent objectives, taken from the National Ambient Air Quality Objectives and provincial objectives in Alberta and British Columbia. Maximum predicted concentrations are well below the corresponding objectives (less than 1% in all cases except for benzene, which is approximately 2.7% of the 30 $\mu g/m^3$ objective).

Effect of Project on Climate Change

The effect of Project activities on overall climate change over its lifetime of 50 years was assessed. As reported by The National Research Council (NRC 2011), an approximately linear global warming occurs per cumulative emissions ranging from roughly 0.27°C to 0.68°C per 1,000,000 Mt CO_2e. Also, a best representative estimate of 0.47°C per 1,000,000 Mt CO_2e of cumulative GHG emissions is reported. Assuming that the operation-related emissions will not change dramatically over the lifetime of the Project, total estimated Project emissions, including construction emissions and operation emissions over a 50-year period, will add up to 55.1 Mt CO_2e, which will result in 2.6×10^{-5} °C increase in Earth's global temperature.

CONSULTING ENGINEERS & SCIENTISTS

TABLE OF CONTENTS

Tables

Figures

Figures

Base Case

<u>Application Case</u>

Appendices

Acronyms

$\mu g/m^3$	microgram per cubic metre
AAAQO	Alberta Ambient Air Quality Objectives
AAQC	Ambient Air Quality Criteria
AAQMG	Alberta Air Quality Model Guideline
AESRD	Alberta Environment and Sustainable Resource Development
ATK	Aboriginal Traditional Knowledge
AIHA	American Industrial Hygiene Association
AAQC	Ambient Air Quality Criteria
BC MOE	British Columbia Ministry of Environment
BC	British Columbia
bpd	barrels per day
BTEX	benzene, toluene, ethylene and xylene
CAAQS	Canadian Ambient Air Quality Standard
CAC	criteria air contaminant
CASA	Clean Air Strategic Alliance
CEAA	Canadian Environmental Assessment Act
CH_4	methane
CO	Carbon Monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
COPC	contaminant of potential concern
EC	Environment Canada
EPP	Environmental Protection Plan
ESA	Environmental and Socio-Economic Assessment

Acronyms

ft	feet
FVRD	Fraser Valley Regional District
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
KMC	Kinder Morgan Canada
GHG	greenhouse gas
H_2S	hydrogen sulphide
LSA	Local Study Area
m	metre
m^3/h	cubic metre per hour
MV	Metro Vancouver
OMOE	Ontario Ministry of Environment
N_2O	nitrous oxide
NAPS	National Air Pollution Surveillance
NEB	National Energy Board
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NPRI	National Pollutant Release Inventory
NRC	National Research Council
OMOE	Ontario Ministry of Environment
PFC	perfluorocarbon
PM	particulate matter
PM_{10}	particulate matter less than 10 µm
$PM_{2.5}$	particulate matter less than 2.5 µm

Acronyms

PMV	Port Metro Vancouver
ppb	parts per billion
Project	Trans Mountain Expansion Project
RSA	Regional Study Area
SGER	Specified Gas Emitters Regulations
SF_6	sulfur hexafluoride
SO_2	sulphur dioxide
SO_X	sulphur oxides
TEK	Traditional Ecological Knowledge
TMEP	Trans Mountain Expansion Project
TOC	Total Organic Carbon equals Total Hydrocarbons (THC)
Trans Mountain	Trans Mountain Pipeline ULC
TRS	total reduced sulphur
TSP	total suspended particulate
TVAU	Tank Vapour Activation Units
US Gal	United States gallon
VCU	Vapor Combustion Unit
VOC	Volatile Organic Compound
VRI	Vegetation Resources Inventory
VRU	Vapor Recovery Unit
WHO	World Health Organization

1. INTRODUCTION

1.1. Project Overview

Trans Mountain Pipeline ULC (Trans Mountain) is a Canadian corporation with its head office located in Calgary, Alberta. Trans Mountain is a general partner of Trans Mountain Pipeline L.P., which is operated by Kinder Morgan Canada Inc. (KMC), and is fully owned by Kinder Morgan Energy Partners, L.P. Trans Mountain is the holder of the National Energy Board (NEB) certificates for the Trans Mountain pipeline system (TMPL system).

The TMPL system commenced operations 60 years ago and now transports a range of crude oil and petroleum products from Western Canada to locations in central and southwestern British Columbia (BC), Washington State and offshore. The TMPL system currently supplies much of the crude oil and refined products used in BC. The TMPL system is operated and maintained by staff located at Trans Mountain's regional and local offices in Alberta (Edmonton, Edson, and Jasper) and BC (Clearwater, Kamloops, Hope, Abbotsford, and Burnaby).

The TMPL system has an operating capacity of approximately 47,690 m^3/d (300,000 bbl/d) using 23 active pump stations and 40 petroleum storage tanks. The expansion will increase the capacity to 141,500 m^3/d (890,000 bbl/d).

The proposed expansion will comprise the following:

- Pipeline segments that complete a twinning (or "looping") of the pipeline in Alberta and BC with about 987 km of new buried pipeline.
- New and modified facilities, including pump stations and tanks.
- Three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

The expansion has been developed in response to requests for service from Western Canadian oil producers and West Coast refiners for increased pipeline capacity in support of growing oil production and access to growing West Coast and offshore markets. NEB decision RH-001-2012 reinforces market support for the expansion and provides Trans Mountain the necessary economic conditions to proceed with design, consultation, and regulatory applications.

Application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The NEB will undertake a detailed review and hold a Public Hearing to determine if it is in the public interest to recommend a Certificate of Public Convenience and Necessity (CPCN) for construction and operation of the Project. Subject to the outcome of the NEB Hearing process, Trans Mountain plans to begin construction in 2016 and go into service in 2017.

Trans Mountain has embarked on an extensive program to engage Aboriginal communities and to consult with landowners, government agencies (e.g., regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

The scope of the Project will involve:

- using existing active 610 mm (NPS 24) and 762 mm (NPS 30) OD buried pipeline segments;
- constructing three new 914 mm (NPS 36) OD buried pipeline segments totalling approximately 987 km:
    - Edmonton to Hinton – 339.4 km
    - Hargreaves to Darfield – 279.4 km
    - Black Pines to Burnaby – 367.9 km;
- reactivating two 610 mm (NPS 24) OD buried pipeline segments that have been maintained in a deactivated state:
    - Hinton to Hargreaves – 150 km
    - Darfield to Black Pines – 43 km;
- constructing two, 3.6 km long 762 mm (NPS 30) OD buried delivery lines from Burnaby Terminal to Westridge Marine Terminal (the Westridge delivery lines);
- installing 23 new sending or receiving traps (16 on the Edmonton-Burnaby mainlines), for in-line inspection tools, at nine existing sites and one new site;
- adding 35 new pumping units at 12 locations (i.e., 11 existing and one new pump station site);
- reactivating the existing Niton Pump Station that has been maintained in a deactivated state;
- constructing 20 new tanks located at the Edmonton (5), Sumas (1) and Burnaby (14) Terminals, preceded by demolition of 2 existing tanks at Edmonton (1) and Burnaby (1), for a net total of 18 tanks to be added to the system; and,
- constructing one new dock complex, with a total of three Aframax-capable berths, as well as a utility dock (for tugs, boom deployment vessels, and emergency response vessels and equipment) at Westridge Marine Terminal, followed by the deactivation and demolition of the existing berth.

This air quality assessment addresses emissions of air contaminants and greenhouse gases from Trans Mountain assets including pipelines, pump stations and storage terminals, both during construction and operations. Emissions were estimated and predictive dispersion modelling was completed for operational emissions for three scenarios, namely, existing, application (Project) and cumulative. Several chemicals were modelled and these values were compared to applicable ambient air quality objectives. Although not explicitly part of the terrestrial assets, for technical completeness in the Westridge/Burnaby study area, emissions from tankers at berth, both fugitives and combustion related, were included in this assessment for combined effects.

1.2. Objectives

The objectives of the air quality assessment were to:

- identify the assessment indicators and measurement endpoints for air quality and greenhouse gas (GHG);
- establish the spatial boundaries for air quality and GHG indicators, comprising the geographic bounds within which potential air quality effects and GHG emissions are predicted and assessed;
- characterize existing (baseline) conditions to gain an understanding of existing air quality along the pipeline corridor and to provide context for the predicted air quality effects;
- characterize existing GHG emissions to provide context to estimate the Project contribution;
- predict residual effects of the Project on air quality and GHG emissions;
- predict cumulative effects of the Project on air quality in addition to baseline conditions and other reasonably foreseeable developments; and,
- provide mitigation recommendations for minimizing the air quality effects from the Project.

This report describes the methods of the air quality and GHG assessment, and provides general air quality mitigation recommendations for the construction and operation phases of the Project. This report does not identify residual or cumulative environmental or socio-economic effects nor provide conclusions regarding significance. Volume 5A provides the potential residual and cumulative effects of the pipeline and facilities component of the Project on air quality and GHG emissions, including an evaluation of significance.

1.3. Regulatory Standards

This air quality technical report supports the ESA, and was completed in accordance with the *NEB Filing Manual* (2013). Requirements under the *Canadian Environmental Assessment Act* (CEAA) (2012) have also been considered. The air quality assessment was conducted as per the Alberta Environment and Sustainable Resource Development (AESRD) *Air Quality Model Guideline* (2013a) and the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (British Columbia Ministry of Environment [BC MOE] 2008).

In addition to the dispersion modelling guidelines, ambient air quality criteria are developed by environmental and health authorities. These criteria are based on scientific studies that consider the influence of various air contaminants on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. These criteria were used to provide context for existing conditions and predicted changes to ambient concentrations of air contaminants due to the Project.

There are no ambient or emission criteria for GHGs. However, there are federal and provincial reporting requirements. All facilities emitting more than 50,000 tonnes of GHGs are required to submit a report under Environment Canada's Greenhouse Gas Emissions Reporting Program (Environment Canada 2013a). Facilities in Alberta emitting more than 50,000 tonnes of GHGs are also required to submit reports under AESRD's Specified Gas Reporting Regulation (AESRD 2004). British Columbia's (BC's) Reporting Regulation under the *Greenhouse Gas Reduction (Cap and Trade) Act* sets out the requirements for reporting GHG emissions from BC facilities emitting 10,000 tonnes of GHGs (BC MOE 2013b). Those facilities with emissions exceeding 25,000 tonnes are required to have emissions reports verified by a third party.

Aboriginal Traditional Knowledge (ATK) is typically documented as a means to "preserve" historical and familial connections, territorial occupation, land and resource use, and temporal execution strategies. ATK is considered within the assessment of air quality as per guidance from the *NEB Filing Manual* (2013) and Section 19(3) of the *Canadian Environmental Assessment Act, (2012)*.

1.3.1. National Air Quality Criteria

The federal government has established national ambient air quality objectives (CEPA 1999) based on recommendations from a National Advisory Committee and Working Group on Air Quality Objectives and Guidelines. These objectives followed a three-tiered approach as follows:

- the national maximum desirable objective is a long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted areas, and for continuing development of control technology;
- the national maximum acceptable objective is intended to provide adequate protection against effects on soil, water, vegetation, materials, visibility, personal comfort and well-being; and,
- the national maximum tolerable objective denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general public.

In December 2012, the federal government issued the Canadian Ambient Air Quality Standards (CAAQS) for particulate matter less than 2.5 µm ($PM_{2.5}$) and ozone, which are intended to replace the existing Canada-wide standards for $PM_{2.5}$ and ozone, as well as the existing national ambient air quality objectives for ozone (Government of Canada 2013). The CAAQS are developed to drive continuous air quality improvement in Canada, and provides a set of metrics to be effective in 2015 and a second set of metrics to be effective in 2020. A review of the 2020 metrics is expected to be conducted in 2015.

Table 1.1 provides the national ambient air quality objectives and CAAQS for the selected assessment indicators (see Section 3.2) where available.

1.3.2. Provincial Standards in Alberta

Alberta ambient air quality objectives (AAAQO), developed by AESRD, are shown in Table 1.2. With a few exceptions like CO and $PM_{2.5}$, Alberta air quality objectives tend to be equal to or more stringent than the national ambient air quality objectives or CAAQS. Where there are no national air quality objectives or CAAQS, AESRD has adopted objectives from other jurisdictions.

1.3.3. Provincial Standards in British Columbia

British Columbia ambient air quality objectives are divided into three categories designated as Levels A, B, and C with Level A being the most stringent. These levels correspond roughly to the national levels as defined in Section 1.3.1. In BC, Metro Vancouver establishes their own ambient air quality objectives for their jurisdiction.

British Columbia and Metro Vancouver ambient air quality objectives are summarized in Table 1.3 (BC MOE 2013a, Metro Vancouver 2011). Metro Vancouver is currently considering adoption of the World Health Organization (WHO) guideline for 24-hour sulphur dioxide (SO_2).

Table 1.1: National Ambient Air Quality Objectives and Canadian Ambient Air Quality Standards (in µg/m³)

Contaminant	Averaging Period	Objectives/Standards			
		National Maximum Desirable Objective	National Maximum Acceptable Objective	National Maximum Tolerable Objective	Canadian Ambient Air Quality Standard
Total Suspended Particulate (TSP)	24-Hour	--	120	400	--
	Annual	60	70	--	
Particulate Matter less than 2.5 µm ($PM_{2.5}$)	24-Hour	--			27 to 28[(a)]
	Annual	--			8.8 to 10[(b)]
Carbon Monoxide	1-Hour	15,000	35,000	--	--
	8-Hour	6,000	15,000	20,000	
Nitrogen Dioxide	1-Hour	--	400	1,000	--
	24-Hour	--	200	300	
	Annual	60	100	--	
Sulphur Dioxide	1-Hour	450	900	--	--
	24-Hour	150	300	800	
	Annual	30	60	--	
Ozone	1-Hour	100 (51 ppb)	160 (82 ppb)	300 (153 ppb)	--
	8-Hour	--			62 to 63 ppb[(c)]
	24-Hour	30 (15 ppb)	50 (25 ppb)	--	--
	Annual	--	30 (15 ppb)	--	--
Hydrogen Sulphide	1-Hour	1	15	--	--
	24-Hour	--	5	--	

Source: CEPA 1999, Government of Canada 2013

Notes:
(a) CAAQS is 28 µg/m³ in 2015 and 27 µg/m³ in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years
(b) CAAQS is 10.0 µ/m³ for 2015 and 8.8 µg/m³ for 2020; compliance based on the average over three consecutive years
(c) CAAQS is 63 ppb in 2015 and 62 ppb in 2020; compliance based on 4th highest annual 8-hour daily maximum value, averaged over three consecutive years

Table 1.2: Alberta Ambient Air Quality Objectives (AAAQO) (in µg/m³)

Contaminant	Averaging Period	Objective
Total Suspended Particulate (TSP)	24-Hour	100
	Annual	60
Particulate Matter less than 2.5 µm ($PM_{2.5}$)	1-Hour[(a)]	80
	24-Hour	30
Carbon Monoxide	1-Hour	15,000
	8-Hour	6,000
Nitrogen Dioxide	1-Hour	300
	Annual	45
Sulphur Dioxide	1-Hour	450
	24-Hour	125
	30-Day	30
	Annual	20
Ozone	1-Hour	82 ppb[(b)]
Benzene	1-Hour	30
	Annual	3
Ethylbenzene	1-Hour	2,000
Toluene	1-Hour	1,880
	24-Hour	400
Xylenes	1-Hour	2,300
	24-Hour	700
Hydrogen Sulphide	1-Hour	14
	24-Hour	4

Source: AESRD 2013b

Notes: [(a)] An Alberta ambient air quality guideline, to be used for monitoring and reporting of the Ambient Air Quality Index

[(b)] Compliance based on the 1-hour daily maximum value

Table 1.3: British Columbia and Metro Vancouver Ambient Air Quality Objectives (in µg/m³)

Contaminant	Averaging Period	Objectives/Standards			
		BC Level A	BC Level B	BC Level C	Metro Vancouver
Total Suspended Particulate (TSP)	24-Hour	120[(a)]	200	260	--
	Annual	60	70	75	
Particulate Matter less than 10 µm (PM_{10})	24-Hour	50			50
	Annual	--			20
Particulate Matter less than 2.5 µm ($PM_{2.5}$)	24-Hour	25[(b)]			25
	Annual	8[(c)]			8[(c)]
Carbon Monoxide	1-Hour	14,300	28,000	35,000	30,000
	8-Hour	5500	11,000	14,300	10,000
Nitrogen Dioxide	1-Hour	--			200
	Annual	--			40
Sulphur Dioxide	1-Hour	450	900	900	450
	24-Hour	160	260	360	20 to 125[(d)]
	Annual	25	50	80	30
Ozone	1-Hour	--			82 ppb
	8-Hour	--			65 ppb
Total Reduced Sulphur	1-Hour	7	28	--	--
	24-Hour	3	6	--	

Source: BC MOE 2013a, Metro Vancouver 2011

Notes: (a) Termed as the maximum desirable level as per National Ambient Air Quality Objectives
(b) Compliance based on 98th percentile value
(c) There is also a planning goal of 6 µg/m³
(d) Current objective is 125 µg/m³; there is intention to change objective to 20 µg/m³ to match the WHO guidelines (WHO 2006)

2. CONSULTATION AND ENGAGEMENT

Trans Mountain and its consultants have conducted a number of engagement activities to inform Aboriginal communities, stakeholders, the public and regulatory authorities about the approach to assessing potential environmental and socio-economic effects of the Project, and to seek input throughout the Project planning process.

2.1. Public Consultation and Aboriginal Engagement

Trans Mountain has implemented and continues to conduct open, extensive and thorough public consultation, Aboriginal engagement and landowner relations programs. These programs were designed to reflect the unique nature of the Project as well as the diverse and varied communities along the proposed pipeline and marine corridors. These programs were based on Aboriginal communities, landowner and stakeholder groups' interests and inputs, knowledge levels, time and preferred methods of engagement. In order to build relationships for the long-term, these programs were based on the principles of accountability, communication, local focus, mutual benefit, relationship building, respect, responsiveness, shared process, sustainability, timeliness, and transparency.

Feedback related to marine transportation/the Project that was raised through various Aboriginal engagement and public consultation activities including public open houses, ESA Workshops, Community Workshops and one-on-one meetings, is summarized below and was considered in the development of this technical report, and the assessment of air quality and greenhouse gas emissions in Volume 5A:

- Increased emissions of CACs, VOCs and greenhouse gases as a result of the expansion facilities;
- Potential for odourous emissions as a result of the expansion facilities;
- Development of ozone and secondary particulate matter as a result of the expansion facilities; and,
- Potential effects of the project on climate change.

In addition, concerns related to the potential effects of spills on air quality and greenhouse gas emissions were also raised and detailed information on pipeline spills is provided in Volume 7A.

The full description of the public consultation, Aboriginal engagement and landowner relations programs are located in Volumes 3A, 3B and 3C, respectively. Section 3.0 of Volume 5A summarizes the consultation and engagement activities that have focused on identifying and assessing potential issues and concerns related to air quality and greenhouse gas emissions which may be affected by the construction and operation of the Project. Information collected through the public consultation, Aboriginal engagement and landowner relations programs for the Project was considered in the development of this technical report, and the assessment of air quality and greenhouse gas emissions in Volume 5A.

While Environment Canada is the lead reviewer for the air quality and GHG portion of the ESA, a number of other regulatory authorities are stakeholders and may provide comments on the ESA. These include BC MOE, Metro Vancouver, the Fraser Valley Regional District (FVRD) and Port Metro Vancouver (PMV). Consultation meetings were held with these regulatory authorities in November, 2012. Table 2.1 summarizes the consultation activities for air quality and GHG.

Table 2.1: Summary of Consultation Activities Related to Air Quality and Greenhouse Gas Assessments

Stakeholder Group / Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues / Concerns	Commitments / Follow-up Actions / Comments
FEDERAL CONSULTATION						
Environment Canada	Roxanne Vingarzan, Head (Air Quality Science Unit)	Meeting	November 21, 2012	Project introduction. Air quality and GHG assessment approach.	Requested addition of air quality monitoring stations for inclusion in baseline assessment. Requested model evaluation. Recommended assessment for secondary ozone, particulate matter and visibility.	Air quality monitoring stations added. Model evaluation added. Assessment for secondary ozone, particulate matter and visibility added.
PROVINCIAL/LOCAL CONSULTATION – BRITISH COLUMBIA						
BC Ministry of Environment and Metro Vancouver	Ali Ergudenler, Senior Engineer (Air Quality Policy and Management Division)	Meeting	November 20, 2012	Project introduction. Air quality and GHG assessment approach.	Requested assessment for odour as per Odour Management Policy currently being drafted. Requested discussion of Project effect on overall climate change. Recommended assessment for secondary particulate matter and ozone.	Assessments for odour, secondary particulate matter and ozone added. Discussion of Project effect on overall climate change added.
Fraser Valley Regional District	Alison Stewart, Senior Planner (Strategic Planning and Initiatives)	Meeting	November 20, 2012	Project introduction. Air quality and GHG assessment approach.	Requested assessment for secondary ozone and particulate matter.	Assessment for secondary particulate matter and ozone added.
Port Metro Vancouver	Gary Olszewski, Environmental Specialist	Meeting	November 21, 2012	Air quality and GHG assessment approach.	Requested Project assessment approach to be aligned with PMV general approach.	The overall assessment approach was discussed and it was noted that it is aligned with PMV general approach.

A series of ESA Technical Workshops were held in March, 2013, (Volume 3). The primary air quality concerns expressed during these workshops were related to potential odours from the tank farms and fugitive dust during the construction phase. It was expressed that Trans Mountain should internalize the concept of “continuous improvement”, in alignment with current goals and commitments by Metro Vancouver and the FVRD. It was further suggested that black carbon, associated with the burning of timber during Project construction, be added as an additional assessment indicator.

3. METHODS

3.1. Project Interactions and Identification of Potential Effects

Activities that occur during the construction and operations phases have the potential to affect air quality and GHG; therefore, Project interactions with air quality and GHG during these phases were assessed.

The Project will result in the following air emissions:

- criteria air contaminants (CACs), a group of commonly found contaminants typically formed from combustion for which there are ambient air quality criteria, including particulate matter (PM), Carbon Monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2);
- volatile organic compounds (VOCs)[2], a group of organic compounds with sufficiently high vapour pressures under ambient conditions to evaporate from the liquid form of the compound and enter the surrounding air, and participate in atmospheric photochemical reactions;
- hydrogen sulphide (H_2S) and mercaptans; and,
- GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) as well as overall climate change.

3.1.1. CAC, VOC and Reduced Sulphurs

Particulate matter (PM) is often defined in terms of size fractions. Particles less than approximately 40 µm in diameter typically remain suspended in the air for some time. Suspended particulate matter less than 10 µm in diameter is termed PM_{10}, and particulate matter less than 2.5 µm in diameter is termed $PM_{2.5}$. Exposure to particulate matter at elevated levels aggravates a number of respiratory illnesses and may even cause premature death in people with existing heart and lung disease. Smaller particles are generally thought to be of greater concern for human health, and therefore, objectives for total suspended particulate (TSP) are not often used as their effect is related to nuisance dust.

