Information Request Package 6 from the Review Panel for the Roberts Bank Terminal 2 Project Environmental Assessment: Responses

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IR6-37 Air Quality – Environmental Management Plan, Operations

IR6-01 Light – Baseline Information

Information Source(s)

EIS Volume 2: Section 9.4; Section 9.4.2.1; Section 9.4.8.2; Table 9.4-9 and Table 9.4-10; Section 2.3 of Appendix 9.4-A

EIS Guidelines: Section 9.1.2

Context

In Section 9.4.2.1 of the EIS, the Proponent indicated that cloud cover can increase sky glow and may obstruct the view of celestial objects. The Proponent stated that it obtained existing sky glow levels from sky quality measurements under minimal cloud cover with no snow on the ground in order to determine the greatest possible change in sky glow attributable to the Project. However, in Section 2.3 of Appendix 9.4-A, the Proponent indicated that light measurements were collected under a variety of cloud cover conditions such as mainly cloudy, partly cloudy and clear skies.

The EIS Guidelines required the Proponent to provide a description of nighttime illumination levels during different weather conditions and seasons. Although Section 2.3 of Appendix 9.4-A described the study methods used for the light assessment, the light measurements taken at each of the 12 points of reception were collected on a single night, and do not represent illumination levels during different weather conditions and seasons as required by the Guidelines. The Proponent therefore did not follow the methodology as described in Section 9.4.2.1 of the EIS and the EIS Guidelines.

Further, the EIS did not address the occurrence of nighttime fog that can cause significant light scatter, and thus intensify sky glow which has the potential to affect people and coastal birds. Additional information is required to determine baseline nighttime illumination levels and sky quality during different weather conditions and seasons, and to determine the influence of nighttime fog on light scatter and sky glow.

Information Request

Provide a description of current nighttime illumination levels and sky quality during different weather conditions (varying cloud cover, type, and height) and seasons at each of the 12 points of reception identified by the Proponent in Section 9.4 of the EIS.

Update Table 9.4-9 and Table 9.4-10 from Section 9.4.8.2 of the EIS to reflect any changes in the predictions for light trespass and sky glow levels as a result of the inclusion of the additional information requested in this information request, and describe whether the classification at any of 12 points of reception would change.

Using available information, provide the seasonal frequency, duration and density of nighttime fog in the area encompassing the 12 points of reception. Assess the potential effects of nighttime fog on light scatter and sky glow at the 12 points of reception.

VFPA Response

Provide a description of current nighttime illumination levels and sky quality during different weather conditions (varying cloud cover, type, and height) and seasons at each of the 12 points of reception identified by the Proponent in Section 9.4 of the EIS.

Current Sky Quality – Varying Cloud Cover Conditions

Section 2.3 of EIS Appendix 9.4-A indicates that light measurements were collected at the 12 points of reception (POR) under a variety of cloud cover conditions, including mainly cloudy, partly cloudy, mainly clear, and clear skies. Cloudy skies increase sky glow in urban environments due to an increased presence of aerosols in the air, which reflect more light downwards. Studies have developed adjustment factors for sky quality as a function of the amount of cloud cover (Kyba et al. 2011) for both urban and rural environments. As the amount of cloud cover increases, sky quality decreases. **Table IR6-01-1** below shows the existing conditions for sky quality, adjusted for cloud conditions. Bold values indicate the measured values that were used in the EIS light assessment for each POR and the remaining values indicate those that have been adjusted based on literature values (Kyba et al. 2011).

Table IR6-01-1 Existing Conditions for Sky Quality and CIE Zone Classifications for Varying Cloud Cover

POR#	Existing Sky Quality – Clear Skies (mag/arcsec^2)	CIE Zone	Existing Sky Quality – Mainly Clear (mag/arcsec^2)	CIE Zone	Existing Sky Quality - Partly Cloudy (mag/arcsec^2)	CIE Zone	Existing Sky Quality – Mainly Cloudy (mag/arcsec^2)	CIE Zone
POR1	21.6	G1	21.6	G1	21.3	G2	**20.9**	**G2**
POR2	21.3	G2	21.1	G2	**20.8**	**G3**	20.4	G3
POR3	21.0	G2	20.8	G3	**20.5**	**G3**	20.1	G4
POR4	20.3	G4	20.2	G4	19.6	G4	**18.3**	**G4**
POR5	19.5	G4	19.4	G4	18.8	G4	**17.5**	**G4**
POR6	19.2	G4	19.1	G4	18.5	G4	**17.2**	**G4**
POR7	19.3	G4	**19.2**	**G4**	18.6	G4	17.3	G4
POR8	19.6	G4	**19.5**	**G4**	18.9	G4	17.6	G4
POR9	18.9	G4	**18.8**	**G4**	18.2	G4	16.9	G4
POR10	20.0	G4	19.9	G4	**19.3**	**G4**	18.0	G4
POR11	18.4	G4	**18.3**	**G4**	17.7	G4	16.4	G4
POR12	**20.6**	**G3**	20.4	G3	20.1	G4	19.7	G4

Notes: mag/arcsec^2 = magnitude per square second of arc. CIE = Commission Internationale de l'Eclairage. For a description of CIE zones, please see Section 2.4.4 of EIS Appendix 9.4-A.

Current Illumination Levels – Varying Cloud Cover Conditions

Light trespass is the direct illumination of nearby off-site locations from the Project. Cloud cover does not typically interact with the propagation of light from the source to nearby locations, due to the height of cloud cover. In the unlikely event that low-lying cloud cover does interact with light propagation from a light source to a receptor location that is higher up, the low-lying cloud cover would limit the propagation of light and decrease the level of light trespass at receptor locations (Narisada and Schreuder 2004). Cloud cover would not have an adverse impact on the measured light trespass at a given location, and therefore the light trespass levels presented in the EIS have not been adjusted for cloud cover.

Update Table 9.4-9 and Table 9.4-10 from Section 9.4.8.2 of the EIS to reflect any changes in the predictions for light trespass and sky glow levels as a result of the inclusion of the additional information requested in this information request, and describe whether the classification at any of 12 points of reception would change.

Update to Light Trespass Predictions

Given that existing illumination levels are not required to be adjusted for cloud cover, as described above, there are no changes to the prediction of potential changes in light trespass. Therefore, EIS Table 9.4-9 sufficiently addresses light trespass and does not require updating.

Update to Sky Glow Predictions

For sky glow, the assessment of future conditions with the Project has been updated considering the existing sky quality conditions for varying cloud cover, presented in **Table IR6-01-1**, and the predicted change in sky glow due to the Project. Results of this analysis are presented in **Tables IR6-01-2** to **IR6-01-5**. These tables are provided as an update to Table 9.4-10 in the EIS. Bold values indicate predicted change in CIE zone classification from existing conditions.

Table IR6-01-2 Predicted Changes in Sky Glow Considering Clear Skies

POR#	Existing Sky Quality – Clear Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Clear Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR1	21.6	0	**G1**	21.3	26	**G2**
POR2	21.3	29	G2	21.2	48	G2
POR3	21.0	69	G2	20.9	94	G2
POR4	20.3	219	G4	19.8	403	G4
POR5	19.5	618	G4	19.1	931	G4
POR6	19.2	820	G4	18.8	1,171	G4
POR7	19.3	724	G4	18.8	1,227	G4
POR8	19.6	549	G4	19.5	562	G4
POR9	18.9	1,102	G4	18.9	1,110	G4

POR#	Existing Sky Quality – Clear Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Clear Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR10	20.0	325	G4	19.8	408	G4
POR11	18.4	1,754	G4	16.3	13,165	G4
POR12	20.6	144	G3	20.6	146	G3

Notes: mag/arcsec^2 = magnitude per square second of arc. CIE = Commission Internationale de l'Eclairage. For a description of CIE zones, please see Section 2.4.4 of EIS Appendix 9.4-A.

Table IR6-01-3 Predicted Changes in Sky Glow Considering Mainly Clear Skies

POR#	Existing Sky Quality – Mainly Clear Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Mainly Clear Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR1	21.6	2	**G1**	21.3	28	**G2**
POR2	21.1	56	G2	21.0	75	G2
POR3	20.8	103	G3	20.7	128	G3
POR4	20.2	250	G4	19.8	434	G4
POR5	19.4	687	G4	19.0	1,000	G4
POR6	19.1	909	G4	18.8	1,260	G4
POR7	19.2	804	G4	18.7	1,307	G4
POR8	19.5	611	G4	19.5	624	G4
POR9	18.8	1,218	G4	18.8	1,226	G4
POR10	19.9	366	G4	19.8	449	G4
POR11	18.3	1,932	G4	16.3	13,343	G4
POR12	20.4	194	G3	20.4	196	G3

Notes: mag/arcsec^2 = magnitude per square second of arc. CIE = Commission Internationale de l'Eclairage. For a description of CIE zones, please see Section 2.4.4 of EIS Appendix 9.4-A.

Table IR6-01-4 Predicted Changes in Sky Glow Considering Partly Cloudy Skies

POR#	Existing Sky Quality – Partly Cloudy Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Partly Cloudy Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR1	21.3	34	G2	21.1	60	G2
POR2	20.8	105	G3	20.7	124	G3
POR3	20.5	168	G3	20.4	193	G3
POR4	19.6	508	G4	19.4	692	G4
POR5	18.8	1,268	G4	18.5	1,581	G4

POR#	Existing Sky Quality – Partly Cloudy Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Partly Cloudy Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR6	18.5	1,654	G4	18.3	2,005	G4
POR7	18.6	1,470	G4	18.3	1,973	G4
POR8	18.9	1,136	G4	18.9	1,149	G4
POR9	18.2	2,191	G4	18.2	2,199	G4
POR10	19.3	709	G4	19.2	792	G4
POR11	17.7	3,432	G4	16.2	14,843	G4
POR12	20.1	287	G4	20.1	289	G4

Notes: mag/arcsec^2 = magnitude per square second of arc. CIE = Commission Internationale de l'Eclairage. For a description of CIE zones, please see Section 2.4.4 of EIS Appendix 9.4-A.

Table IR6-01-5 Predicted Changes in Sky Glow Considering Mainly Cloudy Skies

POR#	Existing Sky Quality – Mainly Cloudy Skies (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Dark Sky)	Existing CIE Zone	Existing + Project Sky Quality – Mainly Cloudy Skies (mag/arcsec^2)	Existing + Project Sky Glow (% Brightness above Natural Dark Sky)	Existing + Project CIE Zone
POR1	20.9	94	**G2**	20.7	120	**G3**
POR2	20.4	196	**G3**	20.4	215	**G4**
POR3	20.1	287	G4	20.1	312	G4
POR4	18.3	1,914	G4	18.2	2,098	G4
POR5	17.5	4,429	G4	17.4	4,742	G4
POR6	17.2	5,708	G4	17.1	6,059	G4
POR7	17.3	5,100	G4	17.2	5,603	G4
POR8	17.6	3,993	G4	17.6	4,006	G4
POR9	16.9	7,486	G4	16.9	7,494	G4
POR10	18.0	2,579	G4	18.0	2,662	G4
POR11	16.4	11,595	G4	15.7	23,006	G4
POR12	19.7	460	G4	19.7	462	G4

Notes: mag/arcsec^2 = magnitude per square second of arc. CIE = Commission Internationale de l'Eclairage. For a description of CIE zones, please see Section 2.4.4 of EIS Appendix 9.4-A.

The results of this sky glow analysis indicate that for clear skies, mainly clear skies, and mainly cloudy skies in existing conditions, there is a predicted change in CIE zone classification at POR1 as a result of light from the Project, which is consistent with the results presented in the EIS. Results for partly cloudy skies indicate no change in CIE zone classification with the addition of light from the Project. When considering mainly cloudy skies in existing conditions, the CIE zone classification changes for an additional POR (POR2); however, this change is due to the value of the existing sky glow at POR2 of 196% being very close to the G3/G4 zone

boundary, which is 200% above natural dark sky. In regard to the sky quality in mag/arcsec^2, there is no change at POR2 to one decimal place (as both the existing conditions and existing + Project are 20.4 mag/arcsec^2). These updated assessment results are consistent, across a range of cloud cover conditions, with the conclusions of the EIS sky glow assessment presented in Section 9.4.8 of the EIS.

Using available information, provide the seasonal frequency, duration and density of nighttime fog in the area encompassing the 12 points of reception. Assess the potential effects of nighttime fog on light scatter and sky glow at the 12 points of reception.

Seasonal Variation in Fog

Seasonal variations in visibility as described in Section 9.1.4.4 of the EIS generally represent seasonal variations in visibility at the 12 PORs. Factors that affect visibility include fog, haze, precipitation, and dust. Visibility data recorded at the Vancouver International Airport meteorology station indicates the frequency of events which reduce atmospheric visibility on a monthly basis (Section 9.1.1.4 or the EIS). The monthly average visibility, in hours by distance, is reproduced in **Table IR6-01-6**.

Table IR6-01-6 Monthly Average Visibility at the Vancouver International Airport Station (1981 to 2010) (Table 9.1.1-4 reproduced from the EIS)

Month	Hours with Visibility		
	< 1 km	**1 to 9 km**	**> 9 km**
January	**29.6**	99	615.4
February	9.2	52.3	615.2
March	2.9	33.9	707.2
April	0.2	21.6	698.2
May	0.2	14.6	**729.2**
June	0.1	12.6	**707.3**
July	0.1	10.0	**734**
August	0.2	11.1	**732.8**
September	2.6	30.1	687.3
October	16.4	83.7	643.9
November	11.8	71.1	637.1
December	**24.1**	90.0	629.3
Year	*97.3*	*529.9*	*8137.4*

Source: Environment Canada 2014.
Notes: < = less than; > = greater than.

As indicated in **Table IR6-01-6**, the longest periods of decreased visibility were recorded in winter, specifically December and January (bold values in <1 km column in table above) and to a lesser extent in the fall (October and November). Low visibility in these months

corresponds to higher sky glow (as indicated by adjusted sky glow values in **Table IR6-01-5**) in fall and winter. The worst-case light trespass occurs with increased visibility, which occurs in spring and summer, specifically May through August (bold values in >9 km column in **Table IR6-01-6** above).

Effect of Fog on Sky Glow

Cloud cover and fog are similar in that they both result in increased presence of aerosols in the air (Narisada and Schreuder 2004). Aerosols are highly reflective, which is why sky glow increases with increased cloud cover. Therefore, the sky quality values adjusted for cloud cover in **Tables IR6-01-1**, **IR6-01-3**, **IR6-01-4**, and **IR6-01-5** and the subsequent sky glow assessment based on these adjusted values in **Table IR6-01-5** are representative of foggy conditions.

Effect of Fog on Light Trespass

Fog, like cloud cover, will scatter and limit the propagation of light through long distances due to the presence of aerosols (Narisada and Schreuder 2004). Therefore, increased fog will decrease the light trespass from the Project. The lux levels presented in the EIS assessment of light trespass (EIS Section 9.4.8.2) are conservative because measurements of existing conditions were taken when no fog was present. Light trespass would be lower in foggy conditions.

References

Environment Canada. 2014. Canadian Climate Normals 1981 – 2000 Station Data. Vancouver International Airport, British Columbia. Available at http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=889&lang=e&dCode=1&province=BC&provBut=Go&month1=0&month2=12. Accessed April 2014.

Kyba, C. C. M., T. Ruhtz, J. Fischer, and F. Holker. 2011. Cloud Coverage Acts as an Amplifier for Ecological Light Pollution in Urban Ecosystems. PLoS ONE 6(3).

Narisada, K. and D. Schreuder. 2004. Light Pollution Handbook. Springer: Dordrecht, The Netherlands.

IR6-02 Light – Sky Glow Estimates

Information Source(s)

EIS Volume 2: Section 9.4.4.2; Table 9.4-4, Table 9.4-5, and Table 9.4-10

EIS Volume 4: Section 25.8.2; Table 25-17

Context

In Section 9.4.4.2 of the EIS, the Proponent indicated that it used the 4-point Commission internationale de l'éclairage (CIE) scale to measure sky glow.

Table 9.4-5 of the EIS indicated that sky glow above 200% is rated as G4, the maximum rating, indicative of areas of high district brightness - generally urban areas having mixed residential and commercial land use with high nighttime activity. However, Table 9.4-4 of the EIS indicated that a full moon in an area free of artificial illumination has a sky glow value of 3000%. A full moon therefore belongs in the same category as an urban area, according to the CIE classification system.

According to the Tsawwassen First Nation, a more finely-graded scale would be more appropriate to measure the potential effects of the Project on sky glow and visual resources. Tsawwassen First Nation indicated that the 9-point Bortle Scale, based on ranges of magnitude per square arc-second, better reflects the human receptor experience of night sky change in areas like the Gulf Islands or Brunswick Point that are valued for their rural quality and darker skies. Additional information is required to determine whether the use of the Bortle Scale classification would result in any changes to the predictions regarding sky glow and its subsequent effects on visual resources.

Information Request

Revise Table 9.4-10 of the EIS to convert sky glow estimates from percentage sky glow to magnitude per square arc-second and identify the corresponding existing and predicted Bortle Scale classification for each of the 12 points of reception.

Provide a comparison of any changes in classification at each of the 12 points of reception between the CIE scale and the Bortle scale.

Describe whether the use of the Bortle scale results in any changes to:

- the criteria ratings for the predicted change in nighttime visual resources as indicated in Table 25-17 of the EIS; and
- the determination of significance for a change in nighttime visual resources.

VFPA Response

Background

The light study for the EIS employed the internationally recognised and accepted CIE (Commission Internationale de l'Eclairage) zone classifications. This methodology was selected because the zone classifications rely on instrument-based measurements, and are therefore considered to be an accurate and appropriate assessment metric. The Bortle scale is based on a subjective analysis of the observability of stars of certain magnitudes. There have been several studies (Spoelstra 2017) that approximately correlate the Bortle scale with measured sky quality (in magnitude per square second of arc (mag/arcsec^2)); however, there are variations within the resulting range definitions (due to the subjectivity of the Bortle scale). The Bortle scale is not intended to be used based on objective measurements using an instrument (i.e., a sky quality meter), as was done for the EIS (Bortle 2001).

Revise Table 9.4-10 of the EIS to convert sky glow estimates from percentage sky glow to magnitude per square arc-second and identify the corresponding existing and predicted Bortle Scale classification for each of the 12 points of reception.

The measurement-based CIE zone classification remains the appropriate methodology for the RBT2 light assessment; nonetheless, a conversion of CIE classifications to the Bortle scale classes is provided as requested. The CIE zone classifications for sky quality presented in the EIS, which are based on measurements of existing sky quality at each point of reception (POR), have been converted to classes within the Bortle scale, relying on the correlation method outlined in Spoelstra (2017). The results are presented in **Table IR6-02-1** and **Table IR6-02-2**.

Table IR6-02-1 Existing Sky Quality Levels at the Identified Measurement Locations

POR ID	Measured Sky Quality (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Background)	CIE Zone Classification	Bortle Scale Class
POR1	20.9	95	G2	4
POR2	20.8	105	G3	4
POR3	20.5	167	G3	4
POR4	18.3	1,909	G4	6-7
POR5	17.5	4,440	G4	8-9
POR6	17.2	5,735	G4	8-9
POR7	19.2	804	G4	5
POR8	19.5	613	G4	5
POR9	18.8	1,218	G4	6-7
POR10	19.3	711	G4	5

POR ID	Measured Sky Quality (mag/arcsec^2)	Existing Sky Glow (% Brightness above Natural Background)	CIE Zone Classification	Bortle Scale Class
POR11	18.3	1,932	G4	6-7
POR12	20.6	144	G3	4

Note: For a description of CIE zone classification, see Section 2.4.4 of EIS Appendix 9.4-A

Table IR6-02-2 Summary of Predicted Future Conditions with the Project Results for Sky Glow

POR ID	Predicted Sky Glow (% Brightness above Natural Background)	Predicted Sky Quality (mag/arcsec^2)	CIE Zone Classification	Bortle Scale Class
POR1	121	20.7	**G3**	4
POR2	124	20.7	G3	4
POR3	192	20.4	G3	4
POR4	2093	18.2	G4	6-7
POR5	4753	17.4	G4	8-9
POR6	6086	17.1	G4	8-9
POR7	1307	18.7	G4	**6-7**
POR8	626	19.4	G4	5
POR9	1226	18.8	G4	6-7
POR10	794	19.2	G4	5
POR11	13343	16.3	G4	**8-9**
POR12	146	20.6	G3	4

Note: **Bold** indicates a change in zone or class.

Provide a comparison of any changes in classification at each of the 12 points of reception between the CIE scale and the Bortle scale.

The Project is predicted to result in a change in CIE zone classification for one POR (POR1) from G2 to G3. Using the Bortle scale, the Project is not predicted to result in a change in Bortle scale class at POR1, but is predicted to result in a change in Bortle scale class at two other PORs: POR7 (Brunswick Point) and POR11 (Existing Roberts Bank terminals). POR7, located at Brunswick Point, is predicted to change from Class 5 (Suburban sky) to 6-7 (Bright suburban sky – Suburban/urban transition). POR11, which is the existing Roberts Bank terminals, is predicted to change from 6-7 (Bright suburban sky – Suburban/urban transition) to 8-9 (City sky – Inner-city sky).

Describe whether the use of the Bortle scale results in any changes to: the criteria ratings for the predicted change in nighttime visual resources as indicated in Table 25-17 of the EIS; and the determination of significance for a change in nighttime visual resources.

A characterisation of residual effect, and determination of significance, is provided below for nighttime visual resources, considering the application of the Bortle scale. Although the conclusions are the same as described in the EIS, the assessment provided in the EIS is considered more accurate as it relies on the instrument-based CIE classification method. The change in classification identified for two of the 12 PORs (POR7 and POR11) when applying the Bortle scale would not alter the criteria ratings for the predicted change in nighttime visual resources as presented in the EIS. The rationale for retention of EIS criteria ratings is outlined in **Table IR6-02-3** below**.**

Table IR6-02-3 Criteria Ratings for Residual Effect – Changes in Nighttime Visual Resources Applying the Bortle Scale Results

Criteria	Criteria Rating	Rationale for Criteria Rating
Magnitude	Low	Visible changes to nighttime visual resources would occur at two PORs, resulting in a minor alteration to nighttime visual resources at these sites which would be consistent with the existing visual character at these locations.
Extent	Local	The two PORs where changes would occur are located within 6 km (i.e., POR 7) and 0.6 km (i.e., POR 11) of the Project area.
Duration	Long Term	Same as that presented in Table 25-16 of the EIS
Frequency	Continuous	Same as that presented in Table 25-16 of the EIS
Reversibility	Partially Reversible	Same as that presented in Table 25-16 of the EIS

Similar to the assessment results as stated in EIS Section 25.8.2, the changes in classification at PORs when applying the Bortle scale represents a minor visible alteration to the overall range of viewscapes of nighttime visual resources. The two PORs that experience change in classification under the application of the Bortle scale are predicted to experience a change in visual character but remain consistent with the existing nighttime visual resource setting where they are located. With the change from Class 5 to Class 6-7 at POR7, a suburban lighting character is retained. With the change from Class 6-7 to Class 8-9 light classification for POR11, a lighting character representative of a bright urban environment, and consistent with industrial activities and developments at Roberts Bank terminals, is retained.

The assessment results when applying the Bortle scale do not result in a change to the significance determination for residual effects on nighttime visual resources as presented in Section 25.9.2 of the EIS. With the application of the Bortle scale there remains a minor level of overall change to the nighttime viewscapes visible from the two affected PORs, and the existing visible landscape remains able to absorb evident features that are similar in character to existing levels of development.

References

Bortle, J. E. 2001. Gauging Light Pollution: The Bortle Dark-Sky Scale. Sky & Telescope. February 2001.

Spoelstra, H. 2017. Sky Brightness Nomogram. Available at http://www.darkskiesawareness.org/nomogram.php. Accessed July 2017.

IR6-03 Light – Methodology (Use of Representative Vessel)

Information Source(s)

Marine Shipping Addendum: Section 7.5; Table 4-3; Table 4-4

Review Panel Information Request IR4-01 (CEAR Doc#946)

Context

In Section 7.5 of the Marine Shipping Addendum, the Proponent stated that no specific light design information was available for the representative container ship described in Table 4-4 that was used in the assessment of the potential effects of marine shipping associated with the proposed Project.

The Proponent maintained that the light emissions of a Project-associated ship would be consistent, with a representative vessel considered in the light assessment for the Woodfibre LNG facility, because those vessels have physical dimensions and operations comparable to the physical dimensions of the container ships that would call on the Project.

The Proponent stated that, based on the information about the light fixtures and light layout for the Woodfibre LNG Project, it was assumed that one representative container ship would be expected to have a luminous output of 44,400 lumens.

As indicated in Table 4-3 of the Marine Shipping Addendum, container ships with capacities in the range of 8,000 - 10,000 TEUs would call on the Project most frequently, and by 2030, 29% of container ship calls would be by ships with capacities greater than 10,000 TEUs.

Information Request

Provide information about the light design, including the light fixtures and light layout, for the representative vessel used in Woodfibre LNG Project assessment. Include figures, if possible.

Provide a comparison of the light design, including the light fixtures and light layout, between the representative vessel used in Woodfibre LNG Project assessment and representative container ships with capacities between 8,000 - 10,000 TEU and with capacities greater than 10,000 TEUs.

Based on that comparison, provide a rationale for why light design for the representative vessel used in Woodfibre LNG Project assessment is an appropriate proxy for the container ships that will call on the proposed Project.

If no specific light information for the representative container ship used in the assessment of the potential effects of marine shipping associated with the Project is available, estimate light trespass and sky glow levels for container ships with capacities between 8,000 - 10,000 TEU and between 10,000 and 15, 000 TEUs. If container ships with capacities greater

than 15,000 TEUs, including ultra large container ships in the 18,000 - 20,000 TEU range, would call on the proposed Project, estimate light trespass and sky glow levels for them.

VFPA Response

Woodfibre Vessel Information

Information regarding the lighting on the Woodfibre LNG vessel, including lighting design figures, can be found in the light assessment for the Woodfibre LNG environmental assessment (Golder 2014). Specifically, information on the lumens produced by each light fixture type is provided in Table 4: Light Fixture Summary in Section 2.4.1, and the lighting layout for the Project, including the floating production barge, is included in Attachment 2 of the assessment (reproduced in **Appendix IR6-03-A**).

Comparison of Light Designs

The VFPA obtained and reviewed a lighting design for the representative container ship (defined in Section 4.2.1.1 of the Marine Shipping Addendum); however, the lighting design itself was considered confidential and could therefore not be included or referenced in the Marine Shipping Addendum. As such, the Woodfibre LNG vessel was selected as a proxy because the lighting designs were publicly available (included in **Appendix IR6-03-A**). The Woodfibre LNG vessel is considered to be a conservative proxy because it is known to produce more light that the representative container vessel, based on a review of both lighting designs. A comparison of the lighting specifications and total light emissions of the two vessels is provided below in **Table IR6-03-1**.

Table IR6-03-1 Comparison of Light Emissions of the Woodfibre Proxy and a Confidential Container Ship

	Light Emissions (lumens)	
	Confidential Container Vessel	**Woodfibre LNG Proxy Vessel**
Total (all luminaires)	709,200	1,405,926
Navigation	20,400	44,400[a]

Notes: a. Assessed in the Marine Shipping Addendum.

Rationale for Use of Woodfibre LNG Vessel as Proxy

The vessel considered in the Woodfibre LNG assessment was a conservative lighting proxy in comparison to typical container vessels lighting while underway. While container ships are underway, only navigational lights are generally in operation / required (*Canada Shipping Act, 2001*[1]). In contrast, the Woodfibre LNG vessel used as a conservative proxy in the assessment

[1] Part C, Lights and Shapes, Collision Regulations, C.R.C., c. 1416; available at http://laws.justice.gc.ca/eng/regulations/C.R.C.,_c._1416/20140129/P1TT3xt3.html.

is a floating production barge, requiring high levels of illumination at all times during operation (*Canada Shipping Act, 2001*[2]).

Light from Larger Vessels

The requirements for navigational lights (as described in the *Canada Shipping Act, 2001*) do not increase once ships are larger than 50 m in length *(Canada Shipping Act, 2001)*. Therefore, while larger container ships may have more light sources, these lights are not all used when the ship is underway. Therefore, the results presented in the Marine Shipping Addendum for light trespass and sky glow levels are considered to be a conservative assessment of container ships with capacities greater than 10,000 twenty-foot equivalent units (TEUs), and up to and including ultra large container ships in the 18,000 to 20,000 TEU range, as well as larger 24,000 TEU vessels as described in the response to IR4-01.

References

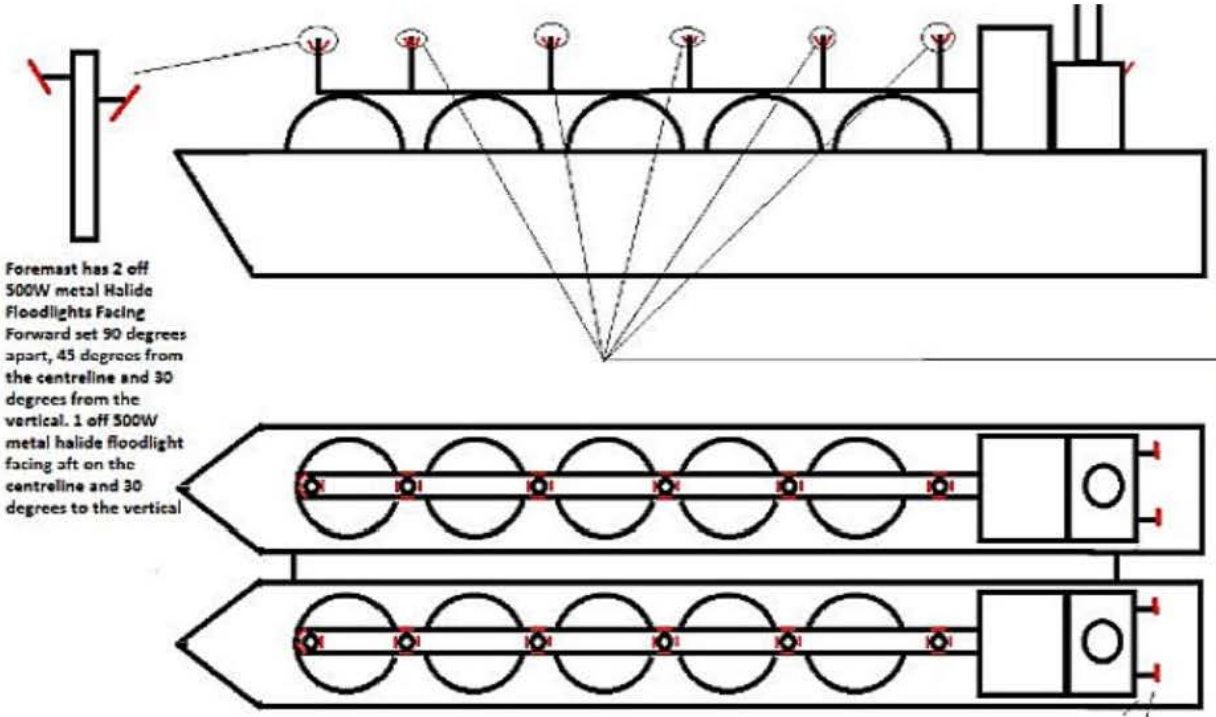
Golder Associates Ltd. (Golder). 2014. Technical Report Light Assessment: Woodfibre LNG Project. September 2014.

Appendices

Appendix IR6-03-A Light Design – Woodfibre LNG Vessel

[2] Rule #23 - Power-driven Vessels Underway and Rule #30 - Anchored Vessels and Vessels Aground (production barge), Collision Regulations, C.R.C., c. 1416; available at http://laws.justice.gc.ca/eng/regulations/C.R.C.,_c._1416/20140129/P1TT3xt3.html.

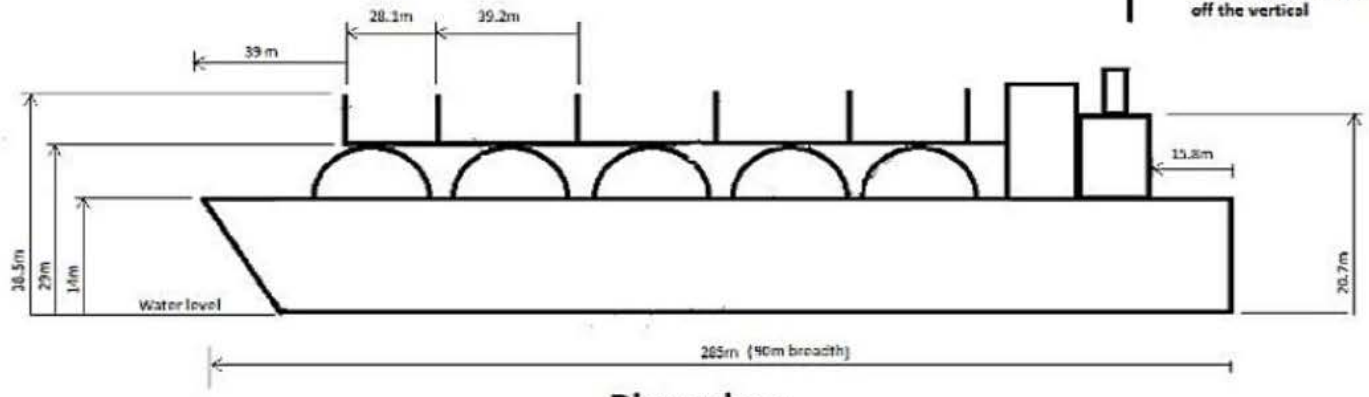
APPENDIX IR6-03-A
LIGHT DESIGN – WOODFIBRE LNG VESSEL



Foremast has 2 off 500W metal Halide Floodlights Facing Forward set 90 degrees apart, 45 degrees from the centreline and 30 degrees from the vertical. 1 off 500W metal halide floodlight facing aft on the centreline and 30 degrees to the vertical

5 off centreline posts each with 4 off 500W Metal Halide Floodlights. Floodlights are set at 90 degrees to each other, 30 degrees from the vertical with two lights facing directly fore and aft and the other directly port and starboard

Machinery Casing has 2 off 500W Metal Halide Floodlights for the aft mooring deck these 5 meters on each side of the centre line and 30 degrees off the vertical



Dimensions

IR6-04 Air Quality – Modelling: NMM-WRF model runs

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2.2, Figures 2-3, 2-4 and 2-5

British Columbia Air Quality Dispersion Modelling Guideline. British Columbia Ministry of Environment, 2015

Context

All model runs (NMM-WRF, CALMET and CALPUFF) were performed on 2010 meteorological conditions, which were then compared with the 1980-2010 climatology. From the EIS:

- Figure 2-3 in Section 2.2 of Appendix C in Appendix 9.2-A in the EIS (annual cycle of temperature) showed that the year 2010 had a warmer winter (J, F, M), a cooler spring and summer (M, J, J, A) and a slightly cooler October than the 1980-2010 climatology;
- Figure 2-4 (annual cycle of precipitation) showed that the year 2010 was wetter in all months except April and September than the 1980-2010 climatology;
- Figure 2-5 (average wind speed panel) showed that the year 2010 had stronger westerly winds than the 1980-2010 climatology; and
- Figure 2-5 (average wind direction panel) showed that the year 2010 had less frequent W, WNW and NNW winds, and more frequent E, ESE, SE, SSE and S winds than the 1980-2010 climatology.

These results do not support the Proponent's assertion that 2010 was deemed to be a representative year for meteorological conditions.

The statistical test used to compare 2010 with the 1980-2010 climatology dealt only with monthly averages, and thus can only inform about seasonal variability. The evaluation should be quantitative and graphical, not only graphical.

The use of three years of meteorology is needed in order to minimize the possibility of modelling results being biased due to the choice of modelling years that are not representative of climatological averages.

Information Request

Repeat the NMM-WRF model runs with three years of data from the recent past.

In these runs, use site specific geophysical parameters over the entire modelling domain, as recommended in the *British Columbia Air Quality Dispersion Modelling Guideline*, 2015.

Perform a comparison between three years of meteorology and 1980-2010 climatology using data from Vancouver International Airport, Sand Heads station and Abbotsford International Airport.

The comparison has to be statistically robust and conform to best statistical practices for model evaluation. It has to cover a wide enough set of meteorological variables to support a conclusion regarding the use of the model years for air pollution modelling purposes.

VFPA Response

Repeat the WRF-NMM model runs with three years of data from the recent past.

The VFPA has not repeated the WRF-NMM model runs with three years of meteorological data from the recent past for several reasons, which are outlined below. Specifically, information is provided on the following aspects:

- 2008 Guidelines for Air Quality Dispersion Modelling in British Columbia (2008 B.C. Guidelines; MOE 2008) – guidance available at the time of the RBT2 Air Quality Study (RBT2 Study) that was incorporated into the RBT2 Study approach (i.e., incorporation of one year of meteorological data);
- 2015 British Columbia Air Quality Dispersion Modelling Guideline (2015 B.C. Guideline; MOE 2015) – updated guidance, which is consistent with the RBT2 Study approach;
- Regulatory input on the RBT2 Study approach – the RBT2 Study approach was informed by pre-assessment discussions with regulatory agency representatives during the Air Quality Scoping Study (AQSS) process; and
- RBT2 Study output validation – based on the validation of model predictions, it was shown that the RBT2 Study approach provided for a conservative assessment of existing and future conditions.

As context, the air quality dispersion modelling analysis for the RBT2 Study was completed in November 2014, in accordance with 2008 BC Guidelines (MOE 2008). The 2015 B.C. Guideline (MOE 2015) was issued in December 2015, after the RBT2 Study was completed and after the March 2015 filing of the RBT2 EIS with the Canadian Environmental Assessment Agency. The approach to the assessment of air quality for RBT2 was aligned with the 2008 B.C. Guidelines, and integrated input from regulators discussed during the AQSS process in 2013 before the analysis was started. One year of meteorological data was used in the analysis, in accordance with the 2008 B.C. Guidelines and regulator input, and is also aligned with requirements outlined in the 2015 B.C. Guideline, as explained below.

2008 B.C. Guidelines

Section 7.3.1 in the 2008 B.C. Guidelines states that, with respect to the length of the meteorological data record for Level 2 or Level 3 modelling assessments[1] such as the RBT2 Study, *"one year of data is acceptable if meteorological data is produced from an MM* [mesoscale meteorological] *model."* Section 7.1.3 also states the following:

> *"While MM models offer many advantages, they require considerable expertise and computational resources (processing, storage) which escalate rapidly with*

[1] The Study was a Level 3 assessment. A Level 2 assessment is a detailed assessment and a Level 3 assessment is a comprehensive assessment; both types of assessments require the use of advanced models (e.g., CALPUFF).

domain size, grid resolution and simulation duration. Thus, it is ***impractical*** [emphasis added] *to apply these models for dispersion modelling in situations where it is required* ***to simulate one or multiple years of hourly meteorology at a fine enough grid scale (on the order of 100 m)*** [emphasis added] *and vertical levels to resolve the effects of small-scale terrain features.*

An alternative approach to the generation of detailed meteorological fields is through the use of a diagnostic model (such as CALMET). This type of model contains simplified physics (e.g., no ability to forecast and the treatments of processes are parameterized) so that the computational resource demands are greatly reduced. However, even with these simplifications, they can efficiently account for very fine scale terrain effects in a dynamically consistent framework.

Finally, there is a combined MM and diagnostic model approach, where coarse spatial resolution MM model output is used as an initial guess field for a fine spatial resolution diagnostic model (such as CALMET). The diagnostic model further applies dynamically consistent diagnostic algorithms in concert with available observed data to develop terrain effects adjustments on a fine scale. This hybrid approach uses the strengths of both models and ***makes it practical to produce fine-scale meteorological fields for simulation periods of a year*** [emphasis added]*. CALMET also has an option to use MM output without any surface or upper-air measurements (i.e. "no obs" option)."*

Based on the guidance stated above, the hybrid approach of combining meteorological model data with a diagnostic model approach (i.e., CALMET) was used in the RBT2 Study[2].

2015 B.C. Guideline

With respect to the request or need for the inclusion of three years of meteorological data for the RBT2 Study, the 2015 B.C. Guideline reiterated statements in the 2008 B.C. Guidelines concerning the practicality of running multiple years of prognostic meteorological model data for analyses conducted on a fine grid resolution. In addition, Section 5.4 of the 2015 B.C. Guideline states *"At least three years of data should be used for the applications where there are significant public concerns about impacts of air quality."* Supporting information is provided below on local air quality in the region to show that significant public concern about impacts on air quality, if any, to the Tsawwassen region is not justified because the region already has some of the best air quality in the Lower Fraser Valley and the RBT2 Study has

[2] The hybrid approach of combining meteorological model data with a diagnostic model approach (i.e., CALMET) defined in the 2008 B.C. Guidelines was used in the RBT2 Study. The VFPA was aware during the scoping phase of the RBT2 Study that the definition of hybrid approach was changing in the forthcoming update to the B.C. Guidelines (issued in 2015). The VFPA considered the pending change (which was raised by regulators during the AQSS process) prior to commencing the RBT2 Study, but was unable to incorporate this approach for the reasons explained in the response in IR6-10.

shown that emissions from the operations at the marine terminals at Roberts Bank will be lower in the future than under existing conditions, both with and without RBT2.

Local Air Quality

With respect to significant public concerns about impacts to air quality, both short-term peak and average concentrations have declined in the Lower Fraser Valley region over the last two decades for most pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter ($PM_{2.5}$) (Metro Vancouver 2015, 2017). Air quality contaminant levels in the Tsawwassen area are low in comparison to other areas of the Lower Fraser Valley and in comparison to regional and provincial ambient air quality objectives.

Additional information to support the conclusions above is provided in the following sections in Appendix B of EIS Appendix 9.2-A:

- Section 3.2.1 outlined the results from monitoring programs completed by Metro Vancouver in 2002 for particulate matter (GVRD 2002) and for gaseous contaminants and particulate matter (GVRD 2006);
- Section 3.2.3 summarised the available air quality monitoring data from station T39 in Pebble Hill Park for the period of June 2010 to December 2012. The data indicated that the observations were below the ambient air quality objectives for Metro Vancouver, except for peak $PM_{2.5}$ and ozone levels during regional scale air quality advisories for $PM_{2.5}$ from smoke due to wildfires in August 2010 and for ozone in August of 2010 and 2012; and
- Section 3.2.5 compared criteria air contaminant levels measured at station T39 in 2012 to other stations in the Lower Fraser Valley to show that observed concentrations of criteria air contaminants in Tsawwassen are among the lowest levels in the Lower Fraser Valley, except for ozone during episodes of regional scale smog conditions. The response to IR6-09 of CEAR Document #1113[3] provides a detailed comparison of observed air quality at station T39 for 2010-2012 and 2013-2015.

Examples of improving trends in the local region, which already experiences good air quality, are provided below for SO_2 and $PM_{2.5}$.

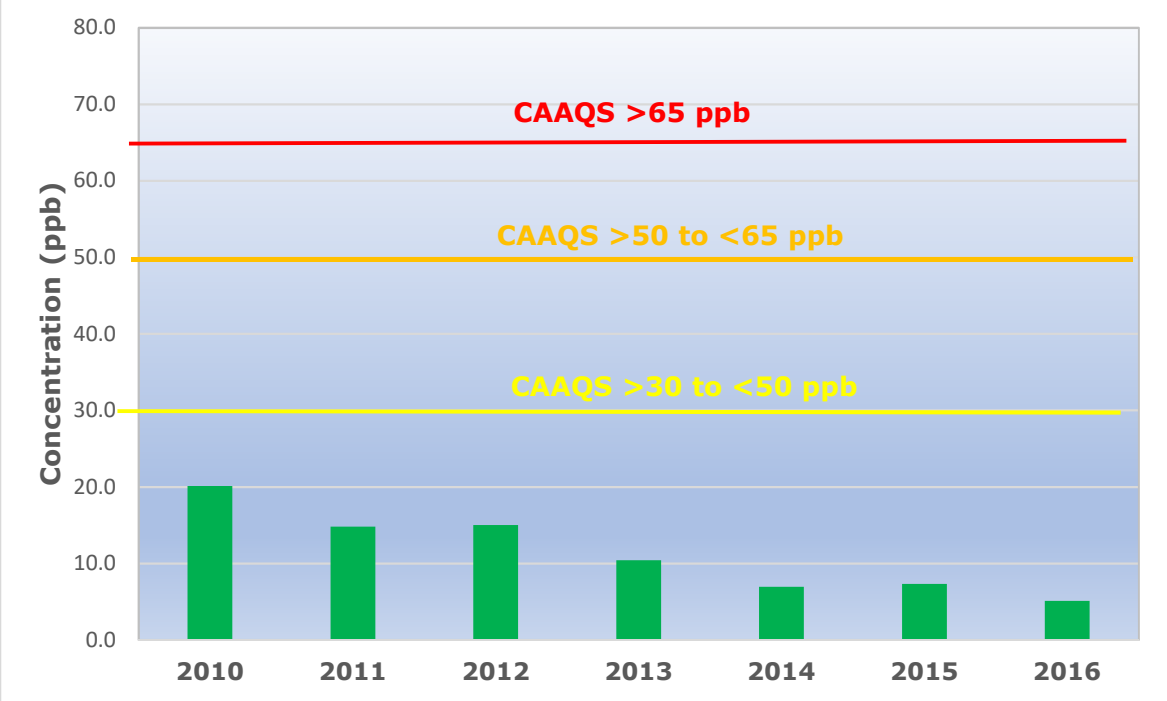
Trends in Hourly and Annual SO_2 Concentrations 2010 to 2016

As measured at station T39, maximum (100th percentile) hourly averaged SO_2 concentrations decreased by 64% from 2010 to 2016 (**Figure IR6-04-1**). The benefits from the implementation of Phase 1 North America Emission Control (ECA) requirements in July 2012 and Phase 2 in January 2015 for reduced sulphur in fuel are shown in **Figure IR6-04-1**. The maximum hourly averaged SO_2 concentrations in recent years are below the newly-defined Canadian Ambient Air Quality Standard (CAAQS; endorsed by the Canadian Council of Ministers of the Environment in 2016) of 70 parts per billion (ppb) or 183 micrograms per

[3] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).

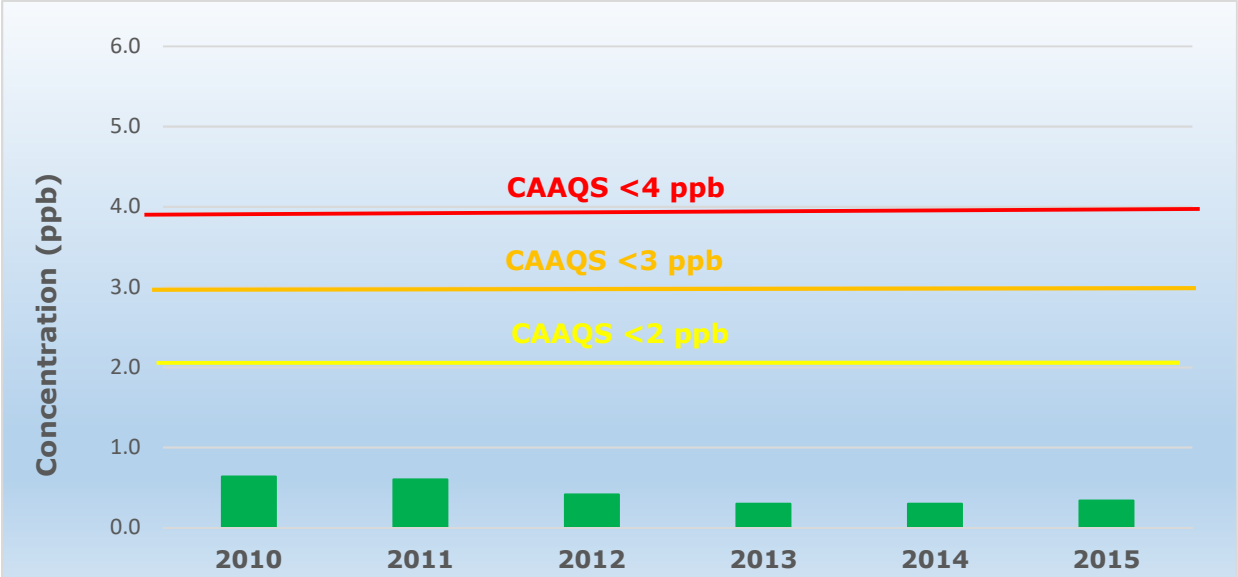
cubic metre (µg/m^3) (effective in 2020) and 65 ppb or 170 µg/m^3 (effective in 2025)[4]. The maximum hourly averaged SO_2 concentrations shown in **Figure IR6-04-1** fall well within the range where proactive measures may be taken *"to keep clean areas clean"* (CCME 2016). **Figure IR6-04-2** shows the decrease in mean annual SO_2 concentrations over 2010 to 2016, and that concentrations are well below the new annual SO_2 CAAQS that will be effective in 2025.

Figure IR6-04-1 Trend in Maximum 1-hour Average SO_2 Concentrations at Station T39 from 2010 to 2016 (CAAQS Effective 2025)



[4] Note that the new 1-hour CAAQS for SO_2 are based on the 99th percentile averaged over three consecutive years, and the comparisons provided above are to the maximum (100th percentile) concentrations.

Figure IR6-04-2 Trend in Annual Average SO_2 Concentrations at Station T39 from 2010 to 2016 (CAAQS Effective 2025)



$PM_{2.5}$ Levels in the Tsawwassen Area

24-hour average $PM_{2.5}$ concentrations in the Tsawwassen area (including locations in Ladner and the Tsawwassen First Nation Lands) in 2004-2006 were the same or lower than levels measured at other monitoring stations in Metro Vancouver, while annual average $PM_{2.5}$ concentrations were less than 50% of the Metro Vancouver ambient air quality objective, and less than $PM_{2.5}$ levels observed in neighbouring municipalities (GVRD 2006).

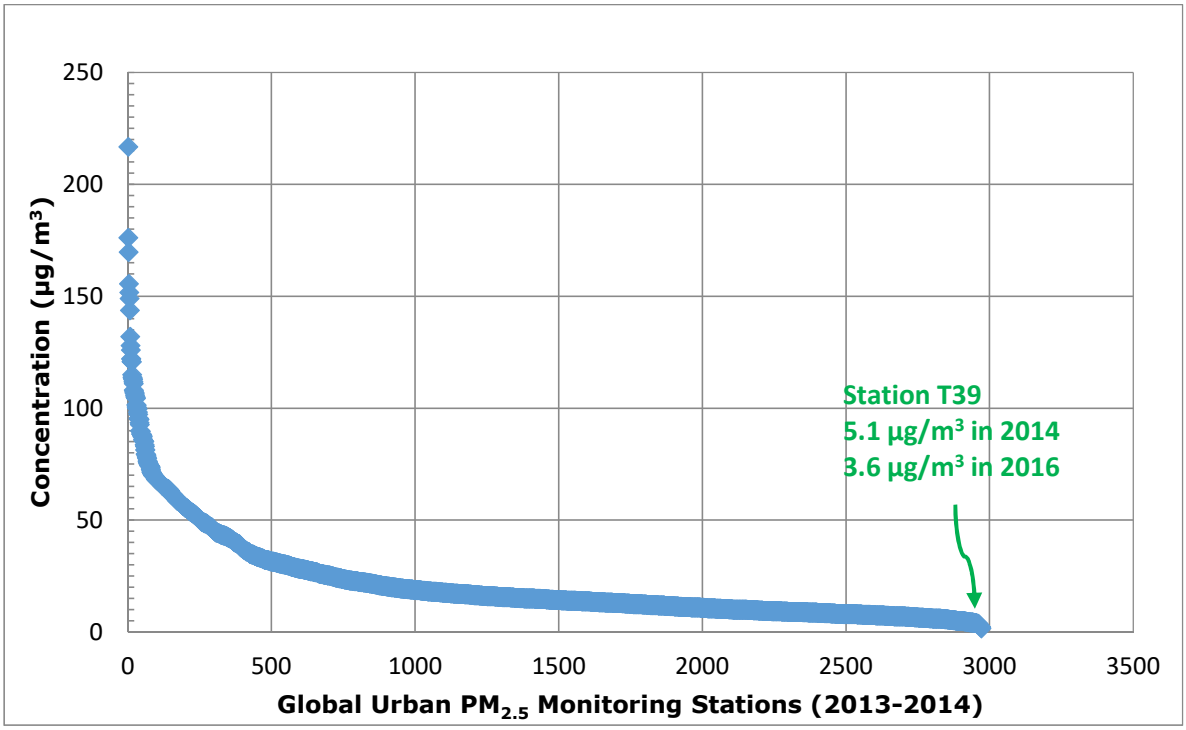
As noted in the response to IR6-09 (CEAR Document #1113), $PM_{2.5}$ levels increased in 2013 compared to prior years of monitoring at station T39 (2010 to 2012) as a result of an equipment upgrade from a Tapered Element Oscillating Microbalance (TEOM) monitor to a Federal Equivalent Method (FEM) monitor. The maximum 24-hour average $PM_{2.5}$ concentration in 2016 was 14.8 $\mu g/m^3$, or 59% of the Metro Vancouver ambient air quality objective. The annual average $PM_{2.5}$ concentration (measured using the FEM), however, declined from 5.7 $\mu g/m^3$ in 2013 to 4.7 $\mu g/m^3$ in 2015 and to 3.6 $\mu g/m^3$ in 2016, consistent with the decline in $PM_{2.5}$ concentrations attributable to the ECA requirements for low sulphur fuels in marine shipping in the Pacific Northwest region (Kotchenruther 2013, 2015, 2017).

To further illustrate good air quality in the region, $PM_{2.5}$ concentrations at station T39 are compared to levels in other urban areas in the world, using the database of $PM_{2.5}$ measurements for 2013-2014 compiled by the World Health Organization (WHO)[5]. **Figure IR6-04-3** depicts the annual average $PM_{2.5}$ concentration from the WHO database for 2,972 urban stations around the world, which includes 126 sites in Canada. The annual average $PM_{2.5}$ concentration measured at station T39 of 5.1 $\mu g/m^3$ in 2014 is one of the best

[5] http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

among stations in the WHO database. Only 45 stations in the WHO database recorded less than 5 µg/m^3 in 2013-2014. In 2016, station T39 recorded an annual average $PM_{2.5}$ concentration of 3.6 µg/m^3. Thus, the $PM_{2.5}$ levels in Tsawwassen fall within the top 1.5% of all urban monitoring sites around the world for good air quality. On this basis, it can be stated that Tsawwassen has some of the best air quality in the world with respect to fine particulate matter.

Figure IR6-04-3 Annual Average PM2.5 Concentrations in Urban Areas for 2013-2014 and Station T39 in 2014 and 2016



Source: Modified from WHO database[5].

Taking into consideration the RBT2 Study results and following the guidance in the 2015 B.C. Guideline regarding significant public concerns on impacts to air quality, one year of meteorological data is adequate for a Level 3 assessment, such as the RBT2 Study, in an area where air quality is good, and expected to continue to improve in the future (with or without RBT2).

Air Quality Scoping Study Process Input

The AQSS process occurred from February 13, 2013 to December 10, 2015, and included representatives from Tsawwassen First Nation, City of Delta, and air quality regulatory agencies including Environment Canada, Metro Vancouver, and the B.C. Ministry of Environment. At the onset of the process, the VPFA proposed to conduct air dispersion modelling using one year of WRF-NMM data. The meeting notes from the first AQSS meeting on February 13, 2013 indicated that Environment Canada recommended that the assessment be completed using *"a **representative year** with a warm summer for meteorology data".*

Section 2.2 in Appendix C of EIS Appendix 9.2-A shows that the average daily temperature derived from the WRF-NMM model for 2010 was 10.9°C, slightly higher than the climate normal of 10.4°C (as presented below).

No other comments regarding the meteorological database were made during the AQSS process, as shown in a AQSS engagement and discussion summary provided in **Appendix IR6-04-A** (Table IR6-04-A1).

Study Output Validation

Based on the validation of model predictions, the RBT2 Study approach provided for a conservative assessment of existing and future conditions. An evaluation of the ability of the WRF-NMM model to adequately capture meteorological variation at space and time scales appropriate for the modelling of plume dispersion from the Project is provided in the response to IR6-05. For more information on comparisons of modelled to observed values, refer to the following:

- Section 2.2 in Appendix C of EIS Appendix 9.2-A for modelled meteorological data;
- The response to IR6-22 for NO_2 concentrations derived using the Ozone Limiting Method; and
- The response to IR6-29 for anticipated reductions in marine source NO_x emissions (some of which have not been factored into the RBT2 Study dispersion modelling analysis because there was insufficient information available at the time of the RBT2 Study).

In these runs, use site specific geophysical parameters over the entire modelling domain, as recommended in the British Columbia Air Quality Dispersion Modelling Guideline, 2015.

As clarification, neither the 2008 B.C. Guidelines nor the 2015 BC Guideline recommend inclusion of site-specific geophysical parameters in prognostic meteorological model data, but guidance is provided for inclusion in CALMET meteorological modelling. The terrain elevation and land use data with fine grid spacing of 100 m were used in the RBT2 Study to accurately resolve water/land boundaries. The other geophysical parameters such as surface roughness length, albedo, Bowen ratio, soil heat flux, vegetation leaf area index, and anthropogenic heat flux were specified as a function of land use and based on default values outlined in the CALMET modelling guidelines (Scire et al. 2000). Geophysical inputs in CALMET, such as land use characterisation and terrain elevation, were set using the global geophysical data compiled by the United States Geological Service at approximately 1 km spatial resolution, and in accordance with the 2008 B.C. Guidelines.

The WRF-NMM model uses the following geophysical parameters interpolated over the modelling domain: soil categories, land use category, terrain height, annual mean deep soil temperature, monthly vegetation fraction, monthly albedo, maximum snow albedo, and slope category[6]. The WRF-NMM model terrain (on a 2 km model grid) provides a reasonably

[6] https://dtcenter.org/wrf-nmm/users/docs/user_guide/V3/users_guide_nmm_chap3.pdf

accurate representation of the local topographic features in the model domain (Figure 2-2 in Appendix C of EIS Appendix 9.2-A shows the terrain data that were used in WRF-NMM simulations).

Additional information on the inclusion of geophysical parameters in CALMET/CALPUFF dispersion modelling completed for the RBT2 Study is provided in Section 2.4.2 in Appendix C of EIS Appendix 9.2-A.

Perform a comparison between three years of meteorology and 1980-2010 climatology using data from Vancouver International Airport, Sand Heads station and Abbotsford International Airport.

A comparison of the WRF-NMM dataset based on one year (2010) meteorology with 30-year climatology is provided and discussed below, as meteorological modelling with three years of data has not been undertaken for the reasons explained above.

The results of statistical analyses (average, minimum, maximum, and standard deviation) for temperature, wind speed and direction, and precipitation data are compared to 2010 data for the following:

- For Vancouver International Airport, to 1981-2010 climate normal data (**Table IR6-04-1**);
- For Abbotsford International Airport, to 1981-2010 climate normal data (**Table IR6-04-2**); and
- For Sand Heads Climate Station, to 1961-1990 climate normal data for wind only (**Table IR6-04-3**). Data for the 1981-2010 climate normal data was unavailable for this station so an earlier 30-year period that provided wind data only (i.e., not temperature or precipitation data) was used for the comparison purposes[7].

It should be noted that the Vancouver International Airport and Sand Heads stations are both located in or near the Strait of Georgia, while the Abbotsford International Airport station is located 58 km inland from Roberts Bank. Any differences between the WRF-NMM dataset and the climate normals at the Vancouver International Airport and the Sand Heads stations, therefore, will have more relevance to the RBT2 Study than any differences with the Abbotsford International Airport station. The quantitative comparisons provided in **Tables IR6-04-1** to **IR6-04-3** indicated that 2010 is a representative year for meteorological conditions, as further explained below.

Temperature Comparison

Compared to the Vancouver International Airport (**Table IR6-04-1**) and Abbotsford International Airport (**Table IR6-04-2**) 1981-2010 climate normals, the WRF-NMM 2010 dataset generally shows warmer winter months (January to March, December), and cooler spring months (May and June). Daily average temperatures in the WRF-NMM 2010 dataset are within the range of conditions (between the daily minimum and daily maximum

[7] Government of Canada website for Canadian Climate Normals: http://climate.weather.gc.ca/climate_normals/index_e.html.

temperatures) observed in the 1981-2010 climatology. The annual average daily temperatures for the Vancouver International Airport and Abbotsford International Airport stations were 0.5°C and 0.4°C warmer in the WRF-NMM dataset, respectively, compared to the 1981-2010 climatology. The difference in ambient temperature between the WRF-NMM dataset and 30-year climatology is not expected to affect the outcomes of the RBT2 Study for the following reasons:

- Although ambient temperatures can affect the thermal buoyancy of point source emissions in dispersion modelling, RBT2 emissions consist primarily of volume sources (i.e., cargo handling equipment, locomotives, and on-road vehicles, during terminal operations, as well as gaseous and particulate matter emissions during the construction phase), for which thermal buoyancy is not a factor for dispersion modelling. The primary source for which thermal buoyancy is a factor in determining dispersion is the exhaust plumes from ships. The high exhaust gas temperature of these plumes (299.9°C to 352.4°C) are considerably higher than ambient temperatures such that a change in ambient temperature of approximately 0.5°C will not result in a significant change in the temperature difference that drives plume rise through thermal buoyancy;
- Although ambient temperatures can affect the rate of conversion of nitric oxide (NO) to nitrogen dioxide (NO_2), ambient temperature is not a factor in the application of the Ozone Limiting Method (OLM). Therefore, the prediction of NO_2 concentrations was calculated independently from temperature variations; and
- Ambient temperature is a factor in the formation of ground-level ozone, and is an important parameter when conducting regional-scale photochemical modelling for ozone. However, the first-order estimate of potential changes in ambient ozone concentrations was based on changes in emission ratios of nitrogen oxides (NO_x) and volatile organic compounds (VOCs), without regard to ambient temperature. The noted differences between modelled and climate normals temperatures, therefore, would not affect the estimated change in ozone concentration.

As described in the bullets above, the small differences observed between the ambient temperatures derived from the WRF-NMM 2010 dataset and 30-year climate normals would not affect the outcome of the air quality dispersion modelling analysis conducted for RBT2.

Wind Speed and Direction Comparison

The average wind speeds in the WRF-NMM dataset are slightly higher than the average wind speeds in 1981-2010 climatology at the Vancouver International Airport (**Table IR6-04-1**) and the Abbotsford International Airport (**Table IR6-04-2**), and slightly lower than average wind speeds in the 1961-1980 climatology at Sand Heads (**Table IR6-04-3**). Differences in monthly average wind speeds are typically less than 2 m/s, which is below the benchmark of 2 m/s to 3 m/s based on typical studies of prognostic models (Hanna and Yang 2001). Since, on an annual average basis, the difference in modelled and climate normals wind speeds for the Vancouver International Airport, Abbotsford International Airport, and Sand Heads Climate Station locations were 0.4 m/s, 1.4 m/s, and 0.5 m/s, respectively, the wind speeds in the WRF-NMM 2010 dataset are reflective of 30-year climatology.

With respect to wind direction, the WRF-NMM dataset shows more frequent westerly to northwesterly winds as compared to 30-year climatology at the Vancouver International Airport and Sand Heads stations. Since the westerly and northwesterly winds would tend to transport RBT2-related emissions toward land, differences in wind direction between the WRF-NMM dataset and 30-year climatology are expected to have resulted in more conservative estimates of RBT2-related changes on air quality locally than would be expected if based on wind direction derived from the 30-year climate normals.

Precipitation Comparison

On a monthly basis, the WRF-NMM 2010 dataset shows less total precipitation than 1981-2010 climatology at the Vancouver International Airport (**Table IR6-04-1**) and Abbotsford International Airport (**Table IR6-04-2**) stations, and annual total precipitation in 2010 is approximately 23% and 36% less than the 30-year climate normals data at these stations, respectively.

Precipitation affects wet deposition of formaldehyde and benzo(a)pyrene, which accounts for approximately 70% to 80% of total predicted annual deposition rates. While the WRF-NMM dataset may have underestimated total (wet plus dry) deposition rates of formaldehyde and benzo(a)pyrene, this difference does not change the conclusions of the air quality assessment.

Summary

In summary, the RBT2 Study approach provided for a conservative assessment of existing and future conditions (based on the validation of model predictions), incorporated regulatory input, and was aligned with guidance provided in both the 2008 B.C. Guidelines and the 2015 B.C. Guideline. Additional modelling is not warranted as the Lower Fraser Valley has good existing air quality (which is expected to improve in the future), and modelling with three years of data would not change the key conclusions of the RBT2 Study.

Table IR6-04-1 Comparison of WRF-NMM 2010 Meteorology to 1981-2010 Climate Normals at Vancouver International Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature *(in °C)*													
Daily Average - WRF	7.3	8.1	8.7	9.6	11.3	13.7	16.5	17.1	15.0	12.4	5.9	5.2	10.9
Daily Average - Climate Normals	4.1	4.9	6.9	9.4	12.8	15.7	18.0	18.0	14.9	10.3	6.3	3.6	10.4
Daily Max - WRF	9.5	10.4	11.6	12.5	13.9	16.5	19.5	20.2	17.7	14.8	8.0	7.2	13.5
Daily Max - Climate Normals	6.9	8.2	10.3	13.2	16.7	19.6	22.2	22.2	18.9	13.5	9.2	6.3	13.9
Daily Min - WRF	5.8	6.3	6.8	7.5	9.3	11.6	14.3	14.9	13.5	10.9	4.2	3.8	9.1
Daily Min - Climate Normals	1.4	1.6	3.4	5.6	8.8	11.7	13.7	13.8	10.8	7.0	3.5	0.8	6.8
Wind *(speed in m/s)*													
Average Speed - WRF	4.2	3.6	4.0	4.7	3.8	3.4	3.5	3.1	3.3	3.7	4.0	4.8	3.8
Average Speed - Climate Normals	3.3	3.3	3.7	3.6	3.5	3.4	3.4	3.2	3.1	3.3	3.6	3.4	3.4
Most Frequent Direction - WRF	E	E	E	W	W	W	W	W	E	E	E	E	E
Most Frequent Direction - Climate Normal	E	E	E	E	E	E	E	E	E	E	E	E	E
Precipitation *(in mm)*													
Total Precipitation - WRF	114.0	99.3	75.6	98.9	53.6	39.6	0.3	15.1	106.1	53.7	123.4	131.7	911.3
Total Precipitation - Climate Normals	168.4	104.6	113.9	88.5	65.0	53.8	35.6	36.7	50.9	120.8	188.9	161.9	1189.0
Days with >=0.2 mm - WRF	22	17	15	15	12	12	1	3	14	13	21	22	167
Days with >=0.2 mm - Climate Normals	20	15	18	15	13	12	6	7	8	15	20	20	169
Days with >=5 mm - WRF	7	8	6	5	4	2	0	2	6	3	9	8	60
Days with >=5 mm - Climate Normals	11	7	8	7	5	3	2	2	3	8	11	10	77
Days with >=10 mm - WRF	5	5	1	4	1	2	0	0	4	2	2	4	30
Days with >=10 mm - Climate Normals	6	4	4	3	2	2	1	1	1	4	7	6	42
Days with >=25 mm - WRF	0	0	0	1	0	0	0	0	1	0	1	1	4
Days with >=25 mm - Climate Normals	1	0	0	0	0	0	0	0	0	1	2	1	7

Table IR6-04-2 Comparison of WRF-NMM 2010 Meteorology to 1981-2010 Climate Normals at Abbotsford International Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature *(in °C)*													
Daily Average - WRF	6.4	7.3	8.4	9.7	11.6	14.2	17.7	18.0	15.5	12.4	4.7	3.9	10.8
Daily Average - Climate Normals	3.6	5.0	7.2	9.8	13.0	15.7	18.1	18.2	15.3	10.5	6.0	2.9	10.4
Daily Max - WRF	9.8	11.4	13.3	14.5	16.1	18.9	23.2	23.7	20.9	17.2	8.0	6.9	15.4
Daily Max - Climate Normals	6.7	9.0	11.6	14.7	18.1	20.8	24.0	24.4	21.3	15.0	9.3	5.9	15.1
Daily Min - WRF	4.0	4.3	4.8	6.0	7.7	10.4	12.9	13.7	12.0	9.2	2.3	1.9	7.4
Daily Min - Climate Normals	0.4	1.1	2.7	4.8	7.8	10.5	12.2	12.0	9.3	5.9	2.7	-0.1	5.8
Wind *(speed in m/s)*													
Average Speed - WRF	4.9	3.8	3.7	4.3	3.3	3.1	2.9	2.7	3.0	3.1	4.7	4.7	3.7
Average Speed - Climate Normals	2.6	2.7	2.7	2.5	2.3	2.3	2.1	1.8	1.7	2.0	2.6	2.6	2.3
Most Frequent Direction - WRF	NE	NE	NE	SW	SW	SW	SW	SW	NE	NE	NE	NE	NE
Most Frequent Direction - Climate Normals	NE	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE	SW
Precipitation *(in mm)*													
Total Precipitation - WRF	153.5	92.8	90.5	78.5	66.6	50.9	0.6	17.4	100.5	51.2	116.9	157.8	977.2
Total Precipitation - Climate Normals	211.7	132.3	149.3	117.8	99.8	74.8	43.2	45.9	75.5	152.7	248.2	186.6	1537.8
Days with >=0.2 mm - WRF	15	17	15	19	15	15	1	5	17	10	22	20	171
Days with >=0.2 mm - Climate Normals	20	16	19	16	14	13	7	7	10	16	21	20	180
Days with >=5 mm - WRF	11	9	8	5	4	3	0	2	8	3	7	9	69
Days with >=5 mm - Climate Normals	12	8	10	8	6	5	3	3	4	9	13	11	92
Days with >=10 mm - WRF	6	3	2	2	2	2	0	0	3	2	5	6	33
Days with >=10 mm - Climate Normals	7	5	5	4	4	2	1	1	3	5	9	6	53
Days with >=25 mm - WRF	0	0	0	0	0	0	0	0	0	0	0	1	1
Days with >=25 mm - Climate Normals	2	1	1	1	1	0	0	0	1	1	3	2	12

Table IR6-04-3 Comparison of WRF-NMM 2010 Meteorology to 1961-1990 Climate Normals at Sand Heads Climate Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Wind *(speed in m/s)*													
Average Speed - WRF	5.6	4.6	5.0	5.6	4.0	3.8	4.4	3.7	4.1	4.6	5.5	6.4	4.8
Average Speed - Climate Normals	5.6	5.6	5.6	5.3	4.7	4.7	4.7	4.7	4.7	5.0	5.8	6.1	5.3
Most Frequent Direction - WRF	E	E	NW	NW	NW	NW	NW	NW	NW	SE	E	E	NW
Most Frequent Direction - Climate Normals	E	E	E	E	SE	SE	SE	SE	NW	E	E	E	E

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APPENDIX IR6-04-A

AIR QUALITY SCOPING STUDY PROCESS ENGAGEMENT AND DISCUSSION SUMMARY 2013-2016

Table IR6-04-A1 Air Quality Scoping Study Process Engagement and Discussion Summary 2013-2016

Date	Communication[a]	Summary
13-Feb-13	Air Quality Scoping Study Workshop with the VFPA, EC, MV, TFN, and CoD	The VFPA (formerly Port Metro Vancouver, or PMV) provided an overview of the RBT2 Project and discussed intent and format to engage on developing the approach to the RBT2 Air Quality Study. EC recommended that 1) the local study area be larger than 16 km x 19 km (i.e., 30 km x 30 km as in the Deltaport Third Berth Project); 2) baseline air quality utilise 98th percentile observations at Station T39; 3) observational data is used for meteorological model, not just prognostic model.
22-Apr-13	Email from the VFPA to 13-Feb-13 AQSS Workshop attendees	The VFPA provided first draft of RBT2 AQSS Assessment Protocol to 13-Feb-13 participants for review and comment.
02-May-13	Email from the VFPA to AQSS participants (MOE, EAO, EC, MV, TFN, CoD)	As follow up to requests from AQSS process participants, the VFPA provided background research articles on the Janssen method for converting NO_x to NO_2 and estimating ship emissions of other compounds discussed 13-Feb-13.
09-May-13	Responses on Air Quality Study proposed approach from MV via email.	Comments on AQSS Assessment Protocol received – key themes included requirement for detailed model plan, modelling of construction phase activities, model domain size, background concentrations, use of surface station data in the CALMET model, providing average and maximum predictions for all temporal cases (baseline, construction phase, future business as usual, future conditions with Project operations, future cumulative condition), visibility impact assessment, provide isopleth maps for diesel particulate matter and black carbon, and mobile source air toxins assessment criteria.
09-May-13	Responses on Air Quality Study proposed approach from EC via email.	Comments on AQSS Assessment Protocol received – key themes included model domain size, baseline air quality, and use of observational data for meteorological model (comments aligned with key points made during 13-Feb-13 workshop).
10-May-13	Response on Air Quality Study proposed approach from MOE via email.	Comments on AQSS Assessment Protocol received – key themes included validation of the WRF model output, running CALMET in hybrid mode, model domain size, receptor grid spatial resolution, background concentrations, emissions from transiting ships, fugitive coal dust emissions, emissions from traffic arteries, NO_x to NO_2 conversion.
6-June-13	Response on Air Quality Study proposed approach from TFN via email.	Comments on AQSS Assessment Protocol received – key themes included air quality concerns, discrete receptor locations, TFN testing locations, worst case meteorological conditions (wind gusts), human health risk assessment process, cumulative air quality impacts, air particulate deposition, collaboration on regional visibility modelling.

Date	Communication[a]	Summary
26-Sep-13	AQSS Workshop with the VFPA, MOE, EC, MV, TFN, and CoD	The VFPA presented information for discussion on three topics in response to comments received: 1) the VFPA's regional air quality initiatives; 2) a summary of comments from stakeholders based on 13-Feb-13 workshop and feedback on AQSS Assessment Protocol, and 3) the proposed methodological approach in revised Assessment Protocol, with supporting rationale. Six key topics were discussed, including size of local study area modelling domain (EC recommended 30 km x 30 km domain); computational grid resolution; baseline air quality; construction phase emissions; emission scenarios, substances, and sources; and meteorological data and processing (EC recommended vertical and horizontal validations).
2-Dec-13	Email from the VFPA to 26-Sep-13 AQSS Workshop attendees	The VFPA provided an Input Memorandum to participants on six key topics discussed at the 26-Sep-13 workshop in response to comments received (see above for list).
6-Mar-14	Email from the VFPA to EC	The VFPA requested a meeting with EC to respond to comments received, and to discuss the following topics: 1) summarise the RBT2 Air Quality Study approach, methodology, and assumptions to assess baseline and future contaminant concentrations (with and without the Project); 2) provide study outcomes plus results of sensitivity analyses for model domain size; and 3) to discuss any remaining areas of uncertainty.
25-Mar-14	Meeting with the VFPA and EC	Meeting to review the scope and preliminary results of the RBT2 Air Quality Study (including sensitivity analyses completed in response to EC input on domain size) and obtain clarification on the assessment approach with respect to the January 2014 EIS Guidelines (e.g., selection of contaminants, expansion of study modelling area, potential modification of meteorology, assessment of modelling outcomes, influence of tidal and Fraser River currents, and quantification of surface temperatures). EC presented on upper air data via aircraft and CALPUFF domain size. Key discussion points included size of regional study area, validation using Fraser River monitoring buoy temperature data, validation of meteorological observations with airline ACARS data, transboundary notification requirements.
26-Mar-14	Email from EC to the VFPA	EC provided water temperature and surface air temperature data for 2010 from the Fraser River Buoy, for the purposes of validating CALMET air temperatures.
27-Mar-14	Email from the VFPA to EC	The VFPA requested input on inclusion of toxic volatile organic contaminants and mobile source air toxins in the air quality study, and provided presentation slides from the 25-Mar-2014 meeting pertaining to the screening approach for identifying relevant toxins and a technical memo on this topic.
4-Apr-14	Email from the VFPA to EC	The VFPA provided to EC a draft meeting record for 25-Mar-14 for review, including a tracking table for meeting-related action items, requested CALPUFF.inf file, and a memo summarising the comparison of CALMET air temperatures to Fraser River buoy observed temperatures.

Date	Communication[a]	Summary
8-Apr-14	Emails between the VFPA to EC	EC provided ACARS data for the Vancouver International Airport for the year 2010. Action item is for the VFPA to provide a memo that compares ACARS data with the meteorological model inputs used in the Air Quality Study. EC provided confirmation that the contaminant selection process presented at the 25-Mar-14 meeting was acceptable based on the rationale provided.
3-Jun-14	Phone discussion with EC and the VFPA	Review of outstanding action items from 25-Mar-14 meeting, including the VFPA to provide memo on validation with ACARS data, transboundary notification requirements, and feedback from EC on memo summarising the comparison of CALMET air temperatures to Fraser River buoy observed temperatures.
10-Jun-14	Email from the VFPA to EC	The VFPA provided a memo to EC regarding the comparison of ACARS data to WRF-NMM vertical profiles of temperature, wind speed, and wind direction at the Vancouver International Airport for 2010.
15-Jul-14	Email from EC to the VFPA	Following from 25-Mar-14 meeting and 4-Apr-14 email, EC provided comments on modelling domain size, upper air model evaluation, and 25-Mar-14 meeting record summary. EC requested revisions to meeting summary record, expansion of the local study area to validate data, and follow-up meeting.
7-Nov-14	Email from the VFPA to EC	The VFPA requested a meeting with EC to discuss any outstanding concerns with the Air Quality Study approach, specific to modelling domain for RBT2 (and recirculation effects through Point Roberts and Tsawwassen), and ACARS data analysis and analysis of wind direction data.
8-Jan-15	Letter from the VFPA to EC	The VFPA provided an engagement summary with the EC Air Quality Group, which outlined EC's direction and advice provided to date with respect to the RBT2 air quality assessment.
16-Jan-15	Email from EC to the VFPA	EC provided feedback on the engagement summary, and confirmed transboundary notification form requirements.
Jun-15	Emails between the VFPA to EC	Emails on completing and submitting the Canada/U.S.A. Air Quality Agreement Transboundary Notification Form.
4-Jun-15	Phone discussion with EC and the VFPA	EC confirmed that they were following up on marine vessel emissions data request, and information was expected shortly. The VFPA indicated that they would be attending the Lower Fraser Valley Air Quality Coordinating Committee meeting on June 25.

Date	Communication[a]	Summary
22-Jun-15	Email from the VFPA to EC	The VFPA acknowledges receipt of 2012 marine emission inventory data from EC to support the assessment of marine shipping, noting that data will not be used for the assessment of marine shipping associated with the Project as it included all shipping on the entire west coast and the extraction of data for Juan de Fuca Strait and the Strait of Georgia traffic would be a non-trivial task, captured the Canadian airshed only (i.e., inbound shipping lane in the U.S.A. is not covered by the data set) and the process to derive 2030 projections was unknown.
6-Jul-15	Email from EC to the VFPA	With respect to 2012 emission inventory data from EC, EC states that they remain open to discussing the parameters of the data set and how marine emission projections were developed (availability in August).
4-Dec-15	Email from the VFPA to EC	The VFPA provided agenda for upcoming meeting and a file with input and output data for the air quality assessment for marine shipping.
10-Dec-15	Meeting with the VFPA and EC	The VFPA and EC discussed the results of the RBT2 Air Quality Study presented in the EIS, and the approach taken and the results of the assessment of RBT2-associated marine shipping in the Marine Shipping Addendum. EC requested a copy of all the model input/output files, and tentative schedule discussed for further engagement once files were reviewed.
23-Dec-15	Email from EC to the VFPA	EC confirmed action item from 10-Dec-15 meeting requesting model input/output files and tentative schedule for follow-up discussions, and pending meeting record summary.
12-Feb-16	Letter from the VFPA to EC	The VFPA provided a letter and enclosed a hard drive with the requested modelling files and outputs for the RBT2 Air Quality Study.
5-Apr-16	Phone discussion with EC and the VFPA	EC indicated that they received the data files, and a subsequent meeting would occur after EC reviewed the technical sufficiency of the EIS and Marine Shipping Addendum
8-Apr-16	Email from EC to the VFPA	EC indicated that based on preliminary review of the input/output data files, EC is not requesting a follow-up meeting as originally planned, and remains open to future discussions as needed.
May/Jun-16	Emails between EC and the VFPA	Emails on completing and submitting the Canada/U.S.A. Air Quality Agreement Transboundary Notification Form, inclusive of the Marine Shipping Addendum information.

Notes: a. MOE = B.C. Ministry of Environment; EAO = B.C. Environmental Assessment Office; EC = Environment Canada; MV = Metro Vancouver; TFN = Tsawwassen First Nation; CoD = Corporation of Delta.

IR6-05 Air Quality – Modelling: Evaluation of WRF-NMM

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2.3: Table 2-2, Figures 2-12, 2-13, 2-14, 2-15, 2-21 and 2-23

British Columbia Air Quality Dispersion Modelling Guideline. British Columbia Ministry of Environment, 2015

Context

In Section 2.3 of Appendix C of Appendix 9.2-A of the EIS, the Proponent evaluated meteorological output from the NMM-WRF modelling system by making graphical and statistical (Table 2-2) comparisons between model output and observations.

Figure 2-12 showed substantial systematic differences between modelled and observed diurnal average temperature cycles at Vancouver International Airport; Figure 2-13 showed the same systematic deviation between modelled and observed monthly average temperatures at Vancouver International Airport as in Figure 2-3; and Figure 2-14 and 2-15 showed substantial systematic deviation between modelled and observed diurnal and monthly average temperature cycles at Sand Heads Climate Station. These results may indicate inadequate model performance.

Further, Figures 2-21 and 2-23 compared modelled and observed vertical profiles of annual average temperature, wind speed and direction at Quillayute and Vancouver International Airport respectively although annual averages of these variables may not contribute to model evaluation in an air quality context.

Table 2-2 tabulated model evaluation statistics (Bias (B), Gross Error (E), Root Mean Square Error (RMSE) and Index of Agreement (IOA) computed at Vancouver International Airport, Abbotsford Airport, and Sand Heads Climate Station. These statistics were compared with evaluation benchmarks from the model evaluation literature, and in some cases, did not meet those benchmarks.

Evaluation of wind fields for dispersion modelling was done using data from Vancouver International Airport, Abbotsford Airport, and Sand Heads Climate Station. These stations are so widely spaced as to make it unlikely that the model evaluation will effectively test the ability of the model to capture local-scale spatial variation of wind fields in this region of very complex coastline and modest topography.

Evaluation of the meteorological output from the NMM-WRF modelling system has to cover meteorological variables that are most important in the dispersion of air pollutants, and at spatial scales that are important for pollutant dispersion.

Information Request

Evaluate the ability of the WRF-NMM 2 kilometre runs for the three chosen model years to adequately capture meteorological variation at space and time scales appropriate for the modelling of plume dispersion from the Project.

This evaluation should include available data from all meteorological stations operated by Environment and Climate Change Canada, Metro Vancouver, British Columbia Ministry of Environment and British Columbia Ferry Corporation in the local study area. The evaluation should exclude those stations chosen for the incorporation of observational meteorological data and prognostic model data in the hybrid mode of CALMET, as referenced in the *British Columbia Air Quality Dispersion Modelling Guideline*, 2015.

The analysis has to specifically address:

- the completeness of the model evaluation exercise in terms of its coverage of meteorological variables that are most important in the dispersion of air pollutants;
- any systematic deviations between model output and observations; and
- the ability of the model to capture local study area-scale spatial variation of wind fields.

The statistical model evaluation has to use (Bias (B), Gross Error (E), Root Mean Square Error (RMSE) and Index of Agreement (IOA), and meet the evaluation benchmarks for those statistics employed in the EIS, Appendix 9.2-A, Appendix C, Section 2.3, Table 2-2 in all variables.

VFPA Response

Evaluate the ability of the WRF-NMM 2 kilometre runs for the three chosen model years to adequately capture meteorological variation at space and time scales appropriate for the modelling of plume dispersion from the Project.

Meteorological variation at space and time scales appropriate for the modelling of plume dispersion from the Project was captured using one year of data for the RBT2 WRF-NMM model run, as outlined in Section 2.3 in Appendix C of EIS Appendix 9.2-A. As supporting information to the content presented in Section 2.3 and this information request regarding WRF-NMM model validation, additional information on the siting guidelines for wind monitoring instruments (anemometers), the limitations of meteorological observation stations in the Roberts Bank region, and benchmark criteria used is provided below.

As outlined in the response to IR6-04, WRF-NMM 2 kilometre runs using three years of data were not repeated as the 2008 Guidelines for Air Quality Dispersion Modelling in British Columbia (2008 B.C. Guidelines; MOE 2008) and the 2015 British Columbia Air Quality Dispersion Modelling Guideline (2015 B.C. Guideline; MOE 2015) do not require three years of meteorological data when using prognostic model data at a fine resolution.

This evaluation should include available data from all meteorological stations operated by Environment and Climate Change Canada, Metro Vancouver, British Columbia Ministry of Environment and British Columbia Ferry Corporation in the local study area. The evaluation should exclude those stations chosen for the incorporation of observational meteorological data and prognostic model data in the hybrid mode of CALMET, as referenced in the British Columbia Air Quality Dispersion Modelling Guideline, 2015.

WRF-NMM model validation did not include all available data from all meteorological stations operated in the local study area (LSA) for the reasons explained below.

Anemometer Siting Guidelines

WRF-NMM model validation was based on meteorological data from both the Vancouver International Airport surface meteorological station and for the Sand Heads Climate Station, located 20 km and 14 km from the Project, respectively. These two stations were chosen for the WRF-NMM validation because they conform to the wind monitoring station siting guidelines defined by the World Meteorological Organization (WMO 2010), by Meteorological Services of Canada (MSC 2001), and by the U.S. Environmental Protection Agency (U.S. EPA 2000). Guidance on anemometer siting requirements from the WMO, MSC, and the U.S. EPA is aligned, as outlined below. The WMO (2010) provides the following guidance:

- *"Wind speed increases considerably with height, particularly over rough terrain. For this reason, a standard height of 10 m above open terrain is specified for the exposure of wind instruments. For wind direction the corresponding shift over such a height interval is relatively small and can be ignored in surface wind measurements. An optimum wind observation location is one where the observed wind is well representative for the wind over an area of at least a few kilometres, or can easily be corrected to make it representative."*
- *"Standard exposure of wind instruments over level, open terrain is 10 m above the ground. Open terrain is defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction. Wind measurements that are made in the direct wake of tree rows, buildings or any other obstacle are of little value and contain little information about the unperturbed wind. Since wakes can easily extend downwind to 12 or 15 times the obstacle height, the requirement of 10 obstruction heights is an absolute minimum. In practice, it is often difficult to find a good or even acceptable location for a wind station. The importance of optimizing the location can hardly be overstressed; nonetheless, it is difficult to give universal guidelines."*
- *"Where a standard exposure is unobtainable, the anemometer might be installed at such a height that its indications should be not too much affected by local obstructions and represent as far as possible what the wind at 10 m would be if there were no obstructions in the vicinity."*

In recognition of the difficulty of siting wind monitoring stations in accordance with the guidelines noted above in urban areas where level, open terrain may be in short supply, the

WMO commissioned Dr. T. Oke, University of British Columbia, to develop siting guidelines specifically for urban stations (Oke 2006). WMO (2010) guidance states *"In more densely built-up districts, with relatively uniform element height and density (buildings and trees), wind speed and direction measurements should be taken with the anemometer mounted on a mast of open construction at a minimum height of 1.5 times the mean height of the elements".*

Canadian siting standards for anemometers state *"The site should be located: (ii) such that the distance from vertical obstructions shall be at least ten times the height of the obstruction"* (MSC 2001).

The U.S. EPA (2000) guidance on anemometer placement specifically for regulatory air quality modelling applications states *"The standard exposure height of wind instruments over level, open terrain is 10 m above the ground. Open terrain is defined as an area where the distance between the instrument and any obstruction is at least ten times the height of that obstruction"*.

Limitations of Meteorological Monitoring Stations in the Local Study Area and Region

Of the meteorological monitoring stations available within and beyond the LSA for WRF-NMM wind data validation, only the stations at the Vancouver International Airport and Sand Heads met the WMO, MSC, and U.S. EPA siting guidelines. Although these stations are located outside of the LSA, as shown in Figure 2-7 in Appendix C of EIS Appendix 9,2-A, meteorological monitoring stations within the LSA, including station T39 (Tsawwassen, Pebble Hill Park) and the Westshore Station, did not meet anemometer siting guidelines. The limitations of these stations, and station T17 (Richmond South) located north of the LSA northern boundary, are described below.

The station at the Abbotsford Airport was also considered in the validation of the WRF-NMM data set, but this station is located 58 km inland from Roberts Bank, and is not representative of meteorological conditions at the RBT2 Project location.

