Tel: 403-232-6771
Fax: 403-232-6762

RWDI AIR Inc.
#1000, 736-8th Avenue S.W.
Calgary, Alberta, Canada
T2P 1H4

CONSULTING ENGINEERS & SCIENTISTS

CANADA'S BEST MANAGED COMPANIES

November 26, 2014

Mr. Jason Smith
Vice-President, Consulting Services/Principal
TERA, a CH2M HILL Company
Suite 1100, 815-8th Ave SW
Calgary, AB
T2P 3P2

Re: Supplemental Marine Air Quality and Greenhouse Gas Technical Report #2 and ESA Significance Ratings
Trans Mountain Expansion Project
RWDI Reference No. 1500417
SREP-NEB-TERA-00035

email: jsmith@teraenv.com

Dear Jason,

Since the Application for the Trans Mountain Expansion Project (the Project) was filed in December, 2013 and the Supplemental Marine Air Quality and Greenhouse Gas Assessment Technical Report No. 1 in June 2014, RWDI AIR Inc. (RWDI) conducted additional marine dispersion modelling to account for the following updates to the Project:

- revision of emission sources for marine transportation;
- boiler emissions from vessels underway, at berth and at anchor were removed from the modelling for the tankers;
- emissions from tug escorts in transit between berth and anchorage locations were added to the modelling;
- non-Project vessel underway traffic, berth and anchorage locations were modelled with the year 2010 Marine Emission Inventory Tool (MEIT) (Base and Application Cases) and year 2030 MEIT (Cumulative Case) in the Marine Air Quality Regional Study Area (RSA);.
- refinements have been made to the approach for estimating nitrogen dioxide (NO_2) levels near the Westridge Marine Terminal;
- new BC interim ambient air quality objectives for 1-hour NO_2 and sulphur dioxide (SO_2) were adopted for this supplemental study; and,

- all existing and Project related carbon dioxide equivalent (CO_2e) emissions were updated based on the global warming potentials (GWP) reported by the Intergovernmental Panel on Climate Change in their Fourth Assessment Report (IPCC 2007), as per Environment Canada's guidelines (Environment Canada 2014).

Updated air quality and greenhouse gas (GHG) results have been created for the Base, Application (Project) and Cumulative Cases, where applicable. The assessment methodology and updated modelling results are discussed in the attached Supplemental Marine Air Quality and Greenhouse Gas Marine Transportation Technical Report No. 2, dated November 26, 2014.

RWDI has reviewed the findings of this supplemental marine air quality and GHG marine transportation assessment in the context of the Environmental and Socio-economic Assessment (ESA) (Volume 8A) and has determined that the significance conclusions of the ESA with regard to air quality and GHG emissions (Sections 4.3.3, 4.3.4 and 4.4.2 of Volume 8A [Filing ID A3S4Y3]) remain unchanged by the results of the supplemental modelling for both Project-related effects and the Project's contribution to cumulative effects. Upon review of the ESA, it became apparent that there was a discrepancy between the cumulative effects reversibilities listed in Table 4.4.2.2 and on pages 8A-460 to 8A-463 (reversibility for air emissions indicators of criteria air contaminants, volatile organic compounds, formation of secondary PM and ozone, visibility and combined cumulative effects). For clarity, the reversibility of those cumulative effects listed is short-term. The rationale is described below:

Air Emissions Indicator – Criteria Air Contaminants

- Reversibility: short-term – Project contribution to cumulative effects will cease and increases in ambient ground-level concentrations will reverse shortly after Project-related marine vessels exit the Marine Air Quality RSA.

Air Emissions Indicator – Volatile Organic Compounds

- Reversibility: short-term – Project contribution to cumulative effects will cease and increases in ambient ground-level concentrations will reverse shortly after Project-related marine vessels exit the Marine Air Quality RSA.

Air Emissions Indicator – Formation of Secondary PM and Ozone

- Reversibility: short-term – Project contribution to cumulative effects will cease and any increases will reverse shortly after Project-related marine vessels exit the Marine Air Quality RSA.

Air Emissions Indicator – Visibility

- Reversibility: short-term – emissions of pre-cursors will cease and any increases in ambient ground-level concentrations of secondary PM and ozone will reverse shortly after tankers exit the Marine Air Quality RSA.

Combined Cumulative Effects on Air Emissions

- Reversibility: short-term – Project contribution to cumulative effects will reverse shortly after Project-related marine vessels exit the Marine Air Quality RSA.

We would be happy to respond to any questions or comments that TERA or Trans Mountain might have with respect to these documents. Please do not hesitate to contact the undersigned at (403) 232-6771 ext. 6228.

Yours very truly,

RWDI AIR Inc.

David S. Chadder
Senior Project Director/Principal

DSC/dvnh
Attach.

Tel: 403.232.6771
Fax: 403.232.6762

RWDI AIR Inc.
#1000, 736-8th Avenue S.W.
Calgary, Alberta, Canada
T2P 1H4

CONSULTING ENGINEERS
& SCIENTISTS

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

Supplemental Report No. 2

SREP-NEB-TERA-00035
RWDI # 1500417
November 26, 2014

SUBMITTED TO

Jason Smith M.Sc.
Vice President Consulting Services - Principal
TERA, a CH2M HILL Company
jsmith@teraenv.com

SUBMITTED BY

David Chadder Hon. B.Sc., QEP
Senior Project Director/Principal
David.Chadder@rwdi.com

Trevor Cavanaugh, P. Eng.
Project Manager
Trevor.Cavanaugh@rwdi.com

Alena Saprykina, M.Sc.
Air Quality Scientist
Alena.Saprykina@rwdi.com

Noam Bar-Nahoum, M.A.
Scientist – GIS Air Quality
Noam.Bar-Nahoum@rwdi.com

Jyotsna Kashyap, M.Sc.
Air Quality Scientist
Jyotsna.Kashyap@rwdi.com

Julia Veerman, B. Eng., EIT
Air Quality Engineer
Julia.Veerman@rwdi.com

EXECUTIVE SUMMARY

In December 2013 (RWDI 2013), Trans Mountain Pipeline ULC (Trans Mountain) submitted its application for a Certificate of Public Convenience and Necessity (CPCN) to the National Energy Board (NEB) for the Trans Mountain Expansion Project (the Project). The CPCN Application consisted of eight volumes including the marine environmental and socio-economic assessment (ESA). Volume 8B of the Application included Technical Report 8B-3 Marine Air Quality and Greenhouse Gas-Marine Transportation Technical Report (RWDI 2013) (NEB Filing IDs A3S1U0 to A3S1U7). This air quality assessment addresses the emissions of air contaminants and greenhouse gases (GHG) from marine transportation including underway traffic, berth and anchorage locations. Emission rates were estimated and dispersion modelling was completed for three operational cases, namely, Base, Application (Project plus Base Case) and Cumulative. Several chemicals were modelled and predicted concentrations were compared to the applicable ambient air quality objectives for marine transportation.

In June, 2014 (RWDI 2014), Trans Mountain submitted the supplemental marine air quality assessment (referred to in this document as the "2014 Supplemental Marine Technical Report No.1" (RWDI 2014a, [NEB Filing IDs A3Y1G0 to A3Y1G2]) which addressed changes in the emissions associated with the Project updates based on refined engineering and marine transportation logistics assumptions. The marine transportation cumulative effects including projected growth of marine vessels in the Marine Air Quality Regional Study Area (RSA) were also addressed in the 2014 Supplemental Marine Technical Report No.1. Updates included changes in the number of dedicated tug escorts, marine vessel speed, product amount per vessel, number of vessels per month, vessel main engine fuel type; and collection and destruction efficiencies for vapour control units at the Westridge Marine Terminal.

Since the filings in December, 2013, and June, 2014, the engineering design has evolved and improvements have been made to the assumptions that will be used in the air quality modelling for the marine transportation. This Supplemental Report No.2 describes these design changes along with modelling of the non-Project vessel underway traffic, berth and anchorage locations with the Environment Canada Marine Emission Inventory (MEIT) (SNC-Lavalin Environment 2013) and provides updated predicted results for the Base, Application and Cumulative Cases.

The following air emissions will result from the Project:

- criteria air contaminants (CACs), including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2);
- volatile organic compounds (VOCs), including benzene, toluene, ethyl benzene, and xylenes, collectively known as BTEX, as well as other compounds with the potential to cause nuisance odours; and,
- GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) with the potential to affect overall climate change.

This marine air quality and GHG technical report comprises three assessments:

1. existing conditions which includes all projects in the Marine Air Quality RSA at the start of the Project (Base Case). For the purpose of this assessment, existing conditions include current marine traffic associated with Trans Mountain, all other existing marine traffic (based on MEIT data for year 2010), and all existing natural and anthropogenic (i.e., human-caused) sources in the Marine Air Quality RSA;
2. Project effects (Application Case) including the proposed increase in marine vessel traffic associated with the Project; and,
3. cumulative effects (Cumulative Case) which includes existing conditions, the Project and all reasonably foreseeable and approved developments (based on MEIT data for year 2030). Note that the spatial boundary of GHG emissions is international, and therefore, cumulative effects assessments for GHG emissions would need to include all international foreseeable future development. Since this is beyond the scope of this assessment, no cumulative assessment is provided for GHG emissions.

Methods

Emissions of CACs, VOCs, and GHGs were estimated for the Base and Project Cases following the methodology discussed in the 2013 Marine Technical Report (Filing IDs A3S1U0 to A3S1U7). For the Cumulative Case, changes to CAC and VOC emissions were estimated based on the year 2030 forecasts provided by MEIT. Emission rates were estimated based on the change in total emissions between year 2010 and 2030 MEIT data. Scaling factors were developed and applied to the year 2010 MEIT modelled emission rates to account for the emission rate change from year 2010 to 2030 available in the database.

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the Marine Air Quality RSA associated with the Base, Application and Cumulative Cases.

Base Case

The maximum predicted CACs and VOCs for the Base Case were below the Metro Vancouver, provincial, and national objectives with the exception of the daily 1-hour maximum 99th percentile predicted SO_2 concentration. The SO_2 prediction exceeded the new British Columbia (BC) interim objective of 196 µg/m^3 1.4% of the time based on one year of modelling data (i.e., there were 5 days in a year where the maximum 1-hour daily SO_2 concentration exceeded the objective).

Application Case

An increase in CACs and VOCs was predicted for the Application Case due to the Project, but modelled maximum concentrations for the Project only, remained well below MV, provincial, and national objectives. For both the Project only and Application Cases, the maximum predicted concentrations were less than the most stringent objectives for all applicable averaging periods, with the exception of the daily 1-hour maximum 99th percentile predicted SO_2 concentration in the Application Case. The SO_2 prediction exceeded the new BC interim objective of 196 µg/m^3 less than 1.4% of the time based on one year of modelling data, which is the same that was predicted for existing conditions. Therefore, the Project's marine contribution to the predicted SO_2 concentrations is very small. No mitigation measures were considered to be warranted beyond emission limits mandated for marine vessels as part of the North American Emissions Control Area.

GHG emissions from the Project will disperse, mix with global emissions, and contribute to global climate change. Assuming that operation emissions will not change over the lifetime of the Project, total estimated emissions over 50 years of Project operation are 3.4 Mt CO_2e (expressed as carbon dioxide equivalents), which will result in an estimated 1.6×10^{-6} °C increase in Earth's global temperature. Emissions of GHG are slightly lower than the earlier estimate of 3.6 Mt CO_{2e} reported in the December 2013 NEB filing.

Cumulative Case

Maximum SO_2, NO_2 and PM concentrations were predicted to decrease for the Cumulative Case relative to the Application Case, while CO and VOC concentrations were predicted to increase slightly. The decrease in the PM and SO_2 concentrations were predicted to occur as a result of more stringent fuel sulphur regulations. The decrease in NO_2 concentrations was predicted due to the higher Tier-II and Tier-III standards for marine vessels built on January 2, 2011, and January 1, 2016[1], or later, respectively. The maximum predicted concentrations of the CACs and speciated VOCs for the Cumulative Case were below their respective Metro Vancouver, provincial and national objectives.

[1] Subject to a technical review by International Marine Organization, this date could be delayed.

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Tables

Figures

Application Case

Cumulative Case

Appendices

Acronyms

AAAQO	Alberta Ambient Air Quality Objectives
AAQC	Ambient Air Quality Criteria
AB	Alberta
BC	British Columbia
BC MOE	British Columbia Ministry of Environment
BTEX	benzene, toluene, ethyl benzene and xylene
CAAQS	Canadian Ambient Air Quality Standard
CAC	criteria air contaminant
CH_4	methane
CMAQ	Community Multi-scale Air Quality Model
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
COPC	contaminant of potential concern
DWT	deadweight tonnes
EC	Environment Canada

ECA	emission control area
EEDI	Energy Efficiency Design Index
EPA	Environmental Protection Agency
ESA	Environmental and Socio-Economic Assessment
FVRD	Fraser Valley Regional District
GHG	greenhouse gas
GIS	Geographic Information System
GWP	Global Warming Potential
H_2S	hydrogen sulphide
HFO	heavy fuel oil
IGS	Insert Gas System
IMO	International Maritime Organization
IPPC	Intergovernmental Panel on Climate Change
IR	Information Request
LFVAQCC	Lower Fraser Valley Air Quality Coordinating Committee
MDO	Marine Diesel Oil
MEIT	Marine Emission Inventory Tool
MPOI	maximum point of impingement
MOE	Ministry of Environment
MV	Metro Vancouver
N_2O	nitrous oxide
NAAQO	National Ambient Air Quality Objective
NAAQS	National Ambient Air Quality Standards
NEB	National Energy Board
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NRC	National Research Council
OMOE	Ontario Ministry of Environment
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5 µm

PM_{10}	particulate matter less than 10 µm
Project	Trans Mountain Expansion Project
RSA	Marine Air Quality Regional Study Area
SEEMP	Ship Energy Efficiency Management System
SOLAS	Safety of Life at Sea
SO_2	sulphur dioxide
TMEP	Trans Mountain Expansion Project
Trans Mountain	Trans Mountain Pipeline ULC
TRS	total reduced sulphur
TSP	total suspended particulate
US	United States
VCU	vapour combustion unit
VCS	vapour control system
VRU	vapour recovery unit
VOC	volatile organic compound
WMT	Westridge Marine Terminal
$\mu g/m^3$	microgram per cubic metre

1. INTRODUCTION

1.1 Overview

Since the December, 2013 filing to the National Energy Board (NEB) for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"), supplemental air quality studies were conducted to refine the number of dedicated tug escorts, marine vessel speed, product amount per vessel, number of vessels per month, vessel main engine fuel type, and the collection efficiency of vapour control units at the Westridge Marine Terminal proposed by Trans Mountain Pipeline ULC (Trans Mountain) as provided in the 2014 Supplemental Marine Technical Report No.1 (RWDI 2014a) (Filing IDs A3Y1G0 to A3Y1G2).

An additional study was also conducted to consider the above mentioned updates along with the additional engineering updates and modelling of the non-Project vessel underway traffic, berth and anchorage locations with the year 2010 Environment Canada Marine Emission Inventory (MEIT) (SNC-Lavalin Environment 2013). In addition, marine transportation cumulative effects were assessed with 2030 Environment Canada MEIT to reflect the projected growth of marine vessels in the Marine Air Quality Regional Study Area (RSA). This supplemental report (referred to in this document as "Supplemental Report No.2") summarizes the methodology and results for these additional air quality studies.

These supplemental air quality studies address emissions of air contaminants and greenhouse gases (GHG) from marine traffic. Although not explicitly part of the marine transportation assessment, for technical completeness, combustion emissions from vessels at berth during product loading at the Westridge Marine Terminal were included in this assessment for combined effects. Emissions were estimated and predictive dispersion modelling was completed for operational emissions for three cases, namely, Base, Application (Project plus Base Case) and Cumulative. Several chemicals were modelled and these values were compared to applicable ambient air quality objectives.

1.2 Study Objectives

Supplemental Report No. 2 addresses changes in the emissions associated with TMEP updates based on refined engineering and marine transportation logistics assumptions proposed by Trans Mountain. The proposed Trans Mountain updates, which included changes in the number of dedicated tug escorts, marine vessel speed, product amount per vessel, number of vessels per month, vessel main engine fuel type; and collection and destruction efficiencies for vapour control units at the Westridge Marine Terminal, were previously addressed in the 2014 Supplemental Marine Technical Report No. 1 (Filing IDs A3Y1G0 to A3Y1G2).

The main focus of Supplemental Report No. 2 is:

- the updated air quality assessment, which incorporates additional improved engineering design assumptions for the marine fleet; and,
- the year 2010 and 2030 Environment Canada MEIT data to assess non-Trans Mountain underway traffic, berth and anchorage locations for the Base, Application and Cumulative Cases, respectively.

The objectives of this air quality assessment were to:

- characterize existing conditions to gain an understanding of existing air quality 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 existing conditions and other reasonably foreseeable and approved developments;
- provide an updated air quality assessment for the Marine Transportation to the NEB and intervenors;
- refine assumptions from the previous air quality assessment; and,
- fulfill commitments for updated air quality modelling made through the NEB Information Request (IR) process from intervenors.

Supplemental Report No. 2 is based on key air quality indicators and is not as comprehensive as the modelling completed as part of Technical Report 8B-3 of Volume 8B of the Application, Marine Air Quality and Greenhouse Gas – Marine Transportation Technical Report (RWDI 2013, Filing IDs A3S1U0 to A3S1U7) (referred to in this document as the “2013 Marine Technical Report”). Dispersion modelling results for Criteria Air Contaminants (CACs), benzene, toluene, ethylbenzene, xylenes (BTEX), hydrogen sulphide (H_2S), and mercaptans are included in this study for the Base (Existing), Application (Project) and Cumulative Cases.

Supplemental Report No.2 describes the methods of the air quality and GHG assessment. This report does not identify residual or cumulative environmental or socio-economic effects nor provide conclusions regarding their significance. Volume 8A Section 4 Environmental and Socio-economic Assessment (ESA) provides the potential residual and cumulative effects of Project-related marine transportation on air quality and GHG emissions, including an evaluation of significance (Filing IDs A3S4X5 to A3S4Y3). A letter to this report has been provided to discuss any changes to the ESA as a result of these supplemental air quality studies. Significance conclusions of the ESA with regard to air quality and GHG emissions (Sections 4.3.3, 4.3.4 and 4.4.2 of Volume 8A; Filing ID A3S4Y3) remain unchanged.

1.3 Regulatory Standards

Supplemental Report No.2 supports the ESA, and was completed in accordance with the *NEB Filing Manual* (2014a) as well as the *NEB Filing Requirements Related to the Potential Environmental and Socio Economic Effects of Increased Marine Shipping Activities* (2013a) and *NEB Trans Mountain Pipeline ULC - Trans Mountain Expansion – List of Issues* (2013b). The air quality assessment was conducted as per the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (Ministry of Environment (MOE) 2008).

In addition to the dispersion modelling guidelines, ambient air quality criteria are discussed in the 2013 Marine Technical Report (Filing ID A3S4J7).

1.4 Commitments from Information Requests from Intervenors Round 1

The first round of IRs from the NEB and Intervenors resulted in additional commitments in the air quality assessment. Supplemental Report No.2 addresses these commitments related to Marine Transportation. The commitments and references to the original IRs are listed in Table 1.1.

Table 1.1: Additional Air Quality Assessment Commitments

No.	IR Reference	Commitment	Discussed in Section
1.	Environment Canada IR 1.058 (NEB Filing ID A3Y2K9) Commitment Number C-100	Trans Mountain proposes to meet with Environment Canada (EC) and the other interveners involved in the Lower Fraser Valley Air Quality Coordinating Committee (LFVAQCC) who are interested, in Q3 2014 to clarify assumptions and methodology for an updated marine air quality/greenhouse gas assessment using the Marine Emission Inventory Tool (MEIT) to be conducted in 2015. (IR: EC requests that the Proponent re-evaluate the Base Case with berth and anchorage emissions included.)	These commitments are met by the filing of this supplemental report.
2.	Environment Canada IR 1.076 (NEB Filing ID A3Y2K9) Commitment Number C-101	Trans Mountain suggests that the air quality experts meet with the (LFVAQCC) in Q3 2014 to discuss a possible update to the CMAQ modelling incorporating the MEIT calculated marine emissions and limited CMAQ model performance evaluation.	Not discussed in this supplemental report. Meetings took place on September 25 and November 13, 2014. Further engagement will be initiated by LFVAQCC after consultation with Health Canada.
3.	Environment Canada IR 1.080 (NEB Filing ID A3Y2K9) Commitment Number C-102	Trans Mountain recognizes that updating the photochemical modelling using the updated MEIT would be valuable to EC, Metro Vancouver and the Fraser Valley Regional District (FVRD) and commits to undertaking a similar modelling effort but using the updated MEIT when it is available. Trans Mountain suggests that the air quality experts meet with the LFVAQCC in Q3 2014 to discuss a possible update to the CMAQ modelling incorporating the MEIT calculated marine emissions and limited CMAQ model performance evaluation.	

No.	IR Reference	Commitment	Discussed in Section
4.	Metro Vancouver IR 1.6.07(a) (NEB Filing ID A3Y2V0) Commitment Number C-134	Trans Mountain recognizes that updating the photochemical modelling using the updated MEIT would be valuable to EC, Metro Vancouver and FVRD and commits to undertaking a similar modelling effort but using the updated MEIT when it is available. This update using the CMAQ model would not include all of the additional scenarios (i.e., another ozone episode, typical ozone episode under other meteorological conditions, seasonal and annual time periods) jointly requested by EC, Metro Vancouver and FVRD. Trans Mountain suggests that the air quality experts meet with the LFVAQCC in Q3 2014 to discuss a possible update to the CMAQ modelling incorporating the MEIT calculated marine emissions and limited CMAQ model performance evaluation.	Not discussed in this supplemental report. Meetings took place on September 25 and November 13, 2014. Further engagement will be initiated by LFVAQCC after consultation with Health Canada.

1.5 Changes to Technical Approach

As noted in the 2013 Marine Technical Report (Filing IDs A3S1U0 to A3S1U7), the predicted air quality results in the Application were based on preliminary engineering design. Improvements have been made to the assumptions that will be used in the air quality modelling, specifically:

1. revision of emission sources for marine transportation;
2. boiler emissions from vessels underway, at berth and at anchor were removed from the modelling for the tankers;
3. emissions from tug escorts in transit between berth and anchorage locations were added to the modelling;
4. non-Project vessel underway traffic, berth and anchorage locations were modelled with the year 2010 MEIT (Base and Application Cases) and year 2030 MEIT (Cumulative Case) in the Marine Air Quality RSA;.
5. refinements have been made to the approach for estimating nitrogen dioxide (NO_2) levels near the Westridge Marine Terminal;
6. new BC interim ambient air quality objectives for 1-hour NO_2 and sulphur dioxide (SO_2) were adopted for this supplemental study; and,
7. all existing and Project related carbon dioxide equivalent (CO_2e) emissions were updated based on the global warming potentials (GWP) reported by the Intergovernmental Panel on Climate Change in their Fourth Assessment Report (IPCC 2007), as per Environment Canada's guidelines (Environment Canada 2014).

Sections 1.5.1 to 1.5.4 further discuss each of these changes individually.

1.5.1 Modelled Marine Transportation Emission Sources

The emission sources modelled for the Project tanker traffic along with the non-Project marine vessel traffic are summarized in Table 1.2. Changes between Supplemental Marine Technical Report No. 1 (RWDI 2014a) and 2013 Marine Technical Report (RWDI 2013) are summarized in Appendix A. A detailed description of the emission sources for Project-related marine vessel traffic is provided in Section 3.4.2. Emission sources from non-Project marine vessel traffic are described in greater detail in Sections 3.4.3 and 3.4.4.