Carbon Monoxide is produced by incomplete combustion of fossil fuels. Short-term health effects related to CO exposure at elevated levels include headache, dizziness, light-headedness and fainting. Exposure

[2] For the purposes of this assessment, total VOC is defined as total hydrocarbon, or total organic compound (TOC), minus methane and ethane, which have negligible photochemical reactivity.

to high CO concentrations can decrease the ability of the blood to carry oxygen and can lead to respiratory failure and death.

Oxides of nitrogen (NO_X), comprised of nitric oxide (NO) and NO_2, are produced when fossil fuels are burned at high temperatures. In humans, NO_2 acts as an irritant at elevated levels affecting the mucous membranes of the eyes, nose, throat, and respiratory tract. Continued exposure to NO_2 can irritate the lungs and lower resistance to respiratory infection, especially for people with pre-existing asthma and bronchitis.

Sulphur oxides (SO_X) are produced mostly in the form of SO_2 by the combustion of fossil fuels containing sulphur. Sulphur dioxide is irritating to the lungs at elevated levels and is frequently described as smelling of burning sulphur.

A number of VOCs can adversely affect human health, wildlife and vegetation. Typical VOCs found in petroleum derivatives include benzene, toluene, ethylbenzene and xylenes, collectively known as BTEX. At elevated levels, benzene is a known carcinogen and has been linked to chromosomal damage and neural birth defects in mammals. Toluene, ethylbenzene and xylenes have harmful effects on the central nervous system at elevated levels.

Reduced sulphur compounds are a complex family of substances defined by the presence of sulphur in a reduced state and are generally characterized by strong odours at relatively low concentrations. A common reduced sulphur compound is H_2S, a foul smelling gas resembling rotten eggs that is a by-product of anaerobic decomposition. Hydrogen sulphide can be further oxidized to form (methyl) mercaptans which are a class of sulphur-containing VOCs that have strong odours resembling that of rotten garlic and are used as odourants to assist with the detection of natural gas. Odour nuisance is the primary concern but H_2S can also affect human health at higher concentrations. It can cause irritation to the nose, throat, eyes and lungs. At much higher concentrations, H_2S can cause respiratory paralysis and death. Individual reduced sulphur compounds are sometimes aggregated into what is known as total reduced sulphur (TRS), expressed in terms of H_2S.

3.1.2. Greenhouse Gases

Greenhouse gases are a group of gases that build up in concentration in the atmosphere and have the potential to contribute incrementally to climate change. Individual GHGs are typically aggregated into "CO_2 equivalents" (CO_2e), which represent an equivalent quantity of CO_2 that would cause the same global warming as the combined gases over a set reference period (typically one hundred years).

Carbon dioxide (CO_2), a naturally occurring, colourless, odourless, incombustible gas, is the most common component of GHG. Through the global carbon cycle, CO_2 is constantly released into the air and transferred back into the soil and water to keep a balanced atmospheric concentration by several processes. Although human-caused releases of CO_2 are relatively small (1/20) compared to the amounts that enter and leave the atmosphere due to the natural active flow of carbon, human activities now appear to be significantly affecting this natural balance as evident in the measurement of the steady increase of atmospheric CO_2 concentrations since preindustrial times across the globe (EC 2013e).

Methane (CH_4) is the simplest alkane and the second most prevalent greenhouse gas emitted from human activities. Like CO_2, methane is exchanged naturally between Earth's surface and the atmosphere. However, methane is lighter than air and is removed from the atmosphere primarily through chemical processes which finally produce water and carbon dioxide. A small amount of methane is also absorbed directly by soils. CH_4 is produced naturally, and by industrial processes (e.g., in fossil fuel extraction, coal mines, incomplete fossil fuel combustion and garbage decomposition in landfills). CH_4 contributed to about 13% of Canada's GHG emissions in 2011 (EC 2013e).

Nitrous oxide (N_2O) is a colourless, non-flammable, sweet-smelling gas that is heavier than air. N_2O is most commonly produced via the heating of ammonium nitrate (NH_4NO_3). It is also released naturally from oceans, by bacteria in soils, and from animal wastes. Other sources of N_2O emissions include the industrial production of nylon and nitric acid, combustion of fossil fuels and biomass, soil cultivation practices, and the use of commercial and organic fertilizers. N_2O contributed to about 7% of Canada's GHG emissions in 2011 (EC 2013e).

Climate change refers to changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the build-up of GHG, which trap heat and reflect it back to Earth's surface. This is usually measured as radiative forcing which is defined as the difference of radiant energy received by Earth and energy radiated back to space. From 1990 to 2012, radiative forcing by long-lived greenhouse gases increased by 32%, with CO_2 accounting for about 80% of this increase, as reported by the World Meteorological Organization (WMO 2013). It is now well known that atmospheric concentrations of GHGs have grown significantly since pre-industrial times. Since 1750, the concentration of atmospheric CO_2 has increased by 41%; of CH_4 by 160%; and of N_2O by 20%. These trends can be largely attributed to fossil fuel use (including energy supply, transportation, residential and commercial buildings and industrial use) and land-use change, including the permanent loss of forest cover (WMO 2013).

In general, as a result of climate change, temperatures and sea levels are expected to rise and the frequency of extreme weather events is expected to increase. In Canada, the effects of climate change may be felt in extreme weather events, the reduction of fresh water resources, increased risk and severity of forest fires and pest infestations, a reduction in arctic ice and an acceleration of glacial melting. Annual temperatures in Canada have been at or above normal since 1993, with a warming trend of 1.5°C over the last 64 years (EC 2013e).

3.1.3. Operational Emissions

During the operations phase, sources of CACs, VOCs and GHGs at the Edmonton, Kamloops, Sumas, Burnaby and Westridge Marine Terminals include regular testing of diesel generators and diesel fired water pumps as well as the operation of line heaters. The proposed additional storage tanks at the Edmonton, Sumas, and Burnaby Terminals could result in fugitive emissions of VOCs and GHGs through working and breathing losses. In addition, the loading of marine vessels at the Westridge Marine Terminal could result in fugitive emissions of VOCs and reduced sulphur compounds, and GHGs. The operation of the proposed pump stations could result in a small amount of fugitive VOC emissions due to tiny leaks.

Emissions associated with all Project operation activities were estimated. Since potential air quality effects from the pump stations are expected to be bounded by potential air quality effects from the Edmonton, Kamloops, Sumas, Burnaby, and Westridge Marine Terminals, dispersion modelling was focused on the terminals. Screening modelling was conducted to provide a first-order estimate of potential air quality effects from the pump stations.

In addition to these direct emissions from the Project, secondary pollutants will be formed from reactions between these primary pollutants in the atmosphere. In the presence of sunlight, precursors such as NO_X and VOCs undergo a complex sequence of reactions to form ozone (O_3), a strong oxidizer that can irritate the eyes, nose and throat and decrease athletic performance at high concentrations. Secondary PM can be formed from reactions between NO_X and SO_X. Primary and secondary PM can absorb and scatter sunlight, causing haze and obscuring visibility.

3.1.4. Construction Emissions

During the construction phase, right-of-way and facility clearing and other construction activities will result in fugitive dust emissions, while the operation of vehicles and equipment will result in emissions of CACs, VOCs and GHGs.

Emissions from Project activities during the construction phase were estimated where information was available. All Project construction emissions will be intermittent and limited in duration. Furthermore, Project related construction activities during this phase are difficult to define. For these reasons, dispersion modelling of the estimated emissions was not deemed valuable for the assessment of potential air quality effects from Project construction.

3.2. Assessment Indicators and Measurement Endpoints

Assessment indicators represent biophysical, social, or economic properties or variables that society considers to be important and are assessed to predict Project-related changes and to focus the effects assessment on key issues. One or more assessment indicators are selected and used as surrogates to describe the present and predicted future condition of an element (i.e. air quality and GHG). Societal views reflect published information such as management plans and engagement with regulators, public, Aboriginal, and other interested groups.

The assessment indicators selected for use in the assessment of the Project on air quality are as follows:

- primary emissions of CACs (PM, CO, NO_2, and SO_2) and VOCs (BTEX);
- secondary smog-related products (ozone and $PM_{2.5}$);

- H_2S and mercaptans (odour potential); and,
- fugitive emissions from pump stations.

The assessment indicators selected for use in the assessment of the Project on GHGs include emissions of CO_2, CH_4, and N_2O, as well as overall climate change.

The measurement endpoints for these indicators and the rationale for their selection are presented in Table 3.1 and Table 3.2. One or more measurement endpoints are identified for each indicator to allow quantitative or qualitative measurement of potential Project effects. The degree of change in these measurable parameters is used to characterize and evaluate the magnitude of Project-related environmental and socio-economic effects. A selection of the measurement endpoints may also be the focus of monitoring and follow-up programs, where applicable.

A number of other VOCs and other contaminants of potential concerns (COPCs) were also considered for the Screening Level Human Health Risk Assessment of Pipeline and Facilities (see Volume 5D).

Table 3.1: Assessment Indicators and Measurement Endpoints for Air Quality

Assessment Indicators	Measurement Endpoints	Rationale
Primary emissions of criteria air contaminants and volatile organic compounds	Emissions from Project construction and comparison to existing emissions Emissions from Project operation and comparison to existing emissions Predicted levels of ground-level concentrations and comparison to ambient air quality criteria	The selection of indicators and measurement endpoints considered NEB Filing Manual requirements, addressed concerns raised through Aboriginal and stakeholder engagement and are supported by government agencies (i.e., Environment Canada, BC MOE, Metro Vancouver, FVRD, PMV).
Secondary smog-related products	Predicted levels of ground-level concentrations and comparison to ambient air quality criteria	
Hydrogen sulphide and mercaptans	Emissions from Project construction and comparison to existing emissions Emissions from Project operation and comparison to existing emissions Predicted levels of ground-level concentrations and comparison to odour thresholds	
Fugitive emissions from pump stations	Predicted change in air quality	

Table 3.2: Assessment Indicators and Measurement Endpoints for GHG

Assessment Indicators	Measurement Endpoints	Rationale
Emissions of CO_2, CH_4 and N_2O	Emissions of CO_2e from Project construction and comparison to local, provincial and national totals Emissions of CO_2e from Project operation and comparison to local, provincial and national totals	The selection of indicators and measurement endpoints considered NEB *Filing Manual* requirements, addressed concerns raised through Aboriginal and stakeholder engagement and are supported by government agencies (i.e., Environment Canada, BC MOE, Metro Vancouver, FVRD, PMV).
Effect on overall climate change	Effects of CO_2e not emissions from Project-related marine vessel traffic or change in environmental parameters such as global average temperatures.	

3.3. Study Area Boundaries

3.3.1. Air Quality

A total of four study areas were used for the assessment of CACs and VOCs as shown in Figure 3.1 to Figure 3.4 for the pipeline and facilities component of the Project. The regional study areas (RSA) are 24 km by 24 km squares centered on each of the terminals, with the Burnaby and Westridge Marine Terminals combined into one study area due to their location less than 3 km apart. The local study areas (LSA) were specified as 12 km by 12 km surrounding the facility boundaries and represent the area within which Project air quality effects of CACs and VOCs are reasonably expected to occur.

The Air Quality LSA for the pipeline and facilities is based on the zone of influence where Project-related effects could be predicted or measured with a reasonable degree of accuracy or confidence. The LSA includes a 1 km wide band generally extending from the proposed pipeline corridor (i.e., the Footprint plus 500 m on both sides of the proposed corridor) or a 5 km radius of a facility (i.e., tank terminal). For modelling purposes, this radius extends to an LSA of approximate dimensions, 12 km by 12 km.

The Air Quality RSA is the area where the direct and indirect influence of other activities could overlap with the Project-specific effects from the pipeline and facilities and cause cumulative effects on the air quality indicators. The RSA was defined as an approximate 5 km wide band extending from the proposed pipeline corridor (i.e., the Footprint plus 2.5 km on both sides of the corridor) and 10 km radius of a facility (i.e., tank terminal). For modelling purposes, this radius extends to an RSA of approximate dimensions, 24 km by 24 km.

The spatial extent of the Air Quality RSAs was submitted as part of a detailed model plan which was reviewed and accepted by BC MOE and Metro Vancouver.

The spatial boundary for the assessment of secondary PM, ozone and visibility was defined as the Lower Fraser Valley (LFV) study area, as shown in Figure 3.5. The CMAQ modelling system used for the assessment of secondary PM, ozone and visibility was configured using a nested domain paradigm, in which a larger, parent domain is used to provide boundary conditions for a higher resolution inner domain (or "nest"). The LFV study area in Figure 3.5 represents the spatial boundary of the inner-most 4 km domain, in which all the Project emissions were modelled.

3.3.2. Greenhouse Gases

Greenhouse gas emissions have a global effect that cannot easily be measured on a local or regional scale. The spatial boundary for GHG is therefore beyond regional (i.e., international) and encompasses all sources of GHG emissions from the Project.