Station T39

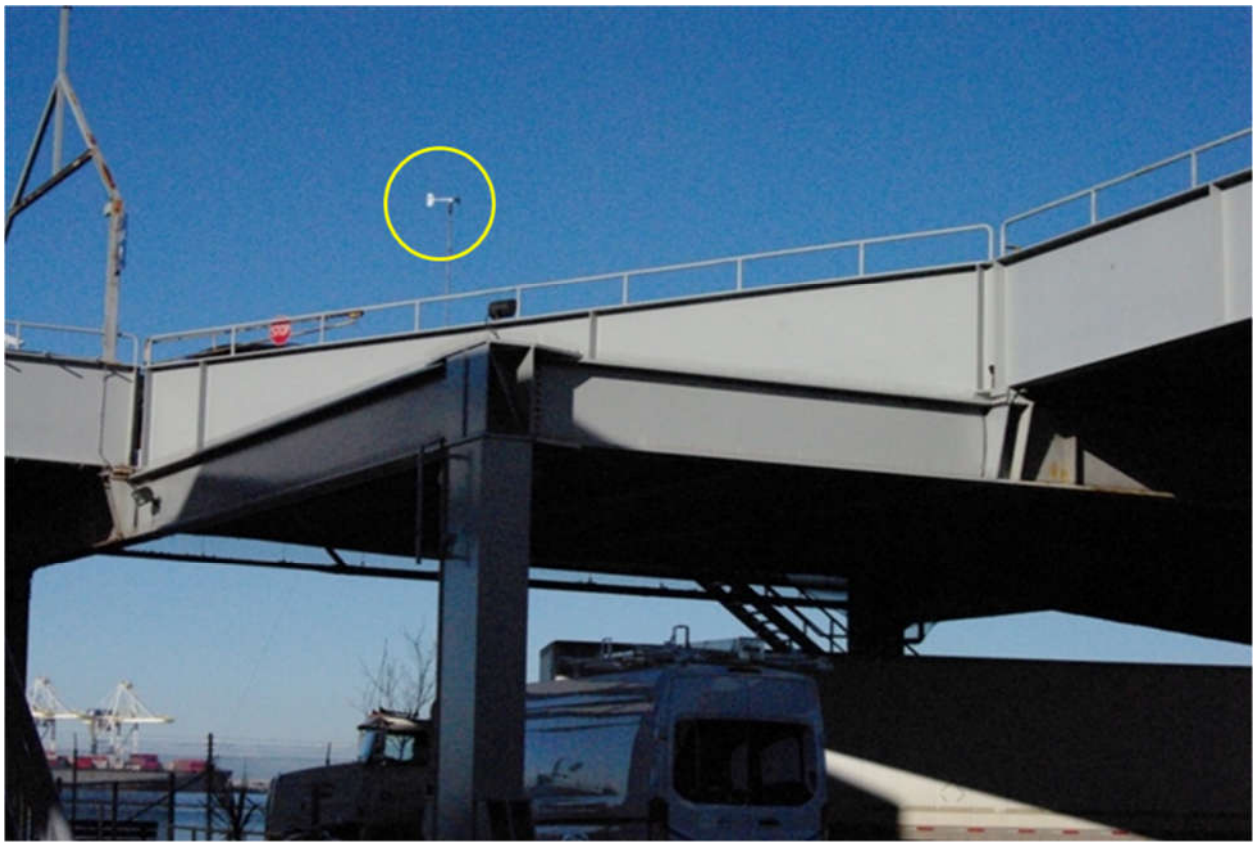
As discussed in Section 2.5.1 and depicted in Figure 2-29 in Appendix C of EIS Appendix 9.2-A, station T39 is surrounded by nearby trees that tower over the station and forested areas on the west and south side of the park. As such, any comparisons between wind data at this station and WRF-NMM (or CALMET) data would not be expected to show good agreement, as explained in Section 2.5.1 and depicted in Figure 2-27. Although the wind direction data at this location shows broad general agreement with the WRF-NMM data, wind speeds measured at station T39 are much lower due to the sheltered exposure of the anemometer.

Westshore Station

The Westshore Station anemometer is located at the BC Ferries Tsawwassen Ferry Terminal above ground, affixed to a vehicle ramp on an upper loading deck (**Figure IR6-05-1**), not

on level, open ground as required by the station siting guidelines. The loading ramp and building structures, as well as the large ferries themselves when at berth, are all obstructions that would affect wind speed and direction recorded at that station. As with station T39, comparisons between modelled and observed wind speed and direction were not aligned (Section 2.5.1 in Appendix C of EIS Appendix 9.2-A), which is to be expected given the poor exposure siting of this station.

Figure IR6-05-1 Location of Westshore Station Anemometer (circled) at BC Ferries Tsawwassen Terminal



Station T17

Station T17 in Richmond South does not conform to the WMO, MSC, and U.S. EPA guidelines for siting of anemometers, or the minimum requirements for anemometer siting at least 1.5 times the height of the nearest obstruction in urban areas. Oke (2006) states that *"Poor placement of wind sensors in cities is the source of considerable wasted resources and effort and leads to potentially erroneous calculations of pollutant dispersion."*

As shown in **Figure IR6-05-2**, with the house adjacent to station T17 (anemometer circled), the anemometer does not meet the minimal requirement of being 1.5 times the height of the roof, and it is surrounded by homes of similar height and scattered tall trees. Therefore, the T17 station was considered to be unsuitable for use in the meteorological data set validation.

Figure IR6-05-2 Location of Station T17 Anemometer (circled) in South Richmond Residential Area

Based on the limitations of these three meteorological monitoring stations, the VFPA relied on observations from stations at the Vancouver International Airport and Sand Heads for the validation of the WRF-NMM data. The inclusion of the observational data from these two stations in the CALMET meteorological data analysis in hybrid mode (i.e., combining WRF-NMM and surface observation data in CALMET) would have precluded using that data to subsequently validate the meteorological data used in CALMET (i.e., the same observational data can not be used for both model input and validation of WRF-NMM and CALMET model outputs). Information on the hybrid mode of CALMET, relevant to the 2015 B.C. Guideline, is provided in the response to IR6-10.

The analysis has to specifically address: the completeness of the model evaluation exercise in terms of its coverage of meteorological variables that are most important in the dispersion of air pollutants; any systematic deviations between model output and observations; and the ability of the model to capture local study area-scale spatial variation of wind fields.

The WRF-NMM model results presented in the RBT2 Air Quality Study (Appendix C in EIS Appendix 9.2-A) provided a reasonably accurate measure of the atmospheric state throughout the modelling domain for input to the air quality dispersion modelling. Differences and uncertainties between modelled winds to observations can be partly attributed to the way that the data are collected and presented. Section 2.3.6 in Appendix C of EIS Appendix 9.2-A stated that "*Model-predicted winds are hourly grid-cell averaged, while observations* [at airports] *are measured for a few minutes once an hour at a point location (i.e. observing*

station). Winds can vary greatly over the course of an hour. In addition, the binning or the categorization of wind speeds into ranges and wind directions into sectors, as is typically done for model-observation comparisons, tends to amplify differences and uncertainties."

As stated by Anderson (2005): *"The objective of evaluating a meteorological data set to be used for a dispersion modeling analysis is to determine through visual and statistical means whether or not that data set is climatologically consistent and captures the features that are important to the determination of air quality impacts in the area being assessed."* Hana and Yang (2001) suggest that there are differences expected between the observations and the simulations due simply to the differences in the averaging volumes and averaging times that they represent. Validation analyses conducted for wind speed and direction, temperature, precipitation, and upper air data used in the RBT2 Air Quality Study showed that the WRF-NMM run in hindcast mode provided wind and temperature variations that were sufficiently representative of meteorological conditions such that the maximum concentrations predicted by the modelling were not limited by the meteorology. The precipitation data from the WRF model followed observed precipitation patterns when compared to data from the meteorological stations at the Vancouver International Airport and Sand Heads. The validation analyses presented in the RBT2 Air Quality Study indicate that the WRF model run on one year of meteorological data provided reasonably representative data[1] of the main meteorological parameters used for dispersion modelling.

Additional validation was conducted using aircraft-measured profiles and surface temperatures from a Fraser River buoy in response to EIS Guidelines requirements and based on input from Environment Canada during the Air Quality Scoping Study process (refer to Appendix IR6-04-A for a summary of discussions with Environment Canada on this topic).

Validation results of WRF-NMM wind data conducted using Aircraft Communications Addressing and Reporting System (ACARS) data provided by Environment Canada was presented in Attachment 2 in Appendix C of EIS Appendix 9.2-A. The comparisons were completed for seasonal and annual data sets, and the results were compared against benchmark criteria cited in the 2008 B.C. Guidelines (MOE 2008), as well as against benchmark evaluation criteria developed by the U.S. EPA and the University Corporation for Atmospheric Research (UCAR).

Validation results of CALMET air temperatures conducted using Fraser River buoy observation data provided by Environment Canada was presented in Attachment 3 in Appendix C of EIS Appendix 9.2-A. The CALMET data adequately reflected the variability of the Fraser River Buoy surface air temperatures, and any differences in the data (maximum average monthly temperature difference was 1.1°C) were noted as being unlikely to affect predicted CALPUFF dispersion modelling results (see response to IR6-04).

Benchmark evaluation criteria and comparisons of the WRF-NMM model results to Vancouver International Airport, Sand Heads, and Abbotsford Airport data is provided below. It should

[1] Statistical comparisons of WRF-NMM results based on 2010 meteorology with 30-year climate normal data, provided in the response to IR6-04, indicate that 2010 was a representative year for meteorological conditions.

be noted that the purpose of comparing prognostic meteorological data to such benchmarks is not necessarily to provide a pass/fail grade when evaluating a particular data set. Rather, such benchmark comparisons are intended to be used to identify any systemic issues which may exist with respect to the prognostic model data set under review.

The statistical model evaluation has to use (Bias (B), Gross Error (E), Root Mean Square Error (RMSE) and Index of Agreement (IOA), and meet the evaluation benchmarks for those statistics employed in the EIS, Appendix 9.2-A, Appendix C, Section 2.3, Table 2-2 in all variables.

Table 2-2 in Appendix C of EIS Appendix 9.2-A listed the statistical performance of the WRF-NMM data set with observed surface wind speed, wind direction and temperature. To consolidate the model performance evaluation, **Table IR6-05-1** summarises the statistical performance of the WRF-NMM model results in comparison to the Vancouver International Airport, Sand Heads Climate Station, and Abbotsford Airport (as previously presented in Table 2-2 in Appendix C of EIS Appendix 9.2-A) observational data.

Table IR6-05-1 Statistical Performance of the RBT2 WRF-NMM Model Compared to Observational Data

Parameter	Model Performance Compared to Meteorological Station Observation Data					
	Metric[a]	Benchmark[b]	UCAR Benchmark[c]	Vancouver Int'l Airport	Sand Heads Climate Station	Abbotsford Airport
Wind Speed (m/s)	RMSE	≤ 2 m/s	n/a	**1.9**	2.4	**2**
	Bias	≤ 0.5 m/s and ≥ - 0.5 m/s	n/a	**0.2**	**-0.5**	0.8
	IOA	≥ 0.6	n/a	**0.8**	**0.8**	**0.8**
Wind Direction (°)	Gross Error	≤ 30°	≤ 45°	42.7	40.9	45.5
	Bias	≤ 10° and ≥ -10°	n/a	**6.9**	**-2.5**	11.1
Temperature (ºC)	Gross Error	≤ 2 °C	≤ 2°C	**1.3**	**1.4**	**1.4**
	Bias	≤ 0.5 °C and ≥ -0.5 °C	n/a	**0.05**	-0.82	**-0.08**
	IOA	≥ 0.8	n/a	**1.0**	**1.0**	**1.0**

Notes: Bolded values represent values within the benchmark range, indicating meteorological predictions are "good"; n/a = not available or not applicable.

a. Metrics: RMSE = root mean square error; IOA = index of agreement.
b. Evaluation benchmarks based on Emery et al. (2001) and Tesche et al. (2001), as indicated in Section 2.3.5 in Appendix C of EIS Appendix 9.2-A.
c. UCARS evaluation benchmark from the University Corporation for Atmospheric Research.
d. Performance against Aircraft Communications Addressing and Reporting System (ACARS) Data for annual and seasonal averages are described independently in Attachment 2 in Appendix C of EIS Appendix 9.2-A, but have been combined above.

Wind speed statistics are within the benchmark values, except for the RMSE at the Sand Heads station and bias at Abbotsford Airport (Section 2.3.5 in Appendix C of EIS Appendix 9.2-A). Wind direction gross error, although higher than the benchmark (Emery et al. 2001) used in the RBT2 Air Quality Study at all three stations, is within the UCAR 45° benchmark except at Abbotsford Airport which is only slightly over at 45.5°. Wind direction gross error and wind speed RMSE at all three stations are also within the benchmark criteria cited in the 2008 B.C. Guidelines. In comparison, McEwen and Murphy (2004) cited Hanna and Yang (2001) who stated that the 'expected' RMSE results for prognostic model-derived winds would be 2 m/s to 3 m/s for a wide range of wind speeds, and 50°to 60° for winds of about 3 m/s to 4 m/s (i.e., less stringent than the benchmark criteria used in the RBT2 Air Quality Study).

Wind direction bias at Vancouver International Airport and Sand Heads is within the benchmark, and slightly over the benchmark at Abbotsford Airport.

Temperature statistics at Vancouver International Airport and Abbotsford Airport are within benchmark values, while Sand Heads station shows a slight temperature bias of less than 1.0°C.

The statistical comparison of the WRF-NMM data against the ACARS data was not performed because the ACARS data were recorded on different vertical levels than WRF-NMM model outputs. Also, the ACARS data represent vertical profiles along an inclined pathway as the aircraft are ascending or descending to/from the airport. Although the aircraft ascents/descents originate or terminate at the airport, the data for higher elevations in the ACARS data set may represent conditions that exist at some distance from the airport and wind and temperature conditions may differ from those that exist directly over the airport. Statistical characteristics should be computed on a homogenized dataset and it would require the spatial interpolation of the WRF-NMM model data, (i.e., vertical interpolation to the elevations where ACARS data were taken, and horizontal interpolation to the locations where ACARS data were recorded). The two spatial interpolations would almost certainly introduce some undetermined errors to the analytical results whose significance would be indeterminate.

Summary

It is important to note that the validation of the WRF-NMM data set used for the RBT2 Air Quality Study does not require perfect agreement between prognostic model data and observation data sets. It has been demonstrated in numerous air quality assessments that the CALPUFF dispersion model is conservative in estimating maximum concentrations and, therefore, can accommodate some disparity between meteorological model predicted parameters and surface meteorological observations without compromising output results.

In summary, while there are differences between all of the meteorological data sets used in the model evaluations, the differences are either one of the following:

- Explainable, such as in a sub-optimal meteorological station location;
- Expected to not affect the final conclusions (e.g., minor temperature differences); or

- Are minor relative to other uncertainties (e.g., conservative assumptions used in worst-case emission scenarios for maximum hourly and maximum daily operations).

As outlined in the response to IR6-04, WRF-NMM 2 kilometre runs using three years of data were not conducted, and therefore an evaluation of three model years to capture meteorological variation has not been completed. Validation of the WRF-NMM data set in the EIS, conducted for surface and upper air wind speed and direction, temperature, precipitation, and upper air data, showed that the WRF model predicted wind and temperature accurately, and followed observed precipitation patterns when compared to data from the meteorological stations at the Vancouver International Airport and Sand Heads, indicating that the WRF model run on one year of meteorological data accurately predicted the main meteorological parameters used for dispersion modelling. In addition, statistical comparisons of WRF-NMM results based on 2010 meteorology with 30-year climate normal data indicate that 2010 was a representative year for meteorological conditions.

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IR6-06 Air Quality – CALMET Modelling

Information Source(s)

EIS Volume 2: Figure 9.3-1; Appendix 9.2-A, Appendix C, Section 2.3.1

Context

Figure 9.3-1 of the EIS showed the proposed Project surrounded by an extensive tidal mud flat. At low tide, the mud flat is two to four kilometres wide, while at high tide the entire mud flat is covered by water.

The aerodynamic roughness length of mud flats is roughly ten times that of open sea. Since roughness length has a substantial effect on atmospheric turbulence, and therefore on pollutant dilution, tidal level is likely to have an influence on the ambient concentration of pollutants emitted by the Project at the immediately onshore region, in winds from the westerly sectors.

Information Request

Evaluate the effect of tidally exposed mud flats at Roberts Bank versus open sea on modelled ambient pollution concentrations in the local study area during onshore wind conditions through a set of idealized CALPUFF simulations involving an appropriate range of wind direction, stability and wind speed conditions.

If the effect is found to be substantial, provide an assessment of the influence of this effect on overall modelled pollutant concentrations.

VFPA Response

Evaluate the effect of tidally exposed mud flats at Roberts Bank versus open sea on modelled ambient pollution concentrations in the local study area during onshore wind conditions through a set of idealized CALPUFF simulations involving an appropriate range of wind direction, stability and wind speed conditions.

A sensitivity analysis was conducted to evaluate the potential effects of exposed mudflats on the dispersion of emitted contaminants. The sensitivity analysis considered three scenarios:

- RBT2: No exposed mudflats (i.e., high tide conditions), as per the assumption incorporated in the RBT2 Air Quality Study;
- LWL: Lower low water level at 1.1 m chart datum (i.e., low tide); and
- MWL: Mean water level at 3.0 m chart datum (i.e., mid tide).

The effects of exposed mudflats were considered in the CALMET model by adjusting the land use category and surface roughness height for affected grid cells in the GEO.DAT file. A

comparison of the land use category and surface roughness height for exposed mudflats versus open water is provided in **Table IR6-06-1**.

Table IR6-06-1 Land Use Category and Surface Roughness Height for Exposed Mudflats and Open Water

	Exposed Mudflat	Open Water
Land Use Category	70	54 or 55
Surface Roughness Height (m)	0.005[a]	0.001

Source: Earth Tech 2000 and Hammond et al. 2012.

Note: a. In the opinion of J. McAlpine of the U.S. Environmental Protection Agency (EPA), the surface roughness value for the exposed mudflats may be higher than actual conditions, since the mudflats can be smoother than open water (J. McAlpine 2017).

The CALMET model was run using a full year of meteorological data (i.e., 2010) for each of the three mudflat exposure scenarios. To test the effect of mudflat exposure on predicted concentrations, CALPUFF was run using a unit emission rate from a single point source simulating a 12,000 TEU (twenty-foot equivalent unit) ship at berth at the RBT2 terminal[1]. Maximum predicted one-hour average concentrations for a non-specific contaminant from one container vessel at berth for the three scenarios are provided in **Table IR6-06-2**, along with the percentage change between fully exposed (LWL scenario), partially exposed (MWL scenario) mudflats, and high tide conditions (RBT2 scenario). Figure IR6-06-A1 in **Appendix IR6-06-A** provides isopleth plots for the three scenarios. The predicted concentrations were evaluated for the same receptor grid and at 18 discrete receptor points defined in the RBT2 Air Quality Study (EIS Section 9.2.5.4).

Table IR6-06-2 Maximum Predicted 1-Hour Concentrations for High Tide (RBT2), Low Tide (LWL), and Mid Tide (MWL) Conditions

X (km)	Y (km)	Discrete Receptor ID	Sensitive Receptor Name	Max. Concentration (µg/m³)			% Change from RBT2	
				RBT2	LWL	MWL	LWL	MWL
493.850	5436.550	R1	Ladner	0.85	0.73	0.67	-13%	-20%
491.150	5434.601	R2	Farmer 1	2.61	2.16	2.31	-17%	-12%
492.500	5432.500	R3	Tsawwassen First Nation	1.50	1.33	1.50	-11%	-0.4%
492.050	5433.101	R4	Farmer 2	1.05	1.08	1.05	3%	-0.3%
489.800	5434.050	R5	Farmer 3	1.51	1.19	1.34	-21%	-11%
493.250	5431.050	R6	Tsawwassen Beach Campsite	2.95	2.72	2.89	-8%	-2%
495.800	5431.351	R7	Beach Grove	1.06	1.08	1.06	2%	0.2%

[1] The use of a single ship at berth is consistent with the sensitivity analysis presented in Attachment 1 of Appendix C in EIS Appendix 9.2-A, in response to concerns expressed by regulatory stakeholders about the size of the modelling domain during the Air Quality Scoping Study.

X (km)	Y (km)	Discrete Receptor ID	Sensitive Receptor Name	Max. Concentration (µg/m³)			% Change from RBT2	
				RBT2	LWL	MWL	LWL	MWL
497.100	5427.951	R8	Boundary Bay	1.64	1.67	1.68	2%	2%
493.575	5429.351	R9	Tsawwassen	1.76	1.67	1.77	-5%	0.8%
497.125	5426.101	R10	Point Roberts 1	1.40	1.36	1.36	-3%	-3%
493.875	5427.601	R11	Point Roberts 2	3.44	3.37	3.50	-2%	2%
495.499	5436.926	R12	Delta Hospital	0.60	0.58	0.60	-4%	-0.8%
490.480	5428.242	R13	Ferry Terminal	4.00	4.02	4.01	0.4%	0.3%
486.900	5438.150	R14	Reifel Bird Sanctuary	1.57	1.36	1.32	-14%	-16%
496.350	5429.851	R15	Boundary Bay GVRD Park	1.15	1.13	1.13	-2%	-2%
492.760	5429.900	R16	English Bluffs Beach	1.94	2.45	1.79	27%	-7%
490.810	5437.300	R17	South Arm Marsh	1.24	1.14	1.16	-8%	-7%
494.008	5428.557	R18	Air Quality Station T39	1.50	1.45	1.47	-3%	-2%
Maximum Over Land				4.7	4.5	4.7	-4%	-0.5%
Maximum Over Water				102	85	102	-17%	0.4%

Compared to high tide conditions (RBT2), the exposure of mudflats during low tide (LWL) is predicted to decrease the overall maximum predicted one-hour average concentrations, both over water and over land. While the difference in maximum predicted one-hour average concentrations at sensitive receptors between high tide (RBT2) and low tide (LWL) ranges from -21% at Farmer 3 (R5) to +27% at the Boundary Bay Regional Park (R16), the overall effect of introducing the mudflats as a separate land use category is to lower the predicted concentrations relative to the results presented in the RBT2 Project dispersion modelling analysis at most locations.

If the effect is found to be substantial, provide an assessment of the influence of this effect on overall modelled pollutant concentrations.

For the reasons discussed in the above section, the effect is not found to be substantial given that tidally exposed mudflats at Roberts Bank lead to a reduction in modelled ambient pollution concentrations in the local study area when compared with open sea (high tide) conditions. In any event, there is no practical means to apply the results of the sensitivity analysis to assess the influence of exposed mudflats on overall modelled pollutant concentrations. Maximum predicted one-hour average concentrations presented in **Table IR6-06-2** and Figure IR6-06-A1 in **Appendix IR6-06-A** represent maximum concentrations within the entire one-year model period and do not correlate to specific hours

when the three scenarios may be applicable (i.e., there are two tidal cycles per day at Roberts Bank resulting in varying conditions). The CALMET/CALPUFF modelling system does not have the capability to consider time-varying geophysical parameters to mimic tidal ebb and flow.

A literature search was conducted, and enquiries made to the U.S. EPA[2] (J. McAlpine 2017) and Exponent (I. Lee 2017), who is the current maintainer and distributor of the CALMET/CALPUFF modelling system. There are no known studies on the effects of exposed mudflats due to tidal activity on dispersion modelling. Given that the surface roughness height, albedo, and Bowen ratio between exposed mudflats and open water are similar, it is expected that the effect of exposed mudflats on overall modelled pollutant concentrations would also be similar (J. McAlpine 2017).

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Appendices

Appendix IR6-06-A Isopleth Plots for Mudflat Exposure Sensitivity Analysis

[2] In the absence of specific guidance by the B.C. Ministry of Environment (MOE) and/or Environment and Climate Change Canada (ECCC), both the MOE and ECCC defer to the U.S. EPA for air quality dispersion model selection, technical evaluations, and guidance (B.C. MOE 2015).

APPENDIX IR6-06-A
ISOPLETH PLOTS FOR MUDFLAT EXPOSURE SENSITIVITY ANALYSIS

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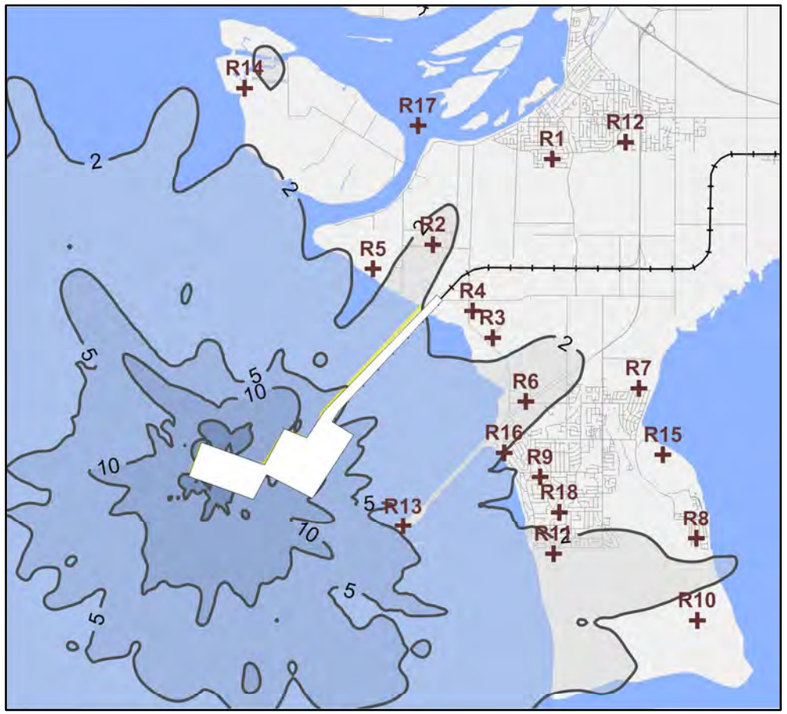
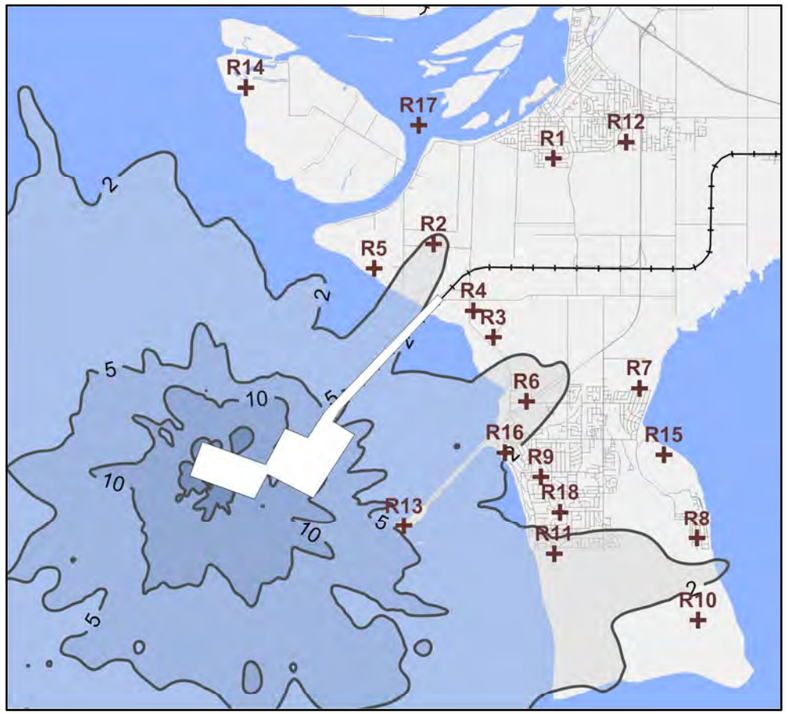
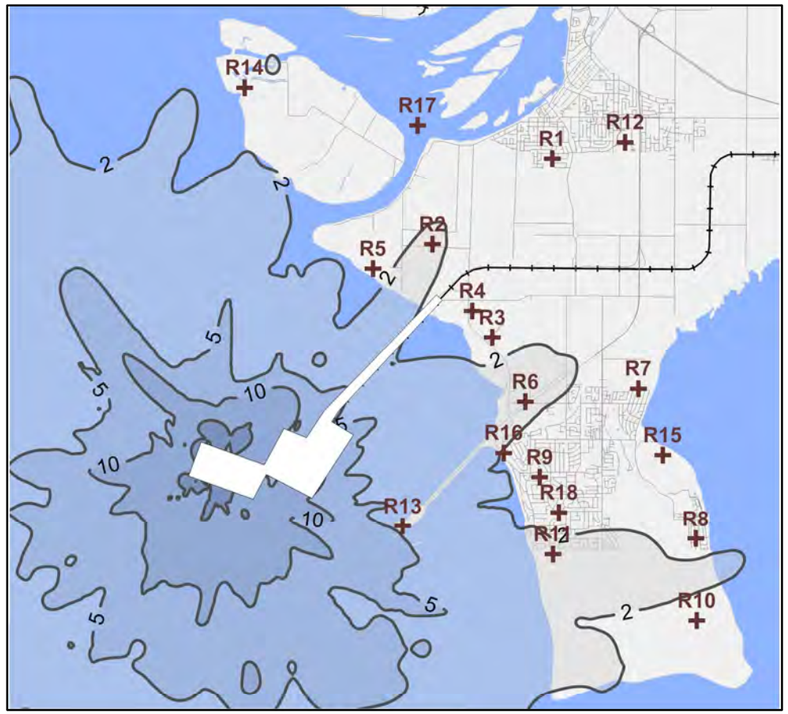
RBT2 SCENARIO



LWL SCENARIO



MWL SCENARIO



Legend

- DISCRETE RECEPTOR LOCATIONS
- PROJECT BLANKING BOUNDARY
- CONCENTRATION CONTOURS (µg/m^3)
- ROADS
- RAILWAYS

0 2.5 5
Kilometres

1:135,000

NAD 1983 UTM Zone 10N

N

Note:
Concentration contour levels are incremental (do not include background concentration) and based on unit emission rate.

PORT of vancouver

ROBERTS BANK TERMINAL 2

MAXIMUM 1-HOUR CONCENTRATIONS (µg/m^3)

DATE: 01/19/2018

FIG No. IR6-06-A1

Sources: VFPA, GeoGratis "CANVEC"

IR6-07 Air Quality – WRF-NMM and CALMET Modelling: Wind Fields

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2.6.1. Figures 2-43, 2-44 and 2-45

Context

The modelled wind fields in Figures 2-43, 2-44 and 2-45 in Appendix C of Appendix 9.2-A of the EIS, are almost completely uniform in the sense that neither wind speed nor wind direction vary in space.

Spatial variation should be evident along the shoreline where there is a sharp change in surface roughness length, and around significant topography such as Surrey uplands at 100 metres above sea level and English Bluffs at 50 metres above sea level.

If the CALMET wind fields used to drive CALPUFF do not capture actual wind fields, modelled pollution fields will be incorrectly located in space.

Information Request

Compare CALMET modelled wind fields shown on Figures 2-43, 2-44 and 2-45 in Appendix C of Appendix 9.2-A of the EIS with wind fields from the Global Environmental Model (GEM) operated by Environment and Climate Change Canada, or similar model output, over the study domain during analogous general meteorological conditions.

Indicate if GEM modelled wind fields show flow features related to changes in surface roughness and terrain elevation in this domain.

Indicate if CALMET modelled wind fields show comparable flow features related to changes in surface roughness and terrain elevation in this domain.

If CALMET modelled fields do not show flow features related to changes in surface roughness and terrain elevation in this domain, explain why.

VFPA Response

Compare CALMET modelled wind fields shown on Figures 2-43, 2-44 and 2-45 in Appendix C of Appendix 9.2-A of the EIS with wind fields from the Global Environmental Model (GEM) operated by Environment and Climate Change Canada, or similar model output, over the study domain during analogous general meteorological conditions.

The Global Environmental Model (GEM) is Environment and Climate Change Canada's numerical weather prediction model used for regional-scale photochemical transport analyses (Moran et al. 2017). It is not possible to provide the requested comparison for the reasons provided below.

GEM, configured with 10-km horizontal grid spacing, would not capture small-scale local topographic effects, such as small changes in terrain elevation of 100 m at the Surrey uplands and 90 m at English Bluffs. As with the Weather Research Forecast Non-hydrostatic Mesoscale (WRF-NMM) wind fields, the GEM-modelled wind fields would need to be processed using a model such as CALMET, which does capture such changes in topography on a finer grid resolution of 100 m. There are no known interfaces, however, with which to convert GEM-modelled wind fields for use in CALMET, whereas the existing CALMET model interface allows the incorporation of wind fields derived from WRF-NMM.

WRF-NMM that was used in the RBT2 Air Quality Study represents the standard prognostic model for use in air quality dispersion modelling analyses. The British Columbia Ministry of Environment has approved a prognostic meteorological dataset based on the WRF model for use in air quality dispersion modelling in B.C[1]. WRF-NMM is accepted for use by the United States Environmental Protection Agency for local-scale air quality modelling analyses and recognised as a state-of-the-art atmospheric simulation system (U.S. EPA 2017). Wind flows at 12-km horizontal grid spacing in the WRF-NMM model used in the RBT2 Air Quality Study would be expected to be comparable to wind flows at 10-km horizontal grid spacing in GEM.

In the RBT2 Air Quality Study, the WRF-NMM meteorological dataset was processed using the CALMET model at a horizontal grid spacing of 100 m to account for small-scale local variations in topography and land use. Figures 2-43, 2-44, and 2-45 in Appendix C of EIS Appendix 9.2-A illustrate that CALMET has appropriately modelled thermally-driven wind flows expected for the model domain (i.e., land and sea breezes; see the response to IR6-08 of CEAR Document #1104[2]). Topography in the model domain is relatively flat, with a maximum terrain elevation of approximately 100 m at Surrey uplands and approximately 90 m at English Bluffs. These figures further illustrate that CALMET has appropriately modelled wind speeds over the model domain, with slightly higher wind speeds (i.e., relatively longer arrow lengths) over open areas, such as water, and slightly lower wind speeds (i.e., relatively shorter arrow lengths) over areas with higher surface roughness lengths.

Overall, the CALMET model with WRF-NMM has provided reasonable wind flows for use in air quality dispersion modelling. There is no known practical method for applying Environment and Climate Change Canada's regional-scale GEM meteorological datasets to integrate small-scale local effects or to incorporate GEM meteorological outputs into local-scale air quality dispersion modelling using the CALPUFF/CALMET modelling system.

[1] The 2015 British Columbia Air Quality Dispersion Modelling Guideline (B.C. MOE 2015) provides a link to the WRF model output produced by Exponent: http://www.src.com/calpuff/data/bc_wrf.html.
[2] CEAR Document #1104 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-08, IR7-01, IR7-02, IR7-08, IR7-36, and IR7-39 (See Reference Documents #991 & #1000)

References

British Columbia Ministry of Environment (B.C. MOE). 2015. British Columbia Air Quality Dispersion Modelling Guideline. Environmental Protection Division, Environmental Protection Branch, Clean Air Section, Victoria, BC.

Moran, M., S. Gravel, V. Svaic-Jovcic, R. Pavlovic, H. Landry, A. Lupu, S. Ménard, S. Cousineau, and D. Davignon. 2017. Recent Upgrade to the Chemical Transport Model Used in the Canadian Operational Regional Air Quality Deterministic Prediction System, 8th International Workshop on Air Quality Forecasting Research, 10-12 Jan. 2017, Toronto, Canada. Environment and Climate Change Canada Presentation available at https://cpaess.ucar.edu/iwaqfr-2017-presentations-en. Accessed December 2017.

U.S. Environmental Protection Agency (U.S. EPA). 2017. 2017 Appendix W Final Rule. Available at https://www3.epa.gov/ttn/scram/appendix_w-2016.htm. Accessed January 2018.

IR6-08 Air Quality – WRF-NMM and CALMET Modelling: Hourly Hodographs

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2.6.1, Figure 2-45

Context

In Appendix C of Appendix 9.2-A of the EIS, there was no indication of the CALMET model fields' ability to capture strong diurnal variation of wind speed and direction that characterize the sea-breeze conditions frequently seen in the Lower Fraser Valley, and which have been shown to be associated with pollutant recirculation, and associated degraded air quality.

It appears that Figure 2-45 (1500 PDT on August 2, 2010) of Appendix C of Appendix 9.2-A depicts a wind field during the afternoon sea-breeze phase of the well-known land/sea-breeze cycle. These conditions are responsible for regional (100 kilometres) scale horizontal recirculation of pollutants in this region. More information is required on the ability of CALMET modelled wind fields to properly capture the land/sea breeze cycle in this region. This information is required in order to assess the ability of the CALMET/CALPUF modelling system to capture wind structures that dominate the dispersion of pollutants in the local study area.

Information Request

Provide information in the form of hourly hodographs for up to five selected days to confirm that the NMM-WRFCALMET modelling system adequately captures the land/sea-breeze cycle in the region.

VFPA Response

Clarification

As clarification, Figure 2-43 of Appendix C in EIS Appendix 9.2-A (not Figure 2-45 as stated in the context section of IR6-08) depicts a CALMET wind field under unstable conditions during the afternoon sea-breeze phase on August 2, 2010 at 1500 PDT.

Provide information in the form of hourly hodographs for up to five selected days to confirm that the NMM-WRFCALMET modelling system adequately captures the land/sea-breeze cycle in the region.

As requested, hourly hodographs are provided to confirm that the NMM-WRF CALMET modelling system adequately captures the land/sea-breeze cycle in the region. Wind speed and direction data were extracted in 1-hour increments from the CALMET model at the east end of the causeway on five days to produce daily hodographs. **Figures IR6-08-1** to **IR6-08-5** include hodographs to illustrate daily changes during spring to summer 2010 when the land/sea-breeze cycle is most predominant. The dates selected include May 11, June 12, June 16, July 4, and August 20, as representative of the spring/summer period. The graphed

hours for each extracted point are labelled[1] to clearly show the wind speed and direction for each hour over 24 hours.

Figure IR6-08-1 Hodograph for May 11, 2010 Showing Daily Land/Sea-breeze Cycle

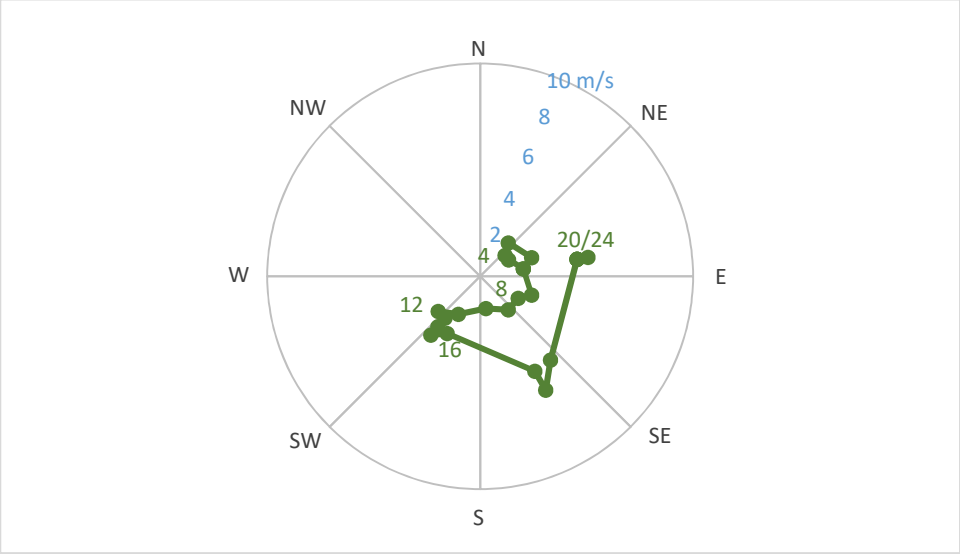
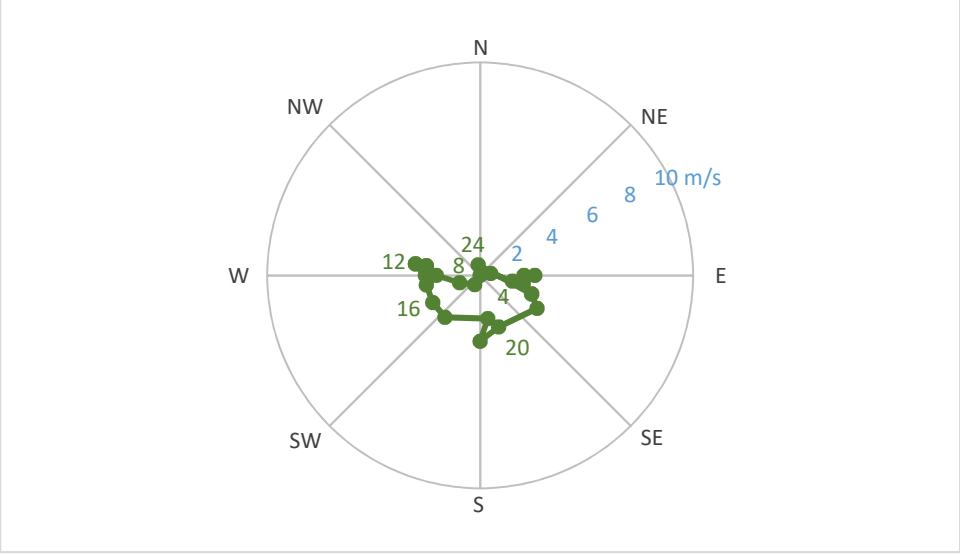


Figure IR6-08-2 Hodograph for June 12, 2010 Showing Daily Land/Sea-breeze Cycle



[1] The wind speed scale is indicated by blue numbers. The hourly wind speed and direction are indicated by the green line and dots, and the corresponding hours are shown by green numbers, in 4-hour increments.

Figure IR6-08-3 Hodograph for June 16, 2010 Showing Daily Land/Sea-breeze Cycle

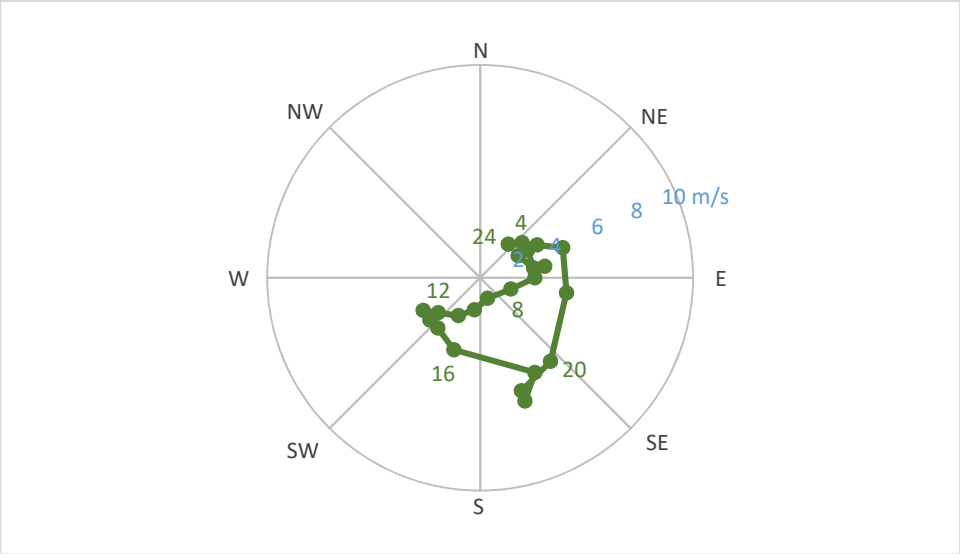


Figure IR6-08-4 Hodograph for July 4, 2010 Showing Daily Land/Sea-breeze Cycle

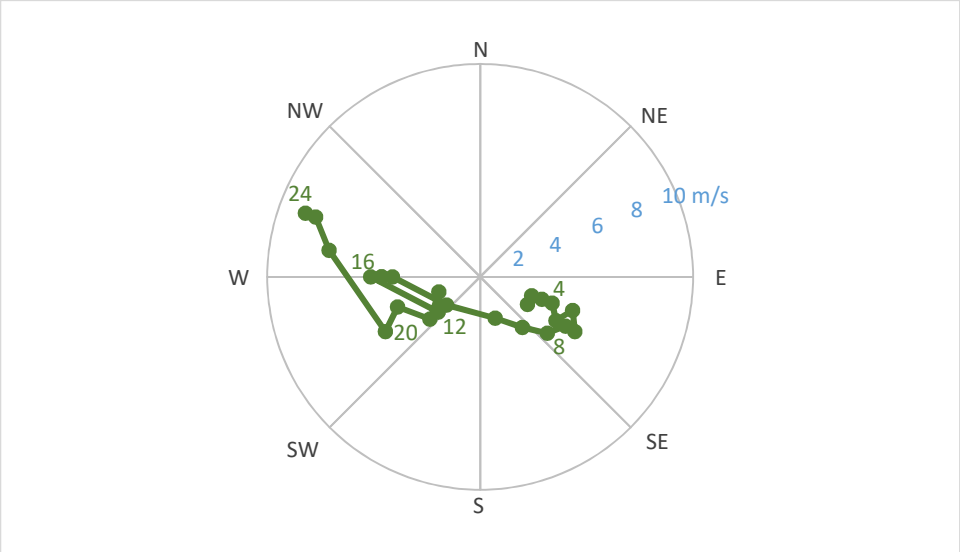
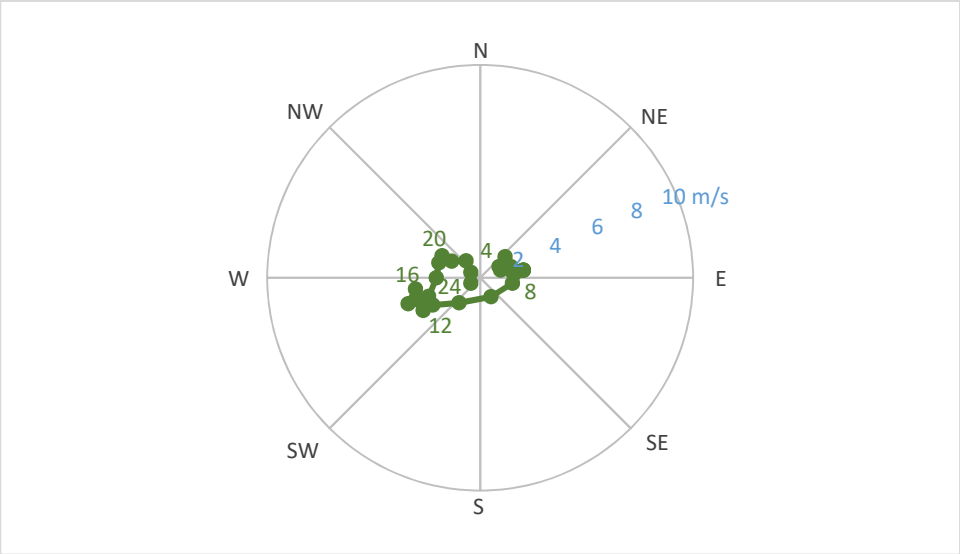


Figure IR6-08-5 Hodograph for August 20, 2010 Showing Daily Land/Sea-breeze Cycle



These hodographs, based on the NMM-WRF CALMET data, illustrate the daily land/sea-breeze cycle: winds from the east (land breeze) in the morning hours, winds from the west (sea breeze) in the afternoon, and winds from the east (land breeze) during the evening to complete the land/sea-breeze cycle.

These hodographs, showing a similar sea-breeze cycle on each representative day, confirm that the NMM-WRF CALMET modelling system adequately captures the daily land/sea-breeze cycle in the region.

IR6-09 Air Quality – Baseline Ambient Conditions

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix B, Section 3.2.3

CEAR Doc#581, Appendix IV

Context

The Proponent determined the background air quality concentrations in the vicinity of the proposed Project based on data from the air quality monitoring station in Tsawwassen, located in the northwest portion of Pebble Hill Park (station T39). In Section 3.2.3 of Appendix B of Appendix 9.2-A in the EIS, the Proponent presented a summary and discussion of air quality observations at this station.

The station is located about 800 metres inland from the shoreline facing the Tsawwassen Ferry Terminal, at an elevation of 52 meters above sea level and is approximately five kilometres east-southeast of the existing Roberts Bank terminals.

According to Environment and Climate Change Canada, the Tsawwassen First Nation indicated that, in addition to the T39 monitoring station, the Proponent had established a new monitoring station at the bottom of the bluff within the community housing area. Environment and Climate Change Canada also reported that a third monitoring station was operated on Tsawwassen lands near the wastewater treatment plant.

These two additional monitoring stations may be the closest air quality monitoring stations to the Project site, and the data from these stations may be more representative of conditions at the Project site.

Further, air quality observation data from station T39 were reported in Table 3-2 of Appendix B, Section 3.2.3 and were used to establish background concentrations for the air quality study. The data covered the period from June 2010 through December 2012. This is a relatively short period of time to establish background concentrations since variability of meteorological conditions from year-to-year can influence results.

Information Request

Provide information on the air quality monitoring stations that were established on Tsawwassen First Nation lands in addition to Tsawwassen Pebble Hill Park (station T39), including the locations and results of meteorological parameters monitored.

Compare the monitoring data from the two additional stations and station T39 for the overlapping monitoring period, focusing on the maximum, mean and 98th percentile concentrations for 1-hour, 8-hour and 24-hour durations, where appropriate.

Update the air quality observation data station T39 to include data from June 2010 through to at least December 2014 to verify that the concentrations in Table 3-2 of Appendix B have not been biased by the limited period of record.

VFPA Response

Provide information on the air quality monitoring stations that were established on Tsawwassen First Nation lands in addition to Tsawwassen Pebble Hill Park (station T39), including the locations and results of meteorological parameters monitored.

Monitoring Station Locations on Tsawwassen First Nation Lands

An air quality monitoring study was conducted on Tsawwassen First Nation (TFN) Lands as part of a joint initiative between the VFPA, Metro Vancouver, Westshore Terminals, and TFN, in response to air quality concerns raised by residents. **Appendix IR6-09-A** includes the Summary Report for the *Tsawwassen First Nation Air Quality Monitoring Study 2014-2015* (Summary Report) referred to in CEAR Document #581: Appendix IV. The study indicates that air quality on TFN Lands is among the best in the region, based on comparisons of measurements to other stations in the lower Fraser Valley.

Data was collected by three mobile air quality monitoring units (MAMUs) that were deployed on TFN Lands over three two-month periods (fall 2014, spring 2015, and summer 2015) at two locations: one near the wastewater treatment plant and the other at Tsatsu Shores. The three MAMUs, referred to as TFN90, Metro Vancouver MAMU, and Westshore MAMU#1, were rotated between the two TFN locations to ensure data for all pollutants were collected at each site, as not all MAMUs were capable of measuring the same pollutants. Additional information on the MAMUs and locations can be found in Appendix A of the Summary Report provided in **Appendix IR6-09-A**.

Fine particulate matter ($PM_{2.5}$), inhalable particulate matter (PM_{10}), nitrogen dioxide (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3) were monitored, and meteorological data, including wind speed and direction, air temperature, and relative humidity, were also collected. During the same time periods, air quality and meteorological data were also collected at the permanent Pebble Hill Park monitoring station in Tsawwassen, which is referred to as station T39.

Meteorological Results

The results for monitored meteorological parameters are provided in the detailed Arcadis Canada Inc. (Arcadis 2016) report entitled *Air Quality Monitoring in the Tsawwassen Area Results from 2014 and 2015*.

In addition to the collection of meteorological data at the wastewater treatment plant, Tsatsu Shores, and station T39, data was also incorporated into the study from the Environment and Climate Change Canada Tsawwassen Weather Station (ECCC Data) located near the BC

Ferries Tsawwassen Ferry Terminal. Since 2012, this station has recorded hourly wind speed and wind direction[1].

For ease of reference, the results for fall 2014 and spring and summer 2015 wind speed and wind direction monitoring described in the Arcadis (2016) report are summarised below.

For fall 2014 monitoring from September to mid-December, the TFN90 station was located at the wastewater treatment plant, and Westshore MAMU#1 was located at Tsatsu Shores. The wind rose and wind speed plots for these two stations, and the ECCC Data station, are provided in **Figure IR6-09-1**.

The wind rose for the ECCC Data station and the TFN90 station show a similar distribution of wind directions; however, the TFN90 station wind rose appears to be rotated by approximately 90° when compared to the ECCC Data station. As shown in **Figure IR6-09-1**, if 90° is added to all of the TFN90 data points to correct for this disparity (shown by dashed purple line), the two wind roses match closely, with the notable exception of the strong easterly component that is missing from the TFN90 data. The 90° offset may have resulted from misalignment of the sensors or channelling from local obstructions. With respect to data on easterly winds at TFN90, there may have been a local obstruction present at the lower anemometer height that shielded winds out of the east.

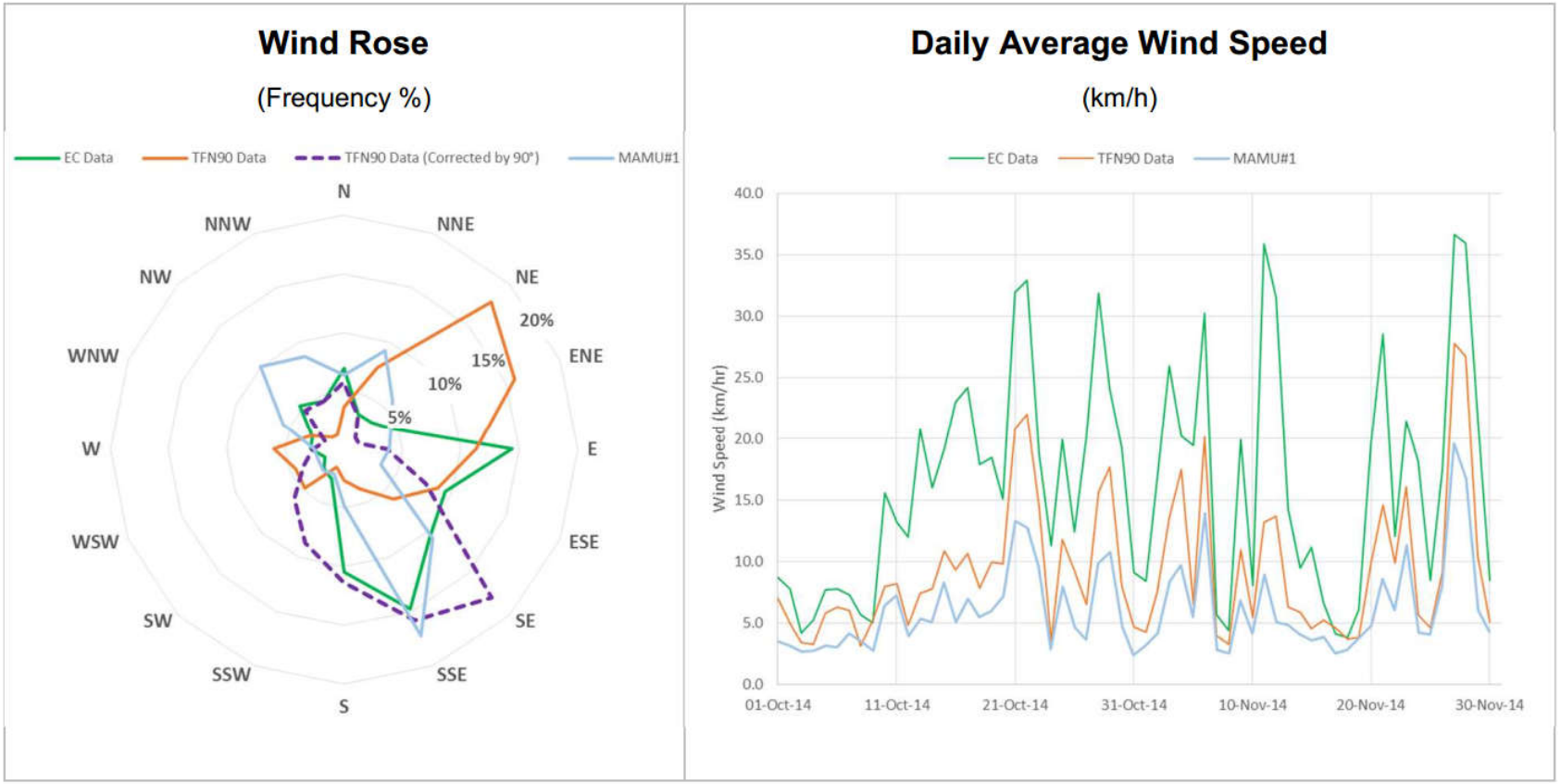
For the daily average wind speed for the TFN90 and ECCC Data station, the two data sets follow similar trends in general, but the daily average wind speeds at the TFN90 station are 7 km/h lower on average across the period. The higher wind speeds at the ECCC Data station may reflect the fact that the station is surrounded by open water and subject to higher wind speeds in general. Arcadis (2016) concluded that the TFN90 wind speeds were measured at a lower elevation than at the ECCC Data station.

For spring 2015 (April to May), the Metro Vancouver MAMU was located at the wastewater treatment plan and the Westshore MAMU#1 was located at Tsatsu Shores. For summer 2015 (July to August) monitoring, Westshore MAMU#1 was located at the wastewater treatment plant and Metro Vancouver MAMU was located at Tsatsu Shores. The wind rose and wind speed plots for these two stations and the ECCC Data station are provided in **Figure IR6-09-2**.

As described by Arcadis (2016) and shown in **Figure IR6-09-2**, the wind rose for the ECCC Data station[2] and the Westshore MAMU#1 station match closely. For daily average wind speeds, the two data sets generally follow similar trends, but the daily average wind speeds at the Westshore MAMU#1 station are 8 km/h and 6 km/h lower on average across the spring and summer periods, respectively. The higher wind speeds at the ferry terminal may reflect the fact that the station is surrounded by open water and subject to higher windspeeds in general.

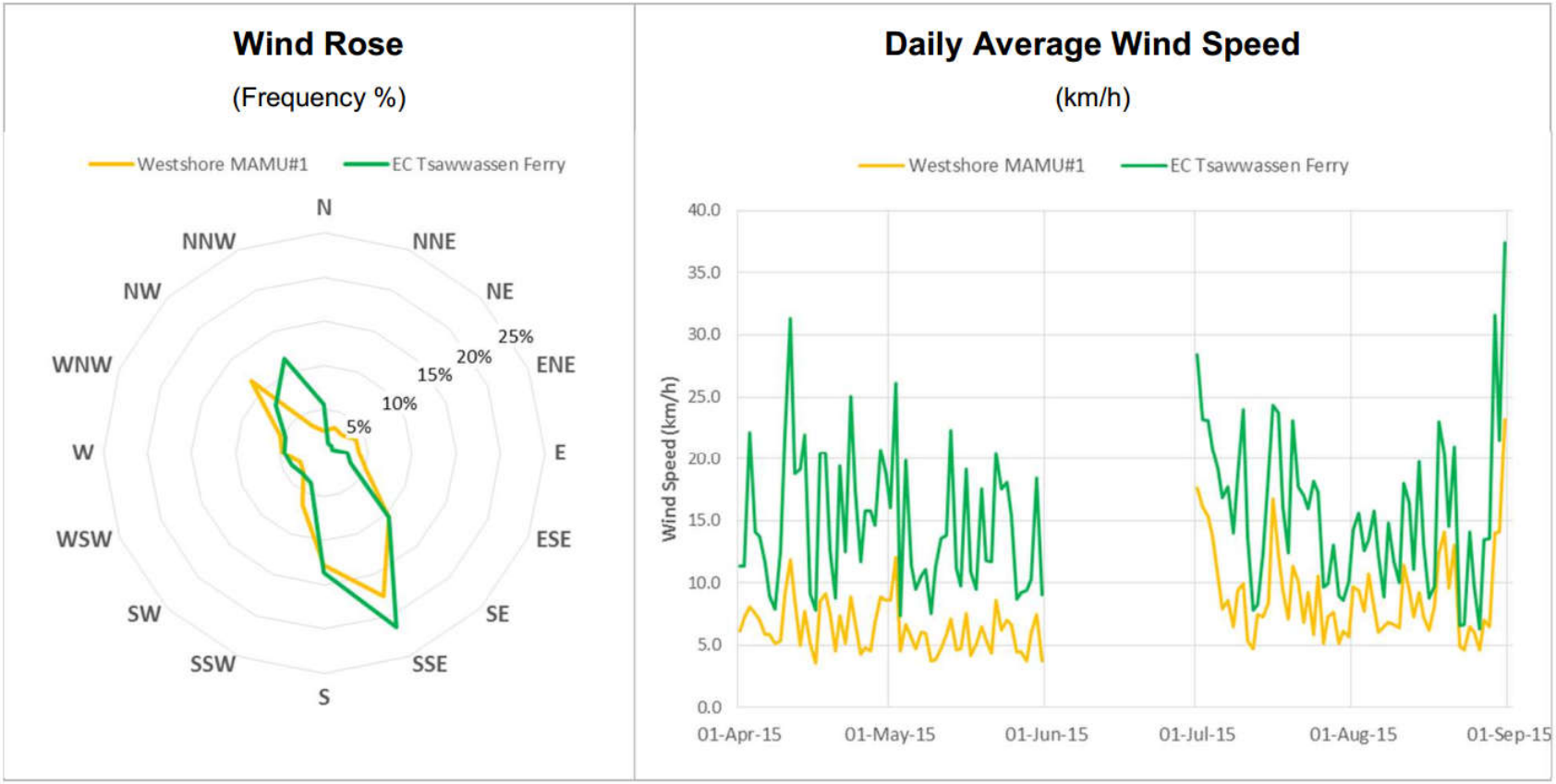
[1] Data from the T39 station is considered appropriate for air contaminant concentrations, but not for meteorological conditions, due to non-conformance with regulatory siting guidelines.
[2] Station referred to in **Figure IR6-09-2** as EC Tsawwassen Ferry.

Figure IR6-09-1 Wind Rose and Wind Speed Plot for Fall 2014 Monitoring



Source: Arcadis 2016.

Figure IR6-09-2 Wind Rose and Wind Speed Plot for Spring and Summer 2015 Monitoring



Source: Arcadis 2016.

Compare the monitoring data from the two additional stations and station T39 for the overlapping monitoring period, focusing on the maximum, mean and 98th percentile concentrations for 1-hour, 8-hour and 24-hour durations, where appropriate.

As outlined in **Appendix IR6-09-A**, the results from the TFN Lands study were compared to station T39 data during the same time period, and also to regional, provincial, and national air quality objectives, as discussed further below. In addition, air quality information collected during the study was compared to those measured at other stations in the lower Fraser valley, and to historical results from a previous Greater Vancouver Regional District study from 2004 to 2006 on TFN Lands (Greater Vancouver Regional District 2006). The key conclusions of the 2014 to 2015 TFN study as described in the Summary Report are as follows:

- Emission concentrations measured at both TFN locations in 2014 to 2015 were comparable to station T39 data. For all parameters except CO, the maximum levels observed at the TFN sites were below station T39 levels;
- All measurements were below regional, provincial, and national air quality objectives and standards;
- Air quality on TFN Lands is among the best in the region, based on comparisons of measurements to other stations in the lower Fraser valley (i.e., most concentrations were on the low end of the range of concentrations observed at lower Fraser valley stations); and
- Emission concentrations measured at both TFN locations in 2014 to 2015 were found to be similar to or lower than historical data for a study conducted in 2004 to 2006. Recent results of CO and SO_2 were found to be lower than the 2004 to 2006 study, whereas NO_2 and $PM_{2.5}$ were found to be similar during each study.

Based on the 2014 to 2015 TFN Lands study (Arcadis 2016), station T39 provides a reasonably accurate representation of the air quality levels on TFN Lands, as concluded in the Summary Report provided in **Appendix IR6-09-A**, and therefore, for Roberts Bank and the Project site as well.

Update the air quality observation data station T39 to include data from June 2010 through to at least December 2014 to verify that the concentrations in Table 3-2 of Appendix B have not been biased by the limited period of record.

To determine if station T39 data from June 2010 to December 2012 have biased the background concentrations (which are used in conjunction with predicted concentrations for comparison to air quality criteria), three additional years of data from 2013 to 2015 for station T39 has been assessed and compared to 2010 to 2012 data.

Table IR6-09-1 provides a comparison for station T39 (located at Tsawwassen Pebble Hill Park) of 2010 to 2012 monitoring data (provided in Table 3-2 in Appendix B of EIS Appendix 9.2-A) to the period of 2013 to 2015. For $PM_{2.5}$, two concentrations are provided:

one with all monitoring data inclusive of periods when Metro Vancouver Air Quality Advisories[3] were issued, and one excluding these periods (the latter concentrations are provided in brackets in **Table IR6-09-1**). The observations can be compared to the most stringent of air quality objectives at the regional (Metro Vancouver), provincial, and national levels, which were previously provided in EIS Table 9.2-4, and are provided at the bottom of the table.

[3] Air Quality Advisories were issued by Metro Vancouver during wildfire episodes when smoke affected air quality in the Lower Fraser Valley.

Table IR6-09-1 Summary of Air Quality Observations at Station T39 for 2010 to 2012 and 2013 to 2015

Year	Parameter	Concentration (µg/m³)[b]									
		CO		NO_2		SO_2		O_3			$PM_{2.5}$[c]
		1-h	8-h	1-h	24-h	1-h	24-h	1-h	8-h	24-h	24-h
2010 to 2012	Max	800.4	626.4	120.1	48.9	53.5	9.7	**135.4**	111.6	**90.9**	**28.2** (14.1)
	Mean	183.6	183.6	12.8	12.8	1.4	1.4	45.9	45.8	**45.9**	3.5 (3.5)
	Median	174	174	9	10.8	0.8	1.1	46.6	46.3	**46.1**	3.1 (3.1)
	98th percentile	371.2	339.3	44.7	34.9	7.7	5.1	88.2	84.7	**79.8**	9.5 (8.7)
2013 to 2015	Max	2146.0	1119.4	84.8	55.1	27.7	6.6	**121.8**	104.9	**93.6**	**58.8** (21.6)
	Mean	174.8	174.9	13.3	13.3	0.9	0.9	43.1	43.0	**43.2**	5.2 (5.2)
	Median	162.4	162.4	9.4	11.3	0.5	0.8	43.6	43.5	**44.1**	4.4 (4.4)
	98th percentile	371.2	345.1	45.1	36.0	4.3	2.9	86.8	83.4	**79.0**	14.2 (14.0)
Air Quality Criteria[a]		14300	5500	200	200	450	125	100	121.6	30	25

Notes:

a. Air quality criteria are the most stringent of national, provincial, and Metro Vancouver air quality standards or objectives, as previously presented in EIS Table 9.2-4. Bolded values indicate exceedance of the applicable criteria.

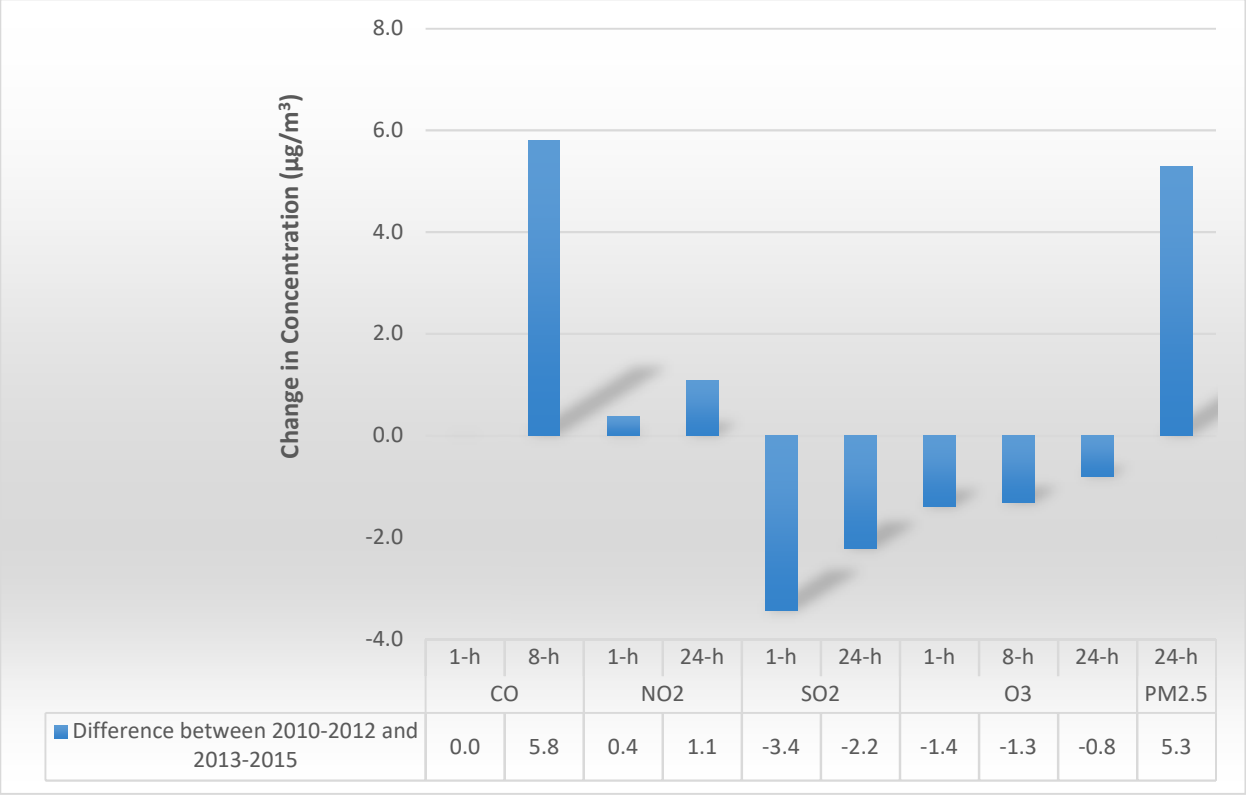
b. The annual average concentration is the 24-h mean background concentration. µg/m³ = micrograms per square metre.

c. For 24-h $PM_{2.5}$ concentrations, numbers in brackets exclude data for August 4-6, 2010, August 14-17, 2010, August 12, 2014, July 1-10, 2015, and August 23, 2015, when Air Quality Advisories were issued by Metro Vancouver as a result of smoke from wildfires.

As shown in **Table IR6-09-1**, the 98th percentile and annual concentrations from station T39 for the 2010 to 2012 period and the 2013 to 2015 period are similar, including exceedances of air quality criteria for 1-h and 24-h ozone, and 24-h $PM_{2.5}$. For 24-h $PM_{2.5}$, the exceedances in both periods result from smoke generated from wildfires, and exceedances for ozone can also be tied to smoke, which carry pollutants that can accelerate ozone formation.

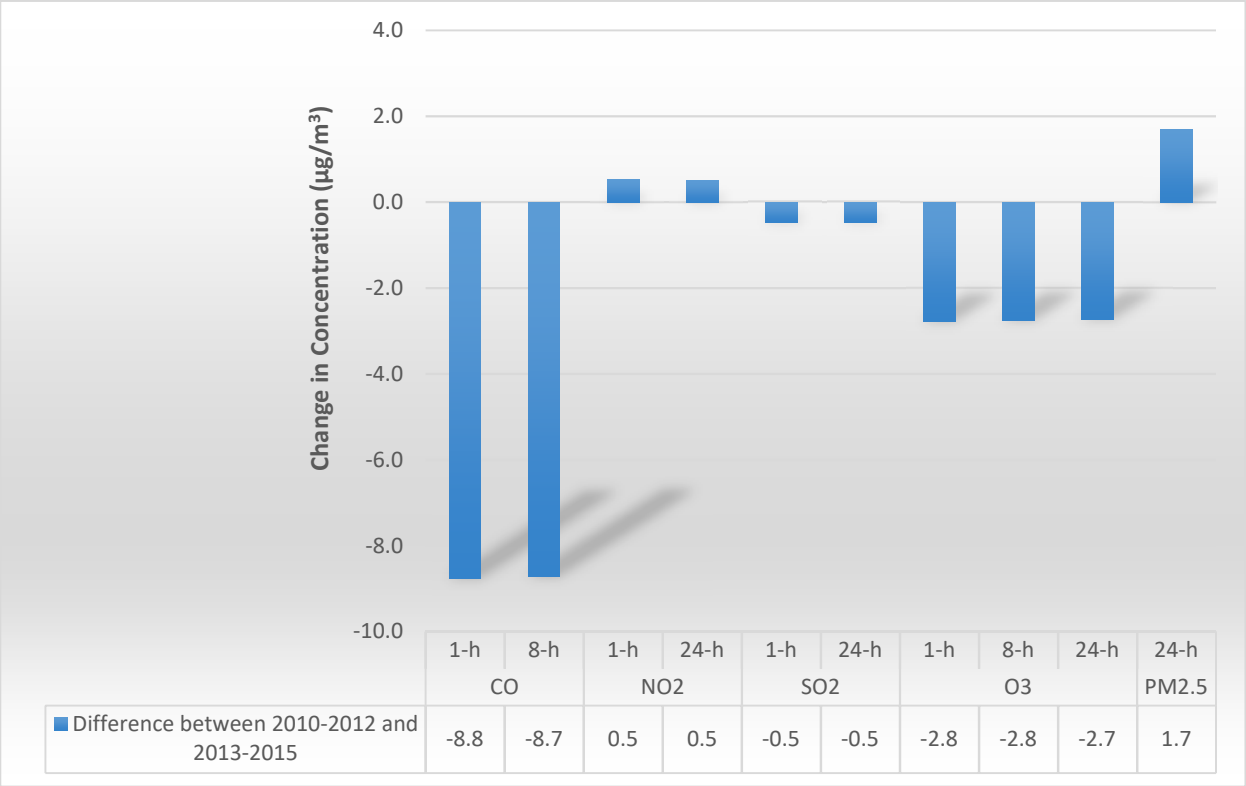
Differences in concentrations between the two periods are graphically illustrated and tabulated in **Figure IR6-09-3** for 1-h, 8-h, and 24-h 98th percentile concentrations (as applicable to the parameters), and in **Figure IR6-09-4** for annual concentrations. A positive value equates to an increase in the 2013 to 2015 period.

Figure IR6-09-3 Difference in 98th Percentile 1-h, 8-h, and 24-h Concentrations at Station T39 Between 2010-2012 and 2013-2015



	1-h CO	8-h CO	1-h NO2	24-h NO2	1-h SO2	24-h SO2	1-h O3	8-h O3	24-h O3	24-h PM2.5
Difference between 2010-2012 and 2013-2015	0.0	5.8	0.4	1.1	-3.4	-2.2	-1.4	-1.3	-0.8	5.3

Figure IR6-09-4 Differences in Mean Annual Concentrations at Station T39 Between 2010-2012 and 2013-2015

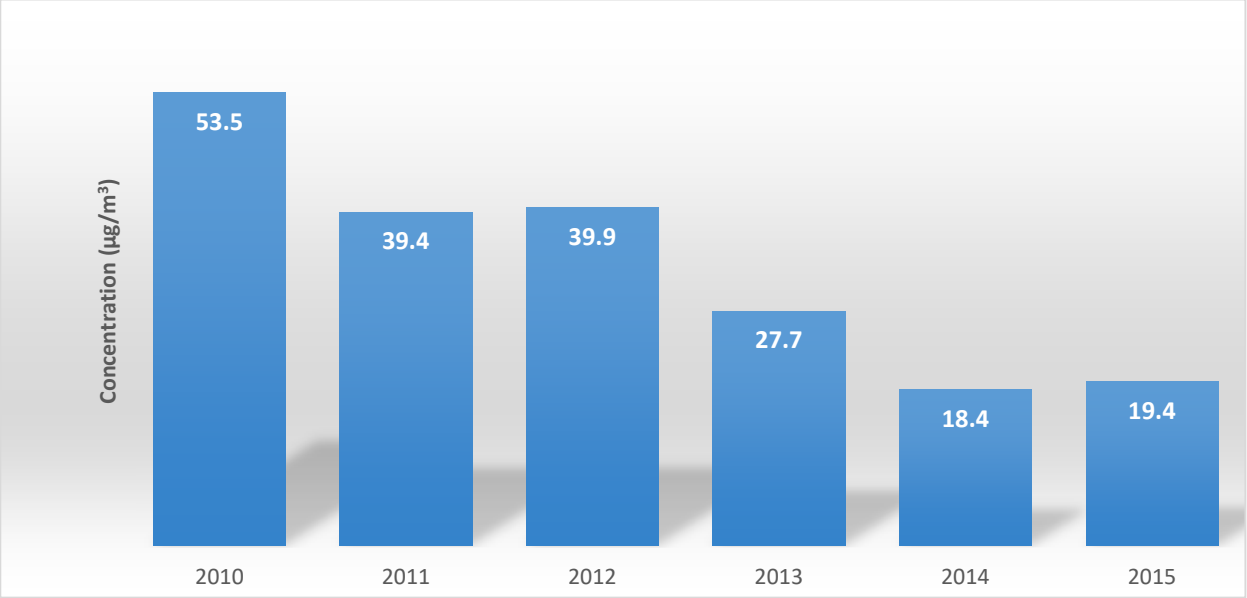


The key findings from the comparison of the 2010 to 2012 period to the 2013 to 2015 period are as follows:

- For CO, the average 98th percentile concentration did not change for the 1-hour averaging period, while the 8-hour concentration increased. The increase may have been related to increased CO levels during periods of wildfires, which increased at the same time as increases in $PM_{2.5}$ levels during the Air Quality Advisory in July 2015. Nevertheless, annual average CO levels decreased by almost 9 µg/m^3 (as shown in **Figure IR6-09-3**);
- For NO_2, the 1-hour, 24-hour, and annual average 98th percentile levels increased slightly;
- For SO_2, the 1-hour, 24-hour, and annual average 98th percentile levels decreased, likely due to the implementation of the Phase 1 and Phase 2 North America Emission Control (ECA) requirements for reduced sulphur in fuel in July 2012 and January 2015, respectively. Evidence of the benefits of ECA on SO_2 concentrations are most clearly seen in the 64% decline in maximum hourly averaged concentrations over the 2012 to 2015 period, as indicated in **Figure IR6-09-5**;
- For O_3, the 1-hour, 24-hour, and annual average 98th percentile concentrations decreased; and
- For $PM_{2.5}$, the 1-hour, 24-hour, and annual average 98th percentile concentrations increased. This is a result of Metro Vancouver replacing a Tapered Element Oscillating

Microbalance (TEOM) $PM_{2.5}$ monitor with a Federal Equivalent Method (FEM) $PM_{2.5}$ monitor at Station T39 in 2013.

Figure IR6-09-5 Trend in Maximum 1-hour Average SO_2 Concentrations at Station T39 from 2010 to 2015



Based on the similarities between the two three-year period data sets, with the exception of $PM_{2.5}$ for which concentrations have increased due to different monitoring equipment (but are still well below the Air Quality Criteria threshold), the VFPA verifies that the 98th percentile background concentrations have not been biased by use of 2010 to 2012 data. In addition, since air quality is expected to improve in the future (as described in EIS Section 9.2.7), a longer period of record to derive background concentrations would not materially change the RBT2 Air Quality Study conclusions. That is, exceedances of criteria will not be more frequent in the future due to the expected improvements in air quality, even when considering future criteria that will apply when RBT2 is in operation in 2025 (e.g., Canadian Ambient Air Quality Standards for SO_2, O_3, and $PM_{2.5}$). Metro Vancouver's monitoring report in 2017 supports the observed reduction in SO_2 concentrations in relation to ECA (Metro Vancouver 2017).

References

Arcadis Canada Inc. (Arcadis). 2016. Air Quality Monitoring in the Tsawwassen Area Results from 2014 and 2015. Prepared for Port Metro Vancouver.

Greater Vancouver Regional District. 2006. Delta Air Quality Monitoring Study June 2004 – March 2006. Prepared by the Air Quality and Management Division, Policy and Planning Department, Burnaby, B.C. Available at http://www.metrovancouver.org/services/air-quality/AirQualityPublications/DeltaAirQualityMonitoringStudy.pdf. Accessed October 2017.

Metro Vancouver. 2017. Caring for the Air Report 2017. Parks, Planning and Environment Department, Burnaby, B.C. Available at http://www.metrovancouver.org. Accessed October 2017.

Appendices

Appendix IR6-09-A Tsawwassen First Nation Air Quality Monitoring Study 2014-2015 Summary Report

APPENDIX IR6-09-A
TSAWWASSEN FIRST NATION AIR QUALITY MONITORING STUDY 2014-2015 SUMMARY REPORT

TSAWWASSEN FIRST NATION AIR QUALITY MONITORING STUDY 2014-2015 SUMMARY REPORT

Submitted to: Christine Rigby, Vancouver Fraser Port Authority
Submitted by: Cariad Garratt, Principal, Pinna Sustainability Inc.

March 8, 2017

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1. Introduction

Context

An air quality monitoring study was undertaken as a joint initiative between Vancouver Fraser Port Authority (VFPA), Metro Vancouver, Westshore Terminals and Tsawwassen First Nation (TFN) from fall 2014 to summer 2015 in response to concerns raised by residents on TFN land. Concerns related to air quality in general, as well as specific concerns about coal dust settling due to the proximity to the Westshore Terminal, which handles coal. The study included collecting air quality data in the area of concern, comparing that data collected at the permanent Pebble Hill Park monitoring station in Tsawwassen during the same time period, as well as to regional, provincial and national air quality objectives. Arcadis Canada Inc. was retained by VFPA to analyze the results of the study. The detailed Arcadis report entitled "Air Quality Monitoring in the Tsawwassen Area Results from 2014 and 2015" is available from both VFPA and TFN.

Objectives

The objectives of the study were to:

1. Compare **air quality at Pebble Hill Park**, which has ongoing monitoring data, to air quality monitoring units temporarily set up on TFN lands at two sites,
2. Compare pollutant levels measured at the TFN sites to **regional, provincial and national air quality objectives and standards**,
3. Assess how much **coal dust** is in particulate matter collected at the TFN and Pebble Hill Park sites, and
4. Identify whether additional air quality studies are needed.

Outside the scope of the study objectives, pollutant levels measured during this study were also compared to those measured at other air quality stations in the Lower Fraser Valley, as well as to historical results from a previous study on TFN lands. These supplemental comparisons serve to provide additional context to the results of the most recent, 2014-2015 assessment.

2. Approach

In order to meet the objectives of the study, monitoring was undertaken at two locations on TFN lands, to complement the existing, ongoing monitoring at Pebble Hill Park. The study monitored air pollutants that have regional, provincial and/or federal air quality objectives or standards at both Tsatsu Shores and the wastewater treatment plant (WWTP) on TFN lands, for three two-month periods (fall 2014, spring 2015, summer 2015) using three mobile air monitoring units (MAMUs). One unit (called TFN90) was only used in fall 2014. It was replaced with the Metro Vancouver MAMU for spring and summer 2015. Westshore MAMU #1 was used for all three monitoring periods. The data collected by these units was compared to the data collected at Metro Vancouver's permanent air quality station located in Pebble Hill Park.

Using a separate method, dustfall was collected at the two TFN locations, as well as at the Pebble Hill Park station during all three periods of the study. The following two tables show the types of pollutants measured by each monitoring unit used in the study, and the locations of each monitoring unit by date, respectively.

Pollutant measured	TFN90	Westshore MAMU #1	Metro Vancouver MAMU	Pebble Hill Park (T39)
Fine Particulate Matter ($PM_{2.5}$)	✔		✔	✔
Inhalable Particulate Matter (PM_{10})		✔	✔	
Nitrogen Dioxide (NO_2)	✔		✔	✔
Sulphur Dioxide (SO_2)	✔		✔	✔
Carbon Monoxide (CO)	✔[a]		✔	✔
Ozone (O_3)	✔		✔	✔
Wind speed and direction	✔	✔	✔	✔
Air temperature and relative humidity		✔	✔	✔

Table note: *[a] Carbon monoxide data for TFN90 are considered unreliable because 81% of the data was invalidated or otherwise modified.*

Because not all MAMUs measured the same pollutants, the MAMUs were rotated between TFN locations to ensure data for all pollutants was collected at each site. More information on monitoring units and locations can be found in Appendix A.

Monitoring unit location	2014 Fall Oct – Nov	2015 Spring Apr – May	2015 Summer Jul – Aug
TFN WWTP	TFN90	Metro Vancouver MAMU	Westshore MAMU #1
Tsatsu Shores	Westshore MAMU #1	Westshore MAMU #1	Metro Vancouver MAMU
Pebble Hill Park	T39 permanent station	T39 permanent station	T39 permanent station

3. Results

Summary

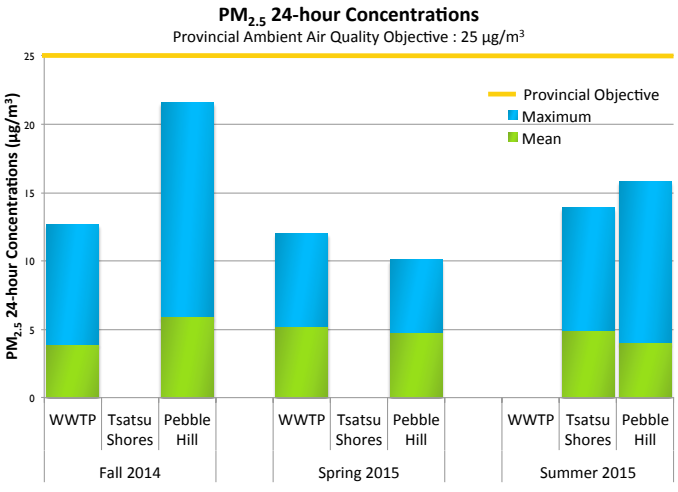
All air pollutants measured were below the regional, provincial and national objectives and standards (see Appendix B for a list of the most stringent objectives and standards). The results also indicate that measurements made at both TFN sites are comparable to the data collected at the permanent Pebble Hill Park station. The following table summarizes the results by pollutant, comparing the maximum pollutant levels measured at the TFN sites to the maximum levels at Pebble Hill Park, the range of levels recorded at other stations in the Lower Fraser Valley, and the most stringent objective or standard.

Pollutant	TFN sites (max)	Pebble Hill (max)	Range at stations in Lower Mainland	Objective or Standard
$PM_{2.5}$ 24-hour (µg/m^3)	14	22	19 → 37	25
NO_2 1-hour (ppb)	42	44	31 → 80	100
SO_2 1-hour (ppb)	6	7	5 → 130	75
CO 1-hour (ppm)	1.9	1.8	0.6 → 2.6	26.2
O_3 8-hour (ppb)	50	53	37 → 73	63
Dustfall (mg/dm^2/day)	0.6	0.4	N/A	1.75
[Coal Dust (mg/dm^2/day)	*0.07*	*0.01*	*N/A*	*N/A]*

The rest of this section describes the results for each pollutant, with a graph of the results for each time period (fall 2014, spring 2015, summer 2015) and site (WWTP, Tsatsu Shores, Pebble Hill Park (PHP)). Blank entries indicate the monitoring unit located at that site during that period was not equipped to collect data for that pollutant. Each graph presents both the mean and maximum values measured for each pollutant based on the averaging period of the corresponding objective or standard.

Fine particulate matter ($PM_{2.5}$)

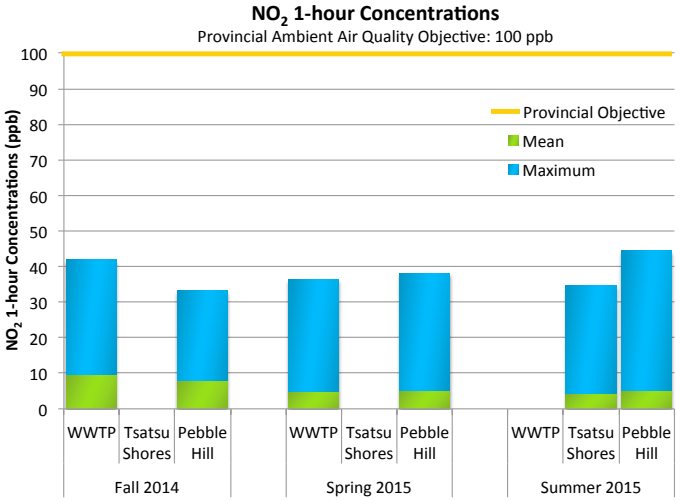
The data collected on TFN land indicate that $PM_{2.5}$ levels were similar to or lower than the levels at Pebble Hill, and all of these were below the ambient air quality objective for Metro Vancouver. The highest 24-hour average readings during the study period were collected at Pebble Hill Park in fall 2014. In general, the mean 24-hour average $PM_{2.5}$ concentration was less than 6 µg/m^3, well below the Metro Vancouver criteria of 25µg/m^3. The readings at TFN locations were lower than readings from all other monitoring stations in the region.[1]



[1] Due to wildfires in BC, $PM_{2.5}$ data from July 1 to 6 2015 are omitted from the study results.

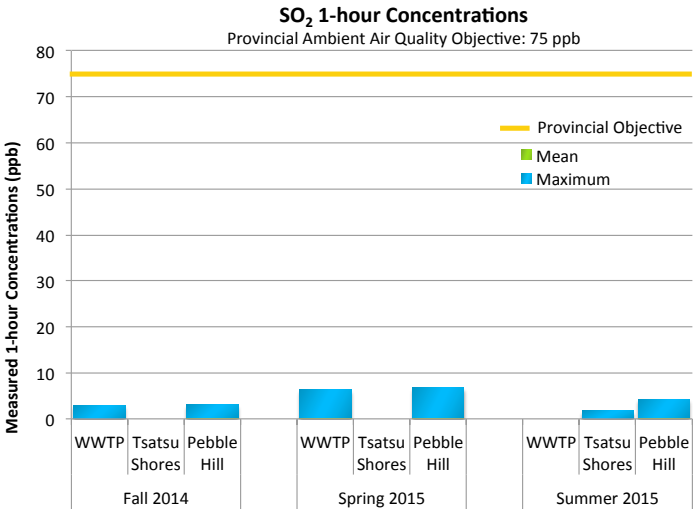
Nitrogen Dioxide (NO_2)

Average 1-hour concentrations of NO_2 are all under 10 ppb during the study period, well below the provincial objective of 100 ppb. The maximum 1-hour concentration observed during the study period was 44 ppb, recorded at the Pebble Hill Park in summer 2015. NO_2 levels in the Tsawwassen area are among the lowest in the Lower Fraser Valley.