Table 1.2: Summary of Project Emission Sources and Non-Project Sources that were used for Dispersion Modelling

Vessel Activity	Location	Emission Source	Source Type for Dispersion Modelling
Berthed Tanker (one location in Base Case, and three locations in Application Case)	Each Berth Location	Auxiliary Engine [1]	Point (one per location)
		No fugitive VOC vapours from tanker holds, 100% collection efficiency for VCU/VRUs[2]	Not Applicable
Anchored Tanker (three locations in Base Case and three locations in Application Case)	Each Anchorage Location	Auxiliary Engine[1]	Point (one per location)
		Fugitive VOC vapours from tanker holds during anchorage[3]	Area
Tugs between Anchorage and Berth	Each Anchorage/Berth Location	Tugs' main engine[4]	Point (one per location)
Tankers Underway (Combustion Emissions)	Segment 1	Auxiliary Engine and Main Engine [5]	Area (one per segment)
	Segment 2		Area (one per segment)
	Segment 3		Area (one per segment)
	Segment 4		Area (one per segment)
	Segment 5		Area (one per segment)
	Segment 6		Area (one per segment)
	Segment 7		Area (one per segment)
Tankers Underway (Fugitive)	Segment 1	Fugitive VOC vapours from tanker holds during underway during normal operations[3]	Area (one per segment)
	Segment 2		Area (one per segment)
	Segment 3		Area (one per segment)
	Segment 4		Area (one per segment)
	Segment 5		Area (one per segment)
	Segment 6		Area (one per segment)
	Segment 7		Area (one per segment)
Non-Project Marine Vessel Traffic	Each MEIT Referenced Underway Transit Location	From MEIT Database	Point (one per 2 km by 2 km grid cell)
	Each MEIT Anchorage and Berth Location		Point (one per location)

Notes: [1] The boiler and main engine will not be running at berth or anchorage.

[2] All fugitive emissions associated with product loading at berth are expected to be captured from the vapour control units at the Westridge Marine Terminal. These land-based emission sources, as well as storage tanks at the Burnaby and Westridge Marine Terminals, are not included in this marine traffic assessment. VCU= Vapour Combustion Unit; VRU= Vapour Recovery Unit.

[3] Fugitive VOC vapour emission from cargo system of modern tankers as those that meet TMEP's Vessel Acceptance Criteria is controlled and contained onboard the tanker, their release within the Marine Air Quality RSA is therefore considered anomalous; however, fugitive VOC vapour emissions have been included in the model as a conservative case.

[4] It was assumed that there could be up to four tug escorts operating at anchorage or berth or between berth and anchorage locations. As a modelling simplification, the combustion emissions from the four tug boats were distributed between four locations in Base Case (one berth and three anchorage locations) and six locations in Application Case. (three berths and three anchorage locations).

[5] Boilers typically do not operate when underway, so their emissions will not be modelled.

1.5.2 NO_2 Estimation

Emissions of total oxides of nitrogen (NO_X) from the marine traffic are comprised of nitrogen oxide (NO) and NO_2. In order to use the chemical reaction scheme within CALPUFF, individual mass emissions of NO and NO_2 are required as input values.

Total NO_X emission rates were calculated from emission factors. Typically, emission factors of NO_X are expressed in terms of NO_2. The estimated mass emission rates of NO_X represents the total mass emission rate of NO_2 after all NO has been oxidized to NO_2, rather than the sum of the NO and NO_2 mass emission rates. Effectively all of the NO_X is reported as NO_2. In the 2013 Marine Technical Report and 2014 Supplemental Marine Technical Report No.1, it was assumed that 90% of the NO_X emissions (reported as NO_2) by mass would be in the form of NO (expressed as NO_2), and 10% by mass would be in the form of NO_2 (RWDI 2013, RWDI 2014a). However, it is necessary to input actual mass of NO (expressed as NO, not as NO_2) into the model. Therefore, 90% of NO_X (modelled as NO) mass should be adjusted by molar mass ratio of NO and NO_2 to input NO emission rates correctly into the model. Calculating emission rates of NO as NO_2 resulted in an over-estimation of NO_X emissions by 35% in the original submissions.

In this supplemental assessment, total NO_X emission rates were first split into NO (expressed as NO_2) and NO_2 emission rates based on 90% and 10% by mass, respectively; second, the NO mass was adjusted by molar mass ratio of NO and NO_2 to input NO emission rates correctly into the modelling. Therefore, the NO emission rates used as inputs into the CALPUFF model were lower than in the December, 2013 and June, 2014 filings, solely as an effect of the refined NO_X splitting methodology discussed here.

1.5.3 New British Columbia 1-Hour NO_2 and SO_2 Interim Ambient Air Quality Objectives

The BC MOE adopted interim air quality objectives for 1-hour NO_2 and SO_2 from the United States (US) Environmental Protection Agency (EPA) National Ambient Air Quality Standards (NAAQS) (BC MOE 2014, US EPA 2010a). The BC interim air quality objectives along with all other relevant objectives considered in this supplemental are summarized in Table 1.3. Alberta (AB) Ambient Air Quality Objectives (AAAQO) were used specifically for BTEX (benzene, toluene, ethylbenzene and xylene) as there are no BC, Metro Vancouver or national objectives available for these contaminants.

Table 1.3: British Columbia, Metro Vancouver, National and Alberta Ambient Air Quality Objectives (in µg/m^3)

Contaminant	Average Period	BC Objective	Metro Vancouver Objective	National Objective	AB Objective
TSP (Total)	24-hour	120	n/a	120	120
	Annual	60	n/a	60	60
PM_{10} (Total)	24-hour	50	50	n/a	n/a
	Annual	n/a	20	n/a	n/a

Contaminant	Average Period	BC Objective	Metro Vancouver Objective	National Objective	AB Objective
$PM_{2.5}$ (Total)	24-hour	25[1]	25	27 to 28[6]	30
	Annual	8	8	8.8 to 10[7]	n/a
CO	1-hour	14,300	30,000	15,000	15,000
	8-hour	5,500	10,000	6,000	6,000
NO_2	1-hour	188[2]	200	400	300
	24-hour	n/a	n/a	200	n/a
	Annual	n/a	40	60	45
SO_2	1-hour	196[3]	450	450	450
	24-hour	160	125	150	125
	Annual	25	30	30	30
Benzene	1-hour	n/a	n/a	n/a	30
	Annual	n/a	n/a	n/a	3.0
Ethylbenzene	1-hour	n/a	n/a	n/a	2,000
Toluene	1-hour	n/a	n/a	n/a	1,880
	24-hour	n/a	n/a	n/a	400
Xylenes	1-hour	n/a	n/a	n/a	2,300
	24-hour	n/a	n/a	n/a	700
H_2S	1-hour	7[4]	n/a	n/a	14.0
	24-hour	3[4]	n/a	n/a	4.0
Total Mercaptans	10-minute	13[5]	n/a	n/a	13[5]

Notes: n/a – not available
[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on the 98th percentile values
[2] Based on daily 1-hour maximum, annual 98th percentile of 1-year data, adopted from US EPA, NAAQS (100 ppb)
[3] Based on daily 1-hour maximum, annual 99th percentile of 1-year data, adopted from US EPA, NAAQS (75 ppb)
[4] Total Reduced Sulphur (TRS) objectives have been presented for comparison, since there are no H_2S objectives
[5] Modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying with a factor of 1.65, as per the AQMG for the Ontario Ministry of the Environment (OMOE 2009); the 10-minute Ontario Ambient Air Quality Criteria (AAQC) has been presented for comparison
[6] Canadian Ambient Air Quality Standard (CAAQS) is 28 µg/m^3 in year 2015 and 27 µg/m^3 in year 2020; compliance based on annual 98th percentile value, averaged over three consecutive years
[7] CAAQS is 10.0 µg/m^3 for year 2015 and 8.8 µg/m^3 for year 2020; compliance based on the average over three consecutive years
TSP = Total Suspended Particulate
PM = Particulate Matter
PM_{10} = Particulate Matter less than 10 µg
$PM_{2.5}$= Particulate Matter less than 2.5 µg
CO = Carbon Monoxide
H_2S = Hydrogen Sulphide

1.5.4 New Global Warming Potentials for Greenhouse Gases

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. Prior to 2014, GWPs from IPCC's second assessment report were used to obtain CO_2e emissions. As of January, 2014, Environment Canada has adopted the GWPs from IPCC's Fourth Assessment Report (Environment Canada 2014). The updated GWPs are presented in Table 1.4.

Table 1.4: Updated Global Warming Potentials

GHG	CO_2	CH_4	N_2O
GWP[1]	1	25	298

Notes: [1] Based on IPCC's Fourth Assessment Report as recommended by Environment Canada (Environment Canada 2014).
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide

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. These activities are discussed in Section 2 of the 2013 Marine Technical Report (Filing ID A3S4J7).

Trans Mountain and its consultants continue to meet with regulatory authorities to discuss the approach to assess the potential environmental effects of the Project stated in Section 1.4 of this report. Meetings were held with the LFVAQCC on September 25 and November 13, 2014, and the agenda for both meetings included discussion on methodologies and assumptions associated with this marine air quality and greenhouse gas assessment.

3. METHODS

3.1 Project Interactions and Identification of Potential Effects

Project interactions with air quality and GHG during the operations phase were discussed in Section 3 of the 2013 Marine Technical Report (Filing ID A3S4J7). No additional Project interactions are expected as a result of the changes mentioned in Section 1.5.

3.2 Assessment Indicators and Measurement Endpoints

Assessment indicators and measurement endpoints discussed in the 2013 Marine Technical Report (Filing ID A3S4J7) were used in these supplemental air quality studies.

The indicators used in the assessment of the increase in Project-related marine vessel traffic on air quality are as follows:

- primary emissions of criteria air contaminants (CACs), including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2); and,
- primary emissions of volatile organic compounds (VOCs), including benzene, toluene, ethyl benzene, and xylenes, collectively known as BTEX, as well as other compounds with the potential to cause odour.

The formation of secondary PM and ozone, and visibility indicators were not considered in this updated assessment.

The indicators used in the assessment of the Project on GHGs include emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as overall climate change.

3.3 Study Area Boundaries

These supplemental air quality studies were conducted using the 150 km by 150 km Marine Air Quality RSA discussed in Section 3 of the 2013 Marine Technical Report (Filing ID A3S4J7). This represents the area where inbound and outbound shipping lanes are relatively defined and can be reasonably represented in dispersion modelling. Beyond this point, shipping lanes diverge into international waters depending on the destination. Project GHG emissions were also estimated for inbound and outbound marine vessel traffic along the known shipping lanes within the Marine Air Quality RSA and within Canadian territorial sea. Emissions from marine vessels generated outside this area were considered to be in international territory, and thus, outside the scope of this assessment. Emissions from land-based non-Project sources were accounted for with an ambient background value at land-based receptors only.

3.4 Assessment Approach and Description of Assessments

The air quality and GHG assessment comprises three assessments:

1. existing conditions (Base Case) which includes all projects in the region at the start of the Project. For the purpose of this assessment, existing conditions include current marine traffic associated with the Trans Mountain Pipeline, all other existing marine traffic, and all existing natural and anthropogenic (i.e., human-caused) sources in the Marine Air Quality RSA (Section 4);
2. Project effects (Application Case) including the proposed increase in marine vessel traffic associated with the Project (Sections 5 and 6); and,

3. cumulative effects (Cumulative Case) which includes existing conditions, the Project and all reasonably foreseeable and approved developments (Section 7). Note that GHG emissions disperse and build up in concentration in the earth's atmosphere and have the potential to contribute incrementally to climate change. Therefore, the spatial boundary for the effects of GHG emissions is international, and a cumulative effect assessment for GHG emissions would have to aggregate the effect of the Project and any approved and foreseeable international development. Currently, such data is not available at an international level, so no cumulative effects assessment for GHG emissions is provided in this report. However, near- and long-term projections of future changes in the climate, based on several scenarios for international development and mitigation, and the associated GHG emissions have been developed by the (IPCC 2007b; 2013).

3.4.1 Project-related Transportation Emission Sources

Currently, the Westridge Marine Terminal receives heavy and light/synthetic crude products from the Burnaby Terminal and ships the product to international destinations, particularly California and Asia. Products are shipped via barges as well as Panamax and Aframax class tankers. In addition, the Westridge Marine Terminal receives jet fuel via barges and delivers it to the Vancouver International Airport via the Trans Mountain jet fuel pipeline.

3.4.1.1 Project-related Marine Traffic Emissions

Emissions from marine traffic associated with Trans Mountain operations include combustion emissions associated with the transit operations of tankers, barges and associated escort tugs. Combustion emissions from Panamax and Aframax class tankers consist of emissions from the main engine and auxiliary engines when they are underway and approaching/departing from anchor/berth, and auxiliary engines only when they are at anchorage and berth. Tanker boilers typically do not operate when underway, or at berth/anchorage within the Marine Air Quality RSA. The 2005-2006 BC Ocean-Going Vessel Emissions Inventory (Chamber of Shipping 2014) showed boilers for tankers consuming an average of 0.10 tonnes/h while underway, 0.11 tonnnes/h while at berth, and 0.13 tonnes/h while at anchor. The Environment Canada MEIT, based on the 2010 inventory also indicates that boilers for tankers operate at anchor, berth and while underway. The boilers are used for heating bunker fuel or Heavy Fuel Oil (HFO) for use in the tanker's main and auxiliary engines. The North American Emission Control Area (ECA) Regulations shall preclude the use of HFO by all vessels in ports, harbors and waterways within 200 nm (370 km) off the Canadian coast (Government of Canada 2010). The HFO will be replaced by distillate fuels like Marine Distillate Oil (MDO), which does not require to be heated prior to its use; therefore, the use of boilers for heating the fuel in use will no longer be necessary while a vessel is within ECA limits.

Based on personal communication with Trans Mountain (Trans Mountain 2014), it was indicated that a tanker might be starting to prepare the onboard HFO for changeover once the tanker leaves the ECA, (i.e. approximately 370 km beyond the Marine Air Quality RSA), by using the boiler at low load in Segment 7 during winter months only. The estimated boiler emissions during outbound underway for a loaded tanker in Segment 7 only during winter months were less than 0.7% of the total emissions for Project combustion emissions in the Base and Application Cases. This contribution is very small and is not expected to make a material change in the predicted concentrations. Therefore, no tanker boiler emissions were considered in this assessment.

In certain segments of the marine corridor (along with the transit between berth and anchorage locations), tankers are escorted by tugboats, for which there are combustion emissions from one engine per each tugboat. Barges are not self-propelled but rather escorted by a standard ocean-going tugboat. Combustion emissions are not associated with the barge itself but with the engine aboard the tugboat.

3.4.1.2 Project-related Emissions at Berth/Anchorage

Emissions associated with tanker stationary operations include combustion emissions associated with three anchorage locations, and one berth (Base Case)/three berths (Application [Project] Case). Combustion emissions from Panamax and Aframax class tankers include emissions from the auxiliary engines only at berth, and anchorage locations. Tanker boilers and main engines typically do not operate at anchorage or berth locations; therefore, no tanker main engine or boiler emissions were considered at stationary operations in this assessment.

3.4.1.3 Project-related Emissions Between Berth and Anchorage Locations

It is highly unlikely that all anchorage locations and berth locations would be used at the same time, and to also have an additional tanker in transit between each location due to physical space limitation; therefore, it was assumed that there are no marine emissions between the berth and anchorage locations.

However, it was assumed that there could be up to four tug escorts operating at anchorage or berth or between berth and anchorage locations. As a modelling simplification, the combustion emissions from the four tug boats were distributed between four locations in the Base Case (one berth and three anchorage locations) and six locations in the Application and the Cumulative Cases (three berths and three anchorage locations). As a modeling simplification, these tug emissions were assumed to be coming from the tankers auxiliary engine(s) stack exhaust, which is justifiable.

3.4.1.4 Project-related Fugitive Emissions During Loading, Anchorage and Underway

There will be no fugitive emissions associated with product loading activities at the Westridge Marine Terminal because 100% of vapours will be collected by the Vapour Control System (VCS) that includes a vapour combustion unit (VCU) and/or vapour recovery units (VRUs) under normal operations. More information on this topic was provided in Trans Mountain's response to Lower Fraser Valley Air Quality Coordinating Committee (LFVAQCC) action items (refer to Part 12, Section 1.0, Informal Information Requests (IIR) No. 1 of Project and Technical Update No. 4 to the NEB).

An emergency scenario of a VCU or VRU failure, which may results in leaks and escaped vapours, was assessed as a follow-up response to an Information Request (IR) from City of Burnaby (F-IR No.1.028.01 [Filing ID: A4D3G2]). All combustion emissions associated with Trans Mountain operations were estimated according to the methodology adopted in Environment Canada's 2010 National Marine Emission Inventory (SNC-Lavalin Environment 2012).

Fugitive emissions are typically not released from inbound and outbound vessel cargo holds during voyage or at anchorage locations under normal operations. Fugitive emissions could potentially occur through the vessel vents, if there is increased gas pressure in vessels that hold crude oil under exposure to high outside temperatures during summer months. More details are provided in Section 3.4.2.2.

Although fugitive vapours from tanker holds are unlikely during normal conditions, fugitive vapours were included from vessels at anchorage and in transit for the current dispersion modelling as a modelling conservatism. As noted in Part 12, Section 3.0, IIR No.5 of the Project and Technical Update No. 4 to the NEB, venting logs have been requested from tanker operations from the summer 2014.

For the Base Case, a typical crude oil (Low TAN[2] Dilbit) was used to represent fugitive vapours from vessels in transit and at anchorage (two locations with Low TAN Dilbit and one location with light sour product). For the Application Case, a typical (most conservative for BTEX) product blend (maximum of High TAN and Low TAN dilbit) was used to represent fugitive vapours from the vessels in transit modelled in the 1-hour and 24-hour modelling scenarios. Fugitive emissions at three anchorage locations were also assessed. High TAN and Low TAN dilbit were considered at two locations, and Light Synthetic/Sweet product was considered at the third location. A weighted blend of the product types based on annual throughput was used to represent fugitive vapours from the vessels modelled in the annual modelling scenario. Additionally, the most conservative product for H_2S and mercaptans, was modelled to represent fugitive vapours from vessels in transit and anchorage location, this is presented in Appendix B. Further discussion on product selection is in Section 3.4.2.4.

3.4.1.5 Non-Project Marine Traffic Emissions

Ambient air quality conditions over water were represented by modelling non-Project vessel underway traffic along with berth and anchorage locations. The Corbett inventory (Corbett *et al*, 2006; Wang *et.al* 2008), which is a set of geographically resolved annual gridded emissions, was previously used to represent marine traffic in the Marine Air Quality RSA in the 2013 Marine Technical Report and in the 2014 Supplemental Marine Technical Report No. 1. The Environment Canada Marine Emission Inventory DRAFT MEIT version 4.1 (for underway emissions) and FINAL MEIT version 4.1 (for anchorage and berth emissions) (SNC-Lavalin Environment 2013), which provides a more comprehensive inventory for the Marine Air Quality RSA, was used in this updated modelling as per Item 1 in Table 1.1. Environment Canada has established a software license agreement allowing RWDI to use the MEIT[3].

Year 2030 MEIT data were used for the Cumulative Case. Emission rates were estimated based on the change in total emissions between year 2010 and 2030 MEIT data. Scaling factors were developed and applied to the 2010 MEIT modelled emission rates to account for the emission rate change from year

[2] TAN – Total Acid Number indicates the quantity of acidifying compounds present in a petrochemical sample.

[3] This product was created using software belonging to Environment Canada; however, Environment Canada has not reviewed and does not endorse any product created by or based on its software.

2010 to 2030 available in the database. This approach implied that underway routes, and berth and anchorage locations are not going to change (as was verified by comparing year 2010 and 2030 databases) and emission growth will be linear for each source.

3.4.1.5.1 Summary of Modelled Emission Sources

The aforementioned emission sources for Project-related marine vessel traffic were broken down into seven source groups for the purpose of dispersion modelling:

- Auxiliary engine at the Westridge Marine Terminal berth (one point source per berth);
- Auxiliary engine at anchorage (one point source per anchorage location);
- Fugitive emissions at anchorage (one area source per anchorage location);
- Combustion emissions – Segment 1 through Segment 7 (series of area sources along inbound and outbound shipping lanes);
- Fugitive emissions – Segment 1 through Segment 7 (series of area sources along inbound and outbound shipping lanes);
- Non-Project marine vessel traffic (one point per 2 km by 2 km grid cell, grid cells were created based on line source emissions using geo-spatial algorithm); and,
- Non-Project marine berth and anchorage location (one point source per anchorage/berth location).

The locations of the seven segments along the inbound and outbound shipping lanes are illustrated in Figure 3.1 (refer to the Figures section).

Fugitive emissions from vessels at berth associated with product loading activities at the Westridge Marine Terminal were not modelled in this set of supplemental air quality studies. All fugitive emissions associated with product loading at the Westridge Marine Terminal will be captured by the Vapour Control System (refer to Part 12, Section 1.0, IIR No. 1 of Project and Technical Report Update No. 4 to the NEB). Collected vapours will be mostly destructed with an efficiency higher than 99% by the vapour recovery and combustion units. Land-based emission sources, as well as storage tanks at the Burnaby and Westridge Marine Terminals, are not included in this marine transportation assessment and were reported separately (RWDI 2014b) as part of design updates.

The assessment approach for existing operations, Project effects and cumulative effects are detailed in the following sub-sections.

3.4.2 Trans Mountain Marine Transit Emissions Estimation – Existing and Project Conditions Assessment

The Westridge Marine Terminal currently handles approximately five tankers[4], two to three crude barges and one to two jet fuel barges per month. With the Project, this is expected to increase to 34[5] tankers, and remain two to three crude barges and one to two jet fuel barges per month.

The following sub-sections explain the methodology and assumptions used to estimate the marine combustion emissions from Trans Mountain operations.

3.4.2.1 Combustion Emissions from Marine Engines

Emissions of CACs and VOCs were estimated for the 150 km by 150 km Marine Air Quality RSA for input into dispersion modelling. Greenhouse gas emissions were also estimated for the Marine Air Quality RSA.

The basic equation used to estimate per vessel emissions from tankers and tugboats is:

$$E = (ME \times LF \times T \times EF_{act}) + (AE \times LF \times T \times EF_{act}) + (BO \times T \times EF_{fuel})$$

Where: E = emissions;

ME = main engine capacity, also known as maximum continuous rating (kW);

AE = auxiliary engine capacity, applicable only to tankers (kW);

BO = boiler fuel consumption rate, applicable only to tankers (tonne/hour);

EF_{act} = activity based emission factor (g/kW);

EF_{fuel} = fuel based emission factor (kg/tonne fuel);

LF = load factor; and,

T = time (hours).

Emission factors were taken from Environment Canada's 2010 National Marine Emission Inventory (SNC-Lavalin Environment 2012). Activity based emission factors are listed based on the engine type (main or auxiliary; 2-stroke or 4-stroke) and type of fuel (heavy fuel oil [HFO] or marine diesel oil [MDO]). Panamax and Aframax tankers were assumed to have 2-stroke main engines and 4-stroke auxiliary engines, both using marine diesel oil (MDO). Marine fuel oil used in Project-related tankers will be required to meet the 0.1% sulphur content limit required in ECAs, starting January 1, 2015 (Chamber of Shipping 2014), prior to the anticipated start of the Project. Therefore, marine vessels will need to use distillate fuels in the North American ECA. A 0.1% sulphur content was used for the Base, Application and Cumulative Cases. A summary of the emission factors used for this assessment is shown in Table 3.1.