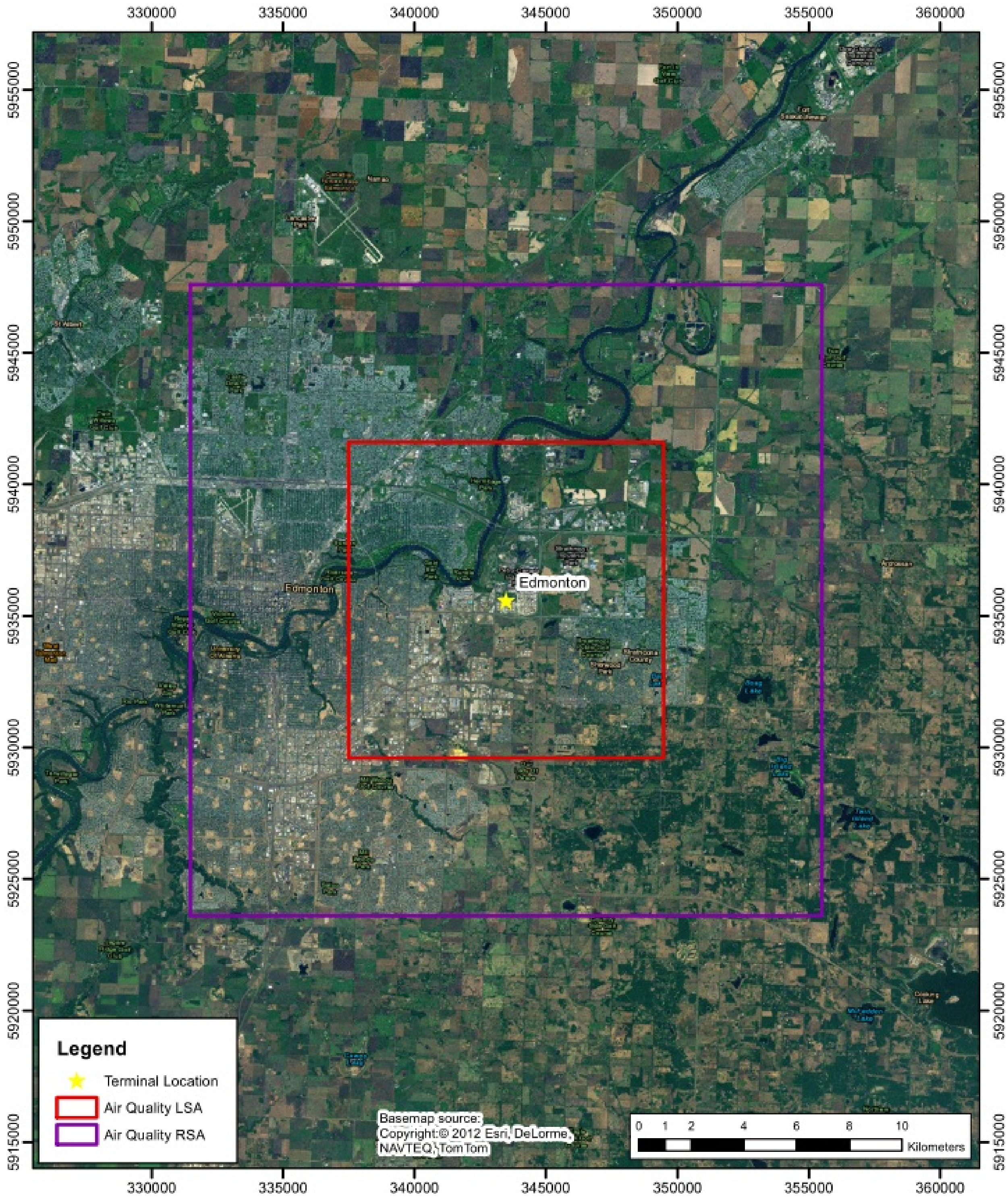

Figure 3.1: Map of Study Areas for Edmonton Terminal

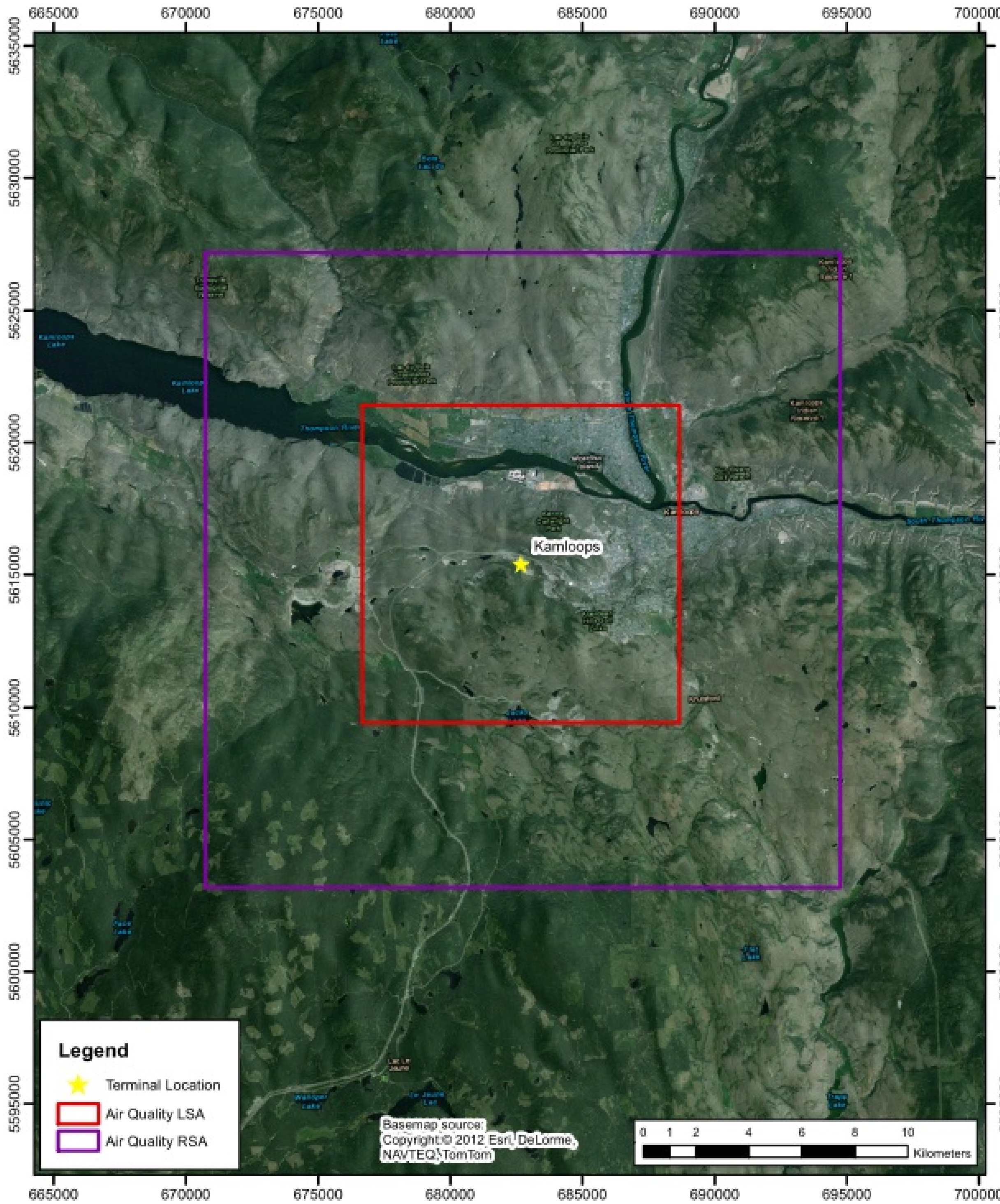

Figure 3.2: Map of Study Areas for Kamloops Terminal

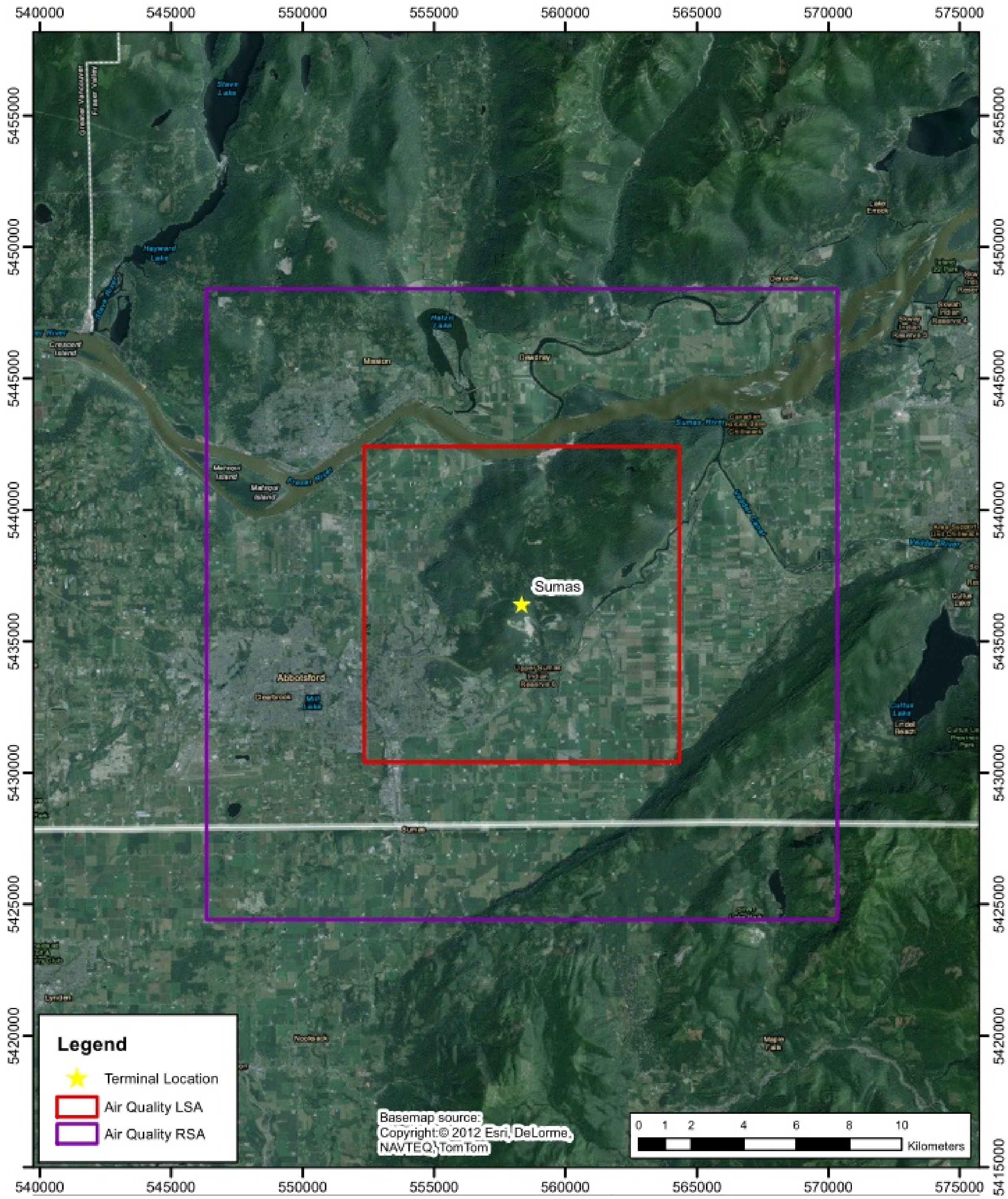

Figure 3.3: Map of Study Areas for Sumas Terminal

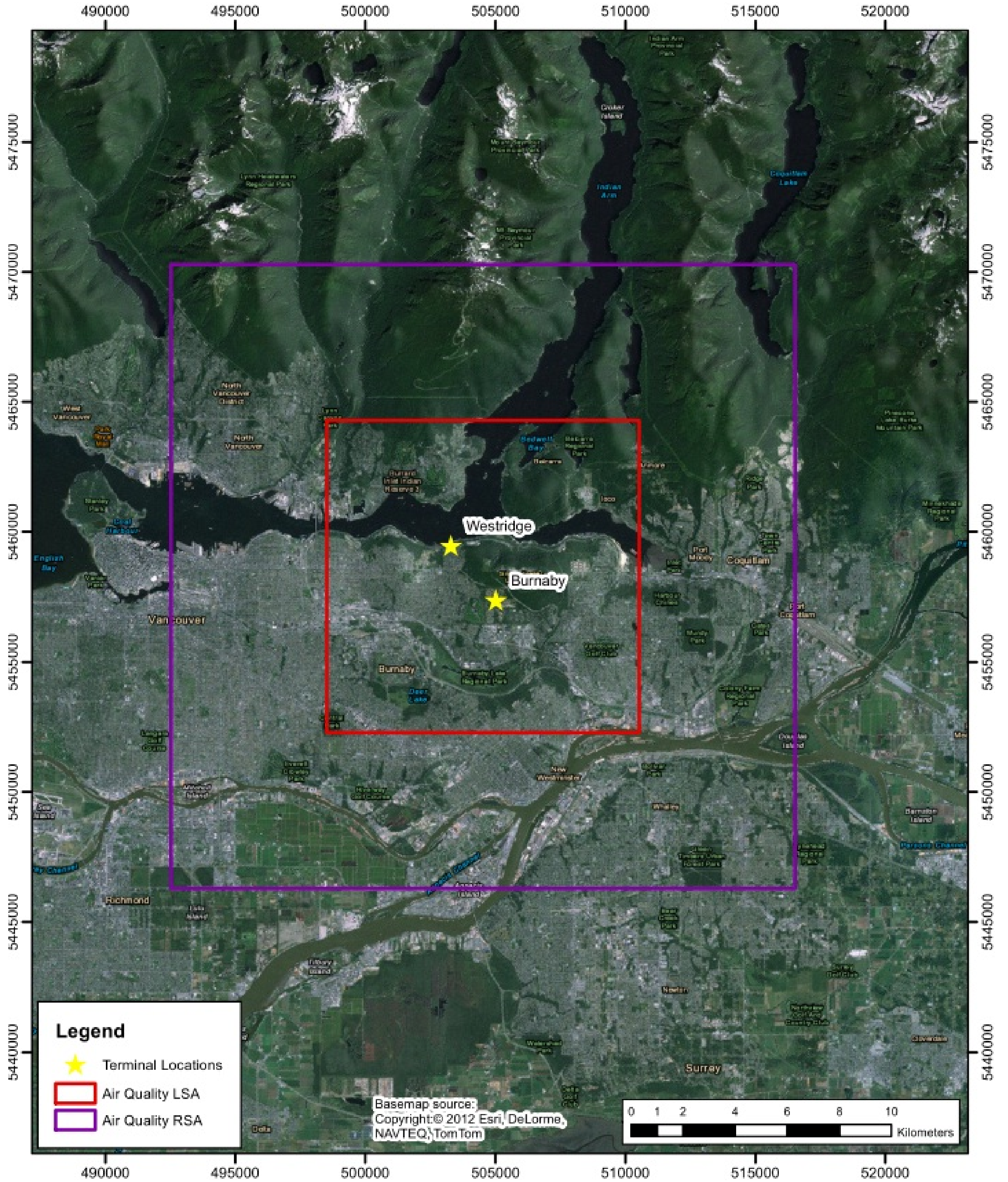

Figure 3.4: Map of Study Areas for Burnaby and Westridge Marine Terminals

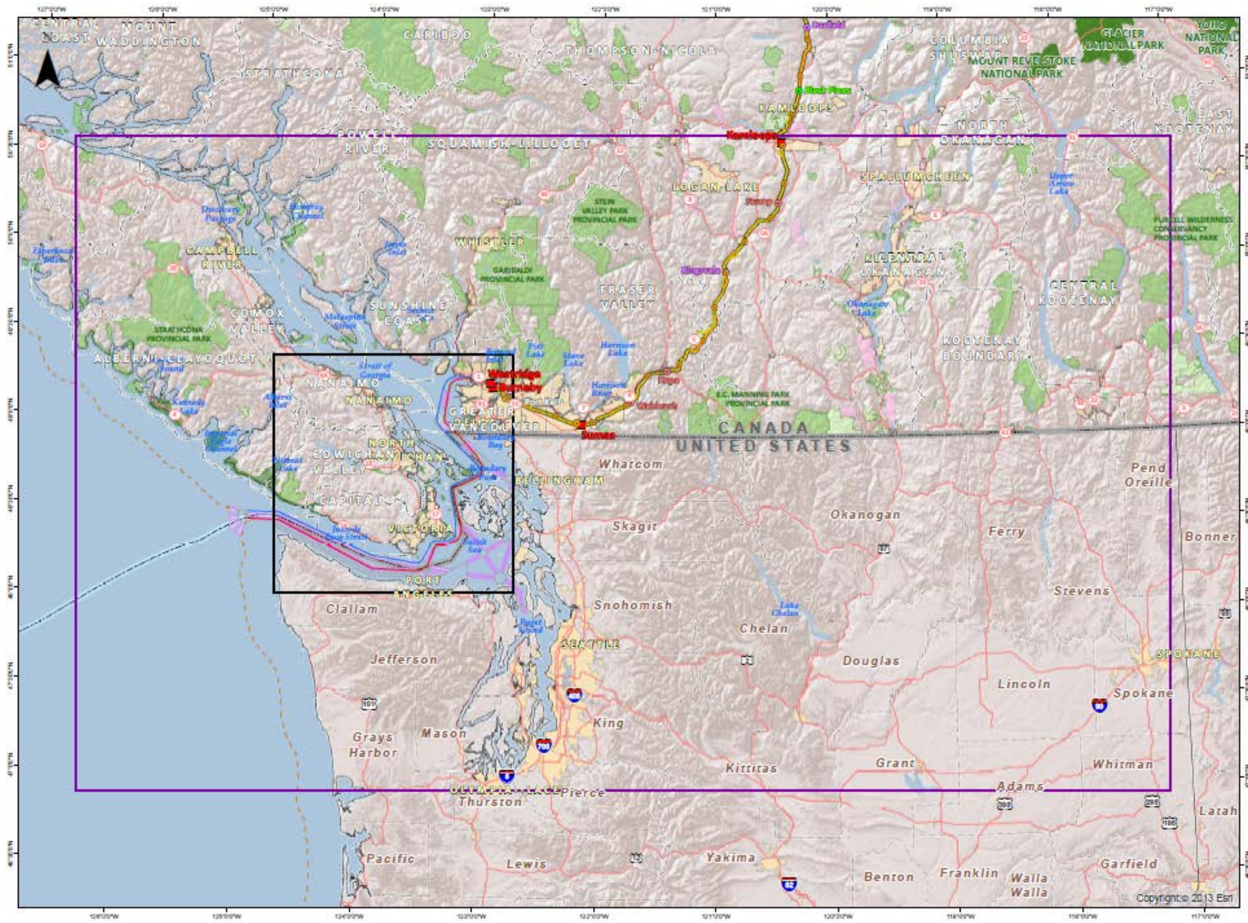

Figure 3.5: Map of LFV Study Area for Assessment of Secondary Smog-Related Products

3.4. Assessment Approach and Description of Assessments

The air quality and GHG assessment comprises three assessments:

- The assessment of existing conditions includes all projects in the region at the start of the Project. For the purpose of this assessment, existing conditions include current operations of the Trans Mountain Pipeline, all projects currently underway at the facilities, and all existing natural and anthropogenic (i.e., human-caused) sources (Section 4);

- The Project effects assessment includes all proposed design changes associated with the Trans Mountain Expansion Project assets and reflects the effects of the Project alone (Sections 5 and 6); and,

- The cumulative effects assessment includes existing conditions, the Project and all reasonably foreseeable projects (Sections 7 and 8).

The assessment approach is discussed in the following sub-sections.

3.4.1. Literature and Desktop Review

This section describes the literature and desktop review conducted to characterize the Project setting for air quality and GHG. Results of the literature and desktop review are discussed in Section 4.1.

The Project setting for air quality is characterized based on a review of historical measurements of ambient concentrations along the pipeline corridor. Meteorological conditions along the pipeline corridor were also reviewed as meteorological conditions determine how airborne contaminants are transported and dispersed in the atmosphere. Meteorological inputs to dispersion modelling are further discussed in Section 3.4.4. Lastly, existing emissions within the Air Quality LSAs and RSAs were reviewed to provide context for estimated emissions from Project construction and operations.

The Project setting for GHG is characterized based on a review of national, provincial and local GHG emission inventories.

The literature/desktop review also includes a review of the results of Aboriginal engagement activities, the collection of Traditional Ecological Knowledge (TEK) during biophysical field study participation and land and resource use information from potentially affected Aboriginal communities (Volume 5D).

3.4.1.1. Meteorological Conditions

Meteorological conditions along the pipeline corridor are described based on climate normal data from Environment Canada meteorological stations. Climate normals are compiled at the completion of each decade and represent average climatic conditions over the last 30 years of meteorological data. The most recent climate normal data are for 1971 to 2000 (Environment Canada 2013b). The meteorological stations used to compile the climate normal are summarized in Table 3.3 and illustrated in Figure 3.6. Stations were selected based on proximity to the pipeline corridor; all stations within 20 km from the Project were analyzed.

Parameters of interest from the climate normal data include wind speed and direction, temperature, precipitation, visibility and relative humidity. To better illustrate wind patterns, hourly wind speed and direction data from the climate normal stations were obtained from Environment Canada for the ten-year period from January, 2002, to December, 2011, and presented as wind roses. Wind roses are essentially bar charts in polar format. The direction of the bar indicates the direction *from* which the wind is blowing, the colour indicates the wind speed class, and the length of the bar indicates the frequency of occurrence.

Table 3.3: List of Meteorological Stations Used to Characterize Climatic Conditions along the Proposed Pipeline Corridor

Pipeline Segment	Station Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)
Edmonton to Hinton	Edmonton International Airport	53.317	-113.583	723
	Stony Plain	53.548	-114.108	766
	Edson Airport	53.583	-116.467	927
	Jasper East Gate	53.233	-117.817	1003
	Jasper	52.883	-118.067	1062
Hargreaves to Darfield	Blue River Airport	52.129	-119.290	683
Black Pines to Hope	Hope Airport	49.368	-121.498	131
	Kamloops Airport	50.702	-120.442	345
Hope to Burnaby	Abbotsford Airport	49.025	-122.360	59
Hope to Burnaby/Burnaby to Westridge	Pitt Meadows Airport	49.217	-122.683	4.9
	Vancouver International Airport	49.195	-123.182	4.3

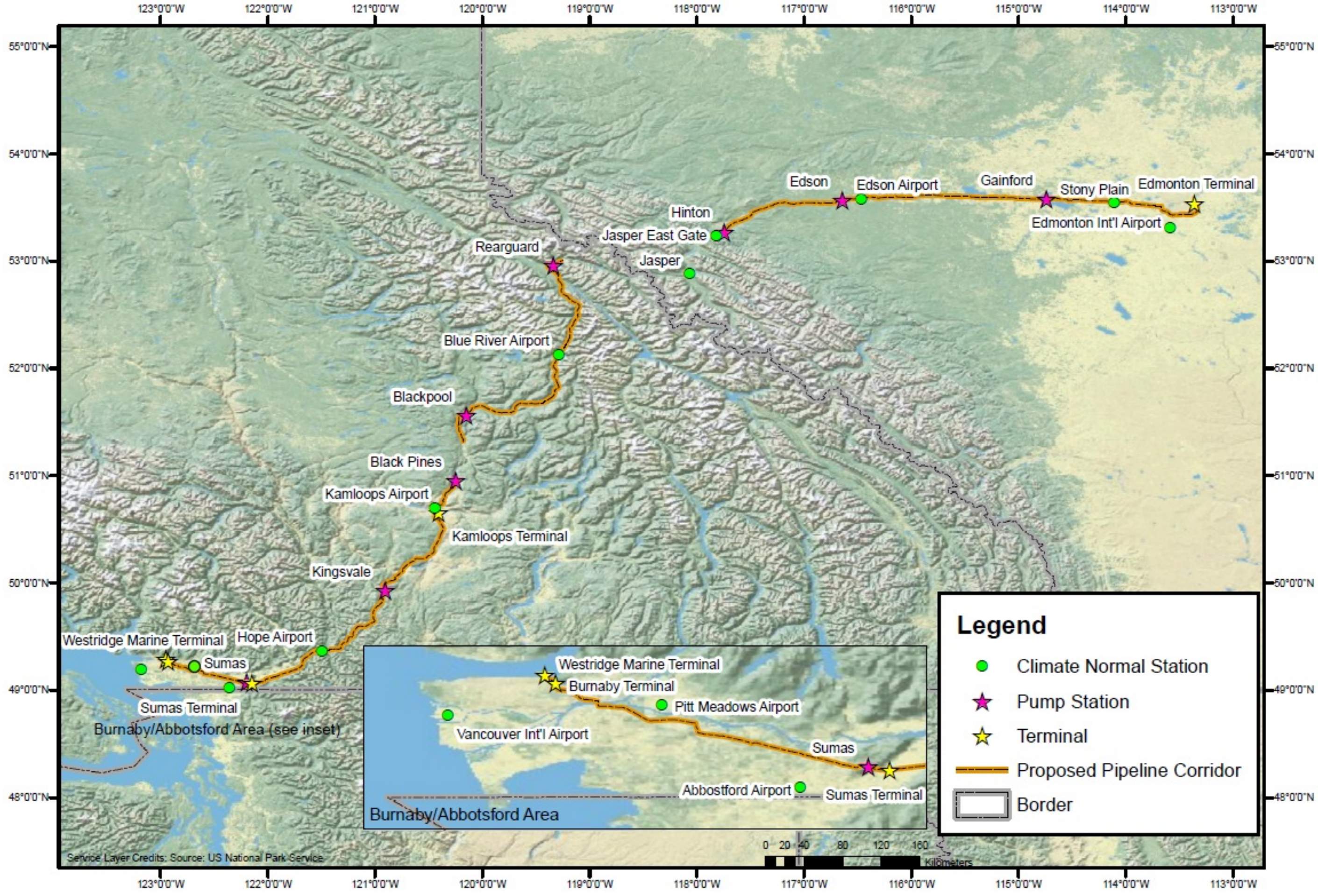

Figure 3.6: Map of Lower Fraser Valley Study Area (with marine RSA shown in black)

3.4.1.2. Ambient Concentrations

Ambient air quality data for CACs, BTEX, TRS and ozone were collected from the Clean Air Strategic Alliance (CASA 2013), BC MOE (2013c), Metro Vancouver (Reid pers. comm.) and Environment Canada's National Air Pollution Surveillance Program (NAPS) (Environment Canada 2013c). The pipeline corridor was divided into 11 areas for the purpose of characterizing ambient concentrations along the corridor and a number of stations were selected to represent each area. A summary of the air quality stations selected and the parameters monitored are shown in Table 3.4. A map of the selected stations is shown in Figure 3.7.

Data from January, 2002, to December, 2011, were reviewed, where available. With the exception of PM, the monitoring data collected were in units of ppb. Ambient concentrations in ppb were converted to $\mu g/m^3$ for comparison to the ambient air quality criteria (see Section 1.3) using co-located hourly temperature data. Trends were analyzed based on the full ten-year period; whereas, existing air quality conditions were analyzed based on the year 2011, or the most recent year with complete data if 2011 is not available. Where applicable, 8-hour and 24-hour averages were calculated for comparison to the ambient air quality criteria.

Diurnal and seasonal variability is illustrated using box and whisker plots which are simplified representations of frequency distribution data. The box spans the 25^{th} and 75^{th} percentiles while the bar spans the full range of data. Annual trends over the ten-year period are illustrated using time series plots showing the 50^{th} percentile of all observations within each year. Existing air quality conditions are presented as bar charts showing pollutant concentration levels for all averaging periods for which there are ambient air quality criteria. For short-term (i.e. 1-hour to 24-hour) averaging periods, the 99^{th} percentile of observations for the corresponding averaging period are shown. The 99^{th} percentile is selected to consider overall air quality excluding outliers and to avoid squeezing longer averaging periods close to zero, making plots visually difficult to compare. The annual averaging period is represented by the 50^{th} percentile of all hourly observations.

In addition to ambient air quality data for the 2002 to 2011 period, special air quality studies relevant to areas along the pipeline corridor were reviewed.

Table 3.4: List of Air Quality Stations Summarized by Pipeline Segment along the Proposed Pipeline Corridor

Pipeline Segment	Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
Edmonton to Hinton	*Edmonton Area (surrounding Edmonton Terminal)*						
	1a	Edmonton East	CASA (ID 1029)	53.548, -113.368	679	$PM_{2.5}$, CO, NO_2, SO_2, H_2S, ozone	2002 to 2011
	1b	Edmonton East	NAPS (ID 90121)	53.548, -113.368	670	BTEX	2002 to 2011
	2a	Edmonton Central	CASA (ID 1028)	53.544, -113.499	663	$PM_{2.5}$, CO, NO_2, ozone	2002 to 2011
	2b	Edmonton Central	NAPS (ID 90130)	53.545, -113.499	663	BTEX	2002 to 2011
	3	Edmonton McIntyre	CASA (ID 1224)	53.486, -113.465	681	$PM_{2.5}$	2006 to 2011
	4	Edmonton South	CASA (ID 1036)	53.5, -113.526	681	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	September, 2005, to 2011 (SO_2 from March, 2007)
	5	Edmonton Northwest	CASA (ID 1031)	53.594, -113.54	679	PM_{10}, $PM_{2.5}$, CO, NO_2, ozone	2002 to 2005
	6	Fort Saskatchewan	CASA (ID N/A)	53.699, -113.223	629	$PM_{2.5}$, CO, NO_2, SO_2, H_2S, ozone	2002 to 2011
	7	Sherwood Park	CASA (ID 1035)	53.532, -113.321	710	SO_2, H_2S	2002 to February, 2004
	8	Elk Island National Park	NAPS (ID 91101)	53.682, -112.868	714	BTEX	2005
	Gainford Area (surrounding Gainford Pump Station)						
	9	Meadows	CASA (ID 1058)	53.53, -114.637	735	NO_2, SO_2	July, 2004, to 2011
	10	Power	CASA (ID 1059)	53.633, -114.42	776	$PM_{2.5}$, NO_2, SO_2	July, 2004, to 2011

Pipeline Segment	Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
	11	Wagner	CASA (ID 1060)	53.395, -114.409	728	NO_2, SO_2	July, 2004, to January, 2009
Edmonton to Hinton (cont'd)	12	Wagner 2	CASA (ID 1241)	53.494, -114.45	684	NO_2, SO_2	2009 to 2011
	13	Tomahawk	CASA (ID 1053)	53.372, -114.769	790	PM_{10}, $PM_{2.5}$, NO_2, SO_2, ozone	2002 to 2011 (PM_{10} until June, 2009)
	Edson Area (surrounding Edson Pump Station)						
	14	Edson	CASA (ID 1062)	53.594, -116.393	894	$PM_{2.5}$, SO_2	$PM_{2.5}$ from November, 2004, to 2011 SO_2 from November, 2008, to 2011
	15	Carrot Creek	CASA (ID 1054)	53.621, -115.869	859	NO_2, SO_2, ozone	2002 to 2011
	Hinton Area (surrounding Hinton Pump Station)						
	16	Hinton	CASA (ID 1056)	53.427, -117.544	984	PM_{10}, $PM_{2.5}$, TRS	PM_{10} from 2004 to 2009 $PM_{2.5}$ from February, 2010, to 2011 TRS from 2004 to 2011
	17	Steeper	CASA (ID 1055)	53.133, -117.091	1431	PM_{10}, $PM_{2.5}$, NO_2, SO_2, ozone	PM_{10} from 2002 to August, 2003, and August, 2009, to July, 2010 $PM_{2.5}$ from August, 2010, to 2011 NO_2, SO_2 and ozone from 2002 to August, 2003, and March, 2009, to 2011
	18a	Hightower Ridge	CASA (ID 1051)	53.647, -118.178	1525	PM_{10}, $PM_{2.5}$, NO_2, SO_2, ozone	2002 to September, 2004, and December, 2007, to 2011 (PM_{10} from 2002 to September 2004)

Pipeline Segment	Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
	18b	Hightower Ridge	NAPS (ID 91201)	53.647, -118.178	1516	BTEX	June, 2003, to June, 2004
Hargreaves to Darfield	n/a	No stations available					
Black Pines to Hope	*Kamloops Area (surrounding Kamloops Terminal)*						
	19	Kamloops Brocklehurst	BC MOE	50.698, -120.397	347	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to May, 2011 (PM_{10} until June, 2009)
	20	Kamloops Fire Station #2	BC MOE	50.703, -120.394	348	$PM_{2.5}$, NO_2, SO_2, TRS, ozone	June to December, 2011
	Merritt Area (surrounding Kingsvale Pump Station)						
	n/a	No stations available					
	Hope Area (surrounding Hope Pump Station)						
	21a	Hope Airport	MV (ID T29)	49.37, -121.499	131	PM_{10}, $PM_{2.5}$, CO, NO_2, ozone	2002 to 2011 ($PM_{2.5}$ from February, 2004)
	21b	Hope Airport	NAPS (ID 101401)	49.37, -121.499	131	BTEX	February, 2002, to March, 2007
Hope to Burnaby	*Chilliwack Area (surrounding Wahleach Pump Station)*						
	22a	Chilliwack Airport	MV (ID T12)	49.156, -121.941	10	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011
	22b	Chilliwack Airport[(a)]	NAPS (ID 101101)	49.156, -121.941	16	BTEX	March, 2002, to 2011

Pipeline Segment	Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
	Abbotsford Area (surrounding Sumas Terminal and Sumas Pump Station)						
	23	Abbotsford Airport	MV (ID T34)	49.024, -122.343	65	$PM_{2.5}$, NO_2, SO_2, ozone	$PM_{2.5}$ and SO_2 from 2002 to April, 2010[b] NO_2 from December, 2003, to 2011 Ozone from August, 2006, to 2011
	24	Abbotsford Airport	NAPS (ID 101004)	49.033, -122.353	59	BTEX	March, 2007, to April, 2010
	25	Abbotsford Central	MV (ID T45)	49.043, -122.310	80	PM_{10}, CO, NO_2, SO_2, ozone	2002 to 2011
Burnaby to Westridge	*Burnaby Area (surrounding Burnaby and Westridge Marine Terminals)*						
	26a	Burmount	MV (ID T22)	49.267, -122.936	101	TRS	2002 to 2011
	26b	Burmount	NAPS (ID 100133)	49.267, -122.936	101	BTEX	2002 to 2011
	27	North Burnaby Capitol Hill	MV (ID T23)	49.288, -122.986	200	SO_2, TRS	2002 to 2011
	28	Burnaby North Eton	MV (ID T24)	49.288, -123.008	70	PM_{10}, SO_2, TRS	2002 to 2011 (PM_{10} from June, 2010)
	29	Burnaby Kensington Park	MV (ID T04)	49.279, -122.971	133	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, TRS, ozone	2002 to 2011 ($PM_{2.5}$ from June, 2003)
	30	Port Moody	MV (ID T09)	49.281, -122.849	15	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011[c] ($PM_{2.5}$ from July, 2003)
	31	Coquitlam	MV (ID T32)	49.288, -122.791	61	CO, NO_2, ozone	2002 to 2011

Pipeline Segment	Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
	32	North Vancouver Mahon Park	MV (ID T26)	49.324, -123.084	80	PM_{10}, CO, NO_2, SO_2, ozone	2002 to 2011
	33	Second Narrows	MV (ID T06)	49.302, -123.020	15	$PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011 ($PM_{2.5}$ from April, 2006)
	34	Burnaby South	MV (ID T18)	49.215, -122.986	122	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011[d]

Sources: CASA 2013, Environment Canada 2013c, BC MOE 2013c, Metro Vancouver 2012, Reid pers. comm.