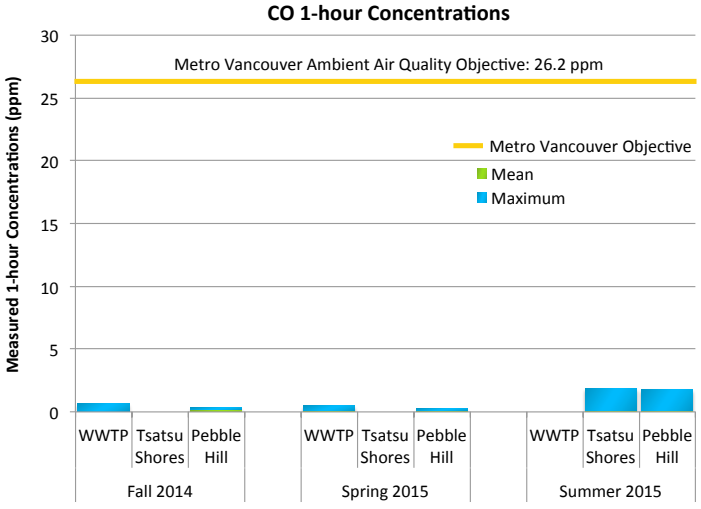
Sulphur Dioxide (SO_2)

SO_2 levels are quite low at the monitoring locations, all well below the provincial objective of 75 ppb. The levels at Pebble Hill Park station were generally higher than the levels at TFN sites with a maximum 1-hour concentration of 6.8 ppb, and an average concentration of 0.4 ppb during spring 2015. The higher SO_2 levels experienced may be due to the Tilbury cement plant or oil refineries at Cherry Point, Washington. SO_2 levels in the Tsawwassen area are among the lowest in the Lower Fraser Valley.



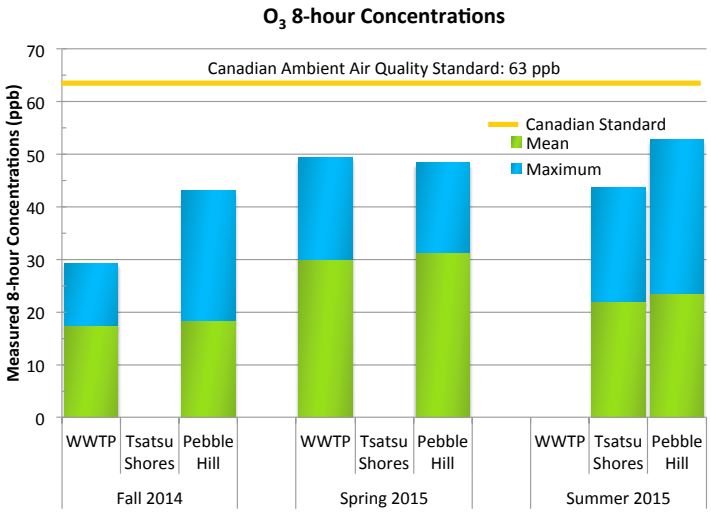
Carbon Monoxide (CO)

The average 1-hour concentrations for CO at the three sites were below 0.5 ppm (with maximum level reaching 1.9 ppm at Tsatsu Shores), all well below Metro Vancouver's objective of 26.2 ppm. The measurements recorded at the WWTP during fall 2014 were considered unreliable for CO (over 80% of the dataset was modified or invalidated); however, the data are included for completeness. CO levels recorded were generally lower than those recorded at other locations within the Lower Fraser Valley.



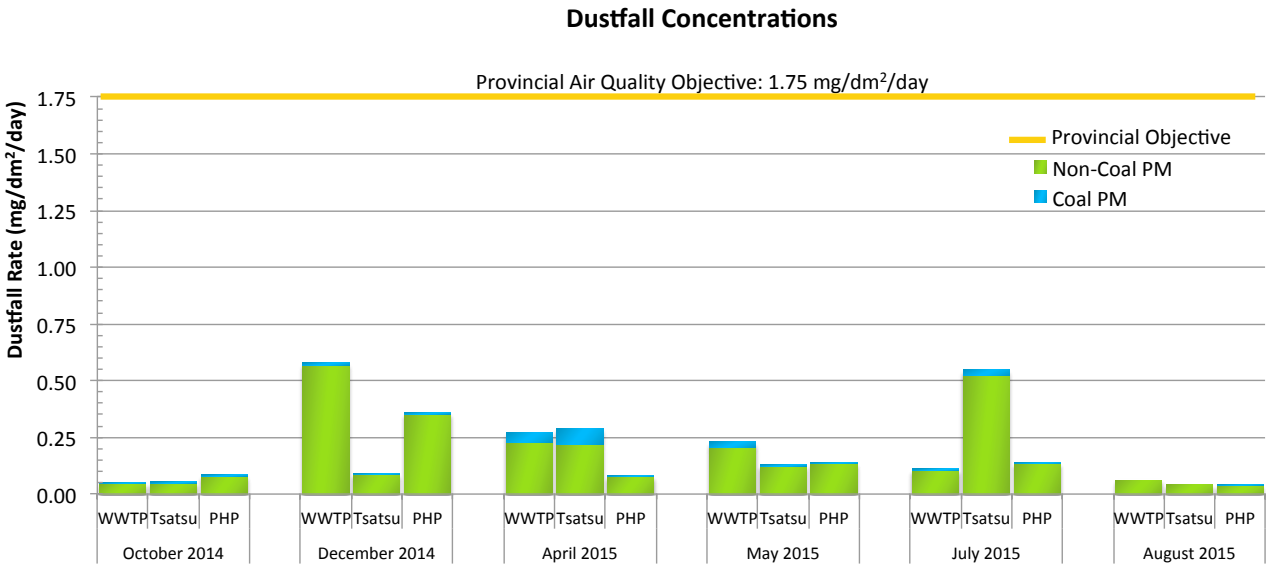
Ground-level Ozone (O_3)

The measured 8-hour O_3 concentrations at the WWTP and Tsatsu Shores were very similar to measurements recorded at Pebble Hill Park station during the same periods. The maximum 8-hour concentration recorded during the study period was 53ppb at Pebble Hill Park, which is below the Canadian air quality standard of 63ppb, and overall low when ranked among other stations in the Lower Fraser Valley.



Dustfall and coal levels in dust

Dustfall rates recorded were well below the BC objective of 1.75 mg/dm^2/day. In all cases, the majority of the dust collected was from non-coal sources. The highest average dustfall was 0.58 mg/dm^2/day at the WWTP in December 2014 and coal particles made up 2% of the total dustfall that month. The sample with the largest proportion of coal particles was collected from Tsastu Shores in April 2015 when the average dustfall was half the maximum at 0.29 mg/dm^2/day and coal dust made up 25% of the total dustfall collected based on particle counts.



4. Conclusions

Comparisons of the study results to those from other air quality stations in the Lower Fraser Valley, and previous monitoring on TFN land showed that air quality on TFN lands is among the best in the region with some of the lowest levels of air pollutants measured in the region. Pollutant levels measured during this study (2014 to 2015) were also found to be similar to or lower than historical pollutant levels on TFN lands based on a comparison to results from a study conducted in 2004 to 2006. Specifically, 2014 and 2015 CO and SO_2 were found at lower concentrations than the study found in 2004 to 2006, while NO_2 and $PM_{2.5}$ were similar in both time periods.

Key findings from the study that address the objectives include:

1. **Air quality on TFN lands compared to Pebble Hill Park in Tsawwassen:**
   - Air quality was generally similar or better on TFN lands than at Pebble Hill Park during the study period.
   - Pebble Hill Park station provides a reasonably accurate representation of air quality on TFN lands.

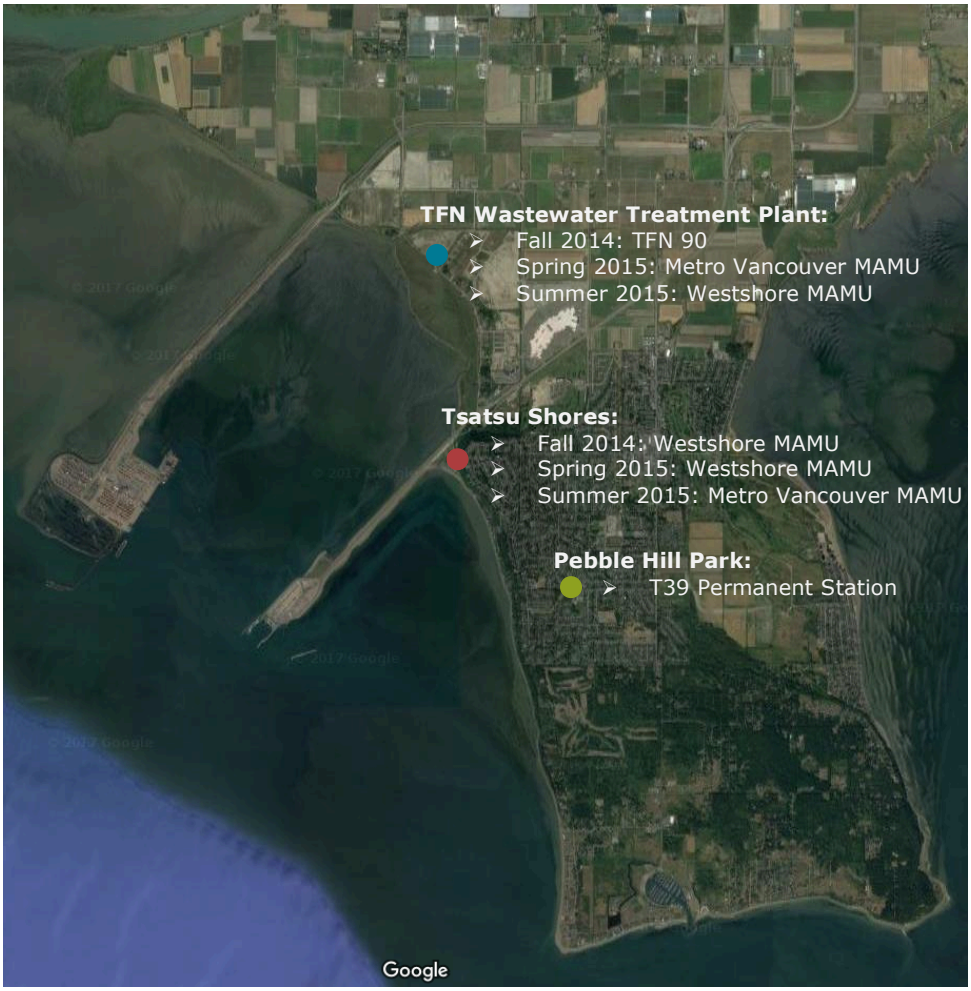
2. **Air quality at study sites compared to regional, provincial and national objectives and standards:**
   - Air pollutants measured at all three study sites (the WWTP, Tsatsu Shores and Pebble Hill Park) were below all regional, provincial and federal air quality objectives and standards during the study period.

3. **Coal dust:**
   - Dustfall rates at all three study sites were all below the provincial objective.
   - Small quantities of coal dust were found in most of the dustfall samples, with the majority of coal present in the coarser size of particulate matter.

4. **Next steps:**
   - Continue discussion of opportunities to work together to improve understanding of port-related air emissions.

Appendix A: Details of monitoring units and locations

Three mobile air quality monitoring units (MAMUs) were used in the 2014-2015 TFN air quality study, and these were rotated to different locations because not all monitors measure the same set of pollutants. The three units are described below, with locations shown on the map to the right:



TFN 90 was operated by Maxxam Analytics on behalf of the Vancouver Fraser Port Authority and was only used in fall 2014. Arcadis Canada Inc., who were retained by VFPA to analyze data for the TFN Air Quality Monitoring Study 2014-2015, identified a number of data issues and, based on their opinion, the carbon monoxide data set is considered unreliable. Approximately 81% of the data was invalidated or otherwise modified. These results are included for completeness only.

Westshore MAMU #1 is maintained by Levelton Consultants on behalf of Westshore terminals.

Metro Vancouver MAMU is operated and maintained by Metro Vancouver and used for specialized, short-term, air quality studies.

Dustfall sampling was used to investigate the coal content in particulate matter and was conducted at T39, TFN WWTP and Tsatsu Shores. The dustfall sampling units were independent of the aforementioned monitoring units, were set out at the beginning of each study month, and were collected by Levelton Consultants. Acuren Group Inc conducted the analysis on the dust collected. Results are provided for total PM, PM_{10}, $PM_{2.5}$, and coal content.

Appendix B: Summary of pollutant objectives and standards

The following table summarizes regional, provincial and national objectives and standards for the air pollutants monitored in the Tsawwassen First Nation air quality monitoring study. Some pollutants have more than one objective at different levels of government. In these cases, only the more stringent is shown.

Acronyms:

- AQOs – Air Quality Objectives
- CAAQS – Canadian Ambient Air Quality Standards
- MV – Metro Vancouver
- NAAQOs – National Ambient Air Quality Objectives

Summary of most stringent Ambient Air Quality Objectives and Standards[2]

Pollutant	Average Period	Air Quality Objective µg/m³	Air Quality Objective ppb	Source	Adopted
Particulate Matter ($PM_{2.5}$)	24-hour	25	-	Provincial AQO	2009
		28	-	CAAQS	2013
	Annual	8	-	Provincial AQO	2009
		10	-	CAAQS	2013
Nitrogen Dioxide (NO_2)	1-hour	188	100(1)	Interim Provincial AQO	2014
	Annual	40	21	MV AQO	
Sulphur Dioxide (SO_2)	1-hour	196	75(3)	Interim Provincial AQO	Dec 2016
	24-hour	125	48(4)	MV AQO	
	Annual	13	5(6)	CAAQS	2016(5)
Carbon Monoxide (CO)	1-hour	30,000	26,200	MV AQO	
	8-hour	10,000	8,700	MV AQO	
Ozone (O_3)	1-hour	160	82	NAAQO(2)	1989
	8-hour	123	63	CAAQS	2013
Dustfall	24-hour	1.75 mg/dm²/day		Provincial AQO(7)	

Table notes

1) Achievement based on annual 98th percentile of daily 1-hour maximum, over one year.
2) The NAAQOs for ozone were replaced by the CAAQS, but the 1-hour NAAQO of 82 ppb is retained for air quality advisories.
3) Achievement based on annual 99th percentile of daily 1-hour maximum, over one year.
4) Achievement based on annual 99th percentile of daily 1-hour maximum, averaged over 3 consecutive years.
5) SO_2 CAAQS were endorsed by the Canadian Council of Ministers of the Environment in 2016; attainment of the CAAQS is expected in 2020.
6) Achievement based on annual average of 1-hour concentrations over one year.
7) 24-hour average based on monthly sample.

[2] http://www.bcairquality.ca/reports/pdfs/aqotable.pdf, accessed online January 6, 2017; and http://www.metrovancouver.org/services/air-quality/AirQualityPublications/CurrentAmbientAirQualityObjectives.pdf, accessed online January 25, 2017.

IR6-10 Air Quality – CALMET Modelling: Hybrid Approach

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2.3.1, Figure 2-8, Figure 2-10; Section 2.5.1; Section 4.4, Tables 4.8 to 4.12.

Guidelines for Air Quality Dispersion Modelling in British Columbia. British Columbia Ministry of Environment, 2008

British Columbia Air Quality Dispersion Modelling Guideline. British Columbia Ministry of Environment, 2015

Context

As stated by Metro Vancouver the Proponent relied on mesoscale model (MM) output instead of using Lower Fraser Valley regional meteorological observations from agencies such as Metro Vancouver and Environment and Climate Change Canada. Metro Vancouver emphasized that the use of MM output without surface meteorological observations in CALMET, especially for the Lower Fraser Valley region, is not recommended because it can introduce considerable uncertainty into the dispersion modelling assessment.

The *Guidelines for Air Quality Dispersion Modelling in British Columbia,* 2008 recommended the use of meteorological data as a first option over outputs produced by models. Further, as underlined by Environment and Climate Change Canada, the Weather Research and Forecasting (WRF) mesoscale model that was used in this assessment of the proposed Project has been shown to over-estimate low wind speeds and under-estimate calm conditions which are both vitally important to simulating stagnant conditions that typically result in poor air quality in the Metro Vancouver region.

Metro Vancouver considered that the Proponent's comparison of WRF model results to meteorological observations measured at Abbotsford Airport in 2010 (Figure 2-10) showed that calm conditions were under-predicted by a factor of more than two. Measurements collected at Abbotsford showed calm conditions occurred 13.5% of the time in 2010 while the WRF output used by the Proponent's assessment was shown to predict only half that amount, with calm conditions predicted for only 5.9% of the year. Similarly, at Vancouver International Airport, the WRF model predicted about half of the calm conditions, 6.8% predicted compared with 12.4% calms measured at the meteorological station (Figure 2-8).

Further, the CALMET meteorological model ultimately dictates how emissions are dispersed in CALPUFF. The Tsawwassen station showed calms 7.1% of the time while the CALMET model results indicated that calms occur 0.3% of the time. This indicates that almost 7% of the time the CALPUFF model results could be incorrect and that one of the more important considerations of dispersion modelling, which is modelling calm conditions, was not properly considered in this assessment. As stated by the Proponent, the Tsawwassen station is located almost a kilometre from the shoreline in a residential neighborhood with tall trees. It could therefore be expected that calms would occur in this neighborhood yet the occurrence of

calms measured at the Tsawwassen station (7.1%) was low in comparison to other nearby stations such as Vancouver International Airport (12.4%) and Abbotsford Airport (13.5%). Due to the reliance of the CALMET model on the WRF model outputs, which does not accurately resolve winds and simulate calms in this neighborhood, the CALPUFF model results in this area could be unreliable.

In Section 2.5.1 of the EIS, the assessment provided an evaluation of the CALMET results by comparing results to meteorological observations. The statistical performance of CALMET used in this assessment showed poor performance for both wind speed and wind direction at all compared sites. The error was shown to be outside the acceptable error for wind direction at all sites in Table 2-5.

The evaluation metrics in Table 2-5 also showed that predicted wind speeds are greater in CALMET compared with actual measurements and are shown to have a positive bias which is outside the acceptable range defined. An over-estimation of wind speed indicated that dispersion has also been over-estimated which likely results in an under-estimation of predicted concentrations.

The *British Columbia Air Quality Dispersion Modelling Guideline*, 2015, stated that at least three years of data should be used for the applications where there are significant public concerns about impacts of air quality. However, only one model year, 2010, was considered in CALMET for this assessment. Metro Vancouver questioned the choice of 2010 as the model year as it was an unusually warm start of the year with unseasonable warm air temperatures.

Further, Metro Vancouver questioned the values for the Geophysical parameters provided in Table 2.4 for being considerably different than those recommended in the *British Columbia Air Quality Dispersion Modelling Guideline*, 2015. In Tables 4.8 to 4.12, for example, the anthropogenic heat flux value for the urban land use used in the assessment was stated as 0, assuming that there is no anthropogenic heat in urban areas, when a value of 8 to 21 is recommended in the Guideline.

In addition, different seasons were not considered in the CALMET model. The *British Columbia Air Quality Dispersion Modelling Guideline*, 2015, recommends that seasonal categories are used in CALMET to consider the differences in surface characteristics experienced throughout the year. The agricultural land use category is a dominant land use in the study area and has considerable differences in surface characteristics throughout the various seasons.

The CALMET model was executed without reliance on meteorological observations; used less than the recommended three years of data; and was run for a single year with an unusually warm winter with no consideration of different seasons. Because the CALMET results support CALPUFF modelling, the CALMET results must be reliable.

Information Request

Rerun CALMET using the Hybrid approach where both new Weather Research and Forecasting (WRF) output and meteorological station data is blended in CALMET.

As recommended in the *British Columbia Air Quality Dispersion Modelling Guideline*, 2015, use in the rerun:

- a minimum of three years of meteorological observations;
- a set of relevant geophysical parameters based on actual local conditions (not default values), incorporating seasonal variation; and

- For the hybrid approach, use meteorological data from T39 (Tsawwassen), T17 (Richmond South), Sand Heads, and Boundary Bay Airport, where data are available, and excluding data used to evaluate WRF model output.

Use the results to support CALPUFF modelling.

VFPA Response

Rerun CALMET using the hybrid approach where both new Weather Research and Forecasting (WRF) output and meteorological station data is blended in CALMET.

Based on the definition of hybrid approach[1] in the 2008 Guidelines for Air Quality Dispersion Modelling in British Columbia (2008 B.C. Guidelines; MOE 2008), the hybrid approach of combining mesoscale prognostic meteorological model data with a diagnostic model (i.e., CALMET) was used in the RBT2 Air Quality Study (Study). The Study approach was conducted in accordance with the 2008 B.C. Guidelines, which were the available guidelines at the time the Study was undertaken.

The VFPA recognises that the definition of hybrid approach described in the 2008 B.C. Guidelines changed when the guidelines were updated in 2015 (MOE 2015a). The 2015 British Columbia Air Quality Dispersion Modelling Guideline (2015 B.C. Guideline) defines the hybrid approach as combining meteorological data derived from a Numerical Weather Prediction (NWP) model (such as the WRF-NMM prognostic model) with surface observation data from meteorological stations near an emission source. This pending change on the hybrid approach was raised by the Ministry of Environment in 2013 and discussed during the scoping phase of the RBT2 Air Quality Study with Air Quality Scoping Study (AQSS) process participants[2]. In principle, the VFPA fully supported the use of the hybrid approach in CALMET of combining prognostic meteorological model (WRF) data with representative surface station data, as defined in the 2015 B.C. Guideline. However, appropriate surface observations were not available in the local study area (LSA) to run in the CALMET in the hybrid mode, as discussed further below.

[1] Definition of 'hybrid approach' from the 2008 B.C. Guidelines: "*There is a combined MM and diagnostic model approach, where coarse spatial resolution MM model output is used as an initial guess field for a fine spatial resolution diagnostic model (such as CALMET).*" Unlike the 2015 B.C. Guideline, the 2008 version of the guideline did not explicitly require the use of surface observation data in the definition of 'hybrid mode' modelling.

[2] Appendix IR6-04-A provides a summary of key topics discussed at the onset of the scoping study for the RBT2 Air Quality Assessment, including running CALMET in hybrid mode.

As recommended in the British Columbia Air Quality Dispersion Modelling Guideline, 2015, use in the rerun: a minimum of three years of meteorological observations; a set of relevant geophysical parameters based on actual local conditions (not default values), incorporating seasonal variation; and for the hybrid approach, use meteorological data from T39 (Tsawwassen), T17 (Richmond South), Sand Heads, and Boundary Bay Airport, where data are available, and excluding data used to evaluate WRF model output.

Justification for the study approach taken and rationale for not re-running the CALMET model for the Study using three years of meteorological observation data in hybrid mode (as described in the 2015 B.C. Guideline) is provided below for the following key aspects:

- Clarification of guidance from the 2008 B.C. Guidelines and 2015 B.C. Guideline;
- Insufficient surface observational meteorological data due to meteorological stations siting inadequacies;
- Validation conducted for model results (comparison of modelled to observed data);
- Consideration of the radius of influence of surface observation stations;
- Uncertain quality and reliability of outputs using a hybrid approach; and
- Current United States Environmental Protection Agency (U.S. EPA) policy on the use of prognostic model data.

B.C. Air Quality Dispersion Modelling Guideline – Three Years of Meteorological Data

The response to IR6-04 clarifies that the 2008 B.C. Guidelines and the 2015 B.C. Guideline do not require three years of meteorological data when using prognostic model data at a fine resolution. Both the 2008 and 2015 B.C. Guidelines state that it is impractical to run a modelling analysis using more than one year of high resolution meteorological data when using the hybrid approach at a fine grid resolution (i.e., 100 metres as was used for the RBT2 Air Quality Study), due to the large amount of data processing that this entails.

The 2015 B.C. Guidelines also state that "at least three years of data should be used for the applications where there are significant public concerns about impacts of air quality". The response to IR6-04 explains that existing air quality in this area is good, and is expected to improve in the future with or without the Project; therefore, this guidance is not considered to be applicable.

Furthermore, based on statistical comparisons provided in the response to IR6-04 of the 2010 dataset to 30-year climate normals, re-running the CALMET model based on three years of meteorological data is unlikely to change the conclusions of the Study. This is because 2010 was a representative year[3] and most predicted parameter concentrations are well below the strictest regulatory criteria applicable for the Roberts Bank and surrounding areas.

[3] As noted in the response to IR6-04, during the AQSS in 2013, Environment Canada specifically stated that the RBT2 assessment should be completed using *"a representative year with a warm summer for meteorology data".*

Observational Data from Meteorological Stations

For CALPUFF model applications conducted for a Level 3 assessment, the 2015 B.C. Guideline recommends using the hybrid approach for the following situations:

- There is appropriate observational data (surface data at a minimum with upper air data if available);
- There are 'complex flow' situations (curved trajectories, non-steady wind speed and
- direction, stagnation, enhanced turbulence, and internal boundary layers);
- The NWP model output is subject to the quality checks described in Section 6.1; and
- The NWP model output is introduced as the Initial Guess field.

Station T39 (Tsawwassen), station T17 (Richmond South), and the Westshore Station located at the Tsawwassen ferry terminal do not conform with wind instrument (anemometer) siting guidance from the World Meteorological Organization (WMO 2010), Meteorological Services of Canada (MSC 2001), and by the U.S. EPA (2000) for air quality dispersion modelling analyses, and therefore are not considered appropriate observational data for use in application of the hybrid approach specified in the 2015 B.C. Guideline. Additional information on anemometer siting guidelines, and the specific limitations for each of these stations for this purpose[4], is provided in the response to IR6-05.

The Boundary Bay Airport Station is also unsuitable because there is no surface observation station at the Boundary Bay Airport. The VFPA verified that the meteorological data listed on the Boundary Bay web site is data obtained from the Vancouver International Airport monitoring station and is re-posted on the Boundary Bay Airport web site.

Since the Vancouver International Airport station and the Sand Heads Climate Station, stations that conform to well-established standard anemometer siting guidance, were used to evaluate WRF-NMM model outputs, observation data from these stations could not be used in running CALMET in hybrid mode. The applicability of data from the Abbotsford International Airport station, for the purposes of assessing the Project and air quality at Roberts Bank, was considered to be of limited use in running the CALMET model in hybrid mode due to the distance of the station inland from Roberts Bank (i.e., approximately 58 km from the Project).

In summary, all available station data in the local area were considered, but could not be used to run CALMET in hybrid mode, as either its representativeness of atmospheric conditions at the station was uncertain due to improper instrument siting (i.e., stations T39, T17 and the Westshore Station) or the station data was used to validate the WRF-NMM model (i.e., the stations at the Vancouver International Airport and Sand Heads). The lack of good agreement between observed and CALMET modelled wind speed and direction in the LSA at station T39 and the Westshore Station (see Section 2.5 in Appendix C of EIS Appendix 9.2-A) does not necessarily reflect poor performance of the CALMET model, but does reflect non-

[4] Note that some monitoring stations (e.g., T39, T17) referred to in this response were installed for the purpose of monitoring air quality within the region, not for the collection of meteorological data for use in dispersion modelling. Hence, anemometer siting was not intended to comply with the siting guidelines referred to in this response.

conformance with anemometer siting guidelines at these two stations as defined by the WMO, MSC, and the U.S. EPA. The comparisons between the CALMET model predictions and observations from these two stations were provided in the EIS to specifically demonstrate that these two stations were not suitable for use in either the hybrid mode or for model output validation.

Comparisons of CALMET Model to Observed Meteorological Data

As outlined in Section 2.5 in Appendix C of EIS Appendix 9.2-A and in the response to IR6-05, the only comparable meteorological data sets for CALMET validation were those from Vancouver International Airport and the Sand Heads stations.

During the AQSS process, the VFPA completed a comparison of temperature data from CALMET against the Fraser River Buoy data set provided by Environment Canada. The comparison, presented in Attachment 3 in Appendix C of EIS Appendix 9.2-A, showed that the two data sets were in close agreement, with the maximum temperature difference of 1.1°C being well within the benchmark criteria of 2°C defined in the 2008 B.C. Guidelines and as defined by the University Corporation for Atmospheric Research (UCAR)[5] for the evaluation of mesoscale prognostic meteorological model data sets. Table IR6-05-1 in the response to IR6-05 summarises all model performance statistics to benchmark criteria.

Information on the inclusion of geophysical parameters in CALMET/CALPUFF dispersion modelling completed for the Study is provided in the response to IR6-04 and in Section 2.4.2 in Appendix C of EIS Appendix 9.2-A. As required by the EIS Guidelines, seasonal variations in wind direction and temperature were noted in the comparison of the WRF-NMM and ACARS[6] data as presented in Attachment 2 in Appendix C of EIS Appendix 9.2-A. Also, with respect to diurnal variations in sea breeze effects along the shoreline of Strait of Georgia, the response to IR6-08 of CEAR Document #1104[7] illustrates that diurnal variation in onshore/offshore wind flows has been appropriately captured by the CALMET model.

Radius of Influence of Surface Observation Stations

The use of other meteorological monitoring stations located farther from the LSA for the application of hybrid approach in CALMET was considered during the Project scoping phase to be inappropriate because stations located further inland would not be representative of coastal conditions in the LSA. It was determined that the inclusion of these stations in the analysis would not have affected the air quality dispersion modelling analysis within the LSA because of their distance from the LSA.

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[5] UCAR is a consortium of over 100 member colleges and universities focused on research and training in the atmospheric and related earth system sciences whose members set directions and priorities for the National Center for Atmospheric Research (NCAR) located in Boulder, CO.

[6] Aircraft Communications Addressing and Reporting System (ACARS) provides aircraft-measured vertical temperature and wind profiles.

[7] CEAR Document #1104 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-08, IR7-01, IR7-02, IR7-08, IR7-36, and IR7-39 (See Reference Documents #991 & #1000).

The distant location of other meteorological monitoring stations from the LSA meant that their influence on the meteorological wind flows would not extend to areas near the Project, and thus would not affect predicted concentrations of contaminants within the LSA. Specifically, combining surface observations within the CALMET model requires the modeller to assign a 'radius of influence' to each station. Within CALMET, the modeller must use professional judgement in assigning values to parameters R1 and R2 (i.e., the distances to the point of equal weighting between the initial guess field from the WRF model and observed data for surface and upper stations, respectively). Typical values assigned to R1 are in the range of 3 km to 10 km. At 10 km, the Vancouver International Airport data would have very little influence on the dispersion of contaminants from Roberts Bank. At a distance of 18 km between the airport and Roberts Bank, a hybrid mode analysis would need to assign a R1 value of at least 20 km for the observed data at the airport to make any difference to the dispersion of contaminants from Roberts Bank. Assigning a R1 value of 20 km to the airport data was considered inappropriate because it would assign too much influence to the airport wind data (compared to the data derived from the WRF-NMM modelled data) over too large an area, an influence that would extend to WRF-derived meteorological data as far north as the north shore in West Vancouver and as far east as the New Westminster/Surrey municipal boundary. The same concern applies to other stations within the network of meteorological monitoring stations in the Lower Fraser Valley—they are simply located too far from Roberts Bank to materially affect wind flows in CALMET near to the sources of emission for the RBT2 dispersion modelling assessment.

Quality and Reliability of a Hybrid Modelling Approach

The 2015 B.C. Guideline states that "*The Hybrid approach uses the strength of both NWP and CALMET models to produce at least as good as or often better results than the use of observations alone.*" This statement assumes that the hybrid approach of combining surface observation data and NWP (i.e., WRF-NMM) data in the CALMET model produces a better meteorological dataset than WRF-NMM data or surface observation data alone because it uses 'real' data from surface observations as opposed to only using modelled data. While the inclusion of surface observation data can improve wind flow data in CALMET, that is not always the case. The VFPA provides evidence below, from the U.S. EPA and other studies, indicating that inclusion of such data has been shown to also degrade the quality of the CALMET data. Hence, even with properly sited meteorological stations, there is no guarantee that combining surface observations with meteorological prognostic model data will always result in better meteorological data sets than would be obtained from the prognostic model alone.

As an example, Lee and The (2003) used MM5 prognostic meteorological model data and observation data from five surface stations to determine whether the assignment of R1 values ranging from 0 km to 100 km improved the CALMET modelled wind fields at five other surface observation stations. The authors reported that:

> *"…only the standard deviations of the error of CALMET's prediction of wind directions showed statistical significance. The best performance was shown when the observed data sites were given the least weight. It would not be appropriate to generalize this to all situations. It is clear, however, that giving weight to high quality measured data may still result in degradation in overall*

model performance."

The Lee and The (2003) study showed that CALMET performance improved without surface observation data compared to when these surface observation data were included. While Lee and The (2003) clearly state that this may not be true in every modelling analysis, their analysis shows that including even representative surface observation data may not always result in better quality CALMET wind fields.

During the RBT2 AQSS process, the VFPA provided evidence that the approach ultimately used for the RBT2 Air Quality Study (i.e., using prognostic data at fine scale resolution) can produce better dispersion modelling results than the hybrid approach recommended by the 2015 B.C. Guideline. The VFPA provided regulatory representatives participating in the AQSS process with a study by Radonjic et al. (2013), which showed that the use of prognostic meteorological data alone in a complex terrain setting in a coastal environment produced predicted air contaminant concentrations that more closely matched observed air quality data than using the hybrid approach recommended by the 2015 B.C. Guideline.

The U.S. EPA et al. (2009) also expressed potential concerns arising from use of the hybrid approach, including the following:

- That the incorporation of observational meteorological data into prognostic model data in the hybrid mode (as recommended by the 2015 B.C. Guideline) can lead to unrealistic physical discontinuities in the wind field, even in areas with only modest topographic relief. They stated that *"Historically, it has been difficult to determine the frequency of occurrence of these discontinuities due to the experience deficit of many end users..."*; and
- That the potential for discontinuities to develop in CALMET wind fields is increased in complex areas such as coastal environments, particularly when observational data are assigned too large of a radius of influence (R1/R2 values).

The concern regarding discontinuities in wind fields raised by the U.S. EPA et al. (2009) occur even when the surface observation data are derived from properly sited anemometers. Discontinuities in wind fields are exacerbated when the exposure of the anemometer is poor due to improperly sited instrumentation (as with stations in the LSA), such that wind speed and direction are inaccurately measured at the observation stations.

Current U.S. EPA Policy on Use of Prognostic Model Data

The approach taken in the RBT2 Air Quality Study is consistent with recent regulatory guidance from the U.S. EPA[8] on the use of prognostic meteorological data for air quality modelling (i.e., when there is a lack of good surface observation data), as explained below.

In 2015, the U.S. EPA (2015) evaluated the use of prognostic meteorological model data using

[8] Environment Canada and the B.C. Ministry of Environment defer to guidance from the U.S. EPA on dispersion model selection and application (MOE 2015b).

the regulatory AERMOD model[9] (a dispersion model similar to the CALPUFF model), in order to determine whether such prognostic model data was comparable to National Weather Service (NWS) or site-specific meteorological data. The evaluation also determined how AERMOD performance compared to observed contaminant concentrations based on prognostic meteorological data with simulations based on NWS or site-specific data. The evaluation was conducted for three areas involving differing complexities of terrain from relatively flat to complex; differing resolutions of prognostic model output; and two different pollutants, SO_2 and lead. Evaluation of the meteorological data for several variables indicated that while there were differences between the prognostic model output and observations, the prognostic model output was not unreasonable.

As a result of this evaluation, in late 2016, the U.S. EPA endorsed the use of prognostic meteorological data (e.g., WRF) to provide meteorological input for regulatory dispersion modelling applications (e.g., the CALMET/CALPUFF System) as part of its update to the Guideline on Air Quality Models (U.S. EPA 2017). The U.S. EPA stated that the update to the modelling guidelines will provide more flexibility and improve the meteorological inputs used for near-field dispersion modelling applications where there is no representative NWS station, or where it is prohibitive or not feasible to collect adequately representative site-specific data.

Summary

In summary, the air dispersion modelling approach used for the RBT2 Air Quality Study was consistent with the air quality dispersion modelling guidelines issued by the MOE (2008 and 2015 versions), as well as with the most recent guidance from the U.S. EPA on the use of prognostic model data such as WRF.

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[9] As with the CALPUFF model used for the RBT2 Air Quality Study, the AERMOD model is a dispersion model used to estimate the concentration of contaminants.

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IR6-11 Air Quality – CALMET-CALPUFF Model Domain Size

Information Source(s)

EIS Volume 2: Section 9.2.5.2, Figures 9.2-1 and 9.2-2; Appendix 9.2-A: Figure 4-10 and 4-12; Appendix C, Section 1.2; Attachment 1, Figure 3-3; Appendix E, Figures 4-10 to 4-14

Context

In Section 1.2 of Appendix C of Appendix 9.2-A, the Proponent stated that the goal of defining the dimensions of the local study area domain for the Project was to ensure that all air quality effects greater than 10% of the ambient air quality objectives were evaluated within its boundaries. However, the many isopleth plots provided demonstrated that air quality effects greater than 10% of the ambient air quality objectives were not evaluated within its boundaries. Following are some examples provided by Metro Vancouver:

- Figure 4-10 showed the 1-hour NO_2 concentrations under existing, expected and future conditions. In this figure, the 160 ug/m^3 isopleth (80% of Metro Vancouver's objective or 40% of the British Columbia provincial objective) was shown to extend beyond the model domain boundary for all scenarios;
- Figure 4-12 showed the annual NO_2 concentrations under existing, expected and future conditions. In this figure, the 15 ug/m^3 isopleth (37.5% of Metro Vancouver's objective or 25% of the federal standard) was shown to be beyond the model domain boundary for existing conditions; and
- In Figure 4-13 Appendix E, the PM_{10} isopleth of 50 ug/m^3 (100% of the objective) was shown near the southern model boundary and the 25 ug/m^3 isopleth (50% of the objective) extends beyond the model domain.

As underlined by Metro Vancouver, the ship plume study cited in the EIS, Section 9.2.5.2, stated that ship plumes can be detected at distances greater than five kilometres from their berths in Vancouver, yet ship emission sources are located less than two kilometres away from the western model boundary in this modelling assessment. To reasonably ensure that ship emissions are modelled appropriately, Metro Vancouver considered that the emission sources should be inset from the model edge by at least five kilometres, as supported in the literature, and by an additional two kilometres to remove any concern about edge effects.

It was also recommended by Metro Vancouver that CALPUFF receptors are not placed on the model edge so that edge effects could be avoided. CALMET results are not reliable near the model domain boundary since the model has no information from the other side of the edge. The CALPUFF model domain should be inset from the CALMET domain by several kilometres so that edge effects can be avoided. Given this, the CALPUFF results within several kilometres of the model edge cannot be relied upon, thus reducing the effective model domain size even further. The modelling assessment had ship emission sources (Figure 3-3 of Appendix C) located less than two kilometres from the model domain boundary.

As underlined by Environment and Climate Change Canada and Metro Vancouver, the dispersion modelling domain was not large enough to appropriately consider onshore and

offshore wind patterns that are prevalent at the Project site and to adequately predict air pollutant concentrations.

The review of assessment results and modelled sources indicate that a larger model domain is required, such as a 50 kilometres by 50 kilometres CALMET/CALPUFF model domain.

Information Request

Rerun CALMET and CALPUFF with a model domain no smaller than 50 kilometres by 50 kilometres that would avoid edge effects and include all air quality effects greater than 10% of the ambient air quality objectives.

Present and discuss the new results for existing, expected and future conditions.

VFPA Response

As clarification and further background information, the RBT2 Air Quality Study (RBT2 Study) 19 km x 16 km local study area (LSA) was selected based on the following:

- Based on previous knowledge and relatively recent experience with air dispersion modelling at Roberts Bank over the past two decades, the LSA was deemed sufficient to determine potential air quality changes from emission sources at Roberts Bank;
- The LSA includes populated areas on Tsawwassen First Nation Lands, and in Ladner, Tsawwassen, and Point Roberts where discrete receptors[1] were selected and where ambient air quality objectives apply (i.e., public areas, as outlined in the response to IR6-37);
- The LSA domain area was intended to include **all Project-related** contaminant concentrations representing greater than 10% of ambient air quality objectives or standards (i.e., LSA was not selected to include all air quality contaminant concentrations from all sources). Note that the isopleth maps illustrate total concentrations from **all sources and** are inclusive of **background** concentrations; and
- The LSA domain would capture ship plumes at distances up to 5 km from their berth (distance based on a study conducted by Lu et al. 2006).

Dispersion modelling using CALPUFF in the RBT2 Study was conducted on a meteorological domain of 26 km x 24 km (see **Figure IR6-11-1**) and the RBT2 Study results were presented within the LSA domain of 19 km x 16 km.

Sensitivity Analysis using 30 km x 30 km Modelling Domain (Extended North and East)

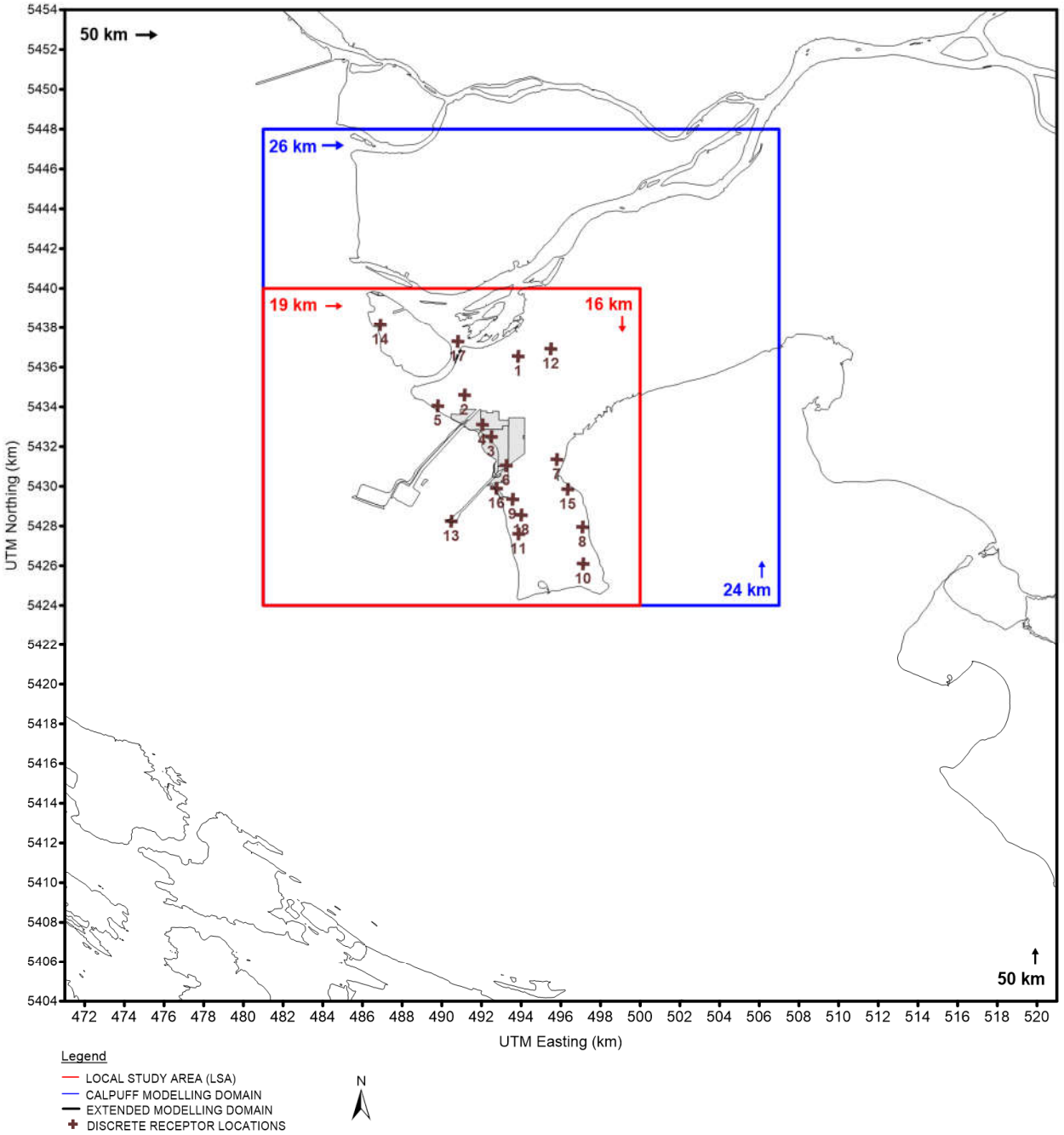
In response to concerns over the modelling domain size raised during the Air Quality Scoping Study (AQSS) process in 2013 (see IR6-04 and Appendix IR6-04-A for more information), the

[1] Eighteen discrete receptors were selected to assist in the discussion of the RBT2 Study results from the 8,642 gridded receptors located in the LSA. For more information on the selection and purpose of discrete receptors, refer to the response for IR6-24.

VFPA conducted a sensitivity analysis to compare results from the 26 km x 24 km modelling domain (as used in the RBT2 Study) to a 30 km x 30 km domain size (size as suggested by AQSS participants based on the modelling domain previously assessed for the Deltaport Third Berth Project in 2005). The domain was extended 6 km northward and 4 km eastward from the 26 km x 24 km RBT2 Study modelling domain to encompass a larger overland region.

In order to test the effect of the extended domain size on concentrations predicted in the RBT2 Study modelling domain, CALPUFF was run assuming emissions from a 12,000 TEU (twenty-foot equivalent) ship at berth and another 12,000 TEU ship in manoeuvring mode at RBT2. The higher release height and thermal plume buoyancy of a ship plume was chosen as the emission source, as emissions from a ship are more likely to be affected by plume recirculation than are emissions from cargo handling equipment, container trucks, or locomotives (i.e., emissions from these sources are released closer to the surface and produce maximum concentrations at locations closer to their source of emission). The sensitivity analysis and results were discussed with AQSS participants (see Appendix IR6-04-A for discussion topic summary) and included in Attachment 1 in Appendix C of EIS Appendix 9.2-A. The sensitivity analysis showed that there was almost complete overlap between the predicted concentrations for both domain sizes, and hence, predicted concentrations at discrete receptor locations were almost identical.

Figure IR6-11-1 RBT2 Local Study Area and Modelling Domain and 50 km x 50 km Modelling Domain



Sensitivity Analysis using 31 km x 34 km Modelling Domain (Extended South and West)

The VFPA conducted another sensitivity analysis in April 2017 on a domain size of 31 km x 34 km, expanding the RBT2 Study modelling domain 5 km westward and 10 km southward (i.e., in opposite direction to the previous sensitivity analysis). The domain extension considered comments regarding the sufficiency of the modelling domain used for the RBT2 Study posted in 2016 to the Canadian Environmental Assessment registry[2]. The analysis used a single point source of NO_x and SO_2 emissions simulating a 12,000 TEU ship at berth at the RBT2 terminal. A memorandum documenting the analysis and results of this sensitivity analysis is provided in **Appendix IR6-11-A**. In summary, the sensitivity analysis showed that there are no appreciable differences in maximum predicted concentrations (i.e., 1-hour (1-h) average NO_2 and SO_2) for a ship at berth between the two modelling domain size simulations.

Sensitivity Analysis using 50 km x 50 km Modelling Domain (Extended in All Directions)

Although the results of prior sensitivity analyses have shown that contaminant concentrations from modelling within a 26 km x 24 km domain are comparable to concentrations predicted from larger modelling domains, a sensitivity modelling analysis has been completed for the requested modelling domain size of 50 km x 50 km[3] (i.e., extended 9 km westward and 15 km eastward, 6 km northward and 20 km southward from the 26 km x 24 km domain), as shown on **Figure IR6-11-1**. The following discussion presents a summary of the methods used for the sensitivity analysis and the results of the 50 km x 50 km sensitivity modelling analysis.

50 km x 50 km Modelling Domain Sensitivity Analysis – Method of Analysis

The meteorological dataset used for the RBT2 Study was derived from the Weather Research Forecast Non-hydrostatic Mesoscale Model[4] (WRF-NMM; Appendix C in EIS Appendix 9.2-A). Hourly surface data and vertical profiles extracted from the WRF-NMM model outputs at 13 locations within the RBT2 modelling domain were combined with data extracted at seven additional locations in order to cover the extended model domain (see **Figure IR6-11-2**, locations 14 to 20). Hourly surface and upper-level data were used in the CALMET meteorological processor as 'pseudo' observations. Terrain, land use, and other geophysical data (such as albedo, Bowen ratio, roughness length, and soil heat flux and leaf area index) were developed over the extended model domain (50 km x 50 km, at the horizontal grid resolution of 1 km) to create an input file to CALMET. The CALMET model was run over 50 km x 50 km domain, with a horizontal grid resolution of 1 km.

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[2] See CEAR Document #629 (BCH-07 B.C. Ministry of Health) and #654 (MV-11 Metro Vancouver) as examples of concerns raised regarding the extent of the modelling domain.

[3] Note that the 2015 B.C. Air Quality Dispersion Modelling Guideline recommend a domain size of 50 km x 50 km for thermally buoyant exhaust plumes from tall stack sources, which is not relevant for exhaust plumes from short ship stacks (and subject to building wake effects, which have been taken into consideration).

[4] Janjic 2001, 2003a, 2003b

Consistent with the approach taken with prior sensitivity analyses, CALPUFF was run using a single point source (i.e., a 12,000 TEU ship at berth at the RBT2 Terminal) in order to test the effect of the extended domain size on NO_x, SO_2, PM_{10}, and $PM_{2.5}$ concentrations within the area, and concentrations predicted in for discrete receptors in the LSA.

Two model runs using a full year of meteorological data (2010) were conducted for the current sensitivity analysis: 1) over the 50 km x 50 km extended modelling domain and 2) over the 26 km x 24 km RBT2 meteorological modelling domain, both with the same horizontal resolution of 1 km for direct comparison. Assumed ship stack parameters and emission rates of NO_x, SO_2, PM_{10}, and $PM_{2.5}$ from a 12,000 TEU ship at a RBT2 berth are provided in **Table IR6-11-1**. These emission rates include emissions from the auxiliary engines and ship's boiler, and do not take into consideration any reductions in emissions due to shore power[5]. The predicted concentrations were evaluated for the same receptor grid and at eighteen discrete receptor points as defined in the RBT2 Study.

[5] Shore power will be available at all three berths at RBT2, but benefits of this technology have not been included in this analysis.

Figure IR6-11-2 CALMET Terrain and 'Pseudo' Meteorological Observation Locations

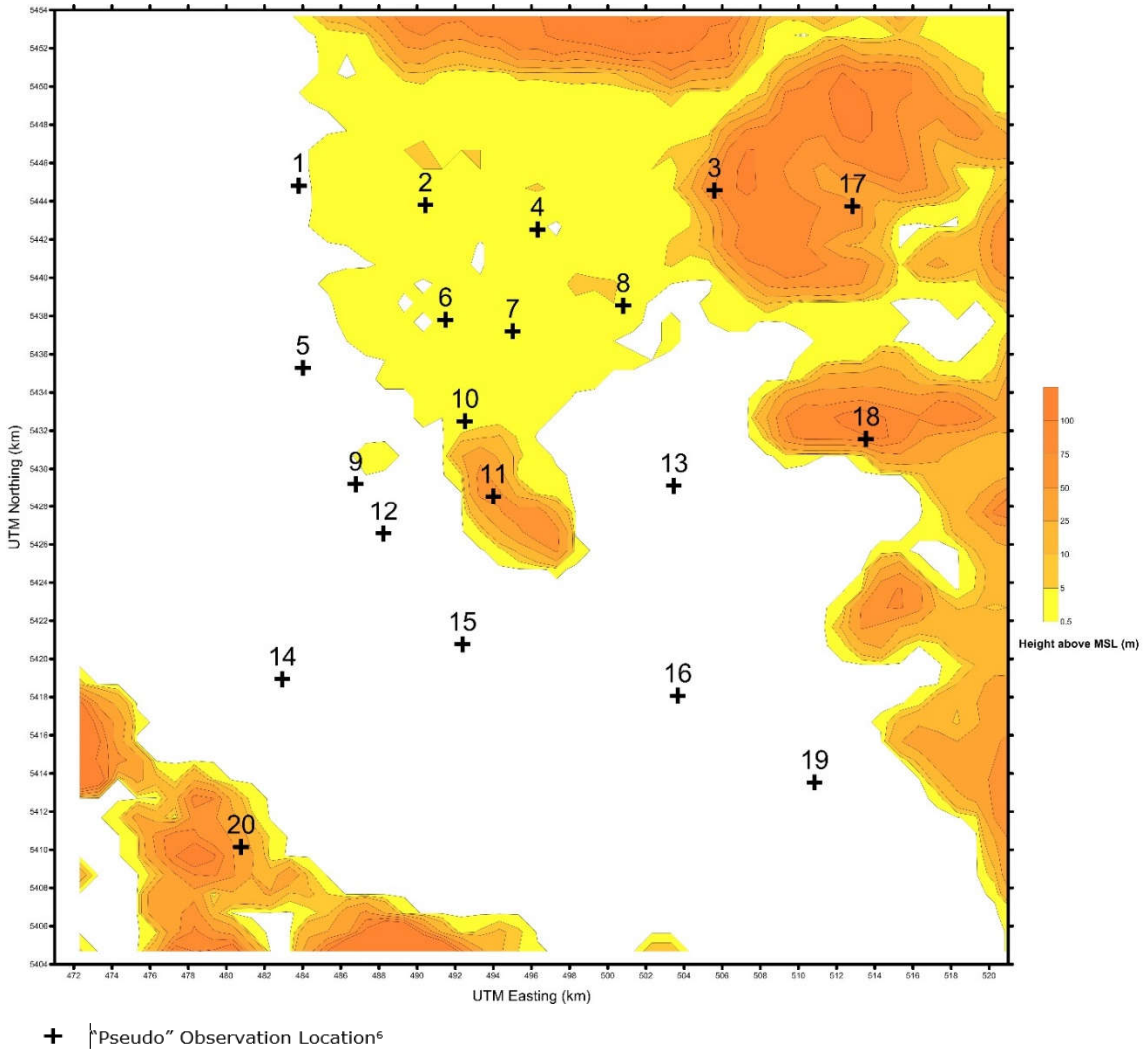

Table IR6-11-1 Source Characteristics and Emission Rates

Stack Height (m)	Stack Diameter (m)	Exhaust Gas Temperature (K)	Exhaust Gas Velocity (m/s)	NOx Emission (g/s)	SO_2 Emission (g/s)	PM_{10} Emission (g/s)	$PM_{2.5}$ Emission (g/s)
49.5	0.5	621	16	4.08	0.47	0.285	0.262

50 km x 50 km Modelling Domain Sensitivity Analysis – Maximum Predicted NO_2 Concentrations

NO_2 concentrations were determined using the 98th percentile observed ozone level at Station T39 with the Ozone Limiting Method (for more information on this method, refer to Section 3.3.1 in EIS Appendix 9.2-A). Figure IR6-11-B1 in **Appendix IR6-11-B** shows the maximum predicted concentrations for 1-h average NO_2 concentrations for the extended modelling domain (left side) and the RBT2 Study modelling domain (right side), while Figure IR6-11-B2 shows the differences in the maximum predicted 1-h average NO_2 concentrations between the two modelling domains[6].

Table IR6-11-2 lists the maximum predicted 1-h average NO_2 concentrations at discrete receptor locations within the LSA for each modelled domain, as well as the difference in concentrations between the two modelling domains[6].

The predicted NO_2 concentrations at the discrete receptor locations in **Table IR6-11-2** for both the extended modelling domain and the RBT2 Study modelling domain ranged from 3.3 µg/m^3 at the Delta Hospital (R12) to 21.9 µg/m^3 at the Ferry Terminal (R13). At 16 of the 18 discrete receptor locations, the difference in predicted 1-h average NO_2 concentrations between the RBT2 modelling domain and the extended modelling domain is less than 0.2 µg/m^3. The maximum difference is 1 µg/m^3 at Boundary Bay (R8). However, as discussed in the response to IR6-22, the use of the Ozone Limiting Method to estimate NO_2 concentrations resulted in over prediction of actual NO_2 concentrations by a factor of 2 using the 98th percentile observed ozone concentration at Station T39, and by a factor of 2.0 to 2.9 if using the 100th percentile observed ozone concentration. Therefore, the difference in maximum predicted 1-h average NO_2 concentrations between the two modelling domains would be half of what is reported in **Table IR6-11-2** (e.g., at Boundary Bay, the difference is more likely ≤0.5 µg/m^3 between the two modelling domain predictions) and shown in Figure IR6-11-B2 (**Appendix IR6-11-B**).

Table IR6-11-2 Maximum Predicted 1-h Average NO_2 Concentrations at Discrete Receptor Locations

UTM Location (km)		Discrete Receptor	Predicted 1-h NO_2 Concentration (µg/m^3)		
Easting	Northing		Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 Km)	Difference (Extended - RBT2)
493.850	5436.550	R1 Ladner	5.6	5.6	0.00
491.150	5434.601	R2 Farmer 1	7.6	7.5	0.17
492.500	5432.500	R3 Tsawwassen First Nation	9.5	9.5	0.00

[6] The difference in predicted concentrations between the two modelling domains at each discrete receptor was calculated by subtracting the RBT2 Study concentration from the extended modelling domain concentration.

UTM Location (km)		Discrete Receptor	Predicted 1-h NO_2 Concentration (µg/m^3)		
Easting	Northing		Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 Km)	Difference (Extended - RBT2)
492.050	5433.101	R4 Farmer 2	6.7	6.7	0.00
489.800	5434.050	R5 Farmer 3	7.2	7.2	0.00
493.250	5431.050	R6 Tsawwassen Beach Campsite	14.6	14.6	0.00
495.800	5431.351	R7 Beach Grove	5.8	5.8	0.00
497.100	5427.951	R8 Boundary Bay	9.4	8.4	1.00
493.575	5429.351	R9 Tsawwassen	8.6	8.6	0.00
497.125	5426.101	R10 Point Roberts 1	10.0	10.0	0.04
493.875	5427.601	R11 Point Roberts 2	12.7	11.7	0.97
495.499	5436.926	R12 Delta Hospital	3.3	3.3	0.00
490.480	5428.242	R13 Ferry Terminal	21.9	21.9	0.02
486.900	5438.150	R14 Reifel Bird Sanctuary	5.6	5.6	0.00
496.350	5429.851	R15 Boundary Bay GVRD Park	6.4	6.4	0.00
492.760	5429.900	R16 English Bluffs Beach	10.8	10.8	0.00
490.810	5437.300	R17 South Arm Marsh	4.5	4.5	0.00
494.008	5428.557	R18 Air Quality Station T39	8.3	8.3	0.01

50 km x 50 km Modelling Domain Sensitivity Analysis – Maximum Predicted SO_2 Concentrations

Figure IR6-11-B3 (**Appendix IR6-11-B**) shows the maximum predicted concentrations for 1-h average SO_2 concentrations for the extended modelling domain (left side) and the RBT2 Study modelling domain (right side), while Figure IR6-11-6-B4 shows the differences in maximum predicted 1-h average SO_2 concentrations between the two modelling domains[6].

Table IR6-11-3 lists the maximum predicted 1-h average SO_2 concentrations at discrete receptor locations within the LSA for each modelled domain, as well as the difference in concentrations between the two modelling domains[6]. The maximum predicted concentrations at the discrete receptor locations for both modelling domains ranged from 0.38 at the Delta Hospital (R12) to 2.52 µg/m^3 at the Ferry Terminal (R13). At 15 of the 18 discrete receptor locations, the maximum predicted 1-h average SO_2 concentrations are the same for the two modelling domains. The largest difference in the maximum predicted 1-h average SO_2 concentration of 0.12 µg/m^3 was at the receptor location at Boundary Bay (R8).

Table IR6-11-3 Maximum Predicted 1-h Average SO_2 Concentrations at Discrete Receptor Locations

UTM Location (km)		Discrete Receptor	Predicted 1-h SO_2 Concentration (µg/m³)		
Easting	Northing		Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 km)	Difference (Extended - RBT2)
493.850	5436.550	R1 Ladner	0.65	0.65	0.00
491.150	5434.601	R2 Farmer 1	0.88	0.86	0.02
492.500	5432.500	R3 Tsawwassen First Nation	1.09	1.09	0.00
492.050	5433.101	R4 Farmer 2	0.77	0.77	0.00
489.800	5434.050	R5 Farmer 3	0.83	0.83	0.00
493.250	5431.050	R6 Tsawwassen Beach Campsite	1.68	1.68	0.00
495.800	5431.351	R7 Beach Grove	0.66	0.66	0.00
497.100	5427.951	R8 Boundary Bay	1.08	0.96	0.12
493.575	5429.351	R9 Tsawwassen	0.98	0.98	0.00
497.125	5426.101	R10 Point Roberts 1	1.15	1.15	0.00
493.875	5427.601	R11 Point Roberts 2	1.46	1.35	0.11
495.499	5436.926	R12 Delta Hospital	0.38	0.38	0.00
490.480	5428.242	R13 Ferry Terminal	2.52	2.52	0.00
486.900	5438.150	R14 Reifel Bird Sanctuary	0.64	0.64	0.00
496.350	5429.851	R15 Boundary Bay GVRD Park	0.74	0.74	0.00
492.760	5429.900	R16 English Bluffs Beach	1.25	1.25	0.00
490.810	5437.300	R17 South Arm Marsh	0.52	0.52	0.00
494.008	5428.557	R18 Air Quality Station T39	0.96	0.96	0.00

50 km x 50 km Modelling Domain Sensitivity Analysis – Maximum Predicted $PM_{2.5}$ and PM_{10} Concentrations

Figures IR6-11-B5 and IR6-11-B7 (in **Appendix IR6-11-B**) show the maximum predicted 24-h average concentrations of PM_{10} and $PM_{2.5}$, respectively, for the extended (left side) and the RBT2 Study (right side) modelling domains. Figures IR6-11-B6 and IR6-11-B8 show the differences in maximum predicted 24-h average PM_{10} and $PM_{2.5}$ concentrations, respectively, between the two modelling domains[6].

Tables IR6-11-4 and **IR6-11-5** list the maximum predicted 24-h average PM_{10} and $PM_{2.5}$ concentrations, respectively, at discrete receptor locations within the LSA for each modelled domain, as well as the difference in concentrations between the two modelling domains[6]. The maximum predicted PM_{10} concentrations for the extended 50 km x 50 km model domain at the discrete receptor locations ranged from 0.03 µg/m^3 (at R1 Ladner and R12 Delta Hospital) to 0.2 µg/m^3 (at R13 Ferry Terminal). Maximum predicted $PM_{2.5}$ concentrations for the RBT2 model domain at the discrete receptor locations were similar, ranging from 0.02 µg/m^3 (at R12 Delta Hospital) to 0.2 µg/m^3 (at R13 Ferry Terminal). At 16 of 18 discrete receptor locations listed in **Table IR6-11-4**, there was either no difference in maximum predicted 24-h average PM_{10} concentrations or the differences were less than 0.01 µg/m^3. The maximum differences at Boundary Bay (R8) and at Point Roberts 1 (R10) were less than 0.02 µg/m^3.

Similarly, the maximum predicted $PM_{2.5}$ concentrations at the discrete receptor locations for both model simulations ranged from 0.03 µg/m^3 (at R1 Ladner and R4 Farmer 2) to 0.18 µg/m^3 (at R13 Ferry Terminal) (**Table IR6-11-5**). The differences in maximum predicted 24-h average $PM_{2.5}$ concentrations were less than 0.002 µg/m^3 at 16 of 18 discrete receptor locations, and less than 0.02 µg/m^3 at Boundary Bay (R8) and Point Roberts 1 (R10).

Table IR6-11-4 Maximum Predicted 24-h PM_{10} Concentrations at Discrete Receptor Locations

X (km)	Y (km)	Sensitive Receptor Name	Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 km)	Difference (Extended-RBT2)
			PM_{10} - 24 h	PM_{10} - 24 h	PM_{10} - 24 h
493.850	5436.550	R1 Ladner	0.03	0.03	0.0000
491.150	5434.601	R2 Farmer 1	0.06	0.06	0.0012
492.500	5432.500	R3 Tsawwassen First Nation	0.07	0.07	0.0000
492.050	5433.101	R4 Farmer 2	0.04	0.04	0.0000
489.800	5434.050	R5 Farmer 3	0.05	0.05	0.0000
493.250	5431.050	R6 Tsawwassen Beach Campsite	0.13	0.13	0.0001
495.800	5431.351	R7 Beach Grove	0.06	0.06	0.0000
497.100	5427.951	R8 Boundary Bay	0.08	0.06	0.0145
493.575	5429.351	R9 Tsawwassen	0.08	0.08	0.0000
497.125	5426.101	R10 Point Roberts 1	0.08	0.06	0.0163
493.875	5427.601	R11 Point Roberts 2	0.14	0.14	0.0014
495.499	5436.926	R12 Delta Hospital	0.03	0.02	0.0003
490.480	5428.242	R13 Ferry Terminal	0.20	0.20	0.0000
486.900	5438.150	R14 Reifel Bird Sanctuary	0.06	0.06	0.0000
496.350	5429.851	R15 Boundary Bay GVRD Park	0.05	0.05	0.0000

X (km)	Y (km)	Sensitive Receptor Name	Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 km)	Difference (Extended-RBT2)
			PM_{10} - 24 h	PM_{10} - 24 h	PM_{10} - 24 h
492.760	5429.900	R16 English Bluffs Beach	0.11	0.11	0.0009
490.810	5437.300	R17 South Arm Marsh	0.04	0.04	0.0001
494.008	5428.557	R18 Air Quality Station T39	0.06	0.06	0.0021

Table IR6-11-5 Maximum Predicted 24-h $PM_{2.5}$ Concentrations at Discrete Receptor Locations

X (km)	Y (km)	Sensitive Receptor Name	Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 km)	Difference (Extended-RBT2)
			$PM_{2.5}$ -24 h	$PM_{2.5}$-24 h	$PM_{2.5}$ -24 h
493.850	5436.550	R1 Ladner	0.03	0.03	0.0000
491.150	5434.601	R2 Farmer 1	0.05	0.05	0.0011
492.500	5432.500	R3 Tsawwassen First Nations	0.06	0.06	0.0000
492.050	5433.101	R4 Farmer 2	0.03	0.03	0.0000
489.800	5434.050	R5 Farmer 3	0.05	0.05	0.0000
493.250	5431.050	R6 Tsawwassen Beach Campsite	0.12	0.12	0.0001
495.800	5431.351	R7 Beach Grove	0.05	0.05	0.0000
497.100	5427.951	R8 Boundary Bay	0.07	0.06	0.0133
493.575	5429.351	R9 Tsawwassen	0.07	0.07	0.0000
497.125	5426.101	R10 Point Roberts 1	0.07	0.05	0.0150
493.875	5427.601	R11 Point Roberts 2	0.13	0.13	0.0013
495.499	5436.926	R12 Delta Hospital	0.02	0.02	0.0003
490.480	5428.242	R13 Ferry Terminal	0.18	0.18	0.0000
486.900	5438.150	R14 Reifel Bird Sanctuary	0.06	0.06	0.0000
496.350	5429.851	R15 Boundary Bay GVRD Park	0.04	0.04	0.0000
492.760	5429.900	R16 English Bluffs Beach	0.10	0.10	0.0008
490.810	5437.300	R17 South Arm Marsh	0.04	0.04	0.0001
494.008	5428.557	R18 Air Quality Station T39	0.06	0.06	0.0019

50 km x 50 km Modelling Domain Sensitivity Analysis – Location of Maximum Predicted Concentrations

Figures IR6-11-B1, IR6-11-B3, IR6-11-B5, and IR6-11-B7 (in **Appendix IR6-11-B**) show that the highest predicted NO_x, SO_2, PM_{10}, and $PM_{2.5}$ concentrations, respectively, from a ship at berth at RBT2 would occur at and in the immediate vicinity of the RBT2 Terminal. This is due to the effect of plume downwash due to the short exhaust stack on a container ship in relation to the ship superstructure and container cargo itself. Consequently, the size of the modelling domain has little, if any, bearing on the location and magnitude of the maximum predicted concentrations in the LSA from ships at berth. Only minor differences in the isopleth plots appear along the southern and western boundary, but this seems to be an artificial effect of the modelling boundary (i.e., an edge effect).

50 km x 50 km Modelling Domain Sensitivity Analysis – Conclusions

As shown in **Tables IR6-11-2**, **IR6-11-3**, **IR6-11-4**, and **IR6-11-5**, the maximum predicted 1-h average NO_2 and SO_2 concentrations and 24-h average PM_{10} and $PM_{2.5}$ concentrations at discrete receptor points are virtually identical in both model simulations or have negligibly differences. In conclusion, based on this and prior sensitivity analyses, there would be no appreciable differences in maximum predicted concentrations if a larger modelling domain was used in the RBT2 Study; therefore, re-modelling with a 50 km x 50 km modelling domain was not required.

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Appendices

Appendix IR6-11-A Arcadis April 20, 2017 Memorandum, Sensitivity Analysis on Modelling Domain Size for RBT2 Air Quality Study

Appendix IR6-11-B Large Format Figures

APPENDIX IR6-11-A

ARCADIS APRIL 20, 2017 MEMORANDUM

SENSITIVITY ANALYSIS ON MODELLING DOMAIN SIZE FOR RBT2 AIR QUALITY STUDY

MEMO

ARCADIS Design & Consultancy for natural and built assets

To:
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From:
Svetlana Music

Date:
April 20, 2017

Arcadis Project No.:
380237-019

Subject:
Sensitivity Analysis on Modelling Domain Size for RBT2 Air Quality Study

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This memo outlines the results of an air quality modelling sensitivity analysis conducted to assess the effect of modelling domain size on predicted ambient air contaminant concentrations within the Local Study Area (LSA) presented in the Roberts Bank Terminal 2 (RBT2) Project Air Quality Study (Figure 1). Dispersion modelling completed for the RBT2 Project was conducted on a meteorological domain of 26 km by 24 km (Figure 1). In response to comments and concerns from regulatory agencies that the modelling domain used for the RBT2 Air Quality Study was insufficient to capture recirculating air flows, a sensitivity analysis has been completed for a larger modelling domain size.

The expanded modelling domain extends the RBT2 modelling domain 5 km westward and 10 km southward (i.e. 31 km by 34 km), as shown on Figure 1.

The meteorological dataset used for the RBT2 Air Quality Study was derived using the Weather Research Forecast Non-hydrostatic Mesoscale Model (WRF-NMM)[1]. Hourly surface data and vertical profiles were extracted from the WRF-NMM model outputs

[1] Janjic et al. 2001, Janjic 2003a, b

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at 13 locations within the RBT2 modelling domain (see Figure 2, locations 1 to 13) and used in the CALMET meteorological processor as “pseudo” observations. For the purpose of this sensitivity analysis, three additional locations were extracted from the WRF-NMM model outputs to cover the extended model domain and used as hourly surface and upper-air data in CALMET (see Figure 2, locations 14 to 16). Terrain data and land use and other surface data (such as albedo, Bowen ratio, roughness length, and soil heat flux and leaf area index) were developed over the extended model domain to create an input to CALMET.

In order to test the effect of the extended domain size on concentrations predicted in the LSA, CALPUFF was run using a single point source with NOx and SO_2 emissions simulating a 12,000 TEU ship at berth at the RBT2 Terminal. The use of a single ship at berth is consistent with the previous sensitivity analysis completed in November 2013 in response to concerns expressed by regulatory stakeholders about the size of the modelling domain during the Air Quality Scoping Study (AQSS), as well as with the internal sensitivity modelling analysis completed by Environment and Climate Change Canada (ECCC) in July 2014. Because the sensitivity analysis was conducted to address concerns about potential recirculation of plumes to the west or south of the LSA, the higher release height and thermal plume buoyancy of a ship plume is more likely to be affected by plume recirculation than are emissions from cargo handling equipment, container trucks and locomotives whose emissions are released closer to the surface and produce maximum concentrations at locations close to their source of emission.

One model run using a full year of meteorological data (i.e., 2010) was conducted using the 31 km by 34 km extended modelling domain, while a second modelling run was conducted over the 26 km by 24 km RBT2 modelling domain. Assumed ship stack parameters and NOx and SO_2 emission rates are provided in Table 1. The predicted concentrations were evaluated for the same receptor grid and at eighteen discrete receptor points defined in the RBT2 Air Quality Study.

Table 1 – Source characteristics and NOx and SO_2 Emission Rates

Stack Height (m)	Stack Diameter (m)	Exhaust Gas Temperature (K)	Exhaust Gas Velocity (m/s)	NOx Emission (g/s)	SO_2 Emission (g/s)
49.5	0.5	621	16	4.08	0.47

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Figure 3 shows the maximum predicted concentrations for 1-hour (1-h) averages of NO_2 for the extended modelling domain (left side) and the RBT2 modelling domain (right side), while Figure 4 shows the differences in maximum predicted 1-h average NO_2 concentrations modelled between the two modelling domains. Table 2 lists the maximum predicted 1-h average NO_2 concentrations at discrete receptor locations within the LSA for each modelled domain, as well as the difference in concentrations between the two modelling domains (i.e., concentrations predicted using extended modelling domain minus concentrations predicted using RBT2 modelling domain).

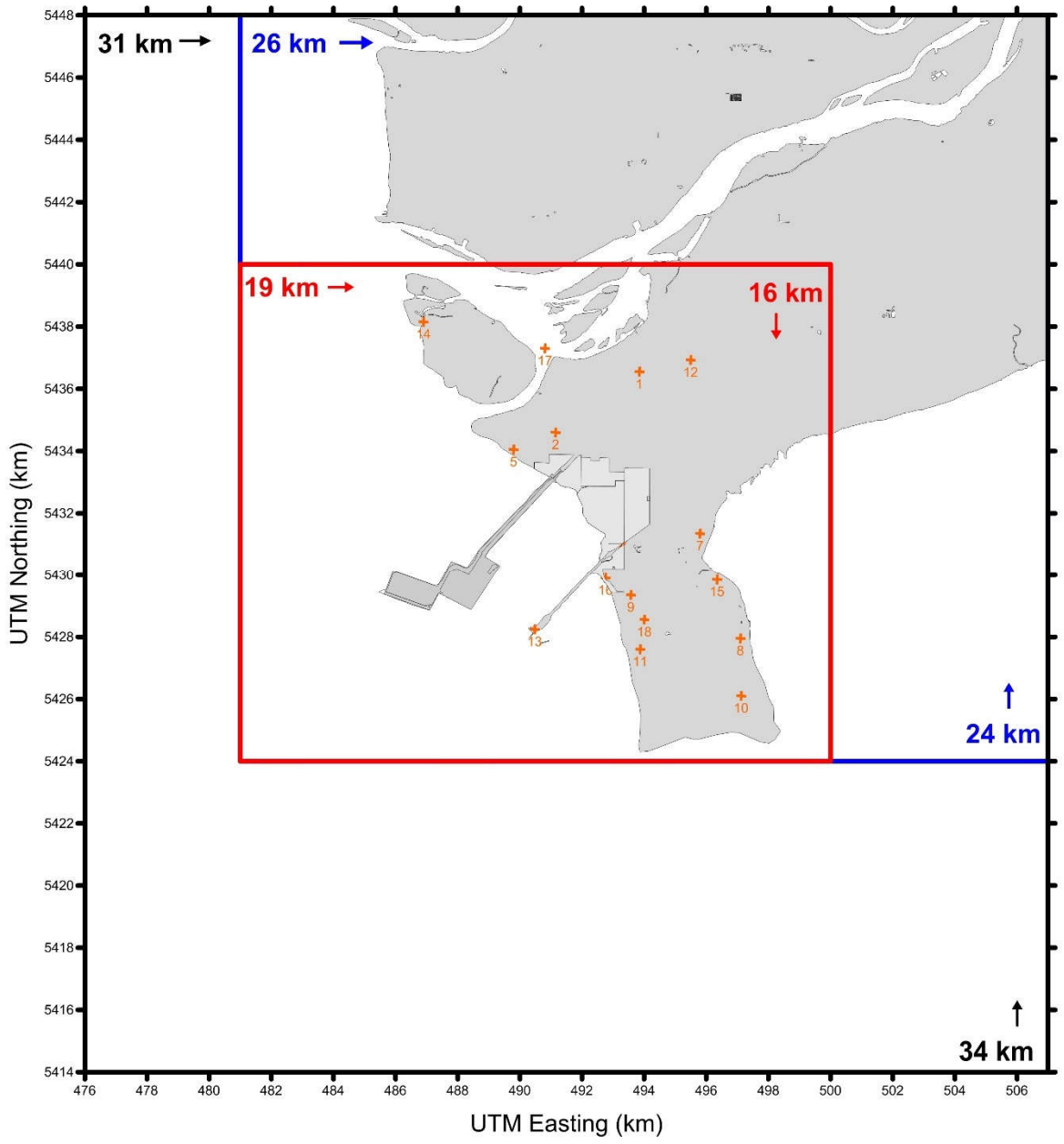
Figure 5 shows the maximum predicted concentrations for 1-h averages of SO_2 for the extended modelling domain (left side) and the RBT2 modelling domain (right side), while Figure 6 shows the differences in maximum predicted 1-h SO_2 concentrations modelled between the two modelling domains. Table 3 lists the maximum predicted 1-h SO_2 concentrations at discrete receptor locations within the LSA for each modelled domain, as well as the difference in concentrations between the two modelling domains.

Figures 3 and 5 show that the highest predicted NOx and SO_2 concentrations, respectively, from a ship at berth occur at, and in the immediate vicinity of, the RBT2 Terminal. This is due to the downwash effect of the short exhaust stack on a container ship in relation to the ship superstructure and container cargo itself. Consequently, the size of the modelling domain has no bearing on the maximum predicted concentrations from ships at berth. Only minor differences in the isopleth plots appear along the southern and western boundary, but this seems to be an artificial effect of the modelling boundary and would not affect the interpretation of the results presented in the RBT2 Air Quality Study.

As shown in Tables 2 and 3, the maximum predicted 1-h average NO_2 and SO_2 concentrations at discrete receptor points are almost identical in both model simulations.

In conclusion, based on this sensitivity analysis, there are no appreciable differences between the two modelling domain simulations in the maximum predicted 1-h average NO_2 and SO_2 concentrations for a ship at berth.