[4] This includes two to three Aframax tankers and one to two Panamax tankers.
[5] All tankers are assumed to be Aframax class.

Note that CO_2e emission factors are calculated based on the IPCC's Fourth Assessment Report as recommended by Environment Canada (Environment Canada 2014).

Emission factors for PM and SO_2 are dependent on fuel sulphur content and for this assessment, the maximum sulphur content of 0.1% within ECAs was used for all tankers. For standard ocean-going tugs (barges) and escort tugs, MDO will be required to meet stricter federal regulations on marine diesel sulphur content starting in June, 2014. The limit for vessels with small diesel engines (less than or equal to 30,000 cc) is 0.0015% and the limit for vessels with large diesel engines (greater than 30,000 cc) is 0.1%. For this assessment, it was assumed that all tugboats will operate as vessels with large diesel engines under the Sulphur in Diesel Fuel Regulations (Government of Canada 2013), and the sulphur content limit of 0.1% was applied. This represents a conservative estimate as surveys completed as part of both Environment Canada's National Marine Emission Inventory and the Chamber of Shipping's BC Ocean-Going Vessel Emissions Inventory found the sulphur content of MDO currently used by vessels in BC to be 0.05%.

With respect to other future initiatives, Trans Mountain followed guidance from Environment Canada on the modelling approach, which is conservative. Benefits of coming into force of future regulations such as IMO NO_X Tier III regulations and programs and initiatives such as the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) will take a phased in approach and will be on top of any mitigation measures that were accounted for in the modelling. All new vessels will be required to meet all applicable local and international regulations. The predicted NO_X results, for example, are expected to be less than the Project-related results reported here as the benefits of EEDI and SEEMP would be felt.

Table 3.1: Emission Factors for Main and Auxiliary Engines (in g/kWh)

Vessel Class	Engine Type	Emission Factor										
		TSP	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC	CO_2	CH_4	N_2O	CO_2e[1]
Tanker	Main, 2-stroke	0.30	0.28	0.26	1.1	17.0	0.42	0.60	588	0.006	0.017	593.2
	Auxiliary, 4-stroke	0.30	0.28	0.26	1.1	13.9	0.42	0.40	670	0.004	0.017	675.2
Tugboat	Main, 4-stroke	0.30	0.28	0.26	1.1	13.2	0.42	0.50	670	0.004	0.017	675.2

Source: SNC-Lavalin Environment 2012.

Note: [1] Based on IPCC's Fourth Assessment Report as recommended by Environment Canada (Environment Canada 2014)

Engine and activity profiles were developed for four representative vessels and summarized in Table 3.2: Panamax tanker; Aframax tanker; Seaspan Raven tug; and standard ocean-going tug. The Seaspan Raven tug refers to the escort tug assist for the tankers in certain segments of travel, as summarized in Table 3.3. The standard ocean-going tug refers to the tugboats towing crude and jet fuel barges to and from the Westridge Marine Terminal. A regression relationship from Environment Canada's National Marine Emission Inventory (SNC-Lavalin Environment 2012) was used to estimate the auxiliary engine capacity (AE) of the tankers:

$$AE = 0.0648 \times ME + 1861$$

Where: AE = auxiliary engine capacity (kW); and,

ME = main engine capacity (kW).

Table 3.2: Main and Auxiliary Engine Rated Capacities (in kW)

Vessel	ME	AE
Panamax tanker	10,800[1]	Two Auxiliary engines each at 600 kW running at 50-55% load[5]
Aframax tanker	14,914[2]	
Seaspan Raven tug (main escort tug)/ Seaspan. Cates III (Additional 4th Escort Tug)	3,728[3]	n/a
Standard ocean-going tug	3,183[4]	n/a

Sources: [1] MAN Diesel & Turbo 2009.
[2] Trans Mountain 2014.
[3] Seaspan ULC 2014.
[4] US EPA 2010b.
[5] Personal communication with Trans Mountain (October, 2014).

Table 3.3: Number of Escort Tugs Modelled by Segment of Travel

Segment	Inbound Existing Conditions	Outbound Existing Conditions	Inbound Application Case	Outbound Application Case
Between Anchorage and Berth[1]	4 or 2	3 or 2	4 or 2	3 or 2
1	3	3	3	3
2	2	3	2	3
3	0	0	0	1
4	0	0	0	1
5	0	1	0	1
6	0	1	0	1
7	0	0	0	1

Note: [1] The first number is the number of escort tugs for Aframax and Panamax tankers and the second number is the number of escort tugs for barges.

Tankers and tugboats travelling to and from the Westridge Marine Terminal operate in five different modes: fast underway; slow cruise underway; maneuvering; anchor; and berth. The mode of operation determines which engines are used and the load on each engine. During anchor and berth, the main engines aboard tankers are assumed to be off and tugboats are assumed to be under load. A summary of the load factors used for this assessment is shown in Table 3.4.

Table 3.4: Load Factors by Mode of Operation

Engine	Mode	Tanker	Tugboat
Main engine	Fast underway	0.8	0.8
	Slow cruise underway	0.4	0.8
	Maneuvering	0.1	0.8
	Maneuvering between berth and anchorage locations[1]	n/a	0.1
Auxiliary engine	Underway (fast + slow cruise + maneuvering)	0.24	n/a
	Anchor	0.26	n/a
	Berth	0.26	n/a

Sources: Chamber of Shipping 2007, SNC-Lavalin Environment 2012.

Note: [1] As per Section 3.4.1.3, tanker main engines were not modelled between berth and anchorage locations. However, it was assumed that there could be up to four tug escorts operating between anchorage and berth locations or between berth and anchorage locations.

Additional low load factors were applied to the activity based emission factors (Table 3.1) for certain contaminants while maneuvering. These low load factors were applied to CO at 2.00, NO_X at 1.22, and VOC at 2.83.

The mode for each segment was determined by applying the propeller law (SNC-Lavalin Environment 2012) and comparing the resulting loading factor to those outlined in Table 3.4:

$$\mathrm{LF} = \left(\frac{\text{actual speed}}{\text{maximum speed}}\right)^3$$

Actual speeds for tankers and escort tugs were provided for each segment by Trans Mountain. Tankers were assumed to have a maximum design speed of 15 knots (MAN Diesel & Turbo 2009) but would operate at less speed within the Marine Air Quality RSA. Speeds for standard ocean-going tugs towing crude and jet fuel barges were set to the same speeds as for tankers and escort tugs, up to a maximum of 10 knots. Vessel speed and mode for each segment are summarized in Table 3.5.

Table 3.5: Mode of Operation and Vessel Speeds in Each Segment (Inbound and Outbound) for the Base and Application Cases (in knots)

Segment	Mode	Base Case Tanker and Escort Tug Speeds	Application Case Tanker and Escort Tug Speeds	Barge and Tug Speeds
1	Maneuvering	6	6	6
2	Maneuvering	6	6	6
3	Slow Cruise Underway	10	11	10
4	Fast Underway	13	11	10
5	Slow Cruise Underway	10	10	10
6	Slow Cruise Underway	10	10	10
7	Fast Underway	14.5	12	10

Note: Based on personal communication with Trans Mountain (October, 2014).

Average times spent underway and maneuvering were estimated based on the vessel route distances and vessel speeds. Typical times at anchorage and berth locations are summarized in Table 3.6 and Table 3.7, respectively. The average time tanks spend at anchor are based on Application Case numbers as there was no information available for the Base Case.

Table 3.6: Anchorage Time, Base and Application Cases (only auxiliary engines are running)

Vessel	Outbound Hours	Inbound Hours	Total Hours
Aframax	11.9	1.5	13.4
Panamax	1.3	2.2	3.5
Crude Barge	0.3	6.8	7.1

Note: Based on personal communication with Trans Mountain (October, 2014).

Table 3.7: Berth Time, Base and Application Cases (only auxiliary engines are running)

Vessel	Base Case Hours	Application Case Hours
Aframax	34	48.3
Panamax	24	34.1
Crude Barge	9	22.4

Note: Based on personal communication with Trans Mountain (October, 2014).

Segment lengths and time spent in each segment of travel, along with the time spent at berth and anchorage, are provided in Tables 3.6 and 3.8.

Table 3.8: Route Distance, and Time-in-Mode Within the Marine Air Quality RSA

Segment	Trip Distance within the Segment (km)	Tanker Time in Mode Existing and Application (hours)	Barge Time in Mode Existing and Application (hours)
Inbound			
1	2.22	0.20	0.20
2	14.12	1.27	1.27
3	24.04	1.30/1.18	1.30
4	42.52	1.77/2.09	2.30
5	83.29	4.50	4.50
6	17.92	0.97	0.97
7[1]	93.13	3.74/4.19	5.03
Outbound			
1	2.22	0.20	0.20
2	14.11	1.27	1.27
3	27.12	1.46/1.33	1.46
4	43.22	1.80/2.12	2.33
5	85.99	4.64	4.64
6	12.47	0.67	0.67
7[1]	91.27	3.40/4.11	4.93

Note: [1] Segment 7 length was updated to its actual length in the Marine Air Quality RSA. The 2013 Marine Technical Report and the 2014 Supplemental Marine Technical Report No. 1submissions included some length outside of the Marine Air Quality RSA.

3.4.2.2 Fugitive Emissions from Vessel Cargo Holds

The 2013 Marine Technical Report and 2014 Supplemental Marine Technical Report No. 1 assessed fugitive VOC emissions from marine vessels in transit based on Environment Canada's National Marine Inventory (SNC-Lavalin Environment 2012), which refers to US EPA Compilation of Air Pollutant Emission Factors, known as AP-42 (US EPA 1995). The AP-42 transit VOC emission factor for tankers and crude barges is 150 mg/week/litre of product. This emission factor refers back to *Evaporation Loss From Tank Cars, Tank Trucks And Marine Vessels, Bulletin No. 2514* (American Petroleum Institute 1959). This study is quite dated and does not account for the evolution of fugitive emission controls through Inert Gas System (IGS) or VCS.

IGS was implemented for tankers built since 1979 to keep the oxygen content low and reduce hydrocarbon concentrations below the lower flammability limit when cargo holds are returning empty to the Westridge Marine Terminal (Safety of Life at Sea (SOLAS) 1974). IGS was required for existing tankers, not later than July 1, 1983, for crude carriers and not later than May 1, 1985, for product tanks between 20,000 - 40,000 deadweight tonnes (DWT).

The VCS standards were adopted by the International Marine Organization (IMO) in 1997 (International Convention for the Prevention of Pollution from Ships MARPOL Annex VI) and implemented for Trans Mountain tankers since the 1990s (IMO 1997). In simple terms, considerable effort is made to ensure leak-proof cargo holds and management of vapour space pressures to prevent or otherwise minimize any VOC vapours to atmosphere.

Although fugitive vapours from tanker holds are very unlikely during normal conditions, they were included in the current dispersion modelling as a modelling conservatism.

The basic equation for fugitive VOC emissions from marine vessels in transit is:

$$E = DWT \times LF \times TF \times EF_{transit}$$

Where: E = VOC emissions (mg);

DWT = deadweight tonnage;

LF = load factor;

TF = transit factor; and,

$EF_{transit}$ = transit VOC emission rate (Table 3.9).

Deadweight tonnage × load factor represents the product amount in vessels and is provided in Table 3.9. The transit factor was set to 0.5 to account for inbound crude vessels and outbound jet fuel barges (i.e., half of the total transit time) from which fugitive emissions are not expected.

The transit VOC emission rates shown in Table 3.9, were obtained from Environment Canada's National Marine Emissions Inventory, and were sourced from the United Stated Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (US EPA 1995). In the AP-42 document, it is noted that the transit VOC emission rates include CH_4 and ethane, and are therefore, reflective of total organic compound (TOC) emissions according to the definition employed in this assessment. VOC emissions were conservatively assumed to be 100% of TOC emissions for crude as the majority of crudes transported in the Application Case do not have CH_4 or ethane in liquid composition analyses.

Table 3.9: Transit VOC Emission Rates and Associated Product Throughput

Product	Transit VOC Emission Rate (mg/week/litre of product)	Product Amount (litre)[1]	
		Baseline Assessment	Project Effects Assessment
Heavy Aframax[2]	150	71,536,500	87,433,500
Light Aframax[3]	150	92,202,600	92,202,600
Panamax	150	51,665,250	58,818,900
Crude Barge	150	12,717,600	12,717,600
Jet Fuel Barge	0.60	18,000,000	18,000,000

Notes: [1] Trans Mountain 2014; Vancouver Airport Fuel Facilities Corporation 2011.
[2] Aframax tanker loaded with heavy crude oil
[3] Aframax tanker loaded with light crude oil

3.4.2.3 Fugitive Emissions from Product Loading

Fugitive emissions associated with the marine vessel loading activity at the Westridge Marine Terminal are discussed in the Supplemental Air Quality Technical Report For Technical Update No. 2 (RWDI 2014b) (Filing A4A4E3).

Fugitive emissions from marine vessel loading are collected and destroyed by vapour abatement technologies at the Westridge Marine Terminal. A VCU is currently used. Based on preliminary engineering design, the Project includes two new VRUs, consisting of a H_2S Guard unit followed by a bed of activated carbon, as well as a H_2S Guard unit followed by a new VCU for back-up use on peak periods when three tankers are berthed. A vapour collection efficiency of 100% was assumed for all technologies based on the existing vapour collection infrastructure (refer to Part 12, Section 1.0, IIR No.1 of the Project and Technical Update No. 4 to the NEB). Non-destructed vapours released from the vapour control units were assessed as part of the pipeline and facilities assessment and are not included in this marine transportation assessment.

3.4.2.4 Speciation of VOCs

Emissions of H_2S, mercaptans and BTEX were estimated by applying speciation profiles to estimated total VOC emissions. As a simplification, the main engine and auxiliary engine were grouped together into a single combustion group for marine vessels in transit. The speciation profile used for this combustion group represents a weighted average of the speciation profiles for main engine and auxiliary engine for underway emissions. The speciation profile used for stationary operations is based on the auxiliary engine only.

The speciation profile for combustion emissions from marine engines were obtained from Environment Canada's National Marine Emissions Inventory (Table 3.8 of SNC-Lavalin Environment 2012).

The speciation profile for fugitive vapour emissions from total calculated VOCs was developed based on available data for representative crude oil products. For the Base Case, a typical heavy crude oil (Low TAN Dilbit) was used to represent fugitive vapours from vessels in transit and at anchorage (two locations with Low TAN Dilbit and one location with light sour product). Low TAN Dilbit was used to represent fugitive vapours in the Base Case, similar to the previous Supplemental filing. For the Application Case, a blend of Low TAN Dilbit and High TAN Dilbit (most conservative for BTEX) was used to represent fugitive vapours from vessels in transit.

Since it is unlikely three vessels at anchorage will hold the same type of product, Low TAN Dilbit/High TAN Dilbit and Light Synthetic/Sweet were used to represent fugitive vapours from vessels at anchorage (two locations with Low TAN Dilbit/High TAN Dilbit and one location with Light Synthetic/Sweet). 1-hour and 24-hour fugitive vapour speciation was based on typical products most often transported from the Westridge Marine Terminal. A weighted blend of the product types based on annual throughput was used to represent fugitive vapours in transit and anchorage locations from the vessels modelled in the annual modelling scenario.

Annual fugitive vapour speciation was based on annual throughput of typical products, as summarized in Table 3.10. A more detailed discussion regarding these products and the rationale for selecting these products to represent crude product shipped through the Westridge Marine Terminal is provided in the Supplemental Air Quality Technical Report for Technical Update No. 2 (RWDI 2014b) (Filing ID No. A4A4E3.)

Additionally, the most conservative product for H_2S and mercaptans (High TAN Synbit/Dilsynbit), which is transported 5% of the time, was modelled to represent fugitive vapours from vessels in transit and anchorage location, as summarized in Appendix B.

A summary of the speciation profile sources is provided in Table 3.11. The speciation profile sources for jet fuel vapours is not included in Table 3.11 as jet fuel barges were not included in the dispersion modelling, as discussed in Section 3.4.3.

Table 3.10: Product Throughput (Line 1 and Line 2 combined), Application Case (in bbl/day)

Product	Westridge Marine Terminal
High TAN Dilbit, Low TAN Dilbit	461,500 (73%)
High TAN Synbit and Dilsynbit	31,500 (5%)
Light Sour	-
Light Synthetic, Light Sweet	135,500 (22%)
Refined Product	-
Total	628,500 (100%)

Table 3.11: Speciation Profile Sources used for VOCs and COPCs

Source Category	Basis of Speciation	Speciation Profile Sources
Combustion from Marine Engines	VOC or TSP	SNC-Lavalin Environment 2012 (based on marine distillate fuel)
Low TAN Dilbit	VOC	Crudemonitor.ca Flux chamber sampling for TMEP KMC Petroleum Properties 2011 Maxxam Analytics laboratory analyses
Light Sour/Light Synthetic	VOC	Crudemonitor.ca KMC Petroleum Properties 2011
High TAN Dilbit	VOC	Crudemonitor.ca KMC Petroleum Properties 2011 Maxxam Analytics laboratory analyses
High TAN Synbit and Dilsynbit	VOC	Crudemonitor.ca KMC Petroleum Properties 2011 Maxxam Analytics laboratory analyses
Light Synthetic, Light Sweet	VOC	Crudemonitor.ca KMC Petroleum Properties 2011

<u>**Note:**</u> RWDI flux chamber sampling report is provided in TERMPOL Section 3.1 Volume 8C (Filing ID A3S4R6)

3.4.3 Non-Project Marine Emissions - Existing Assessment

The ambient air quality conditions over water were represented by modelling non-Project vessel underway, at berth and anchorage locations. The Corbett inventory, a set of geographically resolved annual gridded emissions, was previously used to represent marine traffic in the Marine Air Quality RSA (RWDI 2013, 2014a). The draft MEIT version 4.1 which provides a more comprehensive inventory for the Marine Air Quality RSA was used in the current updated modelling. The MEIT data were used as a baseline comparison reference for the CAC and the GHG emissions over water predicted in the Marine Air Quality RSA.

The MEIT data are divided into line and point sources, representing vessels in transit (underway) and berthed/anchored vessels, respectively.

3.4.3.1 MEIT Underway Emission Sources

For the line sources, the MEIT database provided emission rates for the following contaminants of interest for different vessel classes: PM_{10}; $PM_{2.5}$; CO; NO_X; SO_2; VOC; and GHGs. The total year 2010 emissions extracted from the MEIT for the underway sources by vessel class are shown in Table 3.12.

Table 3.12: Year 2010 MEIT Underway Annual Emissions by Vessel Class (in tonnes/year)

Vessel Class	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC	CO_2e
Coast Guard	1	1	4	48	1	2	2,373
Fishing	15	14	78	947	10	44	37,974
Merchant Bulk	190	174	203	2,228	1,485	87	86,453
Merchant Container	302	278	330	3,572	2,268	150	129,638
Merchant Cruise	47	43	59	684	322	27	31,775
Merchant Other	68	62	72	765	519	32	31,036
Merchant Passenger	350	322	449	5,088	2,463	194	269,320
Special Purpose	1	1	4	44	0	2	1,758
Tanker	51	47	51	518	408	84	21,100
Tug Boat	31	29	131	1,704	25	63	82,092
War	5	5	26	286	5	12	14,229
Total	**1,060**	**975**	**1,406**	**15,884**	**7,505**	**696**	**707,749**

Notes: [1] MEIT emissions modelling in the Marine Air Quality RSA were 8% higher than the values presented in this table as domain size provided to Environment Canada (EC) had a buffer of about 1 km on each side.
[2] CO_2e = GHGs expressed in terms of carbon dioxide. CO_2e were estimated based on the global warming potential values specified in the IPCC Second Assessment Report (IPCC 1996).

The line sources, extracted from the MEIT database, which comprise total emissions shown in Table 3.12, are presented in Figure 3.2. The MEIT underway sources, extracted directly from the database for underway emissions, did not represent actual ship routes – only the start and end locations were provided. Furthermore, personal communication with the MEIT developers revealed that the

Western Canada geographical data are not optimal, and recommended correcting the spatial positioning before using it (SNC-Lavalin Environment pers. comm.). A geospatial workflow, described in the following paragraphs, was developed to re-allocate underway source emission totals within the Marine Air Quality RSA to the spatial distribution of actual shipping routes and activity. This re-allocation was done in order to be able to more accurately spatially distribute the expected emission rates into the model grid cells (2 km by 2 km each). The center of each grid point represented a non-Project vessel underway emission source (in total, there were approximately 1,500 point sources).

Raw line sources were processed and allocated for the underway sources over water areas (Environment Canada pers. comm.) (Figure 3.3). However, the emissions, although now over water, were not well reconciled within the regulated shipping lanes. Figure 3.4 shows an example of the NO_X emissions distribution from the processed data provided by MEIT. The provided dataset was found to show high emissions located very close to shorelines in some areas, such as the southern shore of Vancouver Island, as well as being directed through narrow areas in others, or in general being offset from where the major vessel routes were expected. Based on consultation with the MEIT developers (SNC-Lavalin Environment pers. comm.), it was decided to adopt a geospatial approach leveraging Geographic Information System (GIS) tools to complete an RSA-wide spatial re-allocation of the total MEIT data point emissions. The spatial re-allocation was accomplished using the following steps in GIS:

1. Data points within the Marine Air Quality RSA were sorted into three groups: high, average and low emissions based on the NO_X (Figure 3.4). As a result, high, average and low emission groups contained 85%, 5% and 10% of total mass, respectively (see Figure 3.5).
2. Emissions from data points within the Marine Air Quality RSA were summed together for each pollutant.
3. Areas where commercial vessel traffic would occur in the Marine Air Quality RSA were created in GIS using a vessel density map as a reference (MarineTraffic.com 2014). This density map, in conjunction with Google Earth imagery and GIS datasets for waterbodies and landmass obtained from ESRI and Geobase (Figure 3.6) were used to digitize expected areas of high, medium and low density shipping activity in the Marine Air Quality RSA.
4. The emission data sums from Step 2 were added to the geometries created in Step 3. The geometry was then split by model cells, and proportional emission amounts were calculated and summed by model cell.
5. The model cell centroids were used as point sources, with the emissions calculated for each cell in Step 4 as the point source contributions.

An example of the allocated NO_X emission rates is shown in Figure 3.7.

Stack parameters, as extracted from the MEIT database with the exception of the stack height, for each underway grid point are summarized in Table 3.13. The MEIT database provided different stack heights based on the ship class. To simplify the modeling, the average stack height of 32 m was assumed for all modelled grid points.

Table 3.13: Stack Parameters for Underway Non-Project Emission Sources

Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (°C)
32[1]	1.0	20	275

Note: [1] Based on average values for stack heights for vessel classes using Marine Diesel Oil/Heavy Fuel Oil and Marine Gasoline Oil fuel types provided in email communication between Wayne Boulton (RWDI) and Mourad Sassi (Environment Canada, pers. comm.).

The MEIT emissions shown in Table 3.12 were assumed to be continuous. These total annual underway emissions (converted to g/s) were applied for 1-hour, 8-hour, 24-hour and annual averaging periods. H_2S, mercaptans and BTEX emission rates were estimated from total VOC emissions using a similar approach to that which was discussed in Section 3.4.2.4.

3.4.3.2 MEIT Anchorage and Berth Emission Sources

For the anchorage and berth sources, the MEIT database provided emission rates for the following contaminants of interest for different vessel classes: PM_{10}; $PM_{2.5}$; CO; NO_X; SO_2; VOC; and, GHGs. The total emissions extracted from the MEIT version 4.1 for the underway sources by vessel class are shown in Table 3.14. Anchorage and berth locations as extracted from the MEIT data base are shown in Figure 3.8. Most berthed/anchored emission points (as extracted from MEIT) were already placed over water in areas that seemed logical for berth/anchor locations. Some locations had multiple emission sources and were combined together under one emission source. The stack height that was used was based on the average stack height from all of the sources at one location. A few berthed/anchored emission points that mistakenly appeared over land were re-located to the nearest shore location (as shown in Figure 3.9) and were modelled as individual point sources (approximately 300 point sources).