Notes:
(a) The NAPS website identifies this station to be Chilliwack Works Yard but it is located at the Chilliwack Airport (Reid pers. comm.)
(b) $PM_{2.5}$ data is missing from January to April 2007; data completeness is 77%
(c) PM_{10} data is missing in 2009; data completeness is 85%. $PM_{2.5}$ data is missing from September to December 2008; data completeness is 77%
(d) SO_2 data is missing from May to November 2002; data completeness is 92%

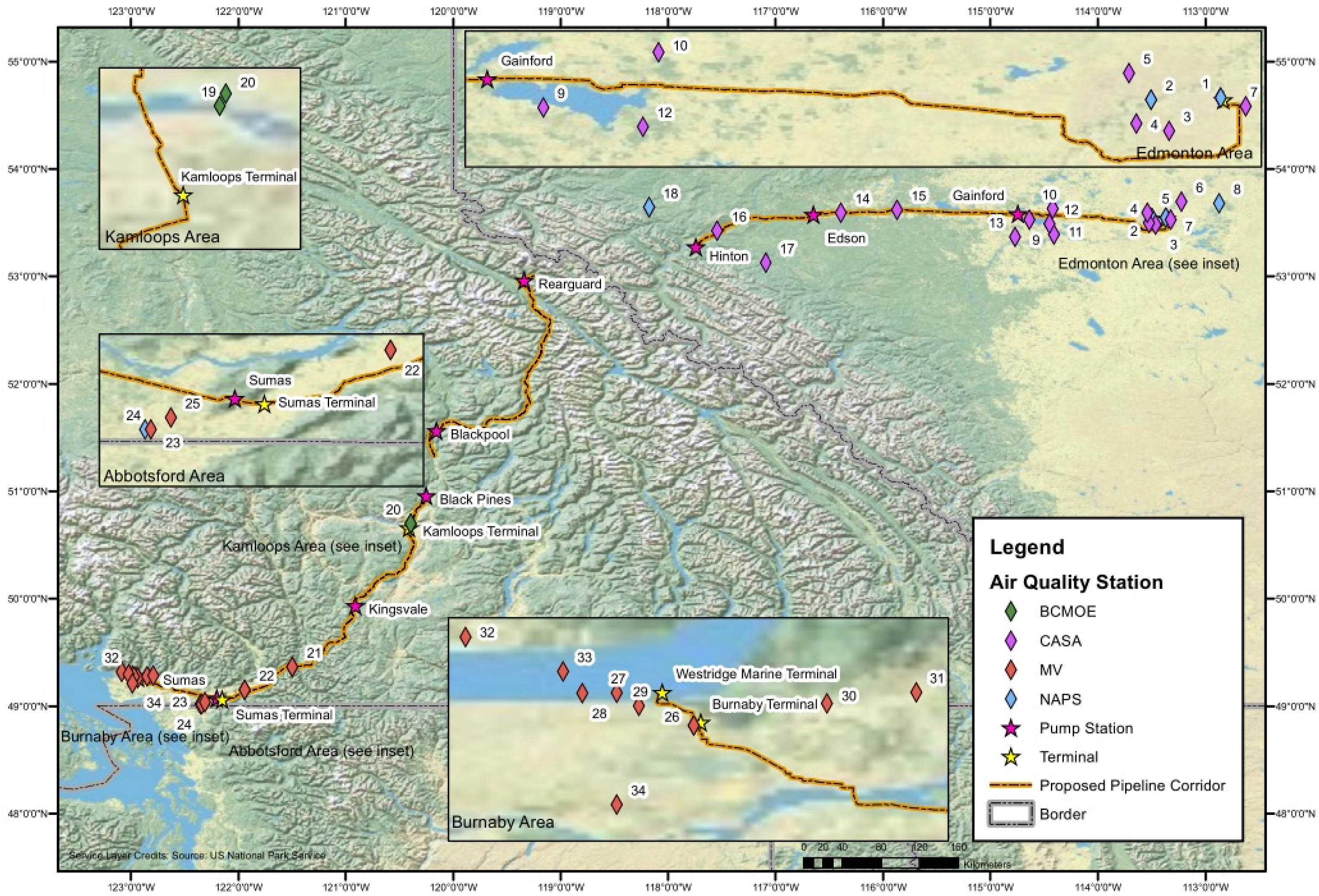

Figure 3.7: Map of Ambient Air Quality Monitoring Stations along the Proposed Pipeline Corridor

3.4.1.3. Emissions

National, provincial and local air emission inventories were reviewed to establish existing emissions of CACs and VOCs in the Air Quality LSAs and RSAs. An emission inventory is an account of total air emissions from all pollution sources within a defined area. Emission inventories typically separate total air emissions into three categories: point, area and mobile. Point sources represent industrial facilities that operate under air discharge permits. Area sources represent smaller, more broadly distributed light industrial, commercial, institutional, residential and naturally occurring sources that do not require air discharge permits. Mobile sources include on-road vehicles, non-road equipment, railways, aircraft and marine vessels.

Existing emissions for point, area and mobile sources within the Air Quality LSA and RSA for Edmonton Terminal were estimated based on information obtained from the AESRD (Melick pers. comm.). Area and mobile source emissions were provided by census-subdivision. The emissions for the census sub-divisions covering the LSA and RSA (Edmonton CY and Strathcona County) were scaled by land area to estimate total existing emissions within the LSA and RSA.

Existing emissions for area and mobile sources within the Air Quality LSA and RSA for Kamloops Terminal were estimated based on information from Environment Canada's air pollutant emission inventory for 2006. Emissions were provided by the BC MOE (McCormick pers. comm.) by census sub-division. The emissions for the census sub-divisions covering the LSA and RSA (Kamloops CY, Kamloops 1 IRI, Thompson-Nicola L RDA and Thompson-Nicola J RDA) were scaled by land area to estimate total existing emissions within the LSA and RSA. Point source emissions were determined based on information from Environment Canada's National Pollutant Release Inventory (NPRI) for 2010 (Environment Canada 2013d).

Existing emissions for point, area and mobile sources within the Air Quality LSAs and RSAs for the Sumas Terminal and for the Burnaby and Westridge Marine Terminals were estimated based on information from the *2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast – Detailed Listing of Results and Methodology* (Metro Vancouver 2010). Point source emissions within the LSAs were determined based on the location of all permitted industrial facilities in the Metro Vancouver inventory. For area sources, emissions by source type were scaled to the individual municipalities based on total area source emissions within the Canadian Lower Fraser Valley, then further scaled to the LSAs and RSAs based on land area. Mobile source emissions by source type and municipality were obtained from the Metro Vancouver inventory and scaled to the LSAs and RSAs based on land area. Road dust emissions are reported separately in the Metro Vancouver inventory and total road dust emissions for the Canadian Lower Fraser Valley were scaled to the LSAs and RSAs based on estimated emissions for on-road vehicles.

Greenhouse gas emissions have a global effect that cannot easily be measured on a local scale; therefore, GHG emissions are typically compared to national and provincial totals rather than to existing emissions in the Air Quality LSAs and RSAs. National and provincial GHG totals were obtained from Environment Canada's National Inventory Report (Environment Canada 2012). For the Sumas, Burnaby and Westridge Marine Terminals, Project-related GHG emission estimates were also compared to regional GHG totals for the Lower Fraser Valley, in alignment with Metro Vancouver's Integrated Air Quality and Greenhouse Gas Management Plan. Regional GHG totals for the Lower Fraser Valley were obtained from the *2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast* (Metro Vancouver 2007).

3.4.2. Emissions Estimation – CACs and VOCs

3.4.2.1. Project Construction

Emissions from pipeline construction activities were estimated where information was available. All pipeline construction emissions will be intermittent and limited in duration. Since the construction schedule is subject to change, construction related emissions were not estimated on an annual basis. Instead, these emissions are estimated as overall totals. Construction related emissions are mainly caused by the operation of construction equipment. Burning of brush will also result in CAC and VOC emissions, but these emissions happen sporadically and are not estimated here.

Operation of construction equipment results in CAC and VOC emissions due to fuel combustion. For tank installation at Trans Mountain terminals, and for construction activities related to the expansion of the Westridge Marine Terminal, Trans Mountain provided a list of equipment categories that are anticipated to be deployed, along with the estimated hours of operation for each equipment category. For the construction of the pipeline, RWDI made use of the equipment list and the estimated average hours of operation for the construction phase of the expansion of the Keystone XL Pipeline project (TransCanada Keystone Pipeline GP Ltd. 2009). Average hours of operation per kilometer of pipeline construction, were then scaled for the lengths of the pipeline segments in the Project. For the segment of Burnaby to Westridge, RWDI used the cumulative length of the two proposed pipelines for the purpose of estimating construction effort. Also, in the absence of any information regarding the construction activities at pump stations, RWDI used the equipment list and estimated hours of operation for the construction of the pump station in the Keystone XL project. The pump station with the highest emissions was selected to conservatively represent the construction effort (equipment and hours of operation) needed to build a new pump station, or relocate an existing one. It was also assumed that no construction effort is required for TMEP potential deactivation of the existing pump stations if further studies indicate that some stations are not required.

Emission factors (emissions per one hour of operation) were obtained from three sources depending on the availability of data: RWDI's emission estimates performed previously for the similar pipeline project of NOVA Gas Transmission Ltd. (NGTL, 2010), Transport Canada's Urban Transportation Emissions Calculator (UTEC, 2013), and Canada's 2010 National Marine Inventory (SNC-Lavalin Environment. 2012a). For each equipment category, the most appropriate conservative representative equipment was selected from the aforementioned sources, and the corresponding emission factors were used to estimate CAC emissions. In NGTL 2010, emission factors of the equipment in the off-road mode were calculated using the U.S. Environmental Protection Agency NONROAD model. For on-road equipment in NGTL 2010, emission factors were modeled using MOBILE6 Vehicle Emission Modeling Software, and assuming an average speed of 50 km/h. For the on-road equipment using gasoline, RWDI made use of UTEC 2013, with the most appropriate conservative assumptions to obtain the corresponding emission factors. Emission factors of boats deployed in the construction of the new Berths at the Westridge Marine Terminal were obtained from the 2010 National Marine Emissions Inventory (SNC-Lavalin Environment. 2012).

3.4.2.2. **Project Operation**

Emissions of CACs and total organic compounds (TOCs) associated with the Project operation phase were estimated for the following equipment or activity:

- diesel generators and fire water pumps;
- line heaters;
- storage tanks;
- loading of marine vessels at Westridge Marine Terminal; and,
- pump stations.

The emission estimation approach is discussed in the following sub-sections. Emissions of TOCs are further speciated to provide VOCs and individual COPCs.

Product Information

The existing pipeline currently transports heavy crude, light and synthetic crude, as well as refined products, in a series or in a "batch train". The capacity of the existing pipeline is 300,000 barrels per day (bpd) including heavy crude, or up to 400,000 bpd without heavy crude. With Project expansion, the proposed pipeline will be used to transport heavy crude at a capacity of 540,000 bpd and the existing pipeline will be used to transport light crude, synthetic crude and refined products at a capacity of 350,000 bpd.

The pipeline may be used to transport many different grades or varieties of product. Each grade is associated with different petroleum properties and a different chemical composition. Bulk properties such as the product vapor pressure affect its tendency to vaporize and form fugitive emissions. The chemical composition affects the relative abundance of each compound, such as BTEX, H_2S, or mercaptans. The total throughput of each product grade in the pipeline varies and is dependent on market demand. Therefore, no one scenario depicting normal operation of the pipeline can be defined. Rather, a "reasonable worst-case" scenario was defined from an air quality perspective.

The "reasonable maximum" scenario was developed based on the total pipeline capacity and typical throughput by terminal as summarized in Table 3.5. The throughput by terminal reflects the quantity of product removed from the mainline and stored in the tank farm for local distribution.

Table 3.5: Product Throughput Used for Reasonable Maximum Operating Scenario (in bpd)

Product Category	Edmonton Terminal	Kamloops Terminal	Sumas Terminal	Burnaby Terminal	Westridge Marine Terminal
Existing Operations					
Heavy Crude	66,000 (22%)	0	0	18,000 (6%)	45,180 (15%)
Light/Synthetic Crude	186,000 (62%)	12,000 (4%)	138,180 (46%)	18,000 (6%)	17,820 (6%)
Refined Products	48,000 (16%)	0	2820 (1%)	48,000 (16%)	0
Total (All Products)	300,000 (100%)	12,000 (4%)	141,000 (47%)	84,000 (28%)	63,000 (21%)
Proposed Operations with the Project					
Heavy Crude	540,000 (61%)	0	0	4153 (0.5%)	532,465 (60%)
Light/Synthetic Crude	278,205 (31%)	8900 (1%)	165,718 (19%)	4153 (0.5%)	99,435 (11%)
Refined Products	71,795 (8%)	0	3382 (0.4%)	71,795 (8%)	0
Total (All Products)	890,000 (100%)	8900 (1%)	169,100 (19%)	80,100 (9%)	631,900 (71%)

Source: Trans Mountain 2013, Kozak pers. comm.

One product grade was selected to represent each of the three product categories, based on actual throughput records from 2011 and 2012 and on product properties and composition data. Cold Lake Blend was selected to represent heavy crude product as this blend accounted for over 60% of heavy crude throughput in 2011 and 2012 and is expected to be one of the major products transported in the proposed pipeline. From an air quality perspective, Cold Lake Blend has a vapor pressure in the mid-range of all heavy crude products transported in 2011 and 2012, and is therefore, likely to provide an average estimate of fugitive emissions. Peace River Sour was selected to represent light and synthetic crude product. This blend accounted for 20% to 25% of light and synthetic crude throughput in 2011 and 2012, and has a vapor pressure and BTEX, H_2S and mercaptan content on the higher end of all light and synthetic crude products. Refined products transported in 2011 and 2012 comprised of 59% to 68% gasoline blends, all of which have similar vapor pressures. Ethanol blend gasoline was conservatively selected to represent refined products as this blend has the highest BTEX content.

Diesel Generators and Fire Water Pumps

A number of diesel generators and fire water pumps are located at the Trans Mountain Terminals in case of an emergency. Additional units are also proposed at the Burnaby and Westridge Marine Terminals as a part of the Project. Emissions from the regular testing of this equipment were estimated following the methodology in Chapter 3.3 of the United States Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (US EPA 1996). Emission factors expressed on the basis of power output were used in conjunction with the power output ratings and testing frequency of the equipment, as summarized in Table 3.6 (existing) and Table 3.7 (proposed), to calculate emissions of CACs and VOCs.

Table 3.6: Specifications of Existing Diesel Generators and Fire Water Pumps

Location	Description	Power Rating (hp)	Testing Frequency
Edmonton Terminal	Terminal Generator	207	½ hour once a month
	Control Centre Generator	207	½ hour once a month
	Fire Water Pump	340	½ hour once a week
Kamloops Terminal	Terminal Generator	335	½ hour once a month
	Fire Water Pump	187	½ hour once a week
Sumas Terminal	Tank Farm Generator	102	½ hour once a month
	Fire Water Pump	152	1 hour once a week
Burnaby Terminal	Terminal Generator	207	½ hour once a month
	Middle Road Generator	147	½ hour once a month
	Upper Road Generator	147	½ hour once a month
	Fire Water Pump	106	½ hour once a week
Westridge Marine Terminal	Terminal Generator	207	½ hour once a month

Source: Kozak pers. comm.

Table 3.7: Specifications of Proposed Diesel Generators and Fire Water Pumps

Location	Description	Power Rating (hp)	Testing Frequency
Burnaby Terminal	Terminal Generator	350	½ hour once a month
	Fire Water Pump	373	½ hour once a week
Westridge Marine Terminal	Terminal Generator	750	½ hour once a month
	Fire Water Pump 1	373	½ hour once a week
	Fire Water Pump 2	373	½ hour once a week

Source: Kozak pers. comm.

Line Heaters

A number of natural gas line heaters currently operate at the Kamloops Terminal. A list of the line heaters, along with their specified power ratings and estimated operating hours, is provided in Table 3.8. All line heaters were conservatively assumed to operate continuously year-round at 100% load. No changes to the line heaters are expected as a result of the Project.

Emissions of CACs and VOCs from the combustion of natural gas in the line heaters were estimated following the methodology in Chapter 1.4 of AP-42 (US EPA 1998). The emission factors are expressed in grams of pollutant released per volume of natural gas input. A thermal efficiency of 75% (Canadian Association of Petroleum Producers [CAPP] 2007) was assumed to estimate the energy input based on the specified power rating. A default heating value for natural gas of 1,020 British thermal units per standard cubic foot (BTU/scf) was used to estimate the natural gas consumption rate (US EPA 1998).

Table 3.8: Specifications of Line Heaters at Kamloops Terminal

Location	Number of Units	Power Rating (Btu/h)	Assumed Operating Hours per Unit (hours per year)
Pipeline Maintenance	2	100,000	8760
Warehouse	1	75,000	
Heavy Equipment Garage	2	205,000	
Mechanical Maintenance	1	100,000	

Source: Roelofsen pers. comm.

Storage Tanks

Fugitive emissions are released from storage tanks as a result of working and storage losses. Working losses are associated with tank filling and withdrawing, whereas storage losses are continuous emissions from the headspace of the tanks. Emissions from storage tanks are dependent on the physical characteristics of the tanks, the type of product stored, tank filling and withdrawal rates, total product throughput, and the surrounding meteorological conditions. Physical characteristics of the tanks and the tank filling and withdrawal rates for the five tank terminals are shown in Table 3.9 to Table 3.17, and were provided by SNC-Lavalin Environment and Kinder Morgan Canada (KMC) (Roelofsen pers. comm., Kozak pers. comm.). The type of product currently stored in existing tanks was assigned based on information from SNC-Lavalin Environment, as used in the 2011 and 2012 NPRI reporting for Trans Mountain assets. Proposed product assignment for all tanks in the future was provided by KMC. Product throughput by tank was calculated based on the product throughput at each terminal (see Table 3.5) assuming that the turnover rate would be the same across all tanks servicing the same product type within a terminal.

Table 3.9: Edmonton Terminal Storage Tank Parameters for TANKS Model – Existing Conditions

Parameter		Value							
Tank Type		External Floating Roof Tank					Domed External Floating Roof Tank		
Working Volume	**(US gal)**	3,360,000	6,300,000	8,390,000	11,400,000	15,200,000	3,360,000	6,300,000	8,390,000
	(L)	12,700,000	23,800,000	31,800,000	43,200,000	57,600,000	12,700,000	23,800,000	26,200,000
Number of Tanks		4	8	1	6	7	1	4	2
Tank Colour		White							
Shell Height	**(ft)**	40	48	70	70	70	40	47.9 or 49.2	52
	(m)	12.2	14.6	21.3	21.3	21.3	12.2	14.6 to 15.0	15.8
Shell Diameter	**(ft)**	109.9 or 120.1	150	150	175	202	120	150	180
	(m)	33.5 or 36.6	45.7	45.7	53.3	61.6	36.6	45.7	45.7
Maximum Fill Rate (m^3/h)		1500							
Maximum Withdrawal Rate (m^3/h)		2770							
Product Stored		Light/Synthetic Crude and Refined Product	All	Light/ Synthetic Crude	Heavy Crude	Heavy Crude and Light/Synthetic Crude	Light/ Synthetic Crude	Light/Synthetic Crude and Refined Product	Heavy Crude

Sources: Roelofsen pers. comm., Kozak pers. comm., Stantec Consulting Ltd. 2011

Table 3.10: Edmonton Terminal Storage Tank Parameters for TANKS Model – Proposed with Project

Parameter		Value									
Tank Type		External Floating Roof Tank							Domed External Floating Roof Tank		
Working Volume	**(US gal)**	3,360,000	6,300,000	8,390,000	9,020,000	11,400,000	15,200,000	16,000,000	3,360,000	6,300,000	8,390,000
	(L)	12,700,000	23,800,000	31,800,000	34,100,000	43,200,000	57,600,000	60,700,000	12,700,000	23,800,000	31,800,000
Number of Tanks		4	8	1	1	6	7	2	1	4	2
Tank Colour		White									
Shell Height	**(ft)**	40	48	70	70	70	70	70	40	47.9 or 49.2	52
	(m)	12.2	14.6	21.3	21.3	21.3	21.3	21.3	12.2	14.6 or 15.0	15.8
Shell Diameter	**(ft)**	109.9 or 120.1	150	150	150	175	202	200	120	150	180
	(m)	33.5 or 36.6	45.7	45.7	45.7	53.3	61.6	61	36.6	45.7	54.9
Maximum Fill Rate (m^3/h)		1500									
Maximum Withdrawal Rate (m^3/h)		1820 (Heavy Crude) OR 2320 (Light/Synthetic Crude or Refined Products)									
Product Stored		Light/Synthetic Crude and Refined Product	Heavy and Light Synthetic Crude and Refined Product	Light/ Synthetic Crude	Heavy Crude	Heavy Crude	Heavy and Light/ Synthetic Crude	Heavy Crude	Light/ Synthetic Crude	All	Heavy Crude

Source: Kozak pers. comm.