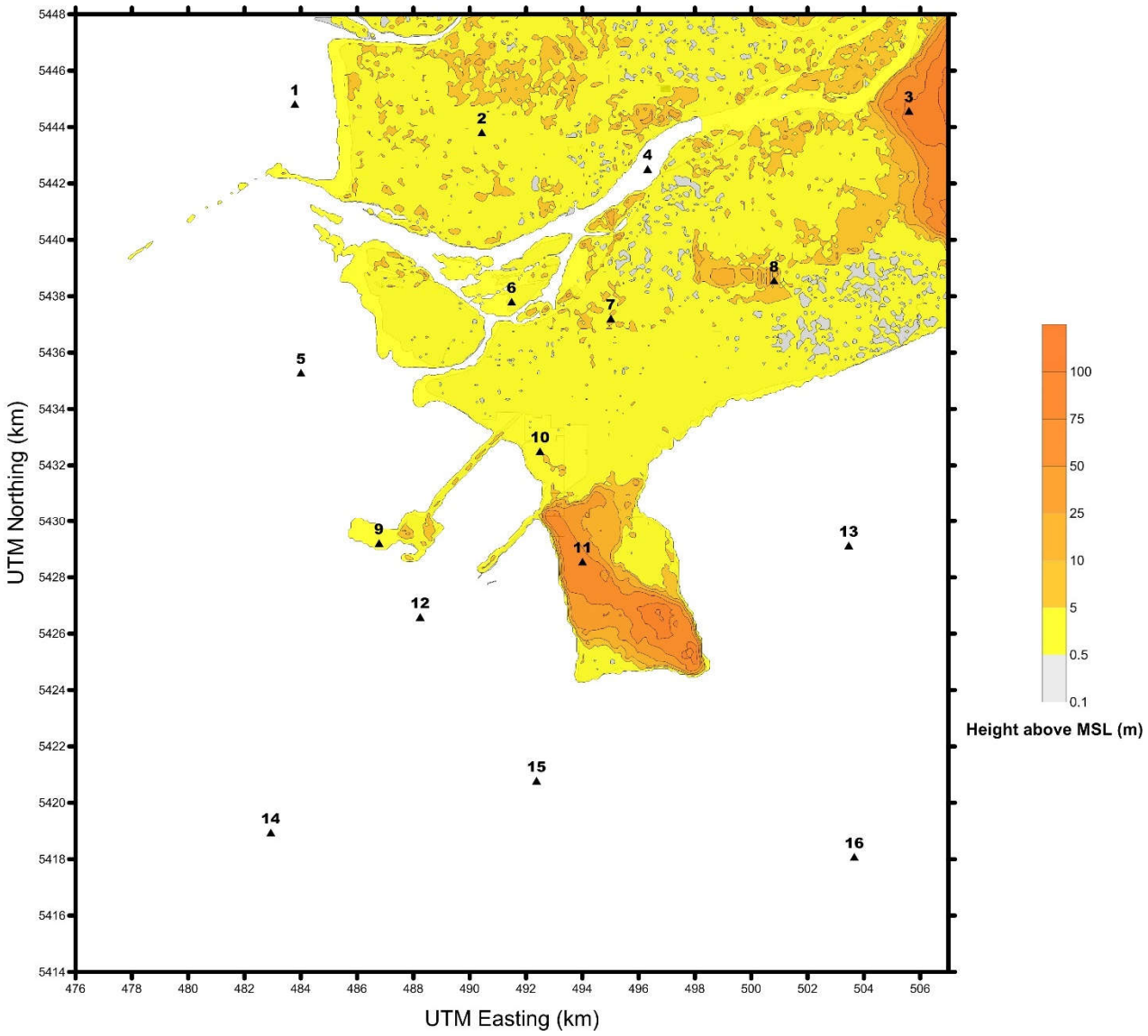
Figure 1 RBT2 Local Study Area and Modelling Domain, and Extended Modelling Domain



Extended Modelling Domain (31 km x 36 km)
RBT2 Modelling Domain (26 km x 24 km)
RBT2 Local Study Area (19 km x 16 km)

+ Discrete Receptor Location

Figure 2 CALMET Terrain and "Pseudo" Observation Locations



▲ "Pseudo" Observation Location

Table 2 – Maximum predicted 1-h NO_2 concentrations at discrete receptor locations

UTM Location (km)		Discrete Receptor	Predicted 1-h NO_2 Concentration (µg/m^3)		
Easting	Northing		Extended Model Domain	RBT2 Model Domain	Difference (Extended-RBT2)
493.850	5436.550	Ladner	4.8	4.8	0.00
491.150	5434.601	Farmer 1	6.8	6.8	0.00
492.500	5432.500	Tsawwassen First Nations	8.2	8.2	0.00
492.050	5433.101	Farmer 2	4.7	4.7	0.00
489.800	5434.050	Farmer 3	8.0	8.0	0.00
493.250	5431.050	Tsawwassen Beach Campsite	14.7	14.7	0.00
495.800	5431.351	Beach Grove	4.2	4.2	0.00
497.100	5427.951	Boundary Bay	9.5	7.9	1.60
493.575	5429.351	Tsawwassen	10.2	10.2	0.00
497.125	5426.101	Point Roberts 1	8.4	8.4	0.00
493.875	5427.601	Point Roberts 2	18.9	17.1	1.81
495.499	5436.926	Delta Hospital	3.4	3.4	0.00
490.480	5428.242	Ferry Terminal	23.6	23.6	0.00
486.900	5438.150	Reifel Bird Sanctuary	5.0	5.0	0.00
496.350	5429.851	Boundary Bay GVRD Park	5.0	5.0	0.00
492.760	5429.900	English Bluffs Beach	14.1	14.1	0.00
490.810	5437.300	South Arm Marsh	4.3	4.3	0.00
494.008	5428.557	Air Quality Station T39	7.4	7.4	0.00

Figure 3 Comparison of Maximum Predicted 1-h NO_2 Concentration Isopleths Modelled over Extended Model Domain (left) and RBT2 Model Domain (right)

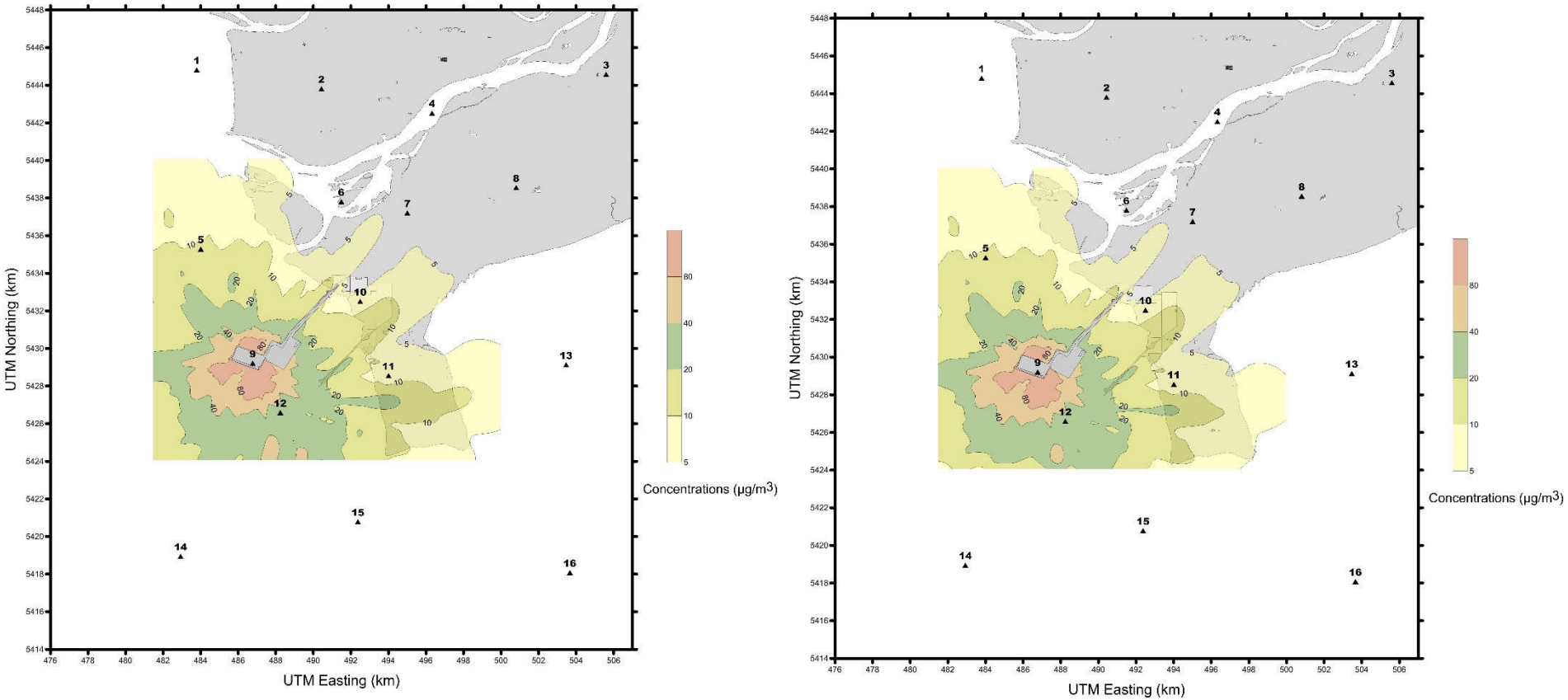


Figure 4 Difference in Maximum Predicted 1-h NO_2 Concentrations using Extended Model Domain and RBT2 Model Domain

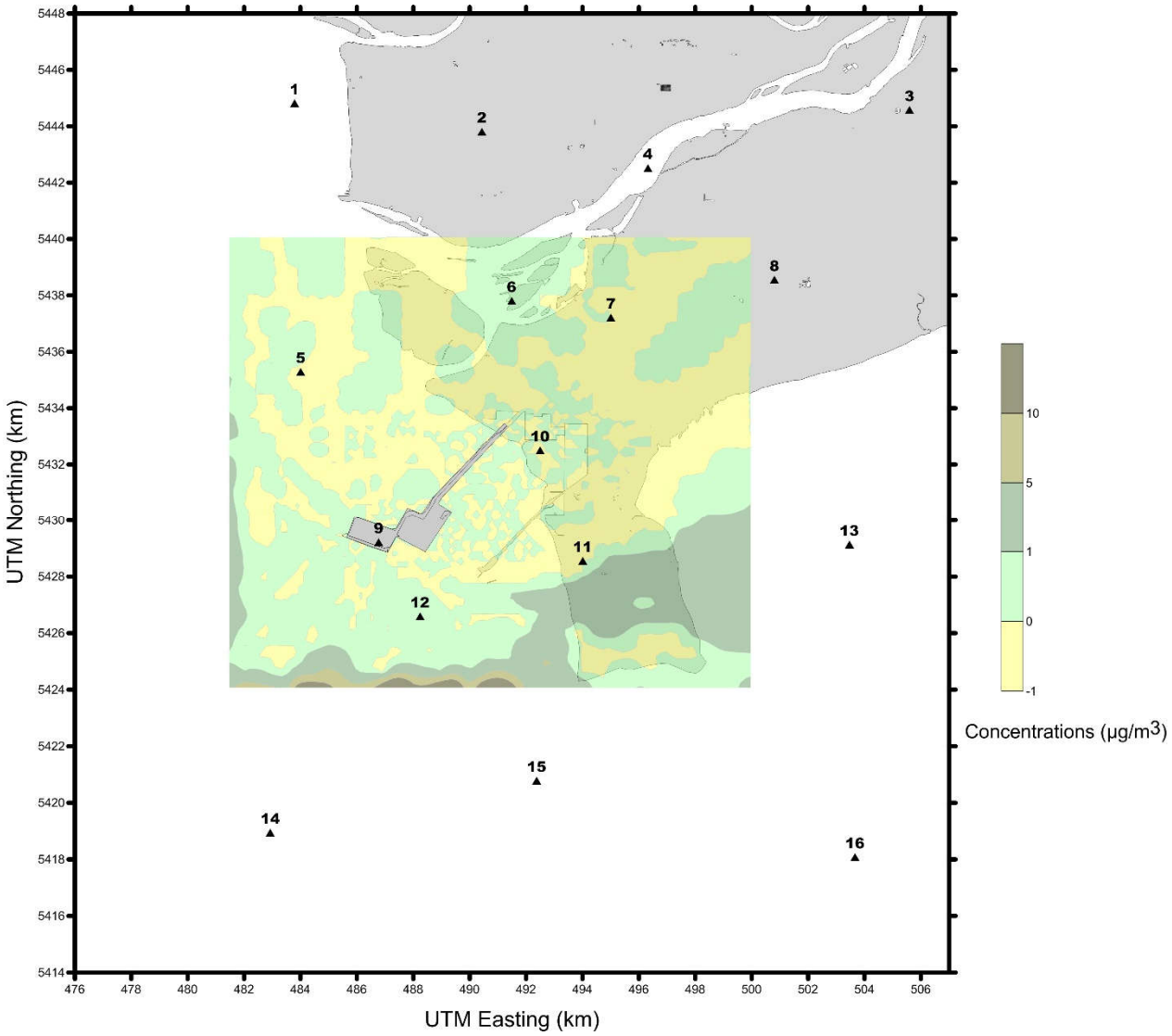


Table 3 – Maximum Predicted 1-h SO_2 Concentrations at Discrete Receptor Locations

UTM Location (km)		Discrete Receptor	Predicted 1-h SO_2 Concentration ($\mu g/m^3$)		
Easting	Northing		Extended Model Domain	RBT2 Modelling Domain	Difference (Extended-RBT2)
493.850	5436.550	Ladner	0.55	0.55	0.00
491.150	5434.601	Farmer 1	0.78	0.78	0.00
492.500	5432.500	Tsawwassen First Nations	0.94	0.94	0.00
492.050	5433.101	Farmer 2	0.54	0.54	0.00
489.800	5434.050	Farmer 3	0.93	0.93	0.00
493.250	5431.050	Tsawwassen Beach Campsite	1.70	1.70	0.00
495.800	5431.351	Beach Grove	0.49	0.49	0.00
497.100	5427.951	Boundary Bay	1.09	0.91	0.18
493.575	5429.351	Tsawwassen	1.17	1.17	0.00
497.125	5426.101	Point Roberts 1	0.97	0.97	0.00
493.875	5427.601	Point Roberts 2	2.18	1.97	0.21
495.499	5436.926	Delta Hospital	0.39	0.39	0.00
490.480	5428.242	Ferry Terminal	2.71	2.71	0.00
486.900	5438.150	Reifel Bird Sanctuary	0.58	0.58	0.00
496.350	5429.851	Boundary Bay GVRD Park	0.57	0.57	0.00
492.760	5429.900	English Bluffs Beach	1.62	1.62	0.00
490.810	5437.300	South Arm Marsh	0.49	0.49	0.00
494.008	5428.557	Air Quality Station T39	0.85	0.85	0.00

Figure 5 Maximum Predicted 1-h SO_2 Concentration Isopleths with Extended Model Domain (left) and RBT2 Model Domain (right)

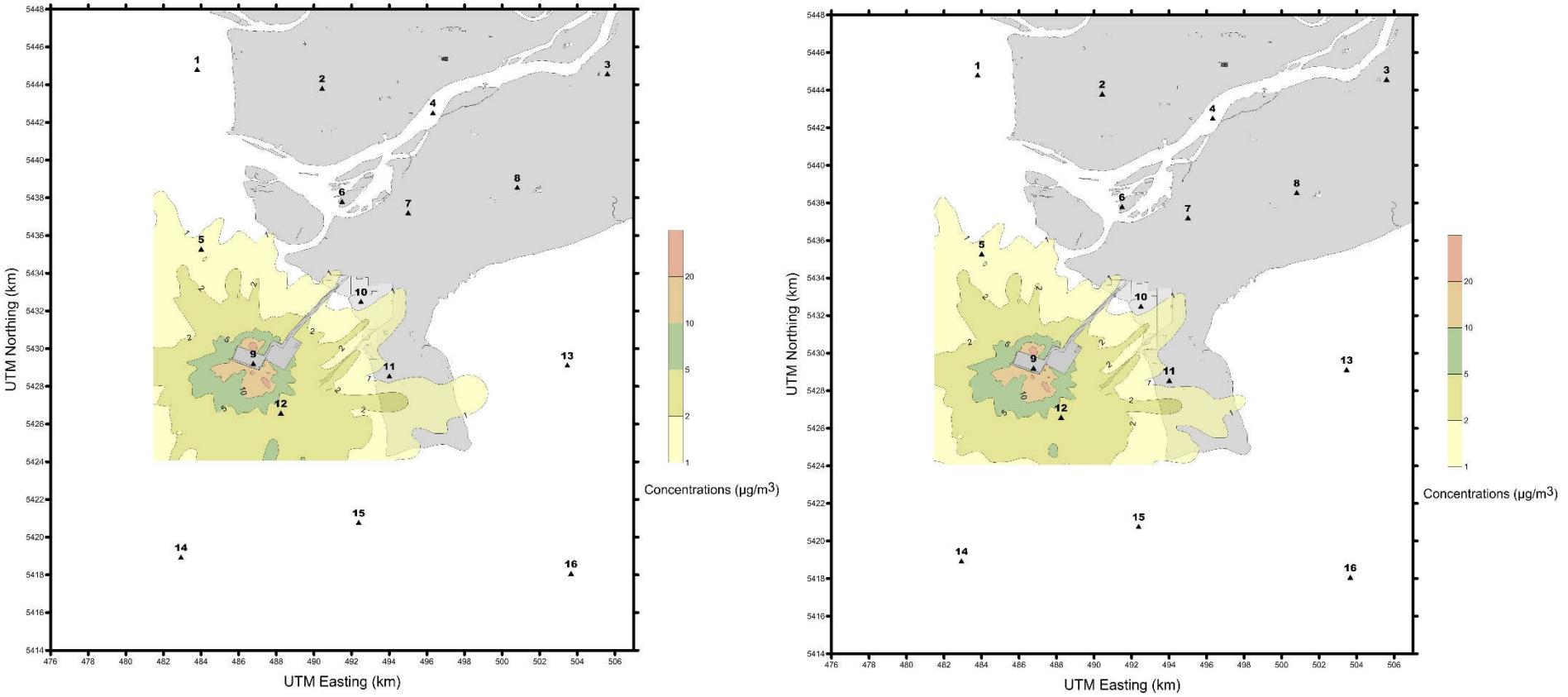
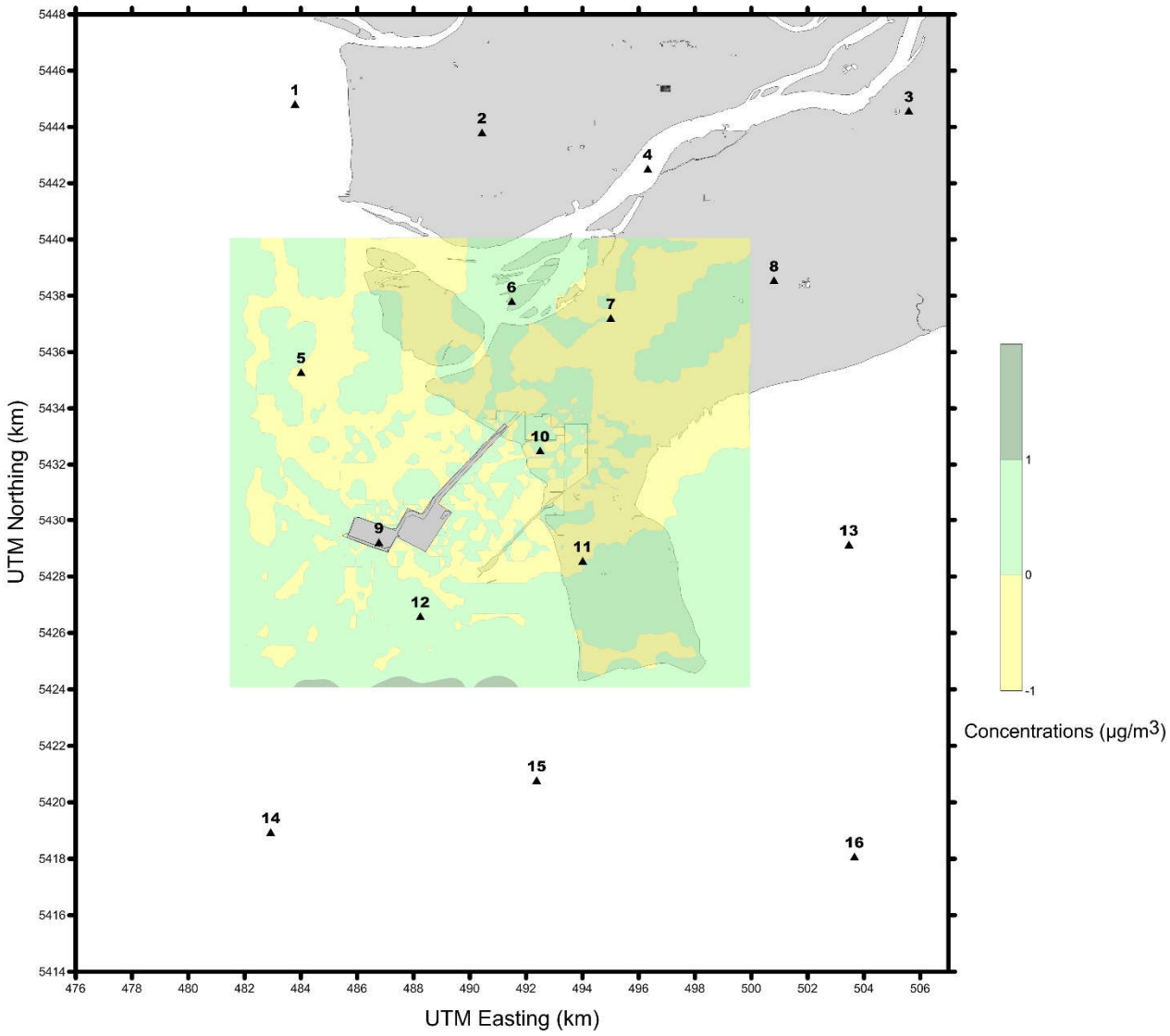


Figure 6 Difference in Maximum Predicted 1-h SO_2 Concentrations over Extended Model Domain and RBT2 Model Domain



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APPENDIX IR6-11-B

LARGE FORMAT FIGURES

Figure IR6-11-B1 Comparison of Maximum Predicted 1-h Average NO_2 Concentration Isopleths Modelled over 50 km x 50 km Model Domain (left) and RBT2 Model Domain (right)

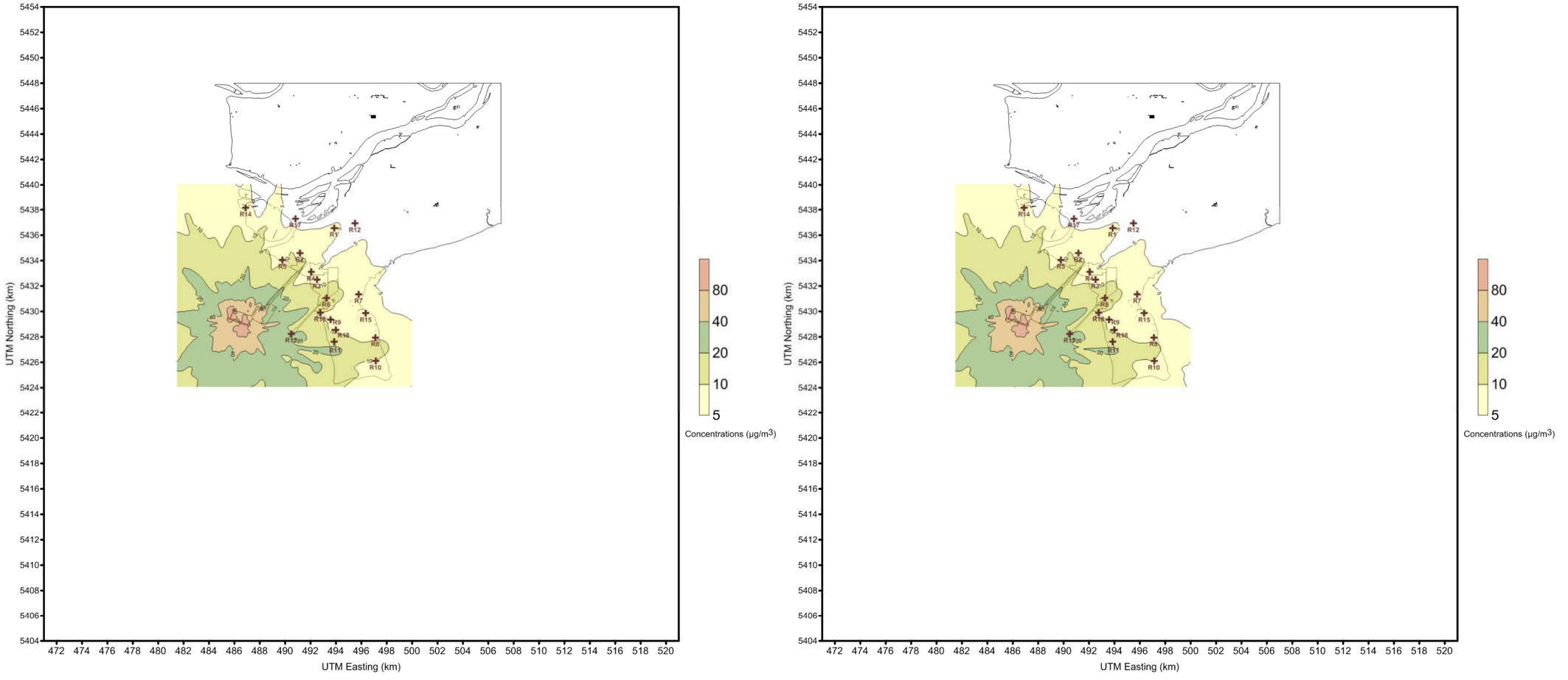


Figure IR6-11-B2 Difference in Maximum Predicted 1-h Average NO_2 Concentrations using 50 km x 50 km Model Domain and RBT2 Model Domain

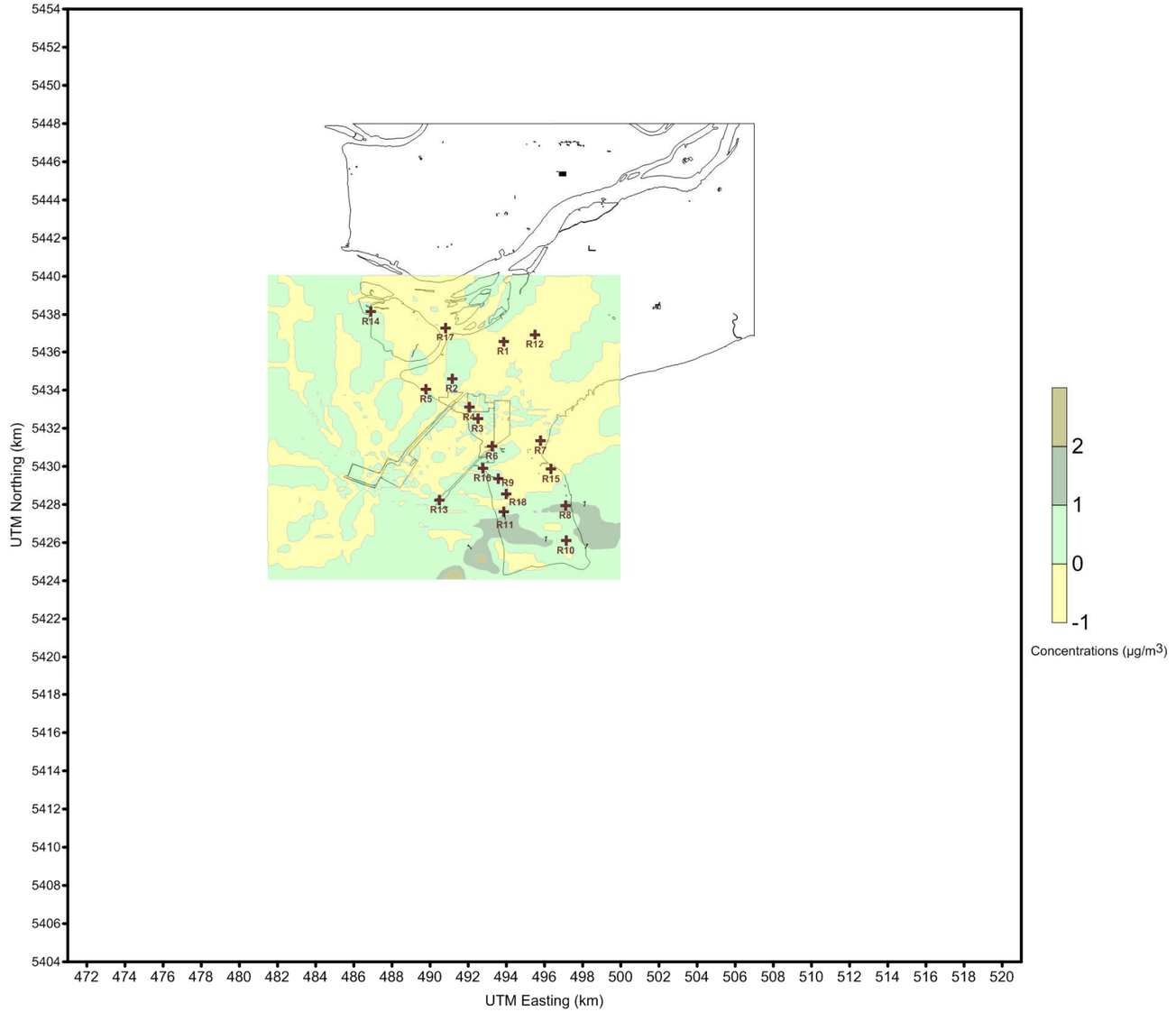


Figure IR6-11-B3 Maximum Predicted 1-h SO_2 Concentration Isopleths with 50 km x 50 km Model Domain (left) and RBT2 Model Domain (right)

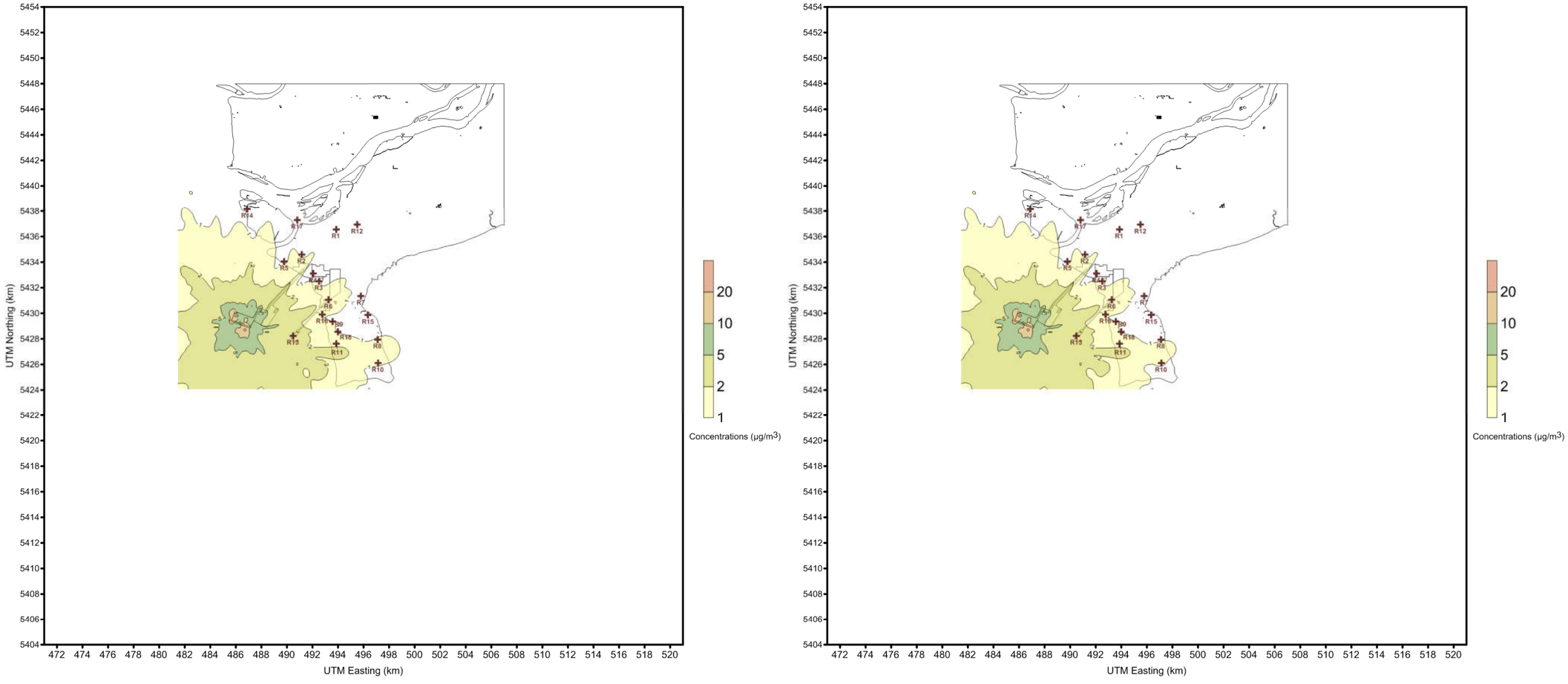


Figure IR6-11-B4 Difference in Maximum Predicted 1-h SO_2 Concentrations over 50 km x 50 km Model Domain and RBT2 Model Domain

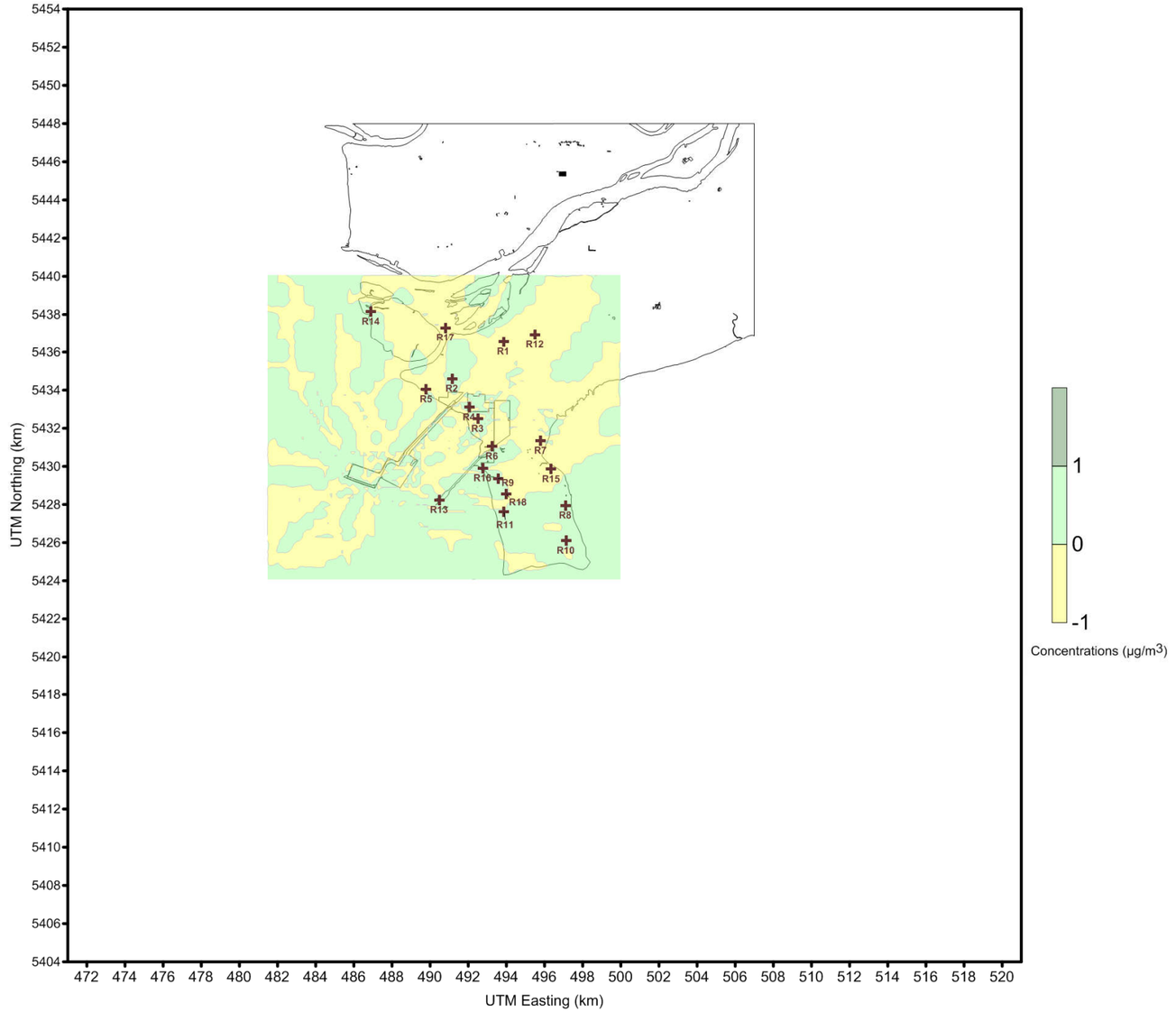


Figure IR6-11-B5 Maximum Predicted 24-h PM_{10} Concentration Isopleths with 50 km x 50 km Model Domain (left) and RBT2 Model Domain (right)

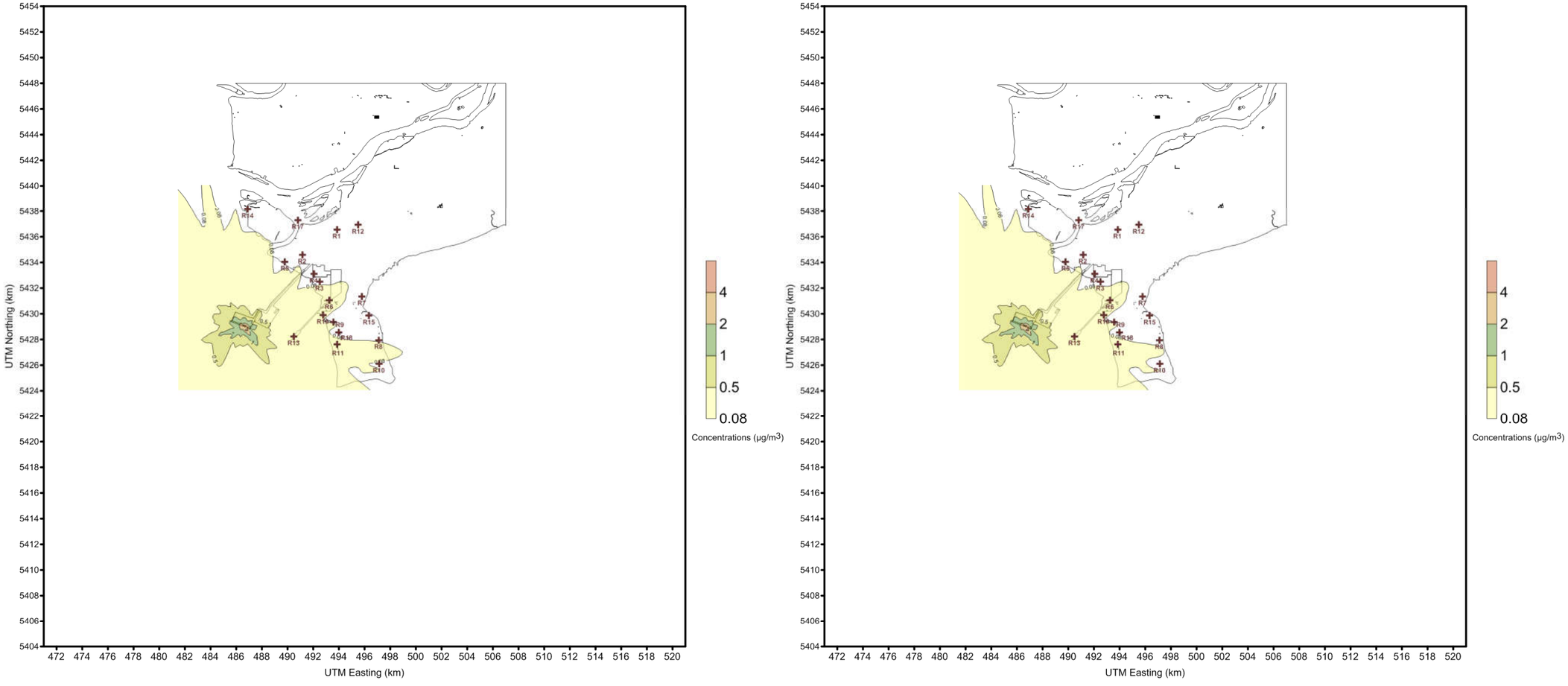


Figure IR6-11-B6 Difference in Maximum Predicted 24-h PM_{10} Concentrations over 50 km x 50 km Model Domain and RBT2 Model Domain

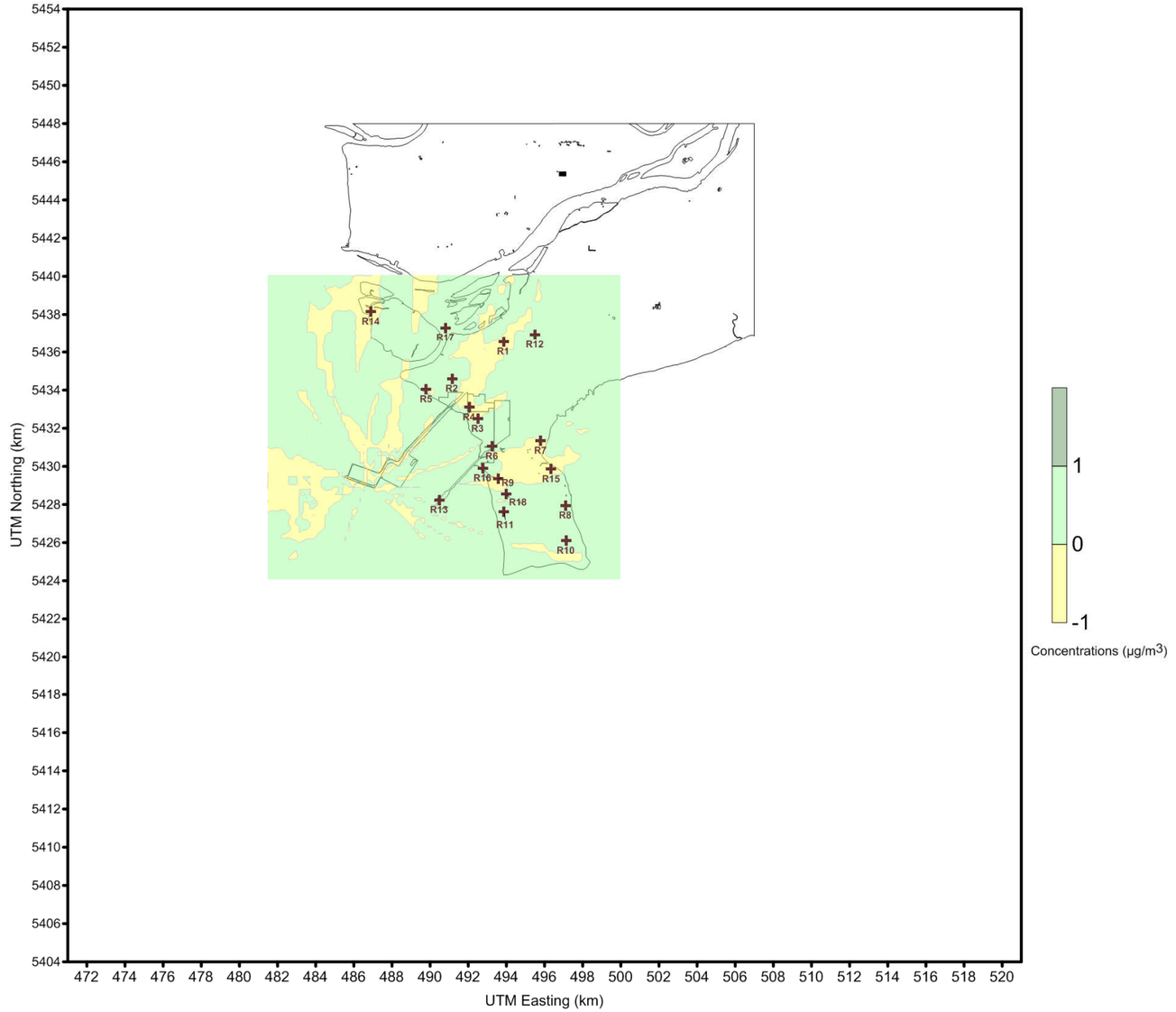


Figure IR6-11-B7 Maximum Predicted 24-h $PM_{2.5}$ Concentration Isopleths with 50 km x 50 km Model Domain (left) and RBT2 Model Domain (right)

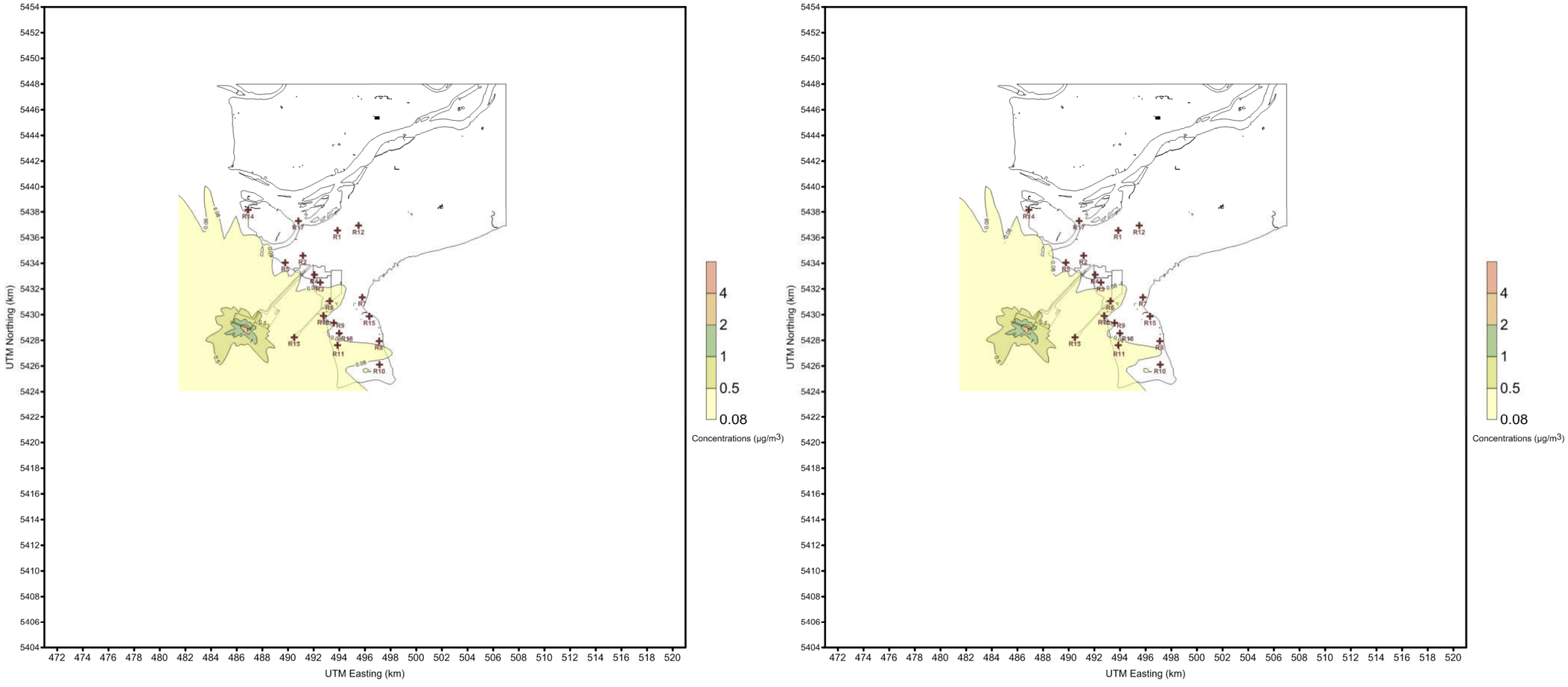
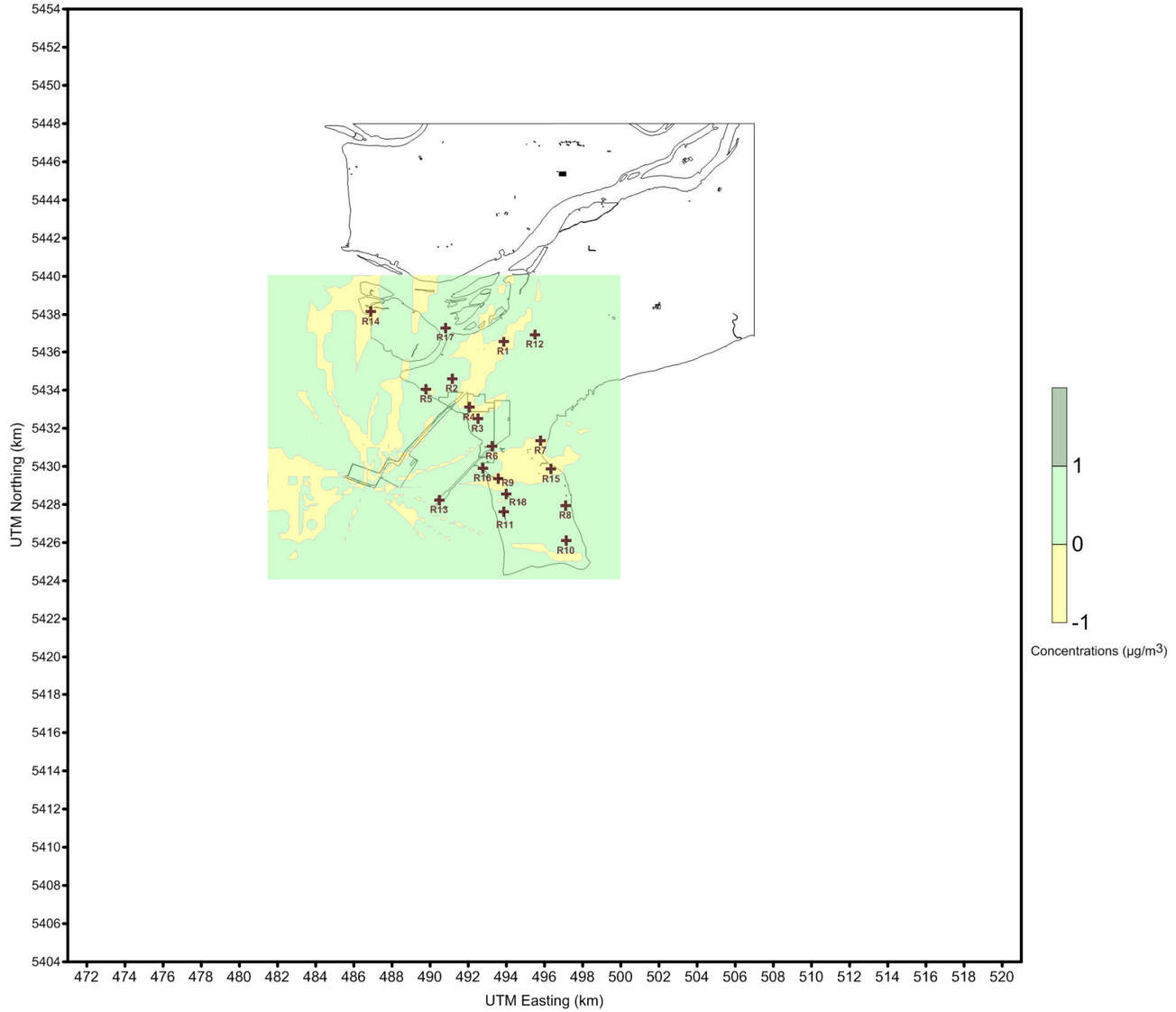


Figure IR6-11-B8 Difference in Maximum Predicted 24-h $PM_{2.5}$ Concentrations over 50 km x 50 km Model Domain and RBT2 Model Domain



IR6-12 Air Quality – Emissions Sources

Information Source(s)

EIS Volume 2: Section 9.2.5.2, Figures 9.2-1; Appendix 9.2-A: Figures 4-10 and 4-12; Appendix C, Section 1.2; Attachment 1, Figure 3-3; Appendix E, Figure 4-13

CEAR Doc#581

Context

Environment and Climate Change Canada considered that the use of a smaller domain size could result in an underestimation of ambient air quality parameter concentrations, since a larger domain, such as 30 x 30 kilometres, may include more emissions sources used for the sensitivity analysis and allow for a comparative analysis and better assessment of environmental effects.

Information Request

List any additional emission sources within a domain of 50 by 50 kilometres that were not accounted for in the 26 by 24 kilometres domain model. Determine whether the model results for ambient air quality parameter concentrations at receptor locations will change.

For NO_2, SO_2, PM_{10} and $PM_{2.5}$ present a comparison of the model output using a 50 by 50 kilometre-domain with the EIS results obtained using a 26 by 26 kilometre-domain.

VFPA Response

Emission sources within the RBT2 Air Quality Study local study area (LSA) and surrounding region (including those within a 50 km x 50 km domain) have been accounted for in the 26 km x 24 km modelling domain used. This response outlines support for this conclusion, including a summary of three domain size sensitivity analyses[1]. This response also provides background information on past evaluations of emissions from large distant sources, and further analyses to support this response.

As clarification, Section 6.1 of the 2008 version of the British Columbia Ambient Air Quality Dispersion Modelling Guideline (MOE 2008) and Section 7.1 of the updated 2015 version of this guideline (MOE 2015) recommend using a 50 km x 50 km modelling domain for tall stacks with thermally buoyant plumes, not for short stacks. Emission plumes from vessels that will call at RBT2 will emanate from short stacks, for which concerns about wake effects on plume dispersion from buildings (i.e., the vessel superstructure and cargo containers)

[1] A 30 km x 30 km sensitivity analysis provided in EIS Appendix 9.2-A: Appendix C, Attachment 1, as well as two sensitivity analyses (50 km x 50 km and 31 km x 34 km) undertaken to support the response to IR6-11.

are more relevant. MOE (2015) also states that for shorter stacks, a smaller modelling domain (e.g., 10 km x 10 km) may be sufficient. The short stack guidelines from MOE would also apply to emissions from tug boats, cargo handling equipment, locomotives, on-road vehicles, and fugitive dust.

Domain Size Sensitivity Analysis

The selection of the 26 km x 24 km modelling domain size considered such factors as the extent of RBT2 contributions to ambient contaminant concentrations, and the modelling results previously determined for the Deltaport Third Berth (DP3) Project in 2005.

In order to address comments made during the Air Quality Scoping Study (AQSS) regarding the 26 km x 24 km modelling domain size, a sensitivity analysis was completed using a 30 km x 30 km modelling domain (see EIS Appendix 9.2-A: Appendix C, Attachment 1). Additional sensitivity analyses have been completed to support the response to IR6-11 and included the following:

- Comparison of 26 km x 24 km modelling domain and a larger domain size of 31 km x 34 km (i.e., 5 km to the west and 10 km to the south); and
- Comparison of 26 km x 24 km modelling domain and a larger domain size of 50 km x 50 km.

In summary, the comparisons illustrated in the three sensitivity analyses show that the 26 km x 24 km modelling domain size used in the RBT2 Air Quality Study adequately assessed local and regional emission sources, and ambient air quality parameter concentrations at receptor locations are not expected to change if modelling was to be conducted using a larger domain size. See IR6-11 for complete response.

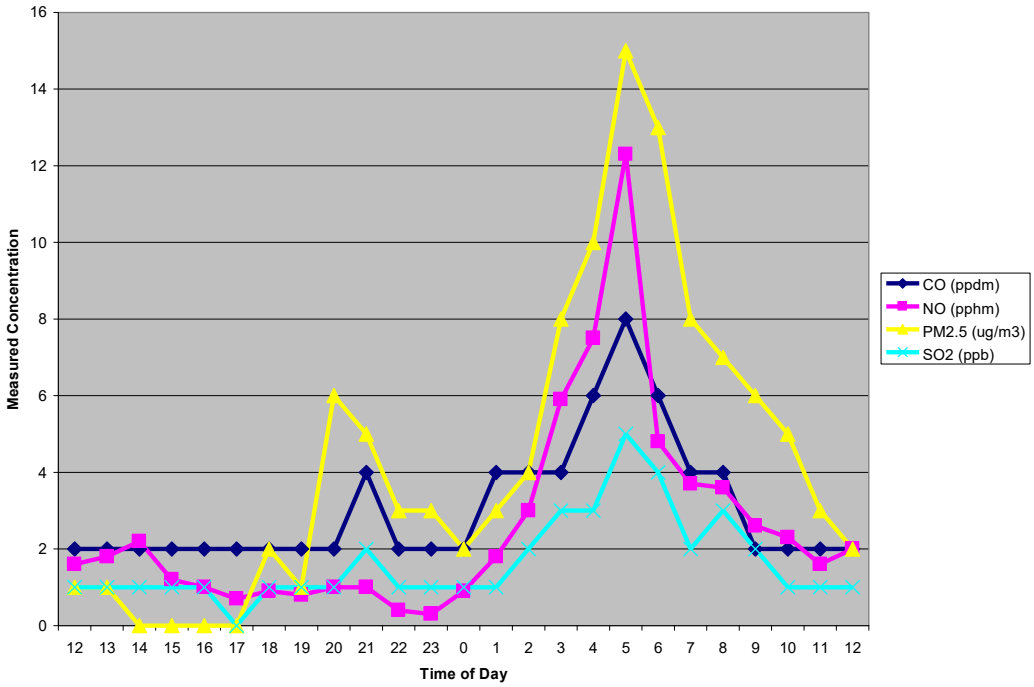
List any additional emission sources within a domain of 50 by 50 kilometres that were not accounted for in the 26 by 24 kilometres domain model. Determine whether the model results for ambient air quality parameter concentrations at receptor locations will change.

Contributions from other emission sources beyond the boundaries of the LSA are included in background air quality levels measured at Station T39 in Tsawwassen. The 98th percentile background concentrations from this station (for 2010) have been added to the predicted future conditions scenarios (with and without the Project) in 2025. Including other existing emission sources in the dispersion modelling analysis for a larger domain would also result in double-counting of these emissions. For anticipated future emissions from certain and reasonably foreseeable projects and activities, sources outside of the LSA were taken into consideration, and incorporated into the assessment of cumulative changes if relevant (see EIS Appendix 9.2-B).

The VFPA had previously established that emissions from large, distant sources could be detected in ambient monitoring data in Tsawwassen. Specifically, Metro Vancouver had conducted ambient air quality monitoring near the Delta Hospital in 2004, and the analysis of that data by the VFPA during the DP3 Project indicated that small, simultaneous spikes in the levels of CO, NO_2, SO_2, and $PM_{2.5}$ were associated with easterly winds from the direction

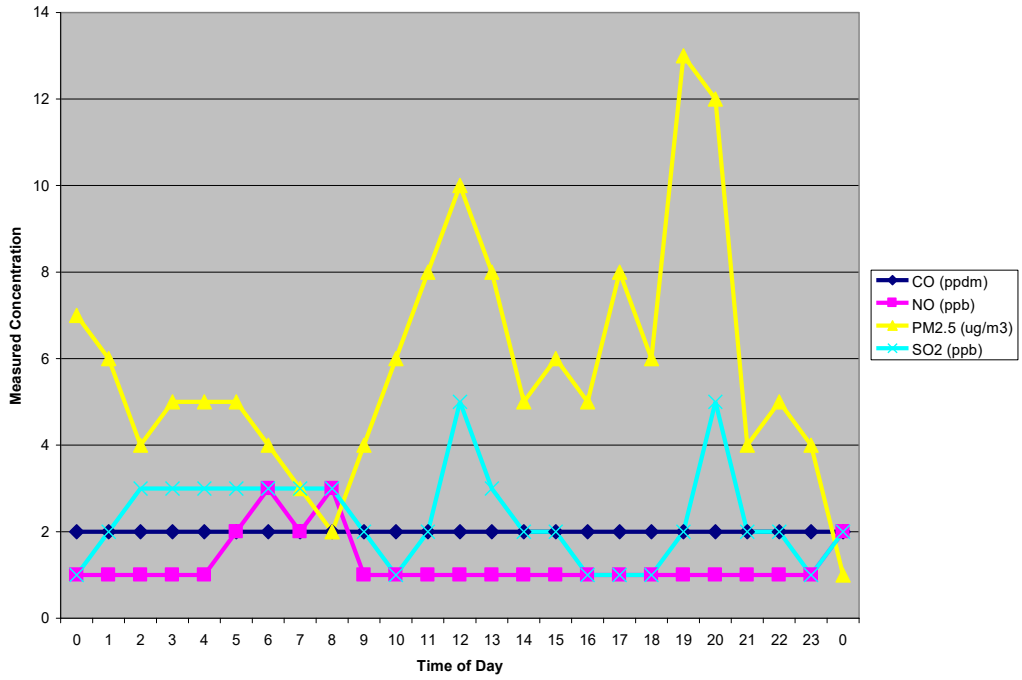
of the cement plant on Tilbury Island. Other spikes in SO_2 and $PM_{2.5}$ were associated with southerly winds from the direction of the oil refineries at Cherry Point, Washington. The analysis of Metro Vancouver's monitoring data was contained in a letter from SENES Consultants Limited to the Vancouver Port Authority (now referred to as the VFPA) on March 13, 2006 (SENES 2006). This letter was subsequently provided to the Greater Vancouver Regional District (GVRD) by the VFPA in response to comments from the GVRD on roadside air quality modelling from container terminal traffic, as an addendum to the DP3 Air Quality and Health Assessment. **Figure IR6-12-1** and **Figure IR6-12-2** provide graphs of time series comparisons made from the Metro Vancouver monitoring program in 2004 to support these conclusions. Given the light NE winds at 5:00 am on June 3, 2004, the most likely source of elevated CO and NO concentrations, with corresponding peak $PM_{2.5}$ and SO_2 concentrations, was determined to be the cement plant on Tilbury Island.

Figure IR6-12-1 Measured Concentrations at GVRD MAMU Site – June 2-3, 2004



Similarly, two peaks in $PM_{2.5}$ and SO_2 concentrations were recorded at noon on June 4 with winds from the SSE and at 8:00 pm with winds from the SE. The most probable source for the concentration peak at 7:00-8:00 pm on June 4 shown in **Figure IR6-12-2** was determined to be most likely the oil refineries at Cherry Point, Washington because the wind direction at 8:00 pm was recoded as being 138°, placing the MAMU monitors in Delta almost directly in line with Cherry Point.

Figure IR6-12-2 Measured Concentrations at GVRD MAMU Site – June 4, 2004



In order to respond to this information request, an analysis of the monitoring data at Station T39 over the period 2010 to 2015 was completed to provide additional evidence of the contribution of large emission sources in the region. Specifically, using observed hourly average SO_2 concentrations, the analysis relates SO_2 concentrations ≥3 ppb (parts per billion) by wind direction to four potential major sources of SO_2 emission, namely the following:

1. Lehigh cement plant on Tilbury Island and the Lafarge cement plant in Richmond;
2. Oil refineries at Cherry Point, Washington;
3. Ships in-transit in the Strait of Georgia; and
4. Vessels at marine terminals at Roberts Bank (i.e., the Tsawwassen Ferry Terminal, Deltaport Terminal, Westshore Terminals).

The locations of the four major source groups are depicted in Figure IR6-12-A1 in **Appendix IR6-12-A.**

While there remains some uncertainty regarding the measured wind direction at Station T39 due to the obstruction of wind flow by trees in Pebble Hill Park, Figure 2-27 in the RBT2 Air Quality Study (EIS Appendix 9.2-A, Appendix C) indicates that the uncertainty is on the order of 22.5°. This variation is sufficient to provide a broad indication of the direction from which the SO_2 observed at Station T39 could have originated.

Figure IR6-12-3 provides a scatter plot of observed SO_2 concentrations ≥3 ppb at Station T39 for the period 2010 to 2012 against observed wind direction. For the purposes of this analysis, SO_2 concentrations originating from 260° to 340° were assigned to the

marine terminals at Roberts Bank, while those from 166° to 259° were assigned to ships in-transit in the Strait of Georgia. Ships in-transit sailing past the Roberts Bank terminals could equally contribute SO_2 emissions from 260° to 340°, such that the boundary indicated in **Figure IR6-12-3** between these two groups is somewhat arbitrary. Similarly, the boundary between SO_2 attributed to the oil refineries at Cherry Point and to ships in-transit is also somewhat arbitrary. The main objective in presenting scatter plot results is to demonstrate that SO_2 concentrations measured at Station T39 can be related to emission sources as far as the Cherry Point refineries, at a distance of 30 km from Station T39. Although only two observations are associated with the cement plants, the wind direction for these two points is sufficiently removed, and hence differentiated, from emissions that could be attributed to the oil refineries at Cherry Point.

As indicated in **Figure IR6-12-3**, observed SO_2 concentrations over 20 ppb were attributed to marine terminals at Roberts Bank, while concentrations of 15 ppb were attributed to ships in-transit in the Strait of Georgia. While one observation of 12 ppb was attributed to the oil refineries at Cherry Point, Washington, most of the observations in this grouping were less than 8 ppb. Contributions from the cement plants were less than 4 ppb and occurred rarely because winds from the direction of the cement plants occur only about 1% of the time. Therefore, the bulk of the 1-hour average SO_2 concentrations observed at Station T39 over the period of 2010 to 2012 were related to ships in-transit or at the marine terminals at Roberts Bank.

While **Figure IR6-12-3** shows the observed SO_2 concentrations largely before the implementation of the first phase of the North American Emission Control Area (ECA) for low sulphur fuels in marine vessels in 2012, **Figure IR6-12-4** shows the observed SO_2 concentrations from 2013 to 2015 after the implementation of the first phase of ECA in 2012 and the second phase in 2015. **Figure IR6-12-4** shows that the contributions from ships in-transit and the marine terminals were greatly reduced in both the number of such observations (i.e., observations only plotted if over 3 ppb) and the magnitude of the highest SO_2 concentrations. For example, during 2013 to 2015, the highest observed 1-hour average SO_2 concentration from marine sources was less than 9 ppb compared with more than 20 ppb in the period 2010 to 2012. By comparison, the SO_2 observations from the direction of the Cherry Point refineries and the Lehigh and Lafarge cement plants were similar in both the 2010 to 2012 and 2013 to 2015 periods of observation.

The analyses presented in **Figures IR6-12-3** and **IR6-12-4** indicate the following:

- The use of low sulphur fuels since 2012 reduced both the absolute magnitude of observed SO_2 concentrations and the frequency of concentrations ≥3 ppb;
- Contributions of emissions from ships in-transit in the Strait of Georgia and from the marine terminals at Roberts Bank are included in the observations at Station T39;
- SO_2 emissions from the oil refineries at Cherry Point, Washington, located at a distance of 30 km from Station T39, contributed to the SO_2 levels observed at Station T39 in the period 2010 to 2015, at levels similar to those that were observed during the short monitoring study conducted by Metro Vancouver near the Delta Hospital in 2004;

- While infrequent, observed SO_2 concentrations ≥3 ppb were recorded at Station T39 for wind directions corresponding to the direction of the cement plants located on Tilbury Island (Lehigh) and in Richmond (Lafarge), located at distances of 15 km and 17 km from Station T39, respectively; and
- If SO_2 emissions from these distant sources are monitored at Station T39, then other contaminants emitted by these sources, as well as other large sources of non-SO_2 emissions, are also monitored at Station T39, and are included in the background air quality levels used for the RBT2 Air Quality Study.

Based on the analyses that indicate that emissions from large, distant sources are recorded in air quality monitoring observations in the Tsawwassen area, the VFPA is confident that regional emissions that are generated beyond the LSA are represented in the monitoring data at Station T39, and no additional modelling of those emission sources is necessary. Expanding the modelling domain to include modelling of large emission sources would have the effect of double-counting those emissions when combining predicted concentrations with the 98th percentile background air quality at Station T39.

Figure IR6-12-3 Observed SO_2 Concentrations ≥3 ppb at Station T39 for 2010 to 2012 Considering Wind Direction and Associated Sources

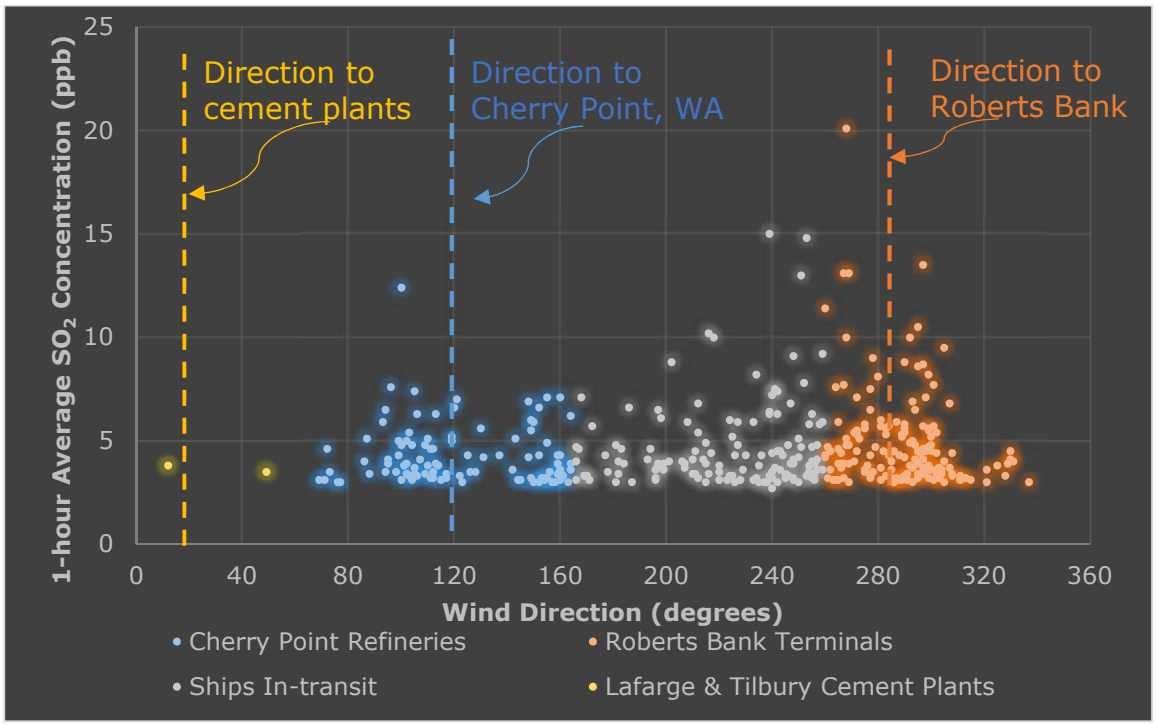
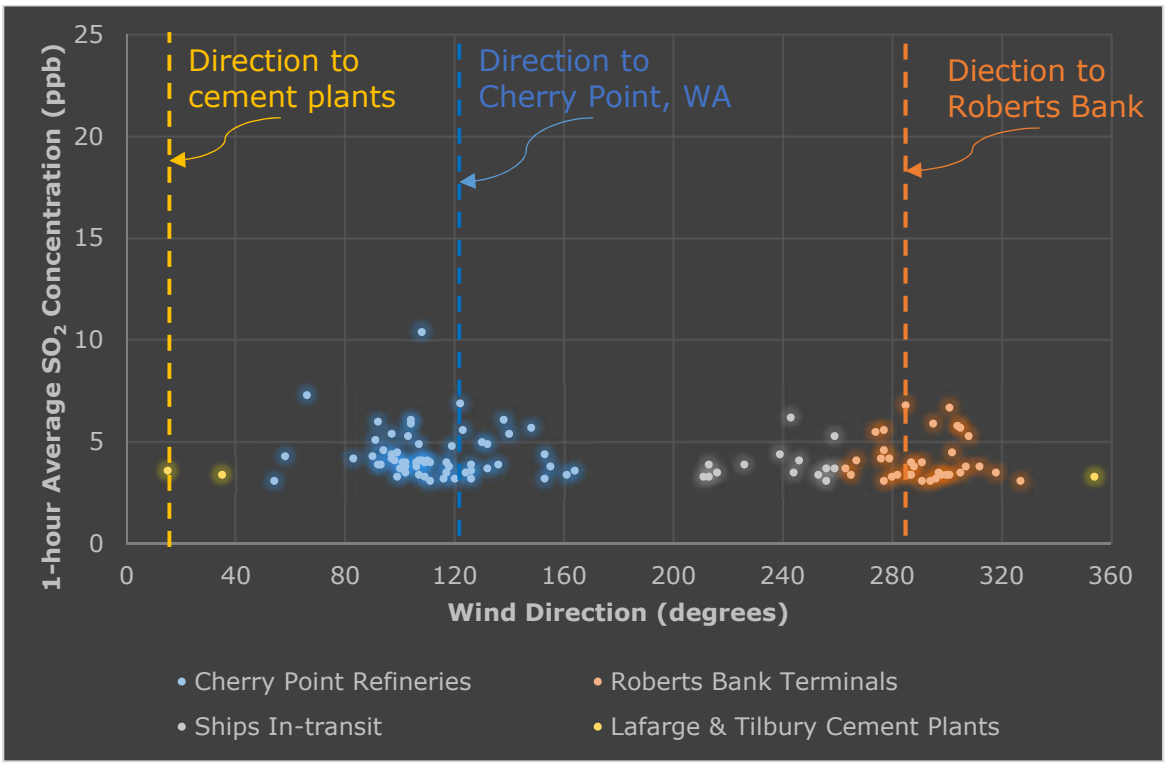


Figure IR6-12-4 Observed SO_2 Concentrations ≥3 ppb at Station T39 for 2013 to 2015 Considering Wind Direction and Associated Sources



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SENES Consultants Limited (SENES). 2006. Addendum to the Air Quality and Health Assessment - Deltaport Third Berth (DP3) Project. Letter to D. Desjardin, Manager, Environment, Container Development Group, Vancouver Port Authority, March 13, 2006.

Appendices

Appendix IR6-12-A Supporting Figure – Major Sources of SO_2 Emission in the Lower Fraser Valley and the Strait of Georgia

APPENDIX IR6-12-A

SUPPORTING FIGURE – MAJOR SOURCES OF SO_2 EMISSIONS IN THE LOWER FRASER VALLEY AND THE STRAIT OF GEORGIA

Path: O:\!1200-\1246\EIS_INFORMATION_REQUEST\SIIR6_12\mxd\IR6_12_A1_AQ_EmissionSources_180131.mxd

Strait of Georgia

Richmond

Lafarge Richmond Plant

Fortis Tilbury Island Plant

Delta

19° - 17.67 km

17° - 15.61 km

Roberts Bank

340° - 5.83 km

Deltaport Terminal

Westshore Terminals

B.C. Ferries Terminal

260° 3.60 km

T39

Boundary Bay

White Rock

CANADA

UNITED STATES

Blaine

249° - 8.03 km

Point Roberts

166° - 12.62 km

126° - 28.82 km

BP Cherry Point Refinery

Ferndale

Langley

Township of Langley

Surrey

Legend

- BOUNDARY OF PROJECT AREA
- AIR QUALITY MONITORING STATION
- DIRECTION AND DISTANCE TO EMISSION SOURCE
- U.S.A.-CANADA BORDER

OTHER EMISSION SOURCES

- CEMENT PLANT
- MARINE VESSELS AT ROBERTS BANK
- REFINERY
- SHIPS IN-TRANSIT IN THE STRAIT OF GEORGIA (WITHIN INTERNATIONAL SHIPPING LANES)

0 5 10 Kilometres

N

1:200,000

NAD 1983 UTM Zone 10N

PORT of vancouver

ROBERTS BANK TERMINAL 2

MAJOR SOURCES OF SO_2 EMISSION IN THE LOWER FRASER VALLEY AND THE STRAIT OF GEORGIA

DATE: 01/31/2018

FIG No. IR6-12-A1

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

IR6-13 Air Quality – Emissions Modelling, BC Ferries Routes 1 and 9

Information Source(s)

EIS Volume 2: Appendix 9.2-A: Section 3.3; Section 4.1, Table 4.4.1; Figures 3-5 to 3-7 and 4.10; Appendix A, Section 2.8 and Attachment 2

Proponent Response to Additional Information Requirements of February 24, 2016 (CEAR Doc#314): IR19, Appendix IR19-A, Table 2-1 and Figures 2-5 and 2-6

Context

In Section 2.8 of Appendix A of Appendix 9.2-A, the Proponent reported that emissions from vessels in transit on BC Ferries routes 1 and 9 (Tsawwassen to Swartz Bay and Southern Gulf Islands) were determined to be insignificant. Since ferries are in transit only for 3 minutes prior to crossing the Canada-US border, the routes were considered to be beyond the modelling boundary and were excluded from the transit emissions estimates and subsequent air quality dispersion.

While routes 1 and 9 do pass into American waters almost immediately after departure from the Tsawwassen Ferry Terminal, it is incorrect to suggest that emissions that occur south of the Canada-US border are beyond the modelling boundary. Figures 3-5, 3-6 and 3-7 of the EIS indicated that the local study area extends approximately four kilometres south of the Canada-US border. Vessels on routes 1 and 9 follow a roughly south-west course from the BC Ferries terminal to the south edge of the local study area, a distance of approximately six kilometres. The emissions inventory and dispersion modelling should include all emissions sources from the Project no matter where they occur.

In the *Air Quality and Human Health Risk Assessments Based on Provincial Interim NO_2 and SO_2 Objectives* (Appendix 19-A of the Proponent's response to IR19-A) future conditions (with Project) for NO_2 levels in the area of BC Ferries terminal are above 160 ug/m^3 (Figure 2-5 of Appendix IR19-A), without emissions from routes 1 and 9 vessels in transit. Metro Vancouver considers that it is reasonable to expect that inclusion of routes 1 and 9 emissions could result in NO_2 levels that exceed the British Columbia interim NO_2 objective of 188 ug/m^3 (98th percentile) in the area of the terminal provided in Table 2-1 of Appendix IR19-A.

Emissions from routes 1 and 9 ferries in transit with the local study area, including south of the Canada-US border are required for the air quality dispersion modelling.

Information Request

Rerun the air quality dispersion modelling for the local study area and include emissions from vessels in transit on BC Ferries routes 1 and 9 for the full length of these routes that fall within the air quality local study area, including the portions of these routes south of the Canada-US border.

Present the results in isopleth plots and discuss these results.

VFPA Response

Clarification and Overview

All Project emissions have been quantified for future conditions with the Project. In addition, emissions from other sources not related to the Project, including ferries on Route 1 (Tsawwassen – Swartz Bay) and Route 30 (Tsawwassen – Duke Point) have also been quantified for existing conditions, expected conditions, and future conditions with the Project, as explained below.

Information on sailings from Tsawwassen Ferry Terminal was supplied to the VFPA by BC Ferries at the start of the RBT2 Air Quality Study. The information consisted of ferry sailings in 2010 for routes 1, 9 (Tsawwassen – Southern Gulf Islands), and 30. Vessels operating on these routes during that year are listed in **Table IR6-13-1**, along with the total number of sailings, the percentage of total sailings by vessel and the size of their main engines, and year of replacement (as anticipated in 2010).

Table IR6-13-1 BC Ferries Tsawwassen Ferry Terminal 2010 Information on Sailings by Vessel Type, Engine Power, and Replacement Schedule

Ferry Vessel	Total No. of Sailings	Percent of Total Sailings	Main Engine (ME) Power (kW)	Proportional ME Power (kW)	Year of Replacement
Route 1 Tsawwassen – Swartz Bay					
Spirit of British Columbia	1,242	16.3%	15,600	2,543.7	2043
Coastal Celebration	937	12.3%	15,600	1,919.0	2057
Coastal Renaissance	16	0.2%	15,600	32.8	2055
Queen of New Westminster	471	6.2%	12,528	774.7	2022
Spirit of Vancouver Island	1,210	15.9%	15,600	2,478.1	2044
Route 9 Tsawwassen – Southern Gulf Islands					
Bowen Queen	102	1.3%	671	9.0	2019
Queen of Burnaby	156	2.0%	4,412	90.4	2017
Queen of Nanaimo	737	9.7%	4,414	427.1	2017
Route 30 Tsawwassen – Duke Point					
Queen of Alberni	1,240	16.3%	8,606	1,401.0	2021
Coastal Inspiration	1,185	15.6%	15,600	2,426.9	2056
Coastal Renaissance	180	2.4%	15,600	368.6	2055
Queen of Cowichan	7	0.1%	8,602	7.9	2024

Ferry Vessel	Total No. of Sailings	Percent of Total Sailings	Main Engine (ME) Power (kW)	Proportional ME Power (kW)	Year of Replacement
Queen of New Westminster	134	1.8%	15,600	274.4	2022
Total No. Sailings – all routes	**7,617**	**Average Proportional Power Rating – all routes**		**12,753.7**	

Source: BC Ferries, personal communication (2010).
Note: Proportional power rating is calculated as the vessel power rating multiplied by the percentage of total sailings from the Tsawwassen Ferry Terminal in 2010.

Due to the complexity of the sailings for various vessels on all three routes (e.g., multiple sailings per day by different vessels, variation in daily and seasonal sailing frequency), it was not feasible to accurately capture all activities for all ferries in the modelling analysis. Consequently, for dispersion modelling purposes in the RBT2 Air Quality Study (EIS Appendix 9.2-A, Appendix C), it was conservatively assumed that two vessels with the average proportional power rating of 13,000 kW (kilowatt) main engine were present at the Tsawwassen Ferry Terminal 100% of the time.

Route 9 vessels were considered in defining the average proportional power rating for the fleet of ferries operating out of the Tsawwassen Ferry Terminal in 2010, but not explicitly included in the modelling analysis because these ferries accounted for only 9.7% of the total number of sailings from the Tsawwassen Ferry Terminal and only 4% of the proportional power rating for main engines for all ferry sailings in 2010. Therefore, the inclusion of ferries on Route 30 in the air quality modelling analysis was a conservative proxy for Route 9 ferries due to the use of larger ferries on Route 30 (i.e., the modelling analysis was based on the most conservative assumption), as explained further below.

The activities of ferries on routes 1 and 30 were conservatively estimated in the air dispersion modelling analysis, in that:

1. Emissions from all ferries at berth and in transit (as well as other vessels in transit near Roberts Bank and other vessels at berth at Roberts Bank) are captured in the background air quality concentrations measured at the T39 air quality station and added to model-predicted concentrations. In addition to being captured in background air quality, ferries at berth were also included in modelling of existing conditions, expected conditions, and future conditions with the Project;
2. The assessment conservatively assumed that two of the larger ferries (those that operate on routes 1 and 30) were berthed at the Tsawwassen Ferry Terminal 100% of the time; therefore, modelling emissions from ferries at berth as well as in transit would double-count the same vessel. Vehicular traffic for all ferry routes was also included in the assessment; and

3. The assessment assumed that all ferries are diesel-fuel powered. Plans confirmed by BC Ferries[1] in 2017 to convert Spirit Class vessels on routes 1 and 30 to dual-fuel (i.e., liquified natural gas (LNG) or ultra-low sulphur diesel fuel), the recent introduction of dual-fuel Salish Class vessels on Route 9, and the expected replacement of three other vessels operating on all three routes before 2025 will mean that future emissions (both with and without the Project) are likely to be much lower than predicted in the RBT2 Project EIS.

The information that follows provides additional detail in support of the three points above, including a discussion on their potential effect on the air dispersion modelling results presented in the EIS.

1. Ferry Emissions in Background Air Quality Concentrations

Emissions from ferries in transit and at berth were incorporated into the predictions of emissions in the local study area, where emissions from the Project are expected to occur. Background air quality concentrations measured at the T39 station in Tsawwassen include local and regional emissions sources, including ferries at berth and in transit, as well as vehicular ferry traffic on the causeway to the Tsawwassen Ferry Terminal. As per the Guidelines for Air Quality Dispersion Modelling in British Columbia (both 2008 and 2015[2] versions; B.C. Guidelines), 98th percentile background concentrations in 2010 were combined with model predictions for each parameter and the combined concentrations were compared to air quality criteria. This was done for each temporal case (existing conditions in 2010, and expected conditions (future conditions in 2025 without the Project), and future conditions with the Project (2025)). At the commencement of the RBT2 air quality assessment when assumptions were being selected, BC Ferries stated that ferry traffic activity is not anticipated to change (i.e., no increase) in the future (assumption previously outlined in EIS Appendix 9.2-A, Section 2.3). BC Ferries (2017) confirmed that ferry traffic is forecast to be flat. Therefore, the 2010 measured background air quality concentrations from station T39 provide an appropriate estimate of future emissions for the diesel-powered ferry fleet in the local study area, but likely overestimates future emissions as dual-fuel ferries are already in operation at the Tsawwassen Ferry Terminal, as discussed in section #3 below.

2. Modelling of Ferry Vehicular and Vessel Traffic Emissions

Ferries transiting to/from, and berthing at, the Tsawwassen Ferry Terminal were included as an emissions source in the RBT2 air quality assessment because emissions from vehicular and ferry traffic are anticipated to overlap with emissions from the Project in the local study area. Although vehicular and ferry traffic emissions are already included in background air quality concentrations that are added to predicted levels, they were modelled separately because of the potential for emission decreases from on-road vehicles on the BC Ferries causeway in the future due to vehicle turnover to newer, lower emitting vehicles. By including the emissions from ferry terminal operations (as well as from Westshore Terminals and Deltaport Terminal)

[1] http://www.cbc.ca/news/canada/british-columbia/bc-ferries-upgrades-spirit-class-vessels-to-operate-on-natural-gas-1.4280211
[2] https://www.bcogc.ca/node/13339/download

in the RBT2 air dispersion modelling analysis, and then adding the 98th percentile background air quality concentrations to the modelling results as per the B.C. Guidelines (and supported by representatives from the regulatory agencies during the RBT2 Air Quality Scoping Study process at the commencement of the RBT2 Air Quality Study), the emissions from the Tsawwassen Ferry Terminal have essentially been double-counted. It is important to note that background air quality concentrations from 2010 do not include the expected benefits from emission reductions that will be realised in observed levels at station T39 in 2025 from the replacement and conversion of ferries, as discussed further below.

As stated above, the RBT2 Air Quality Study conservatively assumed that two Spirit Class ferries that operate on routes 1 and 30 were berthed at the Tsawwassen Ferry Terminal 100% of the time with vessels under load. This is considered to represent the most conservative approach to evaluating the worst-case emission scenario for emissions from ferries (in conjunction with emissions from the Westshore, Deltaport, and RBT2 terminals at Roberts Bank), since the berths at the Tsawwassen Ferry Terminal are occupied less than 100% of the time due to vessels arriving and departing routinely on scheduled voyages. Further explanation of why the modelling of ferries at berth, compared to modelling ferries in transit, is a conservative approach is as follows. Route 1 is typically serviced by two Spirit Class ferries operating between Tsawwassen in Delta and Swartz Bay on Vancouver Island. When one vessel is at berth in Tsawwassen, the second vessel is at berth or near Swartz Bay. It would have been unrealistic to assume that there was a Spirit Class vessel at berth in Tsawwassen, as well as another Spirit Class vessel in transit across the Strait of Georgia between Tsawwassen and Active Pass in the same hour. The same logic would apply to the ferry vessels on Route 30 between Tsawwassen and Duke Point. If the modelling had assumed one vessel for Route 30 at berth in Tsawwassen and a second vessel on Route 1 in transit across the Strait of Georgia, the emissions from the vessel in transit would have been distributed along the transit route between Tsawwassen and Active Pass, thus dispersing the emissions while in transit over a wider area and reducing the emission levels at the Tsawwassen Ferry Terminal.

Alternatively, the analysis could have considered vessels on both routes partially in transit and partially at berth during the period of an hour, but it would be unrealistic to assume that a vessel could be at berth at the same time as it is in transit.

While the engine load factor is slightly higher for a ferry vessel in transit (i.e., 40.5% load factor for main engines while in transit versus 34.3% load factor at berth, as presented in

Table 2-23 in Appendix A of EIS Appendix 9.2-A), the distribution of the emissions[3] while in transit over the transit route would lead to lower overall changes on ambient air quality within the local study area compared to ferries at berth.

Therefore, the approach taken in the EIS of having two large ferries docked at the Tsawwassen Ferry Terminal 100% of the time was a conservative approach for estimating future ferry vessel emissions in the area around Roberts Bank. The conservatism in this approach was also increased by the assumption that all ferries operating out of the Tsawwassen Ferry Terminal in 2025 would be operating on diesel fuel instead of LNG, as discussed in the following section.

3. Anticipated Emission Reductions from Ferries Using LNG Fuel

At the time of RBT2 Air Quality Study, the VFPA had anecdotal information concerning plans by BC Ferries to replace the smaller ferries on Route 9 with new dual-fuel ferries operating on either LNG or ultra-low sulphur diesel and to convert the Spirit Class vessels on routes 1 and 30 to dual-fuel operation after 2018. However, although the VFPA was aware that BC Ferries had plans to convert some of its ferries to operate on LNG fuel, as well as low sulphur diesel after 2018, the certainty and timing of this being accomplished could not be verified at the time that the study was conducted. Furthermore, while there were some general estimates of the potential benefits in terms of emission reductions from the use of LNG as a marine fuel (Germanischer Lloyd and Man Diesel 2011, Deal 2013), the VFPA was unable to identify any studies with peer reviewed emission factors from the use of LNG in ships prior to completion of the RBT2 Air Quality Study and submission of the EIS to the Canadian Environmental Assessment Agency in March 2015. As such, the potential reduction in ferry emissions from the conversion of the ferry vessels to operate on LNG in the future could not be included in the air dispersion modelling analysis.

After submission of the EIS, a study was published by Anderson et al. (2015) that provides LNG fuel emission factors. **Table IR6-13-2** provides a comparison of these emission factors to the assumed emission factors from ferries operating in 2025 out of the Tsawwassen Ferry Terminal that were used in the RBT2 Air Quality Study.

[3] The effect of this distribution of emissions is evident in the predicted 1-hour average NO_2 concentrations presented in Figure 4-1 in Appendix F of EIS Appendix 9.2-A for ships underway in the Strait of Georgia. Whereas the maximum predicted 1-hour average NO_2 concentration at the Tsawwassen Ferry Terminal for two ferries simultaneously at berth for expected conditions is 132.7 µg/m^3, excluding background air quality (see Table 4-5 in EIS Appendix 9.2-A), the maximum predicted 1-hour average NO_2 concentration on the west side of the Strait of Georgia for a ferry approaching Active Pass is approximately 80 µg/m^3 (excluding background air quality). It should be noted that in both cases, the maximum predicted 1-hour average NO_2 concentration with the addition of background air quality is below the RBT2 Air Quality Study criterion of 188 µg/m^3 based on the interim provincial air quality objective for 1-hour NO_2 concentration (98th percentile over one year).

Table IR6-13-2 Comparison of Main Engine Emission Factors (g/kWh) for Diesel and LNG-fuelled Ferries

Contaminant of Potential Concern[a]	RBT2 Air Quality Study 2025 Main Engine Emission Factors for Diesel-fuelled Ferries[b]	Anderson et al. (2015) Main Engine Emission Factors for LNG-fuelled Ferries
NO_x	10.3	1.0
CO	1.1	1.4
THC	n/a	1.1
VOC (NMHC)	0.5	n/a
PM	0.25	0.18
CO_2	670	402

Notes: a. NO_x = nitrous oxides; CO = carbon monoxide; THC = total hydrocarbons, including methane; VOC (NMHC) = volatile organic carbon (non-methane hydrocarbons); PM = particulate matter; CO_2 = carbon dioxide.
b. Attachment 9 in Appendix A of EIS Appendix 9.2-A presents these emission factors, as well as emission factors for other parameters and auxiliary engines.
n/a = information not available; g/kWh = grams per kilowatt hour

The comparison provided in **Table IR6-13-2** indicates that with the use of LNG fuel, NO_x emissions could be reduced by over 90%, PM emissions by 28%, and CO_2 emissions by 40%. The 90% reduction in NO_x emissions with a switch to LNG fuel has been cited in other recent reports of LNG as a marine shipping fuel (DNV-GL 2015).

Conversely, CO emissions would increase by 27%. The increase in CO emissions is not a concern because the maximum predicted CO concentrations at the Tsawwassen Ferry Terminal are well below the ambient air quality objectives (i.e., 720.1 µg/m^3 maximum predicted incremental 1-hour average CO concentration plus 371.2 µg/m^3 background air quality = 1,091.3 µg/m^3, versus 14,300 µg/m^3 as the RBT2 Air Quality Study criterion, as presented in Table 4-5 of EIS Appendix 9.2-A)

Anderson et al. (2015) reports that THC emissions will increase in LNG-fuelled engines due to methane slip at high and low engine load factors. Therefore, some of the benefits from reduced CO_2 emissions could be diminished by an increase in methane emissions.

Update on LNG Fuel Conversion for Tsawwassen Ferry Terminal Ferries

During the summer of 2017, two Salish Class vessels, which are dual-fuel capable[4], replaced both existing vessels (the *Queen of Nanaimo* and the *Bowen Queen*) on Route 9 (BC Ferries 2017). The new vessels (*Salish Eagle* and *Salish Raven),* each have 4,438 kW main engine power rating[5]. The *Spirit of British Columbia* and *Spirit of Vancouver Island* vessels are also being converted to dual-fuel operation, and two other vessels on routes 1 and 30, the *Queen*

[4] Duel-fuel powered engines can operate on either natural gas or ultra-low sulphur diesel fuel.
[5] http://www.bcferries.com/about/intermediatevessel.html

of Alberni and the *Queen of New Westminster*, are scheduled to be replaced with newer vessels before 2025, possibly with ships that are dual-fuel capable (BC Ferries 2017).

The introduction of these dual-fuel ferries on Route 9, plus future conversions or replacement of Spirit and Queen Class ferries on routes 1 and 30 will result in up to a 90% reduction in NO_x emissions, based on emission factors outlined by Anderson et al. (2015). Maximum predicted 1-hour average NO_2 concentrations at the Tsawwassen Ferry Terminal (provided in EIS Section 9.2) will be greatly reduced, as will future background emissions for ferries at berth and along the transit routes. Any re-evaluation of ferry operations at the Tsawwassen Ferry Terminal would result in much lower estimated emissions, especially with respect to NO_x, as well as PM and CO_2 emissions as indicated in **Table IR6-13-2** above, and would result in much lower predicted ambient air concentrations than was indicated in the RBT2 Air Quality Study (EIS Appendix 9.2-A).

Conclusion

The RBT2 Air Quality Study captured emissions from ferry vessels in transit (incorporated in background concentrations) for the RBT2 air quality local study area. The assessment also used the most conservative assumptions about emissions from the operation of ferries at the Tsawwassen Ferry Terminal, assuming two large diesel-fuel powered ferries at berth 100% of the time (i.e., adoption of LNG as the primary fuel for ferries or incorporation of emissions distributed over the ferry routes was not assumed). Therefore, the approach taken in the RBT2 Air Quality Study was appropriate, as ferry emissions were captured in background concentrations, and model-predicted concentrations are conservative (i.e., emissions in 2025 have been overestimated based on recent introduction of dual-fuel ferries with lower emissions). Therefore, additional modelling of ferry emissions from ferries on routes 1 and 9 is not required.

References

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Deal, A. L. 2013. Liquefied Natural Gas as a Marine Fuel. A Closer Look at TOTE's Containership Projects. National Energy Policy Institute (NEPI) Working Paper.

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IR6-14 Air Quality – Populated Areas

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Section 3.3 and Figures 3.6 and 4.10; Appendix E Figures 4-10 to 4-14

Guidelines for Air Quality Dispersion Modelling in British Columbia, Ministry of the Environment, British Columbia, 2008

Context

Regarding the dispersion model receptors, the Proponent stated in Section 3.3 of Appendix 9.2-A that the grid resolution chosen exceeded the requirements of the *Guidelines for Air Quality Dispersion Modelling in British Columbia*, 2008, for all of the populated areas within the local study area to ensure that populated areas in Delta along the shore closest to Roberts Bank had sufficient grid resolution to capture maximum predicted concentrations of pollutants on land. However, Metro Vancouver underlined that the receptor grid used in the dispersion modelling, shown in Figure 3-6, demonstrated that the majority of populated areas in the study area, such as all of Ladner and most of Tsawwassen, do not have a fine 100 metre receptor spacing but a coarser resolution of 500 metres.

As stated by Metro Vancouver, the assessment for operations shown in Figure 4-10 of Appendix 9.2-A indicated that the maximum predicted on-land concentration coincided with a residential location in Tsawwassen and the English Bluff Elementary school; the latter being an area where the maximum 1-hour NO2 concentrations was predicted to be near the maximum Metro Vancouver air quality objective.

In Appendix E of Appendix 9.2-A, the construction phase assessment indicated maximum concentrations that were predicted to occur in populated areas and in the USA, including Point Roberts (Figures 4-10 to 4-14). Further, according to Metro Vancouver, regardless of the frequency of the construction activity, the plots demonstrated that the residential area of Point Roberts is important from a dispersion modelling perspective and that finely spaced receptors with a resolution greater than 500 metres are needed to ensure that the maximum concentrations of all air pollutants of concern are adequately captured.

Information Request

Include finely spaced receptors of 100 metre-spacing over residential areas in the new model domain, to cover at a minimum, Tsawwassen First Nation lands and the farm land area northwest of the causeway, Tsawwassen and the English Bluff Elementary school, the residence in Point Roberts, and the marine surface between the Roberts Bank terminals and the shore.

Present the results in isopleth plots and discuss these results.

Modelling with a larger model domain has been shown to not have an appreciable effect on predicted contaminant concentrations within the RBT2 Air Quality Study (RBT2 Study) local study area (LSA). Refer to the response to IR6-11 for the results of sensitivity analyses conducted for the purposes of comparing larger modelling domains to the RBT2 Study modelling domain[1]. Based on the results of these sensitivity analyses, CALMET and CALPUFF were not re-run on a 50 km x 50 km domain (as was requested in IR6-11).

The response below provides background information on selection of the 26 km x 24 km RBT2 Study modelling domain, and further analyses using a finer receptor spacing of 100 m on this domain.

Selection of RBT2 Study Receptor Grid Resolution

The RBT2 Study receptor grid resolution was selected based on feedback from regulatory agencies (i.e., Environment Canada, B.C. Ministry of Environment, and Metro Vancouver) that participated in the Air Quality Scoping Study (AQSS) process. Appendix IR6-04-A in the response to IR6-04 provides a summary of key topics, including receptor grid resolution, discussed during the scope phase for the RBT2 Study with AQSS participants. Agency participants suggested that the RBT2 Study receptor grid resolution be aligned with the receptor spacing identified within the 2008 *Guidelines for Air Quality Dispersion Modelling in British Columbia* (2008 B.C. Guidelines; MOE 2008).

In response to additional feedback, the VFPA adopted a receptor grid resolution that exceeded the recommended receptor spacing outlined in the 2008 B.C. Guidelines, notably for areas beyond 2 km from the Project area boundary, as summarised in **Table IR6-14-1**, to ensure that populated areas in Delta along the shore closest to Roberts Bank would have sufficient receptor grid resolution to capture maximum predicted concentrations on land. Thus, by adopting a higher resolution receptor grid than those recommended in the 2008 B.C. Guidelines, the RBT2 Study included the assessment of more receptor points per square kilometre over Tsawwassen First Nation Lands and the western part of the City of Delta (including Tsawwassen).

Table IR6-14-1 LSA Receptor Grid Resolution Comparison to 2008 B.C. Guidelines

Area	2008 and 2015 B.C. Guidelines Recommended Grid Resolution	RBT2 Study Grid Resolution based on Regulatory Agency Input
Along Boundary line (water)	20 m	20 m
Within 500 m from source (water)	50 m	50 m
Within 2 km from source (water, causeway)	250 m	200 m

[1] Three sensitivity analyses have been completed to compare model simulation results for the 26 km x 24 km RBT2 Air Quality Study modelling domain to simulations with model domain dimensions of 1) 30 km x 30 km, 2) 31 km x 34 km, and 3) 50 km x 50 km.

Area	2008 and 2015 B.C. Guidelines Recommended Grid Resolution	RBT2 Study Grid Resolution based on Regulatory Agency Input
Within 5 km from source (water, causeway, ferry terminal and causeway)	500 m	200 m
Beyond 5 km from source	1000 m	500 m

Of the 8,642 receptor locations within the LSA, 18 discrete receptors[2] were selected for two reasons:

- To assess populated and publicly accessed locations that could potentially be affected by changes to air quality in the area surrounding the Project; and
- To assist with the interpretation of the more than 8,600 model results for each of the parameters assessed.

In addition to the maximum point of impingement (MPOI) over land, the discrete receptors were selected for presentation purposes to assist with explaining changes in predicted air quality parameter concentrations in the future (with or without the Project) compared to existing conditions. Parameter concentrations could be provided for any of the more than 8,600 receptor locations, including the specific locations in Tsawwassen and English Bluff Elementary School mentioned in the information request, as provided below.