Table 3.14: Year 2010 MEIT Berth and Anchorage Annual Emissions by Vessel Class (in tonnes/year)

Vessel Class	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC	CO_2e
Coast Guard	0	0	0	1	0	0	27
Fishing	0	0	0	0	0	0	1
Merchant Bulk	202	185	210	1,658	1,935	55	138,368
Merchant Container	51	47	73	576	457	19	47,847
Merchant Cruise	37	34	59	585	271	23	33,994
Merchant Other	45	42	47	467	387	14	30,720
Merchant Passenger	0	0	0	1	1	0	62
Special Purpose	0	0	0	1	0	0	31
Tanker	37	34	35	252	382	283	23,093
Tug Boat	0	0	0	2	0	0	163
War	0	0	0	0	0	0	86
Total	**372**	**342**	**424**	**3,543**	**3,433**	**394**	**274,390**

Note: [1] CO_2e = GHGs expressed in terms of carbon dioxide. CO_2e was estimated based on the global warming potential values specified in the IPCC Second Assessment Report (IPCC 1996).

Stack parameters, as extracted from the MEIT database are summarized in Table 3.15.

Table 3.15: Stack Parameters for Anchorage and Berth Locations for Non-Project Emission Sources

Stack Height (m)	Stack Diameter (m)	Velocity Exit (m/s)	Exit Temperature (°C)
19.3 to 53.0[1]	1.0	20	275

Note: [1] Stack heights were estimated as an average of all stack heights at each common location in MEIT.

The MEIT emissions shown in in Table 3.14 for anchorage and berth locations were assumed to be continuous. These total annual underway emissions (converted to g/s) were applied for 1-hour, 8-hour, 24-hour and annual averaging periods. H_2S, mercaptans and BTEX emission rates were estimated from total VOC emissions using a similar approach to that which was used in Section 3.4.2.4.

3.4.4 Non-Project Marine Emissions Estimation – Cumulative Effects Assessment

Emission rates were estimated based on the change in total emissions between year 2010 MEIT data (shown in Table 3.12 for underway and Table 3.14 for anchorage/berth) and year 2030 MEIT data (Table 3.16 for underway and Table 3.17 for anchorage/berth). Emissions were separated into berth/anchorage emissions and underway emissions. Scaling factors were developed to account for the emission rate change from year 2010 to 2030 available in the database for both modes. Overall change in emissions relative to year 2010 is also shown in Table 3.16 and Table 3.14 for underway and anchorage/berth emissions, respectively. This implies that underway routes, and berth and anchorage locations are not going to change (as was verified by comparing as was verified by comparing year 2010 and 2030 databases) and emission growth will be linear for each source.

It is recognized that by year 2030, there will be more stringent emission requirements in place for marine vessels. Specifically, the SO_2 and PM_{10}/$PM_{2.5}$ underway emissions for underway are projected to decrease by 96% and 67%, respectively. This is due to the fact that the maximum sulphur content in fuel oils within ECAs will decrease to 0.1% starting January 1, 2015 (Chamber of Shipping 2014). Also for non-large vessels (less than or equal to 30,000 cc), the maximum sulphur content in fuel oils within ECAs was set to 0.0015% starting from June 1, 2012 (Government of Canada 2013). The SO_2 and PM_{10}/$PM_{2.5}$ anchorage and berth emissions are projected to decrease by 93% and 67%, respectively.

Marine vessel NO_X emissions in year 2030 will be dependent on vessel speed and vessel age. As vessel fleets are replaced, there will be more and more new vessels that are required to follow Tier II NO_X requirements applicable to ships built on January 1, 2011, or after. Some vessels may also be required to follow Tier III NO_X requirements within ECAs; however, the applicable ship construction date is not currently known as the IMO implementation dates are undergoing a technical review. The MEIT database adopted Tier III regulations for NO_X emissions. RWDI did not consider Tier III emission limits for the Project itself as the IMO implementation date for it is not currently known. Therefore, the Project modelled NO_X results will be conservative relative to the MEIT results.

Table 3.16: Year 2030 MEIT Underway Annual Emissions by Vessel Class and Overall Change in Emissions Relative to Year 2010 (in tonnes/year)

Vessel Class	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Coast Guard	1	1	4	42	1	2
Fishing	14	13	78	942	0	44
Merchant Bulk	38	35	194	770	58	83
Merchant Container	87	80	458	1,069	126	208
Merchant Cruise	19	17	73	194	28	33
Merchant Other	15	14	77	388	22	34
Merchant Passenger	122	112	574	4,589	11	248
Special Purpose	1	1	4	38	0	2
Tanker	10	9	53	144	15	92
Tug Boat	35	32	158	1,937	1	77
War	5	5	26	184	5	12
Total (2030)	**346**	**318**	**1,699**	**10,296**	**267**	**835**
Overall Change in Emissions Relative to Year 2010 (in Percent)	**-67**	**-67**	**21**	**-35**	**-96**	**20**

Table 3.17: Year 2030 MEIT Anchorage and Berth Annual Emissions by Vessel Class and Overall Change in Emissions Relative to Year 2010 (in tonnes/year)

Vessel Class	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Coast Guard	0	0	0	0	0	0
Fishing	0	0	0	0	0	0
Merchant Bulk	55	51	271	811	109	71
Merchant Container	30	27	143	340	57	38
Merchant Cruise	17	16	73	268	29	28
Merchant Other	13	12	58	247	23	18
Merchant Passenger	0	0	0	1	0	0
Special Purpose	0	0	0	1	0	0
Tanker	8	7	40	113	16	317
Tug Boat	0	0	0	1	0	0
War	0	0	0	0	0	0
Total (2030)	**123**	**113**	**586**	**1,783**	**234**	**472**
Overall Change in Emissions Relative to Year 2010 (in Percent)	**-67**	**-67**	**38**	**-50**	**-93**	**20**

3.4.5 Modelling

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the Marine Air Quality RSA. The CALMET/CALPUFF modelling approach, and corresponding assumptions and methodology are discussed in Section 3 of the 2013 Marine Air Quality Technical Report (RWDI 2013) (Filing ID A3S4J7).

The CALPUFF modelling is intended to estimate maximum ambient concentrations of air pollutants due to a reasonable maximum operating scenario associated with the increased marine vessel traffic due to the Project. The Aframax class tanker has the largest main engine power among all modelled vessels and is the only type of tanker assumed for the Application Case. A reasonable maximum operating scenario for the one-hour averaging period based on existing marine vessel traffic was therefore developed based on one inbound and one outbound Aframax vessel travelling along the shipping routes with tug escort as discussed in Section 3.4.1.1. Since the Westridge Marine Terminal currently handles seven to nine vessels per month, or one vessel every few days on average, the 8-hour and 24-hour averaging periods also considered one inbound and one outbound Aframax tanker with an associated tug escort.

Since it is highly unlikely for two vessels to traverse the same segment of the shipping route, in the same direction within the same hour, the one-hour averaging period for the Application Case was kept the same as existing conditions. The number of Project-related vessels will increase to 39 per month (with 34 Aframax tankers), or one to two vessels per day on average, and therefore, the 8-hour and 24-hour averaging periods for the Application Case considered two inbound and two outbound Aframax tankers with associated tug escort. The annual averaging period accounts for the total estimated annual emissions from all crude tankers and barges.

Since jet fuel barges travel along a different shipping route from Cherry Point, Washington, they are not expected to overlap to any extent spatially with the shipping routes for heavy and light/synthetic crude product. Emissions associated with jet fuel barges will not be included in the modeling; however, crude barge emissions were included in the modeling. Some spatial overlap may occur in Burrard Inlet but total emissions from jet fuel barges are expected to represent less than 1% of emissions relative to the crude tankers and escort tugs.

4. EXISTING CONDITIONS

Existing ambient conditions in the Marine Air Quality RSA are discussed in Section 4.1 of the 2013 Marine Technical Report (Filing ID A3S4J7). This included a desktop review of historical ambient monitoring data in the Marine Air Quality RSA.

In addition to the desktop review, emission estimates and predicted ambient concentrations due to existing operations are summarized in Sections 4.1 and 4.2, respectively.

4.1 Emission Estimates

4.1.1 Primary Emissions of CACs and VOCs

Total estimated annual marine emissions associated with existing operations of vessels travelling to and from the Westridge Marine Terminal are summarized in Table 4.1. Combustion emissions were compared to total existing emissions in the Marine Air Quality RSA, based on the 2010 MEIT database. Annual marine combustion emissions associated with the product transfer from or to the Westridge Marine Terminal account for up to 1% of the existing marine emissions in the Marine Air Quality RSA for any individual contaminant.

Table 4.1: Existing Annual Marine Combustion Emissions Associated with Vessels in Transit and at Berth (in tonnes/y)

Vessel Type	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Panamax Tankers (including escort tugs)	1.25	1.15	4.92	70.5	1.84	2.57
Aframax Tankers (including escort tugs)	2.09	1.92	8.27	119.5	3.09	4.35
Standard Crude Barge	0.75	0.69	2.94	34.9	1.11	1.35
Standard Jet Fuel Barge	0.25	0.23	0.97	11.5	0.36	0.45
Total Combustion Emissions	**4.34**	**3.99**	**17.10**	**236.4**	**6.40**	**8.72**
Total Marine Emissions in RSA	*1,405*	*1,293*	*3,105*	*26,180*	*7,772*	*1,531*
Percentage of Total Marine RSA Emissions	*0.3*	*0.3*	*0.6*	*0.9*	*0.1*	*0.6*

Table 4.2 presents annual marine fugitive VOC emissions associated with vessels in transit. Annual marine fugitive emission rates associated with existing conditions were calculated based on US EPA AP-42 emission factors, as per Environment Canada guidance. As discussed in Section 3.4.2.2, these factors are likely to over predict concentrations related to the Base Case.

Table 4.2: Annual Marine Fugitive VOC Emissions Associated with Vessels in Transit during Existing Conditions (in tonnes/y)

Vessel Type	VOC
Panamax Tankers	13.6
Aframax Tankers	34.5
Standard Crude Barge	5.9
Standard Jet Fuel Barge	0.02
Total Marine Fugitive Emissions[1]	**54.1**

Notes: [1] Emissions from vessel loading are assumed to be 100% collected at the Westridge Marine Terminal. Therefore, only fugitive emissions included in the marine transportation assessment are from vessels in transit.

4.1.2 Greenhouse Gases

Total estimated marine GHG emissions associated with existing operations for vessels in transit and at berth at the Westridge Marine Terminal as well as the fugitive emissions are summarized in Table 4.3. Marine transportation associated with existing operations at the Westridge Marine Terminal is estimated to represent 0.98% of marine GHG emissions in the Marine Air Quality RSA, 0.30% of marine GHG emissions in BC, and 0.17% of marine GHG emissions in Canada. Note that the total marine emissions in the Marine Air Quality RSA, BC and Canada are based on 2010 emissions obtained from the MEIT tool, and using pre-2014 GWPs.

Table 4.3: Existing Annual Marine GHG Emissions Associated with Vessels in Transit and at Berth (in tonnes/y)

Vessel Type	CO_2e
Panamax Tankers (including escort tugs)	2,700
Aframax Tankers (including escort tugs)	4,520
Standard Crude Barge	1,790
Standard Jet Fuel Barge	586
Total Combustion Emissions in Transit and at Berth and Fugitive Emissions in Transit	9,600
Percentage of Total Marine Emissions in Marine Air Quality RSA	*0.98*
Percentage of Total Marine Emissions in BC	*0.30*
Percentage of Total Marine Emissions in Canada	*0.17*

__Note:__ Total marine emissions in Marine Air Quality RSA, BC, and Canada are obtained from the MEIT tool and are based on pre-2014 GWPs.

4.2 Model Results

4.2.1 CACs and VOCs

4.2.1.1 Project-Related Traffic in the Marine Air Quality RSA, Base Case

Maximum predicted concentrations in the Marine Air Quality RSA for existing conditions due to Project-related traffic in the Base Case are presented in Table 4.4 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background. All modelled concentrations were below all objectives (National Ambient Air Quality Objective [NAAQO], BC and Metro Vancouver). In the absence of any national, provincial, or Metro Vancouver standards for BTEX and mercaptans, the BTEX AAAQO and the mercaptan objective from the Ontario AAQC have been presented in Table 4.4. The same approach has been used in all results tables that present predicted concentrations for BTEX and mercaptans. All modelled BTEX concentrations were below their respective AAAQO. The H_2S and mercaptans concentrations were below the BC TRS and Ontario mercaptans objectives, respectively, which are used for comparison in Table 4.4 in the absence of BC objectives for H_2S and mercaptans.

Table 4.4: Maximum Predicted Concentrations for Project-related Traffic – Base Case (in µg/m^3)

Contaminant	Average Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	0.82	37.1	0.40	120	n/a	120
	Annual	0.03	15.1	0.01	60	n/a	60
PM_{10}	24-hour	0.80	20.9	0.39	50	50	n/a
	Annual	0.03	8.4	0.01	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	0.76	20.2	0.37	25[1]	25	27 to 28[6]
	Annual	0.02	5.2	0.01	8	8	8.8 to 10[7]
CO	1-hour	153	1,372	102	14,300	30,000	15,000
	8-hour	15.4	1,158	7.2	5,500	10,000	6,000
NO_X	1-hour	1,749	1,860	1203	n/a	n/a	n/a
	24-hour	41.7	130	16.3	n/a	n/a	n/a
	Annual	1.3	28.0	0.44	n/a	n/a	n/a
NO_2	1-hour	175	186	120	n/a	200	400
	1-hour 98th	150	161	97.8	188[2]	n/a	n/a
	24-hour	41.7	63.4	16.3	n/a	n/a	200
	Annual	0.79	17.4	0.27	n/a	40	60
SO_2	1-hour	50.2	76.5	34.1	450	450	450
	1-hour 99th	44.5	70.8	29.7	196[3]	n/a	n/a
	24-hour	1.2	18.6	0.5	160	125	150
	Annual	0.04	2.7	0.01	25	30	30
Benzene	1-hour	4.64	9.7	5.13	30	n/a	n/a
	Annual	0.002	1.6	0.003	3	n/a	n/a
Ethylbenzene	1-hour	0.26	3.0	0.25	2,000	n/a	n/a
Toluene	1-hour	2.66	17.0	2.78	1,880	n/a	n/a
	24-hour	1.52	7.2	1.086	400	n/a	n/a

Contaminant	Average Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
Xylenes	1-hour	0.98	14.1	1.05	2,300	n/a	n/a
	24-hour	0.57	5.8	0.39	700	n/a	n/a
H_2S	1-hour	0.55	0.55	0.54	7[4]	n/a	n/a
	24-hour	0.24	0.42	0.21	3[4]	n/a	n/a
Mercaptans	10-minute	3.1	3.1	3.5	13[5]	n/a	n/a

Notes: Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

4.2.1.2 Non-Project Traffic in the Marine Air Quality RSA

Maximum predicted concentrations in the Marine Air Quality RSA for existing conditions due to only non-Project traffic (based on year 2010 MEIT database) are presented in Table 4.5 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background as there are no marine ambient monitoring stations. All modelled concentrations were below all objectives (national, provincial and Metro Vancouver) except the daily 1-hour SO_2 maximum (based on annual 99th percentile of 1-year data).[6] The 1-hour 99th SO_2 concentrations were predicted to exceed the BC interim air quality objective of 196 µg/m^3 approximately 1.1% of the time. This corresponds to four days out of the year (and in fact only one hour on each day) when exceedances of the objective were predicted to occur. All exceedances were predicted to occur in a very limited area (only at one receptor in the Burrard Inlet). The mercaptans and H_2S were predicted to be zero, as there are no mercaptans or H_2S in the combustion profiles used for the non-Project marine vessels.

[6] From now on in this report, this calculated percentile will be referred to as the 1-hour 99th prediction.

Table 4.5: Maximum Predicted Concentrations – Non-Project Traffic Only (in µg/m^3)

Contaminant	Average Period	Over Land (without Background)	Over Land (with Background)	Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	5.3	41.5	4.7	120	n/a	120
	Annual	0.93	15.9	0.95	60	n/a	60
PM_{10}	24-hour	5.1	25.3	4.5	50	50	n/a
	Annual	0.90	9.2	0.93	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	4.9	21.5	4.3	25[1]	25	27 to 28[6]
	Annual	0.85	5.4	0.88	8	8	8.8 to 10[7]
CO	1-hour	19.5	1,368	36.3	14,300	30,000	15,000
	8-hour	9.8	1,160	10.0	5,500	10,000	6,000
NO_X	1-hour	181	291	309	n/a	n/a	n/a
	24-hour	41.2	130	34.7	n/a	n/a	n/a
	Annual	7.5	34.2	8.2	n/a	n/a	n/a
NO_2*	1-hour	79.0	82.9	83.4	n/a	200	400
	1-hour 98th	76.3	81.3	75.5	188[2]	n/a	n/a
	24-hour	41.2	63.3	34.7	n/a	n/a	200
	Annual	4.6	21.2	5.1	n/a	40	60
SO_2	1-hour	164	190	322	450	450	450
	1-hour 99th	145	171	**205**	196[3]	n/a	n/a
	24-hour	38.8	56.1	35.0	160	125	150
	Annual	6.7	9.4	6.5	25	30	30
Benzene	1-hour	1.3	6.3	3.1	30	n/a	n/a
	Annual	0.02	1.6	0.03	3	n/a	n/a
Ethylbenzene	1-hour	0.12	2.8	0.31	2,000	n/a	n/a

Contaminant	Average Period	Over Land (without Background)	Over Land (with Background)	Over Water	BC Objective	Metro Vancouver Objective	National Objective
Toluene	1-hour	0.20	14.5	0.50	1,880	n/a	n/a
	24-hour	0.03	5.8	0.04	400	n/a	n/a
Xylene	1-hour	0.30	13.4	0.74	2,300	n/a	n/a
	24-hour	0.05	5.3	0.06	700	n/a	n/a
H_2S	1-hour	0	0	0	7[4]	n/a	n/a
	24-hour	0	0.18	0	3[4]	n/a	n/a
Mercaptans	10-minute	0	0	0	13[5]	n/a	n/a

Notes: Exceedance values are highlighted in bold

Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

4.2.1.3 All Traffic within the Marine Air Quality RSA, Base Case

Maximum predicted concentrations in the Marine Air Quality RSA for existing conditions due to all marine traffic, including both Project (Base Case) and non-Project vessels, are presented in Table 4.7 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background. Figures 4.1 to 4.12 show concentration contours for the Base Case for CACs including all traffic within the Marine Air Quality RSA, without ambient background.

Figures 4.1 and 4.2, and Figures 4.3 and 4.4 show concentration contours of the maximum predicted 24-hour and annual PM_{10} and $PM_{2.5}$ without ambient background, respectively. All values for modelled PM were below national, provincial, and Metro Vancouver ambient criteria and standards. Table 4.6 presents predicted concentrations for PM_{10} and $PM_{2.5}$ for the 24-hour averaging period using rolling averages (these are presented as a comparison to Table 4.7 where the 24-hour concentrations presented are all daily averages). The predicted levels for 24-hour PM_{10} and $PM_{2.5}$ using rolling averages were below their corresponding objectives.

Table 4.6: Maximum Predicted Concentrations for Particulate Matter Using 24-hour Rolling Averages – Including All Traffic in the Marine Air Quality RSA – Base Case (in µg/m³)

Contaminant	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
PM_{10}	5.9	26.0	5.2	50	50	n/a
$PM_{2.5}$ (Total)	5.5	21.7	4.9	25[1]	25	27 to 28[2]

Notes: [1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] 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

Maximum modelled CO concentrations for both the 1-hour and 8-hour averaging periods were predicted to be below relevant objectives as shown in Table 4.7.

Maximum modelled SO_2 concentrations were below all objectives (national, provincial and Metro Vancouver) for all averaging periods except the 1-hour 99th prediction (i.e., the daily 1-hour maximum based on 99th percentile of annual hourly data). The 1-hour 99th SO_2 concentrations were predicted to exceed the BC interim air quality objective of 196 µg/m³, approximately 1.4% of the time. This corresponds to five days out of the year (and in fact only one hour on each day) when exceedances of the objective were predicted to occur. The five days and hours when exceedances occurred included the same four days and hours when exceedances were predicted due to emissions from only non-Project traffic, in addition to one more hour on one other day. This indicates that the non-Project sources are the dominant contributors to the exceedances. The exceedances also occurred at the same location (see Section 4.2.1.2). Maximum predicted 1-hour, 24-hour, and annual SO_2 concentration contour plots without ambient background for the Base Case including all traffic within the Marine Air Quality RSA are shown in

Figures 4.5 to 4.7, respectively. The predicted 1-hour 99th concentration contour plot is presented in Figure 4.8.

Maximum modelled NO_2 concentrations were below all objectives (national, provincial and Metro Vancouver) for all averaging periods, including the 1-hour 98th prediction (i.e., the daily 1-hour maximum based on 98th percentile of annual hourly data). Figures 4.9 to 4.11 show contours of maximum predicted NO_2 concentrations without ambient background for the 1-hour, 24-hour, and annual averaging periods, respectively. Figure 4.12 shows the predicted 1-hour 98th concentration contour plot. Table 4.7 also shows predicted NO_X concentrations for 1-hour, 24-hour and annual averaging periods.

The maximum predicted BTEX concentrations were all below the AAAQO presented in Table 4.7.

The H_2S and mercaptans concentrations were below the BC TRS and Ontario mercaptans objectives, respectively, which are used for comparison in Table 4.7 in the absence of BC objectives for H2S and mercaptans. The 10-minute averages for mercaptans were calculated from 1-hour maximum predicted results in accordance with the Air Quality Modelling Guideline for Ontario (OMOE 2009). No ambient background data was available for mercaptans, and all mercaptan predictions were zero.

Table 4.7: Maximum Average Predicted Concentrations – Including All Traffic in the Marine Air Quality RSA – Base Case (in µg/m^3)

Contaminant	Average Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	5.4	41.6	4.8	120	n/a	120
	Annual	0.94	15.9	0.96	60	n/a	60
PM_{10}	24-hour	5.2	25.3	4.7	50	50	n/a
	Annual	0.91	9.2	0.94	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	4.9	21.6	4.5	25[1]	25	27 to 28[6]
	Annual	0.86	5.4	0.89	8	8	8.8 to 10[7]
CO	1-hour	153	1,372	102	14,300	30,000	15,000
	8-hour	15.6	1,160	10.9	5,500	10,000	6,000
NO_X	1-hour	1,750	1,860	1,204	n/a	n/a	n/a
	24-hour	55.4	144.1	40.1	n/a	n/a	n/a
	Annual	7.8	34.5	8.4	n/a	n/a	n/a
NO_2	1-hour	175	186	120	n/a	200	400
	1-hour 98th	150	161	98.1	188[2]	n/a	n/a
	24-hour	48.6	65.4	40.1	n/a	n/a	200
	Annual	4.8	21.4	5.2	n/a	40	60
SO_2	1-hour	166	192	326	450	450	450
	1-hour 99th	146	172	**208**	196[3]	n/a	n/a

Contaminant	Average Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
	24-hour	39.0	56.3	35.1	160	125	150
	Annual	6.7	9.4	6.5	25	30	30
Benzene	1-hour	4.6	9.7	5.1	30	n/a	n/a
	Annual	0.02	1.6	0.03	3	n/a	n/a
Ethylbenzene	1-hour	0.26	3.0	0.33	2,000	n/a	n/a
Toluene	1-hour	2.66	17.0	2.8	1,880	n/a	n/a
	24-hour	1.52	7.3	1.1	400	n/a	n/a
Xylenes	1-hour	0.99	14.1	1.0	2,300	n/a	n/a
	24-hour	0.58	5.8	0.40	700	n/a	n/a
H_2S	1-hour	0.55	0.55	0.54	7[4]	n/a	n/a
	24-hour	0.24	0.42	0.21	3[4]	n/a	n/a
Mercaptans	10-minute	3.1	3.1	3.5	13[5]	n/a	n/a

Notes: Exceedance values are highlighted in bold

Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

5. RESULTS OF PROJECT EFFECTS ASSESSMENT – AIR QUALITY

5.1 Emission Estimates

Total estimated annual combustion marine emissions associated with the Project expansion (i.e., vessels in transit and at berth) are summarized in Table 5.1. Total estimated annual fugitive marine emissions associated with the Project expansion (i.e., while vessels are in transit) are summarized in Table 5.2.