Table 3.11: Kamloops Terminal Storage Tank Parameters for TANKS Model – Existing Conditions[(a)]

Parameter		Value
Tank Type		External Floating Roof Tank
Working Volume	**(US gal)**	3,360,000
	(L)	12,700,000
Number of Tanks		2
Tank Colour		White
Shell Height	**(ft)**	40
	(m)	12.2
Shell Diameter	**(ft)**	120
	(m)	36.6
Maximum Fill Rate (m^3/h)		2400
Maximum Withdrawal Rate (m^3/h)		2400
Product Stored		Light/Synthetic Crude

Sources: Roelofsen pers. comm., Kozak pers. comm.

Notes: (a) No changes are expected as a result of the Project

Table 3.12: Sumas Terminal Storage Tank Parameters for TANKS Model – Existing Conditions

Parameter		Value		
Tank Type		External Floating Roof Tank		Domed External Floating Roof Tank
Working Volume	**(US gal)**	2,270,000	6,300,000	6,300,000
	(L)	8,590,000	23,800,000	23,800,000
Number of Tanks		2	2	2
Tank Colour		White		
Shell Height	**(ft)**	48	48 or 56	48
	(m)	14.6	14.6 or 17.1	14.6
Shell Diameter	**(ft)**	90	140.1 or 149.9	150
	(m)	27.4	42.7 or 45.7	45.7
Maximum Fill Rate (m^3/h)		2400		
Maximum Withdrawal Rate (m^3/h)		1400		
Product Stored		Light/Synthetic Crude		

Sources: Roelofsen pers. comm., Kozak pers. comm.

Table 3.13: Sumas Terminal Storage Tank Parameters for TANKS Model – Proposed with Project

Parameter		Value			
Tank Type		External Floating Roof Tank	Domed External Floating Roof Tank		Internal Floating Roof Tank
Working Volume	**(US gal)**	2,270,000	2,270,000	6,300,000	7,210,000
	(L)	8,590,000	8,590,000	23,800,000	27,300,000
Number of Tanks		1	1	4	1
Tank Colour		White			
Shell Height	**(ft)**	48	48	48 or 56	56
	(m)	14.6	14.6	14.6 or 17.1	17.1
Shell Diameter	**(ft)**	90	90	140 or 150	150
	(m)	27.4	27.4	42.7 or 45.7	45.7
Maximum Fill Rate (m^3/h)		2400			
Maximum Withdrawal Rate (m^3/h)		1190			
Product Stored		Light/Synthetic Crude	Light/Synthetic Crude	Light/Synthetic Crude	Heavy Crude

Source: Kozak pers. comm.

Table 3.14: Burnaby Terminal Storage Tank Parameters for TANKS Model – Existing Conditions

Parameter		Value				
Tank Type		External Floating Roof Tank		Domed External Floating Roof Tank		
Working Volume	**(US gal)**	3,360,000	6,300,000	3,360,000	6,300,000	6,590,000
	(L)	12,700,000	23,800,000	12,700,000	23,800,000	25,000,000
Number of Tanks		3	4	1	2	3
Tank Colour		Dark Green				
Shell Height	**(ft)**	40	48	40	47.9	50
	(m)	12.2	14.6	12.2	14.6	15.2
Shell Diameter	**(ft)**	120	150	120	150	150
	(m)	36.6	45.7	36.6	45.7	45.7
Maximum Fill Rate (m^3/h)		2400				
Maximum Withdrawal Rate (m^3/h)		1000				
Product Stored		Light/ Synthetic Crude and Refined Product	Heavy Crude	Refined Product	Light/ Synthetic Crude	Heavy Crude

Sources: Roelofsen pers. comm., Kozak pers. comm.

Table 3.15: Burnaby Terminal Storage Tank Parameters for TANKS Model – Proposed with Project

Parameter		Value							
Tank Type		External Floating Roof Tank		Domed External Floating Roof Tank			Internal Floating Roof Tank		
Working Volume	**(US gal)**	3,360,000	6,300,000	3,360,000	6,300,000	6,590,000	10,500,000	11,800,000	13,700,000
	(L)	12,700,000	23,800,000	12,700,000	23,800,000	25,000,000	39,800,000	44,500,000	52,000,000
Number of Tanks		2	3	1	3	3	1	10	2
Tank Colour		Dark Green							
Shell Height	**(ft)**	40	48	40	47.9	50	60	60	60
	(m)	12.2	14.6	12.2	14.6	15.2	18.3	18.3	18.3
Shell Diameter	**(ft)**	120	150	120	150	150	175	185	200
	(m)	36.6	45.7	36.6	45.7	45.7	53.3	56.4	61.0
Maximum Fill Rate (m³/h)		2400							
Maximum Withdrawal Rate (m³/h)		1550							
Product Stored		Light/ Synthetic Crude and Refined Product	Light/ Synthetic Crude	Light/ Synthetic Crude	Light/ Synthetic and Heavy Crude	Heavy Crude	Heavy Crude	Light/ Synthetic and Heavy Crude	Heavy Crude

<u>Sources:</u> Roelofsen pers. comm., Kozak pers. comm.

Table 3.16: Westridge Marine Terminal Storage Tank Parameters for TANKS Model – Existing Conditions

Parameter		Value	
Tank Type		Vertical Fixed Roof Tank	
Working Volume	**(US gal)**	1,890,000	7,380,000
	(m)	7,150,000	27,800,000
Number of Tanks		1	2
Tank Colour		Dark Green	
Shell Height	**(ft)**	40	79
	(m)	12.2	24.2
Shell Diameter	**(ft)**	90	126
	(m)	27.4	38.4
Maximum Fill Rate (m^3/h)		3000	
Maximum Withdrawal Rate (m^3/h)		N/A	
Product Stored		Jet Fuel	

Sources: Roelofsen pers. comm., Kozak pers. comm., Vancouver Airport Fuel Facilities Corporation 2011

Table 3.17: Westridge Marine Terminal Storage Tank Parameters for TANKS Model – Proposed with Project

Parameter		Value		
Tank Type		Vertical fixed roof		Internal Floating Roof[(a)]
Working Volume	**(US gal)**	1,890,000	7,380,000	1,240,000
	(L)	7,150,000	27,800,000	4,680,000
Number of Tanks		1	2	2
Tank Colour		Dark Green		
Shell Height	**(ft)**	40	79	60
	(m)	12.2	24.2	18.3
Shell Diameter	**(ft)**	90	126	60
	(m)	27.4	38.4	18.3
Maximum Fill Rate (m^3/h)		3000		N/A
Maximum Withdrawal Rate (m^3/h)		N/A		41
Product Stored		Jet Fuel	Jet Fuel	Light/Synthetic Crude

Sources: Roelofsen pers. comm., Kozak pers. comm., Vancouver Airport Fuel Facilities Corporation 2011

Note: (a) These tanks refer to the proposed VRU tanks (see Marine Vessel Loading)

Emissions from all product storage tanks during normal operation (i.e., not considering emergency relief tanks) were estimated using the US EPA TANKS model (US EPA 2006a), with the exception of two existing storage tanks at Westridge Marine Terminal (Tanks 201 and 202). The tank height of Tanks 201 and 202 were outside the acceptable range for the TANKS model, and therefore, emissions were calculated following the approach described in Chapter 7.1 of AP-42 (US EPA 2006b).

Climate data for the Edmonton, Kamloops and Sumas Terminals were obtained from 30-year climate normals at Edmonton International Airport, Kamloops Airport and Abbotsford Airport, respectively. Climate data for the Burnaby and Westridge Marine Terminals were obtained from Metro Vancouver meteorological data at Burnaby Kensington Park (wind and temperature data) and Burnaby South (atmospheric pressure data). Monthly solar insolation for input into the TANKS model was calculated as a function of latitude (Stull 2000).

Product temperatures along the existing and proposed pipelines were obtained from KMC based on Supervisory Control and Data Acquisition (SCADA) monitoring (Ma pers. comm.). Product temperatures in the existing pipeline typically vary between 17.5°C at the Edmonton Terminal to 20°C at the Burnaby Terminal. Product temperatures in the proposed pipeline are expected to be as high as 27°C for the Project effects assessment. Input to the TANKS model was adjusted to account for these product temperatures within the tanks. Fixed roof tanks were modelled as heated tanks. For floating roof tanks, the climate data were modified based on recommendations from the US EPA (Ciolek pers. comm.) – average daily temperatures were set to the product temperature and the solar insolation values were set to 1 Btu/ft^2-d.

Fugitive emissions from storage tanks are reported as a sum of working and standing losses. Standing losses (also known as breathing losses) were estimated on a monthly basis and are caused by thermal expansion that occurs in the vapour headspace due to changes in meteorological conditions (predominantly ambient temperature and surface wind speed). The TANKS model provides monthly standing losses in pounds per month. The resulting losses for each month were assumed to be continuous throughout the month and were converted to units of grams per second (g/s), according to the following equation:

$$Standing\ Loss_{Month\ i}\left(\frac{g}{s}\right) = Standing\ Loss\ (lbs) \times \frac{1}{no.of\ days\ in\ month\ i} \times \frac{1\ day}{24\ hours} \times \frac{1\ hour}{3600\ s} \times \frac{453.59\ g}{lb}$$

A peaking factor of 2 was applied to estimate maximum hourly standing losses for dispersion modelling in order to account for diurnal variations not accounted for in the TANKS model.

Working losses (also known as withdrawal losses) for floating roof tanks were estimated on the basis that product vapours are produced as a result of product clinging to the sides and fittings of the tank upon withdrawal and lowering of the fluid level. Working losses from fixed tanks were estimated on the basis that product vapours are produced primarily as a result of the pressure rise inside the tank during tank filling. Working losses were generated using TANKS based on one turnover (i.e. one complete fill or drain of the tank) per month, or 12 turnovers over the year. Total annual working loss emissions were then calculated based on the total product throughput, while maximum hourly working loss emissions for dispersion modelling were calculated based on the pump rate (i.e. maximum fill rate for fixed roof tanks or maximum withdrawal rate for floating roof tanks), according to the following equation:

$$Working\ Loss\ \left(\frac{g}{s}\right) = \frac{Working\ Loss\ (lb)}{Turnover} \times \frac{Pump\ Rate\ \left(\frac{L}{min}\right)}{Tank\ Volume\ (L)} \times \frac{453.59\ g}{lb} \times \frac{1\ min}{60\ s}$$

Maximum hourly working loss emissions for dispersion modelling also considered the maximum number of tanks that can be filled or emptied simultaneously, which is dependent on the delivering or receiving pipeline capacity. This resulted in a dispersion modelling scenario for existing conditions consisting of one tank withdrawal each at the Edmonton, Kamloops and Sumas Terminals, three tank withdrawals at the Burnaby Terminal, and one tank filling at the Westridge Marine Terminal. With the addition of the Project, the dispersion modelling scenario for the Project effects assessment consists of two additional tank withdrawals each at the Edmonton Terminal, one additional tank withdrawal at the Sumas Terminals, and three additional tank withdrawals at the Burnaby Terminal. The tanks at the Kamloops and Westridge Marine Terminals do not service heavy crude, and therefore, no changes are expected as a result of the Project.

A number of tanks at the Burnaby Terminal are currently installed with tank vapour activation units (TVAUs) to minimize fugitive VOC losses. In addition and based on preliminary engineering, all proposed tanks at the Burnaby and Sumas Terminals will be installed with TVAUs. The capture and destruction efficiency of the TVAUs were assumed to be 80% each, based on best engineering judgement available at the time of writing. The TVAUs were assumed to be equally effective on all VOCs and reduced sulphur compounds.

Marine Vessel Loading

Fugitive TOC emissions from the marine vessel loading/unloading operations at the Westridge Marine Terminal were estimated following the methodology in Environment Canada's 2010 National Marine Inventory (SNC-Lavalin Environment 2012a). The basic equation for fugitive TOC emissions from marine vessel loading is:

$E = DWT \times LF \times EF_{loading} \times (1 - CE)$

Where: E = TOC emissions (mg);

DWT = deadweight tonnage;

LF = load factor;

$EF_{loading}$ = loading TOC emission rate (Table 3.18); and,

CE = control efficiency.

The product throughput quantities identified for the Westridge Marine Terminal in Section 3.4.3.1 were used in place of the deadweight tonnage and load factor. The total product throughput was prorated by vessel capacity and number of vessel calls (see the Marine Air Quality and Greenhouse Gas - Marine Transportation Technical Report [Volume 8B]) to determine throughput by vessel type, as summarized in Table 3.18. In addition to shipping crude product from the Burnaby Terminal, the Westridge Marine Terminal also receives one jet fuel barge per month for delivery to the Vancouver International Airport via the Trans Mountain Jet Fuel pipeline.

Table 3.18: Marine Vessel Loading TOC Emission Rates and Associated Product Throughput

Product	TOC Emission Rate (mg/litre)	Product Throughput (1000 L/y)	
		Existing Conditions	Proposed with Project
Crude Tanker	73	9040	10,939
Crude Barge	120	991	1199
Jet Fuel Barge	1.6	216,000	216,000

Sources: SNC-Lavalin Environment 2012a, Vancouver Airport Fuel Facilities Corporation 2011

Vapour abatement technologies can significantly reduce emissions during loading and unloading. The control efficiency factor accounts for these reductions. The control efficiency represents the net effect of the assumed capture efficiency (90%) and the destruction efficiency.

Fugitive emissions from marine vessel loading are collected and destroyed by vapour abatement technologies at Westridge Marine Terminal. Westridge Marine Terminal currently operates a vapour combustion unit (VCU). Destruction efficiencies for the existing VCU were estimated based on manufacturer design information. The design destruction efficiency for reduced sulphur compounds of 99% was conservatively lowered to 70% to account for the removal of the scrubber upstream of the VCU and resulting higher H_2S concentrations in the inlet stream. Based on preliminary engineering design, the proposed Project design for the new berths includes two new vapour recovery units (VRUs), consisting of a Sulfatreat unit followed by a bed of activated carbon, as well as a new VCU for peak periods and back-up or standby use only when three tankers are berthed. In the absence of specific design information about the new vapour abatement technologies, destruction efficiencies for the proposed VRU were conservatively estimated based on best engineering judgment and it was assumed that the proposed VCU would perform at least as well as the current VCU. Destruction efficiencies associated with the existing and proposed vapour abatement technologies are summarized in Table 3.19. A collection efficiency of 90% was assumed for all technologies. Emissions not collected or destroyed were assumed to be emitted to the atmosphere.

Table 3.19: Destruction Efficiencies Associated with Vapour Abatement Technologies

Contaminant	VCU	VRU
TOC	98%	75%[(a)]
TRS	70%	80%

Note: (a) The 75% destruction efficiency only applies to VOCs other than methane and ethane

The current VCU and proposed backup VCU function by combusting the vapors from marine loading/unloading operations along with propane fuel gas, thereby producing combustion emissions. Emissions of CO, NO_X and soot were estimated following the methodology in Chapter 13.5 of AP-42 (US EPA 1991). Emissions of CO_2 and SO_2 were estimated as a stoichiometric product of TOC, H_2S and mercaptan combustion. Due to the high energy content of the marine loading vapors and a relatively high branched hydrocarbon content, soot formation in the VCU was assumed to be representative of an average smoking flare. Soot formation is expressed on the basis of combustion exhaust flow rate, which was estimated assuming stoichiometric combustion in air. All soot was conservatively assumed to be $PM_{2.5}$.

In addition to fugitive emissions during loading/unloading operations, there are combustion emissions from marine vessels hotelling at berth at the Westridge Marine Terminal. Combustion emissions from marine vessels are discussed in the Marine Air Quality and Greenhouse Gas - Marine Transportation Technical Report (Volume 8B).

Pump Stations

Fugitive TOC emissions from pump stations were estimated following the methodology described in *A Recommended Approach to Completing the NPRI for the Upstream Oil and Gas Industry* (CAPP 2007). Emission rates for the light liquid oil category were chosen. Cold Lake Blend, with a Reid vapour pressure of 51.7 kPa, falls under this category, as do most other products delivered in the Trans Mountain Pipeline. Equipment counts for existing conditions and Project expansion were obtained from available valve numbering diagrams from KMC.

VOC Speciation

Emissions of total VOCs and individual COPCs (including individual VOCs, polycyclic aromatic hydrocarbons [PAHs], metals, H_2S, and mercaptans) were estimated by applying speciation profiles to estimated TOC and PM emissions. The speciation profile for Cold Lake Blend was based on a combination of flux chamber sampling results (RWDI 2013), KMC Petroleum Properties 2011 (Kozak pers. comm.) and Maxxam Analytics liquid laboratory analysis, converted to a vapor speciation using Raoult's Law. Speciation profiles for all other sources were obtained from the California Air Resources Board (CARB 2013), the US EPA SPECIATE 4.3 database (US EPA 2011), AP-42, and other published literature. Since the speciation profiles in each of these information sources were developed based on different studies, the compounds included in the profiles may differ. To be conservative, the final speciation factors used in this assessment were based on the maximum value listed amoung all speciation factors available for the particular source and species. A summary of the speciation profile sources is provided in Table 3.20.

Table 3.20: Speciation Profile Sources used for VOCs and COPCs

Source Category	Basis of Speciation	Speciation Profile Sources
Cold Lake Blend Vapors	TOC	Flux chamber sampling KMC Petroleum Properties 2011 Maxxam Analytics laboratory analysis
Peace River Sour Vapors	TOC	KMC Petroleum Properties 2011 Crude Quality Inc. 2013
Ethanol Blend Gasoline Vapors	TOC	CARB 2013 (profile # 906) United States Department of Health and Human Services 1995
Jet Fuel Vapors	TOC	CARB 2013 (profile # 100) American Petroleum Institute 2010
Line Heaters	TOC (hydrocarbons); TSP (metals)	US EPA 2011 (profile # 92112) CARB 2013 (profile # 3) US EPA 1998

Note: RWDI Flux chamber report is provided in TERMPOL Section 3.1 Volume 8C

3.4.3. Emissions Estimation - Greenhouse Gases

The assessment of GHG emissions is comprised of three assessment cases:

- The assessment of existing conditions comprises GHG emissions from current operations of the Trans Mountain Pipeline and its effect on climate change. The assessment of GHG emissions is based on KMC's annual GHG emissions Inventory for the three-year period from 2010 through 2012 provided by Trans Mountain, and comparison to national, provincial and the LFV emissions. (Section 4.2.2);

- The Project effects assessment – Construction and Operations includes all proposed design changes associated with the Trans Mountain Expansion Project and reflects the effects of the Project alone (Section 6). This assessment includes estimating total emissions from construction, annual emissions from operations and comparison with provincial, national and LFV emissions, as well as effect of the Project on climate change over its lifetime; and,

- The cumulative effects assessment includes all GHG emissions from future operations of the expanded pipeline; no other planned projects are included in the cumulative effects assessment for GHG emissions, because the spatial boundaries for GHG emissions are global and all global

GHG emissions would have to be included; instead, the pipeline's total emissions will be compared to Federal and Provincial totals (Section 8).

3.4.3.1. General Methodology

Alberta's Specified Gas Emitters Regulation (SGER, 2007) requires accounting of six GHG or classes of GHG: including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFC), and hydrofluorocarbons (HFC). The activities related to operations of the existing pipeline, the proposed expansion and associated facilities, and the construction activities related to the Project will be responsible for emissions of CO_2, CH_4, and N_2O. No direct emissions of SF_6 are known to occur as a result of the Project and the existing conditions. However, consumption of electricity leads to indirect emissions of SF_6. These emissions are included in the consumption intensities, which are reported in Canada's Greenhouse Gas Inventory (EC, 2013e), and used in this report to estimate GHG emissions due to electricity consumption. No processes associated with Project activities are known to emit PFC or HFC. Total GHG emissions are expressed in CO_2 equivalent (CO_2e), which is each gas's total emissions multiplied by its 100-year global warming potential (GWP). Global warming potentials compare the integrated radiative forcing over a specified period. The GWP are shown in Table 3.21 and were taken from SGER 2007.

Table 3.21: Global Warming Potentials of Greenhouse Gases

Specified Gas	Chemical Formula	GWP (100-Year Horizon)
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310

Source: Specified Gas Emitters Regulation (2007).

GHG emissions from Trans Mountain facilities will disperse, mix with global emissions, and contribute to global climate change. Although the GHG emissions from any single industrial activity contribute very little to global emissions and climate change, this contribution is quantifiable. It was demonstrated by Matthew and Weaver (2010) that global temperature increases are directly related to cumulative emissions of GHG. The effect of GHG emissions on climate change can be assessed using the methods discussed in 2011 report of National Research Council (NRC 2011). In this report, based on the most current modelling results, NRC estimated an approximately linear warming per cumulative emissions ranging from roughly 0.27°C to 0.68°C per 1,000,000 Mt CO_2e, or roughly 20 years of annual global GHG emissions. The NRC further pointed out that other changes in the climate system and physical environment (e.g., precipitation changes and decreases in crop yields) are likewise proportional to cumulative GHG emissions, and global temperature increase. The low and high estimated changes in some of the environmental parameters per 1 °C of global temperature increase are presented in Table 3.22.

Table 3.22: Changes in Some Environmental Parameters Per 1 °C of Global Warming

Environmental Parameter	Low Estimate	High Estimate
Change in precipitation	5%	10%
Increase in heavy rainfall	3%	10%
Yield reduction in a number of crops	5%	15%
Changes in streamflows	5%	10%
Decrease in the extent of annually averaged Arctic sea ice	15%	25%
Decrease in the extent of September Arctic sea ice	15%	25%

On the basis of these expected changes per cumulative GHG emissions, the effect of the Project on climate change can be quantified.

Emission Sources

The Greenhouse Gas Protocol (World Resources Institute, 2013) categorizes GHG emissions into direct and indirect emissions. Direct emissions occur from sources that are owned or controlled by the reporting entity (e.g., from on-site equipment), and indirect emissions are emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity (e.g., from consumption of purchased electricity, heat, or steam).

The only significant source of indirect GHG emissions is electricity consumption at the facilities, the main portion of which is used by pump assemblies to facilitate the flow of products through the pipeline. Electricity related emissions include emissions from fossil fuel combustion, unallocated energy from transmission line losses, metering differences and other losses, and emissions of SF_6 from gas handling and transferring operations, electrical equipment operation, and from equipment mechanical failures. These emissions are estimated for each province in terms of consumption intensity, which is the total CO_2e emissions per kilowatt-hour of electric energy delivered, and are reported in Canada's Greenhouse Gas Inventory (EC, 2013e) every year. Consumption intensities are used to estimate indirect GHG emissions associated with electricity consumption from the existing Trans Mountain assets and the Project.