Analysis for Finer Receptor Grid in 50 km x 50 km Model Domain

Further explanation is provided below to outline the accuracy of predicted concentrations within the LSA at discrete receptors (or any of the 8,642 grid locations).

Utilising the sensitivity analysis on a point source emission (i.e., a 12,000 TEU (twenty-foot equivalent unit) vessel at berth at the RBT2 terminal) conducted to support the response to IR6-11[3], two additional receptors (R19 Residential Location in Tsawwassen and R20 English Bluff Elementary School) were added to the list of 18 discrete receptors. Maximum predicted 1-hour average NO_2 concentrations for the 50 km x 50 km model domain and the 26 km x 24 km RBT2 model domain are tabulated for each of the 20 discrete receptors in **Table IR6-14-2**, along with the difference in concentration at each receptor[4].

[2] Similar discrete receptor locations were used in the air quality assessment for the Deltaport Third Berth Project in 2005 (i.e., R1 to R11, R14, R15, and R17). New receptor points were added for the Delta Hospital (R12), BC Ferries Tsawwassen Terminal (R13), and the Air Quality Monitoring Station T39.

[3] For further information pertaining to the methods used in the sensitivity analysis and model simulation results, refer to the response provided in IR6-11.

[4] The difference in predicted concentrations between the two modelling domains at each discrete receptor was calculated by subtracting the RBT2 Study concentration from the 50 km x 50 km modelling domain concentration. As outlined in the response to 1R6-11, differences would be less than those shown in **Table IR6-14-2** and **Figure IR6-14-2,** as the Ozone Limiting Method tends to over-predict

Isopleth plots are provided in **Figure IR6-14-1** to show maximum predicted 1-hour average NO_2 concentrations for each modelling domain simulation, and **Figure IR6-11-2** illustrates the differences in the maximum predicted 1-hour average NO_2 concentrations between the two model domains simulations[4]. As examples, the maximum predicted 1-hour average NO_2 concentrations at the residential location in Tsawwassen (R19) and the English Bluff Elementary School (R20) are the same in both model simulations.

Table IR6-14-2 Maximum Predicted 1-hour Average NO_2 Concentrations at Discrete Receptor Locations

UTM Location (km)		Discrete Receptor	Predicted 1-h NO_2 Concentration ($\mu g/m^3$)		
Easting	Northing		Extended Model Domain (50 km x 50 km)	RBT2 Model Domain (26 km x 24 km)	Difference (Extended-RBT2)
493.850	5436.550	R1 Ladner	5.6	5.6	0.00
491.150	5434.601	R2 Farmer 1	7.6	7.5	0.17
492.500	5432.500	R3 Tsawwassen First Nations	9.5	9.5	0.00
492.050	5433.101	R4 Farmer 2	6.7	6.7	0.00
489.800	5434.050	R5 Farmer 3	7.2	7.2	0.00
493.250	5431.050	R6 Tsawwassen Beach Campsite	14.6	14.6	0.00
495.800	5431.351	R7 Beach Grove	5.8	5.8	0.00
497.100	5427.951	R8 Boundary Bay	9.4	8.4	1.00
493.575	5429.351	R9 Tsawwassen	8.6	8.6	0.00
497.125	5426.101	R10 Point Roberts 1	10.0	10.0	0.04
493.875	5427.601	R11 Point Roberts 2	12.7	11.7	0.97
495.499	5436.926	R12 Delta Hospital	3.3	3.3	0.00
490.480	5428.242	R13 Ferry Terminal	21.9	21.9	0.02
486.900	5438.150	R14 Reifel Bird Sanctuary	5.6	5.6	0.00
496.350	5429.851	R15 Boundary Bay GVRD Park	6.4	6.4	0.00
492.760	5429.900	R16 English Bluffs Beach	10.8	10.8	0.00
490.810	5437.300	R17 South Arm Marsh	4.5	4.5	0.00
494.008	5428.557	R18 Air Quality Station T39	8.3	8.3	0.01
491.162	5433.125	R19 Residential Location in Tsawwassen	10.4	10.4	0.00
493.534	5428.634	R20 English Bluff Elementary School	9.7	9.7	0.00

NO_2 concentrations by a factor of 2 (when calculated using 98th percentile concentrations observed ozone concentration at Station T39).

Figure IR6-14-1 Comparison of Maximum Predicted 1-hour Average NO_2 Concentration Isopleths Modelled over the Extended Model Domain (50 km x 50 km) (left) and RBT2 Model Domain (26 km x 24 km) (right)

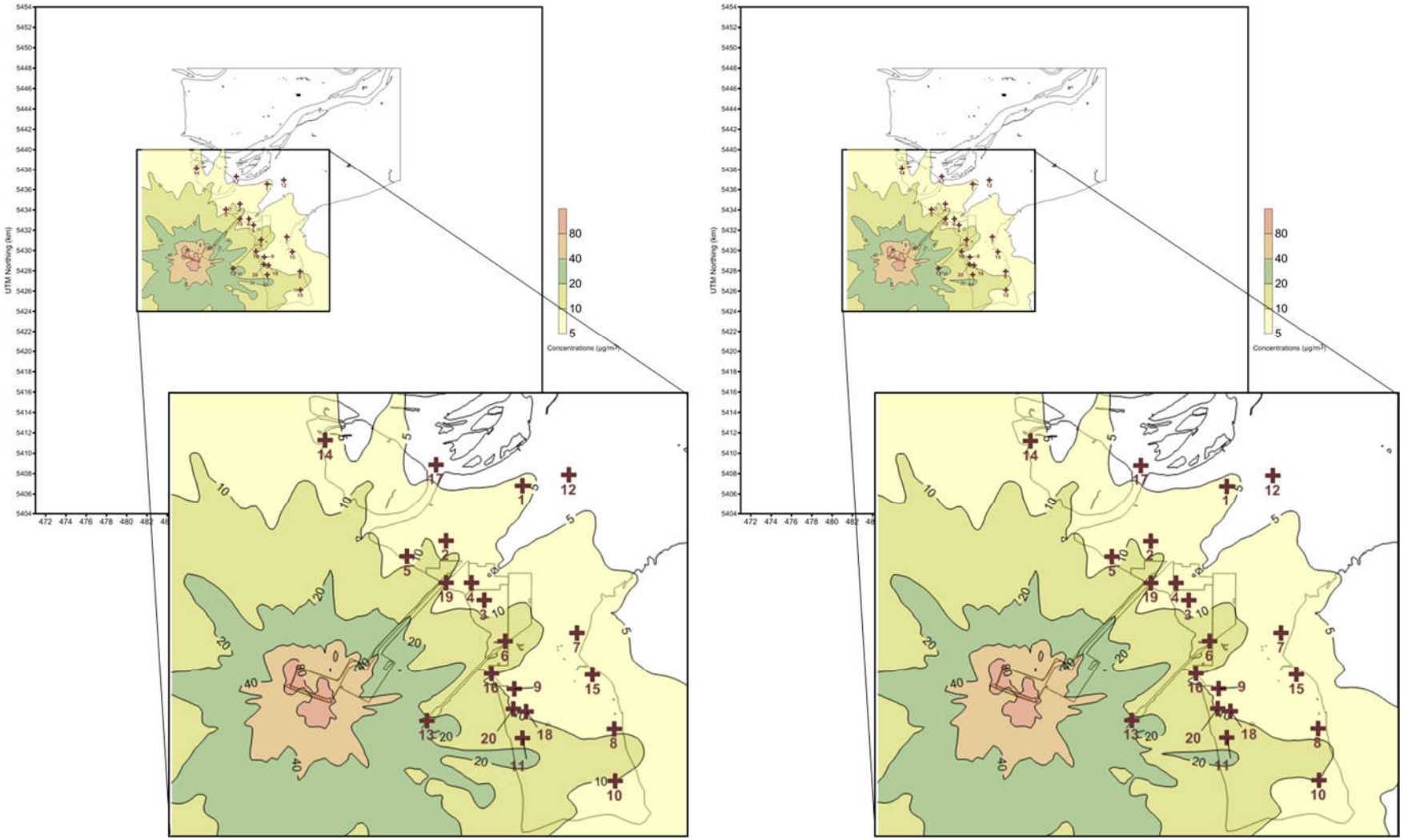
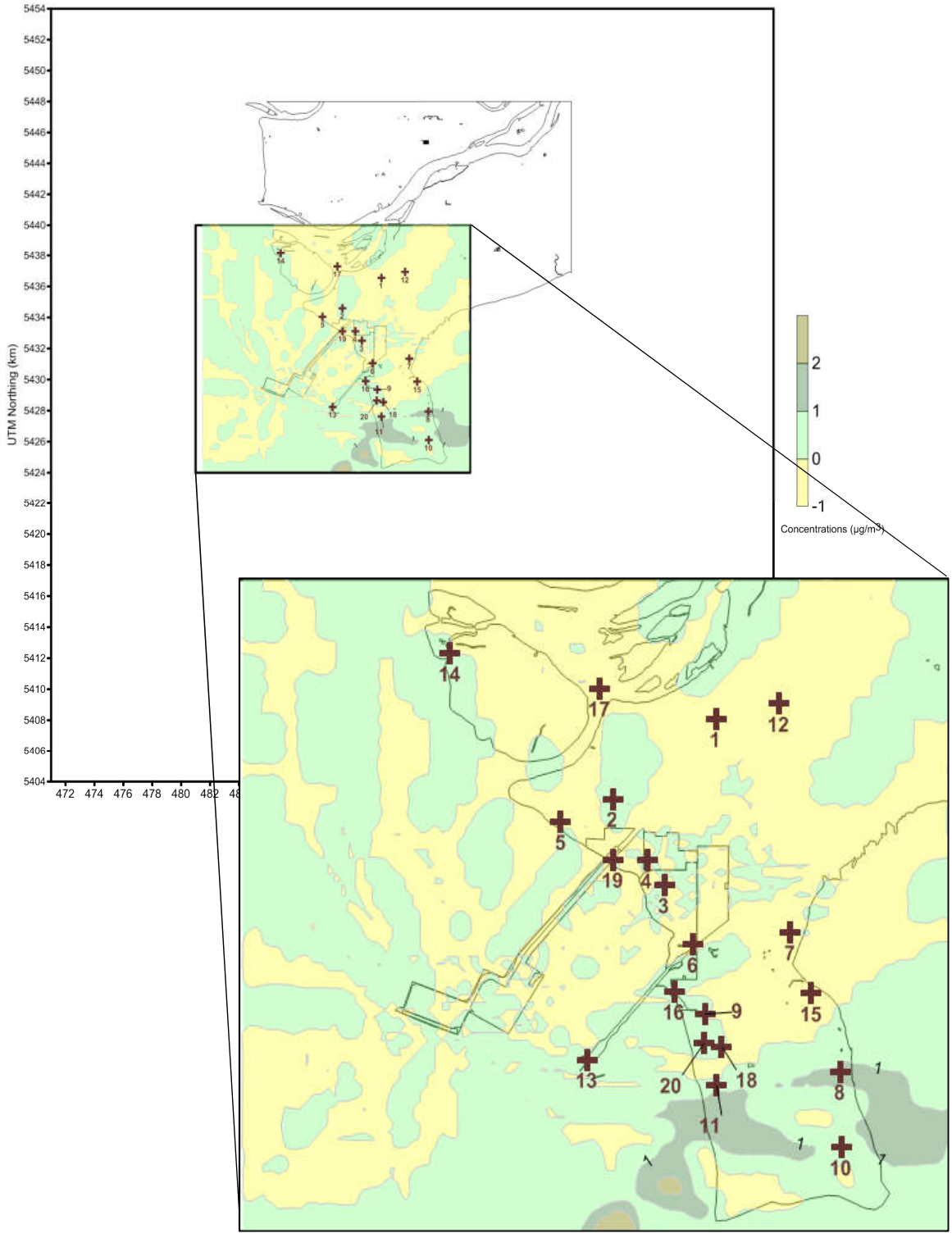


Figure IR6-14-2 Difference in Maximum Predicted 1-hour Average NO_2 Concentrations using Extended Model Domain and RBT2 Model Domain



Predicted concentrations at any receptor of interest over residential areas could be estimated from a proximal receptor, as differences in predicted concentrations at any given location versus a proximal receptor would be small (i.e., concentrations are unlikely to peak or be elevated between receptor locations in proximity to each other) and differences would be within the error of the model[5]. Given the negligible differences in the maximum predicted concentrations presented in the sensitivity analysis, the VFPA reiterates that the requirement to re-model on a 50 km x 50 km model domain at 100 m receptor spacing is unnecessary, as the outcomes of re-modelling are unlikely to change the conclusions RBT2 Study.

Nevertheless, for the purposes of responding to this information request, cases where the MPOI occurred at a 500 m receptor resolution and were close to and/or were predicted to exceed Metro Vancouver ambient air quality objectives (AAQOs), the model domain was re-modelled for NO_2 with finely spaced receptors of 100 m in areas for the following cases:

- Existing conditions: 1-h maximum NO_2 MPOI located west of Pebble Hill Park area (i.e., west of Air Quality Monitoring Station T39 at R18; location shown in Figure IR6-24-A3 in the response to IR6-24);
- Future conditions with the Project: 1-h maximum NO_2 MPOI located near east end of Roberts Bank causeway in Tsawwassen (location shown in Figure IR6-24-A3 in the response to IR6-24); and
- Average day construction scenario: 24-h maximum NO_2 MPOI located in a residential area in Point Roberts (location shown in Figure IR6-24-A22 in the response to IR6-24).

Table IR6-14-1 provides a comparison of MPOI concentrations for these three cases for 500 m and 100 m spacing receptors.

[5] An example of differences being within model error is as follows. Approximately 7 km from the Project area (i.e., approximate distance to English Bluff Elementary School), an uncertainty of 1 degree in wind direction is equivalent to an uncertainty of 120 m in spatial coordinates, which is greater than the requested receptor spacing of 100 m. The 1-degree uncertainty corresponds to the U.S. Environmental Protection Agency recommended resolution for wind direction measurements in support of regulatory air quality modelling applications (U.S. EPA 2000).

Table IR6-14-1 Comparison of MPOI Concentrations from RBT2 Air Quality Study (500 m Receptor Spacing) and IR6-14 Response Re-modelling (100 m Receptor Spacing)

Case/Scenario	Contaminant and Averaging Time	RBT2 Air Quality Study Modelling Results for MPOI Over Land			IR6-14 Modelling Results for MPOI Over Land (100 m Receptor Spacing)		
		Easting X (km)	Northing Y (km)	Concentration[a] ($\mu g/m^3$)	Easting X (km)	Northing Y (km)	Concentration[a] ($\mu g/m^3$)
Existing Conditions	1-h Maximum NO_2	493.013	5428.708	197.1[b]	492.919	5428.606	197.9
Future Conditions with the Project	1-h Maximum NO_2	491.162	5433.125	292.1[c]	491.159	5433.135	305.0
Construction Phase Average Day Scenario	24-h Maximum NO_2	493.813	5426.108	83.8[d]	493.702	5426.218	89.3

Notes:

a. Concentrations included background concentrations of 44.7 $\mu g/m^3$ for 1-h NO_2 and 34.9 $\mu g/m^3$ for 24-h NO_2.

b. Incremental maximum over land concentration of 152.4 $\mu g/m^3$ for 1-h NO_2 provided in EIS Table 9.2-13 (and Table IR6-23-A1 in the response to IR6-23); location of MPOI for existing conditions shown in Figure IR6-24-A3 in the response to IR6-24.

c. Incremental maximum over land concentration of 247.4 $\mu g/m^3$ for 1-h NO_2 provided in EIS Table 9.2-25 (and Table IR6-23-A9 in the response to IR6-23); location of MPOI for future conditions with the Project shown in Figure IR6-24-A3 in the response to IR6-24.

d. Incremental maximum over land concentration of 48.9 $\mu g/m^3$ for 24-h NO_2 provided in EIS Table 9.2-20 (and Table IR6-23-A5 in the response to IR6-23); location of MPOI for construction phase average day scenario shown in Figure IR6-24-A22 in the response to IR6-24.

As shown in **Table IR6-14-1**, MPOI predicted concentrations increased by 0.2%, 4.4%, and 6.6% with re-modelling with finer 100 m spaced grid receptors and at the distance of 0.102 km, 0.010 km, and 0.156 km from the RBT2 Air Quality Study MPOI locations for the three cases, respectively. The NO_2 concentrations presented for both the 500 m and 100 m receptor spacing model runs are anticipated to be 1.7 to 2.9 times higher than what may actually occur, as a result of the methodology used. Additional information of the overprediction of NO_2 is provided in the response to IR6-22. Results of the re-modelling of finer 100 m grid spacing does not change the air quality assessment conclusions provided in EIS Section 9.2.

Furthermore, the emission inventory presented in EIS Appendix 9.2-A (Figures 4-1 and 4-2, Table 4-4-1) indicated a general reduction in total annual emissions of the criteria air contaminants (i.e., CO, NO_x, SO_2, and $PM_{2.5}$) from Roberts Bank terminals in 2025 (for both expected conditions without the Project and future conditions with the Project) compared to existing conditions in 2010. Regarding the conclusions of the RBT2 Air Quality Study and questions over fine grid spacing, ambient air quality concentrations of all contaminants currently meet all Metro Vancouver AAQOs at the monitoring station at Pebble Hill Park (Station T39[6]). Since ambient air quality objectives are being achieved under existing conditions, it is reasonable to assume that AAQOs will not be exceeded in the future when emission rates are expected to be lower.

Hence, regardless of the modelling domain size or computational grid resolution, the conclusions of the RBT2 Study remain the same; specifically:

- Air quality will improve in the future, with or without the Project, as a result of improvements in engine technologies and the use of cleaner fuels; and
- Levels of criteria air contaminants on land are predicted to be below ambient air quality criteria

References

British Columbia Ministry of Environment (MOE) 2008. Guidelines for Air Quality Dispersion Modelling in British Columbia. Environmental Protection Division, Environmental Quality Branch, Air Protection Section, Victoria, BC.

United States Environmental Protection Agency (U.S. EPA). 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. EPA-454/R-99-005. Available at https://www3.epa.gov/scram001/guidance/met/mmgrma.pdf. Accessed February 2018.

[6] Station T39 is representative of ambient concentrations within Tsawwassen First Nation Lands, as discussed in the response to IR6-09 (CEAR Document #1113).

IR6-15 Air Quality – Emissions Modelling Sources Parameters

Information Source(s)

EIS Volume 2: Section 9.2, Appendix 9.2-A, Appendix C: Section 3.3, Table 3-4, Section 3.4

Context

Table 3-4 of Section 3.3 of the EIS presented the nine study scenarios used in CALPUFF to determine potential changes from simultaneous operations of all Project activities ranging from realistic maximum loads, representing potential worst-case air concentrations associated with the Project activities and, the average annual scenarios, representing more typical conditions.

Section 3.4 of the EIS presented the CALPUFF sources such as cargo handling equipment, rail and tugs at berth and parameters used in modelling these sources such as exhaust stack height, diameter, gas temperature and velocity for ocean-going ships. It is not clear which sources were considered for which scenarios (1-hour, 24-hour) and annual averaging periods.

Information Request

Explain how the maximum worst case 1-hour emissions were considered and if any combination of Project activities could result in higher predicted emissions than those presented in the air quality assessment in the EIS.

Provide a table(s) that lists the emission sources considered in each scenario, including a description of the source (such as that a berthed ship was modelled with only the auxiliary engines considered); the location of the source; the frequency of the source (such as constant, variable or intermittent); and how it was modelled (such as point, line or volume).

For emission sources that are intermittent, explain how the emissions were distributed for each averaging period (such as the 1-hour maximum was modelled for every hour of the year or the 8 hours were divided by 24 hours in the day).

VFPA Response

Explain how the maximum worst case 1-hour emissions were considered and if any combination of Project activities could result in higher predicted emissions than those presented in the air quality assessment in the EIS.

The maximum worst-case 1-hour emission scenario assessed in the RBT2 Air Quality Study (EIS Appendix 9.2-A) was developed using emissions from vessels (on approach and departure from the terminal as well as at berth), cargo handling equipment (CHE), rail locomotives, and on-road vehicles. These emissions were modelled simultaneously. Specific details pertaining to the maximum worst-case 1-hour emission scenario for each source are as follows:

- For vessel emissions (container ships, bulkers, tugs, and ferries), it was assumed that all berths at all terminals were fully occupied, and that there was a maximum number of ship movements per day per berth (maximum ship arrival/departure activity levels), which rarely occurs. Larger representative vessels were assumed at all berths, in 2010 and in 2025 for the RBT2, Deltaport, and Westshore terminals. To reflect the maximum 1-hour emission rate, benefits from shore power usage at the Deltaport Third Berth or RBT2 were not included;
- For 2010 and 2025 scenarios, CHE emissions were modelled as an average emission rate because the degree of variability in CHE operations was indeterminate. Emissions will increase in the future with additional capacity at Westshore Terminals, which was also considered in the assessment of fugitive dust emissions and ship emissions at Westshore Terminals;
- Rail emissions were assumed to remain constant during the operation phase, although more efficient engines that use less fuel are anticipated in future years. Switcher locomotives were conservatively assumed to be replaced with Tier 1 engines by 2023 and remain unchanged as Tier 1 engines throughout the operation phase (as represented for conditions modelled for 2025). For more information on assumed switcher engine tier levels, refer to the response to IR6-16; and
- For on-road vehicles, peak traffic levels were assumed, based on on-road vehicle data provided by Port Metro Vancouver (now referred to as the VFPA) and the B.C. Ministry of Transportation.

Based on the assumptions incorporated in the RBT2 Air Quality Study (EIS Appendix 9.2-A) for the assessment of maximum worst-case emissions, there is no combination of Project activities that could result in higher predicted emissions than those already assessed (i.e., the maximum worst-case has been considered).

Provide a table(s) that lists the emission sources considered in each scenario, including a description of the source (such as that a berthed ship was modelled with only the auxiliary engines considered); the location of the source; the frequency of the source (such as constant, variable or intermittent); and how it was modelled (such as point, line or volume).

A description of the assumptions considered for each emission source (i.e., ships, CHE, locomotives, and on-road vehicles) to develop the existing, expected, and future emission scenarios is provided in **Appendix IR6-15-A**, Table IR6-15-A1. For the various scenarios, Table IR6-15-A1 provides a summary description of the emissions considered, location of the emission source, the frequency of the source emissions (constant, variable, or intermittent), and the modelling method (point, line, area, or volume). Detailed information related to this information request is included in attachments to Appendix A of EIS Appendix 9.2-A. For ease of reference, the specific attachments are referenced in Table IR6-15-A1.

For emission sources that are intermittent, explain how the emissions were distributed for each averaging period (such as the 1-hour maximum was modelled for every hour of the year or the 8 hours were divided by 24 hours in the day).

For emissions sources that are intermittent, emissions were modelled at a constant rate for the 1-hour emissions and daily emissions, as indicated in the table provided in

Appendix IR6-15-A. All attachments referred to in the table are included in Appendix A of EIS Appendix 9.2-A. The 8-hour averages for CO were calculated based on the rolling average of maximum 1-hour averages.

For the distribution of emissions, the following assumptions were incorporated:

- Vessel activities for hypothetical maximum hourly and daily emission scenarios were extremely conservative in assuming all berths were occupied 100% of the time and at maximum ship arrival/departure activity levels. As indicated previously, the benefits from shore power were not included in the assessment for any averaging periods;
- Cargo handling equipment emissions were modelled as an average emission rate for all averaging periods because the degree of variability in CHE operations was indeterminate; and
- Emissions from on-road trucks and from rail were modelled at peak activity levels for maximum hourly and daily emission scenarios, and at average activity levels for the annual scenario modelling.

Appendices

Appendix IR6-15-A Scenario Assumptions for Emissions Sources at Roberts Bank

APPENDIX IR6-15-A
SCENARIO ASSUMPTIONS FOR EMISSIONS SOURCES AT ROBERTS BANK

Table IR6-15-A1 Scenario Assumptions for Ships, Cargo Handling Equipment, Locomotives, and On-road Vehicle Emissions at Roberts Bank

Scenario	Vessel/Equipment Type	Source Location	Emission Source Description and Detailed Information Attachment references are located in Appendix A of EIS Appendix 9.2-A	Frequency of Source (Constant, Variable, Intermittent)	How it was Modelled (Point, Line, Area, Volume)
Ships					
1-h average and maximum (max), 24-h average and max, and annual average emissions during existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025)	Bulk Carrier	Westshore Terminals and Roberts Bank	Modelled vessels at berth, while manoeuvring, standby, powerdown, and in transit (as applicable to the vessel category) based on various vessel sizes, specifications, emission rates, and activity levels. See **Attachment 1** for vessel types (if applicable), total engine power ratings, load factors as a constant source for each vessel activity, percent sulphur in fuel and sulphur emission factor, and NOx tier levels and emission factors for each scenario. See **Attachment 2** for activity level assumptions related to number of vessel calls and vessel sizes, berthing and manoeuvring times per call, number of vessels berthed simultaneously, manoeuvring movements (if applicable) for each scenario. See **Attachment 9** for emission factors for gaseous and particulate criteria air contaminants (CACs), greenhouse gases (GHGs), and trace organics for the various vessel engine types for 2010 and 2025.	Constant	Berthed ships were modelled as point sources, including the auxiliary engine and boiler. Manoeuvring ships were modelled as point sources along the path of the ship including the main engine, auxiliary engine, and boiler.
	Container Ship	Deltaport Terminal and Roberts Bank			
1-h average and max, 24-h average and max, and annual average emissions during future conditions with the Project (2025)	Container Ship	RBT2 and Roberts Bank			
1-h average and max, 24-h average and max, and annual average emissions during existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025)	Tugboats	Roberts Bank			At berth, tug boats were modelled as point sources. Tugs assisting a manoeuvring vessel were modelled as point sources along the vessel path.
	Ferries	BC Ferries Terminal and along BC Ferries Route 30			Ferries at berth were modelled as point sources. Ferries in transit were modelled as a series of point sources spread along the Vancouver-Nanaimo ferry route at an approximate distance of 1 km within the local study area. For information on ferries in transit beyond the local study area, refer to Appendix F of EIS Appendix 9.2-A.
Cargo Handling Equipment (CHE)					
1-h average and max, 24-h average and max, and annual average emissions during existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025)	Rubber Tired Gantry (RTG) Cranes	Deltaport Terminal (2010 and 2025)	CHE activities are assumed to occur evenly throughout a daily period; therefore, the same activity level is assumed for the 1-h average and max, 24-h average and max, and annual average. See **Attachment 3** for activity level assumptions, emission factor assumptions and development, and emission factors.	Constant	Emissions from CHE was modelled as multiple volume sources measuring 20 m by 20 m, spread throughout the CHE activity area at all three terminals. The model parameters used in modelling CHE at all three terminals are presented in Table 3-13 of Appendix C of EIS Appendix 9.2-A.
	Reach Stackers, Top/Side Picks				
	Yard Trucks				
	Non-RTG Cranes	Westshore Terminals (2010 and 2025)			
	Terminal Trucks				
	Forklifts, Manlifts, Aerial Lifts				
	Tractors, Loaders, Backhoes, Excavators				
	General Industrial Equipment				
1-h average and max, 24-h average and max, and annual average emissions	Rubber Tire Hydraulic Cranes	RBT2 (2025)			
	Top Picks				

Scenario	Vessel/Equipment Type	Source Location	Emission Source Description and Detailed Information Attachment references are located in Appendix A of EIS Appendix 9.2-A	Frequency of Source (Constant, Variable, Intermittent)	How it was Modelled (Point, Line, Area, Volume)
during future conditions with the Project (2025)	Automated Shuttle Carriers				
	Yard Trucks				
	Forklifts, Manlifts, Aerial Lifts				
	General Industrial Equipment				
Locomotives					
1-h average and max, 24-h average and max, and annual average emissions during existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025)	Switcher	Westshore Terminals, Deltaport Terminal, Roberts Bank causeway (2010 and 2025), and RBT2 (2025)	Emissions from switcher locomotives operating at RBT2 (for 2025) and Deltaport (for 2010 and 2025), as well as line-haul locomotives arriving and departing to/from the Westshore Terminals (2010 and 2025) and RBT2 (for 2025) were modelled. Moving locomotives were modelled along the Roberts Bank causeway and idling locomotives were modelled at the Westshore Terminals and along the Roberts Bank causeway. See **Attachment 4** for locomotive emission rates for idle and work modes, engine tier levels, and emissions factors for each scenario. See **Attachment 5** for locomotive activity levels including distance travelled, speed, and traffic counts for each scenario.	Constant	Emissions from moving locomotives along the Roberts Bank causeway were simulated as individual volume sources measuring 25 m by 25 m, spread evenly along the causeway, approximately every 70 m. Emissions from idling locomotives were modelled as point sources.
	Line-Haul				
On-road Vehicles					
1-h average and max, 24-h average and max, and annual average emissions during existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025)	Heavy-Duty Diesel Vehicle (HDDV)	Deltaport Terminal and Westshore Terminals (2010 and 2025), and RBT2 (2025)	Heavy- and light-duty traffic along the causeway and at the terminals was modelled, based on traffic counts provided by Port Metro Vancouver on an annual, average daily, peak daily, average hourly, and peak hourly basis. See **Attachment 6** for on-road vehicle activity levels, including distance travelled per trip, speed, and traffic counts for each scenario (hour, day, year). See **Attachment 10** for age distributions for on-road vehicles, based on 2010 information from Metro Vancouver. See **Attachment 11** for on-road vehicle emission factors, based on the U.S. Environmental Protection Agency's (EPA's) MOVES emission model.	Constant	Emissions from diesel truck and employee-owned vehicle traffic along the Roberts Bank causeway were combined and modelled as a series of volume sources. These sources, measured 20 m by 20 m, were spread evenly along the causeway and spaced at approximately 80 m distance.
	Light-Duty Vehicle (LDV)				
	Diesel Bus (DB)	BC Ferries Terminal (2010 and 2025)	The vehicle traffic counts on the ferry causeway (Highway 17) to and from the BC Ferries Terminal were modelled, based on annual average daily traffic and maximum peak hourly traffic counts for Highway 17 for the year 2010 through the B.C. Ministry of Transportation and Infrastructure's traffic data program. See **Attachment 6** for on-road vehicle activity levels, including distance travelled per trip, speed, and traffic counts for each scenario (hour, day, year). See **Attachment 10** for age distributions for on-road vehicles, based on 2010 information from Metro Vancouver. See **Attachment 11** for on-road vehicle emission factors, based on the U.S. EPA's MOVES emission model.		Emissions from on-road vehicles on the BC Ferries Terminal causeway were modelled as a series of volume sources (measuring 20 m by 20 m), spread evenly along the causeway at approximately 100 m distance.
	Heavy-Duty Diesel Vehicle (HDDV)				
	Heavy-Duty Gasoline Vehicle (HDGV)				
	Light-Duty Vehicle (LDV)				
	Motorcycle (MC)				

IR6-16 Air Quality – Emissions Modelling, Switcher Locomotive Fleet Turnover Rates

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix A, Section 4.1 and Table 4-3

Context

In Table 4-3 in Appendix A of Appendix 9.2-A in the EIS, the Proponent assumed that, for switcher locomotives, the turnover rate would be 100% from 2010 to 2023 for Tier 1 engines and remained unchanged for 2025. The fleet turnover rate assumed in the analysis from current conditions to future conditions would have an impact on combustion emissions. Considering that the life of a locomotive engine is in the range of 40-50 years and that there are no regulated mandatory upgrade or replacement requirements for locomotives, a more realistic assessment is required which takes into account the possibility that 100 % of the switcher locomotive fleet would not be replaced or upgraded from Tier 0 locomotives to Tier I engine standards by 2025.

Information Request

Include in the modelling and assessment a more realistic approach for the switcher locomotives turnover rates.

Present and discuss the new results for air contaminants of concern (CO, NOx SO_2 and PMs) and greenhouse gas emissions.

VFPA Response

Clarification

The VFPA affirms that a realistic approach to fleet turnover was used to define the fleet turnover rate for switcher locomotives, and this response provides further information to demonstrate that the RBT2 Air Quality Study (EIS Appendix 9.2-A) was based on realistic assumptions.

The Panel's context to this information request states that there "*are no regulated mandatory upgrade or replacement requirements for locomotives*". Since 2011, a Memorandum of Understanding (MOU) between Transport Canada and the Railway Association of Canada (RAC) for Reducing Locomotive Emissions has been in place[1]. This MOU established a framework through which the RAC (and its member companies) and Transport Canada would

[1] The MOU originally covered the period of 2011 to 2015, and was extended until the end of 2017. Prior MOUs to address emissions produced by locomotives during rail operations in Canada were in place from 1995 to 2005 (Memorandum between the RAC and Environment Canada) and 2006 to 2010 (Memorandum between the RAC, Transport Canada, and Environment Canada).

address emissions of criteria air contaminants and greenhouse gases (GHGs) from locomotives operated by Canadian railway companies in Canada. Transport Canada recently developed the Locomotive Emissions Regulations under the *Railway Safety Act*, which came into effect on June 9, 2017.

Both the MOU and Locomotive Emissions Regulations are aligned with emission standards to limit emissions of nitrogen oxides (NO_x), particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO) for newly manufactured and remanufactured locomotives in the U.S.A.[2] Since the RBT2 Air Quality Study (EIS Appendix 9.2-A) was conducted prior to regulations coming into force in Canada, it incorporated the U.S. Environmental Protection Agency (EPA) Regulations for Emissions from Locomotives, as it was known in 2011 at the time of signing of the MOU that Transport Canada was developing regulations that would be aligned with U.S. regulations.

This response provides information on the following three points, which are further explained below, demonstrating that the approach taken in the RBT2 Air Quality Study (EIS Appendix 9.2-A) was based on realistic assumptions:

1. The VFPA obtained information from B.C. Rail on locomotive fleet turnover rates, which informed the emissions inventory and subsequent modelling conducted for the RBT2 Air Quality Study (EIS Appendix 9.2-A);
2. Emission rates for PM and GHGs between Tier 0 and Tier 1 switcher locomotives do not differ, while the differences in NO_x emissions are small and would not materially change the conclusions of the RBT2 Air Quality Study (EIS Appendix 9.2-A); and
3. In demonstrating compliance with the MOU, the RAC publishes an annual, peer-reviewed report summarising the progress that railways have made towards meeting emission targets, and highlighting the actions that the industry has taken to reduce emissions, including upgrading and retiring locomotives.

1. Consultations with B.C. Rail

On April 4, 2013 on behalf of Port Metro Vancouver (now referred to as the Vancouver Fraser Port Authority), SENES Consultants[3] met with G. Westlake of B.C. Rail to discuss assumptions for the assessment of RBT2 rail locomotive emissions. A memorandum detailing the topics discussed at the meeting and the input from Mr. Westlake is provided in **Appendix IR6-16-A**. With regard to switcher locomotives, the memorandum states that *"Switch locomotives will be conservatively assumed to be replaced with Tier 1 engines by 2025 and remain unchanged as Tier 1 engines for 2030."* Thus, the assumption that 100% of the switcher locomotives

[2] U.S. Locomotive Emissions Control Regulations can be found at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr1033_main_02.tpl
[3] In March 2013, SENES Consultants was acquired by ARCADIS to form ARCADIS SENES Canada Inc.

would consist of Tier 1 locomotives was considered by the VFPA to be a conservative estimate (i.e., fleet turnover could potentially be greater than this).[4]

2. Switcher Locomotive Emission Standards

The locomotive emission standards adopted by the U.S. EPA in 1998 defined emission standards for all new locomotives[5] based on their year of manufacture:

- Tier 0 – before 2001;
- Tier 1 – 2002-2004; and
- Tier 2 – after 2005.

Because railway companies in Canada purchase new locomotives from U.S. manufacturers, locomotive *"emissions in Canada are reduced as these new locomotives are acquired"* (RAC 2015).

In 2008, the U.S. EPA introduced more stringent emission standards for locomotives, which are referred to as Tier 0+, Tier 1+, and Tier 2+. New standards were also adopted for Tier 3 (2012-2014) and Tier 4 (2015 or later) locomotives, but none of the switcher locomotives operating at Roberts Bank are expected to include engines manufactured after 2012 for some time.

The new Tier 0+, Tier 1+ standards apply to all new and rebuilt locomotives. As indicated in Table 4-7 in Appendix A of EIS Appendix 9.2-A, the difference in emissions between Tier 0 and Tier 1 switcher locomotives is relatively small. **Table IR6-16-1** provides U.S. Tier 0 and Tier 1 emission standards (U.S. EPA 2016) (previously provided in Table 4-7 of Appendix A of EIS Appendix 9.2-A) as summarised by the RAC (2015), as well as Tier 0+ and Tier 1+ emission standards for remanufactured Tier 0 and Tier 1 engines (RAC 2014), respectively.

[4] It is relevant to note that this same assumption of Tier 1 locomotives by 2025 was incorporated in the air quality assessment for the Deltaport Terminal, Road and Rail Improvement Project (SENES 2012), which was reviewed by Environment Canada and Metro Vancouver, and subsequently approved to proceed.

[5] Note that the applicability of the Tier 1 and Tier 2 standards was based on the date of manufacture of the locomotive, rather than the engine. Thus, a newly manufactured engine in 2005 that was used to repower a 1990 model year locomotive would be subject to the Tier 0 emission standards, which were also applicable to all other 1990 model year locomotives (U.S. EPA 2016).

Table IR6-16-1 U.S. EPA Switcher Locomotive Emission Standards

Tier[a]	Year of Manufacture	Emission Standard (g/bhp-h)[b]			
		CO	NO_x	HC	PM
0	1973-2001	8.0	11.8	2.10	0.26
0+	1973-2001	1.83	10.6	0.57	0.23
1	2002-2004	2.5	11.0	1.20	0.26
1+	2002-2004	1.83	9.9	0.57	0.23

Notes: g/bhp-h = grams per brake horsepower hour

a. 0+ and 1+ = Tier 0 and Tier 1 rebuilt engine standards, respectively (RAC 2015).
b. Emission standards effective in 2010.

As shown in **Table IR6-16-1**, based on information from the RAC at the commencement of the RBT2 Air Quality Study (EIS Appendix 9.2-A), there was no difference between the Tier 0 and Tier 1 emission standards for PM, and only a 7% difference in emission standards for NO_x. Although there are larger differences between Tier 0 and Tier 1 emissions standards for CO and HC, the maximum concentrations of CO predicted in the RBT2 Air Quality Study (EIS Appendix 9.2-A) are well below its ambient air quality objective. The switcher locomotives are a small source of HC emissions compared with emissions from ships, cargo handling equipment, line-haul locomotives, and on-road vehicles. As shown in **Table IR6-16-1**, a rebuilt Tier 0 locomotive engine (i.e., Tier 0+) was previously subject to more stringent emission standards than a new Tier 1 engine, and Tier 1+ emission standards were the same as Tier 0+ standards, except for a slight improvement (reduction) in emission standard for NO_x. Currently, the standards for new and rebuilt Tier 0 are the same, as are the standards for new and rebuilt Tier 1 engines (RAC 2015).

For GHG emissions, the tier-level of a switcher locomotive does not change the emissions of GHGs. It was stated in Section 4.3.2 in Appendix A of EIS Appendix 9.2-A that the RAC emission factors are applicable to all tiers of both line-haul and switcher locomotives.

Locomotive engines can be rebuilt several times such that their useful life can be extended beyond 25 to 30 years, and in some cases, may continue to operate for 40 to 50 years, as noted in the Panel's context. With respect to the useful life of a locomotive engine, DieselNet (2017) states the following:

> "*The useful life, generally specified as MW-hrs* [megawatt hours] *and years, ends when either of the values (MW-hrs or years) is exceeded or the locomotive is remanufactured.*
>
> *The minimum useful life in terms of MW-hrs is equal to the product of the rated horsepower multiplied by 7.50. The minimum useful life in terms of years is 10 years. For locomotives originally manufactured before January 1, 2000 and not equipped with MW-hr meters, the minimum useful life is equal to 750,000 miles or ten years, whichever is reached first. The minimum emission warranty period is one-third of the useful life (with some exceptions).*"

Line-haul locomotives can also be used for lighter duty yard work as switchers to extend their useful life.

3. RAC Reports on Locomotive Engine Upgrades

The three most recent annual reports (i.e., 2012, 2013, and 2014) from the RAC (RAC 2015, 2016, 2017) have stated the following information on the turnover of Canadian locomotive fleet:

- In 2012, Canadian railways invested heavily in fleet upgrades, with 55 Tier 3 high-horsepower locomotives added to the Class I freight line-haul fleet and 180 locomotives upgraded to Tier 0+, Tier 1+, or Tier 2+. Older and lower horsepower locomotives continue to be retired, 63 medium-horsepower locomotives manufactured between 1973 and 1999 were taken out of active duty. A total of 66% of the locomotive fleet in Canada met the U.S. EPA emission standards for their respective Tier level in 2012;
- For the total fleet of locomotives in Canada in 2013, fleet upgrades included the addition of 10 Tier 3 high-horsepower locomotives added to the Class I freight line-haul fleet and 225 locomotives upgraded to Tier 0+, Tier 1+, or Tier 2+. Older and lower-horsepower locomotives continue to be retired, and 94 medium-horsepower locomotives manufactured between 1973 and 1999 were taken out of active duty. A total of 77.1% of the locomotive fleet met the U.S. EPA emission standards for their respective Tier levels; and
- For the total fleet of locomotives in Canada in 2014, 117 locomotives were upgraded to Tier 0+, Tier 1+, or Tier 2+ standards. In addition, the RAC reported that older and lower-horsepower locomotives continued to be retired, and nine medium-horsepower locomotives manufactured between 1973 and 1999 were taken out of active duty. A total of 79.9% of the locomotive fleet met the U.S. EPA emission standards for their respective Tier levels.

These RAC reports indicate that federal railways in Canada are progressively retiring older locomotives and upgrading those that continue to operate to meet the U.S. EPA emission standards for rebuilt or remanufactured engines. With the implementation of the Canadian Locomotive Emission Regulations, engine upgrades will continue, such that it is reasonable to assume that switcher locomotives operating at Roberts Bank will at a minimum meet Tier 1 and Tier 1+ emission standards in 2025 and beyond.

Based on the information provided in this response, the assumption that 100% of the switcher locomotives would meet Tier 1 emissions standards by 2025 was and is considered to be realistic as it was based on regulations and trends in fleet turnover as documented by the RAC. For these reasons, no additional modelling or assessments for air contaminants of potential concern (CO, NO_x, SO_2, and PM) and GHG emissions is required.

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Appendices

Appendix IR6-16-A Memorandum from SENES Consultants to Port Metro Vancouver: Verification of RBT2 Rail Assumptions (5 April 2013)

APPENDIX IR6-16-A
MEMORANDUM FROM SENES CONSULTANTS TO PORT METRO VANCOUVER: VERIFICATION OF RBT2 RAIL ASSUMPTIONS (5 APRIL 2013)

SENES Consultants

MEMORANDUM

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TO:	Jody Addah, PMV	380237-001
cc.	Erin Bishop, Hemmera	
FROM:	Dan Hrebenyk, Sandy Willis, Jennifer Hodowsky	5 April 2013
SUBJ:	Verification of RBT2 Rail Assumptions	

As requested, the following are the assumption updates that were discussed with Gordon Westlake of BC Rail at yesterday's meeting.

Locomotive Parameters

The power ratings of the locomotive fleet that were assumed for the DTRRIP analysis were updated to assume line-haul locomotives to be in the range of 4,000 to 4,400 hp (4,200 hp average) and switcher locomotives to be 3,800 hp on average. It was suggested that CN, CP and BNSF be asked to confirm fuel consumption rates used for the DTRRIP analysis. Unless informed otherwise, the power ratings and fuel consumption rates to be used for RBT2 will be those summarized in Table 1.

Table 1 – Power Rating and Fuel Consumption

Locomotive Type	Fleet Content, %	Power Rating, hp	Idle Fuel Consumption, L/hr	Work Fuel Consumption, L/hr
Line-haul	100	4,200	13.7	259.5
Switch	100	3,800	3.50	95.4

Load factors and duty cycles proposed for the assessment are listed in Table 2, as well as the calculated total effective power for each locomotive type. The Railway Association of Canada (RAC 2008) duty cycle for switch locomotives will be used for all such locomotives at Roberts Bank; however, the load factors for the throttle settings were derived from the emission inventory prepared for the Port of Long Beach, CA (Starcrest 2011). BC Rail confirmed that these assumptions hold true at Roberts Bank.

For the line-haul locomotives, the RAC duty cycle is considered to be unrepresentative of the type of activity that these locomotives would experience in the short distance (25 km) of track between the eastern boundary of the RBT2 Regional Study Area (RSA) and Roberts Bank. Instead, as suggested by BC Rail, it will be assumed that the locomotives operate 50% in notch 3 and 50% in notch 4 for the stretch of tracks from the eastern edge of the RSA to Highway 17, versus 50% in notch 2 and 50% in notch 3 from Highway 17 west to the end of the Deltaport causeway. The rest of their time at the rail yard at Roberts Bank is spent in idle mode.

Table 2 – Locomotive Effective Power

Locomotive Type	Throttle Notch Position	Idle	1	2	3	4	5	6	7	8	Dynamic Brake	Total Effective Power, hp
Line-haul	Load Factor (%)[1,2]	0.4	5.0	11.4	23.5	34.3	48.1	64.3	86.6	102.5	2.1	-
	Idle Duty Cycle (%)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17
	Work Duty Cycle 1 (%)[4]	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	1,214
	Work Duty Cycle 2 (%)[5]	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	733
Switch	Load Factor (%)[2]	0.8	4.7	14.2	27.8	42.0	57.3	72.5	89.7	105.3	3.8	-
	Duty Cycle (%)[3]	84.9	5.4	4.2	2.2	1.4	0.6	0.3	0.2	0.6	0.2	156

Sources:
[1] Port of Los Angeles Inventory of Air Emissions (Starcrest 2009)
[2] Port of Long Beach 2010 Air Emissions Inventory (Starcrest 2011)
[3] EC RAC Locomotive Emissions Monitoring (2008)
[4] Applicable for the stretch of tracks from the eastern edge of the RSA to Highway 17
[5] Applicable from Highway 17 west to the end of the Deltaport causeway

All switch locomotives in 2010 are assumed to be older engines meeting Tier 0 emission levels, while line-haul locomotives are split between 25% Tier 0, 50% Tier 1 and 25% Tier 2 engines.

For future horizon years (2025 and 2030), line-haul locomotives are assumed to be replaced through fleet turnover however CN and CP will continue to place older engines on this line through to 2030. Switch locomotives will be conservatively assumed to be replaced with Tier 1 engines by 2025 and remain unchanged as Tier 1 engines for 2030. The projected locomotive fleet tier mixtures for each locomotive type and each horizon year are summarized in Table 3.

Table 3 – Fleet Tier Mixtures

Horizon Year	Locomotive Type	Port Terminal	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
2010	Line-haul	WS	25%	50%	25%		-
		DP & RBT2	25%	50%	25%		-
	Switch	-	100%	-	-	-	-
2025	Line-haul	WS	-	-	100%		
		DP & RBT2	-	50%	50%	-	-
	Switch	-	-	100%	-	-	-
2030	Line-haul	WS	-	-	100%		
		DP & RBT2	-	50%	50%	-	-
	Switch	-	-	100%	-	-	-

Locomotive Activities

The number of line-haul locomotives operating (on-site and en-route), as well as the number of switch locomotives on-site, form the basis of the calculation methodology as the emissions are directly proportional to the number of locomotives. The emissions are also dependent on the operational time of each locomotive at each engine operating mode.

The DTRRIP analysis assumed that each line-haul container train and each line-haul coal train contains three locomotives. For RBT2, BC Rail has indicated that 9000 foot long trains typically have 4 locomotives while 12,000 foot long trains use 5 locomotives. CN typically runs about the same number of 9,000 foot long trains per day and 12,000 foot long trains, and accounts for about two-thirds of the container trains at Roberts Bank. CP tends to run shorter trains with 4 locomotives and accounts for one-third of the container trains at Roberts Bank. All coal trains would be based on 4 locomotives, including those from BNSF.

The line-haul train activities (on-site idle time, speed, and local and regional distances travelled) for each port terminal are assumed to be identical to those used for the Deltaport Third Berth Project (SENES 2007) and are summarized in Table 4. Note that local distance travelled refers to the distance along the Deltaport causeway, and assumes one-way travel.

Table 4 – Line-haul Train Activity Summary

Port Terminal[1]	On-site Idle Time (hr)	Train Speed (km/hr)	Work Cycle 1 One-way Distance Travelled (km)	En-route Operational Time (hr)
DP	12	24	8.9	0.37
RBT2	12	24	8.9	0.37
WS	21	24	8.9	0.37
	On-site Idle Time (hr)	**Regional Train Speed (km/hr)**	**Work Cycle 2 One-way Distance Travelled (km)**	**En-route Operational Time (hr)**
DP	n/a	56	13.3	0.24
RBT2	n/a	56	13.3	0.24
WS	n/a	56	13.3	0.24

For yard work, it will be assumed that assembling a container train involves three switch locomotives per terminal for a terminal capacity of 2.4 million TEUs and that the existing Deltaport port terminal, based on its current capacity of 1.6 million TEUs, has two switch locomotives on-site. The coal trains and therefore the Westshore port terminal does not utilize yard switchers. The switch locomotives operate 24 hours per day, using the duty cycle listed in Table 2.

IR6-17 Air Quality – Emissions Modelling, Cargo Handling Equipment

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix A, Section 3.3.1 and Table 3-5

Context

According to the Proponent, Deltaport Terminal is considering the purchase of electric cranes to replace existing cranes when they reach the end of their lifespan of 24 years (Table 3-5). Further, the Proponent assumed in the assessment that any new cranes will be electric.

For Metro Vancouver, Deltaport cargo handling equipment contributes a significant portion of the $PM_{2.5}$ estimated under existing conditions for the Project, and diesel exhaust emissions are carcinogenic and a serious health threat.

Information is required as to what extent all crane equipment will be electric and when this is expected to be in place.

Information Request

Provide information regarding the plan for the replacement of diesel equipment with electrical for Deltaport Terminal and the proposed Project. Include the timing of any changes and the obligations for implementation.

If the diesel equipment is not entirely replaced with electric cranes, quantify and present the potential effect in the air quality assessment for $PM_{2.5}$ for existing, expected and future conditions with a more realistic scenario, such as where a portion of the existing cargo handling equipment continues to be used or where a portion of the diesel equipment would have less stringent standards, such as Tier 3.

VFPA Response

Clarification

Deltaport Terminal cargo handling equipment (CHE) does not contribute a significant portion of the $PM_{2.5}$ (respirable particulate matter; particulate matter of 2.5 microns or less in diameter) estimated under existing conditions for Metro Vancouver, as stated in the context to this information request. Deltaport Terminal CHE was estimated to account for 9.7% of total diesel particulate matter (DPM) emissions from the three operating terminals at Roberts Bank (i.e., Deltaport Terminal, Westshore Terminals, and the Tsawwassen Ferry Terminal) under existing conditions in 2010, and represents an even smaller portion of $PM_{2.5}$ emissions in Metro Vancouver. This is not considered to be a 'significant' portion of emissions at Roberts Bank, or for Metro Vancouver as stated in the context to this information request. If a different CHE scenario for Deltaport Terminal CHE was modelled, there would be little change in the

RBT2 Air Quality Study results documented in EIS Appendix 9.2-A, for the reasons explained below.

Provide information regarding the plan for the replacement of diesel equipment with electrical for Deltaport Terminal and the proposed Project. Include the timing of any changes and the obligations for implementation.

The RBT2 Air Quality Study included several assumptions pertaining to CHE, including rubber tire gantry cranes, material handling equipment (e.g., reach stackers, top/side picks, forklifts, manlifts, aerial lifts), yard and terminal trucks, bulk handling equipment (e.g., tractors, loaders, backhoes, and excavators), and general industrial equipment. For Westshore Terminals, Deltaport Terminal, and RBT2, assumptions pertaining to emissions from the various types of CHE are summarised in Table 3-1 and Attachment 3 in Appendix A of EIS Appendix 9.2-A.

Electrification of Cargo Handling Equipment at RBT2

The Project will be built and operated with equipment meeting the applicable standards of the day, and a large proportion of CHE will be electrified from the onset of operations, including ship-to-shore gantry cranes, container yard automatic stacking cranes, and intermodal yard rail-mounted gantry cranes. The replacement of diesel equipment at RBT2, therefore, is not warranted in the first stages of the operations phase.

For RBT2 CHE that was not assumed to be electric from the commencement of operations (including one rubber tire hydraulic crane, one top pick, automated shuttle carriers, yard trucks, forklifts, manlifts, aerial lifts, and general industrial equipment), there was sufficient uncertainty that electric technology would be employed at the commencement of RBT2 operations in 2025. For the purposes of modelling future conditions with the Project, it was more conservative to assume that some types of CHE would be diesel-fuel powered for the duration of the operation phase. For example, material handling equipment at RBT2 was assumed to be diesel-powered and meet Tier 4 emission requirements (effective as of 2012) or Phase 2 requirements (effective as of 2007) for the duration of the operation phase (as outlined in Section 3.3.1 and Attachment 3 in Appendix A of EIS Appendix 9.2-A). This equipment could be electrically-powered from the commencement of RBT2 operations or upgraded during the operations phase to equipment with more-stringent emission standards as it reaches its useful life (i.e., approximately 16 years, as indicated in Table 3-5 in Appendix A of EIS Appendix 9.2-A).

Electrification of Cargo Handling Equipment at Deltaport Terminal

With respect to the timing of any changes and the obligations for replacing diesel-powered equipment with electrically-powered equipment at the Deltaport Terminal, the following information was provided in Section 3.3.1 in Appendix A of EIS Appendix 9.2-A:

- CHE at the existing Roberts Bank terminals (i.e., both Deltaport Terminal and Westshore Terminals) varies in age from less than a year old to 31 years old; therefore, it is expected that some of the older equipment will be replaced by 2025;

- The assumptions pertaining to CHE fleet turnover at Deltaport Terminal followed U.S. Environmental Protection Agency (EPA) guidance (ICF 2009), which states that expected life spans for CHE ranges from 16 to 24 years (for life span information for each CHE type, refer to Table 3-5 in Appendix A of EIS Appendix 9.2-A); and
- The assumption that equipment replacement would not occur until equipment had reached its end of life or maximum operating hours (note that interim changes, such as engine upgrades and exhaust retrofits, were not considered in the air quality assessment).

The U.S. EPA guidance (ICF 2009) for rubber tire gantry cranes states an average lifetime of 24 years. At the commencement of the RBT2 Air Quality Study when developing the assumptions for the purposes of modelling, a list of CHE at Deltaport Terminal, including the year of manufacture, was reviewed to determine when each piece of equipment would likely be replaced. The VFPA was informed that the Deltaport Terminal operator (at the time, TSI Terminal Systems Inc.) was planning to replace existing diesel rubber tire gantry cranes with electric cranes when the existing cranes reach the end of their useful life. Deltaport Terminal is currently operated by Global Container Terminals Inc., and specific plans pertaining to the timing of replacement of diesel-powered equipment with electric-powered equipment is not currently publicly available.

If the diesel equipment is not entirely replaced with electric cranes, quantify and present the potential effect in the air quality assessment for $PM_{2.5}$ for existing, expected and future conditions with a more realistic scenario, such as where a portion of the existing cargo handling equipment continues to be used or where a portion of the diesel equipment would have less stringent standards, such as Tier 3.

The assumptions incorporated in the RBT2 Air Quality Study pertaining to replacement of existing diesel-powered Deltaport Terminal cranes with electrically-powered cranes in the future (2025) are considered to be realistic.

Operations at container terminals are dynamic, and since equipment (i.e., both CHE and other) varies in age, engine size, emission rate, etc., it is impractical to accurately incorporate all of these differences into the characterisation of the emission sources at each terminal. Therefore, the use of simplifying (yet conservative) assumptions is an accepted approach used in modelling to reduce some of the variability across all emission sources (not just CHE), as described in Section 4.7 of EIS Appendix 9.2-A. The overall practice was to assume conservative values for each source, which has the tendency to result in overly conservative predictions of air contaminant emissions and predicted air quality levels associated with those emissions (especially when the various conservative assumptions are applied at the same time). For example, it was assumed that for the maximum 24-hour emission scenario, there was no down time or idling time for CHE, which is a conservative assumption.

For expected conditions in 2025, the fleet turnover of all types of equipment was estimated to reduce the total DPM emissions from the three existing terminals to one-third of the existing conditions emissions in 2010, with Deltaport Terminal CHE emissions accounting for 10.3% of the total DPM emissions. With the scale of reduction in total DPM emissions from sources at the three terminals by 2025, diesel-powered rubber tire gantry cranes at Deltaport would

comprise a larger proportion of total DPM emissions, but would be emitting less DPM than the older units currently in operation at Deltaport Terminal.

In relation to CHE that is assumed to be diesel-powered, the air quality assessment was conservative in not accounting for other anticipated changes that will reduce emissions from CHE. For example, the VFPA is a participant in the Northwest Ports Clean Air Strategy (as described in Section 3.1.4.2 of EIS Appendix 9.2-A), which includes voluntary targets such as 80% of CHE meeting Tier 4 interim emission standards or equivalent by 2020 (VFPA 2017). In line with this strategy, the VFPA implemented the Non-Road Diesel Emissions Program in 2015 to incentivise terminal operators to accelerate the transition to newer, cleaner CHE to reduce diesel particulate emissions (VFPA 2017).

Based on the approach taken in the assessment of CHE for Roberts Bank terminals, a realistic (or conservatively realistic) scenario has been assessed based on information available, and changes to the conclusions of the assessment are not anticipated if diesel cranes at Deltaport Terminal are not entirely replaced with electrically-powered equipment by 2025.

References

ICF International, Inc (ICF). 2009. Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories. Prepared for the U.S. Environmental Protection Agency, Office of Policy, Economics and Innovation, Sector Strategies Program.

Vancouver Fraser Port Authority (VFPA). 2017. Northwest Ports Clean Air Strategy 2016 Implementation Report. Available at https://www.portvancouver.com/wp-content/uploads/2015/05/NWPCAS-Implementation-Report-2016-Updated-Final-2017-11-28.pdf. Accessed December 2017.

IR6-18 Air Quality – Emissions Modelling, Ships

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Section 4, Figure 4-13; Appendix A, Section 2, Tables 2-12 and 2-14; Appendix F, Figure 4-1

Context

In Table 2-13 of Appendix A of Appendix 9.2-A in the EIS, the Proponent used the same ship-age profile for its 2025 emissions scenario, as the period 2005 - 2012 in which 82% of the vessels would be less than 10 years old. This results in a situation where 82% of the 2025 fleet meets the highest NOx standard of Tier III engines. The EIS predicted that the total marine-source NOx emissions in the EIS air quality study area would be reduced by about 30% between 2010 and 2025 (without the Project) despite the assumption of increased activity. If there is a slowdown in the penetration of Tier III engines into the market, it is likely that in 2025, a vast majority of the vessel fleet will in reality be Tier II vessels, rather than Tier III vessels.

Environment and Climate Change Canada recommended that associated references be provided to support these assumptions.

Information Request

Provide the percentage of ships, broken down by ship type, that were assumed to have NOx Tier III engines in the marine emissions estimates for both the EIS and the Marine Shipping Addendum assessments and compare this to what was assumed for Project-associated container ships.

Provide the references that support the Proponent's assumptions, as detailed in Table 2-12 of Appendix A of Appendix 9.2-A in the EIS, of total marine-source NOx emissions reduction and fast penetration of Tier III engines into the market.

VFPA Response

Provide the percentage of ships, broken down by ship type, that were assumed to have NOx Tier III engines in the marine emissions estimates for both the EIS and the Marine Shipping Addendum assessments and compare this to what was assumed for Project-associated container ships.

RBT2 Air Quality Study

Container Vessels

The percentage of container vessels bound for RBT2 that were assumed to have NO_x Tier III engines was established through a review of the actual age distribution of container vessels

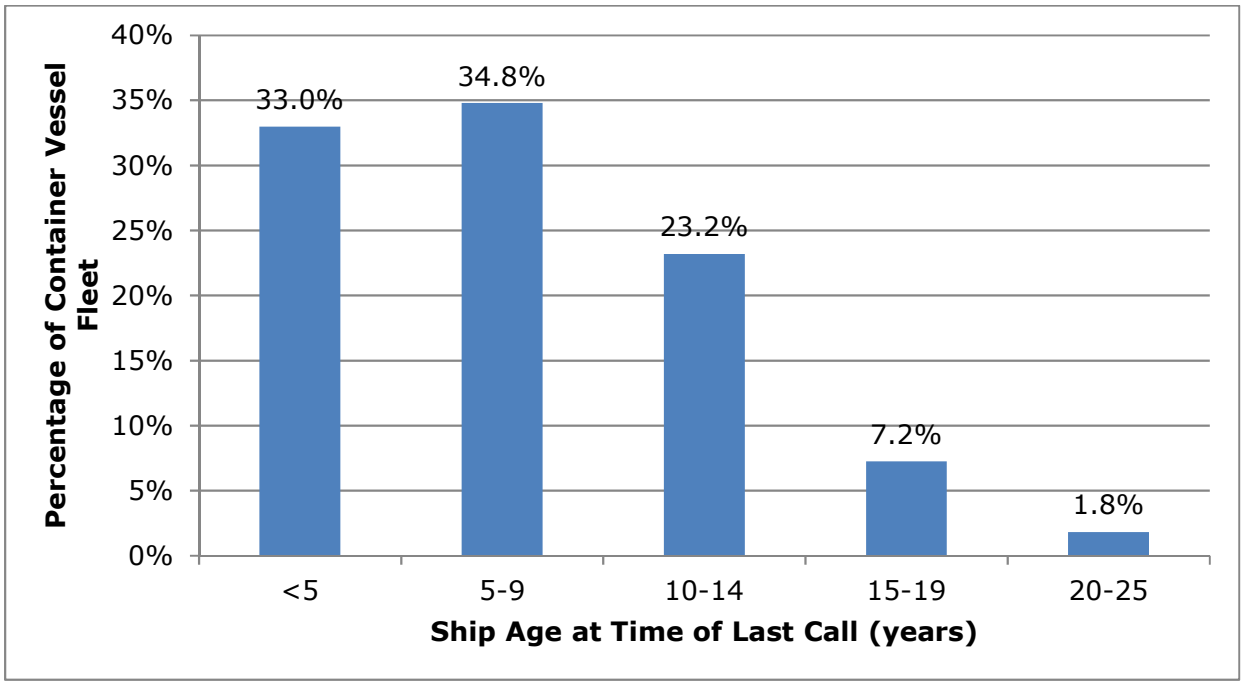
calling at Deltaport Terminal during the period of 2005 to 2012. The analysis of 1,961 vessel calls during the period of 2005 to 2012 by 276 container ships indicated that, at the time of their last call, (Section 2.5.1 in Appendix A of EIS Appendix 9.2-A):

- 91% of all ships were less than 15 years old;
- 98% of all ships were less than 17 years old; and
- 1.8% of the ships were 20 to 25 years old.

Figure IR6-18-1 shows the age distribution of the container ships at the time of their last call during 2005 to 2012 at Deltaport Terminal, and **Figure IR6-18-2** shows the cumulative age distribution, based on this Deltaport Terminal age distribution, which was used to project future vessel age distributions at the Deltaport and RBT2 terminals.

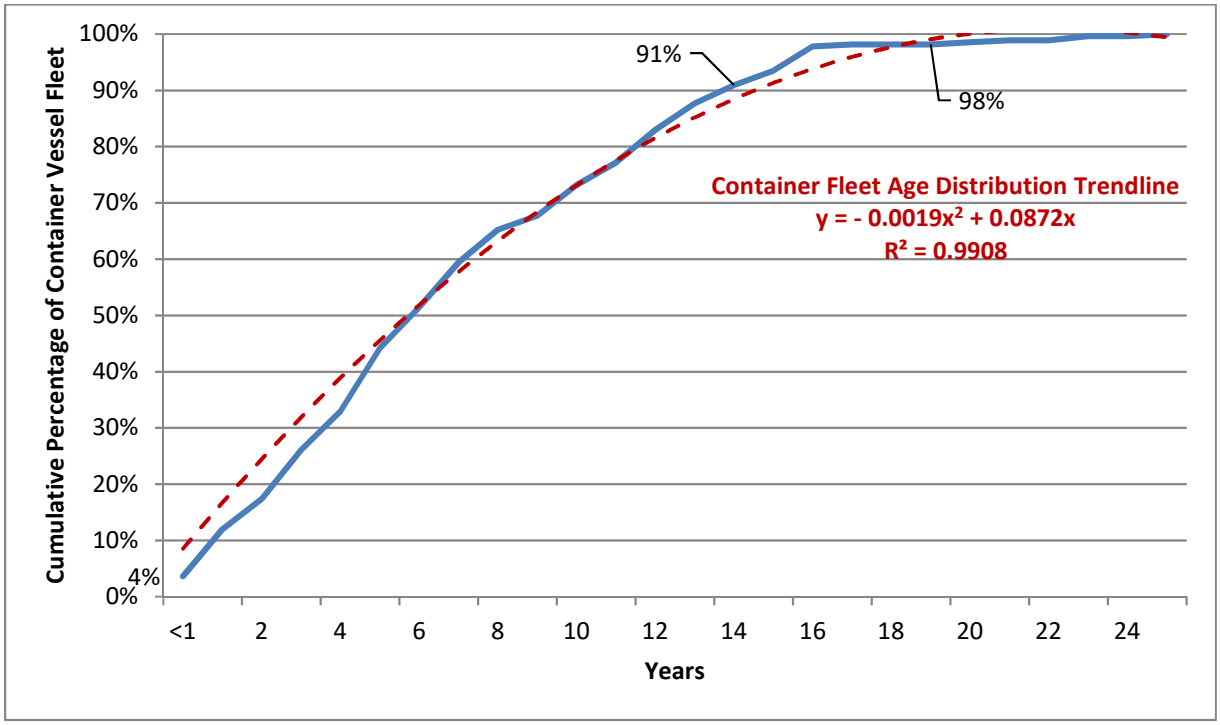
The 2005 to 2012 data demonstrates that the typical container vessel calling at Deltaport Terminal was less than 20 years old. Based on these statistics, it was assumed that 91% of the ships in the current fleet (2010) will have been replaced by 2025 (i.e., ships less than or equal to 15 years old), and that virtually all (i.e., 98% of the current fleet) will be replaced by 2030. By 2030, only the occasional ship calling at Roberts Bank is likely to be more than 20 years old and not subject to newer, more stringent emission standards[1].

Figure IR6-18-1 Container Ship Age at Last Time of Call for the 2005 to 2012 Period at Deltaport Terminal



[1] For more information refer to Marine Shipping Addendum Section 7.1.5.

Figure IR6-18-2 Cumulative Age Distribution of Container Ships at Roberts Bank



Notes:

1. The cumulative ship age distribution (shown as blue line in percent) is based on actual data of container ship age at last time of call for the 2005 to 2012 period at Deltaport Terminal.
2. The ship age distribution in a future year can be determined from the red trendline using the equation $y=-0.0019x^2 + 0.0872x$, where x is equal to the number of years in the future from a base year. For example, looking into the future from 2010 to 2025 (i.e., x = 16 years), the percentage of the container fleet less than or equal to 15 years old would be 91%.

Ship age distribution, as provided by the VFPA for Deltaport and Westshore terminals in 2005 to 2012, was not varied for the operation phase (i.e., 2010 conditions were conservatively assumed to carry through in subsequent operating years). Therefore, ships less than 10 years of age (i.e., those that would have been constructed after 2016) were assumed to meet Tier III NO_x emission standards. The percentage of Tier III ships in the year 2025 is anticipated to be 68% (not 82%, as was stated in the EIS Table 2-13 in Appendix A of EIS Appendix 9.2-A). Nevertheless, based on the relationship depicted in **Figure IR6-18-2** above, 82% of the container ships would meet Tier III NO_x emission standards by 2028, 13 years after the introduction of Tier III requirements for ships built in 2016 and thereafter. By 2030, 91% of the container ships would be expected to meet the Tier III NO_x emission standards.

Other Ocean-going Vessels

Ships operating within 200 nautical miles of the coastline of North America are considered to be within the zone of the North American Emission Control Area (ECA) as of 2012, and ships built in 2016 and later are required to meet Tier III NO_x emission standards (Section 5.2, Appendix A, EIS Appendix 9.2-A). Therefore, emissions from other ocean-going vessel types (i.e., cargo/carrier, passenger, or tanker) were based on a representative ship without

consideration of age distribution for each vessel type. In the absence of information about the age distribution of the fleet of other types of vessels, the calculation of emissions from all vessels other than container ships were based on Tier III NO_x emission standards for future emissions, and are discussed in further detail below.

Marine Shipping Addendum Air Quality Study

Container Vessels

In scoping the air quality study for Project-associated vessels transiting the marine shipping area, the marine shipping emission database completed for the 2010 Environment Canada Marine Emission Inventory (SNC-Lavalin Environment 2012) was considered. A copy of that database, which covered a vast area (Arctic, INNAV[2], and west coast) and included monthly emissions data for 12 compounds from 1980 to 2030, was obtained from Environment Canada in June 2015. Upon examination of the database, it was determined that the data could not be used for the purposes of assessing air quality in the marine shipping area because of the following:

- The data captured the Canadian portion of the airshed in the marine shipping area, and thus, portions of the inbound shipping lane located in U.S. waters were not included in the data set;
- The data included information that went well beyond the shipping activity within the marine shipping area and would require extensive filtering to identify activities restricted only to the marine shipping area in question; and
- It was difficult to determine how the forecasted values for 2030 were derived.

Given the breadth of data and lack of information in specific locations of interest (i.e., inclusive of areas in U.S. waters in Segments A to D), data was not extracted from the Environment Canada database. Instead, for the Marine Shipping Addendum (MSA) emissions from container ships in transit were assumed to have the same age distribution as for Deltaport Terminal and RBT2 ships, and emissions from ships other than container vessels were estimated using a single representative ship in each category, as described below.

Other Ocean-going Vessels

In the MSA, as in the EIS, other ocean-going vessel types (i.e., cargo/carrier, passenger, or tanker) were assumed to be in compliance with ECA, and emissions were based on a representative ship without consideration of age distribution for each vessel type (as ship age data was not available). Consequently, in the absence of age distribution information for other types of vessels, the calculation of emissions from all vessels other than container ships were based on Tier III NO_x emission standards for future cumulative emissions (Table 2-4, MSA Appendix 7.1-A), and will be discussed in further detail below.

[2] INNAV = Information System on Marine Navigation.

Provide the references that support the Proponent's assumptions, as detailed in Table 2-12 of Appendix A of Appendix 9.2-A in the EIS, of total marine-source NOx emissions reduction and fast penetration of Tier III engines into the market.

Information supporting fleet turnover assumptions at the time of commencement of the Air Quality Study (EIS Appendix 9.2-A), and more recent information supporting the original assumptions, is provided below.

Vessel fleet turnover assumptions for the EIS and MSA were based on NO_x emission limits, which drive fleet turnover to maintain compliance with the regulations. International Marine Organization (IMO) NO_x Emission Limits (in grams per kilowatt-hour (g/kW-h)) were sourced from the International Convention for the Prevention of Pollution from Ships (MARPOL) regulations for the Prevention of Air Pollution from Ships (Annex VI[3]), Regulation 13 (Table 2-12 in Appendix A of EIS Appendix 9.2-A).

NO_x emission limits were defined for diesel engines depending on the engine maximum operating speed (i.e., engine rpm (revolutions per minute)). The NO_x emission standards for slow speed engines (i.e., for ocean-going vessels less than 130 rpm) are listed in **Table IR6-18-2**.

Table IR6-18-2 MARPOL Convention NOx Emission Standard for Slow Speed Engines

Tier Level	Ship Build Date or Major Conversion	NO_x Emission Standard (g/kWh)
Tier I	On or after Jan. 1, 2000	17.0
Tier II	On or after Jan. 1, 2011	14.4
Tier III	On or after Jan. 1, 2016	3.4

Tier I and Tier II limits are global, while the Tier III standards apply only in NO_x emission control areas. As stated in MSA Appendix 3-A, Section 8.4, which contains Canada's Marine Safety and Security System document released by Transport Canada in May 2015:

> "*Vessels built after January 1, 2011, must meet new emission standards for nitrogen oxides known as Tier II standards under Annex VI to MARPOL that are 20% more stringent than original Tier I standards. New vessels built after January 1, 2016 that operate in the North American Emission Control Area will*

[3] Annex VI to the MARPOL Convention was adopted in 1997, to address air pollution from shipping. The regulations for the Prevention of Air Pollution from Ships (Annex VI) sought to control airborne emissions from ships (sulphur oxides, nitrogen oxides, ozone depleting substances, volatile organic substances, shipboard incineration) and their contribution to local and global air pollution, human health issues and environmental problems. Annex VI entered into force on May 19, 2005 and a revised Annex VI with significantly strengthened requirements was adopted in October 2008, and entered into force on July 1, 2010.
(http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx)

need to meet standards known as Tier III, that are 80% more stringent than Tier I."

Additional information, with references, is provided below to support the assumptions incorporated in the air quality studies related to total marine-source NO_x reductions in the future, and the fast penetration of Tier III engines into the containerised shipping market.

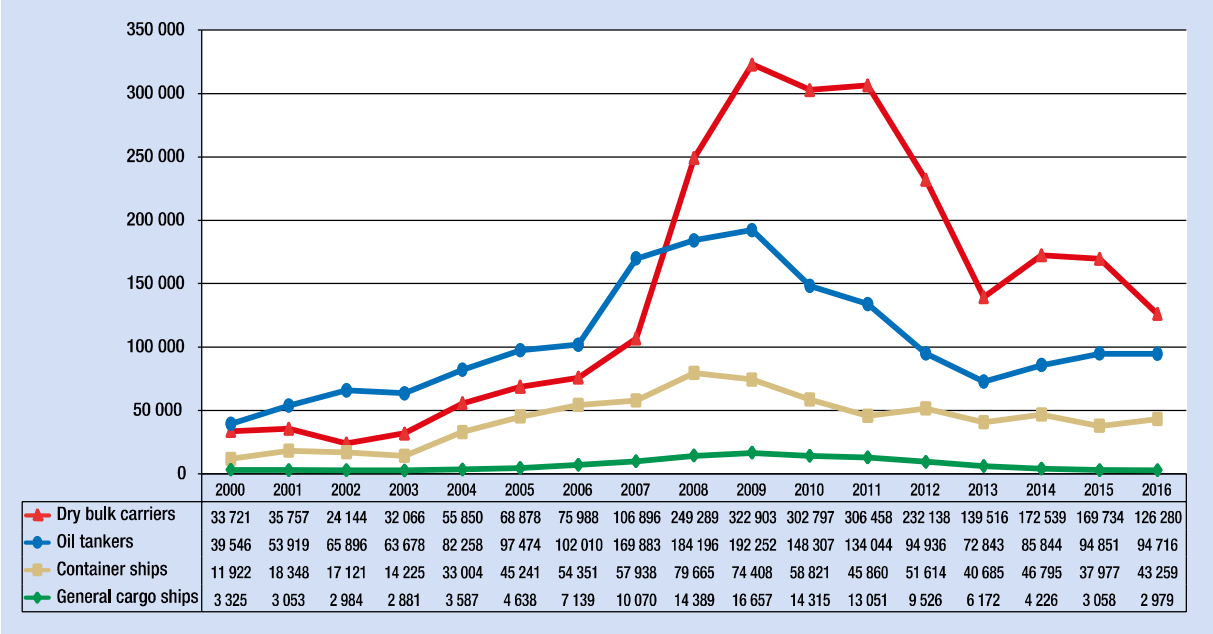
According to the review of maritime transport completed by the United Nations Conference on Trade and Development (UNCTAD) in 2015, market conditions, including demolition of older ships, supports the assumption of new (Tier III) coming online:

> *"Economic and regulatory incentives will continue to encourage individual owners to invest in modernizing their fleets. Unless older tonnage is demolished, this would lead to further global overcapacity, continuing the downward pressure on freight and charter rates. The interplay between more stringent environmental regulations and low freight and charter rates should encourage the further demolition of older vessels; this will not only help reduce the oversupply in the market, but also contribute to lowering the global environmental impact of shipping."*

Furthermore, analysis by UNCTAD (2016) of new ship builds from 2000 to 2016 indicated that new container ship building activity remained steady over that period, as indicated in **Figure IR6-18-3.** This supports assumptions incorporated into the air quality studies about container vessel fleet turnover. Specifically, UNCTAD stated the following:

> *"In line with falling shipyard capacity and the stretched finances of owners and banks, the world order book continued to decline for most vessel types in 2015–2016, with the exception of container ships."*

Figure IR6-18-3 World Tonnage on Order, 2000-2016 (thousands of dead-weight tons)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dry bulk carriers	33 721	35 757	24 144	32 066	55 850	68 878	75 988	106 896	249 289	322 903	302 797	306 458	232 138	139 516	172 539	169 734	126 280
Oil tankers	39 546	53 919	65 896	63 678	82 258	97 474	102 010	169 883	184 196	192 252	148 307	134 044	94 936	72 843	85 844	94 851	94 716
Container ships	11 922	18 348	17 121	14 225	33 004	45 241	54 351	57 938	79 665	74 408	58 821	45 860	51 614	40 685	46 795	37 977	43 259
General cargo ships	3 325	3 053	2 984	2 881	3 587	4 638	7 139	10 070	14 389	16 657	14 315	13 051	9 526	6 172	4 226	3 058	2 979

Source: UNCTAD secretariat calculations, based on data from Clarksons Research.
Note: Propelled seagoing merchant vessels of 100 gross tons and above, as at 1 January.

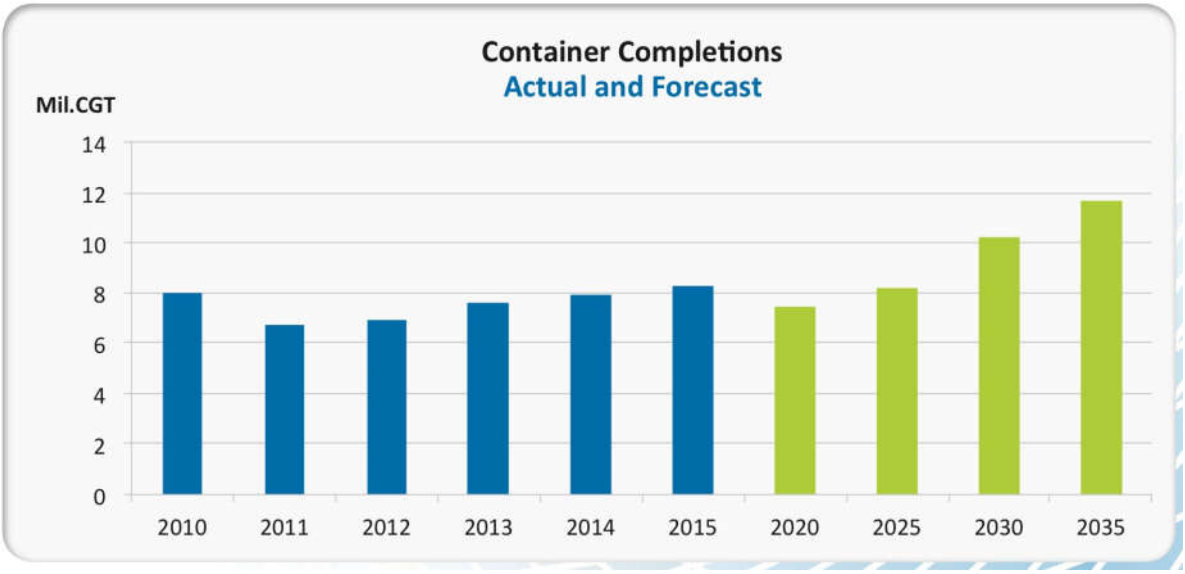
Source: UNCTAD 2016.

In addition, according to Rahul Kapoor, Head of Drewry Financial Research Services Ltd. (2017):

> *"We believe the stress levels for the shipping sector will ease significantly in 2017, primarily driven by supply normalisation, with real profitability and returns emerging over the next 12-18 months."*

According to the market forecast report on new ship builds prepared by SEA Europe (2017), the number of new container ship builds was expected to drop between 2015 and 2020, but the reduction is expected to be on the order of 10% globally. As indicated in **Figure IR6-18-4**, new container ship builds are expected to recover by 2020 and continue to increase until 2035.

Figure IR6-18-4 Container Ship Completions (in million compensated gross tonnage) for Years 2010 to 2015 and Forecast of Five-year Average of Completions to 2035



Note: Compensated Gross Tonnage (CGT) is an indicator of the amount of work that is necessary to build a given ship and is calculated by multiplying the tonnage of a ship by a coefficient, which is determined according to type and size of a particular ship.

Source: SEA Europe 2017.

With respect to the changes in the makeup of the global container ship fleet, SEA Europe (2017) states the following:

> *"Supersized containerships are leading to overcapacity. It is estimated that the demand for very large containerships is coming to an end because it has resulted in low freight rates and also ports struggle to turn them around efficiently, causing the total system cost to rise. This is why it is estimated that ULCS* [ultra-large container ship] *orders will decrease significantly. There will also be more demand for feeders to serve the big ships delivered. In the old Panamax segment, there is also overcapacity as these ships are not any more the most efficient way to transport goods through the Panama Canal and finding new uses has been difficult, as they are inefficient for most other container trades."*

SEA Europe (2017) also states the following:

> *"Year 2016 was again a record busy demolition year. Especially deletion of old Panamaxes which are becoming obsolete due to the new Panama Canal expansion has been high. Higher demolitions will help to stabilise the industry. Today, the fleet is quite young and demolitions are expected to increase further again after 2025. The size of ships being scrapped is also expected to increase and the age of demolition is expected to decrease."*

The expected demolition of Panamax size container ships (i.e., 2,801 to 5,100 twenty-foot equivalent unit capacity) has also been noted elsewhere[4].

The information provided above supports the assumptions pertaining to the 2025 container ship fleet age and engine specifications in the EIS and MSA air quality studies. Furthermore, the container ship fleet is not static as of 2025, as indicated by the 2017 Market Forecast (SEA Europe 2017), and the fleet will continue to turn over beyond 2025 to include newer vessels that meet increasingly stringent future emission requirements.

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[4] http://www.containerst.com/news/view,the-age-of-extinction-for-panamax-ships_44286.htm

IR6-19 Air Quality – Shore Power

Information Source(s)

EIS, Volume 1: Sections 4.2.1.2 and 4.2.3

EIS Volume 2: Section 9.2.6.2, Table 9.2-12; Section 9.2.7.2 and Tables 9.2-15 and 9.2-16; Section 9.2.8.2; Tables 9.2-24; 9.2-28 and 9.2-29; Section 9.2.9.4, Table 9.2-30 and 9.2-36; Appendix 9.2-A, Section 3.1.4.1

Context

Sections 4.0 and 9.2 of the EIS provided a discussion of shore power and indicated that shore power facilities are and will be made available at the tug basin area and at both the proposed Project and the third berth at Deltaport Terminal. No credit for reduced emissions was given in the assessment of emissions from berthing because of the uncertainty as to the proportion of the container vessel fleet capable of using shore power in 2025. The Proponent considered that the projected changes in air quality as defined for emissions from berthing were higher than will likely be the case.

Estimated maximum reductions of ship at berth emissions at Deltaport due to shore power use were given in percentages in Tables 9.2-15 and 9.2-16. In Tables 9.2-28 and 9.2-29, there was an indication of reduction of emissions of gaseous and particulate air contaminants, greenhouse gases and black carbon at the Project. There was no indication as to how the percentages were calculated or if they were included in the presentation of results in Tables 9.2-30 to 9.2-36.

Table 9.2-24 indicated that future conditions with the Project in terms of annual greenhouse gases would potentially double compared to existing conditions. There is a need to explore what initiatives would contribute to further reduction of emissions.

Information Request

Provide details as to how the percentages were calculated for the estimated maximum reductions of ship at berth emissions at Deltaport Terminal due to shore power for both gaseous and particulate matter contaminants; greenhouse gases and black carbon. Indicate if it is based on the existing clientele and existing services at the tug basin area. Provide estimated percentages per ship size for the present users and future users in 2025. Confirm if these percentages were included in the results presented in Tables 9.2-30 to 9.2-36 of the EIS. For these tables, add a column to include, in percentage, the potential reduction for future conditions with the Project due to the use of shore power facilities.

Add a column to Table 9.2-24 to include the actual estimated emission reductions for all terminals for the annual greenhouse gas and black carbon emissions.

Present the initiatives put in place by the Proponent to encourage shore power connection use and their degree of success. Provide any other initiatives or regulations discussed with

Transport Canada, other port authorities, partners or clients that would improve the participation to the programs in place.

VFPA Response

Correction

Section 2.1 in Appendix A of EIS Appendix 9.2-A incorrectly stated that "shore power is currently available on one berth at Deltaport Terminal". A shore power system was incorporated in the design for one berth of the three berths at Deltaport Terminal (the Third Berth), but it was not installed at the time the RBT2 Air Quality Study (EIS Appendix 9.2-A) was conducted. Section 2.1 correctly stated that it was uncertain as to how many of the container vessels calling at the Deltaport Terminal and RBT2 would be capable of connecting to shore power while at berth.

Clarification

In the RBT2 Air Quality Study (EIS Appendix 9.2-A), future predicted changes in gaseous and particulate matter contaminant emissions and greenhouse gases and black carbon emissions did not consider the potential benefits of shore power at the Deltaport Terminal for the reason stated above. Due to uncertainty on what proportion of the container vessel fleet calling at Deltaport would be capable of using shore power in 2025 and subsequent operating years, it was conservatively assumed, for the purposes of modelling and assessment of the RBT2 Project-related changes to air quality, that there would be no reduction in emissions for berthed container vessels connected to shore power.

As emission reductions via use of shore power are anticipated in the future, the potential benefits of shore power were quantified for the existing Deltaport Terminal (specifically the Third Berth, the only berth at the terminal designed to include a shore power system) and presented in the RBT2 EIS to provide context to the predicted future air contaminant concentrations.

Provide details as to how the percentages were calculated for the estimated maximum reductions of ship at berth emissions at Deltaport Terminal due to shore power for both gaseous and particulate matter contaminants; greenhouse gases and black carbon.

The percentages for estimated maximum reductions in emissions, from ships at berth at Deltaport Terminal, from use of shore power were calculated by subtracting the full contribution of emissions from ship auxiliary engines from the total predicted emissions of ships at berth at Deltaport Terminal.

Emissions from ships at berth result from use of the auxiliary engines and boilers (which are used for heating, hot water, and warming of residual fuel oil). While shore power allows vessels to eliminate the need for auxiliary engine power while at berth, the use of boilers is still necessary, and so all emissions are not eliminated through the use of shore power.

The quantification of shore power benefits did not include tug-related emissions, as tugs do not require auxiliary engines to operate while docked and emission reductions were assumed to be negligible.

Indicate if it is based on the existing clientele and existing services at the tug basin area.

For the purposes of quantifying the maximum potential annual benefits of shore power use by container ships at the Deltaport Terminal Third Berth, reductions were calculated for full (100%) utilisation of shore power by 2025 (EIS Section 9.2.7.2). The 100% utilisation rate was used to inform an understanding of the range and maximum potential annual benefits of shore power, and not the expected usage of shore power connections. The 0-100% range was not based on existing clientele usage information at the Deltaport Terminal, but rather on anticipated future usage, as the system is not yet operational (i.e., commissioning of the system at the berth is projected for 2018 (VFPA 2017a)). As stated above, the reductions from shore power do not include consideration of tugs.

Provide estimated percentages per ship size for the present users and future users in 2025.

The VFPA (2016) has indicated that, based on 2015 data, 44 vessel calls[1] were reported to be shore power capable, but the usage rate is difficult to estimate with certainty as it depends upon a variety of factors, including the following:

- Configuration of land-based equipment;
- Location and limitations of ship-based equipment;
- Ship willingness to connect;
- Cost of connection; and
- Availability of power from BC Hydro.

Based on more recent information from 2016 data (VFPA 2017b), 65 vessel calls were reported to be shore power capable. As there is no connection currently available (i.e., no present users) and usage rates are dependent upon a variety of factors, as listed above, it is not possible to estimate the percentages per ship size for present and future (2025) users.

Confirm if these percentages were included in the results presented in Tables 9.2-30 to 9.2-36 of the EIS. For these tables, add a column to include, in percentage, the potential reduction for future conditions with the Project due to the use of shore power facilities.

To confirm, potential benefits of shore power use were not included in EIS Tables 9.2-30 to 9.2-36, which provide emissions estimates and modelling results conducted for future conditions with the Project and other certain and reasonably foreseeable projects and activities in 2025. The RBT2 Air Quality Study (EIS Appendix 9.2-A) quantified the minimum and maximum (i.e., no utilisation and 100% utilisation) annual benefits of shore power use

[1] Note that vessel call numbers may include multiple visits by the same vessel.

for context information only at the existing Deltaport Terminal. For additional information on anticipated annual emission reductions for several connection scenarios, refer to VFPA (2016). As only annual benefits of shore power utilisation have been projected by the VFPA, and the user connection rate is uncertain, it is not possible to add a column to EIS Tables 9.2-30 and 9.2-36 (which present emissions on an annual basis, as well as 1-hour, 8-hour, and 24-hour periods for certain parameters). EIS Tables 9.2-15 and 9.2-16 and EIS Tables 9.2-28 and 9.2-29 provide the estimated maximum annual emission reductions from full utilisation of shore power at the Deltaport Terminal Third Berth and all three RBT2 berths, respectively.