Combustion and fugitive emissions are compared to total existing emissions in the Marine Air Quality RSA, based on the 2010 MEIT database. Annual marine combustion and fugitive emissions associated with the Project expansion represent 0.6% to 7% of marine emissions in the Marine Air Quality RSA depending on the contaminant.

Annual marine fugitive emission rates associated with the Project were calculated based on US EPA AP-42 emission factors, as per Environment Canada guidance (American Petroleum Institute 1959). These factors are likely to over predict concentrations related to the Project.

It was conservatively assumed that all marine vessels associated with the Project expansion would be Aframax tankers, and therefore, the main contribution to the Project marine emissions is associated with Aframax tankers. Some other changes to Aframax tanker combustion emissions were also predicted as a result of the additional dedicated tug escort, as well as reduced berth times at the Westridge Marine Terminal associated with the proposed delivery pipeline from the Burnaby Terminal.

The modelled change in crude barge emissions is related to the variability of vessel distribution based on market conditions and conservative assumptions for the modelling but not as a result of the increase due to the Project. An average of 2.75 barges was estimated for the Base Case versus 3 barges for the Application Case. The Base Case vessel numbers were based on the average of data from 2012 and 2013, and Application Case vessel numbers were based on projected maximum numbers as a modelling conservatism. Therefore, the overall product carried via barges will slightly change, resulting in an increase in fugitive emissions for modelling purposes. No change to combustion emissions associated with jet fuel barges is expected as a result of the Project.

Table 5.1: Changes in Annual Marine Combustion Emissions for Vessels in Transit and at Berth Associated with Project Expansion (in tonnes/y)

Vessel Type	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Panamax Tankers (including escort tugs)	-1.2	-1.2	-4.9	-70.5	-1.8	-2.6
Aframax Tankers (including escort tugs)	32.4	29.8	126.9	1,815.0	47.7	65.5
Standard Crude Barge	0.07	0.06	0.27	3.18	0.10	0.12
Standard Jet Fuel Barge	0.00	0.00	0.00	0.00	0.00	0.00
Total Combustion Emissions	31.2	28.7	122.2	1,747.7	46.0	63.1
Total Marine Emissions in Marine Air Quality RSA	1,405	1,293	3,105	26,180	7,772	1,531
Percentage Increase due to Project	2.2	2.2	3.9	6.7	0.6	4.1

Table 5.2: Changes in Annual Marine Fugitive Emissions for Vessels in Transit Associated with Project Expansion (in tonnes/y)

Vessel Type	Base Case	Application Case	Project Only Case
Panamax Tankers	13.6	0	-13.6
Aframax Tankers	34.5	675.6	641.1
Standard Crude Barge	5.9	6.5	0.5
Standard Jet Fuel Barge	0.02	0.02	0
Total Marine Fugitive Emissions	**54.1**	**682.1**	**628.1**
Percentage Increase from the Base Case		*1,262*	*1,162*

5.2 Model Results

5.2.1 CACs and VOCs

5.2.1.1 Project Traffic in the Marine Air Quality RSA, Application Case

Maximum predicted concentrations in the Marine Air Quality RSA for the Application Case due to only Project-related traffic (Application Case) are presented in Table 5.3 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background. All modelled concentrations were below all objectives (national, provincial and Metro Vancouver). The highest predictions when compared to the most stringent objectives were for 1-hour and 1-hour 98th NO_2 (i.e., the daily 1-hour maximum based on 98th percentile of annual hourly data), which were 87% and 80% of their respective objectives. These maximum NO_2 concentrations predicted for 1-hour and 1-hour 98th were the same as those in the Base Case (see Table 4.4). All other contaminants were predicted to be less than 30% of the corresponding objectives for all averaging periods, with all particulate matter results being less than 7% and BTEX being less than 1%, except 1-hour benzene, which is close to 17% of its objective. The 10-minute maximum mercaptan concentration was predicted to be less than 33% of the Ontario objective. H_2S was predicted to be zero for 1-hour and 24-hour averaging periods, as there is no H_2S in the combustion or fugitive profiles used for the Project-related vessels in the Application Case. Addition modelling results for High TAN Synbit/Dilsynbit Product, which has H_2S in its composition, but only transported about 5% of the time, are presented in Appendix B.

Table 5.3: Maximum Modelled Concentrations – Project Traffic – Application Case (in µg/m^3)

Contaminant	Average Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	1.6	37.9	0.74	120	n/a	120
	Annual	0.21	15.2	0.08	60	n/a	60
PM_{10}	24-hour	1.6	21.7	0.72	50	50	n/a
	Annual	0.21	8.5	0.08	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	1.5	20.4	0.68	25[1]	25	27 to 28[6]
	Annual	0.20	5.2	0.07	8	8	8.8 to 10[7]
CO	1-hour	153	1,372	102	14,300	30,000	15,000
	8-hour	30.9	1,159	14.4	5,500	10,000	6,000
NO_X	1-hour	1,750	1,860	1,204	n/a	n/a	n/a
	24-hour	82.3	171	31.1	n/a	n/a	n/a
	Annual	10.2	37.0	3.6	n/a	n/a	n/a
NO_2	1-hour	175	186	120	n/a	200	400
	1-hour 98th	150	161	97.8	188[2]	n/a	n/a
	24-hour	54.9	68.9	31.1	n/a	n/a	200
	Annual	6.3	22.9	2.2	n/a	40	60
SO_2	1-hour	50.2	76.5	34.1	450	450	450
	1-hour 99th	44.5	70.8	29.7	196[3]	n/a	n/a
	24-hour	2.4	19.7	0.88	160	125	150
	Annual	0.29	3.0	0.10	25	30	30
Benzene	1-hour	5.0	10.0	6.2	30	n/a	n/a
	Annual	0.03	1.6	0.06	3	n/a	n/a
Ethylbenzene	1-hour	0.22	2.9	0.22	2,000	n/a	n/a
Toluene	1-hour	3.1	17.4	3.4	1,880	n/a	n/a

Contaminant	Average Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
	24-hour	1.8	7.6	1.2	400	n/a	n/a
Xylenes	1-hour	0.92	14.0	1.3	2,300	n/a	n/a
	24-hour	0.48	5.7	0.37	700	n/a	n/a
H_2S	1-hour	0	0	0	7[4]	n/a	n/a
	24-hour	0	0.18	0	3[4]	n/a	n/a
Mercaptans	10-minute	2.8	2.8	4.2	13[5]	n/a	n/a

Notes: Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

5.2.1.2 Non-Project Traffic in the Marine Air Quality RSA

Maximum predicted concentrations in the Marine Air Quality RSA for the Application Case due to only non-Project traffic are the same as those presented for the existing conditions (Base Case) in Section 4.2.1.2 and Table 4.5.

5.2.1.3 All Traffic within the Marine Air Quality RSA, Application Case

Maximum predicted concentrations in the Marine Air Quality RSA for the Application Case due to all marine traffic, including both Project and non-Project vessels, are presented in Table 5.4 for CACs, BTEX, H_2S and mercaptans. Modelled concentrations resulting from the Project only are also presented in Table 5.4. Results are presented over land, both with and without ambient background contribution, and over water without background. Figures 5.1 to 5.12 show concentration contours for the Application Case including all traffic within the Marine Air Quality RSA, without ambient background. The same contour intervals have been used for the Application Case figures, as for the Base Case figures, to allow for a comparison between the two cases.

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Table 5.4: Maximum Modelled Concentrations – Including All Traffic in the Marine Air Quality RSA – Application Case and Contribution from Project Only (in µg/m^3)

Contaminant	Average Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	Project Only, Over Land (without Background)	Project Only, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	5.4	41.7	5.0	0.80	0.34	120	n/a	120
	Annual	0.98	15.9	1.0	0.19	0.07	60	n/a	60
PM_{10}	24-hour	5.3	25.4	4.9	0.78	0.33	50	50	n/a
	Annual	0.95	9.3	0.99	0.18	0.07	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	5.0	21.7	4.6	0.74	0.33	25[1]	25	27 to 28[6]
	Annual	0.90	5.5	0.93	0.17	0.06	8	8	8.8 to 10[7]
CO	1-hour	153	1,372	102	10.6	13.0	14,300	30,000	15,000
	8-hour	31.0	1,160	15.4	15.4	7.2	5,500	10,000	6,000
NO_X	1-hour	1,750	1,861	1,204	103	129	n/a	n/a	n/a
	24-hour	94.6	183	47.4	40.6	14.8	n/a	n/a	n/a
	Annual	14.8	41.5	10.4	9.0	3.1	n/a	n/a	n/a
NO_2	1-hour	175	186	120	74.7	76.4	n/a	200	400
	1-hour 98th	150	161	98.3	41.6	73.9	188[2]	n/a	n/a
	24-hour	57.4	70.4	46.3	40.6	14.8	n/a	n/a	200
	Annual	9.2	25.8	6.5	5.6	1.9	n/a	40	60
SO_2	1-hour	166	192	326	2.9	3.7	450	450	450
	1-hour 99th	146	172	**208**	1.6	3.2	196[3]	n/a	n/a
	24-hour	39.2	56.5	35.2	1.2	0.42	160	125	150
	Annual	6.8	9.5	6.6	0.26	0.09	25	30	30
Benzene	1-hour	5.0	10.0	6.2	0.50	1.1	30	n/a	n/a
	Annual	0.05	1.6	0.07	0.03	0.06	3	n/a	n/a
Ethylbenzene	1-hour	0.22	2.9	0.33	0.01	0.02	2,000	n/a	n/a

Contaminant	Average Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	Project Only, Over Land (without Background)	Project Only, Over Water	BC Objective	Metro Vancouver Objective	National Objective
Toluene	1-hour	3.1	17.4	3.4	0.52	0.59	1,880	n/a	n/a
	24-hour	1.8	7.6	1.2	0.30	0.21	400	n/a	n/a
Xylenes	1-hour	0.92	14.0	1.3	0.10	0.21	2,300	n/a	n/a
	24-hour	0.49	5.7	0.37	0.02	0.03	700	n/a	n/a
H_2S	1-hour	0	0	0	0	0	7[4]	n/a	n/a
	24-hour	0	0.18	0	0	0	3[4]	n/a	n/a
Mercaptans	10-minute	2.8	2.8	4.2	0.33	0.69	13[5]	n/a	n/a

Notes: Exceedance values are highlighted in bold

Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

Figures 5.1 and 5.2, and Figures 5.3 and 5.4 show concentration contours of the maximum predicted 24-hour and annual PM_{10} and $PM_{2.5}$ without ambient background, respectively. All values for modelled PM were below national, provincial, and Metro Vancouver ambient criteria and standards. Table 5.5 presents predicted concentrations for PM_{10} and $PM_{2.5}$ for the 24-hour averaging period using rolling averages (these are presented as a comparison to Table 5.4 where the 24-hour concentrations presented are all daily averages). The predicted levels for 24-hour PM_{10} and $PM_{2.5}$ using rolling averages were below their corresponding objectives. All values for modelled PM increase by between 1% and 5% between the Base Case and the Application Case. When compared to the most stringent objectives, the predicted levels for PM (of any size range) from the proposed Project were below 3% of the objectives.

Table 5.5: Maximum Predicted Concentrations for Particulate Matter Using 24-hour Rolling Averages – Including All Traffic in the Marine Air Quality RSA – Application Case and Contribution from Project (in µg/m^3)

Contaminant	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	Project Only, Over Land (without Background)	Project Only, Over Water	BC Objective	Metro Vancouver Objective	National Objective
PM_{10}	5.9	26.0	5.4	0.81	0.41	50	50	n/a
$PM_{2.5}$ (Total)	5.5	21.8	5.1	0.77	0.40	25[1]	25	27 to 28[2]

Notes: [1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values
[2] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

Maximum modelled CO concentrations for the Application Case were predicted to remain the same for the 1-hour period and increase to almost double for the 8-hour period with respect to the Base Case. However, all predicted levels were well below relevant objectives (around 1% for the Application Case, and less than half a percent for the Project) as shown in Table 5.4.

Maximum modelled SO_2 concentrations were below all objectives (national, provincial and Metro Vancouver) for all averaging periods except for the 1-hour 99th prediction (i.e., the daily 1-hour maximum based on 99th percentile of annual hourly data). The 1-hour 99th SO_2 concentrations were predicted to exceed the BC interim air quality objective of 196 µg/m^3 approximately 1.4% of the time. This corresponds to five days out of the year (and in fact only one hour on each day) when exceedances of the objective were predicted to occur. The five days and hours when exceedances occurred, and the location of exceedances, were the same as in the Base Case (see Sections 4.2.1.3 and 4.2.1.2). Maximum predicted 1-hour, 24-hour, and annual SO_2 concentration contour plots without ambient background for the Application Case including all traffic within the Marine Air Quality RSA are shown in Figures 5.5 to 5.7, respectively. The predicted 1-hour 99th concentration contour plot is presented in Figure 5.8. All of the SO_2 predictions increased less than 1% between the Base and Application Cases, and the SO_2 concentrations predicted for the proposed Project were all less than 2% of the corresponding most stringent objectives.

Maximum modelled NO_2 concentrations were below all objectives (national, provincial and Metro Vancouver) for all averaging periods. Figures 5.9 to 5.11 show contours of maximum predicted NO_2 concentrations without ambient background for the 1-hour, 24-hour, and annual averaging periods, respectively. Figure 5.12 shows the predicted 1-hour 98th NO_2 concentration contour plot (i.e., the daily 1-hour maximum based on 98th percentile of annual hourly data). The 1-hour (and 1-hour 98th) Project predictions were almost 40% of the objectives, but the modelled concentrations increased by only a fraction of a percent between the Base and Application Cases. The maximum modelled Project concentrations for 24-hour and annual NO_2 were approximately 20% and 14% of the corresponding objectives, respectively, with larger increases predicted between the Base and Application Cases. The 24-hour NO_2 was predicted to increase by 15% and 18% over water and land, respectively, and the annual NO_2 was predicted to increase around 24% over water, and up to 90% over land.

The maximum predicted benzene and toluene concentrations increased from the Base Case, while ethylbenzene and xylenes decreased at some receptors. All of the BTEX concentrations were below their respective AAAQO, as shown in Table 5.4. The maximum predicted mercaptans decreased from the Base Case over land, but increased over water. The H_2S concentrations was predicted to be zero, since there are no contributions from either the combustion or fugitive profiles used for the Project-related vessels in the Application case or any of the non-Project traffic. Addition modelling results for High TAN Synbit/Dilsynbit Product, which has H_2S in its composition, but only transported about 5% of the time are presented in Appendix B Project vessels.

6. RESULTS OF PROJECT EFFECTS ASSESSMENT – GREENHOUSE GASES

6.1 Emission Estimates

Total estimated marine GHG emissions associated with the Project expansion are summarized in Table 6.1. The increase in marine transportation associated with Project expansion was estimated to represent an increase of approximately 6.9% in marine GHG emissions in the Marine Air Quality RSA, 2.1% in marine GHG emissions in BC, and 1.2% in marine GHG emissions in Canada. Note that the total marine emissions in the Marine Air Quality RSA, BC and Canada are based on 2010 emissions obtained from the MEIT tool, and using pre-2014 GWPs.

Table 6.1: Changes in Annual Marine GHG Emissions for Vessels in Transit and at Berth Associated with Project Expansion (in tonnes/y CO_2e)

Vessel Type	Base Case	Application Case	Project Only
Panamax Tankers (including escort tugs)	2,700	0	-2,700
Aframax Tankers (including escort tugs)	4,520	75,200	70,700
Standard Crude Oil Barge	1,790	1,950	162
Standard Jet Fuel Barge	586	586	0
Total Combustion Emissions in Transit and at Berth and Fugitive Emissions in Transit	**9,600**	**77,700**	**68,100**
Percentage Increase in Marine Emissions in RSA	*0.98*	*7.9*	*6.9*
Percentage Increase in Marine Emissions in BC	*0.30*	*2.4*	*2.1*
Percentage Increase in Marine Emissions in Canada	*0.17*	*1.4*	*1.2*

Note: Total marine emissions in Marine Air Quality RSA, BC, and Canada obtained from the MEIT tools and are based on pre-2014 GWPs.

6.2 Project Effect on Climate Change

GHG emissions from Project activities 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. 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. The NRC further points 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. Assuming that operational emissions will not change over the lifetime of the Project, total emissions over 50 years of the Project life would be 3.4 Mt CO_2e, which is estimated to result in an increase in the Earth's global temperature by 1.6×10^{-6} °C. Other changes to the climate system and physical environment associated with the Project are summarized in Table 6.2.

Table 6.2: Effect of the Project on Overall Climate Change

Climate Change Effects	Low Estimate	Best Estimate	High Estimate
Precipitation changes	±0.000005%	±0.000014%	±0.000023%
Increase in heavy rainfall	0.000003%	0.000013%	0.000023%
Yield reduction in a number of crops	0.000005%	0.000020%	0.000035%
Changes in stream flows	±0.000005%	±0.000014%	±0.000023%
Decrease in the extent of annually averaged Arctic sea ice	0.000014%	0.000036%	0.000058%
Decrease in the extent of September Arctic sea ice	0.000014%	0.000036%	0.000058%

7. RESULTS OF CUMULATIVE EFFECTS ASSESSMENT – AIR QUALITY

7.1 Model Results

7.1.1 CACs and VOCs

7.1.1.1 Project Traffic in the Marine Air Quality RSA, Cumulative Case

Maximum predicted concentrations in the Marine Air Quality RSA for the Cumulative Case due to only Project traffic are the same as those presented for the Application Case in Section 5.2.1.1 and Table 5.3.

7.1.1.2 Non-Project Traffic in the Marine Air Quality RSA

Maximum predicted concentrations in the Marine Air Quality RSA for the Cumulative Case due to only non-Project traffic are presented in Table 7.1 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background. All modelled concentrations were below all objectives (national, provincial and Metro Vancouver).

Modelled PM concentrations (for all size ranges) for the Cumulative Case decreased with respect to the Base/Application Case by around 70%, while modelled SO_2 concentrations decreased by up to 94%. The decrease in PM and SO_2 concentrations were predicted to occur as a result of more stringent fuel sulphur regulations.

NO_2 concentrations were also predicted to decrease for the Cumulative Case relative to the Base/Application Case, due to the more rigorous Tier-II and Tier III standards for marine vessels built on January 2, 2011, and January 1, 2016[7] or later, respectively. The maximum predicted 1-hour and 1-hour

[7] Subject to a technical review by International Marine Organization, this date could be delayed.

98th percentile NO_2 concentrations were predicted to decrease by less than 25%, while the 24-hour and annual concentrations were predicted to decrease by closer to 50% compared to the Application Case. CO and VOC concentrations were predicted to increase by almost 40% and 20%, respectively, from the Base/Application Case due to the growth in marine traffic.

Table 7.1: Predicted Maximum Concentrations – Non-Project Traffic – Cumulative Case (in µg/m^3)

Contaminant	Average Period	Cumulative Case, Over Land (without Background)	Cumulative Case, Over Land (with Background)	Cumulative Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	1.6	37.8	1.4	120	n/a	120
	Annual	0.28	15.2	0.29	60	n/a	60
PM_{10}	24-hour	1.5	21.7	1.4	50	50	n/a
	Annual	0.28	8.6	0.28	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	1.5	20.5	1.3	25[1]	25	27 to 28[6]
	Annual	0.26	5.3	0.27	8	8	8.8 to 10[7]
CO	1-hour	26.9	1,371	50.2	14,300	30,000	15,000
	8-hour	13.4	1,160	13.7	5,500	10,000	6,000
NO_X	1-hour	91.8	202	155	n/a	n/a	n/a
	24-hour	21.6	110	18.0	n/a	n/a	n/a
	Annual	4.2	30.9	4.5	n/a	n/a	n/a
NO_2*	1-hour	73.9	79.9	77.8	n/a	200	400
	1-hour 98th	65.9	78.8	58.0	188[2]	n/a	n/a
	24-hour	21.6	60.2	18.0	n/a	n/a	200
	Annual	2.6	19.2	2.8	n/a	40	60
SO_2	1-hour	11.1	37.3	21.9	450	450	450
	1-hour 99th	9.8	36.0	13.9	196[3]	n/a	n/a
	24-hour	2.5	19.9	2.3	160	125	150
	Annual	0.43	3.1	0.40	25	30	30
Benzene	1-hour	1.5	6.6	3.8	30	n/a	n/a
	Annual	0.02	1.6	0.03	3	n/a	n/a
Ethylbenzene	1-hour	0.15	2.9	0.37	2,000	n/a	n/a
Toluene	1-hour	0.24	14.6	0.59	1,880	n/a	n/a
	24-hour	0.04	5.8	0.05	400	n/a	n/a

Contaminant	Average Period	Cumulative Case, Over Land (without Background)	Cumulative Case, Over Land (with Background)	Cumulative Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
Xylene	1-hour	0.36	13.5	0.89	2,300	n/a	n/a
	24-hour	0.06	5.3	0.07	700	n/a	n/a
H_2S	1-hour	0	0	0	7[4]	n/a	n/a
	24-hour	0	0.18	0	3[4]	n/a	n/a
Mercaptans	10-minute	0	0	0	13[5]	n/a	n/a

Notes: Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants
[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values
[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)
[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)
[4] TRS objectives have been presented for comparison, since there are no H_2S objectives
[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison
[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years
[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

7.1.1.3 All Traffic within the Marine Air Quality RSA, Cumulative Case

Maximum predicted concentrations in the Marine Air Quality RSA for the Cumulative Case due to all marine traffic, including both Project and non-Project vessels, are presented in Table 7.2 for CACs, BTEX, H_2S and mercaptans. Results are presented over land, both with and without ambient background contribution, and over water without background.

Figures 7.1 to 7.12 show concentration contours and maximum concentrations for the Cumulative Case including all traffic within the Marine Air Quality RSA, without ambient background. The same contour intervals have been used for the Cumulative Case figures, as for the Base and Application Case figures, to allow for a comparison between the three cases. Because of this, the Cumulative Case PM_{10}, $PM_{2.5}$ and SO_2 figures have the maximum concentrations but no visible contours, as the levels are all lower than the lowest contour bracket.