Typically, major sources of direct emissions are land clearing, stationary and mobile combustion, industrial processes and fugitive emissions. Right of way and site preparation involve logging. GHG emissions from the burning of timber that will not be salvaged depend on the carbon content of the forested land to be cleared, and are often the major source of carbon release in construction activities. Identified sources of *stationary combustion* in the Project are fuel combustion for space heating, cooking, and similar activities in facilities and worker camps categorized under space heating, and fuel combustion by off-road equipment deployed during the construction period. Also vapor combustion and vapor reduction units at the Westridge Marine Terminal are sources of GHG emissions as they use fuel gas to treat the captured fugitive vapor. *Mobile combustion* sources include all vehicles and aircraft that are used in construction or for transportation purposes during construction and normal operations. The Project is not associated with any known *industrial processes* emitting GHGs. *Fugitive emissions* are other vented or leaked non-combustion-related GHG emissions. Products carried and handled by Trans Mountain contain trace levels of GHGs, and small amounts might be released through fugitive or process emissions (e.g., CH_4 and formation of CO_2). The main sources of fugitive emissions are venting losses from storage tanks and small fugitive leaks from connectors, valves, and pumps at Trans Mountain facilities. Since pipeline segments are buried and sealed underground, no fugitive emissions are expected to occur at pipeline segments under normal operating conditions. In case of an accidental spill, small amounts of GHGs (e.g., CH_4 and formation CO_2) associated with the product would be released, but would be classified as de-minimus (i.e., intermittent, short term or transient in nature) compared with GHG emissions from facility operations.

3.4.3.2. Existing Emissions from Trans Mountain Assets

GHG emissions due to operations of the existing Trans Mountain Assets were estimated based on the emissions in the previous years. Trans Mountain provided KMC's GHG inventory for the years of 2010 through 2012, along with a spreadsheet representing the details of GHG emissions calculations. The spreadsheet includes information about various activities at Trans Mountain facilities that lead to direct or indirect GHG emissions. Where detail information about emission sources was not available, RWDI made the most appropriate and conservative assumptions to allocate the emissions to pipeline segments and facilities. Also where RWDI had access to more accurate information regarding emissions (e.g., modelling results for fugitive emissions), those emission were selected to estimate GHG emissions.

The estimated annual GHG emissions for the years from 2010 through 2012 were averaged to obtain an estimate of the future emissions of the existing pipeline segments and facilities.

Indirect Emissions: Electricity Consumption

Trans Mountain provided annual electricity used at each of its pump stations (Table A.1-1 in Appendix A), and in addition, for BC only, total Provincial miscellaneous electricity consumption for years 2010 to 2012. The latter was divided equally between the eleven pump stations in BC and added to the station specific annual electricity used. Similarly for Trans Mountain terminals, electricity consumption at each terminal was provided (Table A.1-2 Appendix A).

Indirect GHG emissions were then calculated based on consumption intensities of Alberta and BC grids indicated in Table A.1-3 in Appendix A. For the Jasper pump station, which is not connected to the Alberta grid, the consumption intensity was provided by ATCO Electric. Annual emissions of 2010 to 2012 were calculated and averaged in Tables A.1-4 and A.1-5 to obtain estimates of the indirect GHG emissions due to the operations of the existing Trans Mountain assets.

Direct Emissions: Space Heating

For the period from 2010 to 2012, Trans Mountain provided total annual GHG emissions due to combustion of natural gas for space heating and similar activities at all Alberta and BC facilities. Also, annual natural gas consumption for each facility was given. Based on these facility specific fuel consumptions, provincial totals are allocated to the facilities in each province. For BC, total annual GHG emissions due to combustion of propane for space heating purposes were also given. These emissions were allocated equally to BC facilities that were not listed in natural gas consumption list. Detailed information and the proceeding calculations are provided in Tables A.1-6 through A.1-10 in Appendix A.

Direct Emissions: Fleet

Trans Mountain provided annual total GHG emissions caused by consumption of jet fuel for aircrafts and gasoline, diesel, and propane for vehicles in Alberta and BC for the years 2010 to 2012.

Jet fuel is combusted in aircrafts. In the absence of more detailed consumption information, it is assumed that all flights are for survey purposes related to pipeline segments only, and that fuel consumption for each pipeline segment is proportional to pipeline length; therefore, jet fuel GHG emissions were allocated to pipeline segments using a weight factor proportional to each segment's length.

Gasoline, diesel and propane are combusted in vehicles. The percentage of vehicle activities serving pump stations is unknown but likely very small compared to terminals. Therefore, the associated GHGs were assumed to be emitted from terminals, only. In Alberta, all emissions were allocated to the Edmonton Terminal, and in BC, the emissions were allocated to the Kamloops Pump Station, the Sumas, Burnaby, and Westridge Marine Terminals equally. Kamloops is a contiguous facility, which includes pumps and storage tanks, and therefore, it is considered to contribute to fleet emissions similar to terminals. Where the provincial breakdown of total emissions was not provided, emissions were divided equally between the two provinces, pursuant to available data. Finally, the three annual totals were averaged over the period from 2010 to 2012 to reduce the error caused by year-to-year variability. The summary of fleet emissions is provided in Tables A.1-11 and A.1-12 of Appendix A.

Direct Emissions: Fugitives

Fugitive emissions due to Trans Mountain activities are the result of venting (standing and working) losses from storage tanks and small fugitive leaks from connectors, valves and pumps at Trans Mountain facilities. GHGs are present in trace amounts in the fugitive emissions and also, are the byproduct of complicated chains of reactions resulting in formation of CO_2. Trans Mountain provided a conservative estimate for the amount of CH_4 and formation CO_2 that is emitted per tonne of fugitive VOCs in its facilities. (Table A.1-13 in Appendix A).

Annual fugitive VOC emissions from storage tanks, pumps, valves, and connectors in Trans Mountain facilities are estimated using detailed information about facility plans and tank characteristics in Section 5.2, and Appendix F. Total GHG emissions for Trans Mountain facilities are calculated based on these results in Tables A.1-14 and A.1-15 in Appendix A.

Direct Emissions: Vapor Combustion

Vessel loading only occurs at Westridge Marine Terminal, and these emissions are captured and sent to a vapor combustion unit where they are combusted with addition of propane fuel gas. The emissions from the vapor combustion unit, as well as the fugitive emissions from product loading to ships are discussed and calculated in detail in Section 4.2.1.5. The results are used to estimate the corresponding GHG emissions.

3.4.3.3. **Project Effects Assessment – Project Construction**

Emissions from pipeline construction activities were estimated where information was available. All pipeline construction emissions will be intermittent and limited in duration. Since the construction schedule is subject to change, construction related emissions were not estimated on an annual basis. Instead, these emissions are estimated at overall totals. Construction related emissions are caused by two main sources: land clearing and operation of construction equipment.

Land clearing emissions refer to the CO_2 equivalent of the carbon content of the forest lands that will be cleared for right of way and site preparation. Trans Mountain is committed through its Environment Protection Plan (EPP) to comply with local government bylaws, the *Forest and Prairie Protection Act* (Alberta Reg. 310/72) and BC *Open Burning Smoke Control Regulation* and the *Forest Fire Prevention and Suppression Regulation* when burning slash. In accordance with applicable provincial regulations pertaining to mulching depth requirements, not all non-merchantable timber can be disposed of by mechanical means, therefore, slash burning is required. Since the maximum depth of mulch will not exceed 5 cm or will be in accordance with the applicable provincial regulations, whichever is less, any remaining vegetation and non-salvageable timber not retained for rollback will be burned. In the absence of any information about potential re-foresting and detailed information regarding any planned salvage logging or harvesting during Project construction, it is conservatively assumed that all the biomass content of the cleared lands will be burnt. Total fuel loading for the construction of the pipeline segments was estimated based on the information provided by Trans Mountain. This information includes the estimated total biomass (fuel loading) for the BC portion of the Project based on the BC Vegetation Resources Inventory (VRI 2013), and assuming a 45 meter pipeline corridor, and only accounts for live tree and above ground components of the forest. In the absence of more detailed information, RWDI assumed a uniform fuel loading per kilometer of pipeline construction, and allocated the resulting emissions to pipeline segments, accordingly. Also, Trans Mountain provided the total estimated biomass in the Alberta portion of the pipeline's right of way, which corresponds to total fuel loading of Edmonton to Hinton. More details on methods of biomass estimates in Alberta and BC are provided in Sections A.2 and A.3 of Appendix A. The emission factors for open combustion of biomass were obtained from Canada's National Emission Inventory (EC 2005), and presented in Table A.2-1 of Appendix A. Note that the National Emission Inventories after 2005 do not provide emission factors for prescribed burning any longer, because these emissions are now estimated in the larger context of modelling Land Use, Land-Use Change and Forestry (EC 2013e). No information regarding land clearing activities for the construction of the pump stations, tank installation, and the expansion of the Westridge Marine Terminal were provided; therefore, the corresponding emissions are not estimated in this report.

Operation of construction equipment results in GHG emissions due to fuel combustion. For tank installation at Trans Mountain terminals, also for construction activities related to the expansion of the Westridge Marine Terminal, Trans Mountain provided a list of equipment categories that are anticipated to be deployed, along with the estimated hours of operation for each equipment category. For the construction of Pipeline, RWDI made use of the equipment list and the estimated average hours of operation for the construction of the Keystone XL Pipeline Project (TransCanada 2009). Average hours of operation per kilometer of pipeline construction, were then scaled for the lengths of the pipeline segments in the Project. For the segment of Burnaby to Westridge, RWDI used the cumulative length of the two proposed pipelines for the purpose of estimating construction effort. Also, in the absence of any information regarding the construction activities at pump stations, RWDI used the equipment list and estimated hours of operation for the construction of the pump stations using the Keystone XL data. Among the pump stations, the one with the highest emissions was selected to conservatively represent the construction effort (equipment and hours of operation) needed to build a new pump station, or relocate an existing one. It was also assumed that no construction effort is required for potential deactivation of the existing pump stations if further studies indicate that some stations are not required.

Emission factors (emissions per one hour of operation) were obtained from three sources depending on the availability of data: RWDI's emission estimates performed previously for the similar pipeline project of NOVA Gas Transmission Ltd. (NGTL, 2010), Transport Canada's Urban Transportation Emissions Calculator (UTEC, 2013), and Canada's National Marine Inventory (SNC-Lavalin Environment. 2012a). For each equipment category, the most appropriate conservative representative equipment was selected from the aforementioned sources, and the corresponding emission factors were used to estimate GHG emissions. In NGTL 2010, emission factors of the equipment in the off-road mode were calculated using the U.S. Environmental Protection Agency NONROAD model. For on-road equipment in NGTL 2010, emission factors were modeled using MOBILE6 Vehicle Emission Modeling Software, and assuming an average speed of 50 km/h. For the on-road equipment using gasoline, RWDI made use of UTEC 2013, with the most appropriate conservative assumptions to obtain the corresponding emission factors. Emission factors of boats deployed in the construction of the new Berths at the Westridge Marine Terminal were obtained from the 2010 National Marine Emissions Inventory (SNC-Lavalin Environment. 2012a).

3.4.3.4. Project Effects Assessment – Project Operation

Greenhouse gas emissions due to operations of the Project were estimated and reported as annual totals. These estimates were based on the available information regarding project plans for future operations of the Trans Mountain Pipeline. Where this information was not available, RWDI made use of the existing case emissions, and conservative assumptions to provide emissions from the future operations of the Project.

Electricity-related emissions from Project operations were estimated based on the total anticipated electricity consumption at all Trans Mountain facilities in the future, and the current electricity consumption at the existing facilities. The anticipated future consumptions are obtained based on the number and the output horsepower (HP) of the pumps provided by Trans Mountain. It was conservatively assumed that all pumps (except for the spare ones) will work at full capacity at all the times. Based on previous RWDI projects, an efficiency of 63% was assumed for all pumps. The corresponding emissions were then obtained based on the consumption intensities of Alberta and BC obtained from the National Inventory Report (EC 2013). For the Jasper pump station which not connected to the Alberta grid, the consumption intensity is provided by ATCO (Table A.1-3 of Appendix A). The electricity related GHG emissions of the Project, were then obtained by subtracting the electricity-related emissions of the existing facilities from the electricity-related emissions caused by future operations.

It is assumed that the operations of the Project will not affect the space heating activities at existing Trans Mountain facilities; however, there will be additional space heating at the new pump stations. In the absence of any further information, RWDI assumed that the emissions corresponding to space heating at the new pump stations will be similar to the existing emissions of the closest pump station. Also, it was assumed that no space heating activities will occur at the pump stations that will be de-commissioned.

The fleet activities of the Project are mainly for maintenance and inspection purposes. It is anticipated that no net increase in the frequency of these activities will occur as a result of Project operations so no net increase in the fleet-related emission is expected to happen.

The fugitive VOC emissions from storage tanks, as well as connectors, valves and pumps contain trace levels of GHG. RWDI used Trans Mountain's conservative estimate of the amount of CH_4 and formation CO_2 that is emitted per tonne of fugitive VOC to obtain the resulting GHG emissions. Fugitive VOC emissions from the future operations of all Project storage tanks are discussed in detail in Section 0. For pump stations, fugitive VOC emissions from connectors, valves and pumps, are also obtained and discussed in Appendix F. For terminals where detailed valve drawings were not available, RWDI obtained the corresponding emissions by conservatively scaling the existing emissions based on the expansion activities. The contribution of the Project activities to the future emissions is then obtained by subtracting the existing fugitive emissions from the overall future emissions.

Vessel loading only occurs at the Westridge Marine Terminal, and is associated with fugitive emissions from ships at berth. These emissions are considered as a part of terrestrial operations emissions at the Westridge Marine Terminal. The fugitive emissions are captured and sent to a vapour recovery units (VRU) and new removal media, combined with the standby vapour combustion unit (VCU). The emissions from the VRU, VCU, as well as the fugitive emissions from ships are discussed in detail in Section 0. The results were used to estimate the corresponding GHG emissions.

3.4.3.5. Project Effects on Climate Change

It was demonstrated by Matthew and Weaver (2010) that global temperature increases are directly related to cumulative emissions of GHG. In its report, the National Research Council (NRC 2010) estimated, based on the most current modelling results, approximately linear warming per cumulative emissions ranging from roughly 0.27°C to 0.68°C per 1,000,000 Mt CO2e, or roughly 20 years of 2010 annual global GHG emissions. The NRC further pointed out that other changes in the climate system and physical environment (e.g., precipitation changes and decreases in crop yields) are likewise proportional to cumulative GHG emissions. On the basis of these expected changes per cumulative GHG emissions, the effect of the Project on climate change can be quantified and is provided in Section 6.4.

3.4.4. Modelling

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the Air Quality RSAs due to existing and projected future emissions from the Trans Mountain Terminals. CALMET is a meteorological model that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport within CALPUFF. CALPUFF is a multi-layer, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition.

The CALMET/CALPUFF modelling approach, and corresponding assumptions and methodology were summarized in a detailed model plan for the four storage terminals in BC. This model plan was reviewed and updated based on input from Metro Vancouver and the BC MOE and approved in October, 2013. A copy of the approved and signed final model plan is provided in Appendix B.

In addition to the CALMET/CALPUFF dispersion modelling, photochemical modelling was conducted using the Community Multiscale Air Quality (CMAQ) modelling system to provide estimates of secondary smog-related products (ozone and $PM_{2.5}$). A description of the CMAQ model is provided in Appendix C.

3.4.4.1. CALMET

The development of the CALMET model is described in this section. A detailed list of inputs and model switch settings are included in Appendix D, as well as plots of CALMET model output.

Model Period

The CALMET model period for the four storage terminals in BC was January to December, 2011. This represents the most recent complete year of data available when work was started. For the Edmonton Terminal, the CALMET model period was January, 2002, to December, 2006, corresponding to the period of mesoscale meteorological output available in Alberta's Multi-Model Extraction Utility.

Model Domain

The CALMET model domains were set to the 24 km by 24 km Air Quality RSAs defined in Section 3.3. Domain resolution was set at 250 m. In the vertical direction, 10 layers were modeled for the four storage terminals in BC, with the top of each layer set as 20, 40, 80, 160, 320, 500, 1000, 1500, 2200 and 3000 m above ground level. This is consistent with common practice in BC. For the Edmonton Terminal, 12 layers were modeled, with the top of each layer set as 20, 40, 80, 120, 280, 520, 880, 1320, 1820, 2380, 3000 and 4000 m, in accordance with the AESRD *Air Quality Model Guideline* (2013).

Prognostic Meteorology

For the four storage terminals in BC, the CALMET model was initialized using Weather Research and Forecasting (WRF) prognostic model output at 1 km resolution. The WRF model is a mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. It represents the latest numerical weather forecasting model to be adopted by the United States National Weather Service as well as the United States military and private meteorological services.

For the Edmonton Terminal, the CALMET model was initialized using prognostic model output from Alberta's Multi-Model Extraction Utility. This model output is based on the Pennsylvania State University/National Center for Atmospheric Research mesoscale model known as MM5, at a 12 km resolution.

Surface Meteorology

Hourly meteorological data from all known surface stations within the Air Quality RSAs, with the exception of the Edmonton Central station which only measures temperature, were included as input to CALMET. The surface stations are listed in Table 3.23 and are shown in Figure 3.8 to Figure 3.11. Note that the Edmonton International Airport, Kamloops Airport, and Vancouver International Airport stations are located outside the CALMET model domains and are not shown in these figures. These stations were included to provide cloud cover and ceiling height data required for CALMET.

Table 3.23: Surface Stations Used in CALMET

Model Domain	Station Name	Data Provider	Data Period
Edmonton Terminal	Edmonton East	CASA	2002 to 2006
	Sherwood Park	CASA	2002 to March, 2004
	Edmonton McIntyre	CASA	2006
	Edmonton South	CASA	2006
	Edmonton Northwest	CASA	2002 to 2005
	Edmonton International Airport	MSC[a]	2002 to 2006
Kamloops Terminal	Afton	BC MOF[b]	2011
	Kamloops Brocklehurst	BC MOE	January to May, 2011
	Kamloops Fire Station #2	BC MOE	June to December, 2011
	Kamloops Airport	MSC[a]	2011
Sumas Terminal	Abbotsford Central, T33	MV	2011
	Abbotsford Airport	MSC[a]	2011
Burnaby and Westridge Marine Terminals	Mahon Park, T26	MV	2011
	Second Narrows, T6	MV	2011
	Burnaby North, T24	MV	2011
	Capitol Hill, T23	MV	2011
	Kensington Park, T4	MV	2011
	Burmount, T22	MV	2011
	Burnaby Mountain, T14	MV	2011
	Rocky Point Park, T9	MV	2011
	Coquitlam, T32	MV	2011
	Burnaby South, T18	MV	2011
	Vancouver International Airport	MSC[a]	2011

Notes: (a) MSC = Meteorological Service of Canada, a division of Environment Canada
(b) BC MOF = British Columbia Ministry of Forests

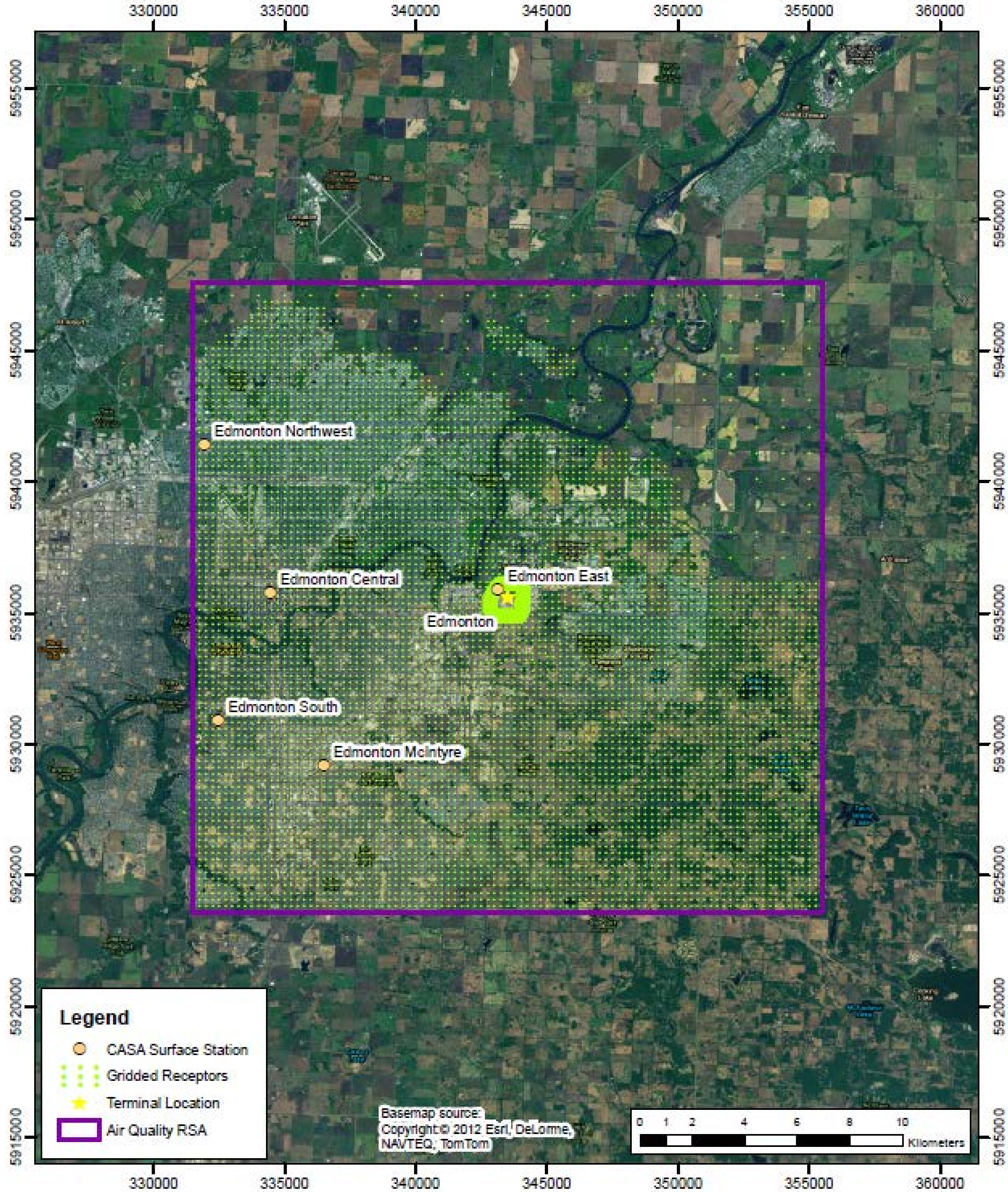

Figure 3.8: Model Receptor Grid and Surface Stations in the Edmonton Terminal RSA