Add a column to Table 9.2-24 to include the actual estimated emission reductions for all terminals for the annual greenhouse gas and black carbon emissions.

Note that, of the marine terminals at Roberts Bank, only the Deltaport Terminal Third Berth and RBT2 have been designed with shore power systems to reduce future emissions. There is no publicly-available information on future shore power system installation initiatives for Westshore Terminals bulkers or BC Ferries Tsawwassen Terminal ferries. It is not possible to add a column to EIS Table 9.2-24 to include actual estimated emission reductions for Deltaport Terminal or RBT2, as emission reduction data is not available due to the lack of actual connection usage data for Deltaport Terminal, as explained above.

Present the initiatives put in place by the Proponent to encourage shore power connection use and their degree of success. Provide any other initiatives or regulations discussed with Transport Canada, other port authorities, partners or clients that would improve the participation to the programs in place.

The VFPA promotes the use of shore power, and recognises cleaner ships through its EcoAction Program (VFPA 2017c). Ships obtain a discount on harbour dues of up to 47% for going beyond requirements by implementing voluntary emission reduction measures and other environmental practices, including implementing vessel and engine technologies (such as shore power), using cleaner fuels, and participating in energy efficiency programs.

In 2009, the VFPA Canada Place cruise ship terminal became the first in Canada and third in the world to offer shore power for cruise ships, allowing ships to turn off their engines while in port. Between 2009 and 2015, there were 416 connections at the Canada Place cruise ship terminal, resulting in a decrease of 13,953 tonnes of carbon dioxide equivalent and 423 tonnes of air quality pollutants (VFPA 2017c). In partnership with Transport Canada, and through collaboration with terminal operators, the VFPA will provide shore power enabled berths for container ships at Centerm Berth Five and Deltaport Third Berth which are currently in development and expected to be operational in 2018.

The VFPA is working with industry and government partners to promote shore power technology at the Port of Vancouver, and has improved operational procedures and facilities to support increased connections.

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IR6-20 Air Quality – CALPUFF, Ozone Methodology

Information Source(s)

EIS Volume 2: Section 9.2.6.1, Table 9.2-10; Section 9.2.10.2

Guidelines for Air Quality Dispersion Modelling in British Columbia, Ministry of Environment, British Columbia, 2015

Context

Table 9.2-10 of the EIS indicated that background concentrations exceed presently the air contaminant criteria for the 24-h and 1-y periods. In Section 9.2.10.2, the Proponent stated that the change in O_3 levels without the proposed Project (expected conditions) and with the Project (future conditions) was expected to be within the error level of O_3 monitoring equipment and therefore possibly not measurable within the local study area.

While background ozone may exceed established criteria, the 98th percentile background air quality concentrations for expected and future conditions should still be included for average and peak days as done for other air contaminants.

Information Request

In a table, present for all averaging periods (1-h; 8-h; 24-h; 1-y) the ozone 98th percentile results for expected and future conditions and for other certain and reasonably foreseeable projects and activities, with and without the Project.

All pollutant concentration must be determined by adding background concentrations to modelled concentrations.

Present an assessment of the changes from existing conditions.

VFPA Response

The VFPA has not conducted the extensive modelling requested in this information request, as the RBT2 Air Quality Study (EIS Appendix 9.2-A) is aligned with current regulatory guidance and modelling practice, and consistent with regulator input during the air quality assessment scoping phase. The extent of the work requested is not considered to be technically feasible for a project of the scope and scale of RBT2, or warranted based on approaches used on other projects in the region.

The discussion below provides the rationale and clarification to demonstrate why this approach was sufficient given the magnitude of the expected changes in emissions from the Project, and is consistent with current United States Environmental Protection Agency (U.S. EPA) regulatory guidance on photochemical modelling of emissions from new sources.

Note that the B.C. Ministry of Environment (MOE), in a document entitled *A Primer on the British Columbia Air Quality Dispersion Modelling Guideline* (MOE 2015b), states that the British Columbia Air Quality Dispersion Modelling Guideline (B.C. Guideline) limits the dispersion model possibilities to those endorsed by the U.S. EPA, since Environment and Climate Change Canada does not develop and support models of this type. Models that are endorsed by the U.S. EPA have been subject to numerous technical evaluations, stakeholder review, and are used across Canada and internationally. Hence, several U.S. EPA documents are referred to in the information provided below.

Note that future conditions for other certain and reasonably foreseeable projects and activities *without* the Project (as stated in the request) was not assessed in the RBT2 Air Quality Study (EIS Appendix 9.2-A). The study provided a project-specific assessment that focussed on the prediction of future changes *with* the Project combined with additional future changes from other certain and reasonably foreseeable projects and activities, in accordance with Operational Policy Statement *Assessing Cumulative Environmental Effects Under the Canadian Environmental Assessment Act, 2012* (CEA Agency 2013).

The following sections provide background information to explain typical requirements for, and current regulatory guidance on, regional photochemical modelling; outline why the requested modelling is not applicable for a project of the nature and scale of RBT2; and summarise regulatory engagement relevant to the assessment of ozone for RBT2.

Background Information on Regional Ozone Modelling

In order to present the requested 98th percentile ozone concentrations for 1-hour, 8-hour, and annual averaging periods for expected and future emission scenarios, regional photochemical modelling with a model such as Community Multiscale Air Quality (CMAQ), the Comprehensive Air Quality Model with Extensions (CAMx), or the Unified Regional Air-quality Modelling System (AURAMS) would be required. These models would require an emissions inventory of all sources for the entire lower Fraser Valley and Georgia Basin, for the full year in 2025 (representative year for the operation phase). To conduct the requested modelling, the chemically speciated emissions data would need to be broken down spatially (for a grid basis) within the lower Fraser Valley and Georgia Basin, and temporally into 1-hour average emissions for all hours of the year, with differences in daytime and nighttime emissions, and with consideration of seasonal variations. Such data is not currently available for 2025 and, therefore, to complete this request, the development of a regional air emissions inventory would be required. The extent of such work would more appropriately be conducted by a regulatory agency such as Environment and Climate Change Canada or Metro Vancouver, rather than by a project proponent for a project that is not regional in scale. As examples, regional emission inventories have been previously compiled for use in photochemical modelling exercises for 2015 for Environment Canada (RWDI 2006) and for 2020 for Metro Vancouver (RWDI 2009).

The MOE (2015b) supports this position that conducting such an advanced level of modelling is not appropriate for a single project:

> *"An advanced model includes comprehensive treatments of the physics and chemistry of emissions in the atmosphere, and thus requires considerable expertise and computer resources to set-up, run and interpret the results. Advanced models are not covered in the Guideline* [2015 British Columbia Air Dispersion Modelling Guideline] *although they are typically used to assess air quality impacts from large areas (such as cities) and over broad emission sectors for a selected time period (a few days is typical)."*

An example to illustrate that such a detailed analysis of future ozone emissions is not typically expected of a project proponent, as requested in this information request, is as follows. For the Trans Mountain Pipeline Expansion (TMX) Project, CMAQ modelling was completed for only a short period of meteorology from one ozone episode (i.e., June 24 to July 2, 2006) (RWDI 2013). It considered four emission scenarios:

- Existing case in 2010 that accounted for emissions from Kinder Morgan's current operations and existing activities at the Deltaport Terminal;
- Existing case plus TMX Project application case, including fugitive and combustion emissions changes from storage tanks at Sumas, Burnaby, and Westridge and from marine vessels at berth and anchor locations;
- Future case #1 in 2014 (also referred to as Deltaport 2014), that accounted for existing and predicted TMX Project emissions plus for emissions associated with capacity increases[1] at Roberts Bank container terminals (i.e., RBT2[2] and Deltaport[3] Terminal expansion); and
- Future case #2 in 2030 (also referred to as Deltaport 2030), that accounted for Future case #1 combined with an 80% reduction in marine NO_x emissions triggered by regulations from the International Maritime Organization for Tier III emission standards for ships constructed on or after January 1, 2016 and operating within the North American Emission Control Areas[4].

Based on the scenarios assessed, other certain and reasonably foreseeable projects and activities (or fleet turnover for the various emission sources) were not included as part of the TMX Project study. Therefore, none of the emission scenarios for the TMX Project considered the changes in future emissions from all sources in the lower Fraser Valley or the Georgia Basin (e.g., the effects of population growth on automobile emissions coupled with the effect of fleet turnover to newer, lower emitting vehicles). Instead, the CMAQ modelling only considered isolated changes in emissions from the TMX Project itself and for the Future case #2 emission scenario, container terminal emissions at Roberts Bank based on a study by SENES (2012). The Future case #2 emission scenario is not representative of future conditions

[1] Emission estimates for container terminal capacity increases were sourced from SENES (2012).
[2] RBT2 was considered in this TMX scenario for 2014, and therefore, this scenario is purely hypothetical.
[3] Deltaport Terminal expansion a result of the Deltaport Terminal, Road and Rail Improvement Project (DTRRIP).
[4] http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx

with RBT2, as emission estimates for container (and other) terminals at Roberts Bank were subsequently refined in the RBT2 Air Quality Study (EIS Appendix 9.2-A).

U.S. EPA Guidance and Benchmark Criteria

As stated above, to predict the requested 98th percentile ozone levels for expected and future conditions in 2025, a full year of modelling would be required. Due to their complexity, photochemical models are typically run for multi-day episodes and not up to year (as conducted for the TMX Project assessment and indicated by MOE (2015a)). Furthermore, these models are best suited to evaluate broad regional changes in air quality due to air quality management policies, and are not well-suited to evaluating small changes related to emissions from individual projects, especially for predicted concentrations within a few hundred metres from the emission source.

In the absence of defined MOE policy on when photochemical modelling should be required for proposed developments, the VFPA relied on guidance from the U.S. EPA, as generally recommended by the MOE (2015a). As reported by Arasa et al. (2012):

> *"The US Environmental Protection Agency developed guidelines indicating that it is inappropriate to establish a rigid criterion for model acceptance or rejection (i.e., no pass/fail test). However, building on past ozone modelling applications a common range of values for bias, error, and accuracy has been established. The three multisite metrics used are the unpaired peak prediction peak accuracy (UPA), the mean normalised bias error (MNBE), and the mean normalised gross error (MNGE)."*

The accepted EPA criteria listed by Arasa et al. (2012) for the performance of a photochemical modelling exercise using the CMAQ model for 1-hour average ozone concentrations, the benchmark criteria would be as follows:

- UPA – Ozone concentration < ±20%
- MNBE – Ozone concentration < ±15%
- MNGE – Ozone concentration < ±35%

Using the National Ambient Air Quality Objective (NAAQO) of 82 parts per billion (ppb; 160 µg/m^3 (micrograms per square metre)) for hourly averaged ozone concentrations, the CMAQ model would be considered to have acceptable performance if the maximum predicted ozone concentration was within about 16 ppb (i.e., within ±20% of the maximum observed concentration at the NAAQO concentration) during an ozone episode. Thus, for photochemical modelling to provide more accurate outcomes than what has already been provided in the RBT2 Air Quality Study (EIS Appendix 9.2-A), the predicted maximum change in future hourly averaged ozone concentration would have to be many times higher than the 1 ppb (24-hour average) predicted for RBT2 using a first-order estimate based on previous photochemical modelling in the lower Fraser Valley.

For comparison, Steyn et al. (2013) conducted a retrospective analysis of ozone formation in the lower Fraser Valley using the WRF/CMAQ models. Steyn et al. (2013) reported mean bias

errors (i.e., where the predicted ozone concentration exceeded the observed concentration) ranging from 5.7 ppb to 10.8 ppb for three episodes, and normalised mean errors of 47.0%, 54.4%, and 78.9% for these episodes. Steyn et al. (2013) attributed some of the differences between predicted and observed ozone concentrations to an underestimation in NO_x emissions in the historical emission inventory used for the modelling. As such, even with the benefit of hindsight, the analyses by Steyn et al. (2013) were still subject to large uncertainties in predicted ozone concentrations. It would be reasonable to assume that photochemical modelling of future ozone episodes based on projected estimates of emissions would be subject to greater uncertainties than those presented by Steyn et al. (2013).

Therefore, the first order estimate of an ozone increase presented in the RBT2 Air Quality Study (EIS Appendix 9.2-A, Section 4.5) of 1 ppb (2 µg/m^3) is well below the degree of uncertainty that can be expected from the performance of regional scale photochemical models such as CMAQ, CAMx, or AURAMS, and is within the precision and limit of detection for ozone monitoring equipment[5]. On this basis, the VFPA maintains that the first-order estimate of changes in regional scale ozone concentration was consistent with current U.S. EPA guidance, as summarised below.

In recognition of the limitations in photochemical modelling of individual sources in an airshed, the U.S. EPA (2015) has issued guidance for a two-tiered approach on this issue. Specifically, the U.S. EPA recommends the following:

- *The first tier screening-level approaches for estimating single source secondary impacts described in the 2015 revision to Appendix W are intended to reduce burden on sources that can rely on existing information to characterize their impacts. …For first tier assessments, it is generally expected that applicants would use existing empirical relationships between precursors and secondary impacts based on modeling systems appropriate for this purpose as detailed in this guidance. It is also possible screening approaches based on full science chemical transport modeling systems (e.g. reduced form models) could provide information to satisfy the first tier in some situations.*
- *For second tier assessments (Sections 5.3.2.c and 5.4.2.c) when necessary, guidance is provided on the air quality models, inputs, run time options, receptor placement, and application approach for the purposes of estimating the impacts on ozone and secondarily formed PM2.5 from single project sources. Within the second tier described in Appendix W, applicants are provided flexibility in terms of the complexity of model application for comparison to both the SIL and NAAQS. The sub-tiers of the Appendix W second tier allow for simpler approaches to be compared conservatively*

[5] As outlined in EIS Appendix 9.2-A, Section 4.5, the first-order estimate for the increase in ozone concentration was approximately 1 ppb for a 24-hour average concentration (attributable to the decrease in NO_x emissions projected by the Project and other marine terminal emissions at Roberts Bank), which is within the range of accuracy for ozone monitoring equipment. For example, the performance specifications for ambient air gas analysers under the National Air Pollution Surveillance (NAPS) Network specify that ozone monitors must have a Minimum Detection Limit (MDL) of 2 ppb and a precision of ±2 ppb (Environment Canada 2004). Therefore, the first-order estimate of anticipated changes in expected ozone concentration of 1 ppb fall below the MDL for NAPS monitoring stations.

to the SIL and NAAQS and more sophisticated approaches could be applied to provide a more representative impact for a source.

In summary, the 2015 U.S. EPA guidance on photochemical modelling analyses for proposed new sources accepts simplified analyses (Tier 1) based on previously completed analyses in the region. This guidance is consistent with the approach used for the RBT2 Air Quality Study (EIS Appendix 9.2-A), which relied on previous photochemical modelling analyses completed in the lower Fraser Valley by Steyn et al. (2011). Since the B.C. Guideline does not provide guidance on advanced models or when advanced modelling such as photochemical modelling is required, the VFPA maintains that the first-order analysis of changes in ozone concentrations was completed in a manner consistent with recent guidance from the U.S. EPA. Air quality modellers in B.C. have historically been encouraged to seek assistance and guidance from the U.S. EPA on issues not covered by MOE guidelines or instructions.

If photochemical ozone modelling were to be conducted for a selected period (i.e., a few days as outlined in MOE (2015a)), the modelling results, subject to large uncertainties as discussed above, are expected to show only very minor changes that would not be materially informative for assessing potential human health effects associated with future changes in emissions at Roberts Bank.

Inverse Relationship of Ozone and Nitrous Oxides

Ozone is formed through a complex set of atmospheric chemical reactions with NO_x and volatile organic contaminants (VOCs). Project-related changes described in EIS Appendix 9.2-A are as follows:

- A small increase in ozone (i.e., 1 ppb) is expected primarily due to an expected net decrease in NO_x emissions from the marine terminals at Roberts Bank. The projected net decrease in NO_x emissions is a result of regulatory mandates for cleaner diesel engines for ships within the North American Emission Control Area and VFPA mitigation measures for reducing NOx emissions from port-related activities as part of the Northwest Ports Clean Air Strategy and other initiatives. Therefore, an increase in ground level ozone concentrations may result from the implementation of emission reduction measures specifically mandated by regulatory agencies or other initiatives, which are not specific to RBT2; and
- Increases in local VOC emissions from the Project are conservatively estimated to be approximately 54 t/y (tonnes per year) during operations (see Table 4-4-1 in EIS Appendix 9.2-A), but with anticipated changes in technology and use of shore power, the actual net increase in VOC emissions in the future from the Project and other Roberts Bank terminals could be much lower (i.e., 17 t/y without the use of shore power and as low as 10 t/y with maximum use of shore power).

Therefore, potential ozone production could increase slightly with a small increase in the availability in VOCs, but a larger increase in ozone production could result from regulatory mandates for NO_x reductions from gasoline and diesel engines, as well as the switch from low sulphur diesel to liquefied natural gas (LNG) fuel for the ferries operating out of the BC Ferries

Tsawwassen Terminal. The implication of further NO_x reducing initiatives is further explained below.

The magnitude of the estimated NO_x emission reductions between existing conditions and future conditions with the Project was depicted in EIS Appendix 9.2-A, Figure 4-1 and tabulated in Table 4-4-1. Total NO_x emissions from the three existing Roberts Bank marine terminals were estimated at 2,223 t/y in 2010. The estimated emissions in 2025 for the future conditions with the Project were estimated at 1,706 t/y, excluding the potential emission reductions due to shore power and the switch to LNG fuel for the ferries operating out of the ferry terminal. Without considering LNG for ferries and shore power for the container terminals, the net decrease in NO_x emissions is estimated at 517 t/y. If all ferries at the BC Ferries Tsawwassen Terminal were converted to operate as dual fuel vessels, the potential 90% reduction in NO_x emissions from the ferries could amount to a further reduction of over 630 t/y. If all container ships at RBT2 and the third berth at the Deltaport Terminal used shore power, NO_x emissions from Roberts Bank could be reduced by a further 257 t/y. Therefore, the potential reduction in annual NO_x emissions from the marine terminals at Roberts Bank could be from a total of 2,223 t/y in 2010 to 818 t/y in 2025 under future conditions with the Project, a combined total NO_x reduction of 1,404 t/y. This reduction would be the largest cause of ozone increases in the future, and would only be partially related to RBT2 because the majority of the reduction in emissions would arise from changes at the three existing terminals, with the greatest change from the conversion to dual-fuel ferries.

Regulatory Engagement

The B.C. MOE supports the early engagement of the ministry and other interested parties at the commencement of a modelling project. Specifically, MOE (2015b) states:

> *"Although the Guideline provides direction on model selection, set-up and application, there can be difference in professional opinion in these areas. These differences may be significant enough so that the Ministry (or other interested parties) will not accept the modelling results. This means delays, a waste of time/resources and confusion among those who have a stake in the decisions based on the modelling results. In order to avoid this unfortunate situation, the Guideline recommends the submission and Ministry agreement on a dispersion modelling plan for the modelling project. The Guideline provides a plan template to facilitate this practice."*

The VFPA followed this recommendation and in 2013 initiated the Air Quality Scoping Study (AQSS), which was a collaborative process to determine the approach to quantifying air quality changes resulting from Project development and activities. Participants included Environment Canada, Metro Vancouver, Tsawwassen First Nation, the Corporation of Delta, and the MOE. As described in EIS Section 9.2.2.1, consultation on the proposed assessment approach involved the distribution of the AQSS Protocol document, which was reviewed by participants. Photochemical modelling was discussed and feedback was considered and incorporated where possible into the RBT2 Air Quality Study (EIS Appendix 9.2-A). Based on this collaborative process it was determined that the Tier 1 approach was appropriate

Summary

In summary, the methodology used in the RBT2 Air Quality Study (EIS Appendix 9.2-A) is consistent with current guidance from the U.S. EPA (2015), whom the MOE defers to and endorses for model selection, technical evaluations, and guidance. The VFPA has not conducted the extensive modelling requested in this information request, as the RBT2 Air Quality Study (EIS Appendix 9.2-A) is aligned with current regulatory guidance and modelling practice, and consistent with regulator input during the air quality assessment scoping phase. The extent of work requested is not considered to be technically feasible for a project of the scope and scale of RBT2, or warranted based on approaches used on other projects in the region. The results from such an analysis would be subject to a large degree of uncertainty, and the outcomes of such work are unlikely to change the outcomes of the RBT2 Air Quality Study (EIS Appendix 9.2-A).

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IR6-21 Air Quality – Baseline and Modelling, Ozone and $PM_{2.5}$

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix B, Section 3.2.3

Canadian Council of Ministers of the Environment *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone*

Context

As stated by Environment and Climate Change Canada, the Canadian Council of Ministers of the Environment *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* is intended as a reference tool outlining the methodologies, criteria and procedures for reporting on achievement of Canadian ambient air quality standards (CAAQS) for particulate matter and ozone. Table 1 (page 2) of the CAAQS manual indicates 3 years of data is suggested for the $PM_{2.5}$ 24-hour and annual metrics as well as the ozone 8-hour metric.

Air quality observation data from the Tsawwassen Pebble Hill Park (station T39) were reported in Table 3-2 of Section 3.2.3 of Appendix B of Appendix 9.2-A, and have been used to establish background concentrations for the air quality study. The data covered the period from June 2010 through December 2012. This is a relatively short period of time to establish background concentrations since variability of meteorological conditions from year-to-year can influence results.

Further, background pollution concentrations were determined using only one monitoring site. Incorporation of air quality observations from Richmond South (station T31) could increase confidence in the background pollutant concentration estimations.

Information Request

Update the ozone and fine particulate matter ($PM_{2.5}$) observations and analysis used as background concentrations in the air quality study to include at least 3 years of data as suggested in the *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone*.

Update the air quality observation data from the Tsawwassen Pebble Hill Park (station T39) provided in Table 3-2 of Section 3.2.3 to include data from June 2010 through to at least September 2016 to verify that the concentrations in this table have not been biased by the limited period of record.

Include air quality observations from Richmond South (station T31) for 2010 to September 2016 in the analysis of background pollution to demonstrate that values from T39 are not station specific, but have regional relevance.

If any of the updated 98th percentile concentrations of ozone and fine particulate matter change appreciably as a consequence of using the longer period of record, any implications for the Project's air quality study should be provided.

VFPA Response

***Update the ozone and fine particulate matter ($PM_{2.5}$) observations and analysis used as background concentrations in the air quality study to include at least 3 years of data as suggested in the* Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone.**

Ozone and $PM_{2.5}$ (respirable particulate matter; particulate matter of 2.5 microns or less in diameter) background concentrations based on June 2010 to December 2016 (6.5 years of data) from Tsawwassen Pebble Hill Park (Station T39) are summarised in **Table IR6-21-1** for maximum, mean, median, and 98^{th} percentile concentrations. Data for other parameters and stations is also provided in **Table IR6-21-1** to support subsequent responses.

Table IR6-21-1 Summary of Air Quality Observations 2010 to 2016 from Monitoring Stations T39, T31, and T17

Station	Monitoring Period	Parameter	Concentration (µg/m³)									
			CO[a]		NO_2		SO_2		O_3			$PM_{2.5}$[a]
			1-h	8-h	1-h	24-h	1-h	24-h	1-h	8-h	24-h	24-h
T39	2010 to 2012[b]	Max	800.4	626.4	120.1	48.9	53.5	9.7	135.4	111.6	90.9	28.2 (14.1)
		Mean	183.6	183.6	12.8	12.8	1.4	1.4	45.9	45.8	45.9	3.5 (3.5)
		Median	174.0	174.0	9.0	10.8	0.8	1.1	46.6	46.3	46.1	3.1 (3.1)
		98th percentile	371.2	339.3	44.7	34.9	7.7	5.1	88.2	84.7	79.8	9.5 (8.7)
T39	2010 to 2016[b]	Max	2120.1 (951.2)	1105.9 (717.1)	120.1	60.3	53.5	9.7	135.4	111.6	93.6	58.8 (21.6)
		Mean	174.0 (173.6)	174.0 (173.5)	12.9	12.9	1.1	1.1	44.8	44.7	44.8	4.3 (4.3)
		Median	160.4 (160.4)	161.9 (161.9)	9.0	10.8	0.8	0.9	45.4	45.3	45.4	3.7 (3.7)
		98th percentile	355.3 (355.3)	330.9 (329.5)	45.1	35.9	5.9	3.9	87.2	83.7	78.9	12.3 (11.8)
T31	2010 to 2016	Max	2349.3 (2349.3)	1729.0 (1729.0)	118.8	87.3	46.6	8.0	125.8	105.2	87.2	71.2 (29.8)
		Mean	284.5 (284.2)	284.9 (384.5)	27.4	27.4	1.7	1.7	33.3	33.2	33.3	5.1 (5.1)
		Median	229.2 (229.2)	240.7 (239.2)	23.7	25.3	1.1	1.4	32.0	31.8	33.1	4.4 (4.4)
		98th percentile	859.5 (859.5)	773.6 (772.7)	68.0	57.6	7.2	5.0	81.6	77.4	70.5	14.1 (13.6)
T17	2010 to 2016	Max	3151.5 (3151.5)	1592.9 (1592.9)	107.5	75.1	34.6	7.3	139.8	127.9	92.5	60.8 (29.9)
		Mean	234.2 (234.0)	234.7 (234.5)	24.1	24.1	1.3	1.3	34.7	34.6	34.7	5.3 (5.3)
		Median	183.4 (183.4)	186.2 (186.2)	20.8	21.9	0.8	1.1	33.2	33.0	34.4	4.5 (4.5)
		98th percentile	848.0 (848.0)	747.3 (747.8)	61.4	52.0	5.3	3.7	86.4	81.6	72.9	15.1 (14.9)

Notes: a. Numbers in brackets exclude data for August 4 to 6 and August 14 to 17, 2010, and July 5 to 10 and August 23, 2015 (periods when poor air quality resulted from smoke from forest fires).
b. Station T39 data from June 2010 to December 2012 was used in the RBT2 Air Quality Study as background concentrations, as the station was operational by mid-2010 and the study commenced in 2013. For the 6.5-year period, concentrations from 2010 to 2016 were used, with the 2010 year being limited to the period of June to December.

Update the air quality observation data from the Tsawwassen Pebble Hill Park (station T39) provided in Table 3-2 of Section 3.2.3 to include data from June 2010 through to at least September 2016 to verify that the concentrations in this table have not been biased by the limited period of record.

Table IR6-21-2 provides a comparison of June 2010 to December 2012[1] 98th percentile background concentrations for criteria air contaminants measured at Station T39 (i.e., those used in the RBT2 Air Quality Study and presented in Table 3-2 of Appendix B in EIS Appendix 9.2-A) to 98th percentile background concentrations measured at Station T39 for the period June 2010 to December 2016.

Table IR6-21-2 Comparison of 2010-2012 RBT2 Air Quality Study and 2010-2016 Station T39 98th Percentile Background Concentrations

Criteria Air Contaminant	Averaging Period	98th Percentile Background Concentrations (µg/m³)	
		RBT2 Air Quality Study (T39 2010-2012)	T39 2010-2016
CO	1-h	371.2	355.3
	8-h	339.3	330.9
NO_2	1-h	44.7	45.1
	24-h	34.9	35.9
	1-y	12.8[a]	12.9
SO_2	1-h	7.7	5.9
	24-h	5.1	3.9
	1-y	1.4[a]	1.1
O_3	1-h	88.2	87.2
	8-h	84.7	83.7
	24-h	79.8	78.9
	1-y	45.9[a]	44.8
PM_{10}	24-h	23.1[b]	23.3
	1-y	10.3[a,b]	11.3
$PM_{2.5}$	24-h	8.7	11.8
	1-y	3.5[a]	4.3

Notes: a. Where 98th percentile concentrations were not available for the annual averaging period, 24-h mean background concentrations were assumed.
b. Based on observations from Vancouver International Airport (T31) for 2010 to 2016.

While the maximum observed 1-hour average CO concentration has increased (**Table IR6-21-1**), the 98th percentile 1-hour concentration has decreased by approximately 4% (**Table IR6-21-2**). The maximum 1-hour average CO concentration is not reflective of a

[1] June 2010 to December 2012 Station T39 data was used in the RBT2 Air Quality Study as background concentrations, as the station was operational by mid-2010 and the study commenced in 2013.

typical maximum concentration, as this value was observed on July 5, 2015 when an air quality advisory was issued in Metro Vancouver for $PM_{2.5}$ due to smoke from forest fires burning north of Squamish and Pemberton. These elevated CO concentrations coincided with elevated $PM_{2.5}$ concentrations, indicating that the increased concentrations for both contaminants were related to the influence of wildfires in the region.

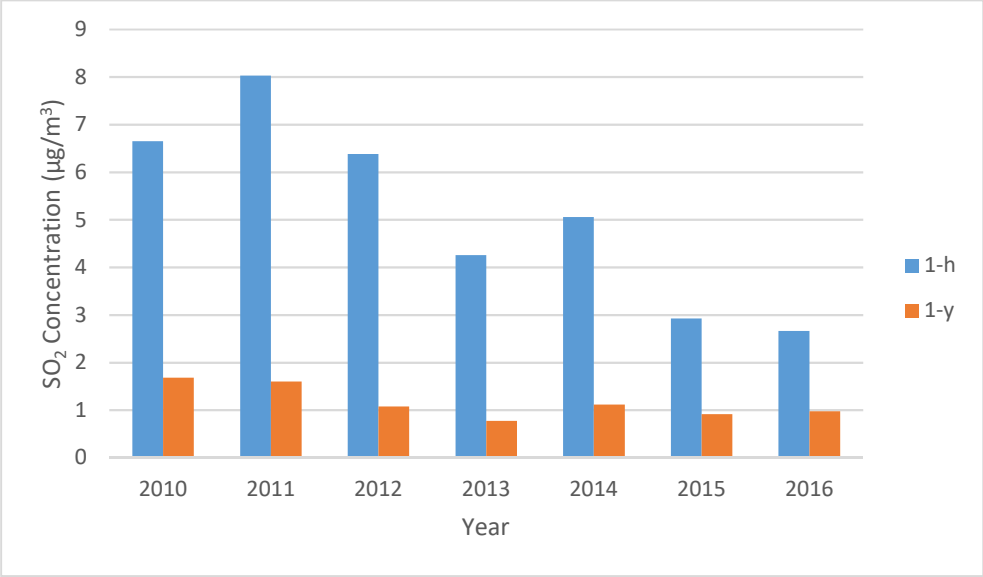
The 98th percentile 1-hour and 24-hour average NO_2 concentrations increased by approximately 1% and 3%, respectively. Median concentrations over the 6.5-year period are the same as median concentrations over the 2.5-year period used in the RBT2 Air Quality Study.

Concentrations of SO_2 have decreased over recent years as shown in **Figure IR6-21-1**, particularly in 2015 when the sulphur content limit of marine fuel for vessels was reduced from 1% to 0.10% under the North American Emissions Control Area (ECA) regulations. The 98th percentile 1-hour average SO_2 concentrations over the 6.5-year period is more than 20% lower than the 98th percentile 1-hour SO_2 concentrations over the 2.5-year period used in the RBT2 Air Quality Study.

Ozone concentrations over the 6.5-year period are very similar to ozone concentrations over the 2.5-year period, with the mean, median, and 98th percentile concentrations decreasing by 1% to 3%.

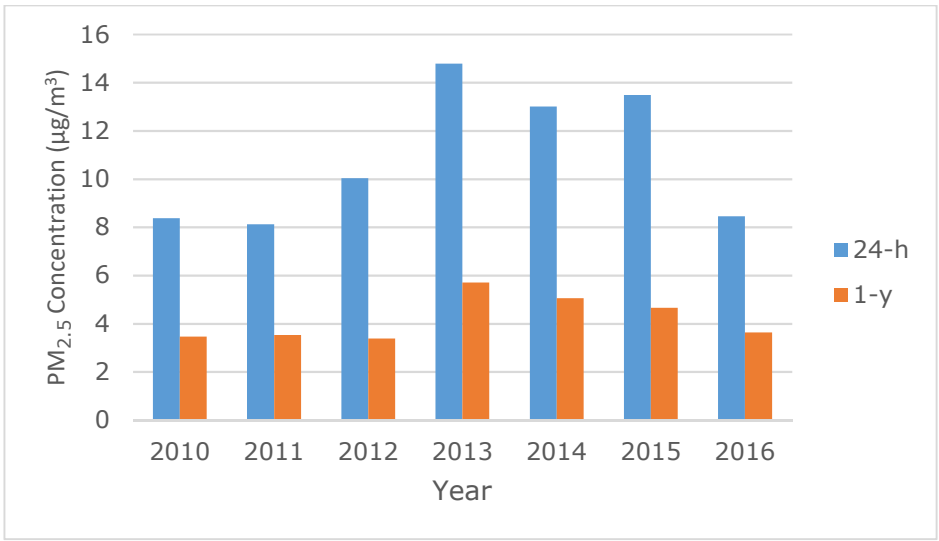
$PM_{2.5}$ concentrations in the 6.5-year period are higher than those in the 2.5-year period. As shown in **Figure IR6-21-2**, the 24-hour and annual average $PM_{2.5}$ concentrations spike in 2013 when Metro Vancouver switched the $PM_{2.5}$ monitoring instrument from a Tapered Element Oscillating Microbalance (TEOM) device to a Synchronized Hybrid Ambient Real Time Particulate (SHARP) device. Increases in $PM_{2.5}$ concentrations, therefore, are understood to be related to the change in instrumentation rather than any actual increases in $PM_{2.5}$ concentrations over recent years. Annual average $PM_{2.5}$ concentrations showed a steady decline from 5.7 $\mu g/m^3$ in 2013 to 3.6 $\mu g/m^3$ in 2016, coinciding with the reduction in SO_2 concentrations as a result of the implementation of the ECA regulations in 2012 and 2015.

Figure IR6-21-1 Change in 98th Percentile 1-hour SO_2 Concentrations from 2010 to 2016



Note: Excludes data for August 4 to 6 and 14 to 17, 2010 and July 5 to 10 and August 23, 2015 (periods of smoke from forest fires).

Figure IR6-21-2 Change in 98th Percentile 24-hour and Annual $PM_{2.5}$ Concentrations from 2010 to 2016



Note: Excludes data for August 4 to 6 and 14 to 17, 2010 and July 5 to 10 and August 23, 2015 (periods of smoke from forest fires).

Overall, air quality concentrations have not changed appreciably over recent years, except for SO_2 which has decreased as a result of more stringent fuel sulphur limits in the ECA. The SO_2 results presented in the RBT2 Air Quality Study are therefore conservative given the recent decline in SO_2 concentrations. Although $PM_{2.5}$ concentrations increased in 2013 as a

result of the change in measurement instrumentation, $PM_{2.5}$ concentrations also decreased steadily after 2013 due to the use of marine fuels with low sulphur content.

Include air quality observations from Richmond South (station T31) for 2010 to September 2016 in the analysis of background pollution to demonstrate that values from T39 are not station specific, but have regional relevance.

Air quality data from the Vancouver International Airport (Station T31) and Richmond South (Station T17) for the period January 2010 to December 2016 are summarised in **Table IR6-21-1**, along with air quality data for both the 2.5-year and 6.5-year periods for Station T39.

Concentrations of CO, NO_2, SO_2, and $PM_{2.5}$ observed at Stations T31 and T17 are higher than those observed at T39. Both Stations T31 and T17 are located outside the RBT2 Air Quality Study local study area (LSA) and the higher concentrations of these four criteria air contaminants indicate that they are not representative of background air quality in the LSA. Using data from these two stations in conjunction with the observations from Station T39 to define the background contaminant concentrations would skew the background levels to artificially increase concentrations to levels not actually experienced in the LSA.

As context, Station T31 is located at the Vancouver International Airport, near the east end of a major take-off runway. Air quality observations at Station T31 are, therefore, influenced by aircraft emissions that are not representative of conditions in the LSA. Station T17 is located in a residential neighbourhood in Richmond, a city with a much higher population density of 1,534 per square kilometre compared to Tsawwassen which has a population density of only 124 per square kilometre (Statistics Canada 2016). Station T17 is also located less than 75 m from Williams Road, and close to other major road corridors such as Steveston Highway and Highway 99. Therefore, Station T17 is influenced by residential and vehicle traffic emissions that are not representative of the residential areas in the LSA.

Consequently, background concentrations in the LSA are more appropriately represented using air quality observations from Station T39. It should be noted that Station T39 was expressly established in 2010 to capture air contaminant emissions from the marine terminals at Roberts Bank. The observations at Station T39 have been shown to be representative of air quality on Tsawwassen First Nation Lands through a monitoring study conducted in 2014 to 2015 (see response to IR6-09, Appendix IR6-09-A of CEAR Document #1113[2]). As such, Station T39 is representative of air quality in the region most affected by emissions from Roberts Bank, and introducing observational data from Stations T31 and T17 would not be representative of actual conditions near the proposed Project.

[2] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).

If any of the updated 98th percentile concentrations of ozone and fine particulate matter change appreciably as a consequence of using the longer period of record, any implications for the Project's air quality study should be provided.

As shown in **Table IR6-21-1**, the 98th percentile ozone concentrations over the 6.5-year period are approximately 1% to 2% lower than the background ozone concentrations used in the RBT2 Air Quality Study. Therefore, the change as a consequence of using a longer period of record is not appreciable.

The 98th percentile $PM_{2.5}$ concentrations over the 6.5-year period are higher than the background concentrations used in the RBT2 Air Quality Study, as a result of the change in measurement instrumentation (**Table IR6-21-1**). **Table IR6-21-3** provides maximum predicted $PM_{2.5}$ concentrations over land for existing, expected, and future conditions (with the Project), along with the percentage that the maximum over land concentration (including the 6.5-year period background concentration) represents relative to air quality criteria[3]. There are no exceedances of air quality criteria over land for either the 24-hour or annual averaging period. Overall, the conclusions of the RBT2 Air Quality Study remain unchanged.

Table IR6-21-3 Predicted $PM_{2.5}$ Concentrations, Including Background Concentrations Based on 2010 to 2016 Station T39 Monitoring Data

		$PM_{2.5}$ Concentration (µg/m^3)	
		24-h	**Annual**
Updated RBT2 Air Quality Criteria[3]		*25*	*8*
Background Concentration		*11.8*	*4.3*
Existing Conditions	Maximum Over Land[a]	5.3	0.5
	Max Over Land % of Criteria[b]	69%	79%
Expected Conditions	Maximum Over Land[a]	1.9	0.2
	Max Over Land % of Criteria[b]	55%	74%
Future Conditions with the Project	Maximum Over Land[a]	4.1	0.5
	Max Over Land % of Criteria[b]	64%	79%

Notes: a. Predicted maximum concentrations over land do not include background concentrations.
b. Maximum concentrations over land as a percentage of the criteria include the background concentration, as determined from Station T39 for June 2010 to December 2016 monitoring data.

References

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[3] For more information on air quality criteria, which has been updated to reflect current standards or objectives from regional, provincial, and federal authorities, refer to the response to IR6-23.

IR6-22 Air Quality – Ozone Limiting Method

Information Source(s)

EIS Volume 2: Appendix 9.2-A: Section 3.3.1; Table 3-2 and Figure 4.10; Appendix B, Section 3.2.6; Appendix C, Section 3.6.2; Appendix E

British Columbia Air Quality Dispersion Modelling Guideline. British Columbia Ministry of Environment, 2015

Context

The ozone limiting method (OLM) for the conversion of NOx to NO_2 was applied by the Proponent in the environmental assessment. The *British Columbia Air Quality Dispersion Modelling Guideline*, 2015, states that the OLM uses the Cole and Summerhays (1979) equation. This equation requires the maximum ozone value (100^{th} percentile) to be used in the calculation. However, in Section 3.6.2 of Appendix C, the Proponent indicated that the 98th percentile was used.

In addition, the *British Columbia Air Quality Dispersion Modelling Guideline*, 2015, specified that the background NO_2 concentration must be added to the predicted NO_2 concentration.

Information Request

Use the maximum (100th percentile) ozone value for the years used in the rerun of the NMM-WRF and CALMET models and add the background NO_2 concentration in the calculation of the ozone limiting method conversion.

Update the following figures and tables:

- Figure 4-10 and Tables 4-4, 4-5, 4-6, 5-2, and 5- 12 in Appendix 9.2-A; and
- Figures 4-1 and 4-10 and Tables 4-1, 4-2 and 4.7 in Appendix E of Appendix 9.2-A.

Evaluate the number of persons that are predicted to be exposed to isopleth plots of 160 ug/m^3 and higher of 1-hour NO_2 when the maximum ozone value is used in the calculation.

Present conditions/measures that could be imposed to further reduce NO_2 concentrations resulting from the Project occurring on land and at the Tsawwassen Ferry Terminal.

VFPA Response

Background Information

As context, and in support of the responses that follow, background information is provided below on the following:

- The various methods used to predict NO_2 concentrations;
- Regulatory discussions on the RBT2 approach for estimating NO_2 concentrations; and
- Information to support the interpretation of predicted NO_2 concentrations.

Methods Used to Predict NO_2 Concentrations

The RBT2 Air Quality Study (RBT2 Study) used the 98th percentile ozone concentration for the conversion of NO_x emissions to ambient NO_2 concentrations, for the reasons provided below. The Ozone Limiting Method (OLM) using the 100th percentile ozone concentration (as stated by both the 2008 Guidelines for Air Quality Dispersion Modelling in B.C. (MOE 2008; 2008 B.C. Guidelines) and the 2015 B.C. Air Quality Dispersion Modelling Guideline (MOE 2015; 2015 B.C. Guideline)) for the conversion of NO_x emissions to ambient NO_2 concentrations was not used in the RBT2 Study. The B.C. Ministry of Environment (MOE) produced the B.C. 2015 Guideline "to help ensure that dispersion modelling studies developed for the Ministry are appropriate for the needs of the application, correctly and consistently applied and used to reliably inform air quality management decisions" (MOE 2015). The B.C. 2015 Guideline provides 'guidelines' not 'requirements' for modelling, and applies to modelling submitted to MOE as well as Metro Vancouver.

Due to the spatial and temporal variability of oxidants such as ozone, as well as diurnal and seasonal variability in ambient temperature and levels of sunlight that affect the rate of chemical transformation of NO_x emissions to ambient NO_2 concentrations, and the gradual transformation of NO_x to NO_2 with distance from the source, the most appropriate methods for estimating NO_2 concentrations are photochemical models, which take all sources of variability into account. However, due to the complexity of the computational requirements of these models, these models can only be applied for short-term evaluations of air quality episodes lasting a few days (i.e., photochemical models are not suitable for application over an entire year). Furthermore, photochemical models are applied on a regional basis and are not suitable for estimating NO_2 concentrations over short distances (e.g., a few hundred metres) as was necessary in the assessment of emissions from RBT2.

Because of the difficulties in applying complex photochemical models to individual projects, regulatory agencies have developed a large variety of simplified methods for estimating NO_2 concentrations. The 2008 B.C. Guidelines and 2015 B.C. Guideline follow the guidance from U.S. Environmental Protection Agency (EPA), which endorses conservative, screening-level techniques or theoretically-based models. Screening-level methods, however, simplify complex photochemical reactions that lead to NO_2 formation. As such, the recommended methods are generally conservative (meaning that they tend to overestimate actual maximum NO_2 concentrations) to avoid underestimating predicted NO_2 concentrations.

The B.C. 2015 Guideline recommends the following methods for estimating the chemical transformation of NO_x emissions to ambient levels of NO_2:

- "100% conversion. If there are exceedances, use one of three methods described next." The U.S. EPA (2010) stated that this approach is a "very conservative" assumption when applied to estimating peak hourly NO_2 concentrations.

- "If there are adequate (at least one year) hourly NO and NO_2 monitoring data, use the ambient ratio method [ARM]".[1] This method also conservatively predicts maximum 1-hour average NO_2 concentrations. Moreover, the ratio of NO to NO_2 at a land-based monitoring site such as the Station T39 at Pebble Hill Park in Tsawwassen is unlikely to be representative of the ratio of these compounds everywhere in the modelling domain, but especially over water in the Strait of Georgia.
- "If adequate monitoring data are not available, use the ozone limited method." The 2015 B.C. Guideline states that the O_3 concentration used for the OLM be based on the maximum hourly O_3 concentration (100^{th} percentile)[2] measured from one-year of representative monitoring data (i.e., typically the closest station if it represents the conditions that the plume would experience). The U.S. EPA (2010) notes that the OLM is considered to be a "detailed screening level" method, which can be considered for use on a case-by-case basis for demonstrating compliance with the U.S. EPA 1-hour average NO_2 standard. It should be noted that the 2015 B.C. Guideline recommendation of using the 100^{th} percentile ozone concentration is unique to B.C. and is not a practice followed in other regulatory jurisdictions.[3]
- "If AERMOD is used, apply the plume volume molar ratio method [PVMRM]." As with the OLM, the U.S. EPA (2010) considers the PVMRM a detailed screening-level method for estimating 1-hour average NO_2 concentrations.

As cited in Appendix C of EIS Appendix 9.2-A, Podrez (2013) reported that current methods (i.e., ARM version 2, OLM, and PVMRM) recommended by both the U.S. EPA and the B.C. MOE for estimating 1-hour average concentrations over-predict actual NO_2 concentrations. The overestimation of NO_2 concentrations by these methods was confirmed by Podrez (2015):

> *"The NO_2 performance of the ARM2, PVMRM, and OLM methods is similar; all 3 methods over-predict NO_2 concentrations by a factor of approximately 1.7-2.0, based on the geometric mean across all the test data sets."*

[1] The U.S. EPA (2010) noted that it may be difficult *"to determine an appropriate ambient NO_2/NOx ratio based on monitoring data for the new 1-hour NO_2 standard than for the annual standard."* The U.S. EPA 1-hour average NO_2 standard of 188 µg/m^3 is identical to the B.C. interim ambient air quality objective adopted by the MOE in 2014 and is less stringent than the objective adopted by Metro Vancouver (200 µg/m^3).

[2] The use of the 100^{th} percentile ozone concentration to estimate NO_2 concentrations does not take into consideration the complexity of the actual chemical reactions in the atmosphere (i.e., NO_x to NO_2 conversion does not occur instantaneously, but occurs gradually as the plume is transported away from the source).

[3] In the U.S.A., for example, the application of the OLM requires the use of simultaneously recorded hourly averaged concentrations of NO_x and ozone, and the hourly averaged NO_2 concentration is based on the hour-to-hour variability in ozone concentrations, not just for the maximum ozone concentration measured at any time of the year. Similarly, the dispersion modelling guidelines for both Alberta and Saskatchewan recommend using the hourly variable ozone concentrations from an on-site monitoring station if such data are available, or regional ozone concentrations as defined by each province's Ministry of Environment. The regional ozone concentrations are not set at the 100^{th} percentile as is done in B.C.

Table IR6-22-A1 in **Appendix IR6-22-A** summarises methods currently in use for estimating NO_2 concentrations in various jurisdictions (adapted from Todoroski et al. (2015)).

Regulatory Discussions on the RBT2 Approach for Estimating NO_2 Concentrations

At the start of the Air Quality Scoping Study (AQSS) process, the VFPA expressed concern about the conservative nature of the methods (such as the OLM and ARM) recommended in the 2008 B.C. Guidelines for estimating NO_2 concentrations[4]. As the VFPA was concerned that the use of recommended methods would result in substantial overprediction of NO_2 concentrations, the VFPA proposed the use of the Janssen method, which would predict NO_2 concentrations in better agreement with observations at the Station T39 in Tsawwassen. Use of the OLM, nevertheless, was favoured over the use of the Janssen method by AQSS regulatory agency representatives, and therefore, was the method used in the RBT2 Study. Additional information on the limitations of the OLM and rationale for using this alternative method is provided in **Appendix IR6-22-A**.

Interpretation of Predicted NO_2 Concentrations

The maximum predicted NO_2 concentrations derived using the OLM in the RBT2 Study must be viewed within the context that maximum predicted 1-hour average NO_2 concentrations may be over-predicted by a factor of 1.7 to 2.0. Therefore, the concentrations are expected to meet the Metro Vancouver Ambient Air Quality Objective (AAQO) for 1-hour NO_2 of 200 $\mu g/m^3$ in all land areas of Tsawwassen and on Tsawwassen First Nation Lands for existing conditions, expected conditions, and future conditions with the Project.

A comparison of predicted and observed 1-hour average NO_2 concentrations in Tsawwassen from the assessment of the Deltaport Third Berth (DP3) Project shows that over-prediction of NO_2 concentrations was also experienced in that project, which used the ARM instead of the OLM conversion methodology. **Table IR6-22-1** provides a summary of the maximum predicted (100^{th} percentile) and the 98^{th} percentile NO_2 concentrations for DP3 at a discrete receptor location in Tsawwassen (referred to as Receptor R10 in RWDI (2005)) and observations from 2010 to 2015 at air quality monitoring Station T39 in Tsawwassen. **Table IR6-22-1** also presents predicted concentrations under existing conditions (2010) at Station T39 (R18) in the RBT2 Study. In both cases (i.e., using the ARM for DP3 and the OLM for RBT2), the over-prediction of NO_2 concentrations is consistent with the analysis of the performance of these methods as reported by Podrez (2013, 2015).

[4] For additional information pertaining to AQSS discussions on this topic, refer to Appendix IR6-04-A in the response to IR6-04 (applicable dates are May 2 and May 10, 2013).

Table IR6-22-1 Comparison of Predicted and Observed NO_2 Concentrations

	1-hour Average NO_2 Concentrations (µg/m³)			
	Predicted		Observed at Station T39 (2010-2015)	
	100th Percentile	98th percentile	100th Percentile	98th percentile
DP3 at Station R10[a] (2005)	122	115	85[c]	45[c]
RBT2 at R18[b] (Existing Conditions, 2010)	119	105	79[d] (120)[e]	43[d] (45)[e]

Notes:

a. Receptor R10 for the DP3 air quality study is in Tsawwassen (RWDI 2005).
b. Receptor R18 for the RBT2 Study is at Station T39 in Tsawwassen.
c. Observed concentrations include observations from all wind directions in 2013 to 2015.
d. Observed concentrations include observations from wind directions 260° to 340° (the direction of winds coming from the existing Roberts Bank terminals) from 2010 to 2012.
e. Observed concentrations include observations from all wind directions in 2010 to 2012.

The maximum predicted 1-hour average NO_2 concentrations for both the DP3 and RBT2 Study modelling analyses predicted similar concentrations in Tsawwassen (i.e., 122 µg/m³ for DP3 versus 119 µg/m³ for RBT2) (**Table IR6-22-1**). The maximum observed NO_2 concentrations at Station T39 in 2010 to 2012 was 120 µg/m³ for all wind directions, but 79 µg/m³ for wind coming from the direction of the Roberts Bank marine terminals. The maximum observed NO_2 concentration in 2013 to 2015 for all wind directions was 85 µg/m³. The disparity between predicted and observed NO_2 concentrations at the 98th percentile level is greater than the disparity between predicted and observed NO_2 concentrations at the 100th percentile level, illustrating that the RBT2 Study was conservative, even though it was based on the use of the 98th percentile ozone concentration. Note that the use of the OLM (as well as conservative assumptions for the worst-case hourly emission scenario) and over-predictions of ambient NO_2 concentrations would extend to the RBT2 Study predictions for expected conditions and future conditions with the Project.

Table IR6-22-1 shows that predicted and observed 1-hour average NO_2 concentrations at Station T39 were below both the Metro Vancouver AAQO of 200 µg/m³ (100th percentile concentration) and the B.C. MOE interim AAQO of 188 µg/m³ (98th percentile concentration)[5], even when adding the 98th percentile background concentration of 44.7 µg/m³ from 2010 to

[5] On November 16, 2017, the Canadian Council for Ministers of the Environment (CCME) posted new Canadian Ambient Air Quality Standards (CAAQS) for NO_2 (http://www.ccme.ca/en/current_priorities/air/caaqs.html). The new NO_2 CAAQS are intended to apply to the years 2020 and 2025 and are more stringent than current criteria. The posting of the new CAAQS indicates that provincial ministries have endorsed the new standards; however, it may be six months before B.C. MOE or Metro Vancouver indicate they have formally adopted the new CAAQS. Since there is the potential for change to the CAAQS within that period, these criteria have not been incorporated in the updated study criteria presented below.

2012 observations at Station T39 (i.e., in accordance with the B.C. 2008 Guidelines and B.C. 2015 Guideline).

Use the maximum (100th percentile) ozone value for the years used in the rerun of the NMM-WRF and CALMET models and add the background NO_2 concentration in the calculation of the ozone limiting method conversion. Update the following figures and tables: Figure 4-10 and Tables 4-4, 4-5, 4-6, 5-2, and 5- 12 in Appendix 9.2-A; and Figures 4-1 and 4-10 and Tables 4-1, 4-2 and 4.7 in Appendix E of Appendix 9.2-A.

As outlined above, background concentrations of ozone used in the OLM for the RBT2 Study were based on the observed 98th percentile 1-hour and 24-hour average concentrations at Station T39 for the period of 2010 to 2012.

For the purposes of responding to this information request and considering that WRF-NMM and CALMET models were not re-run (refer to the responses in IR6-04 and IR6-10 for further explanation), predicted NO_2 concentrations have been updated using the maximum (100th percentile) ozone value from observations over the 2010 to 2012 time period at Station T39. The maximum (100th percentile) 1-hour, 24-hour, and annual average ozone values are 135.4 µg/m^3, 90.9 µg/m^3, and 46.1 µg/m^3, respectively.

Appendix IR6-22-B provides updates[6] to the following EIS figures and tables as requested:

- Figure 4-10 in EIS Appendix 9.2-A – updated in Figures IR6-22-B1 and IR6-22-B2 for locations over land (based on Metro Vancouver AAQO using 100th percentile NO_2 concentration) and over water (based on B.C. AAQO using 98th percentile NO_2 concentration), respectively[7];
- Tables 4-4, 4-5, 4-6, 5-2, and 5-12 in EIS Appendix 9.2-A – updated in Tables IR6-22-B1 to IR6-22-B5, respectively;
- Figure 4-1 in Appendix E of Appendix 9.2-A – updated in Figures IR6-22-B3 and IR6-22-B4 for locations over land (based on Metro Vancouver AAQO) and over water (based on B.C. AAQO), respectively;
- Figure 4-10 in Appendix E of Appendix 9.2-A – updated in Figures IR6-22-B5 and IR6-22-B6 for locations over land and over water, respectively; and
- Tables 4-1, 4-2, and 4-7 in Appendix E of Appendix 9.2-A – updated in Tables IR6-22-B6 to IR6-22-B8, respectively.

[6] The updated information incorporates maximum (100th percentile) 1-hour, 24-hour, and annual average ozone values and updated study criteria for NO_2 for over land and over water locations in Canada and the U.S.A., as per Table IR6-23-1 provided in the response to IR6-23. SO_2 concentrations in the tables provided in **Appendix IR6-22-B** have also been updated to reflect the updated study criteria for over land and over water locations in Canada and the U.S.A.

[7] As outlined in EIS Section 9.2.10.5, isopleth plots indicate the highest hourly or daily concentrations for the specific hour or day in the year that results in the maximum concentration at each grid receptor point and should not be interpreted as an aggregate plume.

The updated data and figures based on 100th percentile ozone concentrations presented in **Appendix IR6-22-B** should be viewed with caution as they overestimate the levels that are likely to be observed if the Project proceeds. As stated in the background information above, this is because the OLM methodology is known to over-predict emissions and hypothetical worst-case emission scenarios that were used for short-term (i.e., 1-hour, 8-hour, and 24-hour average) dispersion modelling (refer to the response to IR6-15 of CEAR Document #1113[8] for more information on scenario assumptions). The figures provided in **Appendix IR6-22-B** also present maximum concentrations (shown in blue text) and the frequency of exceeding applicable criteria (shown in red text as days and percentage of the year) at the maximum point of impingement over land or over water, and also for certain receptors (i.e., R13 BC Ferries Terminal and R18 Air Quality Station T39) where applicable for contextual purposes.

As shown in the updated figures and tables provided in **Appendix IR6-22-B**, the use of the maximum ozone value (i.e., 100th percentile ozone concentration) in calculating NO_2 levels increases the degree of overprediction. As additional clarification, a comparison can be made between the maximum predicted 1-hour average NO_2 concentrations for existing conditions from the RBT2 Study (using the 98th percentile ozone value), with the predicted concentrations for existing conditions using the maximum (100th percentile) ozone value, shown in Table IR6-22-B1 of **Appendix IR6-22-B**. The incremental maximum predicted concentration (using the maximum ozone value) at Station T39 is 165.8 µg/m^3. When the background concentration of 44.7 µg/m^3 is added, this results in a total maximum predicted concentration of 210.5 µg/m^3 (Figure IR6-22-B1 in **Appendix IR6-22-B**). This is 2.7 times the maximum observed concentration of 78 µg/m^3 at Station T39 for 2010 to 2012, with winds blowing from the direction of the Roberts Bank marine terminals. Similarly, for the 2013 to 2015 period, the maximum predicted concentration of 210.5 µg/m^3 (as shown in Figure IR6-22-B1 in **Appendix IR6-22-B**) is 1.8 to 2.9 times the maximum observed NO_2 concentration of 72 µg/m^3 to 120 µg/m^3 for winds from the direction of the marine terminals. Therefore, use of the maximum (100th percentile) ozone value for the OLM results in an overprediction of 1-hour average NO_2 concentrations of 1.8 to 2.9 times the maximum observed concentration at Station T39 for existing conditions at Roberts Bank in any year for the period 2010 to 2015.

The updated data and figures based on 100th percentile ozone concentrations show that use of 100th percentile ozone concentrations compared to the use of 98th percentile ozone concentrations in OLM leads to even greater overpredictions and increased frequency of exceeding applicable criteria, whereas actual monitoring data does not exceed applicable criteria.

[8] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).

In summary, increasing the predicted NO_2 concentrations by using the 100th percentile ozone value for the application of the OLM increases the disparity between predicted and observed NO_2 concentrations.

Evaluate the number of persons that are predicted to be exposed to isopleth plots of 160 ug/m³ and higher of 1-hour NO_2 when the maximum ozone value is used in the calculation.

Updated study criteria (presented in Table IR6-23-1 in the response to IR6-23 and incorporated in the information provided above) for 1-hour NO_2 is 188 µg/m³ for over water locations and 200 µg/m³ for over land locations. Figure IR6-22-B1 in **Appendix IR6-22-B** provides the 160 µg/m³ isopleth contours predicted when using the maximum (100th percentile) ozone value for existing conditions, expected conditions, and future conditions with the Project. The region over land within and above this contour level shows the area in which people may be exposed to these concentrations, and the area of interest used to evaluate exposure.

The number of persons estimated to be exposed to 1-hour NO_2 levels of 160 µg/m³ was estimated by generating population density factors (number of people per square kilometre) for 2010 (representing existing conditions) and 2025 (for expected and future conditions) for the relevant areas, including Delta, B.C., Tsawwassen First Nation Lands, Musqueam IR4, and Point Roberts, WA. Population densities for 2010 were based on actual population for that year. Population densities for 2025 were derived from Statistics Canada 2016 census population and growth rate data, as well as additional local population growth predictions that consider planned residential development in Delta and Tsawwassen First Nation Lands (Statistics Canada 2016a, 2016b, 2016c; United States Census Bureau 2017; Tsawwassen First Nation 2017; City of Delta 2017).

Table IR6-22-2 summarises the number of persons (land-based receptors) that are estimated to be exposed to 1-hour NO_2 concentrations of 160 µg/m³ or higher for existing conditions (2010), expected conditions (2025), and future conditions with the Project (2025), based on dispersion modelling using both the 98th percentile and maximum (100th percentile) ozone values and actual or projected population densities, as applicable.

Table IR6-22-2 Persons Exposed to 160 µg/m³ and above 1-hour NO_2 Levels

	Existing Conditions (2010)		Expected Conditions (2025)		Future Conditions with the Project (2025)	
	With Over-prediction	Without Over-prediction	With Over-prediction	Without Over-prediction	With Over-prediction	Without Over-prediction
100th Percentile ozone	34,197	0	17,700[b]	0	32,681[a,b,c]	0
98th Percentile ozone (EIS)	5,051	0	1,966[b]	0	7,203 [a,b,d]	0

Notes:

a. The incremental number of persons exposed in the future with the Project are likely overestimated, given that the land areas that are incrementally 'exposed' with the addition of

the Project are primarily unpopulated agricultural areas, where actual population density would be much lower than the standard density factors used for these estimates.

b. The estimates for persons exposed in expected and future conditions (2025) are likely overestimated because planned housing developments are included in population density figures used in the calculations, and:
   - 100% occupancy of planned residential land developments in Delta and on Tsawwassen First Nation Lands may not be achieved by 2025; and
   - Not all planned housing developments are located within the exposure areas shown on Figures IR6-22-A1, and Figure 4-10 of the EIS (Appendix 9.2-A).

c. The estimated number of persons exposed in the future with the Project is lower than the number of persons exposed in existing conditions, despite increasing population density, due to predicted improvements in local air quality.

d. The estimated number of persons exposed in the future with the Project is higher than the number in existing conditions because of the assumed increase in population density (11 fold increase from 2010 to 2025) relative to the decrease (47%) in area exposed to 160 µg/m^3.

As indicated earlier in this response, predicted NO_2 concentrations must be viewed within the context that maximum predicted 1-hour average NO_2 concentrations may be over-predicted (i.e., by a factor of 1.7 to 2.0 based on Podrez (2015), and 1.8 to 2.9 times based on comparison to the maximum observed concentration at Station T39 for existing conditions at Roberts Bank for the period 2010-2015). As such, **Table IR6-22-2** provides the number of persons estimated to be exposed at or above a 1-hour NO_2 concentration of 160 µg/m^3 based on predicted NO_2 concentrations ('overprediction' column) and when taking into consideration the level of overprediction ('without overprediction' column). Predicted NO_2 concentrations (for predictions based on 98th and 100th percentile ozone values) were divided by a factor of 1.7 that align with measured exposure levels and more realistic future exposure level projections. The number of persons exposed to 160 µg/m^3 and higher concentrations of 1-hour average NO_2 concentrations in the local study area are zero (0) for both 98th and 100th percentile-based predictions without over-predictions (i.e., predicted values divided by a factor of 1.7). As further context in support of presenting more realistic estimates of exposure, measured NO_2 values at Station T39 have not exceeded 160 µg/m^3 in recent years, and the current concentration level is predicted to decrease in the future, with or without the Project, due to reductions in NO_x emissions due to fleet turnover of ships, cargo handling equipment, locomotives, and on-road vehicles.

Present conditions/measures that could be imposed to further reduce NO_2 concentrations resulting from the Project occurring on land and at the Tsawwassen Ferry Terminal.

The RBT2 Study provides a conservative evaluation of NO_2 concentrations for existing conditions and future conditions (both with and without the Project). Mitigation measures to reduce NO_x emissions at the Roberts Bank marine terminals are summarised in the responses to IR6-28 and IR6-37. The response to IR6-13 of CEAR Document #1134[9] discusses the conversion of the Spirit Class ferries on Route 1 (i.e., Tsawwassen to Swartz Bay) to operate on liquefied natural gas (LNG), which will further reduce NO_x emissions from the largest ferries at the terminal by about 90% from the emission rates that were used in the RBT2 Study. This

[9] CEAR Document #1134 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-20, IR5-30, IR5-31, IR6-13, IR7-12, IR7-37 & IR7-41. (See Reference Documents #975, #991, & #1000).

reduction in emissions will contribute to further reductions in ambient NO_2 concentrations in the area.

The incremental contribution of the Project on NO_2 concentrations occurring on land and at the Tsawwassen Ferry Terminal is expected to be small. As shown in Table IR6-22-B5 in **Appendix IR6-22-B**, and Tables 5-13 and 5-14 in EIS Appendix 9.2-A, the predicted changes in NO_2 concentrations are less than 40% for the 1-hour average, less than 27% for the 24-hour average and less than 10% for the annual average. If the conservativeness of the NO_x and NO_2 conversion is considered, the maximum predicted NO_2 concentrations under future conditions occurring over land and at the Tsawwassen Ferry Terminal are expected to remain below the applicable air quality criteria. As noted in the response to IR6-14, air quality is expected to improve in the future, with or without the Project, as a result of improvements in engine technologies and the use of cleaner fuels.

Refer to the responses to IR6-28 and IR6-37 for a discussion of specific measures that will be implemented for construction and operation phases of the Project to ensure that applicable air quality criteria are met.

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Appendices

Appendix IR6-22-A Supporting Information on RBT2 Approach for Estimating NO_2 Concentrations and Summary of NO_2 Estimation Methods Applicable in Canada and Other Jurisdictions

Appendix IR6-22-B Revised EIS Tables and Figures – NO_2 Concentrations Using Maximum (100^{th} percentile) Ozone Value

APPENDIX IR6-22-A

SUPPORTING INFORMATION ON RBT2 APPROACH FOR ESTIMATING NO_2 CONCENTRATIONS AND SUMMARY OF NO_2 ESTIMATION METHODS APPLICABLE IN CANADA AND OTHER JURISDICTIONS

RBT2 Approach for Estimating NO_2 Concentrations

At the start of the Air Quality Scoping Study (AQSS) process, the VFPA expressed concern about the conservative nature of the methods for estimating NO_2 concentrations recommended in the 2008 B.C. Guidelines such as the Ozone Limiting Method (OLM) and ambient ratio method (ARM). The VFPA was concerned that the use of any of those methods would result in substantial overprediction of NO_2 concentrations, as experienced in the air quality assessment for the Deltaport Third Berth Project in 2005. Consequently, the VFPA proposed to the AQSS participants the use of an empirically-derived methodology (i.e., the Janssen method in use in the Netherlands and in New South Wales, Australia), which would have produced predicted NO_2 concentrations that were in better agreement with observations at the Station T39 in Tsawwassen. Detailed rationale for using this alternative method to the OLM (as discussed with AQSS participants prior to commencing modelling for the RBT2 Air Quality Study (RBT2 Study)) was as follows:

- The use of the 100^{th} percentile ozone concentration in the OLM in B.C. to estimate NO_2 concentrations does not account for the complexity of the actual chemical reactions in the atmosphere. The conversion of NO_x to NO_2 occurs gradually (i.e., not instantaneously), as the plume is transported away from the source and does not account for the photodissociation of NO_2 by sunlight during daytime hours;
- As applied in B.C., the OLM requires that the maximum 1-hour average ozone concentration recorded at a station in the spring or summer be applied throughout the year, day or night, and without regard to the distance of the receptor from the emission source. In the atmosphere, NO_x conversion rates occur faster in the summer than in the winter, and faster in the daytime than at night. Because there is less sunlight available to drive the wintertime reactions, which break down NO_2 after it is formed, NO_2 concentrations are generally higher in the winter than in the summer. The OLM does not account for these processes; and
- As outlined above, it is important to vary the ozone concentrations as the conversion of NO_x to NO_2 is a complex process of formation and disassociation that is dependent on the concentrations of NO_x, ozone, and other oxidants, the availability of sunlight, and air temperature. The use of a single ozone concentration (i.e., the maximum 1-hour average ozone level measured at any time in the year) in the OLM does not account for the actual complexity of NO_2 formation.

Use of the OLM, nevertheless, was favoured over the use of the Janssen method by AQSS regulatory agency representatives, and therefore, was the method used in the RBT2 Study. For additional information pertaining to AQSS discussions on this topic, refer to Appendix IR6-04-A in the response to IR6-04 (applicable dates are May 2 and May 10, 2013).

Summary of NO_2 Estimation Methods Applicable in Canada and Other Jurisdictions

The OLM is only one of the many methods that have been developed to estimate NO_2 concentrations; some methods are based on photochemical modelling schemes, while others are based on simplified statistical or empirically-derived relationships.

Table IR6-22-A1 summarises methods currently in use for estimating NO_2 concentrations in various jurisdictions (adapted from Todoroski et al. (2015)). It should be noted that none of the available methods can be expected to provide accurate estimates of maximum predicted 1-hour average NO_2 concentrations under all circumstances. For methods that are based on statistically or empirically-derived relationships, the accuracy of the methods may be limited to the locations where those relationships were originally derived, and may not apply to other locations.

Table IR6-22-A1 Summary all NO_2 Estimating Methods Currently in Use in Canada and Other Jurisdictions (adapted from Todoroski et al. (2015))

Methods	Where Used	Advantages	Disadvantages

Photochemistry models	Canada, U.S.A., Europe, Australia, New Zealand, etc.	Computer model-based application. Only suitable for evaluating multi-day air quality episodes. Best suited for evaluating changes in air quality due to management policies on a regional scale.
		Some examples of models in use include:
		• Canada
		  ○ GEM-Mach (in progress)
		  ○ AURAMS
		• Canada/U.S.A.
		  ○ CMAQ
		  ○ CAMx
		• Chemical schemes used in Europe
		  ○ GRS
		  ○ EMEP
		  ○ SAPRC99 and SARPC07 mechanism
		  ○ CBM-IV
		  ○ CB05
		  ○ RACM
		  ○ MELCHIOR2
			Costly, require specialist to operate, may take a long time to run. Results highly variable, depending on quality of emission input data and modelling approach used.
			Due to complexity of computational requirements, cannot be used to evaluate air quality over time periods greater than a few days.
			Not suitable for estimating near-field concentrations (i.e., within a few hundred metres from a source).
			Not well-suited for project-specific evaluations.

Total Conversion Method	Canada, U.S.A., New Zealand, South Africa	Simple screening method, unlikely to underestimate impact.	Conversion of all NO_x to NO_2. Over estimates likely impact significantly.
Ambient Ratio Method (ARM)	Canada, U.S.A., China (Hong Kong), South Africa	Simple operation.	Only applicable for localities with the required ambient monitoring data necessary to determine the NO_2/NO_x ratio. **Over predicts NO_2 concentrations, especially near the source**; replaced by ARM2 method.
Ambient Ratio Method 2 (ARM2)	Canada, U.S.A	Simple operation. **Programmed into AERMOD.**	Based on U.S. monitoring data of NO_2 and NO_x. **Ratios may not be representative of jurisdictions outside the U.S.A**. U.S. EPA's ARM2 parameters have only been tested on sources with relatively low ISR (0.1-0.2) and typical ozone concentrations and thus may not be applicable with sources of higher in-stack ratio's and locations of higher ozone levels (Podrez 2015). Validation tests indicate **over prediction of NO_2 by a factor of 1.7 to 2.0, especially near the source** (Podrez 2015).
Plume Volume Molar Ratio Method	Canada, U.S.A., Australia (Victoria)	Can simulate multiple industrial plumes. Ambient NO_x monitoring is not required. **Programmed into AERMOD.**	Requires an initial in-stack NO_2/NO_x ratio. Requires ambient ozone concentrations. **Not recommended in estimating NO_2 from motor vehicle exhaust plumes due to potential for rapid oxidation.** Validation tests indicate **over prediction of NO_2 by a factor of 1.7 to 2.0** (Podrez 2015).
Ozone Limiting Method	Canada, U.S.A., China (Hong Kong), Australia (Victoria), New Zealand	Simple operation.	Requires an initial in-stack NO_2/NO_x ratio. Requires ambient ozone concentrations. Assumes instantaneous mixing of ozone into the emission plume and conversion of NO to NO_2. Validation tests indicate **over prediction of NO_2 by a factor of 1.7 to 2.0, especially near the source** (Podrez 2015).
RIVAD/ARM3	Canada (Alberta, Newfoundland & Labrador), U.S.A.	Incorporated into CALPUFF.	Assumes low background VOCs making it suited for relatively clear non-urban areas. Requires knowledge of background concentrations of ozone and ammonia. Requires both NO and NO_2 emission rates.
Discrete Parcel Method	China (Hong Kong)	Incorporated in CALINE4 Computes NO_2 concentrations without the need for an external background concentration file capable of predicting NO_x concentrations. **Suitable for road emissions.**	**Only for roads.** Under predicts NO_2 concentrations under high wind velocity. Assumes initial NO_x emissions composing of 92.5% NO and 7.5% NO_2 by mass.

Methods	Where Used	Advantages	Disadvantages
Methodologies developed for the UK Department for Environment, Food & Rural Affairs (DEFRA)	United Kingdom	Empirically derived relationships between NO_2 and NO_x based on monitoring data. Simple operation. Only appropriate for combustion processes where no more than 10% of NO_x is emitted as NO_2. • Screening/worst-case scenario: 50% and 100% of modelled values should be used for short-term and long-term average concentration respectively; • Worst-case scenario: 35% for short-term and 70% for long-term average concentration; • Case specific scenario: use of percentages lower than the worst-case scenario should be justified; and • The validity of an 'ozone-limiting' procedure for assessment of likely maximum conversion of NO_x to NO_2 should be assessed on a case-by-case basis. Ozone photochemistry algorithms used in some models must have valid inputs of ozone concentrations, sunlight, etc.	**Only suitable for roads.** May not be representative of jurisdictions outside the UK.
Airviro	Sweden	Simple operation.	Algorithm may not be representative of jurisdictions outside Sweden.
Romberg Method	Germany	Simple operation. Incorporated in models such as PROKAS, IMMIS, and MISKAM.	Empirically derived relationship. May not be representative of jurisdictions outside Germany. Requires NO_2 and NO_x monitoring data. Requires ambient ozone concentrations.
Standard Calculation Method in the Netherlands	Netherlands	Simple operation.	Empirically derived relationship based on initial NO_2, NO_x emission ratio and ambient ozone concentrations. May not be representative of jurisdictions outside Netherlands. Applicable for only road applications. Tends to overestimate by approximately 5% close to the road and underestimates by approximately 15% away from the road.
SAPPHO	Netherlands	Simple operation.	May not be representative of jurisdictions outside Netherlands.
Keller	Switzerland, Netherlands	Simple operation.	May not be representative of jurisdictions outside Switzerland. Although its performance is considered satisfactory in Switzerland, it **performs poorly in the Netherlands**.
Oxidant Partitioning Model	United Kingdom	Considers inter-relationships between NO, NO_2, and ozone. Considers source-receptor distance.	May not be representative of jurisdictions outside UK. **Applicable only to annual average concentrations.**
Limited mixing steady state approach applied to annual averages	Germany	Requires traffic station and background station monitoring data for NO_2, NO_x, and ozone. Applicable only to annual average concentrations or in time series calculations.	May not be representative of jurisdictions outside Germany. Determination of constants for time series calculations can be cumbersome. **Applicable only for road applications.**
Steady-state chemical models: • AIRQUIS-EPISODE • IFDM-POLCA • OSPM • OSPM (annual averages)	Europe	Simple operation	Unknown
Janssen et al. (1988)[a]	Netherlands, New Zealand	Simple operation.	Assumes constant ozone and uses an empirical fit. Based on empirical data from power plant emissions in the Netherlands. Predicted NO_2 concentration increases with distance from the source to receptor of interest.
Exponential Function Model	Japan	Simple operation. An exponential function is generally used in estimating NO_2 impacts from stationary sources and a statistical model is used for automobile influences.	Unknown.

Note: a. During the AQSS process, the VFPA suggested using the Janssen Method for the RBT2 Study, but the regulatory agency representatives in the AQSS process rejected its use in favour of the OLM instead.

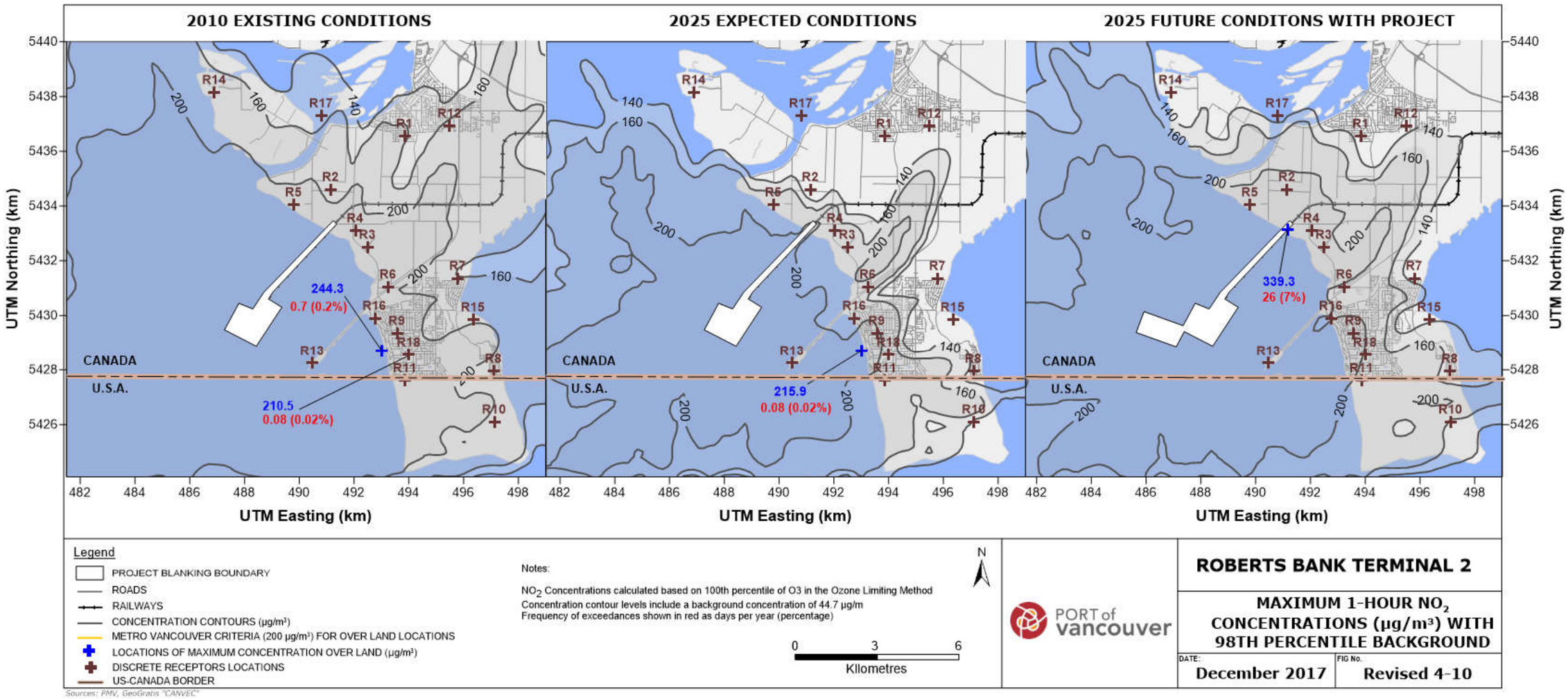
APPENDIX IR6-22-B

REVISED EIS TABLES AND FIGURES – NO_2 CONCENTRATIONS USING MAXIMUM (100^{TH} PERCENTILE) OZONE VALUE

Explanation of Appendix IR6-22-B Content:

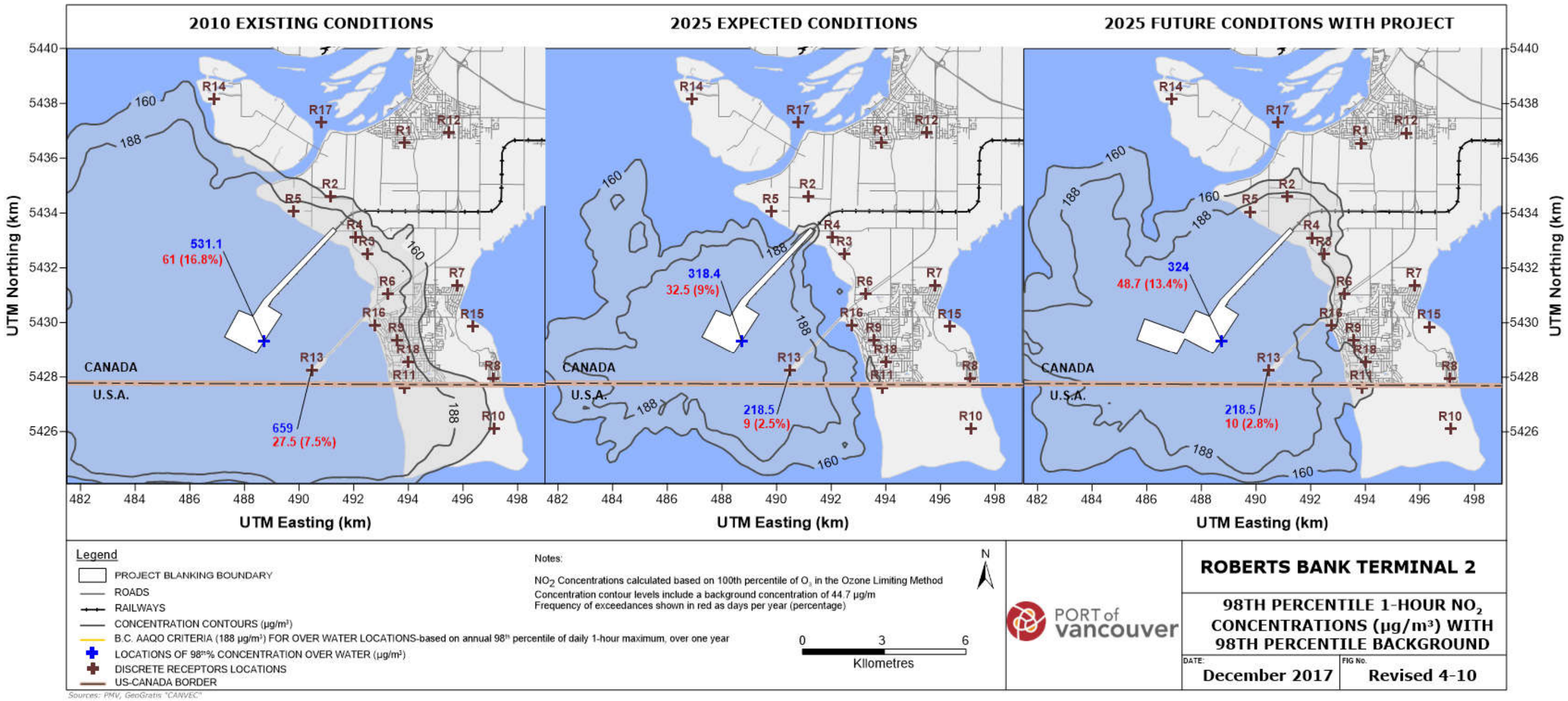
Update to EIS Appendix 9.2-A Content	Appendix IR6-22-B Table Reference Number	Appendix IR6-22-B Figure/Table Content
Figure 4-10	Figure IR6-22-B1	Maximum 1-hour NO_2 Concentrations (µg/m³) Over Land based on 100th Percentile Ozone Concentration under Existing Conditions, Expected Conditions, and Future Conditions with the Project
	Figure IR6-22-B2	98th Percentile 1-hour NO_2 Concentrations (µg/m³) Over Water based on 100th Percentile Ozone Concentrations under Existing Conditions, Expected Conditions, and Future Conditions with the Project
Table 4-4	Table IR6-22-B1	Predicted Concentrations (µg/m^3) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Existing Conditions
Table 4-5	Table IR6-22-B2	Predicted Concentrations (µg/m^3) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Expected Conditions
Table 4-6	Table IR6-22-B3	Predicted Concentrations (µg/m^3) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Future Conditions
Table 5-2	Table IR6-22-B4	Predicted 1-h and 24-h Concentrations (µg/m^3) of NO_2 based on 100th Percentile Ozone Concentrations for Cumulative Change Assessment of Future Conditions
Table 5-12	Table IR6-22-B5	Estimated Percent Cumulative Change from Expected Conditions based on 100th Percentile Ozone Concentrations: Predicted 1-h NO_2 Concentrations (µg/m^3)
Appendix E Figure 4-1	Figure IR6-22-B3	Construction Average Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) Over Land with 100th Percentile Ozone including 98th Percentile Background
	Figure IR6-22-B4	Construction Average Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³) Over Water with 100th Percentile Ozone including 98th Percentile Background
Appendix E Figure 4-10	Figure IR6-22-B5	Construction Peak Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) Over Land with 100th Percentile Ozone
	Figure IR6-22-B6	Construction Peak Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³) Over Water with 100th Percentile Ozone
Appendix E Table 4-1	Table IR6-22-B6	Predicted Maximum Gaseous CAC Concentrations (µg/m^3) – Average Day Construction
Appendix E Table 4-2	Table IR6-22-B7	Predicted Maximum Gaseous CAC Concentrations (µg/m^3) – Average Day Construction plus Operations at Westshore Terminals, Deltaport Terminal and B.C. Ferries Terminal (i.e., the *Expected Conditions* Scenario)
Appendix E Table 4-7	Table IR6-22-B8	Predicted Maximum Gaseous CAC Concentrations (µg/m^3) – Peak Day Construction

Figure IR6-22-B1 Maximum 1-hour NO_2 Concentrations (µg/m³) based on 100th Percentile Ozone Concentration under Existing Conditions, Expected Conditions, and Future Conditions with the Project – Over Land (Revised EIS Appendix 9.2-A Figure 4-10)



Note: Maximum 1-hour NO_2 concentration (shown in blue text) and frequency of exceedance (shown in red text) also provided for R18 (Air Quality Station T39) for existing conditions, as information is referred to in the response.

Figure IR6-22-B2 98th Percentile 1-hour NO_2 Concentrations (µg/m³) based on 100th Percentile Ozone Concentrations under Existing Conditions, Expected Conditions, and Future Conditions with the Project – Over Water (Revised EIS Appendix 9.2-A Figure 4-10)



Note: 98th Percentile 1-hour NO_2 concentration (shown in blue text) and frequency of exceedance (shown in red text) also provided for R13 B.C. Ferries Terminal for context.

Table IR6-22-B1 Predicted Concentrations (µg/m³) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Existing Conditions (Revised EIS Appendix 9.2-A Table 4-4)

	CO		NO_2[b]			SO_2[c]			Formaldehyde
	1-h	**8-h**	**1-h**	**24-h**	**Annual**	**1-h**	**24-h**	**Annual**	**1-h**
Updated Study Criteria (see IR6-23, Table IR6-23-1)	14,300	5,500	200 (188)	200	40 (60)	196 (170)	125 (150)	10	60
Background Concentration	371.2	339.3	44.7	34.9	12.8	7.7	5.1	1.4	3.58
Discrete Receptor[a]									
Ladner	79.7	26.8	120.7	9.9	0.6	51.7	6.4	0.1	0.8
Farmer 1	197.2	61.5	151.8	21.0	1.2	62.9	5.6	0.1	2.0
Tsawwassen First Nations	508.4	85.7	168.2	33.5	2.1	90.4	15.7	0.3	4.3
Farmer 2	366.8	72.5	162.8	27.6	1.9	114.6	13.3	0.2	3.5
Farmer 3	258.2	66.5	164.3	33.6	2.3	77.2	9.0	0.2	2.6
Tsawwassen Beach Campsite	350.1	119.0	160.5	39.7	1.9	95.1	21.0	0.3	2.6
Beach Grove	175.2	37.4	118.9	11.9	0.8	41.5	7.1	0.1	1.5
Boundary Bay	131.6	55.1	152.8	22.6	0.9	74.5	10.9	0.1	1.2
Tsawwassen	354.4	98.7	174.9	41.0	2.2	102.7	15.4	0.4	1.9
Point Roberts 1	115.3	38.3	110.6	21.8	1.2	46.2	9.1	0.2	0.9
Point Roberts 2	334.6	97.6	154.4	47.6	3.1	76.0	16.9	0.5	2.5
Delta Hospital	75.5	31.8	126.2	9.6	0.5	66.7	5.8	0.1	0.7
B.C. Ferries Terminal	2035.2	1104.8	198.5	112.1	20.2	216.5	71.1	2.1	13.4
Reifel Bird Sanctuary	181.1	31.5	135.6	18.2	1.1	40.8	7.5	0.2	1.5
Boundary Bay GVRD Park	163.4	43.4	154.4	15.1	0.8	74.9	6.8	0.1	1.4
English Bluffs Beach	539.2	195.6	174.4	43.4	3.2	147.7	18.3	0.5	2.8
South Arm Marsh	101.9	29.7	109.0	14.7	0.7	49.3	5.4	0.1	1.0
Air Quality Station T39	302.0	94.0	165.8	33.5	2.1	112.7	15.0	0.3	2.4
Maximum Over Water[a]	8855.8	5350.8	486.4	243.1	62.7	567.5	334.1	41.5	66.2
Maximum Over Land[a]	665.3	256.4	199.6	88.7	12.0	195.2	30.6	0.7	7.3
Max Over Land % of Study Criteria	7%	11%	122%	62%	62%	104%	29%	21%	18%

Notes: For comparison purposes, the 2014 interim B.C. AAQO for hourly NO_2 (188 µg/m³) and the 2025 CAAQS for SO_2 (170 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010).

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively, while over water study criteria (in brackets) are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for the RBT2 Study based on method used).