Table 7.2: Predicted Maximum Concentrations – Including All Traffic in the Marine Air Quality RSA – Cumulative Case (in µg/m^3)

Contaminant	Average Period	Cumulative Case, Over Land (without Background)	Cumulative Case, Over Land (with Background)	Cumulative Case, Over Water	BC Objective	Metro Vancouver Objective	National Objective
TSP	24-hour	2.2	38.4	1.9	120	n/a	120
	Annual	0.39	15.3	0.35	60	n/a	60
PM_{10}	24-hour	2.1	22.2	1.9	50	50	n/a
	Annual	0.38	8.7	0.34	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	2.0	20.8	1.8	25[1]	25	27 to 28[6]
	Annual	0.36	5.3	0.32	8	8	8.8 to 10[7]
CO	1-hour	153	1,374	102	14,300	30,000	15,000
	8-hour	31.1	1,161	15.7	5,500	10,000	6,000
NO_X	1-hour	1,750	1,861	1,204	n/a	n/a	n/a
	24-hour	87.4	176	36.5	n/a	n/a	n/a
	Annual	12.8	39.5	6.8	n/a	n/a	n/a
NO_2	1-hour	175	186	120	n/a	200	400
	1-hour 98th	150	161	98.1	188[2]	n/a	n/a
	24-hour	56.0	69.6	36.5	n/a	n/a	200
	Annual	7.9	24.5	4.2	n/a	40	60
SO_2	1-hour	50.3	76.5	34.1	450	450	450
	1-hour 99th	44.6	70.8	29.7	196[3]	n/a	n/a
	24-hour	3.2	20.6	2.6	160	125	150
	Annual	0.53	3.2	0.47	25	30	30
Benzene	1-hour	5.0	10.0	6.2	30	n/a	n/a
	Annual	0.05	1.6	0.07	3	n/a	n/a
Ethylbenzene	1-hour	0.22	2.9	0.39	2,000	n/a	n/a
Toluene	1-hour	3.1	17.4	3.4	1,880	n/a	n/a
	24-hour	1.8	7.6	1.2	400	n/a	n/a
Xylenes	1-hour	0.92	14.0	1.3	2,300	n/a	n/a
	24-hour	0.49	5.7	0.37	700	n/a	n/a
H_2S	1-hour	0	0	0	7[4]	n/a	n/a
	24-hour	0	0.18	0	3[4]	n/a	n/a
Mercaptans	10-minute	2.8	2.8	4.2	13[5]	n/a	n/a

Notes: Alberta objectives have been presented for benzene, ethylbenzene, toluene and xylenes as BC does not have objectives for these pollutants

[1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

[2] Based on daily 1-hour maximum, annual 98th percentile of 1 year data, adopted from US EPA, NAAQS (100 ppb)

[3] Based on daily 1-hour maximum, annual 99th percentile of 1 year data, adopted from US EPA, NAAQS (75 ppb)

[4] TRS objectives have been presented for comparison, since there are no H_2S objectives

[5] No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE 2009); the 10-minute Ontario AAQC has been presented for comparison

[6] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[7] CAAQS is 10.0 µg/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

All modelled concentrations for the Cumulative Case were below all objectives (national, provincial and Metro Vancouver) for all averaging periods. Concentrations of PM, SO_2 and NO_2 were predicted to decrease in the Cumulative Case with respect to the Application Case (see Table 5.4), while concentrations of CO and VOCs were predicted to increase. The results reflect the changes in the non-Project vessel emission rates between the Base/Application and Cumulative Cases, as discussed in Section 7.1.1.2.

Table 7.3 presents predicted concentrations for PM_{10} and $PM_{2.5}$ for the 24-hour averaging period using rolling averages (these are presented as a comparison to Table 7.2 where the 24-hour concentrations presented are all daily averages). The predicted levels for 24-hour PM_{10} and $PM_{2.5}$ using rolling averages were below the corresponding objectives.

Table 7.3: Maximum Predicted Concentrations for Particulate Matter Using 24-hour Rolling Averages – Including All Traffic in the Marine Air Quality RSA – Cumulative Case (in µg/m^3)

Contaminant	Cumulative Case, Over Land (without Background)	Cumulative Case, Over Land (with Background)	Cumulative Case, Over Water	BC Objective	MV Objective	National Objective
PM_{10}	2.1	22.2	2.0	50	50	n/a
$PM_{2.5}$ (Total)	2.0	20.8	2.0	25[1]	25	27 to 28[2]

Notes: [1] The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values
[2] CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive year

8. SUPPLEMENTAL STUDIES, MITIGATION, AND MONITORING RECOMMENDATIONS

8.1 Supplemental Studies

No further supplemental studies are proposed for the marine component of the Project.

8.2 General Mitigation Recommendations

As indicated in Section 7 of the 2013 Marine Technical Report, all Project-related vessels are required to adhere to federal and international emission standards which are expected to reduce air emissions associated with the marine component of the Project, relative to existing conditions. Implementation dates for the proposed IMO Tier III NO_X emission reductions in the ECA are undergoing a technical review so the proposed year 2016 Tier III emission reductions were not accounted for in this updated assessment for Project-related marine traffic. As a result of this conservative model assumption, these updated results are likely overestimated with respect to predicted NO_2 levels in year 2030 and should be considered to be conservative.

8.3 Post-Construction Environmental Monitoring

Post-construction environmental monitoring is not required or recommended based on these modeling results although the National Energy Board (NEB 2014b) has proposed draft Condition No. 21 for the Westridge Marine Terminal that includes ambient air quality monitoring.

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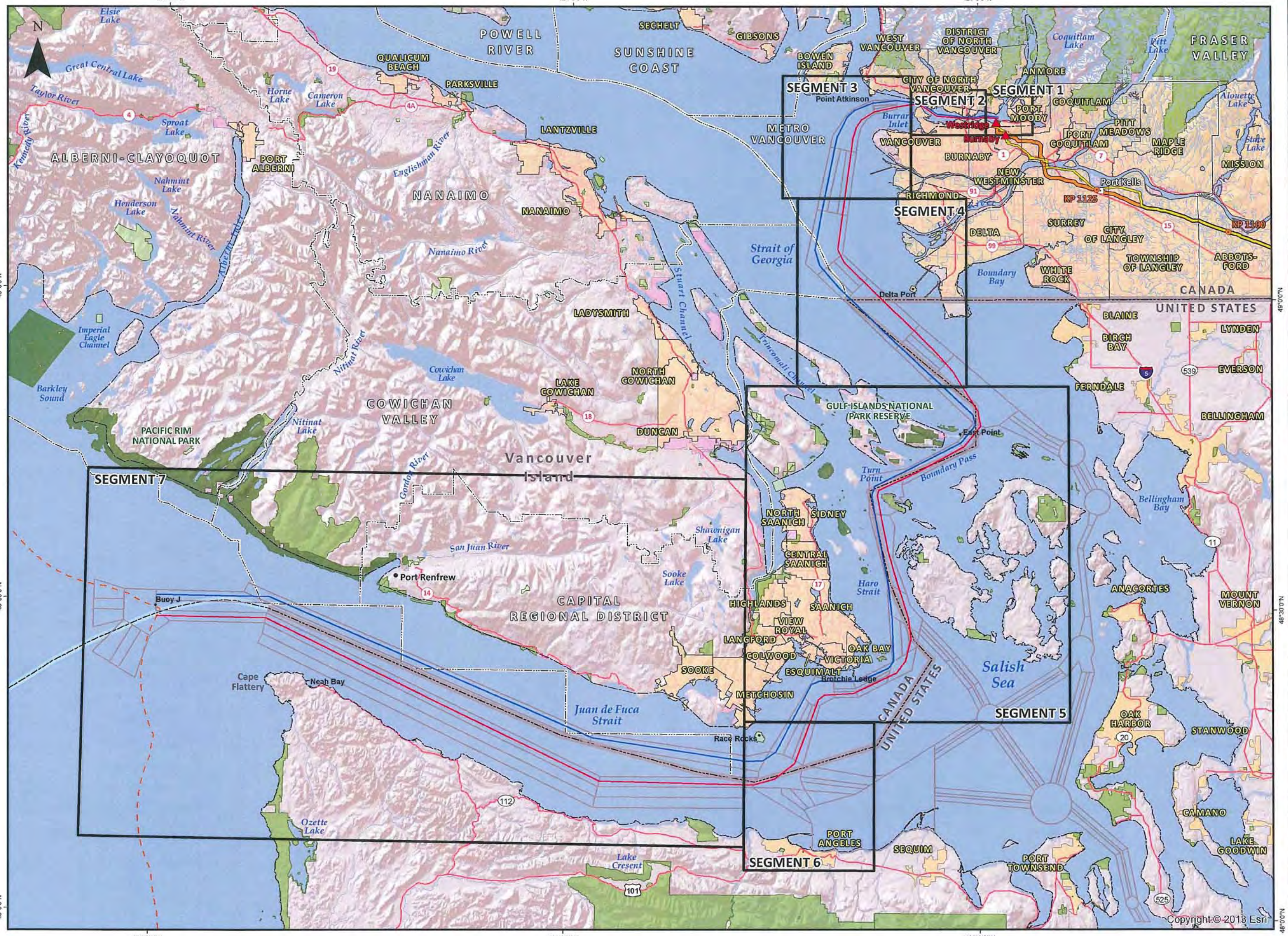
FIGURES

TRANS MOUNTAIN

FIGURE 3.1

MARINE TRANSPORTATION SEGMENTS

TRANS MOUNTAIN EXPANSION PROJECT



- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal
- Existing Pump Station
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Traffic Separation Scheme
- Marine Traffic Segments
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
- Provincial / State Park
- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area
- Regional District Boundary

Projection: UTM Zone 10N.
Routing: Baseline TMPL Route Revision 0, provided by KMC, May 2012. Proposed Corridor V6 provided by UPI, August 23, 2013.; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007 & ESRI, 2005, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; CHS Marine Features: Government of Canada, 2013; Marine Vessel Inbound/Outbound Shipping Lanes: Moffatt and Nichol, 2013; Hillshade: ESRI, 2009.

RWDI

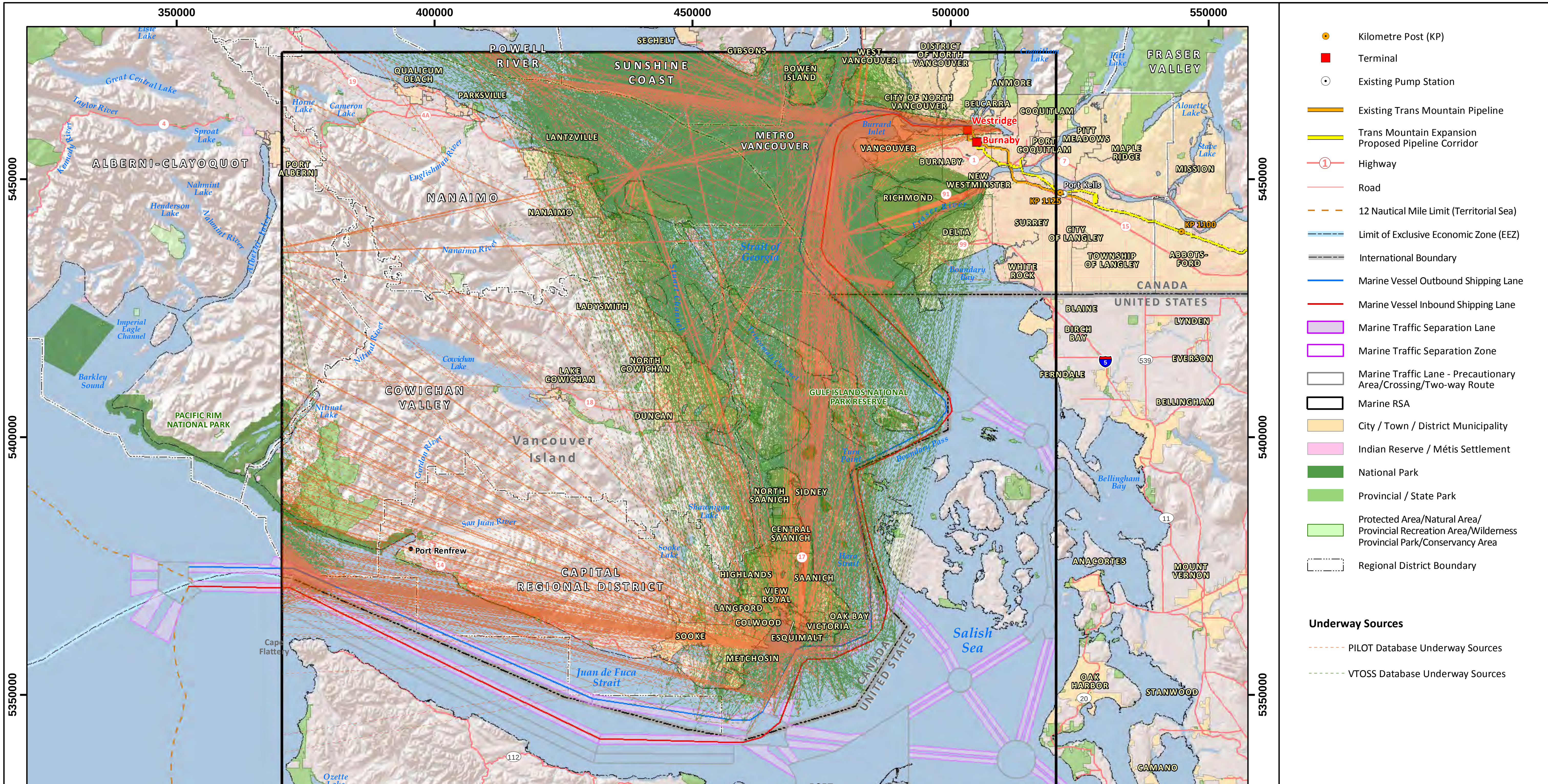
Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

MAP NUMBER		PAGE
1202006_TMEP_MR_NOISE_FIG4.2-17		SHEET 1 OF 1
DATE December 2013	TERA REF. 7894	REVISION 0
SCALE 1:650,000	PAGE SIZE 11x17	DISCIPLINE NOISE
DRAWN NBN	CHECKED AKH	DESIGN TGG

0 5 10 15 20 25 km

ALL LOCATIONS APPROXIMATE

1202006_TMEP_MR_NOISE_FIG4.2-17.mxd



Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Underway Sources Extracted from the Year 2010 MEIT Database
(Non-Project Marine Traffic)
(Straight Lines drawn between Start and End Location)

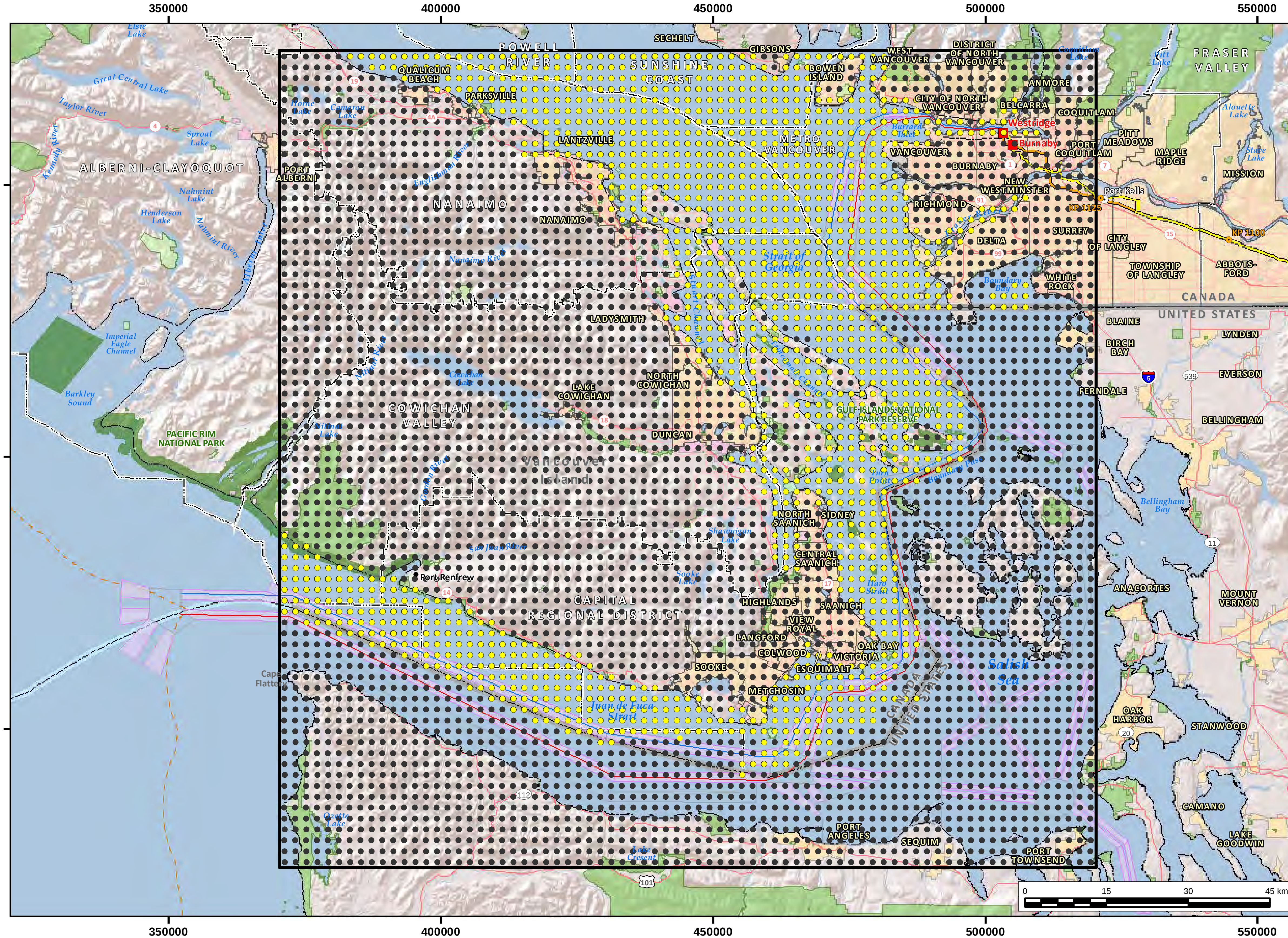
Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

Drawn by: CAM | Figure: 3.2
Approx. Scale: 1:750,000
Date Revised: Nov. 14, 2014

Project #1500417

1500417_TMEP_AQ_Marine_Figure_3.2_StraightLine_Underway_Sources.mxd



Kilometre Post (KP)
Terminal
Existing Pump Station
Existing Trans Mountain Pipeline
Trans Mountain Expansion Proposed Pipeline Corridor
Highway
Road
12 Nautical Mile Limit (Territorial Sea)
Limit of Exclusive Economic Zone (EEZ)
International Boundary
Marine Vessel Outbound Shipping Lane
Marine Vessel Inbound Shipping Lane
Marine Traffic Separation Lane
Marine Traffic Separation Zone
Marine Traffic Lane - Precautionary Area/Crossing/Two-way Route
Marine RSA
City / Town / District Municipality
Indian Reserve / Métis Settlement
National Park
Provincial / State Park
Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area
Regional District Boundary

Grid Cells with Underway Source Activity

Cells with Data
Cells without Data

Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Grid Points (Non-Project Marine Traffic) Representing the Underway Sources from the Year 2010 MEIT Database for the Marine Air Quality RSA

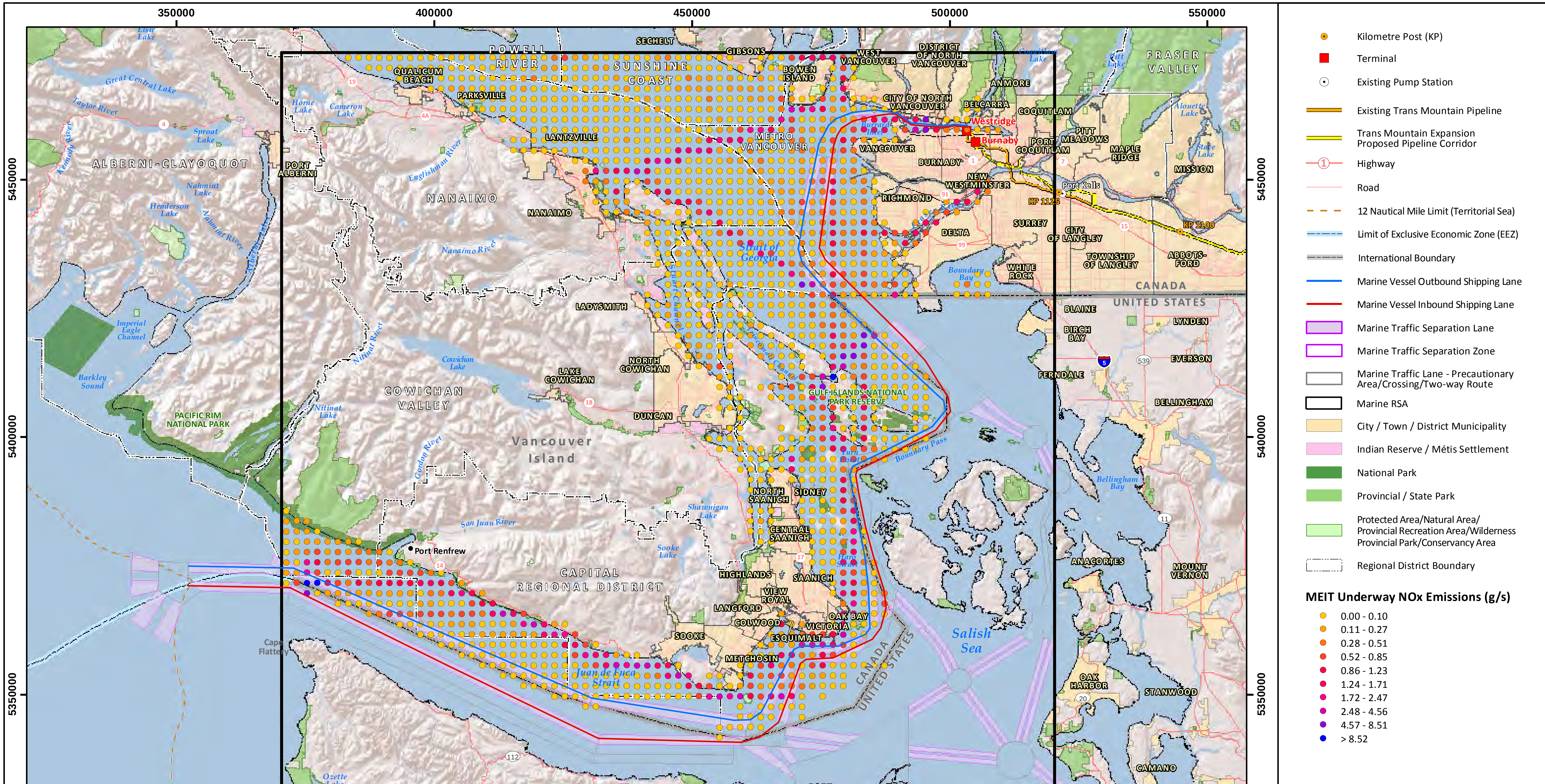
Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

Drawn by: CAM | Figure: 3.3
Approx. Scale: 1:750,000
Date Revised: Nov. 14, 2014

Project #1500417

1500417_TMEP_AQ_Marine_Figure_3.3_Grid Points Representing_Underway_Sources.mxd



Map Notes:
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Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

NOx Emission Rates (Non-Project Marine Traffic) Representing the Underway Sources Extracted from Year 2010 MEIT Database for the Marine Air Quality RSA