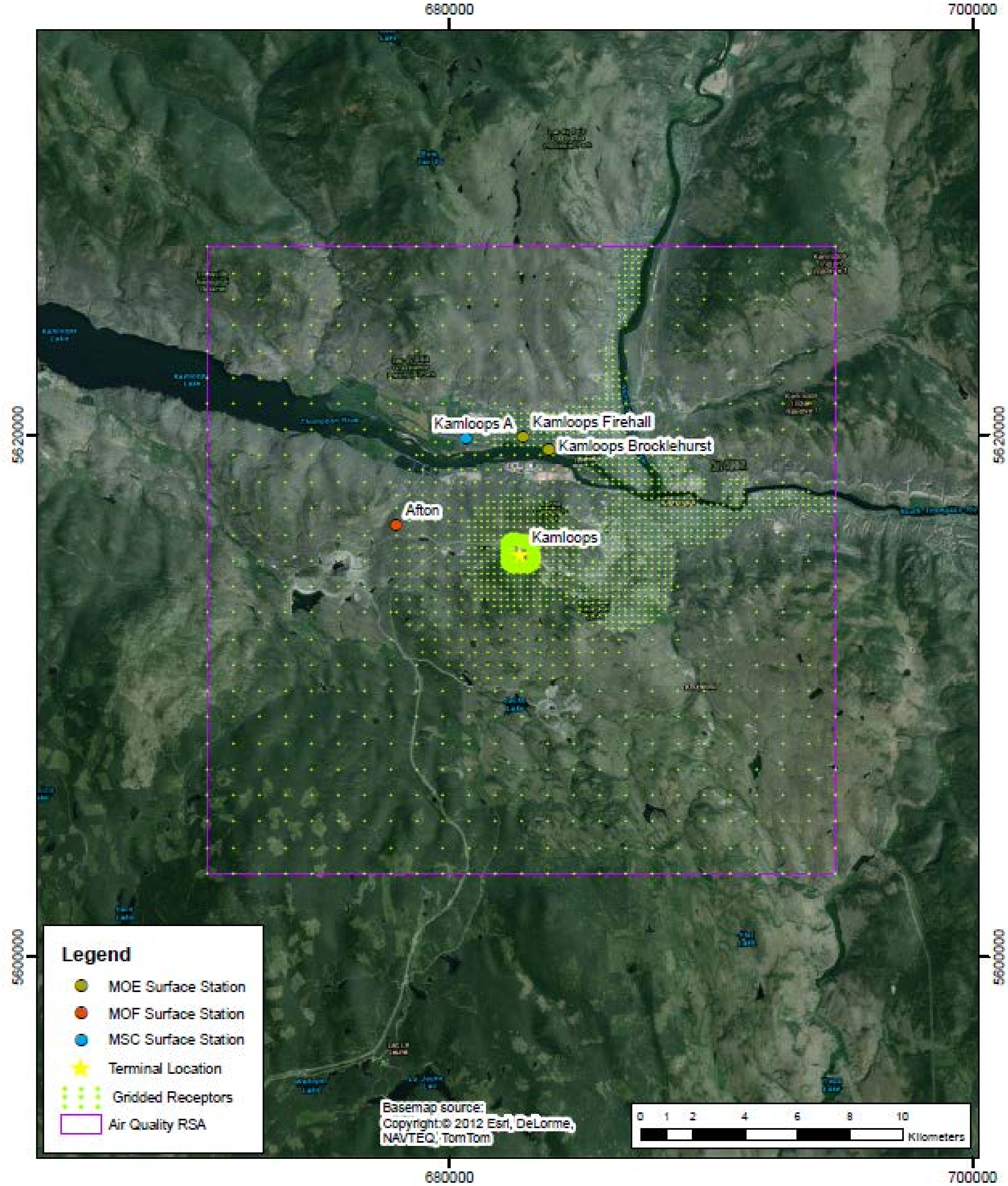

Figure 3.9: Model Receptor Grid and Surface Stations in the Kamloops Terminal RSA

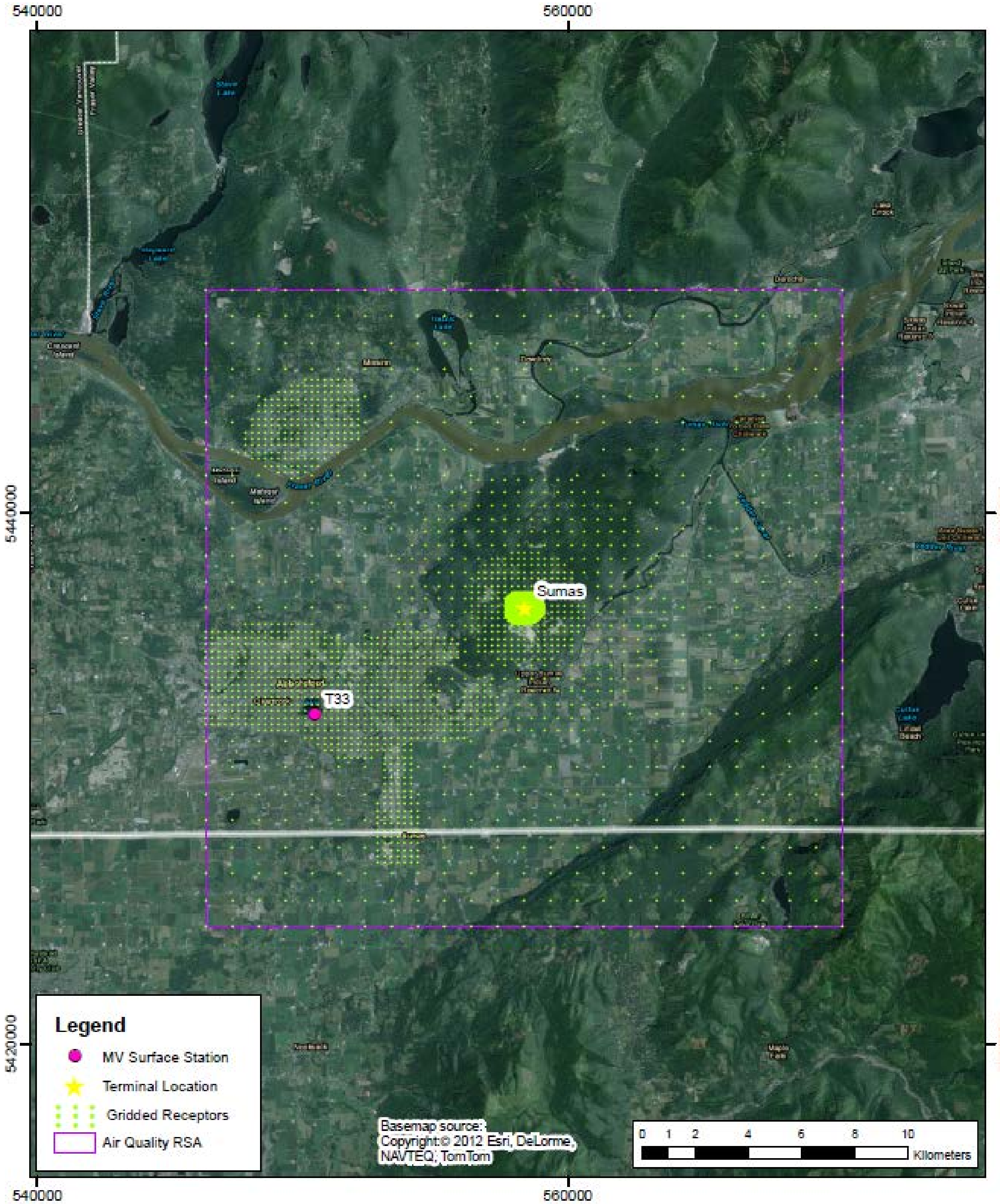

Figure 3.10: Model Receptor Grid and Surface Stations in the Sumas Terminal RSA

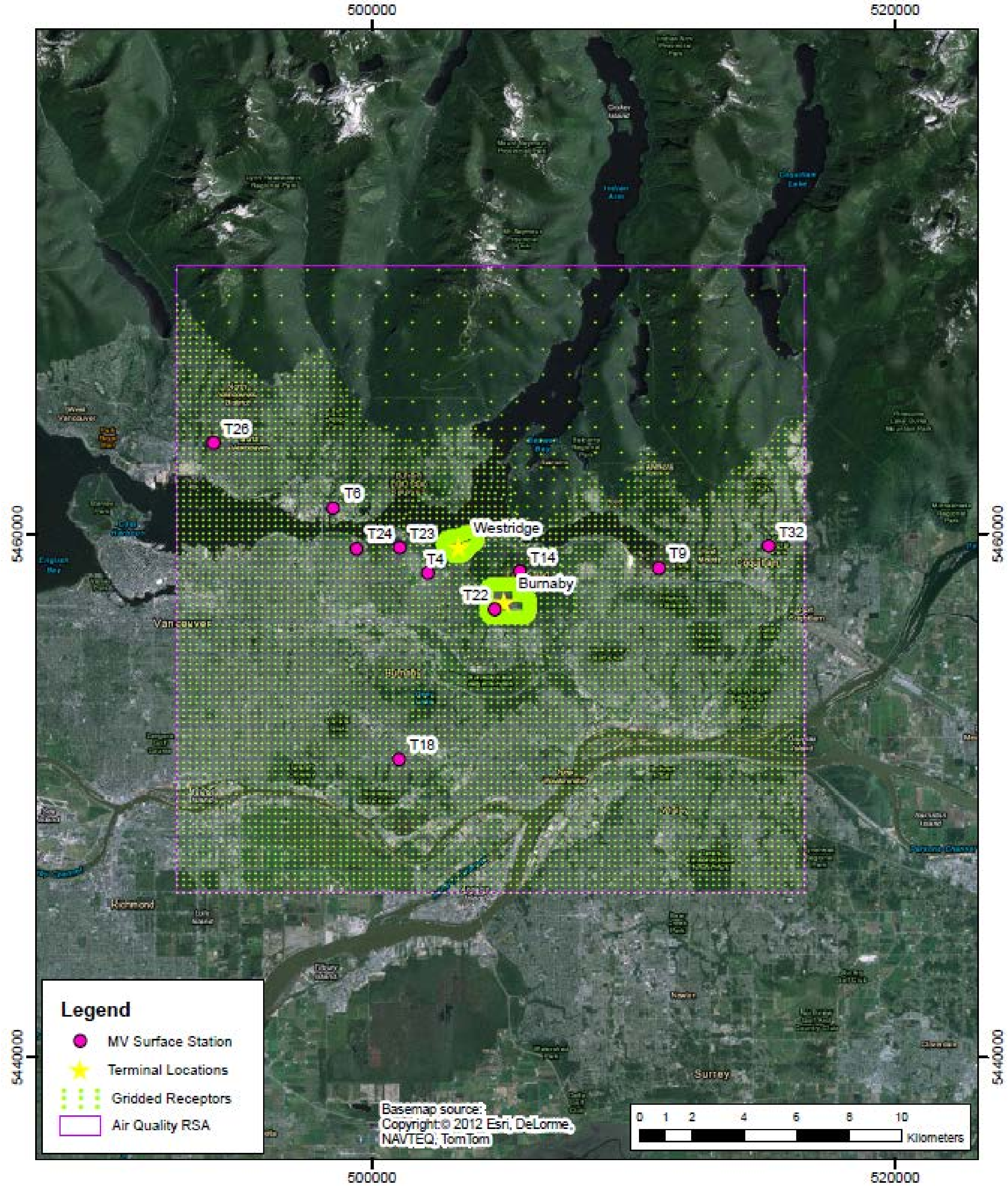

Figure 3.11: Model Receptor Grid and Surface Stations in the Burnaby and Westridge Marine Terminals RSA

Terrain Elevation and Land Use Characterization

Terrain elevations were obtained from 1:50,000 scale Canadian Digital Elevation Data available from GeoBase.

Land use information for the four storage terminals in BC was obtained from baseline thematic maps available from GeoBC. For the Edmonton Terminal, land use information was obtained from the POSTEL Service Centre/MEDIAS-France global land cover dataset.

A portion of the Sumas Terminal RSA lies in the United States (US). Terrain elevations for the US portion of the model domain were obtained from 1 arc-second US Geological Survey Shuttle Radar Topography Mission data. Land use information for the US portion of the Sumas Terminal RSA was obtained from the POSTEL Service Centre / MEDIAS-France global land cover dataset.

Model Switch Settings

A list of the switch settings used in the CALMET model is provided in Appendix D. In general, model switch settings were chosen in accordance with the Alberta *Air Quality Model Guideline* for the Edmonton Terminal and with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* for the four storage terminals in BC (AESRD 2013a, BC MOE 2008).

3.4.4.2. **CALPUFF**

This section outlines the overall CALPUFF methodology. A detailed listing of model switch settings is provided in Appendix D.

Model Domain

The CALPUFF model domains for the storage terminals were the same as the CALMET 24 km by 24 km Air Quality RSAs as defined in Section 3.3. Each domain resolution was set at 250 m.

Receptor Locations

A set of discrete receptors was defined for which ground-level concentrations of CACs and VOCs were predicted using the CALPUFF model. A Cartesian grid of receptors was applied with the following receptor spacing:

- 20-m spacing along the terminal boundary or fenceline,
- 50-m spacing within 0.5 km from the terminal boundary,
- 250-m spacing within 2 km from the terminal boundary,
- 500-m spacing within 5 km from the terminal boundary; and,

- 1000 m spacing for the remainder of the Air Quality RSAs.

Due to the degree of urbanization surrounding the Trans Mountain Terminals, most notably the Edmonton, Burnaby and Westridge Marine Terminals, a maximum receptor spacing of 250 m was set over heavily populated areas.

Since pollutant concentrations within the terminal boundaries may be a concern from an occupational health perspective rather than an environmental perspective, receptors generated from the Cartesian grid described above that are located within the terminal boundaries were removed from the CALPUFF modelling.

Gridded receptors in each study area are illustrated in Figure 3.8 to Figure 3.11. In addition to the gridded receptors described above, a number of discrete receptors were modelled for the Screening Level Human Health Risk Assessment of pipeline and facilities.

Model Switch Settings

A list of the switch settings used in the CALPUFF model is provided in Appendix D. In general, model switch settings were chosen in accordance with the Alberta *Air Quality Model Guideline* for the Edmonton Terminal and with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* for the four storage terminals in BC (AESRD 2013a, BC MOE 2008).

Source Characterization – Line Heaters

The line heaters at the Kamloops Terminal were modelled as point sources. Table 3.24 outlines the point source parameters for each heater. Stack heights, diameters and exit temperatures were specified according to operation manuals for the line heaters and verbal communication with suppliers. Exit velocities were estimated assuming stoichiometric combustion with 5% excess air.

Table 3.24: Point Source Parameters for Line Heaters at Kamloops Terminal

Line Heater	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
PLM Line Heater (DTH-40-100N) 1	5.51	0.10	2.31	477.6
PLM Line Heater (DTH-40-100N) 2	5.51	0.10	2.31	477.6
Central Stores Paint Room Line Heater (Re-Verber-Ray DTHS)	4.16	0.10	1.63	449.8
Heavy Duty Mechanical Line Heater (UA205) 1	4.16	0.10	4.47	449.8
Heavy Duty Mechanical Line Heater (UA205) 2	4.16	0.10	4.47	449.8

Mechanical Maintenance Line Heater (CTH2-100) 1	7.16	0.10	2.18	449.8
Mechanical Maintenance Line Heater (CTH2-100) 2	7.16	0.10	2.18	449.8

Source Characterization – Storage Tanks

Tank emissions were generally modelled in accordance with the *Air Dispersion Modelling Guideline for Ontario* (Ontario Ministry of Environment 2009). Each floating tank was modelled with four point sources around the circumference of the tank to represent the seals between the roof and the wall[3]. Each fixed roof tank was modelled with one point source in the centre to represent the vent.

As discussed in Section 3.4.2, the maximum hourly emission rate used for modelling consists of maximum hourly standing losses as well as maximum hourly working losses. Maximum hourly standing losses were calculated on a monthly basis using the US EPA TANKS model. This was modelled using the option for monthly variation factors in CALPUFF.

The stack height was specified at the tank height. The stack diameter and exit velocity were set to 0.001 m and 0.001 m/s, respectively (Ontario Ministry of Environment 2009). The exit temperature was estimated to be the average of the ambient temperature, for the month with the highest emissions, and the product temperature.

Source Characterization – Marine Vessel Loading

The existing and proposed backup VCUs at Westridge Marine Terminal were modelled as point sources. The stack height, stack diameter and exit temperature of the existing VCU were obtained from KMC (Kozak pers. comm.) and manufacturer information. The exit velocity was estimated assuming stoichiometric combustion of the collected fugitive vapours and propane fuel gas in air. The resulting exit velocity varies depending on the product being loaded. Due to the lack of specific design information, the proposed backup VCU was modelled with the same stack parameters as the existing VCU. Therefore, only the location of the VCU was changed as a part of the Project.

The proposed VRUs at Westridge Marine Terminal were modelled as point sources with stack parameters estimated from photographs of typical VRU systems. The stack height was estimated at 10 m, while the stack diameter and exit velocity were estimated at 0.001 m and 0.001 m/s, respectively, similar to fugitive emissions from storage tanks. The exit temperature was assumed to be the same as ambient temperature.

In addition to the VCUs and VRUs, uncollected fugitive vapours at the berth were also modelled as area sources representing ship tanker holds, with an estimated release height of 17 m and an initial sigma-z of 10 m.

[3] To reduce model run times, the floating roof tanks at Edmonton Terminal were modelled with four point sources around the circumference of the tank, not eight.

The emission rate and VCU exit velocity varies depending on the product being loaded. For the 1-hour to 24-hour averaging periods, modelling was based on heavy crude, represented by Cold Lake Blend, as this is the product to be transported in the proposed pipeline, and therefore, forms the focus of the Project assessment. For the annual averaging period, all products to be loaded at Westridge Marine Terminal were considered, based on the product throughput shown in Table 3.5. Unloading of jet fuel at Westridge Marine Terminal was also considered for the annual averaging period.

Source Characterization – Marine Vessel Exhaust

Combustion emissions from marine vessels hotelling at berth at the Westridge Marine Terminal were modelled as point sources. The stack height was selected to represent a typical exhaust stack from an Aframax vessel, and was estimated based on drawings from KMC. Due to the lack of specific information pertaining to the Aframax vessels that may call at the Westridge Marine Terminal, the remaining stack parameters represent a bulk average for all marine vessels, as recommended by the US EPA, CARB, and Environment Canada (Boulton *et al.* 2008). Stack parameters for marine vessels hotelling at berth are summarized in Table 3.25.

Table 3.25: Point Source Parameters for Marine Vessels Hotelling at Berth

Parameter	Value
Stack Height (m)	37.0
Stack Diameter (m)	0.80
Exit Velocity (m/s)	25.0
Exit Temperature (K)	555.2

Building Effects

Buildings and other structures, including tanks, located close to point sources may influence the dispersion of emissions. The effect of large buildings and structures at the Trans Mountain Terminals, on the modelled point sources was incorporated using the Building Profile Input Program Plume Rise Model Enhancement (BPIP-PRIME) algorithm. The algorithm explicitly treats the trajectory of the plume near the building, and uses the position of the plume relative to the building to calculate interactions with the building wake. All building dimensions were obtained from KMC (Kozak pers. comm.).

Chemistry

The CALPUFF model has the ability to consider the chemical transformation of SO_2 to sulphates (SO_4), and NO_X to nitrates (NO_3) and nitric acid (HNO_3). CALPUFF v6.42, used for this assessment, now includes three chemical reaction schemes. Based on recommendations from the BC MOE, the new RIVAD/ISORROPIA scheme was used, as this module includes a treatment for inorganic gas-particle equilibrium and studies show this new module can avoid over-predictions in nitrate concentrations sometimes seen in the other chemical reaction schemes.

The RIVAD/ISORROPIA chemical reaction scheme requires background concentrations of ozone and ammonia. For this assessment, hourly ozone concentrations concurrent to the meteorological time span were input to the model, along with monthly ammonia concentrations, based on representative monitoring data, as outlined in Table 3.26. Since no nearby ammonia monitoring data could be found for the Kamloops Terminal RSA, monitoring data from Coffeyville, Kansas was used. This represents the nearest station with a surrounding land use mix (e.g., urban, agricultural) similar to the Kamloops Terminal RSA.

Table 3.26: Monitoring Stations for Background Ozone and Ammonia Concentrations

Study Area	Monitoring Station	Pollutant	Data Period
Kamloops Terminal RSA	Kamloops Brocklehurst (BC MOE)	Ozone	January to May, 2011
	Kamloops Fire Station #2 (BC MOE)	Ozone	June to December, 2011
	Coffeyville (National Atmospheric Deposition Program)	Ammonia	November, 2007, to 2011
Burnaby and Westridge Marine Terminal RSA	Burnaby Kensington Park (MV)	Ozone	2011
	Port Moody (MV)	Ozone	2011
	Coquitlam (MV)	Ozone	2011
	North Vancouver Mahon Park (MV)	Ozone	2011
	Second Narrows (MV)	Ozone	2011
	Burnaby South (MV)	Ozone	2011
	Burnaby South (NAPS)	Ammonia	2009 to 2011

Wet and Dry Deposition

Wet and dry deposition was enabled for all pollutants in CALPUFF. Deposition of nitrogen and sulphur gases and particles (primary and secondary) was modelled using the parameters shown in Table 3.27 to Table 3.29. These deposition parameters were derived for a Trace Metal and Air Contaminant report (RWDI 2007) based on values provided by ENSOR International from their review of the Design Institute for Physical Properties Data of the American Institute of Chemical Engineers data bank and the US EPA human health risk assessment protocols.

Due to the lack of specific size and reactivity information, dry deposition of PM and VOC was modelled using bulk deposition velocities. A bulk deposition velocity of 1.67 cm/s was used for TSP and PM_{10}, and a bulk deposition velocity of 0.167 mm/s was used for $PM_{2.5}$ (Tombach and Brewer 2005). For VOC, a bulk deposition velocity of 0.5 cm/s was used, based on the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA 2005).

Table 3.27: CALPUFF Dry Deposition Parameters for Gases

Parameter	SO_2	NO	NO_2	HNO_3
Diffusivity (cm^2/s)	0.1372	0.2203	0.1585	0.1041
Alpha star	1000	1.0	1.0	1.0
Reactivity	8.0	2.0	8.0	18
Mesophyll resistance (s/cm)	0.0	94	5.0	0.0
Henry's Law coefficient	0.033	18	3.5	8×10^{-8}

Table 3.28: CALPUFF Dry Deposition Parameters for Particles (in μm)

Parameter	SO_4^{2-}	NO_3^-
Geometric mass mean diameter	0.48	0.48
Geometric standard deviation	2.0	2.0

Table 3.29: CALPUFF Wet Deposition Parameters (in s^{-1})

Pollutant	Scavenging Coefficient in Liquid Precipitation	Scavenging Coefficient in Frozen Precipitation
SO_2	3.21×10^{-5}	0.0
SO_4^{2-}	1.0×10^{-4}	3.0×10^{-5}
NO	2.85×10^{-5}	0.0
HNO_3	6.0×10^{-5}	0.0
NO_3^-	1.0×10^{-4}	3.0×10^{-5}
TSP	1.0×10^{-4}	3.0×10^{-5}
PM_{10}	1.0×10^{-4}	3.0×10^{-5}
$PM_{2.5}$	1.0×10^{-4}	3.0×10^{-5}

3.4.4.3. Model Output Interpretation

To understand the contribution of various source groups, and to enable scaling of model results to predict maximum concentrations of all individual COPCs, emission sources were grouped into numerous model runs based on the speciation profiles discussed in Section 3.4.2.2. Results for all model runs for each source group were summed to determine the combined effects of all sources within each Air Quality RSA.