Table IR6-22-B2 Predicted Concentrations (µg/m³) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Expected Conditions (Revised EIS Appendix 9.2-A Table 4-5)

	CO		NO_2[b]			SO_2[c]			Formaldehyde
	1-h	**8-h**	**1-h**	**24-h**	**Annual**	**1-h**	**24-h**	**Annual**	**1-h**
Updated Study Criteria (see IR6-23, Table IR6-23-1)	14,300	5,500	200 (188)	200	40 (60)	196 (170)	125 (150)	10	60
Background Concentration	371.2	339.3	44.7	34.9	12.8	7.7	5.1	1.4	3.58
Discrete Receptor[a]									
Ladner	33.2	12.0	60.0	5.1	0.3	2.5	0.3	0.0	0.4
Farmer 1	77.1	31.0	84.0	9.9	0.7	3.2	0.3	0.0	1.1
Tsawwassen First Nations	167.1	32.3	145.4	15.8	1.2	4.8	0.8	0.0	2.2
Farmer 2	136.3	35.5	128.0	11.2	1.2	6.0	0.7	0.0	1.8
Farmer 3	124.0	32.5	145.5	16.8	1.5	4.0	0.5	0.0	1.5
Tsawwassen Beach Campsite	111.6	65.6	150.5	18.4	1.1	5.2	1.1	0.0	1.3
Beach Grove	58.4	17.3	57.0	5.2	0.5	2.2	0.4	0.0	0.8
Boundary Bay	53.7	23.1	91.1	10.0	0.5	4.0	0.6	0.0	0.7
Tsawwassen	153.2	45.8	156.8	21.3	1.3	5.5	0.8	0.0	1.1
Point Roberts 1	49.8	16.5	62.8	11.6	0.7	2.4	0.5	0.0	0.6
Point Roberts 2	116.6	35.8	104.8	22.5	1.9	4.3	0.9	0.1	1.5
Delta Hospital	38.6	16.3	71.4	4.6	0.3	3.1	0.3	0.0	0.4
B.C. Ferries Terminal	720.1	490.7	173.8	98.0	9.6	12.5	4.2	0.2	6.8
Reifel Bird Sanctuary	59.4	13.8	65.1	8.0	0.7	2.2	0.4	0.0	0.8
Boundary Bay GVRD Park	66.2	18.9	76.5	6.6	0.5	4.1	0.4	0.0	0.8
English Bluffs Beach	256.7	101.4	151.4	18.0	1.8	8.3	1.0	0.0	1.6
South Arm Marsh	37.3	12.2	57.0	7.0	0.4	2.5	0.3	0.0	0.5
Air Quality Station T39	119.6	38.2	126.9	15.0	1.3	6.3	0.8	0.0	1.4
Maximum Over Water[a]	2548.3	1530.4	273.7	153.2	53.7	32.0	17.6	2.3	32.4
Maximum Over Land[a]	329.7	165.3	171.2	43.9	8.1	10.5	1.7	0.1	4.3
Max Over Land % of Study Criteria	5%	9%	108%	39%	52%	9%	5%	15%	13%

Notes:

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively, while over water study criteria (in brackets) are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for the RBT2 Study based on method used).

Table IR6-22-B3 Predicted Concentrations (µg/m³) for Gaseous CACs and Formaldehyde based on 100th Percentile Ozone Concentrations under Future Conditions (Revised EIS Appendix 9.2-A Table 4-6)

	CO		NO_2[b]			SO_2[c]			Formaldehyde
	1-h	**8-h**	**1-h**	**24-h**	**Annual**	**1-h**	**24-h**	**Annual[d]**	**1-h**
Updated Study Criteria (see IR6-23 Table IR6-23-1)	14,300	5,500	200 (188)	200	40 (60)	196 (170)	125 (150)	10	60
Background Concentration	371.2	339.3	44.7	34.9	12.8	7.7	5.1	1.4	3.58
Discrete Receptor[a]									
Ladner	68.3	26.1	89.2	6.0	0.4	3.3	0.4	0.01 (0.004)	1.2
Farmer 1	179.2	54.6	161.8	14.8	1.0	4.3	0.6	0.02 (0.01)	3.3
Tsawwassen First Nations	219.9	72.8	167.0	18.5	1.7	6.9	1.2	0.03 (0.01)	3.9
Farmer 2	234.4	81.6	172.1	19.1	1.8	5.7	0.7	0.03 (0.01)	4.7
Farmer 3	213.9	61.0	165.4	20.8	2.1	5.5	0.7	0.03 (0.01)	3.4
Tsawwassen Beach Campsite	143.4	85.2	153.5	20.6	1.5	8.6	1.9	0.04 (0.01)	1.7
Beach Grove	80.3	24.0	86.3	7.2	0.6	3.6	0.6	0.02 (0.01)	1.1
Boundary Bay	81.1	34.1	100.1	13.0	0.7	6.5	0.9	0.02 (0.01)	1.1
Tsawwassen	173.1	64.9	164.3	25.5	1.6	8.3	1.1	0.04 (0.01)	1.4
Point Roberts 1	67.1	23.6	77.8	14.1	0.8	3.5	0.7	0.02 (0.01)	0.8
Point Roberts 2	146.9	44.7	129.7	26.8	2.2	5.5	1.4	0.06 (0.02)	1.9
Delta Hospital	51.4	27.4	86.2	5.3	0.4	3.5	0.4	0.01 (0.004)	0.8
B.C. Ferries Terminal	729.2	507.8	173.8	100.0	10.1	12.4	4.2	0.26 (0.04)	6.9
Reifel Bird Sanctuary	72.8	21.6	80.9	9.4	0.8	3.6	0.5	0.02 (0.01)	0.9
Boundary Bay GVRD Park	87.2	27.2	92.7	8.0	0.6	5.1	0.5	0.02 (0.01)	1.1
English Bluffs Beach	284.2	118.5	153.5	22.6	2.2	8.3	1.3	0.06 (0.01)	2.2
South Arm Marsh	70.6	22.2	91.4	8.7	0.5	3.0	0.4	0.01 (0.005)	1.2
Air Quality Station T39	143.2	48.0	153.1	17.3	1.5	6.4	1.0	0.04 (0.01)	1.6
Maximum Over Water[a]	2599.1	1539.8	279.3	153.1	53.7	30.7	16.9	2.3	33.0
Maximum Over Land[a]	953.9	480.4	294.6	97.8	16.4	14.9	2.7	0.1	19.9
Max Over Land % of Study Criteria	9%	15%	170%	66%	73%	12%	6%	15%	39%

Notes:

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively, while over water study criteria (in brackets) are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for the RBT2 Study based on method used).

d. Bracketed values for the annual SO_2 represent the contribution from the Project.

Table IR6-22-B4 Predicted 1-h and 24-h Concentrations (µg/m³) of NO_2 based on 100th Percentile Ozone Concentrations for Cumulative Change Assessment of Future Conditions (Revised EIS Appendix 9.2-A Table 5-2)

	1-h NO_2[b]				% of Study Criteria (including Background)	24-h NO_2[b]				% of Study Criteria (including Background)
	Future Conditions	Ships Underway	Combined Rail Activity	Cumulative Change (Future Conditions + Rail Yards)	Cumulative Change (Future Conditions + Rail Yards)	Future Conditions	Ships Underway	Combined Rail Activity	Cumulative Change (Future Conditions + Rail Yards)	Cumulative Change (Future Conditions + Rail Yards)
Updated Study Criteria (see IR6-23 Table IR6-23-1)	200 (188)				-	200				-
Background Concentration	44.7				-	34.9				-
Discrete Receptor[a]										
Ladner	89	18	36	121	83%	6.0	3.4	9.5	12.8	24%
Farmer 1	162	19	73	164	104%	14.8	3.5	13.1	24.2	30%
Tsawwassen First Nations	167	20	57	167	106%	18.5	4.5	10.0	24.8	30%
Farmer 2	172	18	68	174	109%	19.1	4.2	17.1	30.0	32%
Farmer 3	165	16	61	167	106%	20.8	3.8	9.8	21.6	28%
Tsawwassen Beach Campsite	154	20	32	154	99%	20.6	4.3	5.6	22.0	28%
Beach Grove	86	21	43	86	66%	7.2	4.4	6.3	11.4	23%
Boundary Bay	100	28	13	100	72%	13.0	5.2	1.7	13.8	24%
Tsawwassen	164	26	20	164	105%	25.5	4.2	3.2	27.0	31%
Point Roberts 1	77.8	19.1	4.	78	65.2%	14.1	5.4	1.1	14.1	25%
Point Roberts 2	129.7	14.6	8.3	130	92.9%	26.8	5.7	1.7	26.8	31%
Delta Hospital	86	17	55	99	72%	5.3	3.6	10.6	13.7	24%
B.C. Ferries Terminal	173.8	16.3	7.1	173.8	116%	100.0	4.1	1.6	100.0	67%
Reifel Bird Sanctuary	81	17	17	81	63%	9.4	3.5	2.9	10.1	22%
Boundary Bay GVRD Park	93	26	21	93	69%	8.0	4.7	2.7	9.2	22%
English Bluffs Beach	153	23	25	154	99%	22.6	4.7	3.2	24.0	29%
South Arm Marsh	91	19	20	100	72%	8.7	3.5	4.7	9.6	22%
Air Quality Station T39	153	34	16	153	99%	17.3	5.2	2.3	18.2	27%

Notes:

a. Concentrations presented for discrete receptors are incremental and do not include the influence of background. The background concentration can be added to these incremental concentrations when comparing to the updated study criteria.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

Table IR6-22-B5 Estimated Percent Cumulative Change from Expected Conditions based on 100th Percentile Ozone Concentrations: Predicted 1-h NO_2 Concentrations (µg/m³) (Revised EIS Appendix 9.2-A Table 5-12)

Discrete Receptor	1-h NO_2			Percent Cumulative Change[d] [D]
	Expected Conditions and other future Projects/Activities[a] [A]	Incremental RBT2 Operations[b] [B]	Cumulative Future Conditions[c] [C]	
Background Concentration	44.7			
Ladner	108.4	56	165.26	52%
Farmer 1	138.5	75	208.25	50%
Tsawwassen First Nations	190.1	77	212.01	12%
Farmer 2	172.7	77	218.81	27%
Farmer 3	195.5	78	211.35	8%
Tsawwassen Beach Campsite	195.2	76	198.22	2%
Beach Grove	101.7	60	131.03	29%
Boundary Bay	135.8	32	144.81	7%
Tsawwassen	201.5	65	209.00	4%
Point Roberts 1	107.5	6	122.46	14%
Point Roberts 2	150.5	13	174.42	16%
Delta Hospital	122.6	33	143.3	17%
B.C. Ferries Terminal	218.5	76	218.51	0%
Reifel Bird Sanctuary	110.0	39	125.56	14%
Boundary Bay GVRD Park	121.3	31	137.56	13%
English Bluffs Beach	196.1	74	198.65	1%
South Arm Marsh	101.9	53	144.83	42%
Air Quality Station T39	171.6	48	197.76	15%

Notes:

a. Concentrations represent cumulative expected conditions, including emissions from Deltaport Terminal, Westshore Terminals, and BC Ferries Terminal operations, represents future conditions with other certain and reasonably foreseeable projects and activities (i.e., rail locomotive emissions in rail yards and activity off the Roberts Bank causeway beyond the Project area), and background concentrations.

b. Incremental concentrations represent the maximum difference in hourly predicted concentrations from expected conditions (without Project) to future conditions with the Project.

c. Concentrations represent cumulative future conditions, including changes from RBT2 in combination with the cumulative expected conditions. Cumulative future conditions concentrations are not necessarily the same as the sum of cumulative expected conditions (Column [A]) and incremental RBT2 operations (Column [B]) as they may not occur in the same time period (e.g., 1-h, 24-h, etc.).

d. The percent cumulative change associated with cumulative future operations and rail activity, as compared with expected operations and rail activity; Column [D] = (Column [C]-Column [A])/Column [A].

Figure IR6-22-B3 Average Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) with 100th Percentile Ozone including 98th Percentile Background – Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-1)

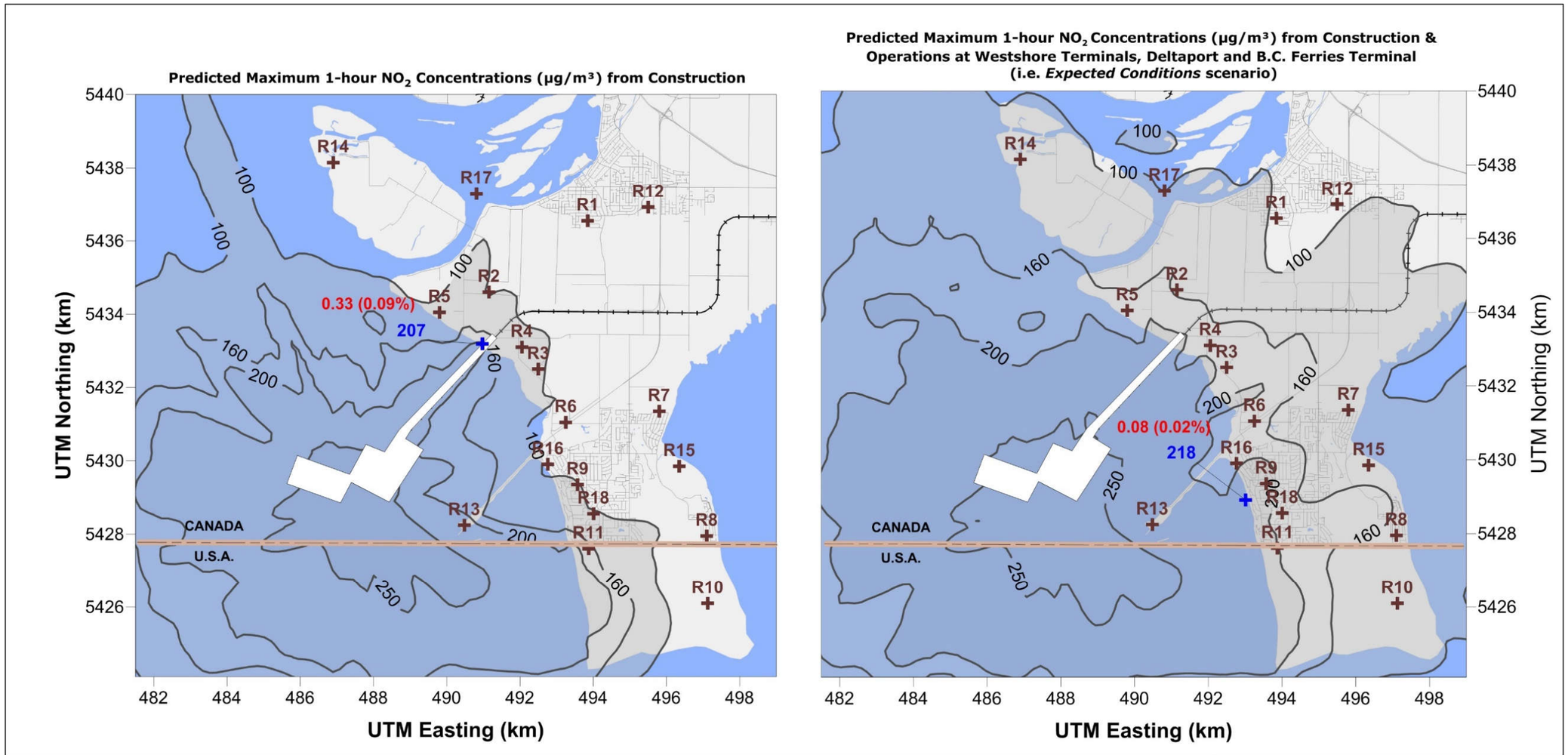
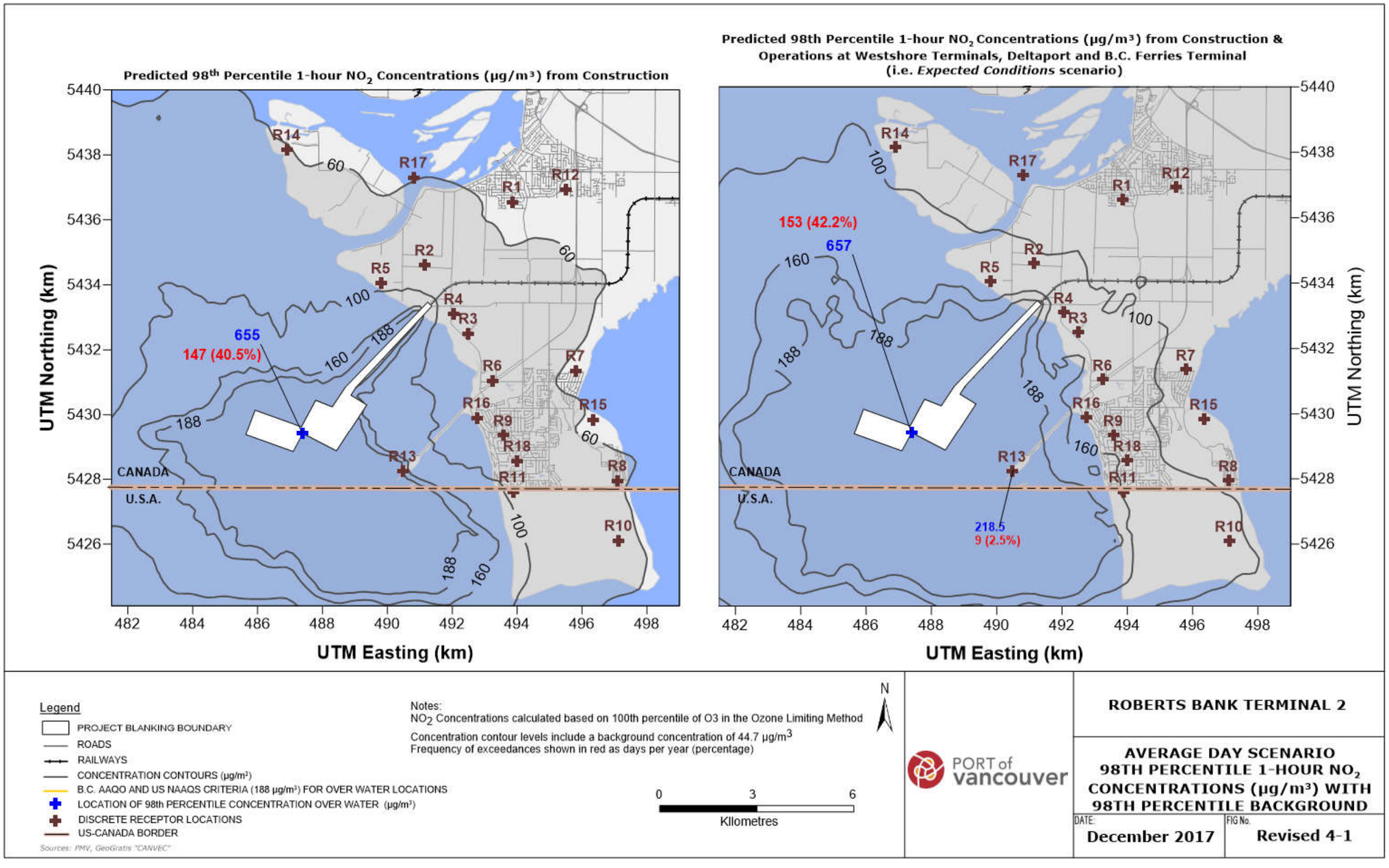


Figure IR6-22-B4 Average Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³) with 100th Percentile Ozone including 98th Percentile Background – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-1)



Note: 98th Percentile 1-hour NO_2 concentration (shown in blue text) and frequency of exceedance (shown in red text) also provided for R13 B.C. Ferries Terminal for expected conditions scenario for context.

Figure IR6-22-B5 Peak Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) with 100th Percentile Ozone – Over Land (Revised Appendix 9.2-A, Appendix E, Figure 4-10)

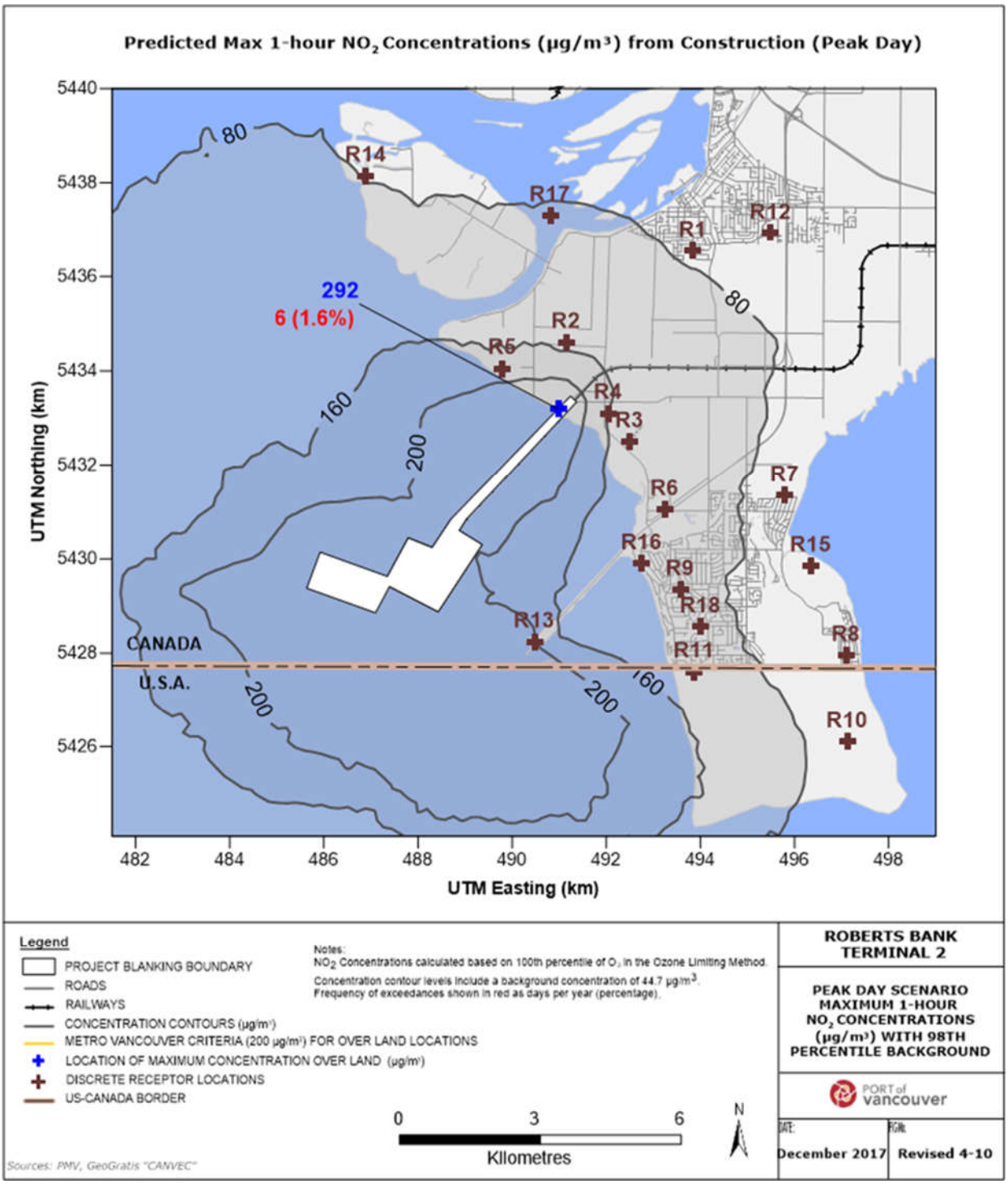
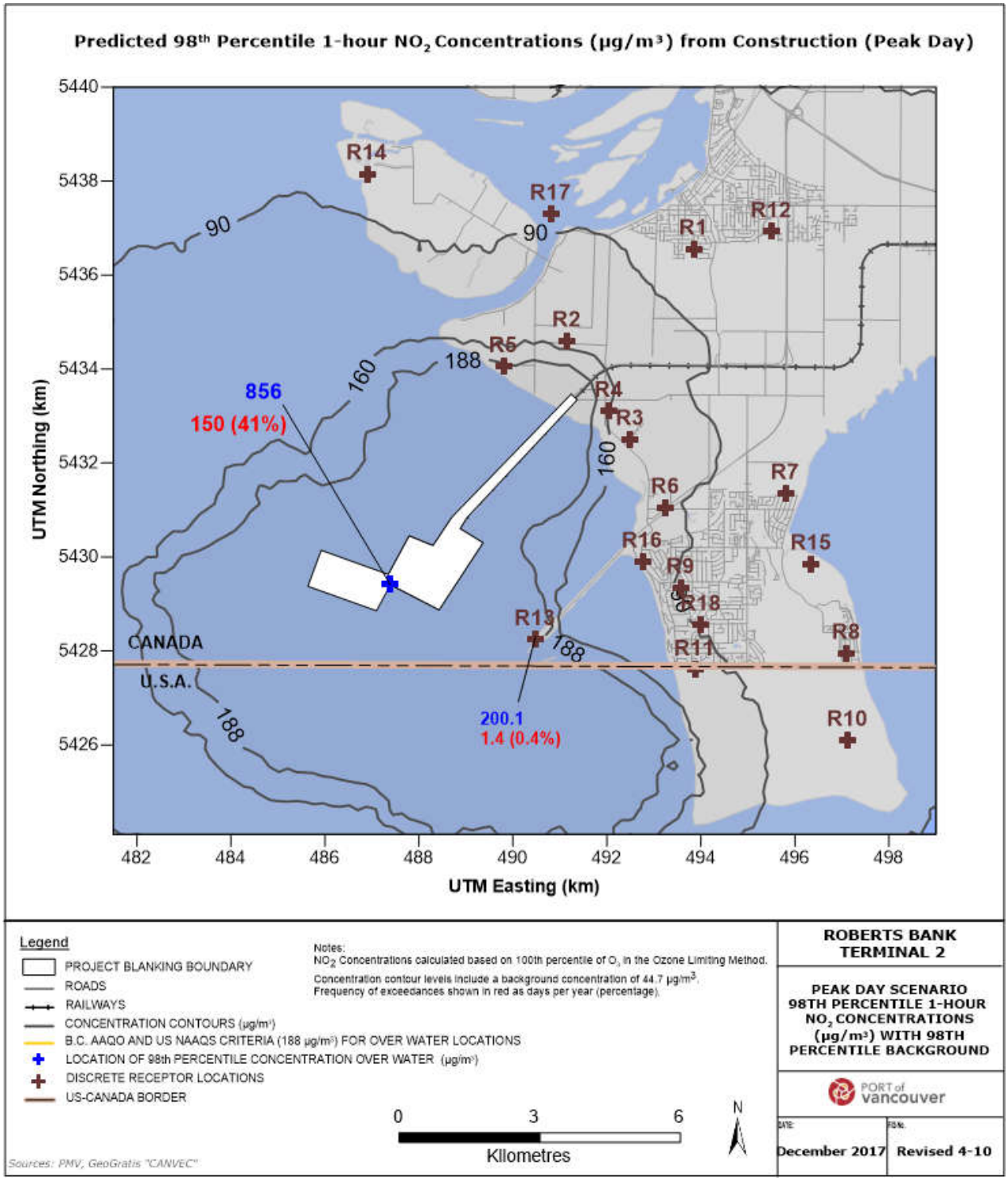


Figure IR6-22-B6 Peak Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³) with 100th Percentile Ozone – Over Water (Revised Appendix 9.2-A, Appendix E, Figure 4-10)



Note: 98th Percentile 1-hour NO_2 concentration (shown in blue text) and frequency of exceedance (shown in red text) also provided for R13 B.C. Ferries Terminal for context.

Table IR6-22-B6 Predicted Maximum Gaseous CAC Concentrations (µg/m³) – Average Day Construction (Revised Appendix 9.2-A, Appendix E, Table 4-1)

Discrete Receptor	CO		NO_2[b]			SO_2[c]		
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual
Updated Study Criteria (see IR6-23 Table IR6-23-1)	14,300	5,500	200 (188)	200	40 (60)	196 (170)	125 (150)	10
Background Concentration[a]	371.2	339.3	44.7	34.9	12.8	7.7	5.1	1.4
Ladner	7.6	2.6	22.3	2.1	0.2	0.01	0.002	0.0001
Farmer 1	16.8	5.5	49.7	5.0	0.5	0.03	0.003	0.0003
Tsawwassen First Nations	21.7	5.5	62.6	6.7	0.7	0.04	0.004	0.0004
Farmer 2	26.4	6.7	77.1	7.4	0.7	0.05	0.005	0.0004
Farmer 3	22.9	8.4	65.2	9.9	1.3	0.04	0.006	0.0008
Tsawwassen Beach Campsite	15.4	8.1	43.4	4.8	0.7	0.03	0.005	0.0004
Beach Grove	10.0	2.5	28.5	2.7	0.3	0.02	0.002	0.0002
Boundary Bay	14.1	4.1	39.8	4.5	0.3	0.02	0.003	0.0002
Tsawwassen	20.6	6.3	58.2	6.5	0.6	0.04	0.004	0.0004
Point Roberts 1	10.1	2.6	18.9	3.4	0.3	0.01	0.002	0.0002
Point Roberts 2	48.0	8.7	41.3	12.9	0.9	0.04	0.009	0.0005
Delta Hospital	5.9	2.7	17.1	1.7	0.2	0.01	0.002	0.0001
B.C. Ferries Terminal	124.5	31.1	140.3	42.2	3.0	0.1	0.028	0.0018
Reifel Bird Sanctuary	12.1	2.3	34.4	2.7	0.4	0.02	0.002	0.0002
Boundary Bay GVRD Park	9.6	2.5	27.0	2.9	0.3	0.02	0.002	0.0002
English Bluffs Beach	18.0	5.8	50.7	7.5	0.9	0.03	0.005	0.0005
South Arm Marsh	10.6	2.9	30.1	3.0	0.2	0.02	0.002	0.0001
Air Quality Station T39	22.9	4.7	64.3	5.8	0.6	0.04	0.004	0.0004
Maximum Over Water[a]	2898.7	1079.1	610.1	250.4	83.8	3.4	1.4	0.2
Maximum Over Land[a]	199.4	38.8	191.3	48.9	5.2	0.30	0.04	0.003
Max Over Land % of Study Criteria (including background)	4%	7%	118%	42%	45%	4%	4%	14%

Notes:

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively, while over water study criteria (in brackets) are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for the RBT2 Study based on method used).

Table IR6-22-B7 Predicted Maximum Gaseous CAC Concentrations (µg/m³) – Average Day Construction plus Operations at Westshore Terminals, Deltaport Terminal, and BC Ferries Terminal (i.e., the *Expected Conditions* Scenario) (Revised Appendix 9.2-A, Appendix E, Table 4-2)

Discrete Receptor	CO		NO_2[b]			SO_2[c]		
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual
Updated Study Criteria (see IR6-23 Table IR6-23-1)	14,300	5,500	200 (188)	200	40 (60)	196 (170)	125 (150)	10
Background Concentration	371.2	339.3	44.7	34.9	12.8	7.7	5.1	1.4
Ladner	27.8	10.2	47.6	6.3	0.7	2.2	0.3	0.02
Farmer 1	65.5	22.5	104.4	14.9	1.6	2.6	0.3	0.03
Tsawwassen First Nations	161.0	30.0	153.7	19.1	2.5	4.7	0.8	0.06
Farmer 2	121.7	23.7	152.9	17.7	2.4	6.0	0.7	0.05
Farmer 3	90.6	24.5	150.8	24.6	3.4	3.8	0.5	0.04
Tsawwassen Beach Campsite	108.0	48.9	139.7	22.4	2.4	5.2	1.1	0.06
Beach Grove	58.5	13.7	69.9	7.6	1.1	2.2	0.4	0.03
Boundary Bay	58.0	21.8	102.8	14.5	1.2	3.9	0.6	0.03
Tsawwassen	105.2	38.2	161.2	27.8	2.8	5.5	0.8	0.08
Point Roberts 1	46.9	14.7	59.9	15.1	1.5	2.3	0.5	0.04
Point Roberts 2	118.2	39.18	108.3	35.0	4.1	4.3	0.9	0.11
Delta Hospital	29.5	12.6	47.9	5.5	0.6	2.3	0.3	0.01
B.C. Ferries Terminal	578.3	307.1	178.3	100.4	18.5	12.2	4.2	0.45
Reifel Bird Sanctuary	54.8	11.2	70.4	9.8	1.5	2.1	0.4	0.03
Boundary Bay GVRD Park	64.8	15.9	96.5	9.0	1.0	4.1	0.4	0.02
English Bluffs Beach	143.1	51.3	153.1	24.1	3.6	8.2	1.0	0.10
South Arm Marsh	36.3	11.4	54.2	8.5	0.9	2.0	0.3	0.02
Air Quality Station T39	105.1	33.6	139.1	19.8	2.7	6.3	0.8	0.07
Maximum Over Water[a]	2991.5	1510.2	612.0	253.4	85.2	31.938	17.6	4.4
Maximum Over Land[a]	239.5	84.1	194.8	70.8	12.5	10.4	1.7	0.1
Max Over Land % of Study Criteria (including background)	4%	8%	120%	53%	63%	9%	5%	15%

Notes:

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively, while over water study criteria (in brackets) are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h and annual ambient air quality criteria of 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively.

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively, while over water study criteria (in brackets) are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for RBT2 study based on method used).

Table IR6-22-B8 Predicted Maximum Gaseous CAC Concentrations (µg/m³) – Peak Day Construction (Revised Appendix 9.2-A, Appendix E, Table 4-7)

Discrete Receptor	CO		NO_2[b]		SO_2[c]	
	1-h	8-h Rolling	1-h	24-h	1-h	24-h Rolling
Updated Study Criteria (see IR6-23 Table IR6-23-1)	14,300	5,500	200 (188)	200	196 (170)	125 (150)
Background Concentration	371.2	339.3	44.7	34.9	7.7	5.1
Ladner	21.5	8.0	58.2	5.3	0.05	0.01
Farmer 1	62.9	17.0	152.6	14.5	0.13	0.01
Tsawwassen First Nations	82.9	23.1	158.0	22.2	0.18	0.02
Farmer 2	74.5	24.0	155.5	24.0	0.16	0.02
Farmer 3	86.9	34.4	159.1	33.6	0.19	0.03
Tsawwassen Beach Campsite	32.7	13.3	89.4	13.5	0.07	0.01
Beach Grove	20.8	6.1	55.6	5.7	0.04	0.01
Boundary Bay	22.1	8.0	58.0	6.9	0.04	0.01
Tsawwassen	31.7	13.9	83.4	14.4	0.06	0.01
Point Roberts 1	15.3	4.4	27.7	5.2	0.03	0.00
Point Roberts 2	73.4	15.63	58.8	18.9	0.07	0.02
Delta Hospital	14.9	7.0	39.9	4.0	0.03	0.01
B.C. Ferries Terminal	190.2	47.5	155.4	60.1	0.18	0.05
Reifel Bird Sanctuary	21.3	7.1	56.3	6.9	0.04	0.01
Boundary Bay GVRD Park	16.5	6.1	43.5	5.7	0.03	0.01
English Bluffs Beach	33.6	15.0	91.9	18.6	0.07	0.02
South Arm Marsh	24.9	7.3	67.6	6.0	0.05	0.01
Air Quality Station T39	35.1	11.4	92.9	11.0	0.07	0.01
Maximum Over Water[a]	4431.4	1650.3	811.3	318.5	6.0	2.55
Maximum Over Land[a]	411.2	164.3	247.1	108.4	0.88	0.14
Max Over Land % of Study Criteria (including background)	5%	9%	146%	71.6 %	4%	4%

Notes:

a. Predicted concentrations presented for discrete receptors and maximum over land and over water concentrations in this table are incremental and do not include the influence of background. For comparison to the updated study criteria, predicted concentrations must be added to the background concentration.

b. NO_2 predicted concentrations are based on the observed 100th percentile ozone monitoring data at Station T39 from 2010 to 2012 using the Ozone Limiting Method. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h NO_2 study criterion for receptor locations in Canada over land is 200 µg/m^3 while the over water study criterion (in brackets) is 188 µg/m^3 (based on annual 98th percentile of daily 1-h maximum, over one year). Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h ambient air quality criterion of 188 µg/m^3 (based on the 98th percentile of daily 1-h maximum, over three years).

c. As indicated in Table IR6-23-1 in the response to IR6-23, the 1-h and 24-h SO_2 study criteria for receptor locations in Canada over land are 196 µg/m^3 and 125 µg/m^3, respectively, while over water study criteria (in brackets) are 170 µg/m^3 (based on annual 99th percentile of daily 1-h maximum, over three years) and 150 µg/m^3, respectively. Receptors located in the U.S.A. (i.e., Point Roberts 1 and Point Roberts 2) are subject to the U.S. over land and over water 1-h criterion of 196 µg/m^3 (based on the 99th percentile over daily 1-h maximum, over three years; concentrations over one year used for the RBT2 Study based on method used).

IR6-23 Air Quality – Objectives

Information Source(s)

Additional Information Requirements of July 31, 2015 (CEAR Doc#271) IR19

EIS Volume 2: Section 9.2, Table 9.2-4; Appendix 9.2-A: Table 3-4, Tables and Figures of Sections 4.2 to 4.5 and Tables 5-1 to 5-24, Appendix B, Table 3-4

Canadian Ambient Air Quality Standards for Sulphur Dioxide. Canadian Council of Ministers of the Environment, October 3, 2016

Canadian Ambient Air Quality Standards for 2015 and 2020 for Fine Particulate Matter and Ozone. Government of Canada, May 25, 2013

Metro Vancouver's new Ambient Air Quality Objectives. Metro Vancouver, updated June 30, 2016

Guidance on Application of Provincial Air Quality Objectives for SO_2. British Columbia Ministry of Environment, February, 7, 2017

Context

Metro Vancouver has the delegated authority and responsibility to provide the service of air pollution control within its boundaries. The Greater Vancouver Regional District updated its air quality objectives June 30, 2016. It stated that the objectives were not to be exceeded and should not be viewed as levels to pollute to but as continuous improvements to air quality. Corrections to the Proponent's assessment using 400 ug/m^3 for NO_2 instead of 188 ug/m^3 British Columbia *Interim Air Quality Objectives* were requested in IR #19 by the Canadian Environmental Assessment Agency. As new Canadian Air Quality Standards (CAAQS) for NO_2 are not yet available, Metro Vancouver standards are to be used, including the annual criterion of 40 ug/m^3 instead of 60 ug/m^3 as used by the Proponent.

CAAQS for Ozone and PM2.5 to be implemented in 2015 and 2020 were listed in Table 9.2-4 and used by the Proponent, as indicated in Table 3-4 of Appendix 9.2-A.

On October 3, 2016, the Canadian Council of Ministers of the Environment announced new annual and 1-hour SO_2 standards to be effective in 2020 and 2025. These standards are more stringent than the ones recently adopted by Metro Vancouver as interim criteria. They were not used in the Proponent's assessment, except for a stricter annual criterion than the 2020 proposed but not the one for 2025. The Canadian Council of Ministers of the Environment proposed annual criteria of 2025 is to be used in the assessment.

Starting in 2014, the British Columbia Ministry of Environment issued an interim air quality standard for SO_2, and formalized this with a guideline in 2016. This standard is essentially equivalent to that of Canadian Council of Ministers of the Environment, but provided for a phase-in period starting in 2017.

In order to evaluate health effects of the Project, the air quality assessment must be revised with the use of the most stringent existing air quality criteria or criteria that will apply in 2020 or 2025.

Figure 4-10 shows areas of predicted exceedances of Metro Vancouver's 1-hour NO_2 objective overwater and exceedances on land for the Future 2025 case. The Cumulative Future Conditions of Table 5-12 show predicted exceedances of Metro Vancouver's 1-hour NO_2 objective at Tsawwassen First Nations and other resident locations. It is therefore inappropriate for the Proponent to conclude in the assessment that "There are no instances of exceedances overland and in populated areas under any averaging period or horizon year for the CACs, and only a marginal exceedance of NO_2 at the B.C. Ferries Terminal in 2010" as found in Section 4.2, p. 47 of Appendix 9.2-A.

In scenarios where the exceedance of objectives has been predicted, frequency of exceedance tables and isopleth plots in the EIS sections and appendices must be revised.

Information Request

Using the most stringent existing criteria or the criteria that will apply in 2020 or 2025, update the frequency of exceedance tables in the EIS with comparisons to the objectives used in the assessment.

Where the tables show exceedances for expected and future conditions and for the cumulative future conditions case, provide isopleth plots for maximum 1-hour and 24-hour, and annual concentrations for gaseous and particulate air contaminants.

Provide isopleth plots of the frequency of exceedance and tabulated results for each discrete receptor.

In all scenarios where exceedances of CAAQS or Metro Vancouver objectives have been predicted (including overwater), provide frequency of exceedance in tables and isopleth plots for discrete receptors.

Propose additional mitigation measures and/or control technologies that could substantially reduce NO_2 maximum 1-hour concentrations beyond what is currently predicted in the future 2025 case with the Project found in Figure 4-10.

VFPA Response

Clarification

The VFPA would like to clarify three areas of the Panel's context to this information request, in support of and as context for the responses provided below:

1. The RBT2 Air Quality Study (RBT2 Study), specifically EIS Table 9.2-4 and Table 3-4 in EIS Appendix 9.2-A, presented ambient air quality criteria (standards or objectives) used in comparisons to predicted concentrations of gaseous and particulate criteria air contaminants (CACs) and formaldehyde. RBT2 study criteria were selected based on the most stringent of federal and provincial ambient air quality criteria in place at the time the assessment was undertaken (2013 to November 2014). Study criteria were presented in the assessment result tables along with Metro Vancouver Ambient Air Quality Objectives (MV AAQOs) for comparison to predicted concentrations, as

explained in the response to IR7.31.15-20 of CEAR Document #314[1]. MV AAQOs were presented alongside the study criteria for comparison purposes, as the MV AAQOs are only applicable within Metro Vancouver boundaries, as noted in the Panel's context above, not over water. With submission of the EIS to the Canadian Environmental Assessment Agency (CEA Agency) in early 2015, it was not possible to integrate criteria adopted by the various regulatory agencies from December 2014 to present within the EIS. The study criteria used for comparison purposes in EIS Section 9.2 and supporting appendices, therefore, were those criteria applicable at the time of the assessment. Comparisons to more recently adopted criteria have been updated[2] in the response provided in IR7.31.15-19 (CEAR Document #314) for NO_2 and SO_2 predictions based on 2014 provincial interim objectives and associated statistical methods issued at the end of 2014[3]. For the purposes of responding to this information request, the study criteria have been updated as of December 2017[4], and used for comparison to RBT2 Study predictions and revised predictions (i.e., if statistical methods changed with the adoption of new criteria).

2. Regarding the statement in the Panel's context, "It is therefore inappropriate for the Proponent to conclude in the assessment that '*There are no instances of exceedances overland and in populated areas under any averaging period or horizon year for the CACs, and only a marginal exceedance of NO_2 at the B.C. Ferries Terminal in 2010*'", this is the concluding statement (stated in Section 4.2 on page 47 of EIS Appendix 9.2-A) that pertains to tables found on pages 48 to 50 (Tables 4-4 to 4-6). This statement does not apply to information contained in EIS Appendix 9.2-A, Section 5.25 (including Table 5-12) on page 94. This statement is correct based on the incremental predictions shown in Tables 4-4 to 4-6 (i.e., that show incremental emissions without background concentrations included).

3. The Panel has requested that the VFPA update frequency of exceedance tables. EIS Section 9.2 and supporting appendices (EIS Appendix 9.2-A and Appendices A to F contained therein) do not provide the frequency that study criteria are exceeded. As

[1] CEAR Document #314 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements (See reference document # 271) for the Environmental Impact Statement.

[2] The Panel's context to this information request implies that corrections to the assessment were required ("Corrections to the Proponent's assessment…") when in fact, further assessments have been conducted as requested from the CEA Agency or the Panel to update the RBT2 Study.

[3] Note that the B.C. Ministry of Environment (MOE) formally adopted new interim objectives for NO_2 and SO_2 in October 2014; however, the new objectives were not publicly disseminated until December 22, 2014. Consequently, these interim objectives were not incorporated into the analyses presented in the RBT2 Study, which was completed prior to their issuance.

[4] On November 16, 2017, the Canadian Council for Ministers of the Environment (CCME) posted new Canadian Ambient Air Quality Standards (CAAQS) for NO_2 (http://www.ccme.ca/en/current_priorities/air/caaqs.html). The new NO_2 CAAQS are intended to apply to the years 2020 and 2025, and are far more stringent than current criteria. The posting of the new CAAQS indicates that provincial ministries have endorsed the new standards; however, it may be six months before B.C. MOE or Metro Vancouver indicate they have formally adopted the new CAAQS. Since there is the potential for change to the CAAQS within that period, these criteria have not been incorporated in the updated study criteria presented below.

clarification, the 'Max. Overland % of Criteria (including background)' percentages provided in EIS Appendix 9.2-A, Tables 4-4 to 4-10, and '% of Study Criteria (including background)' in EIS Appendix 9.2-A, Tables 5-1 to 5-9 represent the percentage that the emission prediction (inclusive of background concentrations) represents of the study criteria (i.e., how close the prediction is to meeting (1-100%) or exceeding the criteria (above 100%)). For the purposes of responding to this information request, frequency of exceedance information (using updated study criteria), is provided below.

Using the most stringent existing criteria or the criteria that will apply in 2020 or 2025, update the frequency of exceedance tables in the EIS with comparisons to the objectives used in the assessment.

As part of this response, frequency of exceedances to updated study criteria are provided as new information in subsequent parts of this response.

Table IR6-23-1 provides background concentrations for CACs and updated study criteria, as of December 2017, based on the following:

- For receptor locations over land within Metro Vancouver jurisdiction (referred to as Canada Over Land in **Table IR6-23-1**), updated study criteria were selected from the most stringent standards/objectives from amongst the MV AAQOs, B.C. Ambient Air Quality Objectives (B.C. AAQO), Canada-wide Standards (CWSaq), National Ambient Air Quality Objectives (NAAQO), and Canadian Ambient Air Quality Standards (CAAQS);
- For receptor locations within the marine environment in Canadian waters (referred to as Canada Over Water in **Table IR6-23-1**), updated study criteria were selected from the most stringent standards/objectives from amongst the B.C. AAQO, CWSaq, NAAQO, and CAAQS;
- For maximum concentrations over land and over water receptors within the U.S.A. (referred to as U.S. Over Land and Water in **Table IR6-23-1**), study criteria were based on the U.S. Environmental Protection Agency National Ambient Air Quality Standards (U.S. EPA NAAQS);
- Provincial interim 1-hour and annual NO_2 and 1-hour SO_2 objectives adopted in October 2014 (note that RBT2 Study results were updated according to these objectives in the response provided in IR7.31.15-19 (CEAR Document #314));
- CAAQS for SO_2 for 2020 and 2025 released in October 2016; and
- The inclusion of U.S. EPA NAAQS, for comparison to predictions within U.S. jurisdiction.

Tables provided in EIS Appendix 9.2-A have been updated to incorporate the updated study criteria and associated statistical methods summarised in **Table IR6-23-1**. **Appendix IR6-23-A** contains the following updated tables:

- For existing conditions – Tables IR6-23-A1 and IR6-23-A2 for predicted maximum concentrations for gaseous CACs and formaldehyde, and particulate CACs (updated EIS Tables 9.2-13 and 9.2-14, respectively);

- For expected conditions – Tables IR6-23-A3 and IR6-23-A4 for predicted maximum concentrations for gaseous CACs and formaldehyde, and particulate CACs (updated EIS Tables 9.2-18 and 9.2-19, respectively);
- For the construction phase – Tables IR6-23-A5 and IR6-23-A6 for predicted maximum concentrations for gaseous CACs and formaldehyde on an average construction day for Project construction only emissions and Project construction plus expected conditions emissions, respectively (updated EIS Tables 9.2-20 and 9.2-21);
- For the construction phase – Tables IR6-23-A7 and IR6-23-A8 for predicted maximum concentrations for particulate CACs on an average construction day for Project construction only emissions and Project construction plus expected conditions emissions, respectively (updated EIS Tables 9.2-22 and 9.2-23);
- For future conditions with the Project – Tables IR6-23-A9 and IR6-23-A10 for predicted maximum concentrations for gaseous CACs and formaldehyde and particulate CACs (updated EIS Tables 9.2-25 and 9.2-26, respectively); and
- For future conditions with the Project and other certain and reasonably foreseeable projects and activities – Tables IR6-23-A11 to IR6-23-A14 for predicted CO, NO_2, SO_2, and $PM_{2.5}$ concentrations, respectively (updated EIS Tables 9.2-30 to and 9.2-32, and Table 9.2-36, respectively).

Based on the comparisons to updated study criteria provided in Tables IR6-23-A1 to IR6-23-A14, there are no exceedances of the updated study criteria over land[5] (inclusive of background concentrations) as presented in the 'Over Land as % of Criteria' row, with the exceptions of 1-hour SO_2 under existing conditions (see Table IR6-23-A1, noting in 2010 the updated study criteria did not apply) and 1-hour NO_2 under future conditions with the Project (see Table IR6-23-A9).

Exceedances of the updated study criteria for 1-hour average NO_2 and SO_2 concentrations are predicted over water at the B.C. Ferries Terminal receptor (R13) location under existing conditions (see Table IR6-23-A1, noting that the updated study criteria did not apply in 2010).

Based on modelling outputs, hourly NO_2 is predicted to exceed the updated study criteria (i.e., provincial objective of 188 µg/m^3)[6]; however, this outcome is not expected to be realised during Project operation, as outlined below and explained in the responses to IR6-22, IR6-29, and IR6-37. The maximum predicted hourly NO_2 concentration under existing conditions in 2010 at Station T39 was 163 µg/m^3, including the background concentration, while the 2010 maximum observed hourly NO_2 concentration was 78 µg/m^3 for winds blowing from the direction of the existing Roberts Bank terminals (i.e., less than half of the predicted concentration). Observed maximum NO_2 concentrations during Project operation, therefore, are expected to be lower than those predicted in the RBT2 Study using the Ozone Limiting

[5] The B.C. Ferries Terminal is located on a causeway in the marine environment (i.e., seaward of the shoreline, as per the definition of over water provided in the response to IR6-24) and is therefore not considered as on land.

[6] The Metro Vancouver objective for hourly NO_2 is 200 µg/m^3, while the WorkSafeBC ceiling level short-term exposure limit (STEL) for NO_2 is 1 ppm (i.e., 1,910 µg/m^3) as of June 1, 2017, more than an order of magnitude greater than either the provincial or MV AAQOs.

Method (based on the over-prediction of hourly NO_2 concentrations by more than double), and below 1-hour NO_2 updated study criteria.

Additional reasons why observed hourly average NO_2 concentrations during Project operation are expected to be lower than the predicted concentrations are as follows:

- The RBT2 Study assessed a conservative hypothetical operating scenario to provide for a conservative assessment. As examples, conservative assumptions included higher than observed berth occupancy at any one time, concurrent vessel departures and arrivals with vessels at berth, use of conservative load factors, etc. (refer to Appendix A in EIS Appendix 9.2-A for more information);
- The RBT2 Study did not factor in decreases in emissions from container ships using shore power while ships are berthed, as the anticipated connection rate was unknown for the three berths at RBT2 or the third berth at the Deltaport Terminal at the time of the study (refer to the response to IR6-19 of CEAR Document #1113[7] for more information); and
- The RBT2 Study did not factor in decreases in emissions from the replacement or conversion of diesel-powered ferries to dual-fuel ferries (which operate on liquified natural gas or ultra-low sulphur diesel), as the timing of replacement/conversion was uncertain at the time of the study (refer to the response to IR6-13 of CEAR Document #1134[8] for more information).

[7] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).
[8] CEAR Document #1134 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-20, IR5-30, IR5-31, IR6-13, IR7-12, IR7-37 & IR7-41. (See Reference Documents #975, #991, & #1000).

Table IR6-23-1 Applicable Ambient Air Quality Standards/Objectives (µg/m^3) in 2025 for Canadian and U.S. Over Land and Over Water Locations

Criteria Air Contaminant	CO		NO_2			SO_2				Formald-ehyde	PM		PM_{10}		$PM_{2.5}$	
Averaging Period	**1-h**	**8-h**	**1-h**	**24-h**	**Annual**	**1-h**		**24-h**	**Annual**	**1-h**	**24-h**	**Annual**	**24-h**	**Annual**	**24-h**	**Annual**
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*		*5.1*	*1.4*	*3.58*	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Receptor Location	**Applicable Criteria in 2025**															
Canada Over Land	14,300	5,500	200	200	40[c]	196		125	13[a]	10[b]	60	120	60[p]	50	20	25	8
Canada Over Water	14,300	5,500	188[d]	200	60[c]	183[e]	170[f]	150	13[a]	10[b]	60	120	60[p]	50	N/A	25[g]	8[h]
U.S. Over Land and Water	40,000[i]	10,300[j]	188[k]	N/A	100[c]	196[l]		N/A	N/A		N/A	N/A	N/A	150[m]	N/A	35[n]	12[o]

Notes: N/A = not applicable as no standard or objective in effect.

a. Based on annual mean concentration (average of all 1-hour average SO_2 concentrations over a single year); standard effective in 2020 (during RBT2 construction).
b. Based on annual mean concentration (average of all 1-hour average SO_2 concentrations over a single year; standard effective in 2025 (during RBT2 operation).
c. Based on arithmetic mean concentration.
d. Based on annual 98th percentile of daily 1-hour maximum, over one year.
e. Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years; standard effective in 2020 (during RBT2 construction).
f. Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years; standard effective in 2025 (during RBT2 operation).
g. Based on annual 98th percentile of daily average, over one year.
h. Based on annual average, over one year.
i. Maximum, not to be exceeded more than once in a year.
j. Maximum, not to be exceeded more than once in a year; based on second highest, non-overlapping 8-hour average concentration.
k. Based on 98th percentile, 1-hour daily maximum, averaged over 3 years. Concentrations over one year used for RBT2 Study based on method used.
l. Based on 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years. Concentrations over one year used for RBT2 Study based on method used.
m. Not to be exceeded more than once per year on average over 3 years.
n. Based on 98th percentile, averaged over 3 years. Concentrations over one year used for RBT2 Study based on method used.
o. Based on annual mean, averaged over 3 years. Concentrations over one year used for RBT2 Study based on method used.
p. Based on geometric mean concentration.

Where the tables show exceedances for expected and future conditions and for the cumulative future conditions case, provide isopleth plots for maximum 1-hour and 24-hour, and annual concentrations for gaseous and particulate air contaminants.

For expected conditions, future conditions with the Project, and for the cumulative future conditions case, the only predicted exceedance of the updated study criteria is for 1-hour NO_2 under future conditions with the Project (see Table IR6-23-A9). As previously indicated, this model-predicted criteria exceedance is unlikely to be realised.

Although there is only one exceedance, the VFPA has prepared isopleth plots for maximum 1-hour, 8-hour, 24-hour, and annual concentrations for gaseous and particulate air contaminants, acrolein, and formaldehyde to update the isopleth plots provided in EIS Appendix 9.2-A (including Appendix E) and EIS Appendix 27-A. The updated isopleth plots[9], which incorporate the statistical methods associated with the updated study criteria (**Table IR6-23-1**), are provided in the response to IR6-24 for existing, expected, and future conditions. The locations of maximum over land and over water concentrations (i.e., maximum points of impingement (MPOIs)) are also shown in these isopleth plots, along with the frequency that the updated study criteria are exceeded at MPOI locations, if applicable. For the location of the 1-hour NO_2 MPOI over land, refer to Figure IR6-24-A3 in the response to IR6-24. The frequency that the MV AAQO of 200 µg/m^3 will be exceeded is predicted to be 3.5 days per year, or 1% of the year, but exceedances are unlikely to be realised, as explained above.

Provide isopleth plots of the frequency of exceedance and tabulated results for each discrete receptor.

For discrete receptors, exceedances of the updated study criteria for 1-hour average NO_2 and SO_2 concentrations are predicted over water at only one receptor, the B.C. Ferries Terminal (discrete receptor R13), under existing conditions (2010)[10]. The frequency of exceedance results for this discrete receptor are tabulated in **Table IR6-23-2**. Updated study criteria for 1-hour NO_2 and 1-hour SO_2 are predicted to be exceeded 3.3% and 1.9% of the year under existing conditions. Note that for comparison purposes, the updated study criteria for 1-hour NO_2 (for over water locations) and 1-hour and annual SO_2 (for both over land and over water locations) applicable to future conditions during construction and operations has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding the criterion applicable in 2010. For the spatial extents of exceedances to the updated study criteria (B.C.

[9] As outlined in EIS Section 9.2.10.5 and the response to IR6-24, isopleth plots indicate the highest hourly or daily concentrations for the specific hour or day in the year that results in the maximum concentration at each grid receptor point, and should not be interpreted as an aggregate plume.

[10] As outlined in the response to IR6-14, there are 8,642 receptor locations within the LSA, and 18 of those receptors were selected as 'discrete receptors' to: 1) assess populated and publicly accessed locations that could potentially be affected by changes to air quality in the area surrounding the Project; and 2) to assist with the interpretation of the 8,642 model results for each of the parameters assessed. The discrete receptors, therefore, do not represent the locations of maximum concentrations, but were selected for presentation purposes to assist with explaining changes in predicted air quality parameter concentrations in the future (with or without the Project) compared to existing conditions.

AAQO for NO_2 and the CAAQS for SO_2), refer to Figure IR6-24-A4 for 1-hour NO_2 and Figure IR6-24-A9 for 1-hour SO_2. **Table IR6-23-2** reflects that air quality is predicted to improve in future conditions (with or without the Project) [11], one of the RBT2 air quality effects assessment conclusions.

No exceedances are predicted at any discrete receptor locations in 2025 under expected conditions or future conditions with the Project scenarios, as shown in the isopleth plots provided in the response to IR6-24.

Table IR6-23-2 Frequency of Exceedance of 1-hour NO_2 and 1-hour SO_2 Updated Study Criteria (as Percentage of Year) at B.C. Ferries Terminal (Discrete Receptor R13)

	Existing Conditions[a] 2010		Expected Conditions 2025		Future Conditions with the Project 2025	
	1-h NO_2	**1-h SO_2**	**1-h NO_2**	**1-h SO_2**	**1-h NO_2**	**1-h SO_2**
Study Criteria ($\mu g/m^3$)	188[b]	170[c]	188[b]	170[c]	188[b]	170[c]
Frequency that Updated Study Criteria is Predicted to be Exceeded (% of year)	0.2	0.1	0	0	0	0

Notes:

a. For comparison purposes, the 2014 interim B.C. AAQO for hourly NO_2 (188 $\mu g/m^3$) and the 2025 CAAQS for SO_2 (170 $\mu g/m^3$) applicable to future conditions (2025) has also been applied to existing conditions (2010).
b. Based on annual 98th percentile of daily 1-hour maximum, over one year.
c. Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years; standard effective in 2025 (during RBT2 operation).

In all scenarios where exceedances of CAAQS or Metro Vancouver objectives have been predicted (including overwater), provide frequency of exceedance in tables and isopleth plots for discrete receptors.

Exceedances of CAAQS or MV AAQOs are not predicted to occur at any discrete receptors within Metro Vancouver jurisdiction (on land locations). Since locations within the marine environment are not within Metro Vancouver boundaries, the updated study criteria for 'Canada Over Water' was used for locations in the marine environment (i.e., the most stringent standards/objectives from amongst the B.C. AAQO, CWSaq, NAAQO, and CAAQS). As summarised above in **Table IR6-23-2**, exceedances of the updated study criteria (applicable in 2025) are predicted at the B.C. Ferries Terminal (R13) under existing conditions

[11] NO_2 concentrations predicted at R13 for expected conditions and future conditions with the Project will be lower than predicted by the RBT2 Study, as BC Ferries has recently converted diesel-fuel ferries to dual-fuel ferries. With the use of liquified natural gas fuel, NO_x emissions could decrease by over 90%. For more information, refer to the response to IR6-13 of CEAR Document #1134.

(2010)[12], while there are no exceedances predicted at this receptor in 2025 under expected conditions or under future conditions with the Project scenarios. Isopleth plots are provided in Figures IR6-24-A4 and IR6-24-A9 in the response to IR6-24.

Propose additional mitigation measures and/or control technologies that could substantially reduce NO_2 maximum 1-hour concentrations beyond what is currently predicted in the future 2025 case with the Project found in Figure 4-10.

As explained above, the predicted elevated 1-hour NO_2 concentrations shown in Table IR6-23-A9 of **Appendix IR6-23-A** and Figure IR6-24-A4 in the response to IR6-24 (which updates EIS Appendix 9.2-A, Figure 4-10 referred to in this information request to reflect updated study criteria) are unlikely to be realised. Nevertheless, the VFPA will continue to seek opportunities to mitigate and/or control NO_x emissions during the operation phase of the Project, as described in the responses to IR6-29 and IR6-32. VFPA initiatives currently in place and those proposed to reduce marine source NO_x emissions are described in the response to IR6-29, while VFPA emission reduction initiatives targeting other combustion related sources of NO_x (trucks, rail, cargo handling equipment) are described in the response to IR6-32.

Appendices

Appendix IR6-23-A RBT2 Air Quality Study Updated Tables of Maximum Predicted Air Quality Concentrations Over Water and Over Land

[12] Since the 2014 interim B.C. AAQO for hourly NO_2 (188 µg/m^3) and the 2025 CAAQS for SO_2 (170 µg/m^3) applicable to future conditions (2025) has also been applied to existing conditions (2010), the Exceedances shown in **Table IR6-23-2** and isopleth plot figures provided in the response to IR6-24 are not representative of the criteria applicable in 2010 (i.e., criteria applicable in 2010 for hourly NO_2 and SO_2 are 400 µg/m^3 and 450 µg/m^3, respectively).

APPENDIX IR6-23-A

RBT2 AIR QUALITY STUDY UPDATED TABLES OF MAXIMUM PREDICTED AIR QUALITY CONCENTRATIONS OVER WATER AND OVER LAND

Explanation of Appendix IR6-23-A Content:

Temporal Case	Table Content	EIS Table Reference Number	Appendix IR6-23-A Table Reference Number
Existing Conditions	Predicted maximum concentrations for gaseous criteria air contaminants (CACs) and formaldehyde	Table 9.2-13	Table IR6-23-A1
	Predicted maximum concentrations for particulate CACs	Table 9.2-14	Table IR6-23-A2
Expected Conditions	Predicted maximum concentrations for gaseous CACs and formaldehyde	Table 9.2-18	Table IR6-23-A3
	Predicted maximum concentrations for particulate CACs	Table 9.2-19	Table IR6-23-A4
Construction Phase	Predicted maximum concentrations for gaseous CACs and formaldehyde on an average construction day for Project construction only emissions	Table 9.2-20	Table IR6-23-A5
	Predicted maximum concentrations for gaseous CACs and formaldehyde on an average construction day for Project construction plus expected conditions emissions	Table 9.2-21	Table IR6-23-A6
	Predicted maximum concentrations for particulate CACs on an average construction day for Project construction only emissions	Table 9.2-22	Table IR6-23-A7
	Predicted maximum concentrations for particulate CACs on an average construction day for Project construction plus expected conditions emissions	Table 9.2-23	Table IR6-23-A8
Future Conditions with the Project	Predicted maximum concentrations for gaseous CACs and formaldehyde	Table 9.2-25	Table IR6-23-A9
	Predicted maximum concentrations for particulate CACs	Table 9.2-26	Table IR6-23-A10
For future conditions with the Project and other certain and reasonably foreseeable projects and activities	Predicted CO concentrations	Table 9.2-30	Table IR6-23-A11
	Predicted NO_2 concentrations	Table 9.2-31	Table IR6-23-A12
	Predicted SO_2 concentrations	Table 9.2-32	Table IR6-23-A13
	Predicted $PM_{2.5}$ concentrations	Table 9.2-36	Table IR6-23-A14

Table IR6-23-A1 Existing Conditions – Predicted Maximum Concentrations for Gaseous CACs and Formaldehyde
(Updated EIS Table 9.2-13)

Concentrations (µg/m³)	CO		NO_2[c,d]			SO_2 [e,f]			Formaldehyde
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual	1-h
Updated Study Criteria	*14,300*	*5,500*	*200 (188)*	*200*	*40 (60)*	*196 (170)*	*125 (150)*	*10*	*60*
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*	*5.1*	*1.4*	*3.6*
Discrete Receptors[a]									
Tsawwassen First Nation	508.4	85.7	121.0	33.5	2.1	90.4	15.7	0.3	4.3
Point Roberts 1[g]	115.3	38.3	99.3	21.8	1.2	46.2	9.1	0.2	0.9
Delta Hospital	75.5	31.8	100.8	9.6	0.5	66.7	5.8	0.1	0.7
B.C. Ferries Terminal	2,035.2	1,104.8	151.3	92.9	20.2	216.5	71.1	2.1	13.4
Air Quality Station T39	302.0	94.0	118.6	33.5	2.1	112.7	15.0	0.3	2.4
Maximum Predicted Over Land Concentration									
Over Land[a]	665.3	256.4	152.4	80.6	12.0	195.2	30.6	0.7	7.3
Over Land as % of Criteria[b]	7%	11%	99%	58%	62%	104%	29%	21%	18%

Notes: '-' indicates no criteria; for comparison purposes, the 2014 interim B.C. AAQO for NO_2 (188 µg/m³) and the 2025 CAAQS for SO_2 (170 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010).

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
d. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
e. The 1-h, 24-h and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively.
f. The 1-h, 24-h and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and 8-h CO ambient air quality criteria is 40,000 µg/m³ and 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration), respectively. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. The 1-h SO_2 ambient air quality criteria is 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years).

Table IR6-23-A2 Existing Conditions – Predicted Maximum Concentrations for Particulate CACs (Updated EIS Table 9.2-14)

Concentrations (µg/m³)	PM		PM_{10}[c]		$PM_{2.5}$[d]	
	24-h	Annual	24-h	Annual	24-h	Annual
Updated Study Criteria	*120*	*60*	*50*	*20 (N/A)*	*25*	*8*
Background Concentration	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Discrete Receptors[a]						
Tsawwassen First Nation	2.4	0.12	2.8	0.11	2.5	0.10
Point Roberts 1[e]	1.5	0.06	1.6	0.06	0.7	0.05
Delta Hospital	0.7	0.03	0.9	0.03	0.8	0.02
B.C. Ferries Terminal	15.8	1.04	16.1	1.04	6.7	0.91
Air Quality Station T39	2.5	0.11	2.9	0.11	2.6	0.10
Maximum Predicted Over Land Concentration						
Over Land[a]	5.1	0.6	6.5	0.6	5.3	0.5
Over Land as % of Criteria[b]	43%	35%	59%	55%	56%	50%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The annual PM_{10} study criterion for receptor locations in Canada over land is 20 µg/m³. There are no annual PM_{10} standards or objectives for receptor locations in Canada or the U.S. over water.
d. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

Table IR6-23-A3 Expected Conditions – Predicted Maximum Concentrations for Gaseous CACs and Formaldehyde
(Updated EIS Table 9.2-18)

Concentrations (µg/m³)	CO		NO_2[c,d]			SO_2 [e,f]			Formaldehyde
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual	1-h
Updated Study Criteria	*14,300*	*5,500*	*200 (188)*	*200*	*40 (60)*	*196 (170)*	*125 (150)*	*10*	*60*
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*	*5.1*	*1.4*	*3.6*
Discrete Receptors[a]									
Tsawwassen First Nation	167.1	32.3	102.7	15.8	1.2	4.8	0.8	0.02	2.2
Point Roberts 1[g]	49.8	16.5	62.8	11.6	0.7	2.4	0.5	0.02	0.6
Delta Hospital	38.6	16.3	71.4	4.6	0.3	3.1	0.3	0.01	0.4
B.C. Ferries Terminal	720.1	490.7	126.6	81.6	9.6	12.5	4.2	0.22	6.8
Air Quality Station T39	119.6	38.2	100.9	15	1.3	6.3	0.8	0.03	1.4
Maximum Over Land Predicted Concentration									
Over Land[a]	329.7	165.3	124.0	43.9	8.1	10.5	1.7	0.06	4.3
Over Land as % of criteria[b]	5%	9%	84%	39%	52%	9%	5%	15%	13%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
d. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
e. The 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively.
f. The 1-h, 24-h, and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and 8-h CO ambient air quality criteria is 40,000 µg/m³ and 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration), respectively. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. The 1-h SO_2 ambient air quality criteria is 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years).

Table IR6-23-A4 Expected Conditions – Predicted Maximum Concentrations for Particulate CACs (Updated EIS Table 9.2-19)

Concentrations (µg/m³)	PM		PM_{10}[c]		$PM_{2.5}$[d]	
	24-h	**Annual**	**24-h**	**Annual**	**24-h**	**Annual**
Updated Study Criteria	*120*	*60*	*50*	*20 (N/A)*	*25*	*8*
Background Concentration	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Discrete Receptors[a]						
Tsawwassen First Nation	0.9	0.07	1	0.1	0.8	0.05
Point Roberts 1[e]	0.6	0.04	0.6	0	0.3	0.03
Delta Hospital	0.2	0.01	0.3	0	0.3	0.01
B.C. Ferries Terminal	6.4	0.58	6.7	0.6	2.5	0.46
Air Quality Station T39	1	0.07	1.1	0.1	0.9	0.06
Maximum Over Land Predicted Concentration						
Over Land[a]	2.7	0.37	3.5	0.4	1.9	0.24
Over Land as % of criteria[b]	41%	35%	53%	54%	42%	47%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The annual PM_{10} study criterion for receptor locations in Canada over land is 20 µg/m³. There are no annual PM_{10} standards or objectives for receptor locations in Canada or the U.S. over water.
d. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

Table IR6-23-A5 Predicted Maximum Concentrations for Gaseous CACs and Formaldehyde (µg/m³) – Average Day Project Construction (Project Only) (Updated EIS Table 9.2-20)

Concentrations (µg/m³)	CO		NO_2[c,d]			SO_2 [e,f]			Formaldehyde
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual	1-h
Updated Study Criteria	*14,300*	*5,500*	*200 (188)*	*200*	*40 (60)*	*196 (170)*	*125 (150)*	*10*	*60*
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*	*5.1*	*1.4*	*3.58*
Discrete Receptors[a]									
Tsawwassen First Nation	21.7	5.5	62.6	6.7	0.7	0.04	0.004	0.0004	0.821
Point Roberts 1[g]	10.1	2.6	18.9	3.4	0.3	0.01	0.002	0.0002	0.397
Delta Hospital	5.9	2.7	17.1	1.7	0.2	0.01	0.002	0.0001	0.224
B.C. Ferries Terminal	124.5	31.1	102.2	42.2	3	0.1	0.028	0.0018	4.934
Air Quality Station T39	22.9	4.7	64.3	5.8	0.6	0.04	0.004	0.0004	0.907
Maximum Over Land Predicted Concentration									
Over Land[a]	199.4	38.8	144.1	48.9	5.2	0.3	0.04	0.003	7.9
Over Land as % of criteria[b]	4%	7%	94%	42%	45%	4%	4%	14%	19%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
d. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
e. The 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively.
f. The 1-h, 24-h, and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and 8-h CO ambient air quality criteria is 40,000 µg/m³ and 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration), respectively. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. The 1-h SO_2 ambient air quality criteria is 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years).

Table IR6-23-A6 Predicted Maximum Concentrations for Gaseous CACs and Formaldehyde – Average Day Project Construction plus Expected Conditions (Operations at Westshore Terminals, Deltaport Terminal, and the BC Ferries Terminal) (Updated EIS Table 9.2-21)

Concentrations (µg/m³)	CO		NO_2[c,d]			SO_2[e,f]			Formaldehyde
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual	1-h
Updated Study Criteria	*14,300*	*5,500*	*200 (188)*	*200*	*40 (60)*	*196 (170)*	*125 (150)*	*10*	*60*
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*	*5.1*	*1.4*	*3.58*
Discrete Receptors[a]									
Tsawwassen First Nation	161	30	106.5	19.1	2.5	4.7	0.8	0.06	2.8
Point Roberts 1[g]	46.9	14.7	59.9	15.1	1.5	2.3	0.5	0.04	0.8
Delta Hospital	29.5	12.6	47.9	5.5	0.6	2.3	0.3	0.01	0.5
B.C. Ferries Terminal	578.3	307.1	126.6	81.8	18.5	12.2	4.2	0.45	6.7
Air Quality Station T39	105.1	33.6	102.1	19.8	2.7	6.3	0.8	0.07	1.7
Maximum Over Land Predicted Concentration									
Over Land[a]	239.5	84.1	147.6	70.8	12.5	10.4	1.7	0.1	8.5
Over Land as % of criteria[b]	4%	8%	96%	53%	63%	9%	5%	15%	20%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
d. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
e. The 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³,and 10 µg/m³, respectively.
f. The 1-h, 24-h, and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and 8-h CO ambient air quality criteria is 40,000 µg/m³ and 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration), respectively. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. The 1-h SO_2 ambient air quality criteria is 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years).

Table IR6-23-A7 Predicted Maximum Particulate CAC Concentrations for Average Day Project Construction Activities (Project Only) (Updated EIS Table 9.2-22)

Concentrations (µg/m³)	PM		PM_{10}[c]		$PM_{2.5}$[d]	
	24-h	Annual	24-h	Annual	24-h	Annual
Updated Study Criteria	*120*	*60*	*50*	*20 (N/A)*	*25*	*8*
Background Concentration	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Discrete Receptors[a]						
Tsawwassen First Nation	2.6	0.4	2.2	0.19	0.4	0.04
Point Roberts 1[e]	0.8	0.1	0.8	0.07	0.1	0.02
Delta Hospital	0.5	0.04	0.6	0.03	0.2	0.01
B.C. Ferries Terminal	11.9	1	10.2	0.66	1.5	0.24
Air Quality Station T39	1.7	0.2	1.4	0.14	0.5	0.04
Maximum Over Land Predicted Concentration						
Over Land[a]	37.8	5.3	15.9	1.9	5.6	0.25
Over Land as % of criteria[b]	70%	43%	78%	61%	57%	47%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The annual PM_{10} study criterion for receptor locations in Canada over land is 20 µg/m³. There are no annual PM_{10} standards or objectives for receptor locations in Canada or the U.S. over water.
d. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

Table IR6-23-A8 Predicted Maximum Particulate CAC Concentrations for Average Day Project Construction Activities plus Expected Conditions (Operations at Westshore Terminals, Deltaport Terminal, and the BC Ferries Terminal) (Updated EIS Table 9.2-23)

Concentrations (µg/m³)	PM		PM_{10}[c]		$PM_{2.5}$[d]	
	24-h	Annual	24-h	Annual	24-h	Annual
Updated Study Criteria	*120*	*60*	*50*	*20 (N/A)*	*25*	*8*
Background Concentration	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Discrete Receptors[a]						
Tsawwassen First Nation	3.3	0.5	2.6	0.3	1.2	0.12
Point Roberts 1[e]	1.3	0.2	1.3	0.1	0.5	0.08
Delta Hospital	0.7	0.1	0.9	0.1	0.4	0.03
B.C. Ferries Terminal	14.2	1.8	13.2	1.6	3.8	0.96
Air Quality Station T39	2.6	0.3	2.4	0.3	1.4	0.14
Maximum Over Land Predicted Concentration						
Over Land[a]	38.6	5.7	17.1	2.3	6.9	0.49
Over Land as % of criteria[b]	71%	44%	80%	63%	62%	50%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The annual PM_{10} study criterion for receptor locations in Canada over land is 20 µg/m³. There are no annual PM_{10} standards or objectives for receptor locations in Canada or the U.S. over water.
d. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

Table IR6-23-A9 Future Conditions with the Project – Predicted Maximum Concentrations for Gaseous CACs and Formaldehyde (Updated EIS Table 9.2-25)

Concentrations (µg/m³)	CO		NO_2[c,d]			SO_2 [e,f]			Formaldehyde
	1-h	8-h Rolling	1-h	24-h	Annual	1-h	24-h Rolling	Annual	1-h
Updated Study Criteria	*14,300*	*5,500*	*200 (188)*	*200*	*40 (60)*	*196 (170)*	*125 (150)*	*10*	*60*
Background Concentration	*371.2*	*339.3*	*44.7*	*34.9*	*12.8*	*7.7*	*5.1*	*1.4*	*3.58*
Discrete Receptors[a]									
Tsawwassen First Nation	219.9	72.8	119.8	18.5	1.7	6.9	1.2	0.03	3.9
Point Roberts 1[g]	67.1	23.6	77.8	14.1	0.8	3.5	0.7	0.02	0.8
Delta Hospital	51.4	27.4	86.2	5.3	0.4	3.5	0.4	0.01	0.8
B.C. Ferries Terminal	729.2	507.8	126.6	81.8	10.1	12.4	4.2	0.26	6.9
Air Quality Station T39	143.2	48.0	105.9	17.3	1.5	6.4	1	0.04	1.6
Maximum Over Land Predicted Concentration									
Over Land[a]	953.9	480.4	247.4	81.5	16.4	14.9	2.7	0.08	19.9
Over Land as % of criteria[b]	9%	15%	146%	58%	73%	12%	6%	15%	39%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
d. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
e. The 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³, and 10 µg/m³, respectively.
f. The 1-h, 24-h, and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and 8-h CO ambient air quality criteria is 40,000 µg/m³ and 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration), respectively. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. The 1-h SO_2 ambient air quality criteria is 196 µg/m³ (based on the 99th percentile over daily 1-h maximum, over three years).

Table IR6-23-A10 Future Conditions with the Project– Predicted Maximum Particulate CAC Concentrations (Updated EIS Table 9.2-26)

Concentrations (µg/m³)	PM		PM_{10}[c]		$PM_{2.5}$[d]	
	24-h	Annual	24-h	Annual	24-h	Annual
Updated Study Criteria	*120*	*60*	*50*	*20 (N/A)*	*25*	*8*
Background Concentration	*46.2*	*20.6*	*23.1*	*10.3*	*8.7*	*3.5*
Discrete Receptors[a]						
Tsawwassen First Nation	1.1	0.09	1.3	0.09	1.1	0.07
Point Roberts 1[e]	0.7	0.04	0.8	0.04	0.4	0.04
Delta Hospital	0.3	0.02	0.5	0.02	0.4	0.02
B.C. Ferries Terminal	6.4	0.61	6.7	0.61	2.6	0.48
Air Quality Station T39	1.2	0.08	1.3	0.08	1.0	0.07
Maximum Over Land Predicted Concentration						
Over Land[a]	5.6	0.75	7.6	0.75	4.1	0.48
Over Land as % of criteria[b]	43%	36%	61%	55%	51%	50%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors and the maximum overland receptor point do not include background concentrations.
b. The maximum overland concentration as a percentage of the air quality criteria includes the background concentration.
c. The annual PM_{10} study criterion for receptor locations in Canada over land is 20 µg/m³. There are no annual PM_{10} standards or objectives for receptor locations in Canada or the U.S. over water.
d. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

Table IR6-23-A11 Future Conditions with the Project and Other Certain and Reasonably Foreseeable Projects and Activities – Predicted CO Concentrations (Updated EIS Table 9.2-30)

	Predicted Concentrations (µg/m³)[a]				Cumulative Change as % of Study Criteria (incl. background)
	Future Conditions with Project	Ships Underway[b]	Combined Rail Activity[c]	Cumulative Change[d]	
	1-h Average CO				
Updated Study Criteria	*14,300*				
Background Concentration	*371*				
Tsawwassen First Nations	220	2	15	220	4%
Point Roberts 1[e]	67	3	2	67	3%
Delta Hospital	51	2	15	60	3%
B.C. Ferries Terminal	729	3	4	730	8%
Air Quality Station T39	143	3	4	143	4%
	8-h Rolling Average CO				
Updated Study Criteria	*5,500*				
Background Concentration	*339*				
Tsawwassen First Nations	73	1	9	74	8%
Point Roberts 1[e]	24	1	1	24	4%
Delta Hospital	27	1	6	33	7%
B.C. Ferries Terminal	508	1	2	508	15%
Air Quality Station T39	48	1	2	49	7%

Notes:

a. Predicted maximum concentrations for discrete receptors do not include background concentrations.
b. To avoid double-counting of emissions from ships underway (i.e., 88% of ship emissions concentrations are included in background air quality for existing conditions due to current ship activity levels), this column is not included in the cumulative change total.
c. Combined rail activity includes line-haul locomotives travelling along the main rail lines within the local study area (LSA) as well as low notch and switching operations occurring within yards A and B beyond the Project area boundary.
d. Cumulative change included future conditions with the Project and combined rail activity. Cumulative change concentrations are not necessarily the same as the sum of the individual activities.
e. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 8-h CO ambient air quality criteria is 10,300 µg/m³ (based on the second highest, non-overlapping 8-h average concentration).

Table IR6-23-A12 Future Conditions with the Project and Other Certain and Reasonably Foreseeable Projects and Activities – Predicted NO_2 Concentrations (Updated EIS Table 9.2-31)

	Predicted Concentrations (µg/m³)[a]				Cumulative Change as % of Study Criteria (incl. background)
	Future Conditions with Project	Ships Underway[b]	Combined Rail Activity[c]	Cumulative Change[d]	
	1-h Average NO_2[e,f]				
Updated Study Criteria	*200 (188)*				
Background Concentration	*44.7*				
Tsawwassen First Nations	120	20	57	120	82%
Point Roberts 1[g]	77.8	19.1	4.4	77.8	65%
Delta Hospital	86	17	55	86	65%
B.C. Ferries Terminal	127	16	7.1	127	91%
Air Quality Station T39	106	34	16	106	75%
	24-h Average NO_2				
Updated Study Criteria	*200*				
Background Concentration	*34.9*				
Tsawwassen First Nations	18.5	4.5	10	24.8	30%
Point Roberts 1[g]	14.1	5.4	1.1	14.1	-N/A
Delta Hospital	5.3	3.6	10.6	13.7	24%
B.C. Ferries Terminal	81.8	4.1	1.6	81.8	58%
Air Quality Station T39	17.3	5.2	2.3	18.2	27%
	Annual Average NO_2 [e,f]				
Updated Study Criteria	*40 (60)*				
Background Concentration	*12.8*				
Tsawwassen First Nations	1.7	0.6	1.3	3.1	40%
Point Roberts 1[g]	0.8	0.8	0.1	0.9	14%
Delta Hospital	0.4	0.5	1.5	1.9	37%
B.C. Ferries Terminal	10.1	0.6	0.1	10.3	39%
Air Quality Station T39	1.5	0.8	0.2	1.7	36%

Notes: '-' indicates no criteria.

a. Predicted maximum concentrations for discrete receptors do not include background concentrations.
b. To avoid double-counting of emissions from ships underway (i.e., 88% of ship emissions concentrations are included in background air quality for existing conditions due to current ship activity levels), this column is not included in the cumulative change total.
c. Combined rail activity includes line-haul locomotives travelling along the main rail lines within the LSA as well as low notch and switching operations occurring within yards A and B beyond the Project area boundary.
d. Cumulative change included future conditions with the Project and combined rail activity. Cumulative change concentrations are not necessarily the same as the sum of the individual activities.
e. The 1-h and annual NO_2 study criteria for receptor locations in Canada over land are 200 µg/m³ and 40 µg/m³, respectively.
f. The 1-h and annual NO_2 study criteria (in brackets) for receptor locations in Canada over water are 188 µg/m³ (based on annual 98th percentile of daily 1-h maximum, over one year) and 60 µg/m³, respectively.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h and annual NO_2 ambient air quality criteria is 188 µg/m³ (based on the 98th percentile of daily 1-h maximum, over three years) and 100 µg/m³, respectively. There is no standard for 24-h NO_2 in the U.S.A, therefore, a comparison of predicted concentrations to a criterion is not applicable (N/A).

Table IR6-23-A13 Future Conditions with the Project and Other Certain and Reasonably Foreseeable Projects and Activities – Predicted SO_2 Concentrations (Updated EIS Table 9.2-32)

	Predicted Concentrations (µg/m³)[a]				Cumulative Change as % of Study Criteria (incl. background)
	Future Conditions with Project	Ships Underway[b]	Combined Rail Activity[c]	Cumulative Change[d]	
	1-h Average SO_2 [e,f]				
Updated Study Criteria	*196 (170)*				
Background Concentration	*7.7*				
Tsawwassen First Nations	6.9	0.5	0.04	6.9	7%
Point Roberts 1[g]	3.5	0.62	0.004	3.5	6%
Delta Hospital	3.5	0.4	0.05	3.5	6%
B.C. Ferries Terminal	12.4	0.5	0.01	12.4	12%
Air Quality Station T39	6.4	1	0.01	6.4	7%
	24-h Rolling Average SO_2				
Updated Study Criteria	*125 (150)*				
Background Concentration	*5.1*				
Tsawwassen First Nations	1.2	0.1	0.01	1.2	5%
Point Roberts 1[g]	0.7	0.1	0.001	0.7	-N/A
Delta Hospital	0.4	0.1	0.009	0.4	4%
B.C. Ferries Terminal	4.2	0.1	0.002	4.2	6%
Air Quality Station T39	1	0.1	0.002	1	5%
	Annual Average SO_2 [e,f]				
Updated Study Criteria	*10*				
Background Concentration	*1.4*				
Tsawwassen First Nations	0.03	0.014	0.0009	0.035	14%
Point Roberts 1[g]	0.02	0.019	0.0001	0.024	-N/A
Delta Hospital	0.01	0.012	0.0012	0.011	14%
B.C. Ferries Terminal	0.26	0.016	0.0001	0.258	17%
Air Quality Station T39	0.04	0.018	0.0001	0.043	14%

Notes:

a. Predicted maximum concentrations for discrete receptors do not include background concentrations.

b. To avoid double-counting of emissions from ships underway (i.e., 88% of ship emissions concentrations are included in background air quality for existing conditions due to current ship activity levels), this column is not included in the cumulative change total.

c. Combined rail activity includes line-haul locomotives travelling along the main rail lines within the LSA as well as low notch and switching operations occurring within yards A and B beyond the Project area boundary.

d. Cumulative change included future conditions with the Project and combined rail activity. Cumulative change concentrations are not necessarily the same as the sum of the individual activities.

e. The 1-h, 24-h, and annual SO_2 study criteria for receptor locations in Canada over land are 196 µg/m³, 125 µg/m³,and 10 µg/m³, respectively.

f. The 1-h, 24-h, and annual SO_2 study criteria (in brackets) for receptor locations in Canada over water are 170 µg/m³ (based on annual 99th percentile of daily 1-h maximum, over three years), 150 µg/m³, and 10 µg/m³, respectively.

g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 1-h SO_2 ambient air quality criteria is 196 $\mu g/m^3$ (based on the 99^{th} percentile over daily 1-h maximum, over three years). There is no standards for 24-h or annual SO_2 in the U.S.A, therefore, comparisons of predicted concentrations to criteria are not applicable (N/A).

Table IR6-23-A14 Future Conditions with the Project and Other Certain and Reasonably Foreseeable Projects and Activities – Predicted $PM_{2.5}$ Concentrations (Updated EIS Table 9.2-36)

	Predicted Concentrations (µg/m³)[a]					Cumulative Change as % of Study Criteria (incl. background)
	Future Conditions with Project	Ships Underway[b]	Combined Rail Activity[c]	Fugitive Coal Dust[d]	Cumulative Change[e]	
	24-h Rolling Average $PM_{2.5}$					
Updated Study Criteria	*25*					
Background Concentration	*8.7*					
Tsawwassen First Nations	1.1	0.09	0.31	0.13	1.1	39%
Point Roberts 1[g]	0.38	0.07	0.02	0.04	0.38	26%
Delta Hospital	0.4	0.07	0.25	0.04	0.6	37%
B.C. Ferries Terminal	2.6	0.05	0.04	0.4	2.6	45%
Air Quality Station T39	1	0.1	0.07	0.16	1	39%
	Annual Average $PM_{2.5}$					
Updated Study Criteria	*8*					
Background Concentration	*3.5*					
Tsawwassen First Nations	0.07	0.01	0.029	0.009	0.1	45%
Point Roberts 1[g]	0.04	0.02	0.002	0.007	0.04	30%
Delta Hospital	0.02	0.01	0.035	0.003	0.05	44%
B.C. Ferries Terminal	0.48	0.01	0.003	0.079	0.48	50%
Air Quality Station T39	0.07	0.02	0.004	0.012	0.07	45%

Notes:

a. Predicted maximum concentrations for discrete receptors do not include background concentrations.
b. To avoid double-counting of emissions from ships underway (i.e., 88% of ship emissions concentrations are included in background air quality for existing conditions due to current ship activity levels), this column is not included in the cumulative change total.
c. Combined rail activity includes line-haul locomotives travelling along the main rail lines within the LSA as well as low notch and switching operations occurring within yards A and B beyond the Project area boundary.
d. Due to different properties of fugitive coal dust particulate matter and fuel combustion-related particulate matter, this column is presented separately for information purposes only and is not included in the cumulative change total.
e. Cumulative change included future conditions with the Project and combined rail activity. Cumulative change concentrations are not necessarily the same as the sum of the individual activities.
f. The 24-h and annual $PM_{2.5}$ study criteria for receptor locations in Canada over land and over water are 25 µg/m³ and 8 µg/m³, respectively, with over water 24-h concentrations based on annual 98th percentile of daily average, over one year.
g. Receptors located in the U.S.A. (i.e., Point Roberts 1) are subject to the U.S. over land and over water criteria. The 24-h and annual $PM_{2.5}$ ambient air quality criteria are 35 µg/m³ (based on the 98th percentile, over three years) and 12 µg/m³ (based on annual mean, over three years), respectively.

IR6-24 Air Quality – Methodology, Maximum Over-water and Overland

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Tables 4-4 and 4-5; Appendix E

EIS Volume 4: Appendix 27-A

Proponent Response to Additional Information Requirements of July 31, 2015 (CEAR Doc#314): IR-19, Appendix 19-A

Context

In the EIS, the Proponent referred to tabular data indicating the maximum over-water and maximum overland concentrations for contaminants of potential concern, such as in Tables 4-4 and 4-5 of Appendix 9.2-A in the EIS. The Air Quality Human Health Risk Assessment Technical Report (Appendix 27-A) also included tabulated data of maximum points of impingement representing the highest predicted chemical concentrations in air, overland and over water, such as in Tables 14 and 15.