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

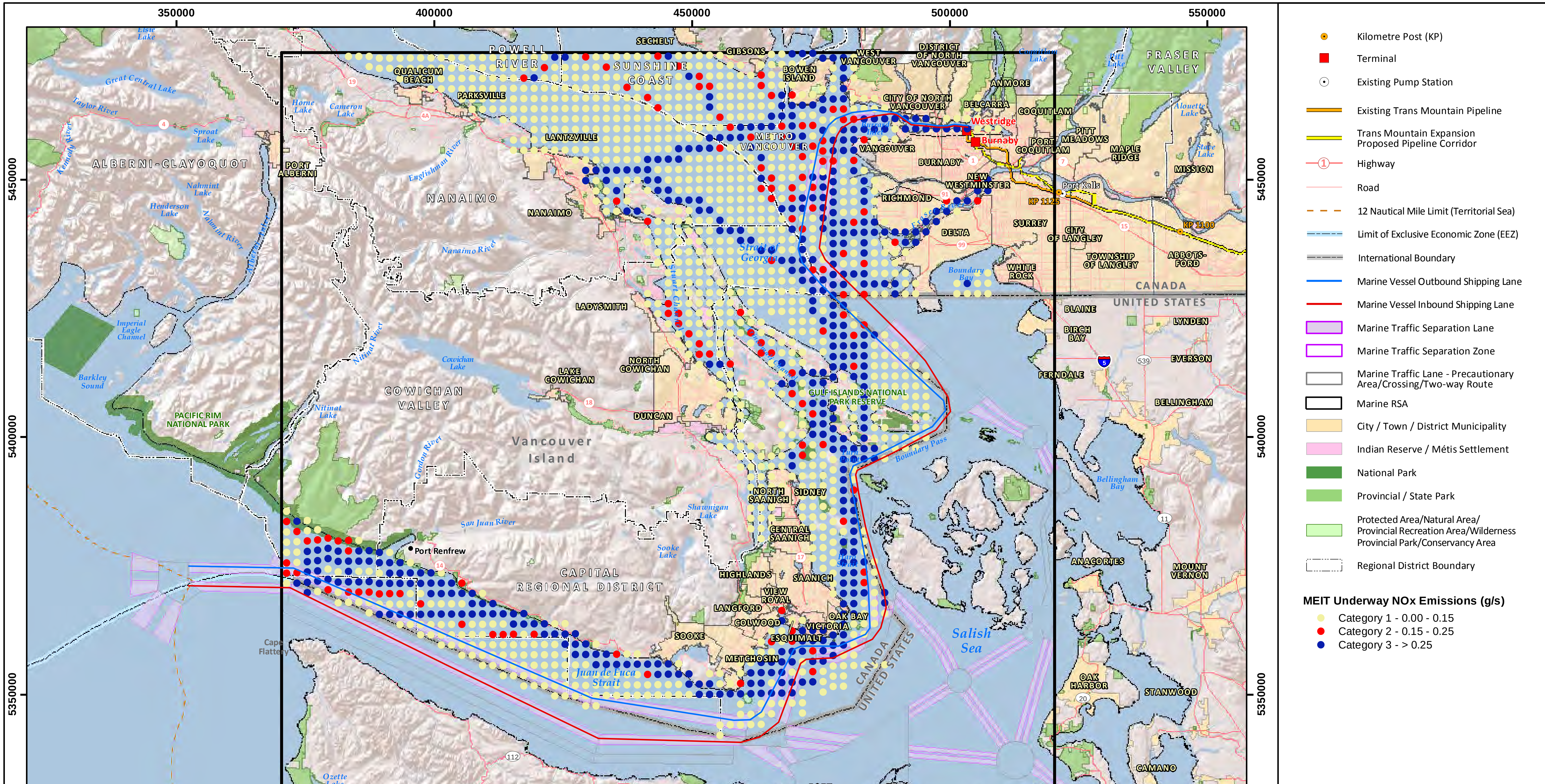
Project #1500417

Drawn by: CAM | Figure: 3.4

Approx. Scale: 1:750,000

Date Revised: Nov. 16, 2014

1500417_TMEP_AQ_Marine_Figure_3.4_NOx Emission Intensities Representing Underway Sources.mxd



Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

NOx Emission Rates Grouped into Three Categories (High, Medium and Low) for Non-Project Marine Traffic, Year 2010 MEIT Database for the Marine Air Quality RSA

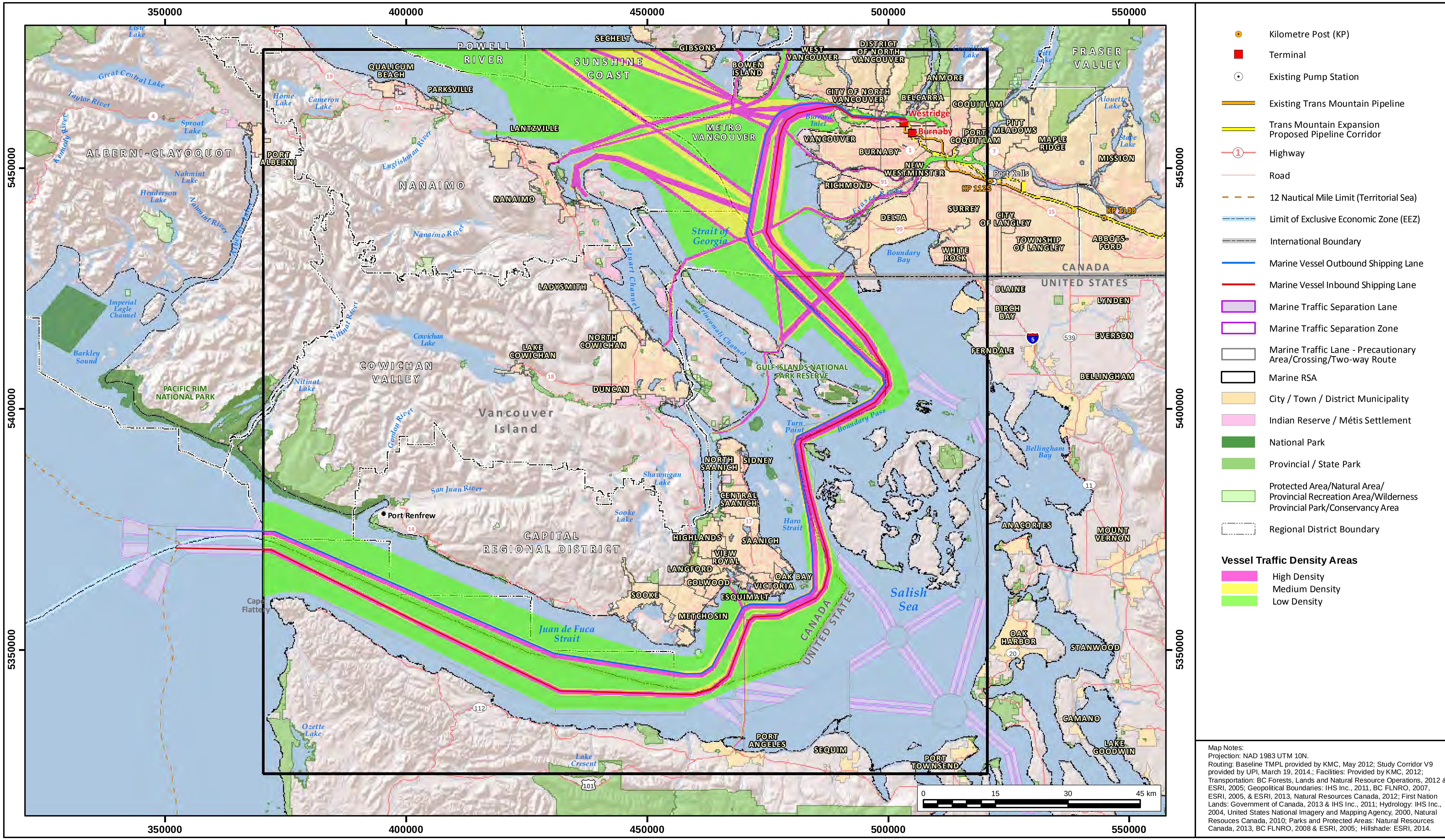
Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

Drawn by: CAM	Figure: 3.5
Approx. Scale: 1:750,000	
Date Revised: Nov. 16, 2014	

Project #1500417

1500417_TMEP_AQ_Marine_Figure_3.5_NOx Emission Intensities Categorized Representing Underway Sources.mxd



Vessel Traffic Density Geometry derived from MarineTraffic.com Density Map

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

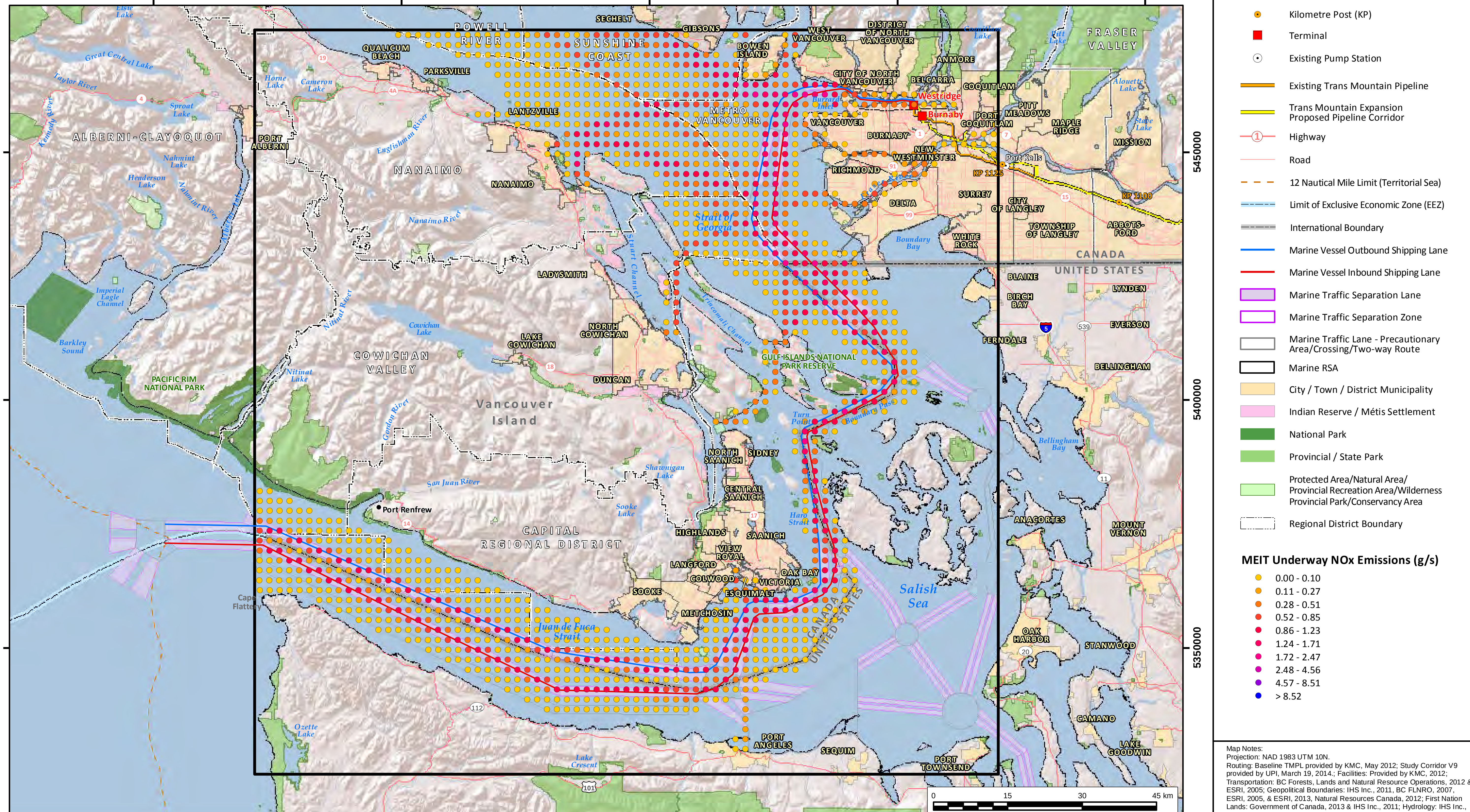
True North

Project #1500417

Drawn by: CAM	Figure: 3.6
Approx. Scale:	1:750,000
Date Revised:	Nov. 16, 2014

RWDI

1500417_TMEP_AQ_Marine_Figure_3.6_New Marine Vessel Traffic Density Geometry.mxd



Map Notes:
Projection: NAD 1983 UTM 10N.
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Allocated NOx Emission Rates (Non-Project Marine Traffic) in the Marine Air Quality RSA

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

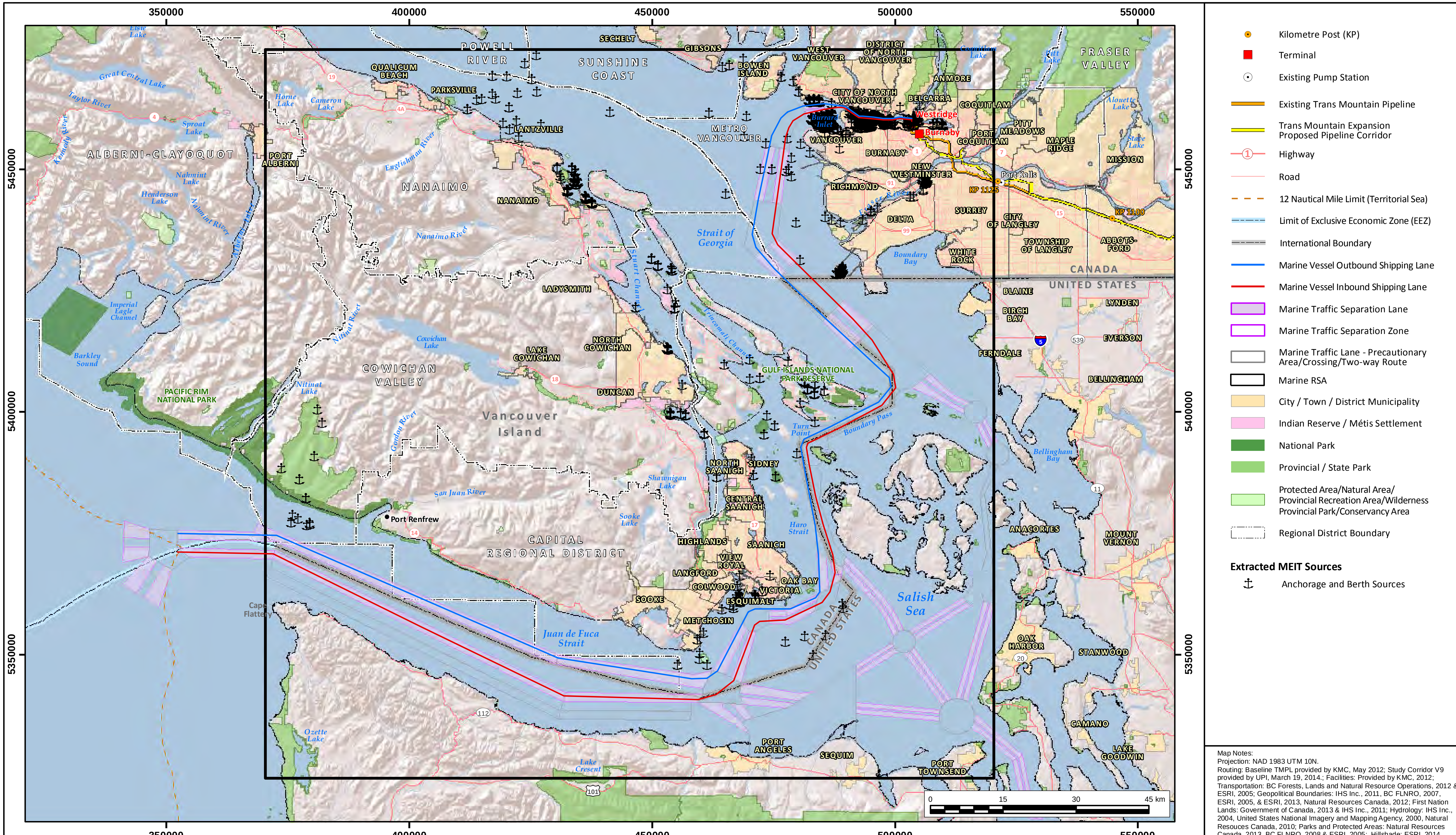
Drawn by: CAM | Figure: 3.7

Approx. Scale: 1:750,000

Date Revised: Nov. 17, 2014

Project #1500417

1500417_TMEP_AQ_Marine_Figure_3.7_Resulted NOx emission rate intensities.mxd



Map Notes:
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Anchorage and Berth Sources Extracted from the Year 2010 MEIT Database (Non-Project Marine Stationary Emission Sources)

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

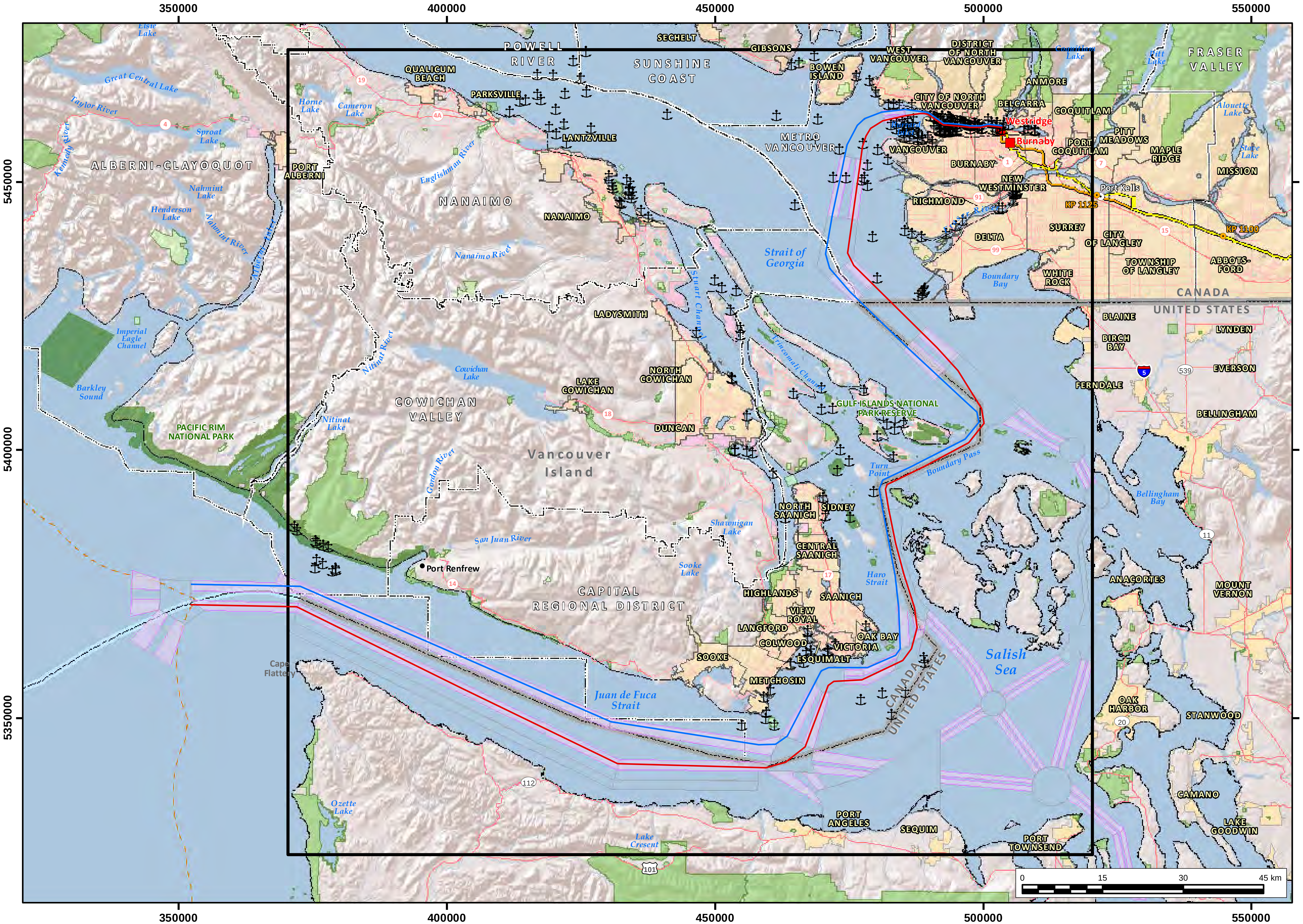
Project #1500417

Drawn by: CAM	Figure: 3.8
Approx. Scale:	1:750,000
Date Revised:	Nov. 14, 2014

RWDI

1500417_TMEP_AQ_Marine_Figure_3.8_Anchorage and Berth Sources Extracted from MEIT.mxd

Modelled Anchorage and Berth Sources (Non-Project Marine Stationary Emission Sources)



- Kilometre Post (KP)
- Terminal
- Existing Pump Station
- Existing Trans Mountain Pipeline
- Trans Mountain Expansion Proposed Pipeline Corridor
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Marine Traffic Separation Lane
- Marine Traffic Separation Zone
- Marine Traffic Lane - Precautionary Area/Crossing/Two-way Route
- Marine RSA
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
- Provincial / State Park
- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area
- Regional District Boundary

Modelled MEIT Sources

- Anchorage and Berth Sources

Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

Project #1500417

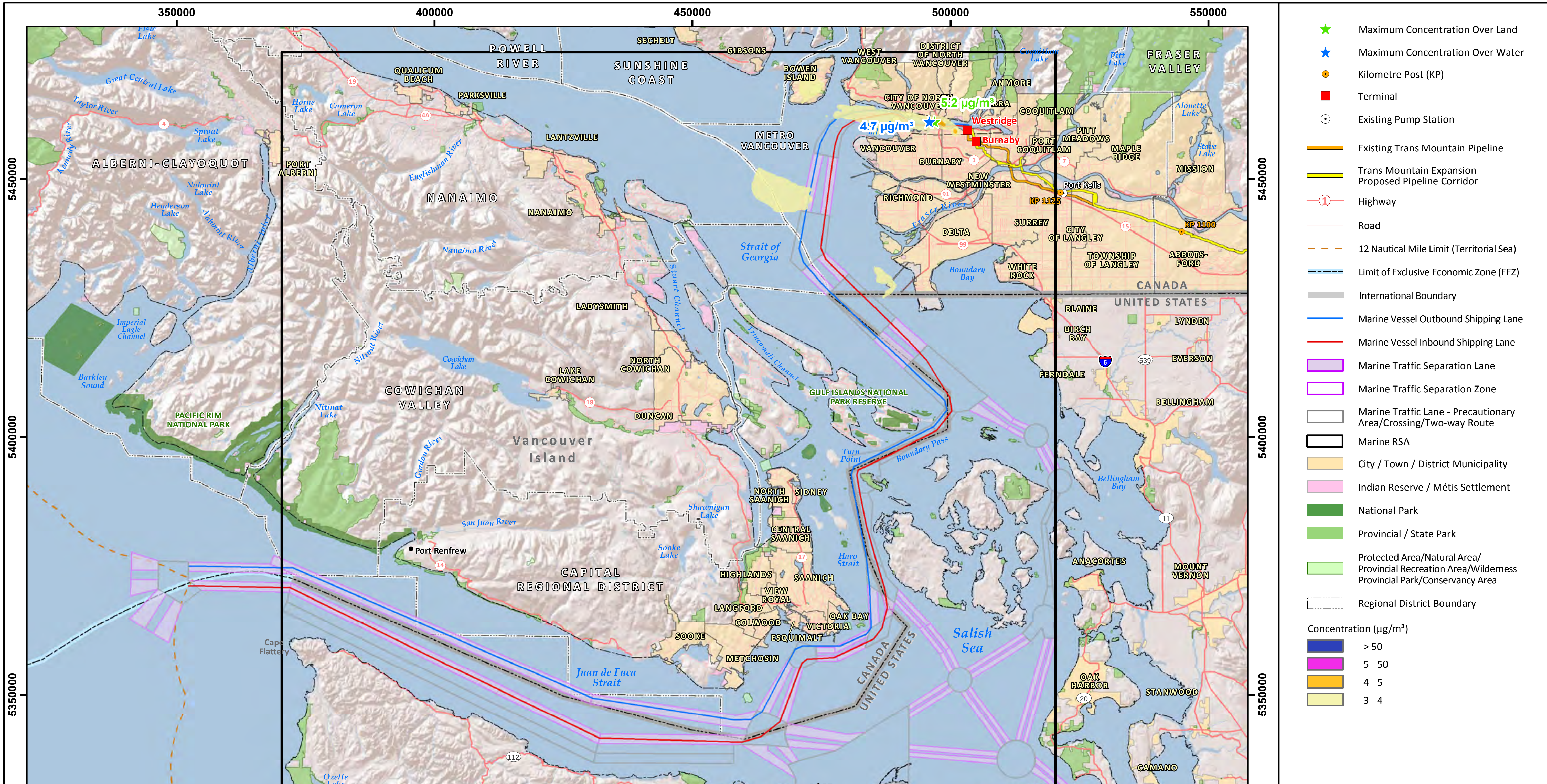
True North

Drawn by: CAM	Figure: 3.9
Approx. Scale: 1:750,000	
Date Revised: Nov. 14, 2014	

1500417_TMEP_AQ_Marine_Figure_3.9_Anchorage and Berth Sources Modelled.mxd

FIGURES

Base Case



Map Notes:
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Predicted Maximum 24-Hour PM_{10} Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)