Determination of Combined Effects for CACs and Total VOC

The CALSUM post-processing software was used to sum the predicted concentrations at each receptor from each of the model runs to obtain the predicted concentrations from the combined effect of all emission sources within each Air Quality RSA.

Since the CALPUFF modelling was based on peak hourly emission rates, a direct summation of the results from all model runs yielded maximum expected 1-hour average concentrations. To estimate annual average concentrations, scaling factors were applied in CALSUM to account for total product throughput at the Trans Mountain Terminals.

The CALPUFF dispersion model simulates and predicts the formation of sulphates and nitrates. Predicted concentrations of sulphates and nitrates were combined using the POSTUTIL post-processing software to estimate secondary $PM_{2.5}$. The POSTUTIL post-processing software was also used to combine predicted concentrations of secondary $PM_{2.5}$ with predicted concentrations of primary PM to estimate total PM.

The CALPOST post-processing software was then used to extract the maximum predicted concentrations of CACs associated with operations at the Trans Mountain Terminals.

NO_X to NO_2 Conversion

Emissions of NO_X from the Trans Mountain Terminals are comprised of NO and NO_2. The primary emission is in the form of NO with reactions in the atmosphere resulting in the conversion of NO to NO_2. In order to use the RIVAD/ISORROPIA chemical reaction scheme, individual emissions of NO and NO_2 are required. For this assessment, it was assumed that 90% of the NO_X emissions would be in the form of NO, and 10% would be in the form of NO_2.

In light of over-predictions of NO_2 in the higher concentration range seen in previous studies, and to more accurately account for the conversion of total atmospheric NO_X, predicted NO and NO_2 concentrations were combined using the POSUTIL post-processing software, added to background NO_X concentrations (see Section 3.4.4.2), then converted to NO_2.

According to the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008), the first and most conservative method of estimating NO_2 is to assume 100% conversion of NO_X into NO_2. If a more accurate estimate is desired, the ambient ratio method or the ozone limiting method may be used. The ambient ratio method is recommended in areas where representative NO_X and NO_2 ambient monitoring data are available. For this assessment, NO_2 concentrations were estimated using the ambient ratio method, based on the ambient monitoring data discussed in Section 3.4.1.2.

The ratio of 1-hour and 24-hour NO_2/NO_X versus total NO_X, based on ambient monitoring data for the Kamloops Terminal RSA are shown in Figure 3.12 and Figure 3.13. The ratio of 1-hour and 24-hour NO_2/NO_X versus total NO_X, based on ambient monitoring data for the Burnaby and Westridge Marine

Terminals RSA are shown in Figure 3.14 and Figure 3.15. An exponential curve was fitted to the upper-envelope of the scatter plots, as shown in the figures. The maximum NO_2/NO_X ratio was set to 1 and a minimum NO_2/NO_X ratio was set to 0.1, as per the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008). For the annual averaging period, a single NO_2/NO_X ratio of 0.69 was used for the Kamloops Terminal RSA, and a single NO_2/NO_X ratio of 0.73 was used for the Burnaby and Westridge Marine Terminals RSA, based on the average of all ambient monitoring data.

There are no CACs from operations at the Edmonton or Sumas Terminals, and therefore, NO_X to NO_2 conversion is not necessary for these Air Quality RSAs.

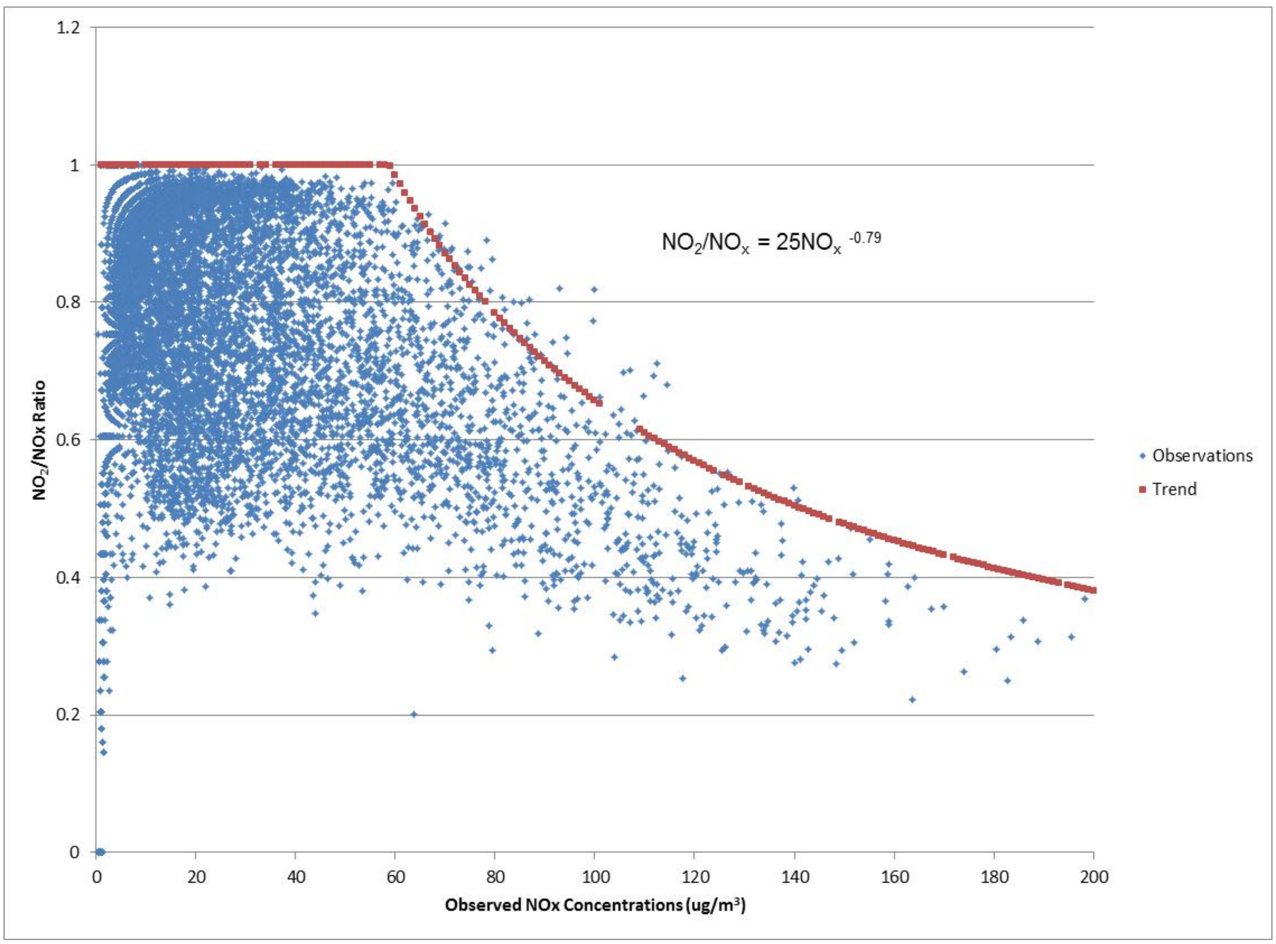

Figure 3.12: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 1-Hour Observations for the Kamloops Terminal RSA

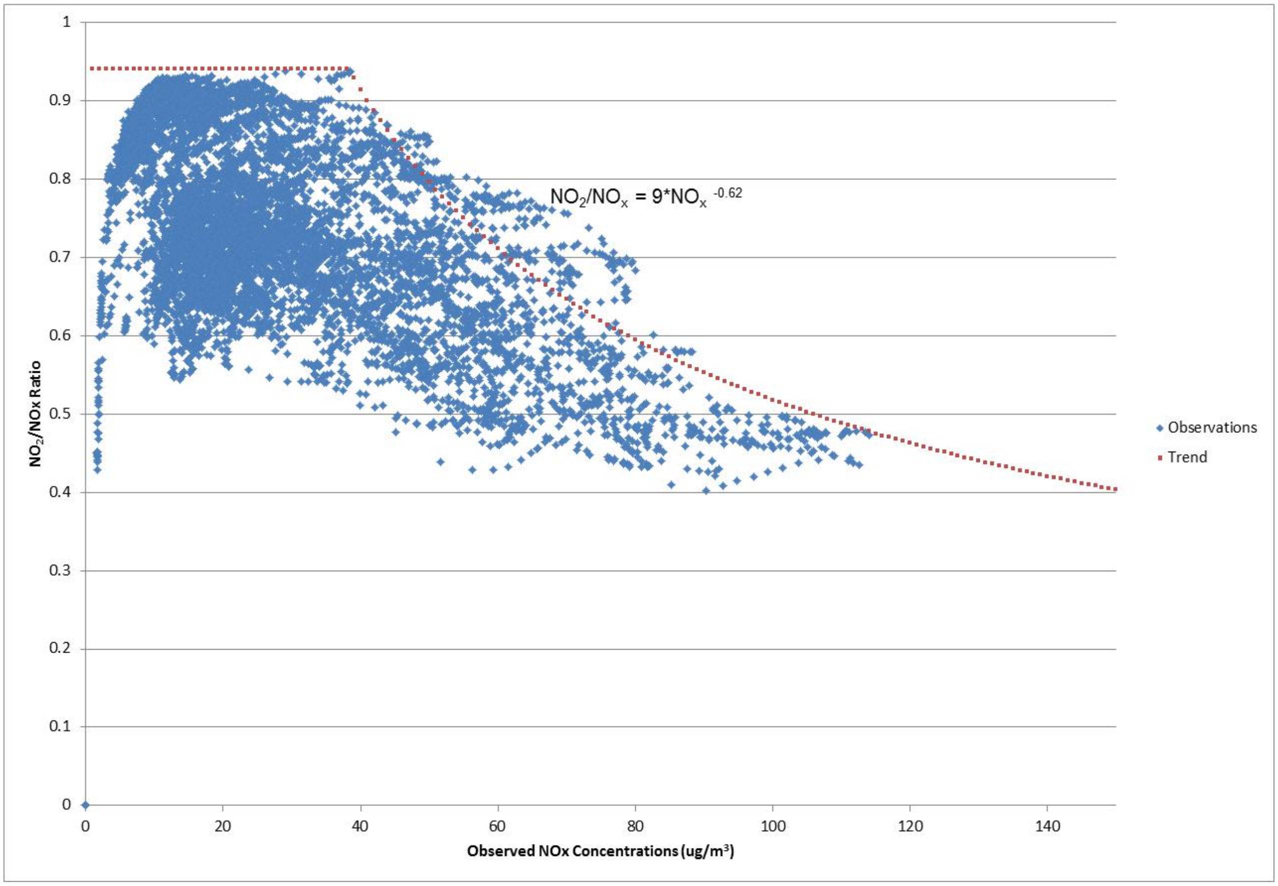

Figure 3.13: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 24-Hour Observations for the Kamloops Terminal RSA

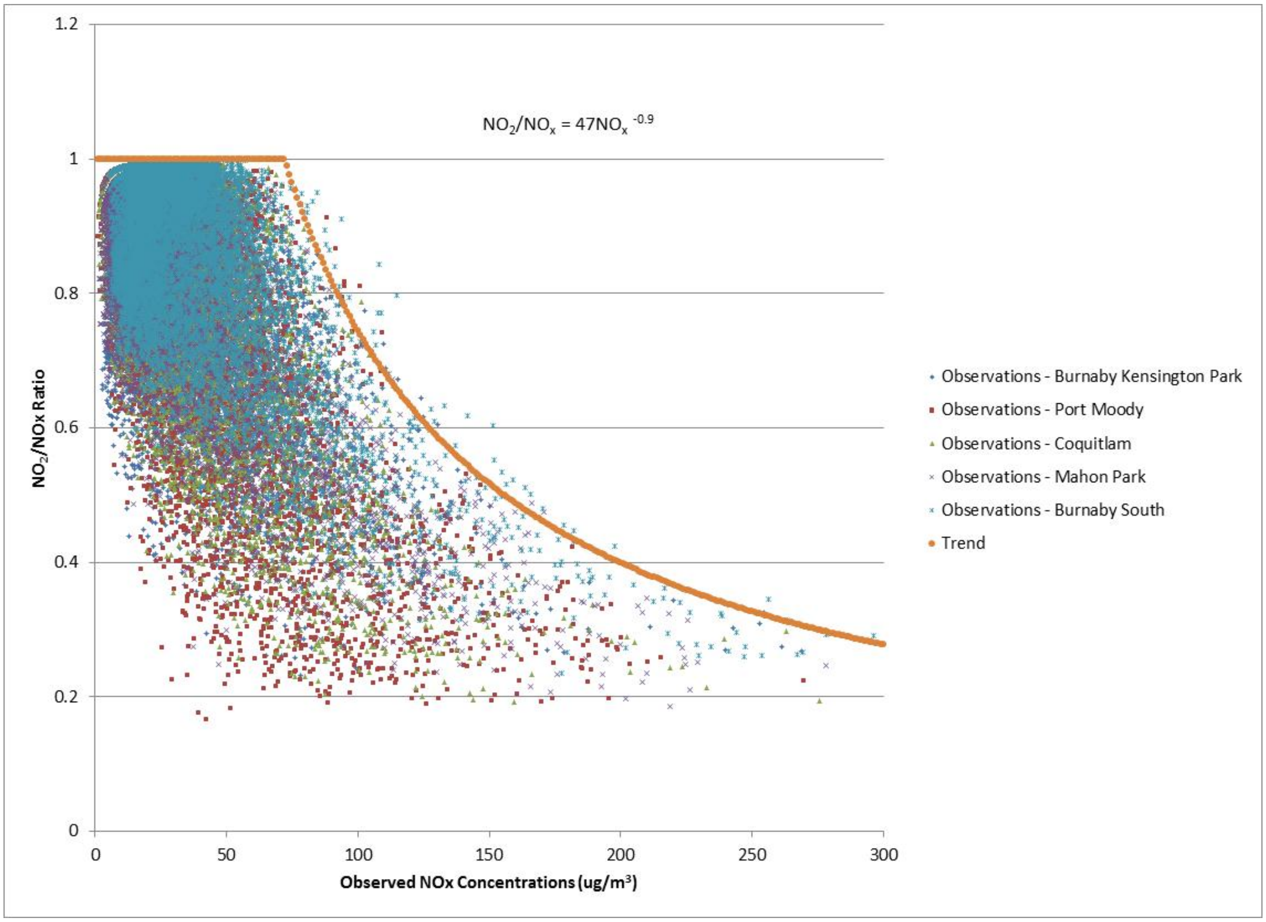

Figure 3.14: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 1-Hour Observations for the Burnaby and Westridge Marine Terminals RSA

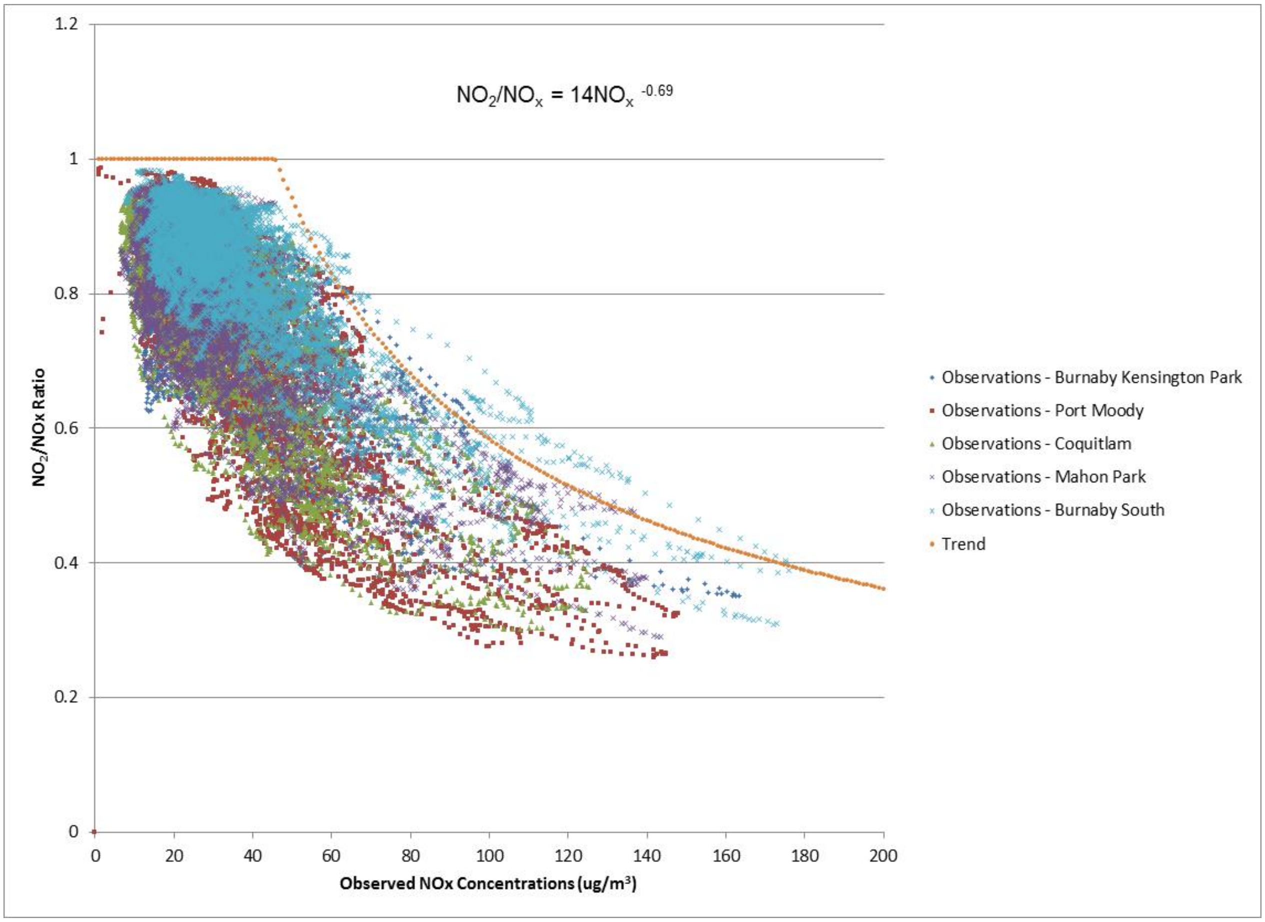

Figure 3.15: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 24-Hour Observations for the Burnaby and Westridge Marine Terminals RSA

VOC Speciation

Due to the number of COPCs required for the Screening Level Human Health Risk Assessment of Pipeline and Facilities, it was impractical to model each of the COPCs directly in CALPUFF. Instead, maximum predicted concentrations of individual COPCs were estimated by scaling the VOC and total TSP concentrations predicted by CALPUFF for each source category, using the speciation profiles discussed in Section 3.4.2.2.

For each receptor, the maximum concentration of each COPC was calculated using the following equation:

$$\text{Maximum COPC}_i = \sum_{j=1}^{n} (\text{Maximum VOC or TSP from } (\text{Source Category}_j \times \text{Speciation Factor}_{i,j})$$

This represents a conservative approach in estimating maximum concentrations of individual COPCs as the maximum VOC or TSP concentration from each source category may occur at different times.

3.4.4.4. Determination of Background

Background Concentrations

As per the Alberta *Air Quality Model Guideline* and the *Guidelines for Air Quality Dispersion Modelling in British Columbia*, background concentrations are used to represent the contribution from all other natural and anthropogenic sources in the area, and are added to dispersion modelling results for assessment of combined effects (AESRD 2012, BC MOE 2008). Typically a single value is chosen as background, which is assumed to apply for every hour of the model period and for every location within the model domain. For this assessment, one station was selected to represent overall background in each of the Air Quality RSAs. For CACs and H_2S, three years of data from 2009 to 2011 (or the most recent three-year period if 2009 to 2011 was not available) were included for determination of background. For VOCs, due to the lesser amount of data available based on intermittent sampling, five years of data from 2007 to 2011 were included for determination of background. Background concentrations for short-term averaging periods (1-hour to 24-hour) were based on the 90^{th} percentiles of observations for the Edmonton Terminal RSA and the 98^{th} percentiles of observations for the RSAs in BC. Annual average background concentrations were based on the 50^{th} percentiles of observations.

In order to select one station to represent the background in each of the Air Quality RSAs, parameters such as data completeness and station location were assessed.

For CACs, the combination of Kamloops Brocklehurst and Kamloops Fire Station #2 stations was selected to represent background in the Kamloops Terminal RSA. Burnaby Kensington Park station data was selected to represent background in the Burnaby and Westridge Marine Terminals RSA. Other stations in the Burnaby area with higher ambient concentrations were not selected for use as background because they are known to observe influences from nearby sources and therefore may not be representative of the entire Air Quality RSA. Metro Vancouver describes the Kensington Park station to be situated in a location “typical of other surrounding areas within the North Burnaby region” (Metro Vancouver 2012a).

Background BTEX concentrations were developed based on the Edmonton East NAPS station (Edmonton Terminal RSA), the Chilliwack Airport NAPS station (Kamloops Terminal RSA), the Abbotsford Airport NAPS station (Sumas Terminal RSA), and the Burnaby Burmount NAPS station (Burnaby and Westridge Marine Terminals RSA). The Edmonton East station was selected to provide a background more representative of the industrial setting in the Edmonton Terminal RSA, as opposed to the Edmonton Central station which would provide an urban background. As this station is located only 200 m from the Edmonton Terminal, and industrial facilities within 5 km of the Edmonton Terminal were included in the modelling (see Background Emissions Modelling below), the use of Edmonton East data as background is conservative as this station is located about 200 m from Edmonton Terminal. Since no VOC monitoring data are available within the Kamloops Terminal RSA, the Chilliwack Airport was selected as the nearest representative station. Abbotsford Airport and Burnaby Burmount represent the only VOC monitoring stations within their respective Air Quality RSAs. Background concentrations for hydrocarbon COPCs were also developed based these station data, as available.

Background H_2S concentrations were developed based on H_2S monitoring data from Edmonton East (Edmonton Terminal RSA), and TRS monitoring data from Kamloops Fire Station #2 (Kamloops Terminal and Sumas Terminal RSAs) and Burnaby Kensington Park (Burnaby and Westridge Marine Terminal RSA). Selection of stations is based on the same reasoning as discussed above for CACs and VOCs. Since no information is available to estimate H_2S based on TRS monitoring data, it was conservatively assumed that all TRS was H_2S for the purpose of defining background concentrations.

In addition, background metals concentrations for the Burnaby and Westridge Marine Terminal RSA were obtained from Metro Vancouver's Burrard Inlet Area Local Area Quality Study (Metro Vancouver 2012b) for the Screening Level Human Health Risk Assessment of Pipeline and Facilities. No background metals concentrations were available for the other Air Quality RSAs.

A summary of the background concentrations used for this assessment is provided in Table 3.30.