Base Case

* 24-hr PM_{10} Metro Vancouver Objective = 50 µg/m³;
BC Provincial Objective = 50 µg/m³

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

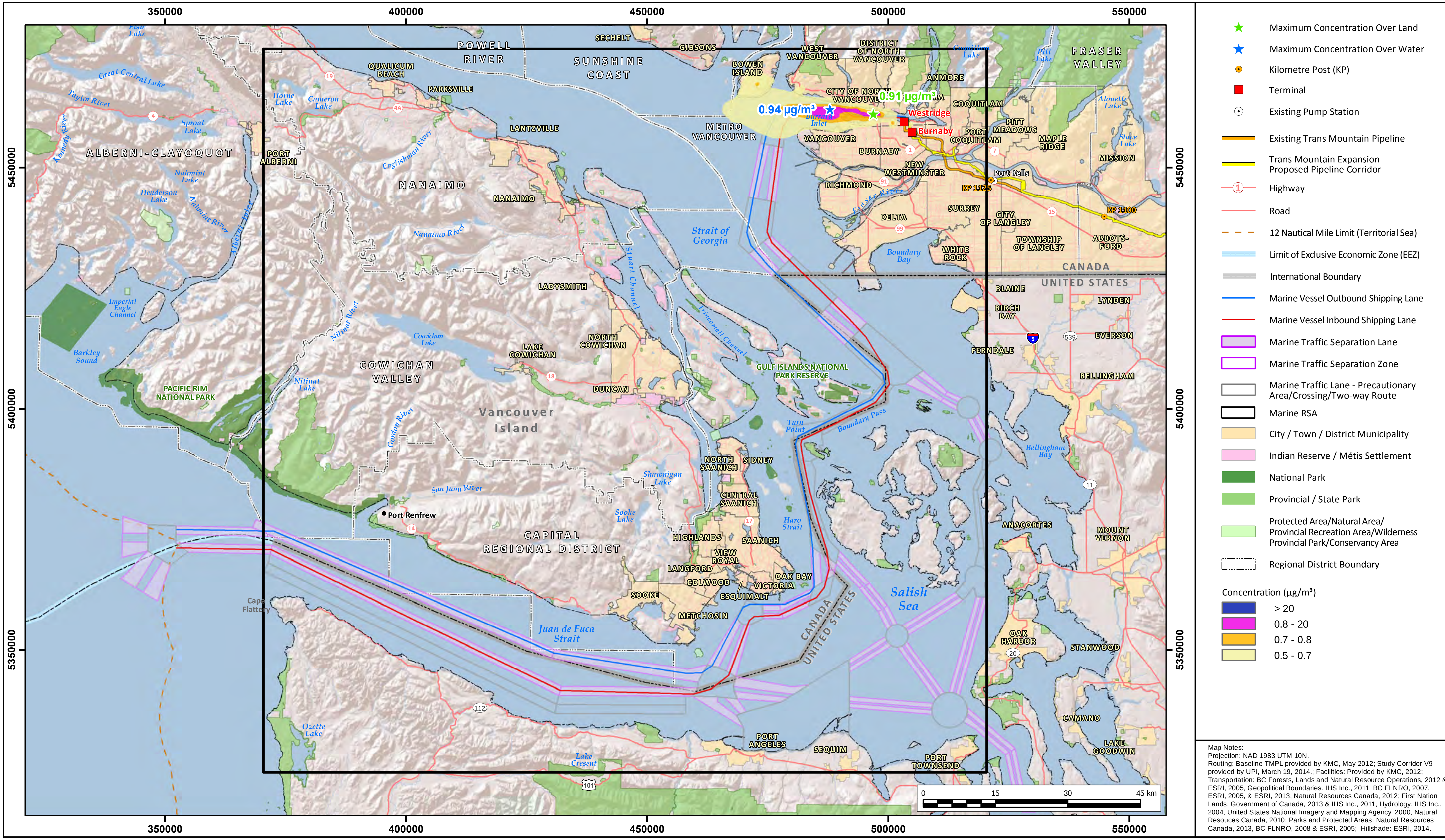
Project #1500417

True North

Drawn by: NBN	Figure: 4.1
Approx. Scale:	1:750,000
Date Revised:	Nov. 13, 2014

RWDI

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd



Predicted Maximum Annual PM_{10} Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)

Base Case

* Annual PM_{10} Metro Vancouver Objective = 20 µg/m³

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

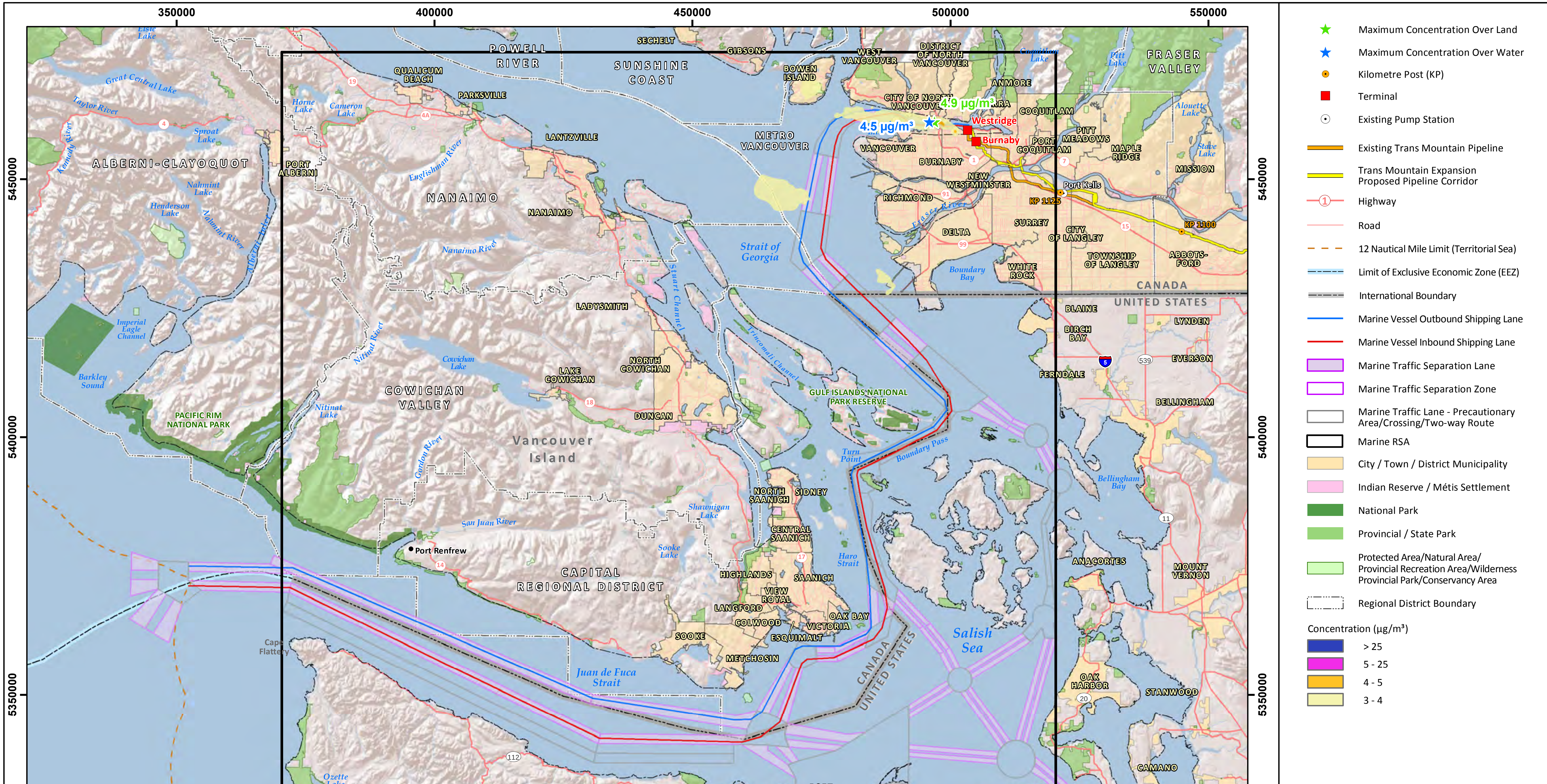
Drawn by: NBN | Figure: 4.2

Approx. Scale: 1:750,000

Date Revised: Nov. 13, 2014

Project #1500417

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd



Map Notes:
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Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Predicted Maximum 24-Hour $PM_{2.5}$ Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)

Base Case

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

*** 24-hr $PM_{2.5}$ Metro Vancouver Objective = 25 µg/m³;**
BC Provincial Objective = 25 µg/m³

Project #1500417

True North

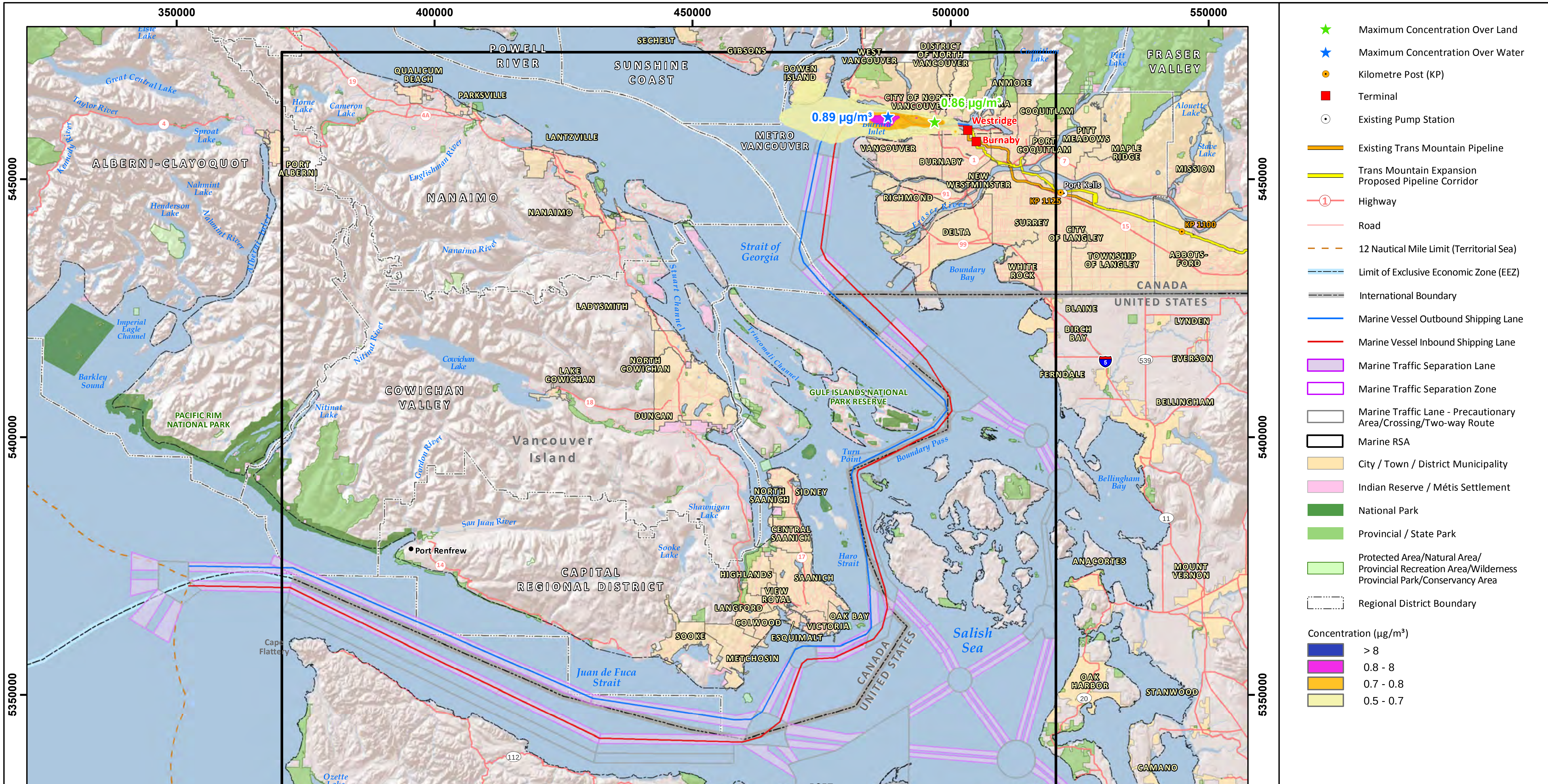
Drawn by: NBN | Figure: 4.3

Approx. Scale: 1:750,000

Date Revised: Nov. 13, 2014

RWDI

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd



Map Notes:
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Predicted Maximum Annual $PM_{2.5}$ Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)
Base Case

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

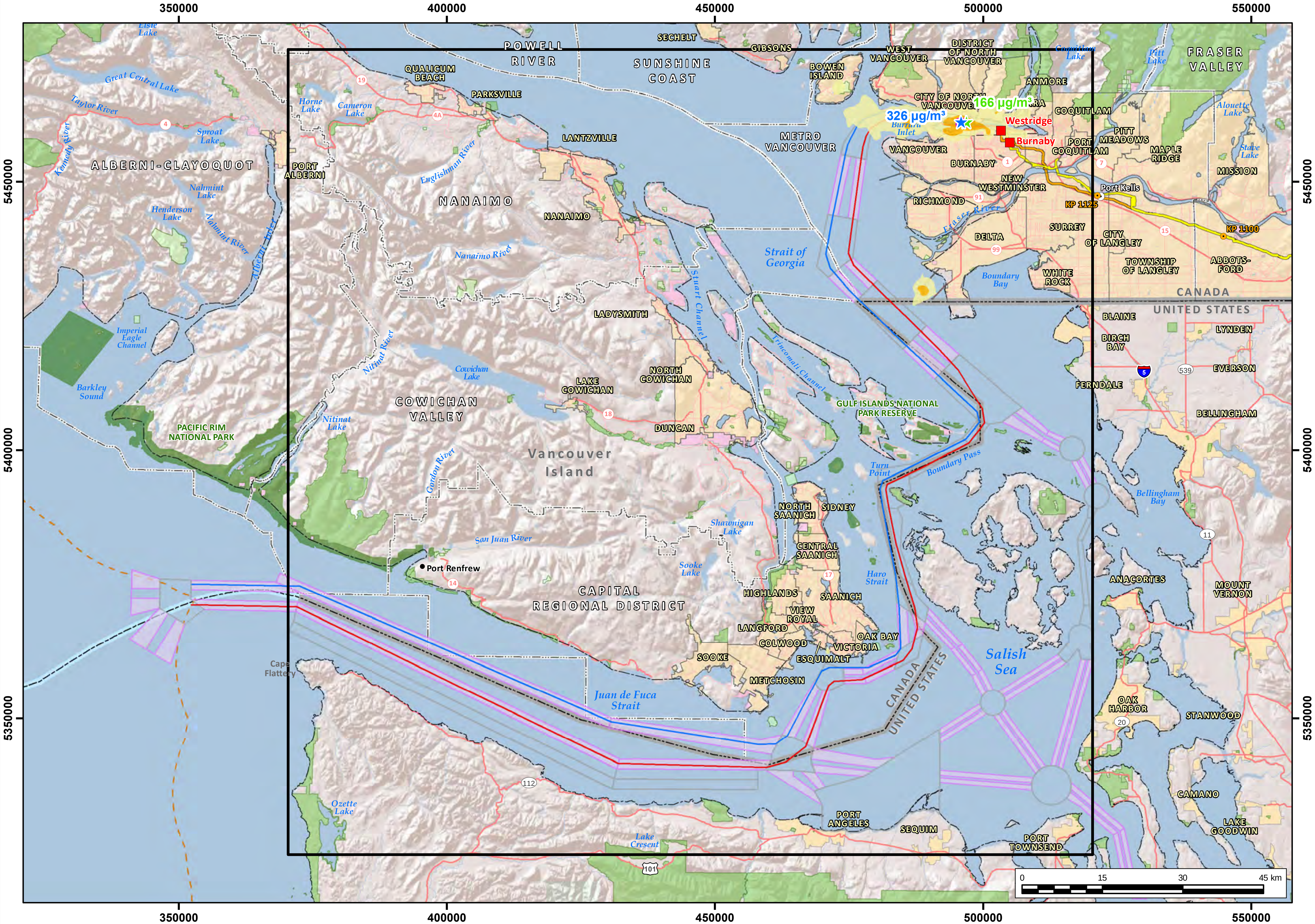
*** Annual $PM_{2.5}$ Metro Vancouver Objective = 8 µg/m³;**
BC Provincial Objective = 8 µg/m³

True North

Drawn by: NBN	Figure: 4.4
Approx. Scale: 1:750,000	
Date Revised: Nov. 13, 2014	

Project #1500417

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd



Maximum Concentration Over Land
Maximum Concentration Over Water
Kilometre Post (KP)
Terminal
Existing Pump Station
Existing Trans Mountain Pipeline
Trans Mountain Expansion Proposed Pipeline Corridor
Highway
Road
12 Nautical Mile Limit (Territorial Sea)
Limit of Exclusive Economic Zone (EEZ)
International Boundary
Marine Vessel Outbound Shipping Lane
Marine Vessel Inbound Shipping Lane
Marine Traffic Separation Lane
Marine Traffic Separation Zone
Marine Traffic Lane - Precautionary Area/Crossing/Two-way Route
Marine RSA
City / Town / District Municipality
Indian Reserve / Métis Settlement
National Park
Provincial / State Park
Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area
Regional District Boundary

Concentration (µg/m³)
> 450
150 - 450
100 - 150
60 - 100

Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Predicted Maximum 1-Hour SO_2 Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)

Base Case

*** 1-hr SO_2 Metro Vancouver Objective = 450 µg/m³; BC Level A Objective = 450 µg/m³**

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

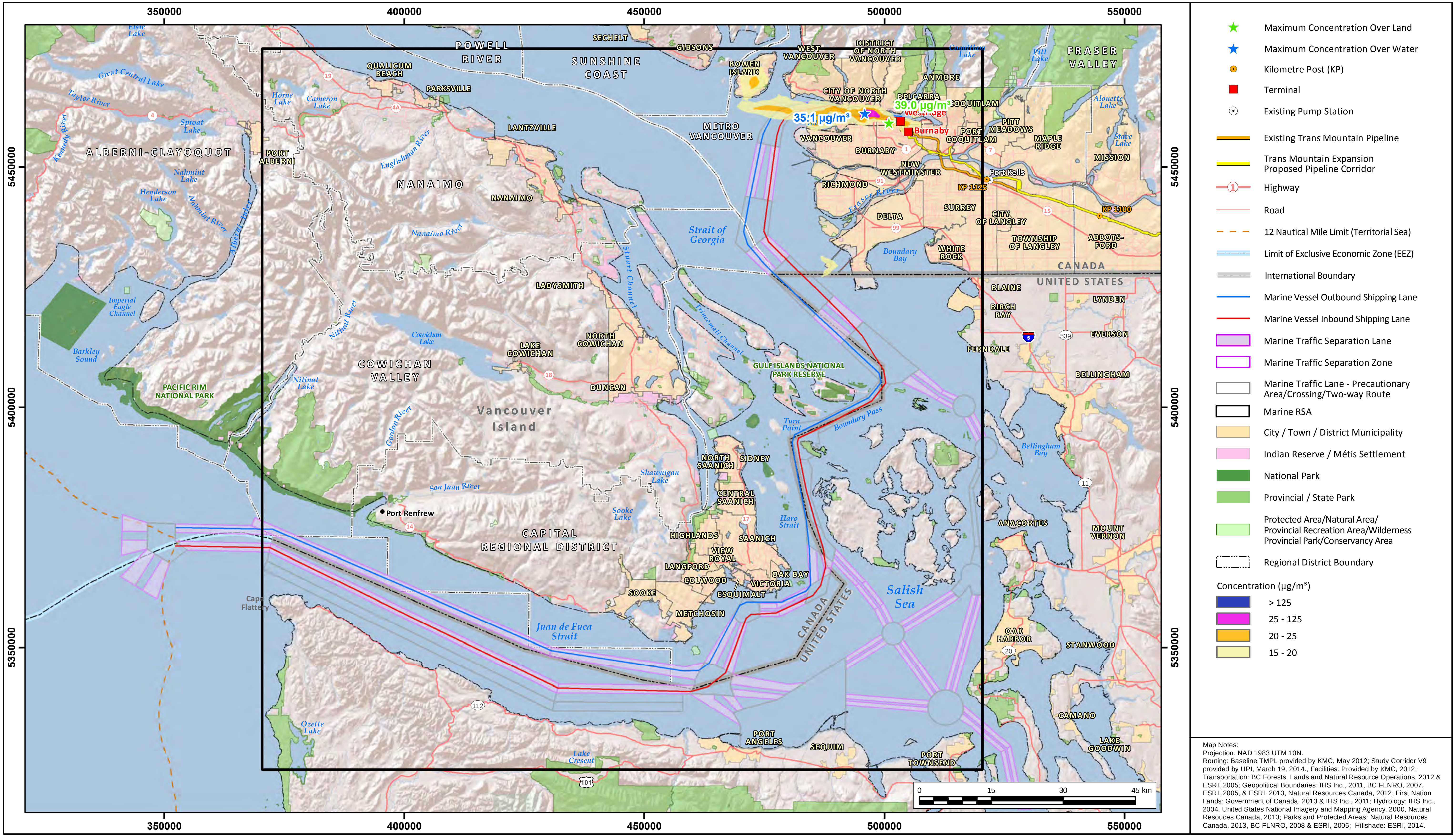
Project #1500417

True North

Drawn by: NBN	Figure: 4.5
Approx. Scale: 1:750,000	
Date Revised: Nov. 13, 2014	

RWDI

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd



Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005, & ESRI, 2013, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008 & ESRI, 2005; Hillshade: ESRI, 2014.

Predicted Maximum 24-Hour SO_2 Concentration without Ambient Background for the Marine Air Quality RSA (in µg/m³)

Base Case

*** 24-hr SO_2 Metro Vancouver Objective = 125 µg/m³; BC Level A Objective = 160 µg/m³**

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

Project #1500417

Drawn by: NBN	Figure: 4.6	RWDI
Approx. Scale: 1:750,000		
Date Revised: Nov. 13, 2014		

1500417_TMEP_CEA_AQ_Base_Marine_Contour_Plots_12NOV2014.mxd