In Tables 4-4 and 4-5 the maximum over-water and maximum overland information did not include the background concentrations, unlike the maximum overland percentage and isopleths maps which did. Yet footnote 1 in the tables indicated that the concentrations presented were incremental and did not include the influence of background. For the health assessment, the maximum points of impingement overland and over water took into consideration estimated risk quotients as well. There is a need for clarification of the definitions of the terms maximum over-water and maximum overland as they were used in the assessments of health and air quality.

In Table 4-4, the 1-hour NO_2 predicted concentration at BC Ferries Terminal was 202.5 ug/m^3, the maximum over-water was 570.8 ug/m^3 and maximum on land was 152.4 ug/m^3. It is not clear why the predicted BC Ferries Terminal result was greater than the on-land result. This example illustrates the need for clarification as to how the discrete receptors were considered in the assessment of both health and air quality.

The Proponent indicated the location of the maximum points of impact overland and overwater for NO_2 and SO_2 concentrations in its response to additional information requirement IR #19 from the Canadian Environmental Assessment Agency. Other maximum points of impingement are not shown graphically on concentration isopleth maps in Appendix 9.2-A or 27-A. This does not allow a visual comparison with the locations of discrete receptors chosen for measurements of air quality - or for the human health risk assessment - with these points of maximum impact.

Information Request

Provide a definition and a comparison of the terms **maximum over-water** and **maximum overland** used in the air quality assessment and in the health assessment.

Provide clarification as to how discrete receptors are used (included or excluded) for the air quality and health assessments of maximum points of impingement overland and over water.

Provide the location and value of the maximum point of impingement for both over-water and overland in all results plots for the following plots and include the location of the discrete receptors:

- Figures 4-8 to 4-22, inclusive, in Appendix 9.2-A;
- Figures 4-1 to 4-14, inclusive, in Appendix E of Appendix 9.2-A; and
- Figures 4 to 8, inclusive, in Appendix 27-A.

VFPA Response

Provide a definition and a comparison of the terms maximum over-water and maximum overland used in the air quality assessment and in the health assessment.

The terms 'maximum over water' and 'maximum over land' were defined as follows for both assessments of air quality and human health[1]:

- The maximum over land location represents the point where the highest concentration for a specific parameter was predicted to occur within the City of Delta or in Point Roberts, Washington (i.e., on the mainland); and
- The maximum over water location represents the point where the highest concentration for a specific parameter was predicted to occur in the marine environment (i.e., seaward of the shoreline). Based on this definition, discrete receptor R13 B.C. Ferries Terminal is considered to be an over water location.

Provide clarification as to how discrete receptors are used (included or excluded) for the air quality and health assessments of maximum points of impingement overland and over water.

Eighteen discrete receptors were selected to assist in the discussion of the air quality study results from the 8,642 gridded receptors located in the air quality study local assessment area[2]. All 8,642 receptor locations, inclusive of the 17 discrete receptors located on land and the one discrete receptor located over water (B.C. Ferries Terminal receptor R13) were included in the determination of where the maximum point of impingement concentrations were predicted for over water or over land locations, based on the definitions provided above.

As further clarification, the discrete receptors, which do not represent the maximum points of impingement over land, were selected for two reasons:

- To assess populated locations that could potentially be affected by changes to air quality in the area surrounding the Project; and

[1] For the air quality assessment, refer to EIS Section 9.2 and EIS Appendix 9.2-A, and for the human health assessment refer to EIS Section 27.0 and EIS Appendix 27-A, and Appendix 19-A in the response to IR7.31.15-19 (CEAR Document #314).

[2] Similar discrete receptor locations were used in the air quality assessment for the Deltaport Third Berth Project in 2005 (i.e., R1 to R11, R14, R15, and R17). New receptor points were added for the Delta Hospital (R12), BC Ferries Tsawwassen Terminal (R13), and the Air Quality Monitoring Station T39.

- For presentation purposes to assist with explaining changes in predicted air quality parameter concentrations in the future with or without the Project compared to existing conditions (i.e., to reduce the 8,642 model results for each parameter to a reasonable number of receptors still representative of the area to assist with the interpretation and discussion of the results).

Provide the location and value of the maximum point of impingement for both over-water and overland in all results plots for the following plots and include the location of the discrete receptors: Figures 4-8 to 4-22, inclusive, in Appendix 9.2-A; Figures 4-1 to 4-14, inclusive, in Appendix E of Appendix 9.2-A; and Figures 4 to 8, inclusive, in Appendix 27-A.

Figures 4-8 to 4-22 (EIS Appendix 9.2-A), Figures 4-1 to 4-14 (Appendix E of EIS Appendix 9.2-A), and Figures 4 to 8 (EIS Appendix 27-A) that provide isopleths, or contour plots showing lines of equal contaminant concentration to illustrate the maximum predicted concentrations[3], have been updated to show the location of discrete receptors and the maximum point of impingement concentrations over water and over land (shown in blue text). Revised figures are provided in Figures IR6-24-A1 to IR6-24-A45 in **Appendix IR6-24-A**. Reference to the original figure number is provided in the figure caption for ease of reference. These revised figures also incorporate updated study criteria and associated statistical methods, as discussed in response to IR6-23 and Table IR6-23-1.

All concentrations represented on the isopleth plots include background concentrations, as per the British Columbia Air Quality Dispersion Modelling Guideline (B.C. MOE 2015). Comparisons are provided to the air quality objectives or standards (criteria) relevant to the location (i.e., over land in Metro Vancouver or U.S. jurisdiction, or over water), with areas exceeding the applicable criterion shaded in yellow. For parameters where the criteria differ for the over land and over water locations, two figures (one for over land concentrations and one for over water concentrations) are provided to update each EIS figure.

For comparison purposes, the criteria for 1-hour NO_2 (for over water locations) and 1-hour and annual SO_2 (for both over land and over water locations) applicable to future conditions during construction and operations has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding an objective applicable in 2010 (e.g., as shown in Figure IR6-24-A4 for 1-hour NO_2 and Figure IR6-24-A9 for 1-hour SO_2).

The isopleths for 1-hour, 8-hour, and 24-hour averaging periods provided in **Appendix IR6-24-A** also include the frequency of exceedance of criteria in days per year

[3] The isopleths indicate the highest hourly or daily concentrations for the specific hour or day in the year that results in the maximum concentration at each receptor. These plots should not be interpreted as an aggregate plume that covers the air quality study area, but as an indicator of the maximum concentrations that could occur on a once-per-year basis in a given location. In addition to the isopleth contours representing multiple points in time, they also include the 98th percentile background concentrations. It is unlikely that the 98th percentile background levels would occur simultaneously with the hour having the highest predicted concentration presented in the isopleths at all receptors. Refer to EIS Section 9.2.10.5, including EIS Figures 9.2-8 and 9.2-9 for additional explanation.

(and percentage of the year) for maximum concentrations that exceed the relevant criteria (shown in red text). During Project operations, the only predicted exceedance over land is for 1-hour NO_2, and the frequency of exceedance is predicted to occur for only 3.5 days or 1% of the year at the east end of the causeway (see Figure IR6-24-A3).[4]

Predicted maximum points of impingement concentrations over water that occur immediately adjacent to the marine terminals, as well as those that are predicted over land at the east end of the Roberts Bank causeway, should be interpreted with caution. Maximum concentrations at such locations do not accurately represent ambient contaminant concentrations that are expected to occur in those locations, as they are an artifact of the model analyses. Predicted concentrations are likely overestimated at these locations for two reasons:

1. The location is too close to an emission source for the CALPUFF model to have reliably resolved the dispersion of the emissions from that source[5]. Dispersion coefficients, which are incorporated into the CALPUFF model, may not provide reliable estimates of the dispersion of contaminants at short distances from the emission source (i.e., at the marine terminal berths and at the east end of the Roberts Bank causeway); and
2. For NO_2 concentrations in particular, maximum predicted concentrations that occur close to an emissions source are based on the assumption that the conversion of NO_x emitted to ambient NO_2 occurs instantaneously. In reality, the conversion rate occurs gradually as the emission plume is transported away from the source. Consequently, predicted maximum concentrations over land or over water that are predicted to occur adjacent to a NO_x emission source are likely overestimated.

References

British Columbia Ministry of Environment (B.C. MOE). 2015. British Columbia Air Quality Dispersion Modelling Guideline. Available at https://www.bcogc.ca/node/13339/download. Accessed October 2017.

Appendices

Appendix IR6-24-A Figures of Maximum Predicted Air Quality Concentrations Over Water and Over Land

[4] As outlined in the response to IR6-22, observed maximum NO_2 concentrations during Project operation are expected to be lower than those predicted using the Ozone Limiting Method in the RBT2 Air Quality Study (based on the over-prediction of hourly NO_2 concentrations by more than double), and below updated study criteria for hourly NO_2.

[5] The CALPUFF model requires the dispersion of the contaminants over a minimal distance for the dispersion coefficients to accurately reflect the transport and spread of the emission plume.

APPENDIX IR6-24-A
FIGURES OF MAXIMUM PREDICTED AIR QUALITY CONCENTRATIONS OVER WATER AND OVER LAND

Explanation of Appendix IR6-24-A Content:

EIS Figure Reference Number	Table Content	Appendix IR6-24-A Figure Reference Number
Appendix 9.2-A, Figure 4-8	Maximum 1-hour CO Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A1
Appendix 9.2-A, Figure 4-9	Maximum 8-hour CO Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A2
Appendix 9.2-A, Figure 4-10	Maximum 1-hour NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land	Figure IR6-24-A3
Appendix 9.2-A, Figure 4-10	98^{th} Percentile 1-hour NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water	Figure IR6-24-A4
Appendix 9.2-A, Figure 4-11	Maximum 24-hour NO2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A5
Appendix 9.2-A, Figure 4-12	Annual NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land	Figure IR6-24-A6
Appendix 9.2-A, Figure 4-12	Annual NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water	Figure IR6-24-A7
Appendix 9.2-A, Figure 4-13	Maximum 1-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land	Figure IR6-24-A8
Appendix 9.2-A, Figure 4-13	99^{th} Percentile 1-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water	Figure IR6-24-A9
Appendix 9.2-A, Figure 4-14	Maximum 24-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A10
Appendix 9.2-A, Figure 4-15	Annual SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A11
Appendix 9.2-A, Figure 4-16	Maximum 1-hour Formaldehyde Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A12
Appendix 9.2-A, Figure 4-17	Maximum 24-hour PM Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A13
Appendix 9.2-A, Figure 4-18	Annual PM Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A14
Appendix 9.2-A, Figure 4-19	Maximum 24-hour PM_{10} Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A15
Appendix 9.2-A, Figure 4-20	Annual PM_{10} Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A16

EIS Figure Reference Number	Table Content	Appendix IR6-24-A Figure Reference Number
Appendix 9.2-A, Figure 4-21	Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land	Figure IR6-24-A17
Appendix 9.2-A, Figure 4-21	98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water	Figure IR6-24-A18
Appendix 9.2-A, Figure 4-22	Annual $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water	Figure IR6-24-A19
Appendix 9.2-A, Appendix E, Figure 4-1	Construction Phase Average Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) – Over Land	Figure IR6-24-A20
Appendix 9.2-A, Appendix E, Figure 4-1	Construction Phase Average Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³)– Over Water	Figure IR6-24-A21
Appendix 9.2-A, Appendix E, Figure 4-2	Construction Phase Average Day Scenario – Maximum 24-hour NO_2 Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A22
Appendix 9.2-A, Appendix E, Figure 4-3	Construction Phase Average Day Scenario – Annual NO_2 Concentrations (µg/m³)– Over Land	Figure IR6-24-A23
Appendix 9.2-A, Appendix E, Figure 4-3	Construction Phase Average Day Scenario – Annual NO_2 Concentrations (µg/m³) – Over Water	Figure IR6-24-A24
Appendix 9.2-A, Appendix E, Figure 4-4	Construction Phase Average Day Scenario – Maximum 24-hour PM Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A25
Appendix 9.2-A, Appendix E, Figure 4-5	Construction Phase Average Day Scenario – Annual PM Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A26
Appendix 9.2-A, Appendix E, Figure 4-6	Construction Phase Average Day Scenario – Maximum 24-hour PM_{10} Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A27
Appendix 9.2-A, Appendix E, Figure 4-7	Construction Phase Average Day Scenario – Annual PM_{10} Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A28
Appendix 9.2-A, Appendix E, Figure 4-8	Construction Phase Average Day Scenario – Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) U.S. Over Land	Figure IR6-24-A29
Appendix 9.2-A, Appendix E, Figure 4-8	Construction Phase Average Day Scenario – 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Water	Figure IR6-24-A30
Appendix 9.2-A, Appendix E, Figure 4-9	Construction Phase Average Day Scenario – Annual $PM_{2.5}$ Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A31

EIS Figure Reference Number	Table Content	Appendix IR6-24-A Figure Reference Number
Appendix 9.2-A, Appendix E, Figure 4-10	Construction Phase Peak Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) – Over Land	Figure IR6-24-A32
Appendix 9.2-A, Appendix E, Figure 4-10	Construction Phase Peak Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³), including 98th Percentile Background – Over Water	Figure IR6-24-A33
Appendix 9.2-A, Appendix E, Figure 4-11	Construction Phase Peak Day Scenario – Maximum 24-hour NO_2 Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A34
Appendix 9.2-A, Appendix E, Figure 4-12	Construction Phase Peak Day Scenario – Maximum 24-hour PM Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A35
Appendix 9.2-A, Appendix E, Figure 4-13	Construction Phase Peak Day Scenario – Maximum 24-hour PM_{10} Concentrations (µg/m³) – Over Land and Over Water	Figure IR6-24-A36
Appendix 9.2-A, Appendix E, Figure 4-14	Construction Phase Peak Day Scenario – Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Land	Figure IR6-24-A37
Appendix 9.2-A, Appendix E, Figure 4-14	Construction Phase Peak Day Scenario – 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Water	Figure IR6-24-A38
Appendix 27-A, Figure 4	Maximum 1-hour Acrolein Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water	Figure IR6-24-A39
Appendix 27-A, Figure 5	Maximum 1-hour Formaldehyde Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water	Figure IR6-24-A40
Appendix 27-A, Figure 6	Maximum 1-hour NO_2 Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land	Figure IR6-24-A41
Appendix 27-A, Figure 6	Maximum 1-hour NO_2 Concentrations (µg/m³) During an Average and Peak Construction Day – Over Water	Figure IR6-24-A42
Appendix 27-A, Figure 7	Maximum 24-hour PM_{10} Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water	Figure IR6-24-A43
Appendix 27-A, Figure 8	Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land	Figure IR6-24-A44
Appendix 27-A, Figure 8	98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) During an Average and Peak Construction Day – Over Water	Figure IR6-24-A45

Figure IR6-24-A1 Maximum 1-hour CO Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-8)

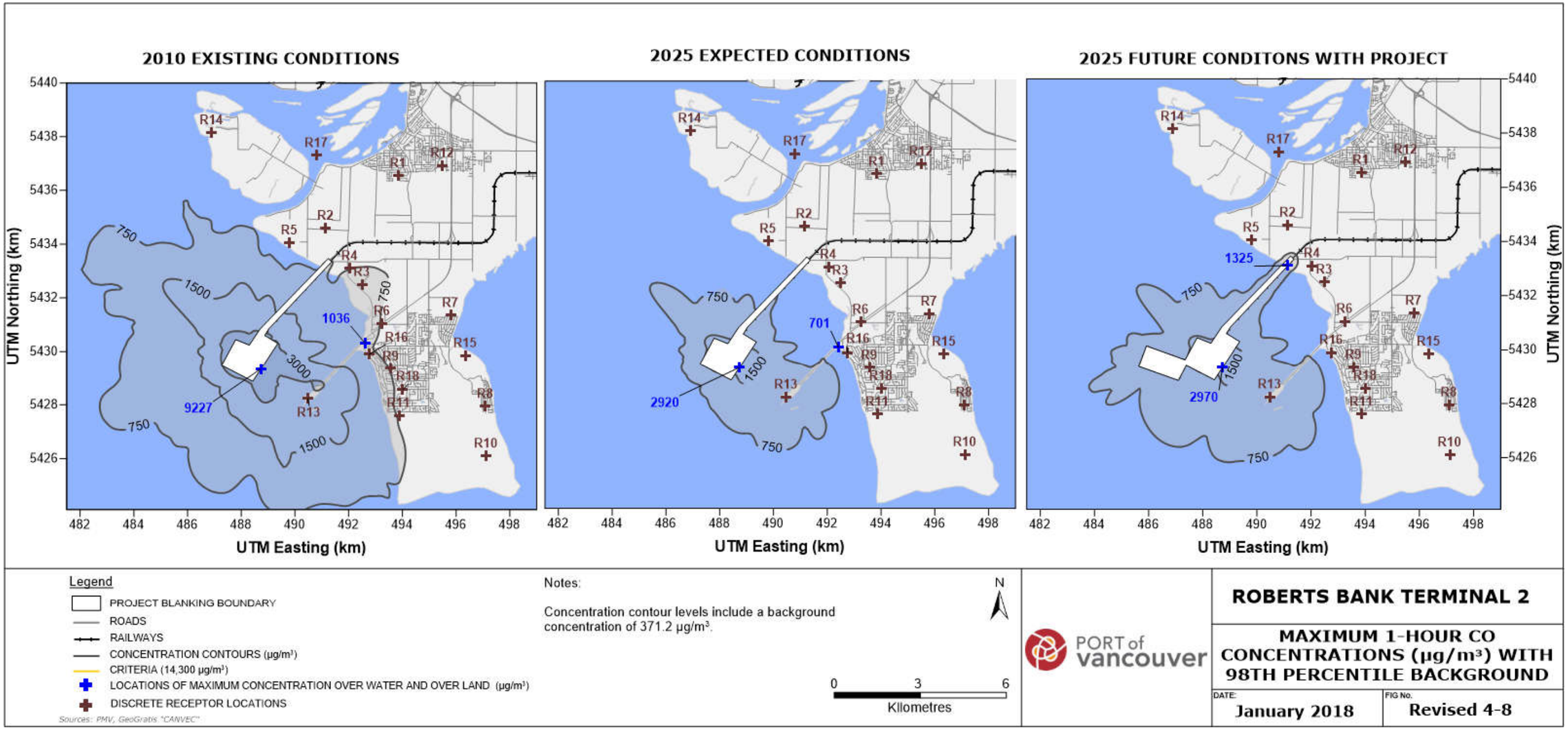


Figure IR6-24-A2 Maximum 8-hour CO Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-9)

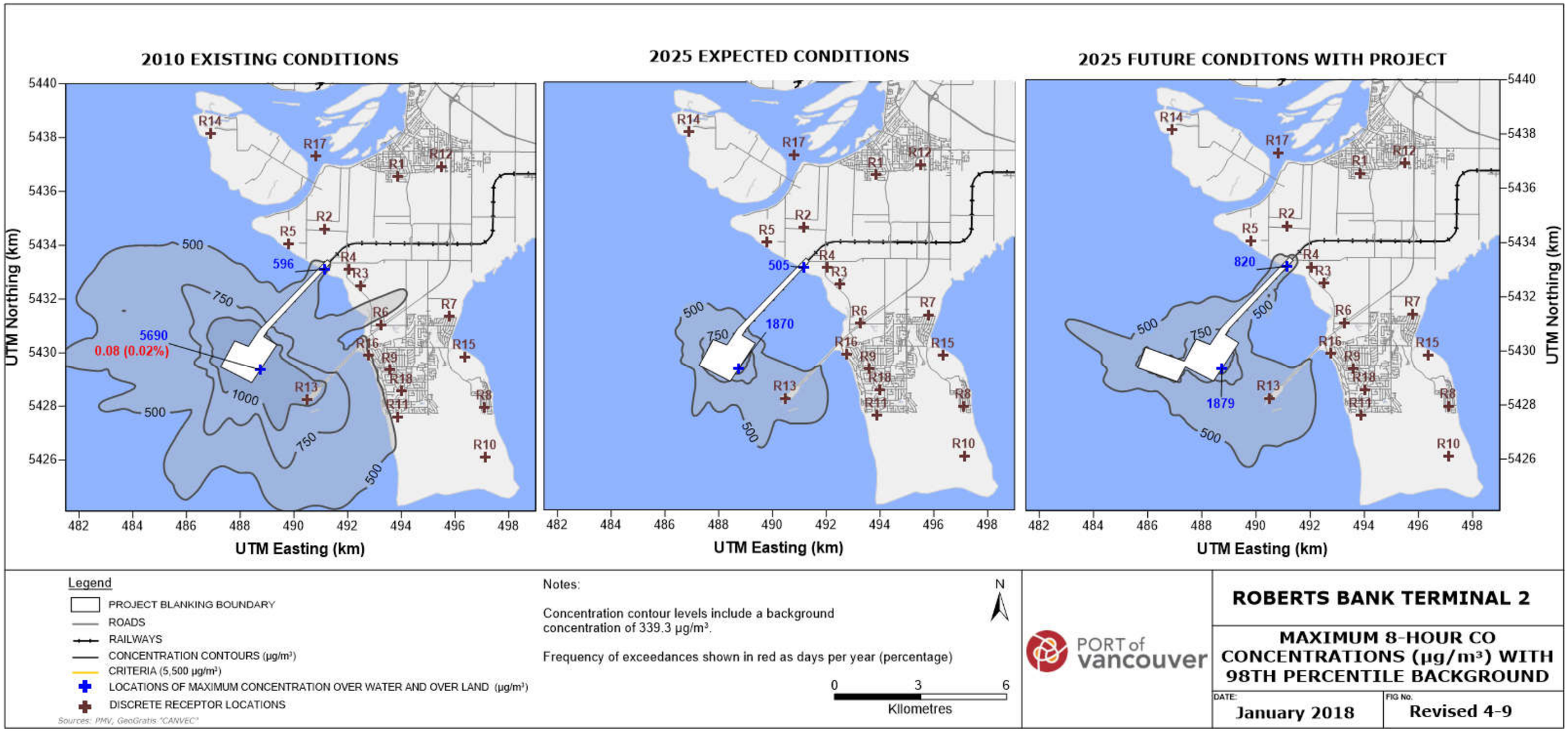


Figure IR6-24-A3 Maximum 1-hour NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land (Revised EIS Appendix 9.2-A, Figure 4-10)

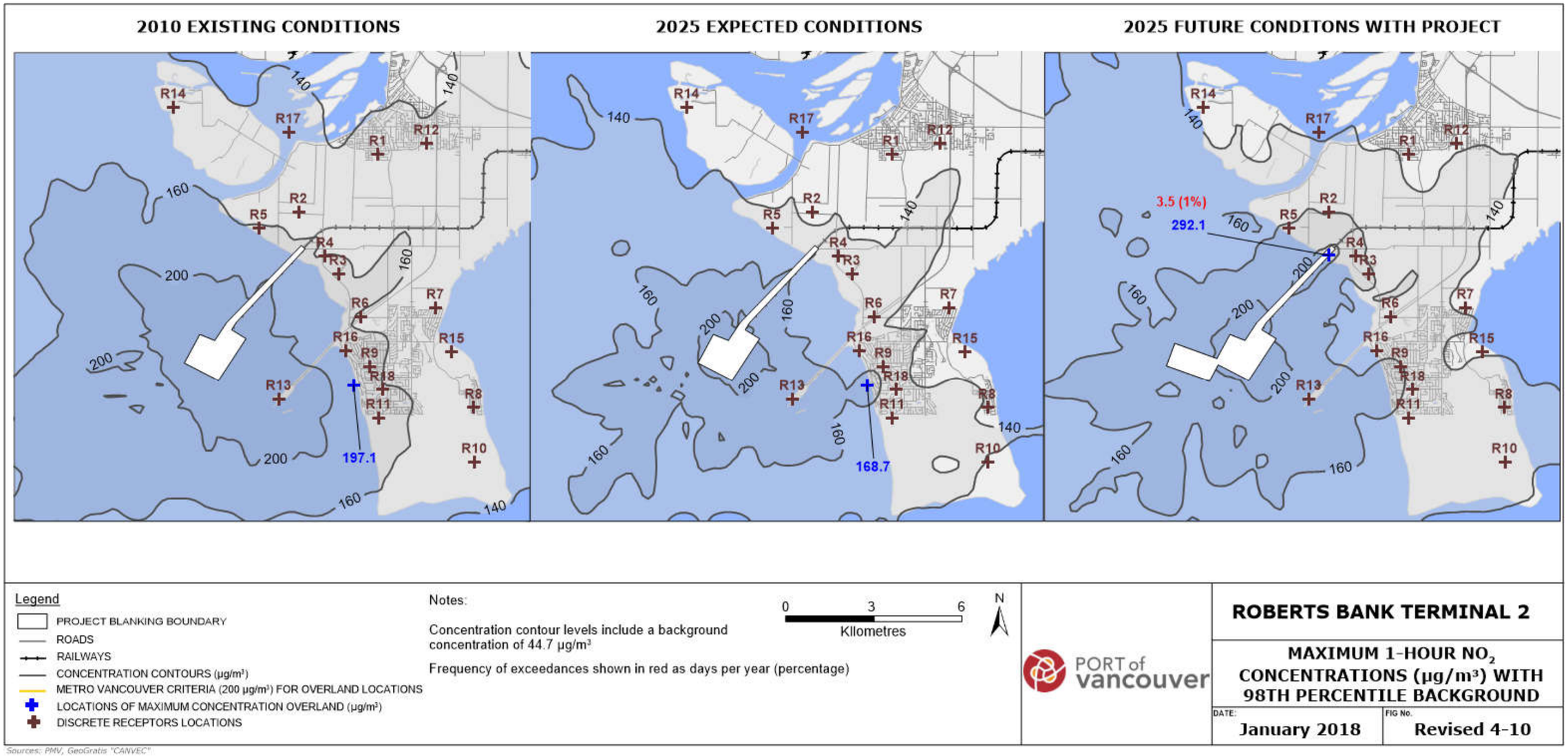
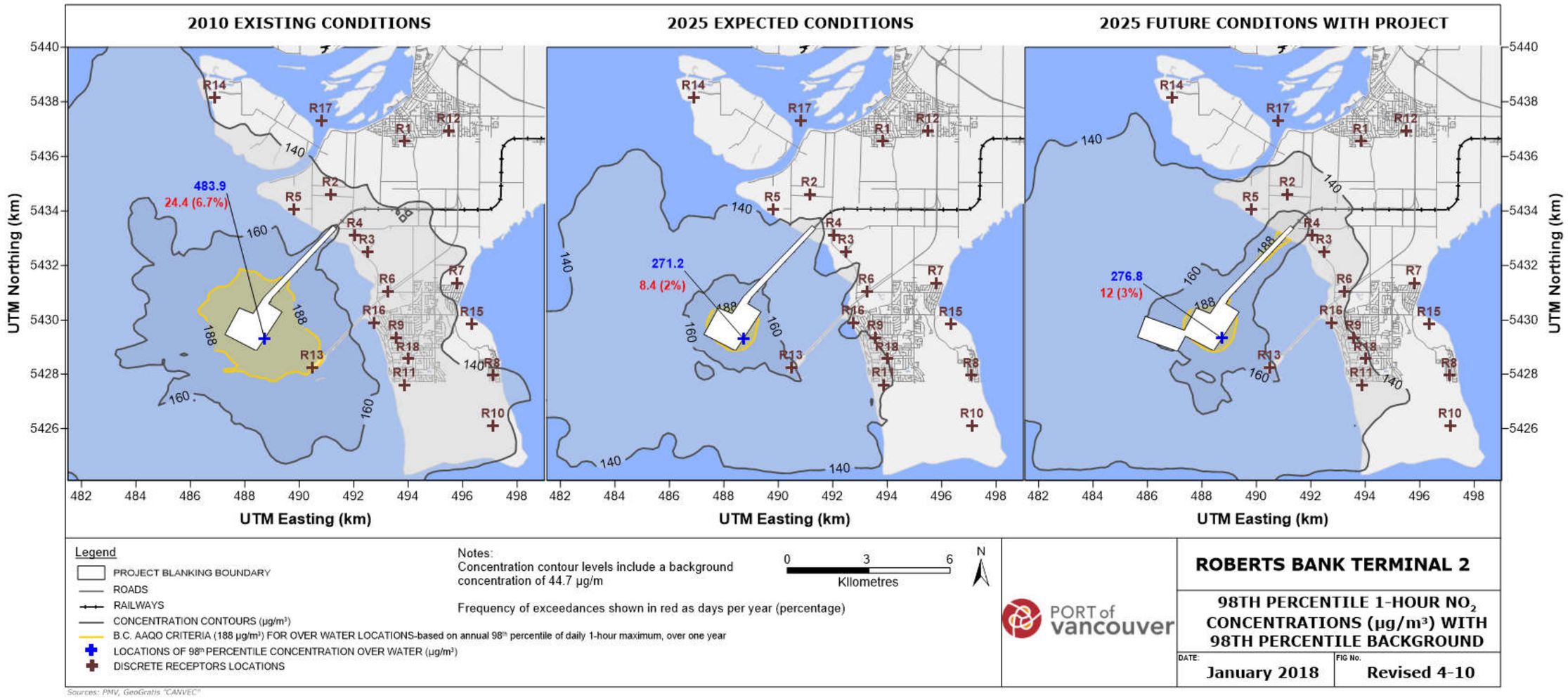


Figure IR6-24-A4 98th Percentile 1-hour NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water (Revised EIS Appendix 9.2-A, Figure 4-10)



Note: For comparison purposes, the 2014 interim provincial air quality objective (188 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding the objective applicable in 2010 (400 µg/m³).

Figure IR6-24-A5 Maximum 24-hour NO2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-11)

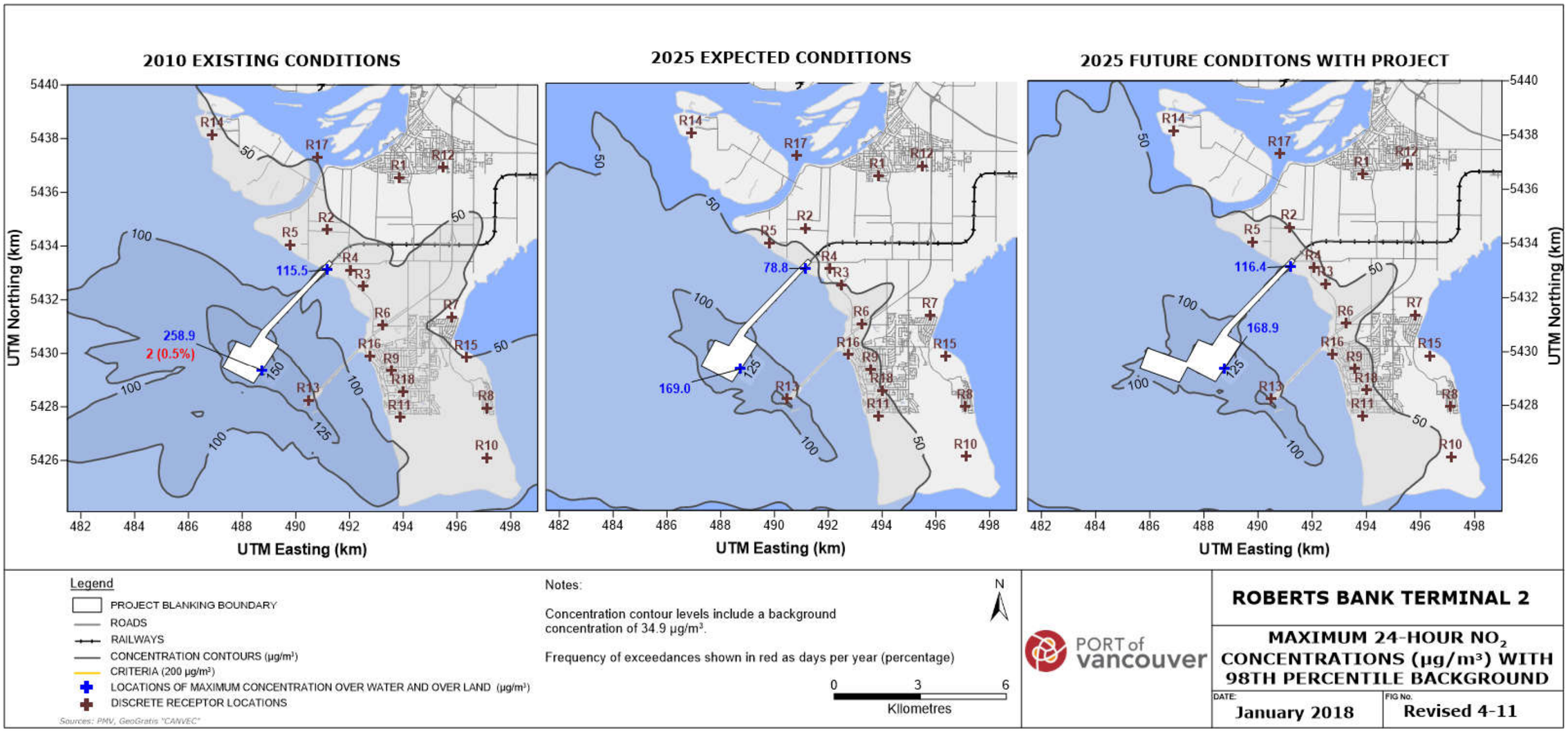


Figure IR6-24-A6 Annual NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land (Revised EIS Appendix 9.2-A, Figure 4-12)

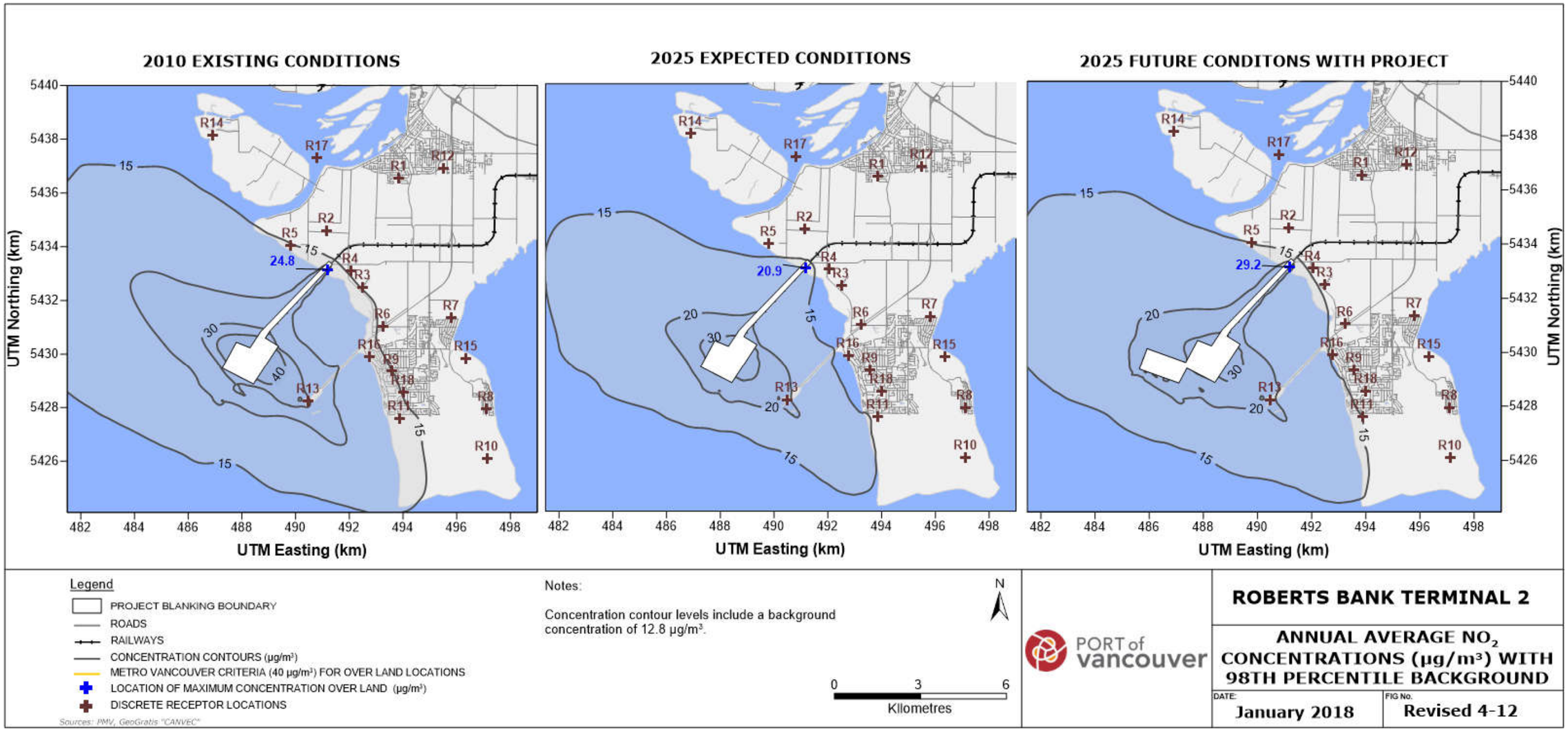


Figure IR6-24-A7 Annual NO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water (Revised EIS Appendix 9.2-A, Figure 4-12)

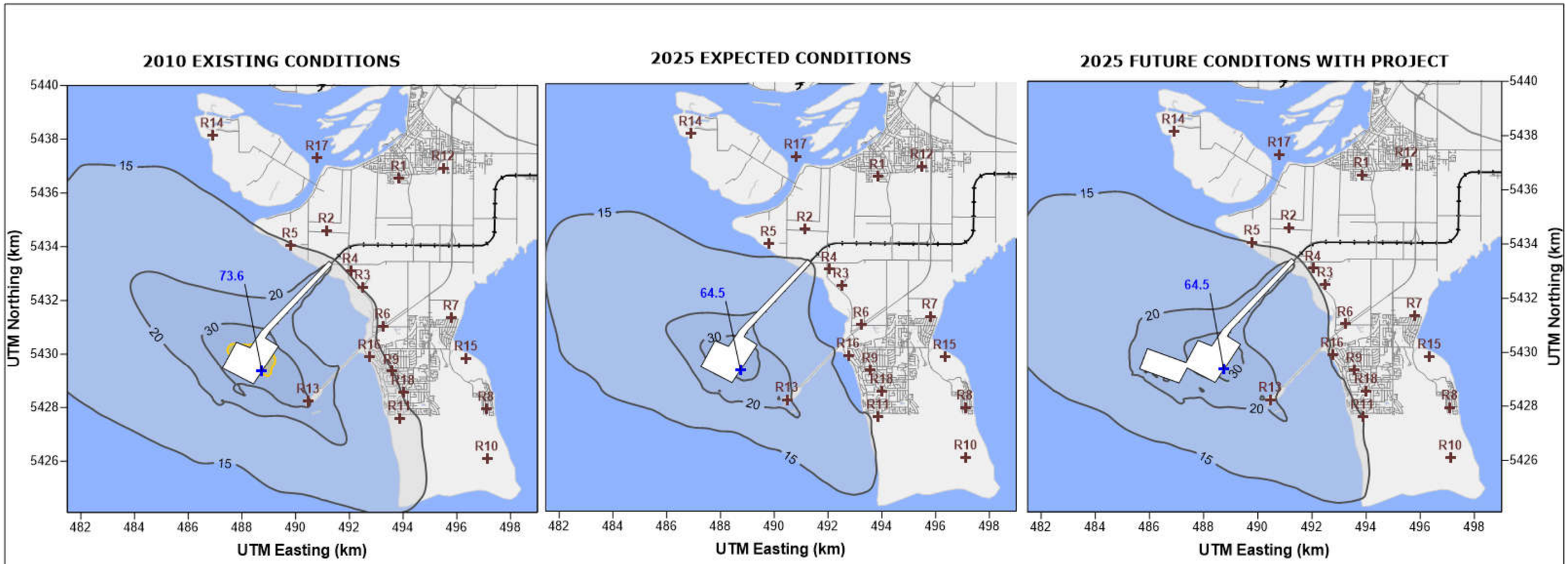
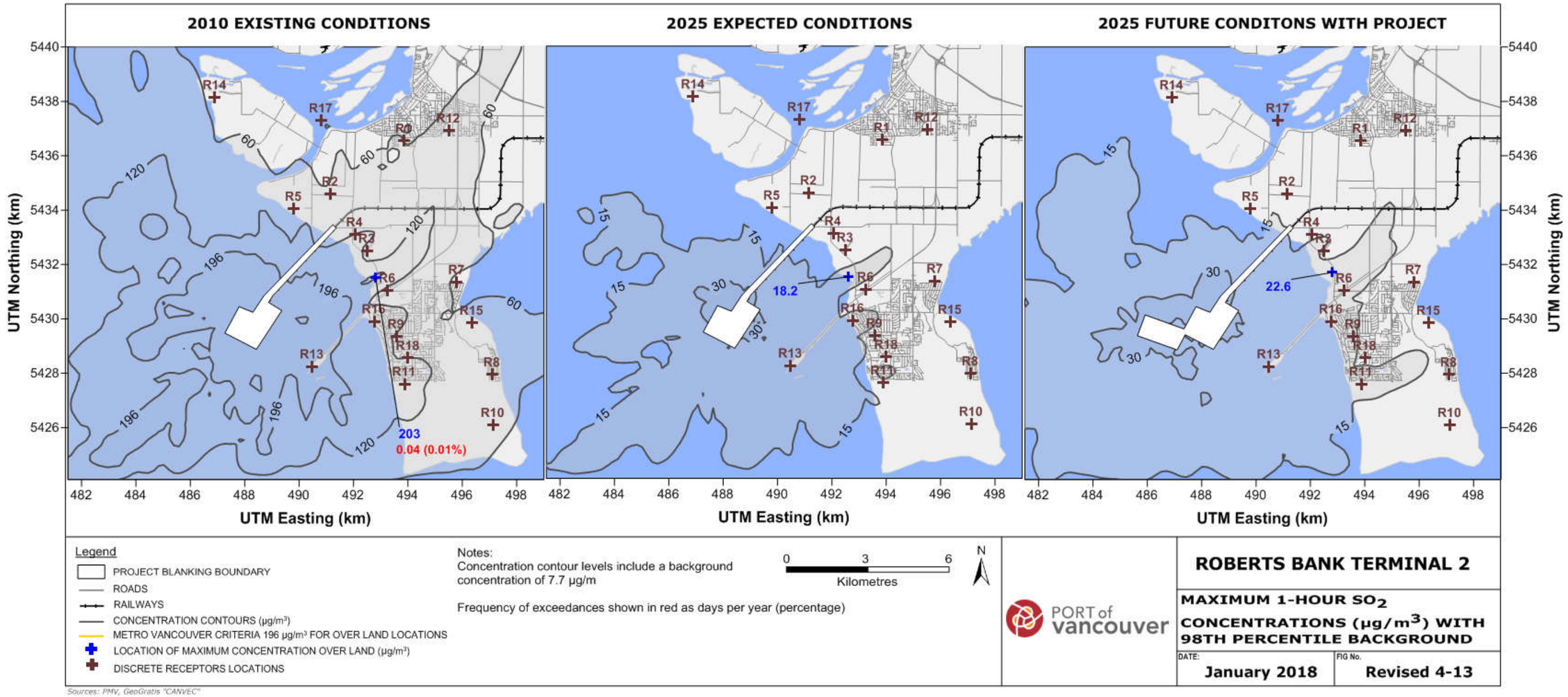
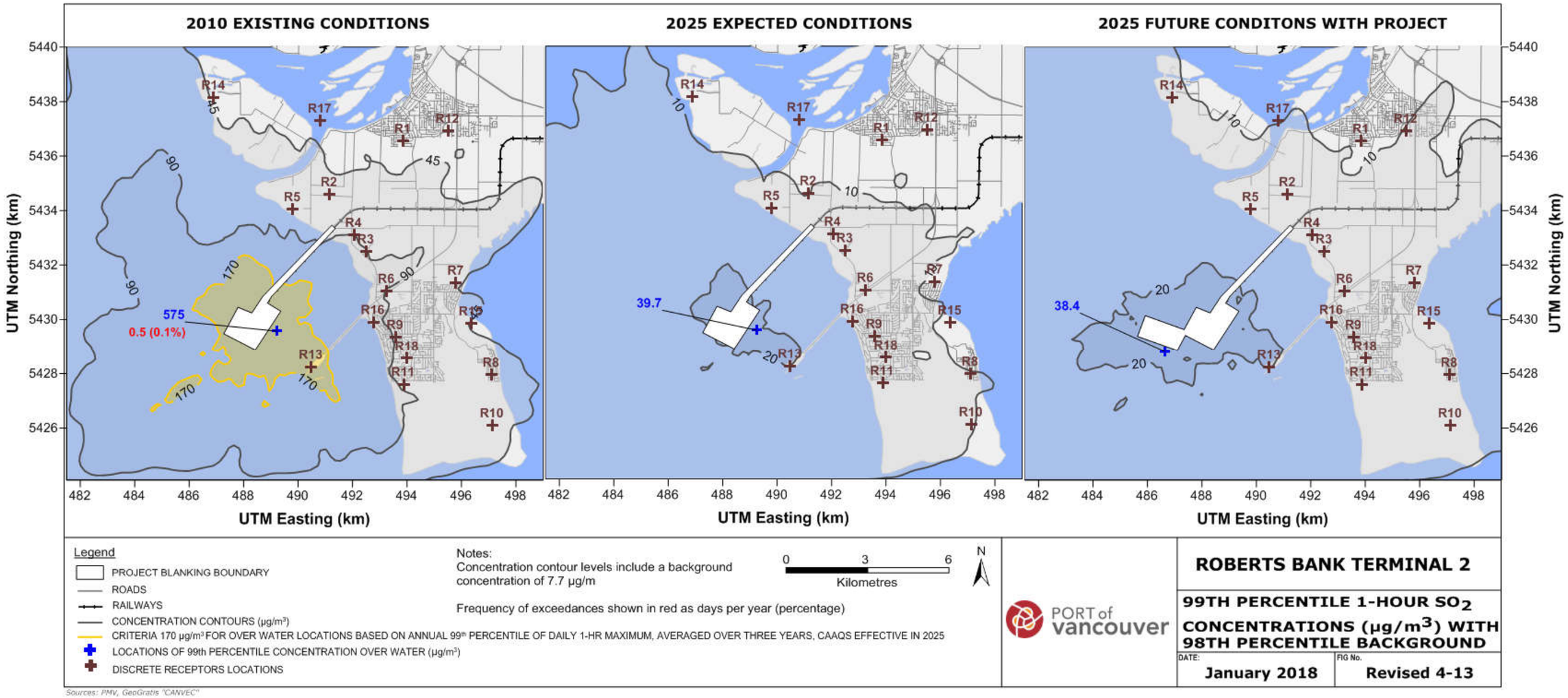


Figure IR6-24-A8 Maximum 1-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land (Revised EIS Appendix 9.2-A, Figure 4-13)



Note: For comparison purposes, the 2016 Metro Vancouver air quality objective (196 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding the objective applicable in 2010 (450 µg/m³).

Figure IR6-24-A9 99th Percentile 1-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water (Revised EIS Appendix 9.2-A, Figure 4-13)



Note: For comparison purposes, the 2016 Canadian Ambient Air Quality Standards (CAAQS; 170 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding the objective applicable in 2010 (450 µg/m³).

Figure IR6-24-A10 Maximum 24-hour SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-14)

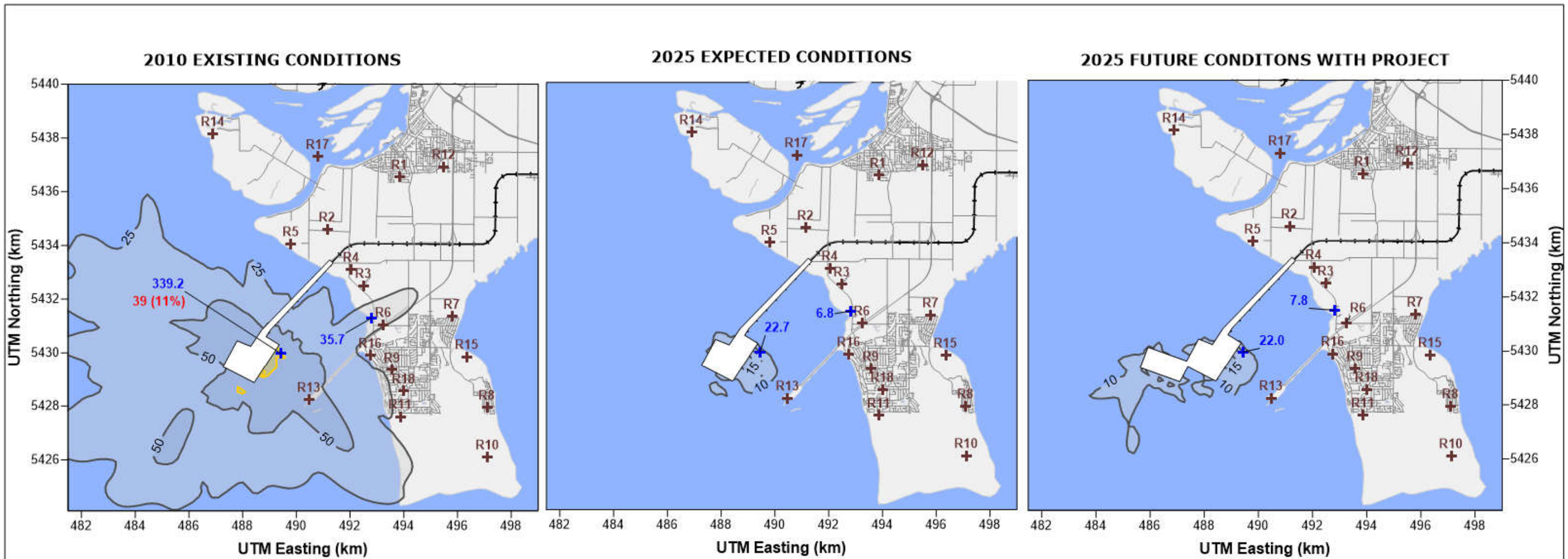
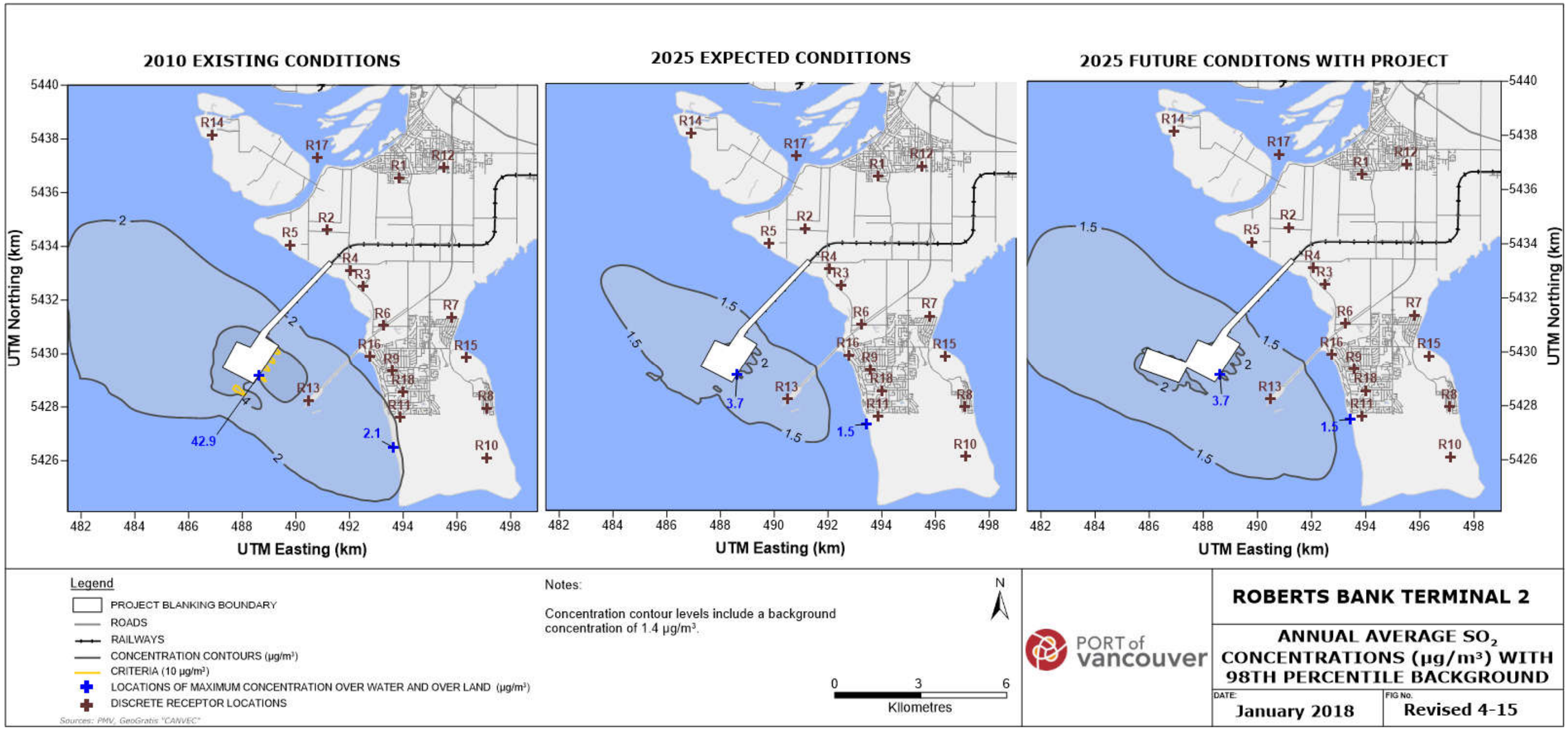


Figure IR6-24-A11 Annual SO_2 Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-15)



Note: For comparison purposes, the 2016 CAAQS (10 µg/m³) applicable to future conditions (2025) has also been applied to existing conditions (2010). The area of exceedance shown for existing conditions, therefore, is not an accurate spatial representation of the area exceeding the objective applicable in 2010 (30 µg/m³ and 25 µg/m³ for over land and over water locations, respectively).

Figure IR6-24-A12 Maximum 1-hour Formaldehyde Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-16)

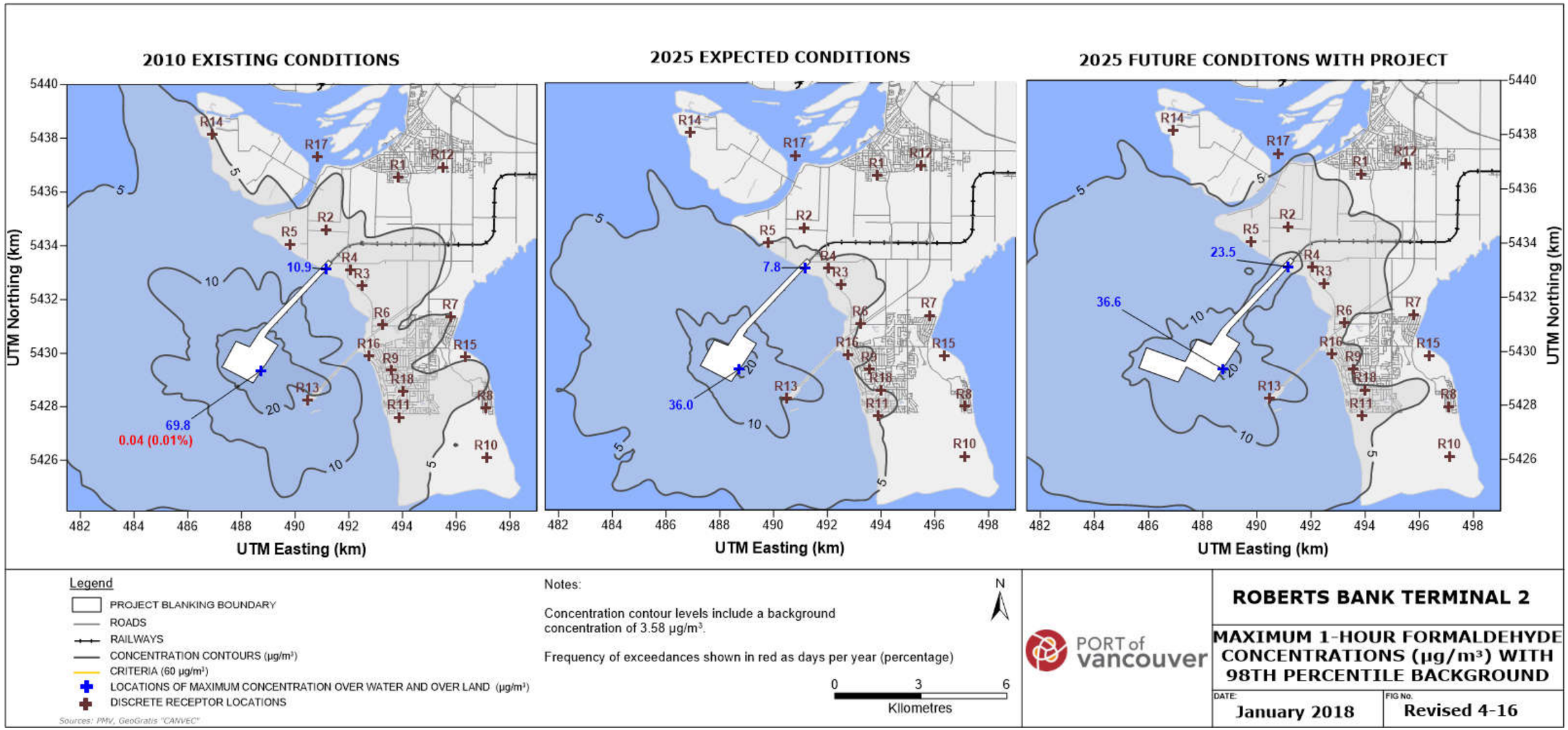


Figure IR6-24-A13 Maximum 24-hour PM Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-17)

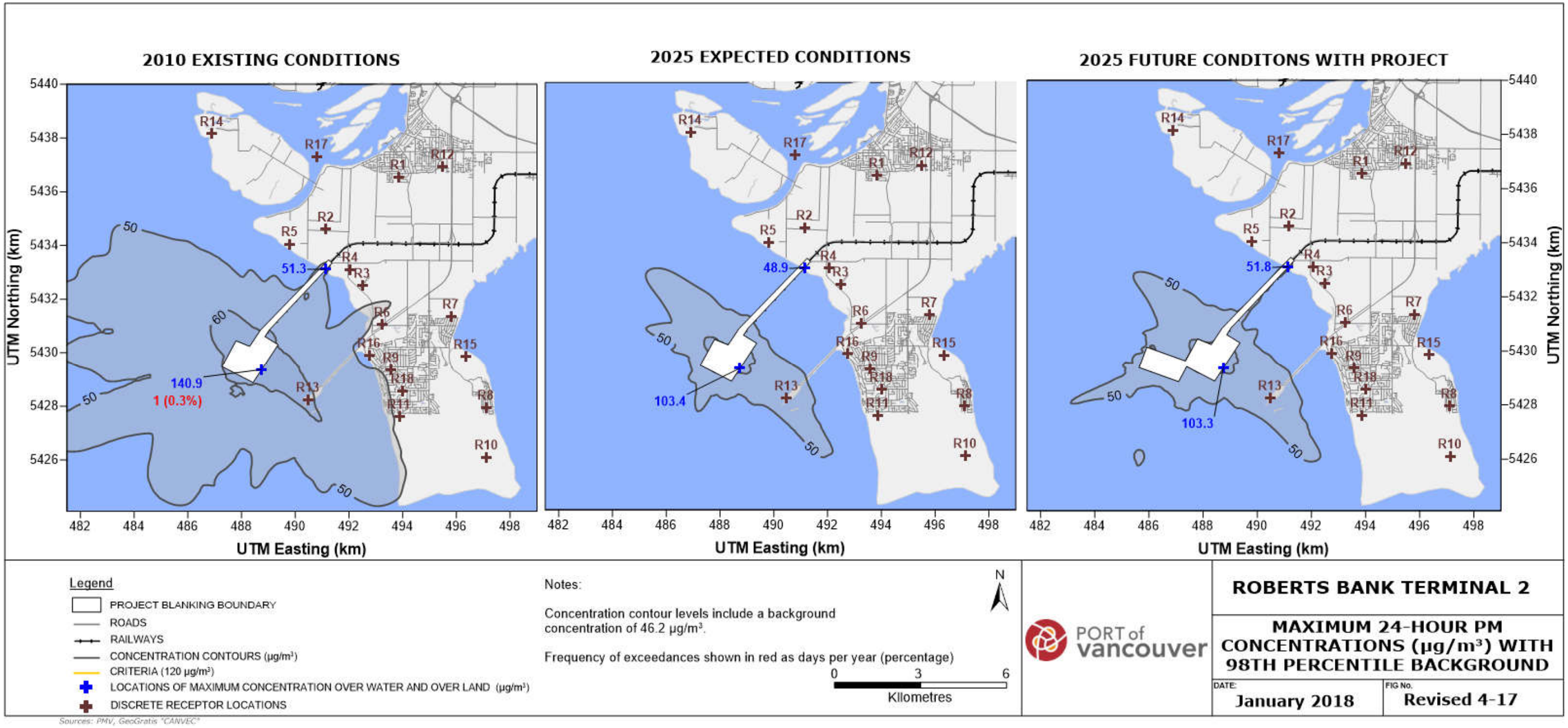


Figure IR6-24-A14 Annual PM Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-18)

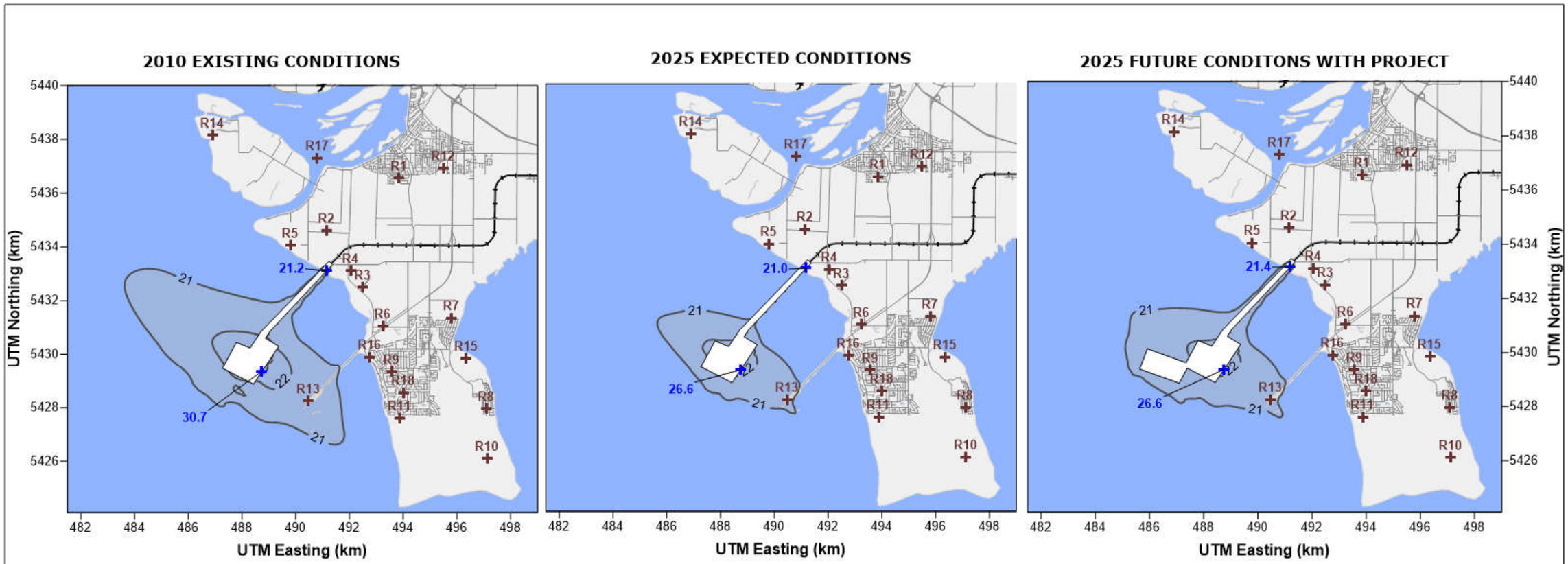


Figure IR6-24-A15 Maximum 24-hour PM_{10} Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-19)

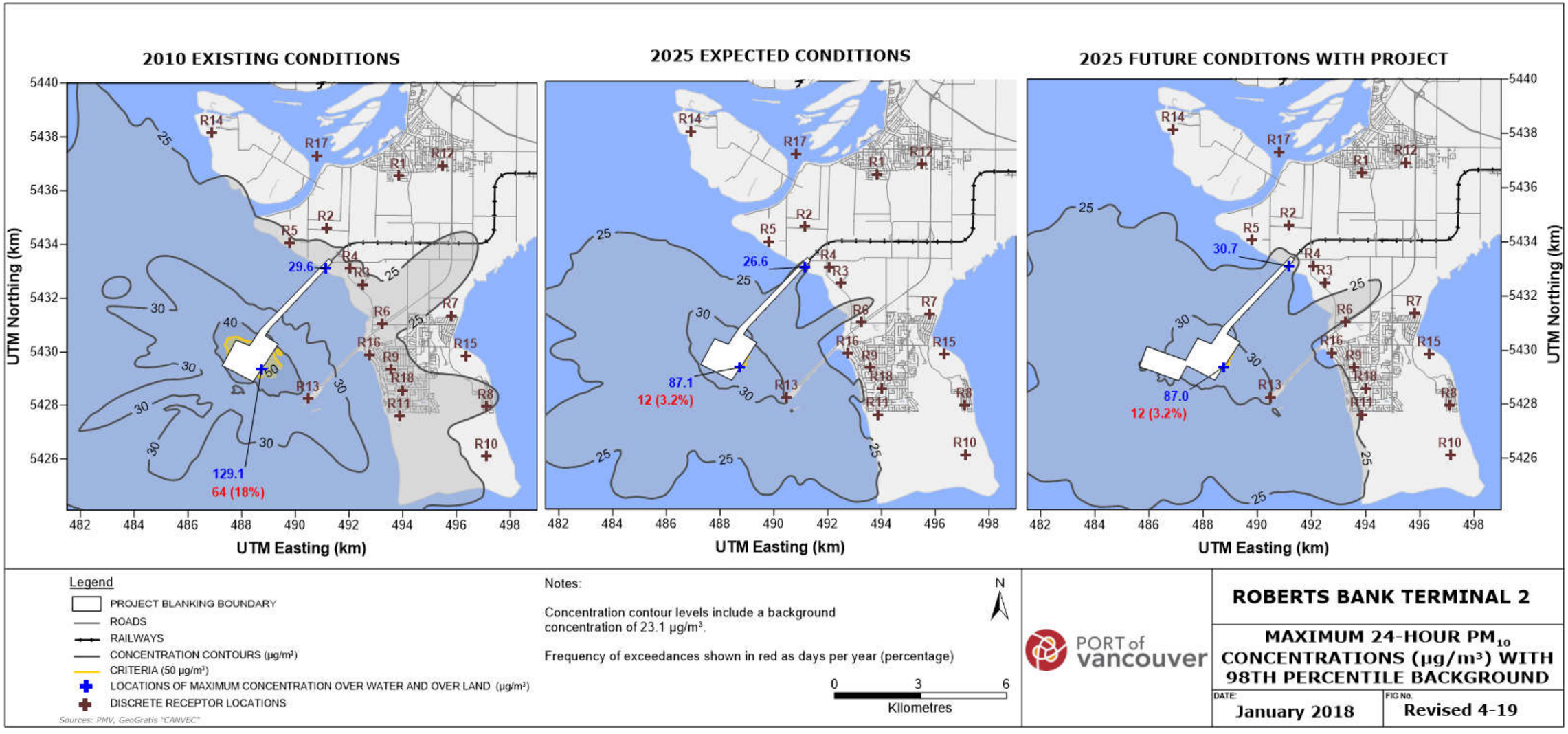


Figure IR6-24-A16 Annual PM_{10} Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-20)

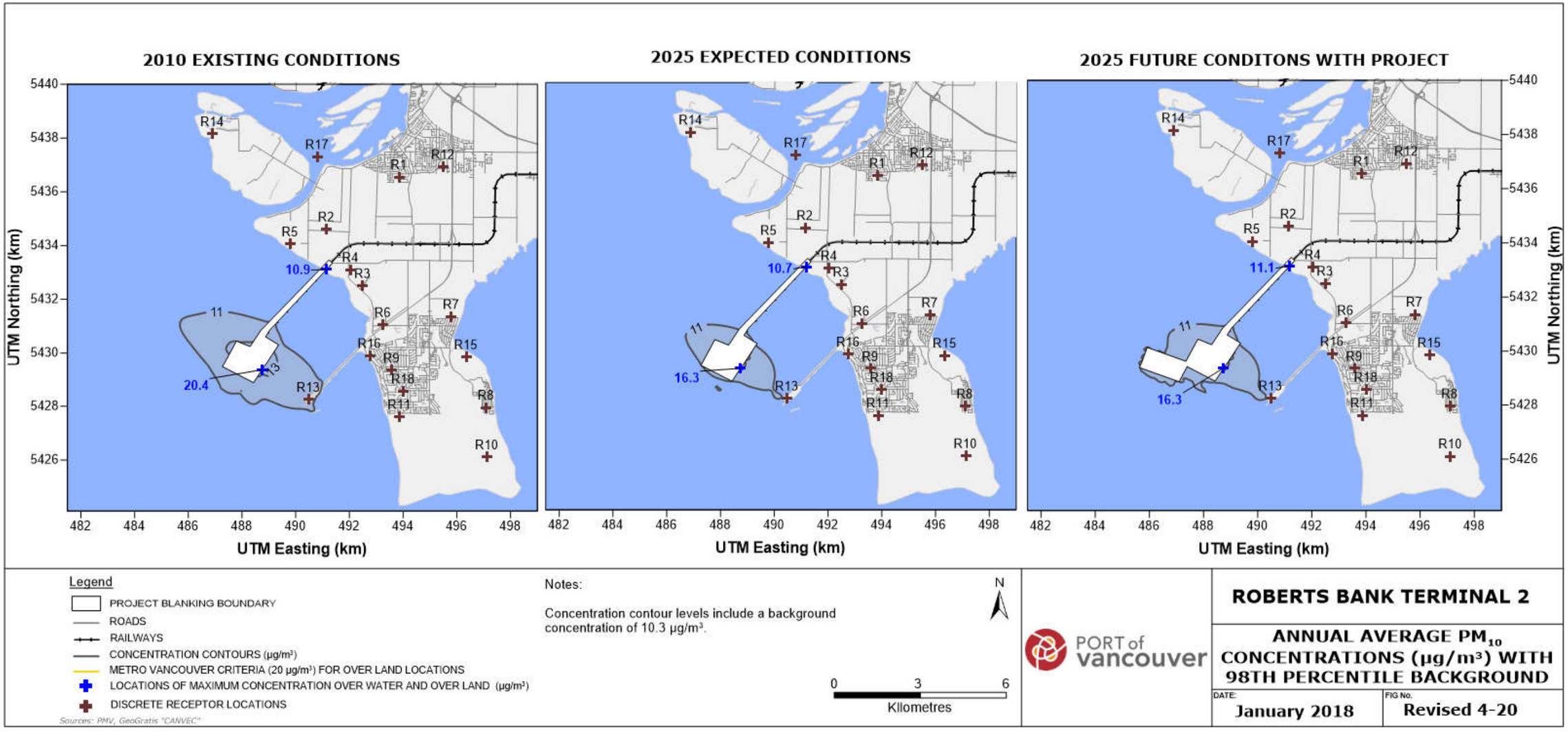


Figure IR6-24-A17 Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land (Revised EIS Appendix 9.2-A, Figure 4-21)

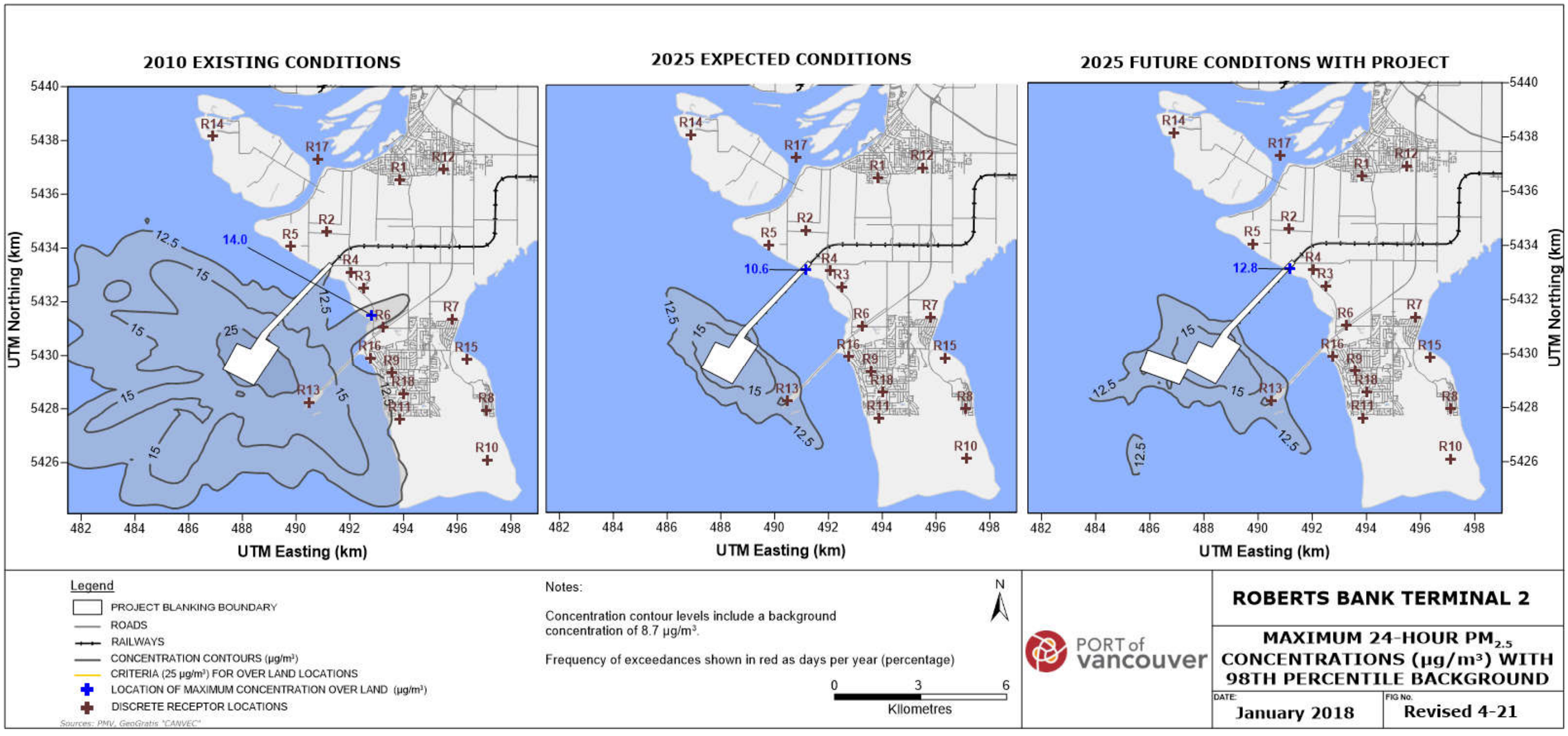


Figure IR6-24-A18 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Water (Revised EIS Appendix 9.2-A, Figure 4-21)

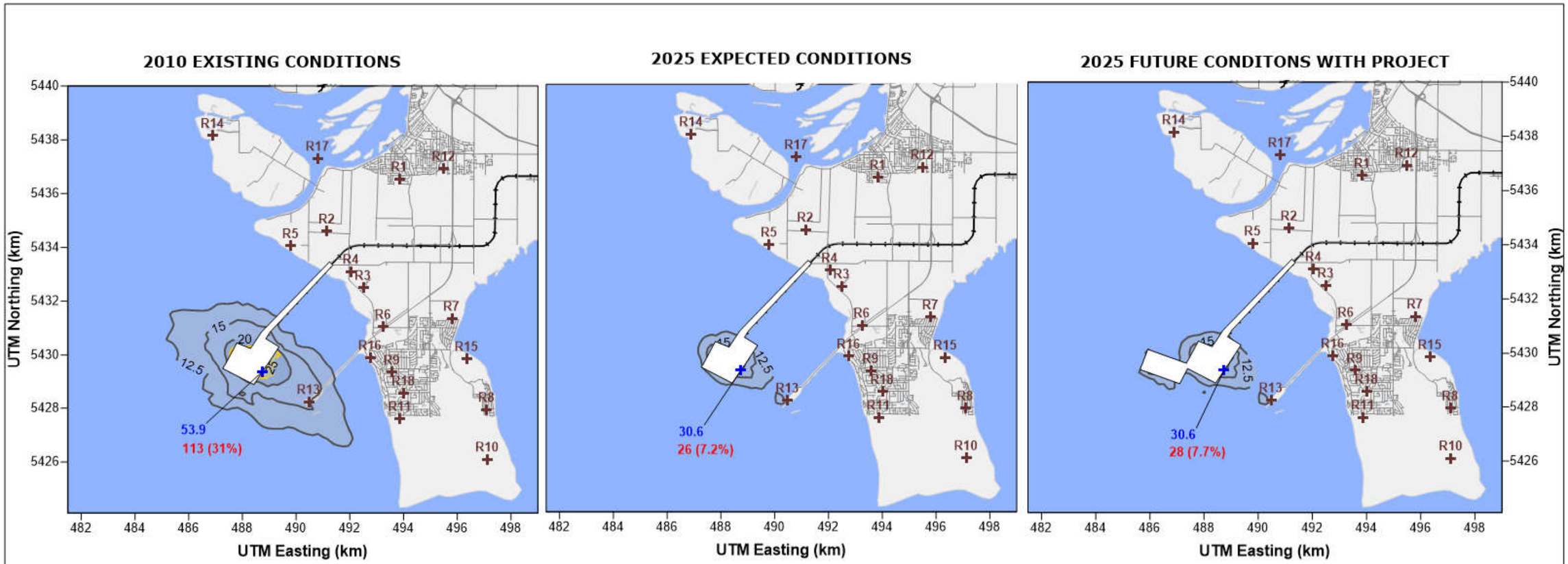


Figure IR6-24-A19 Annual $PM_{2.5}$ Concentrations (µg/m³) under Existing, Expected, and Future Conditions – Over Land and Over Water (Revised EIS Appendix 9.2-A, Figure 4-22)

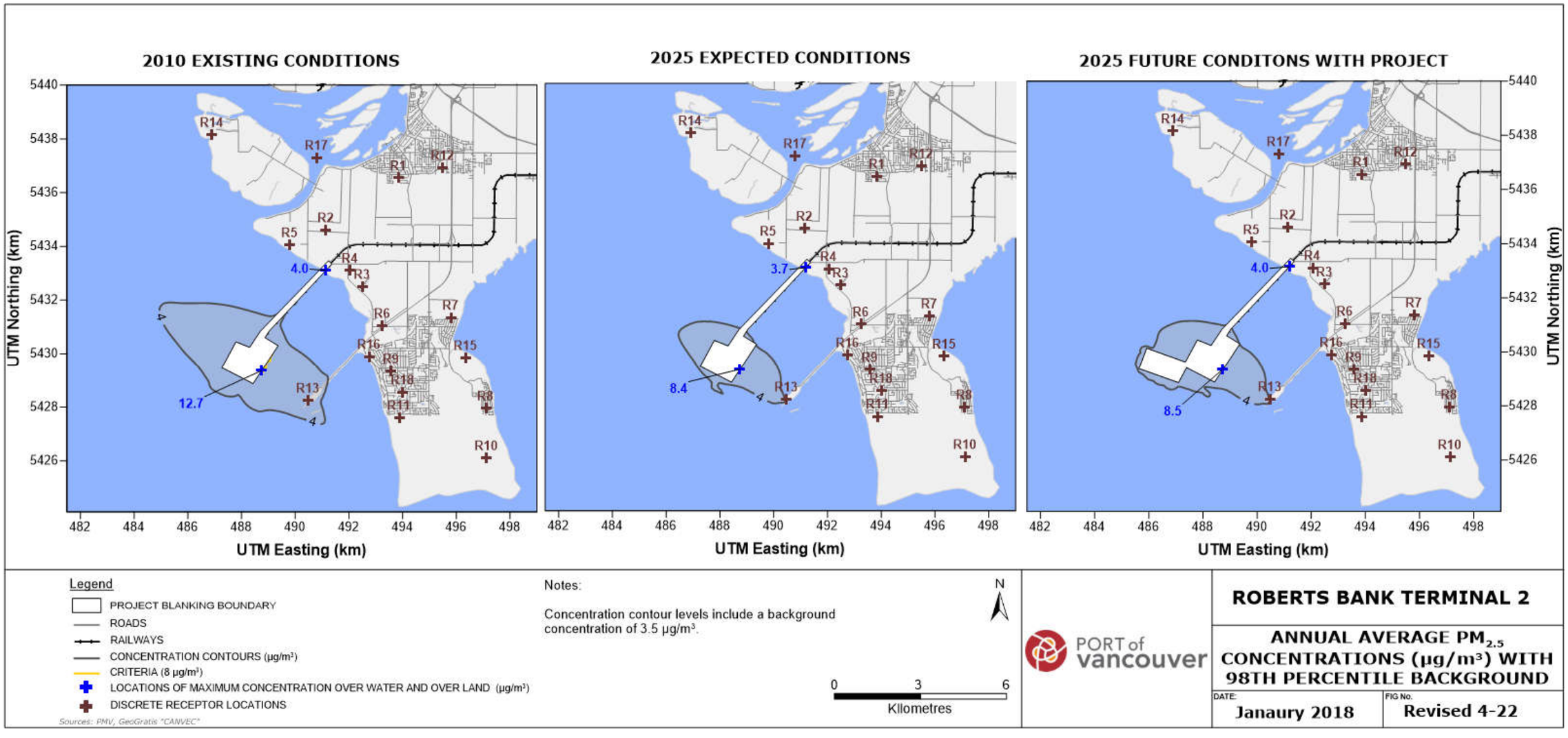


Figure IR6-24-A20 Construction Phase Average Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) – Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-1)

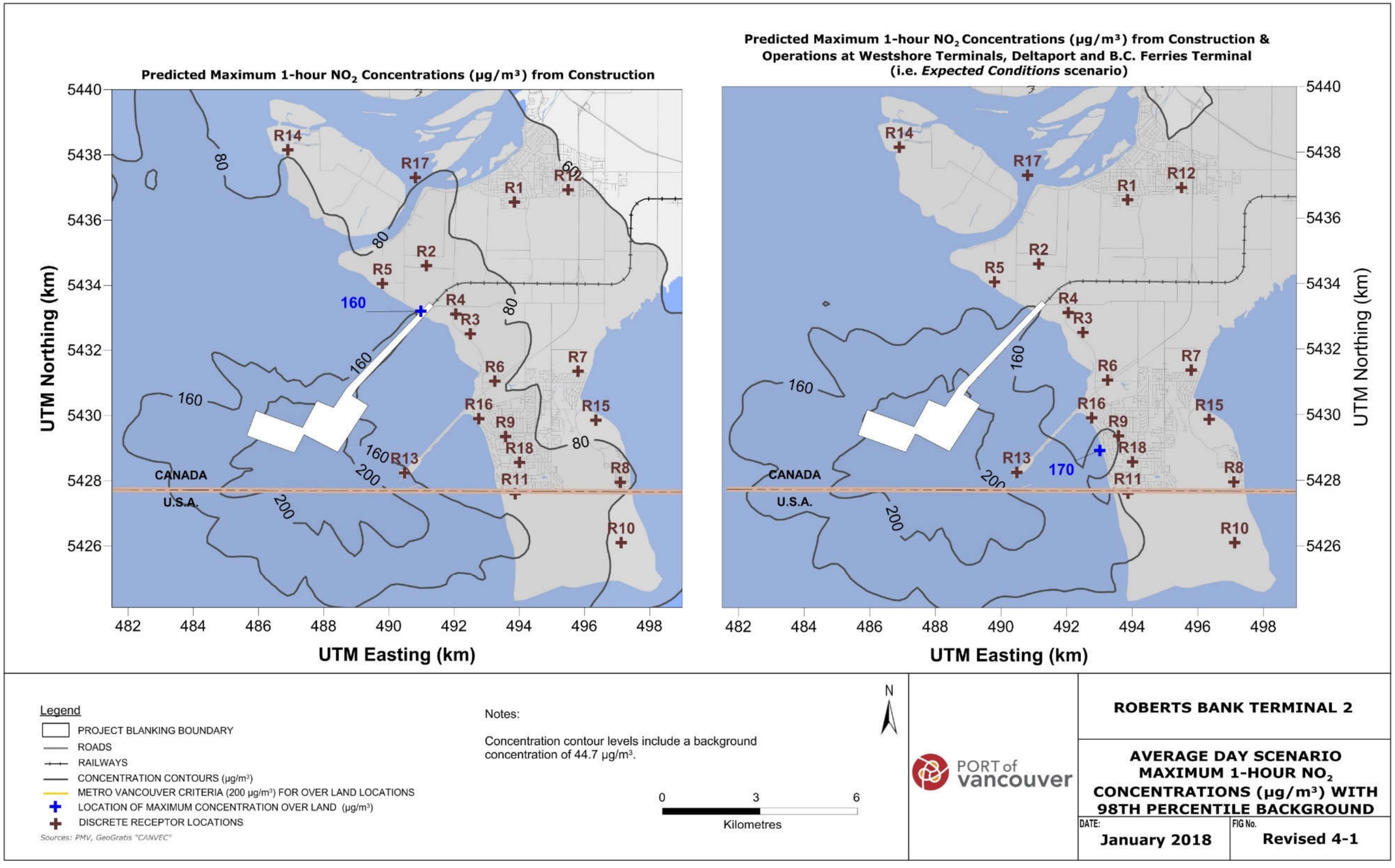


Figure IR6-24-A21 Construction Phase Average Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³) – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-1)

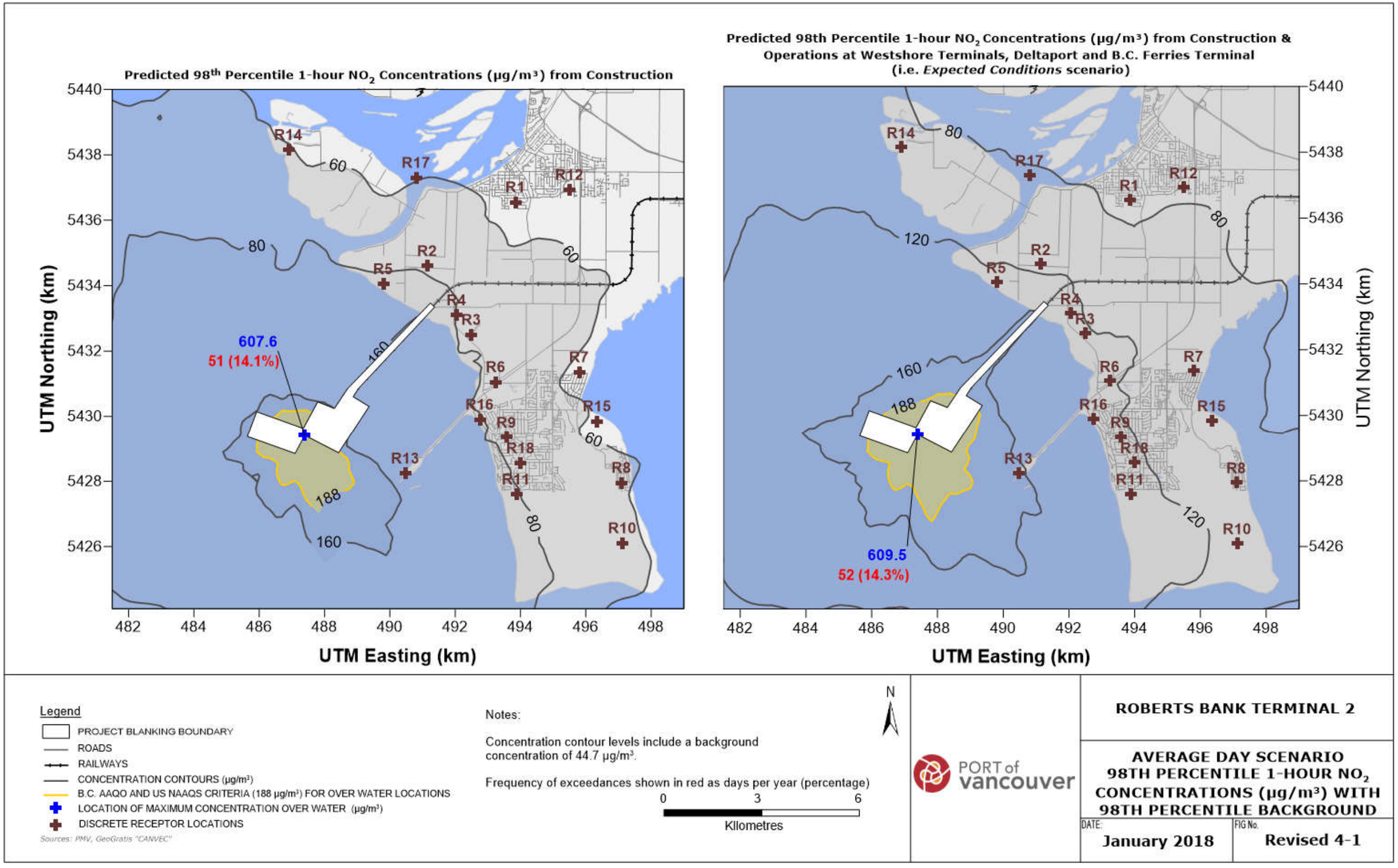


Figure IR6-24-A22 Construction Phase Average Day Scenario – Maximum 24-hour NO_2 Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-2)

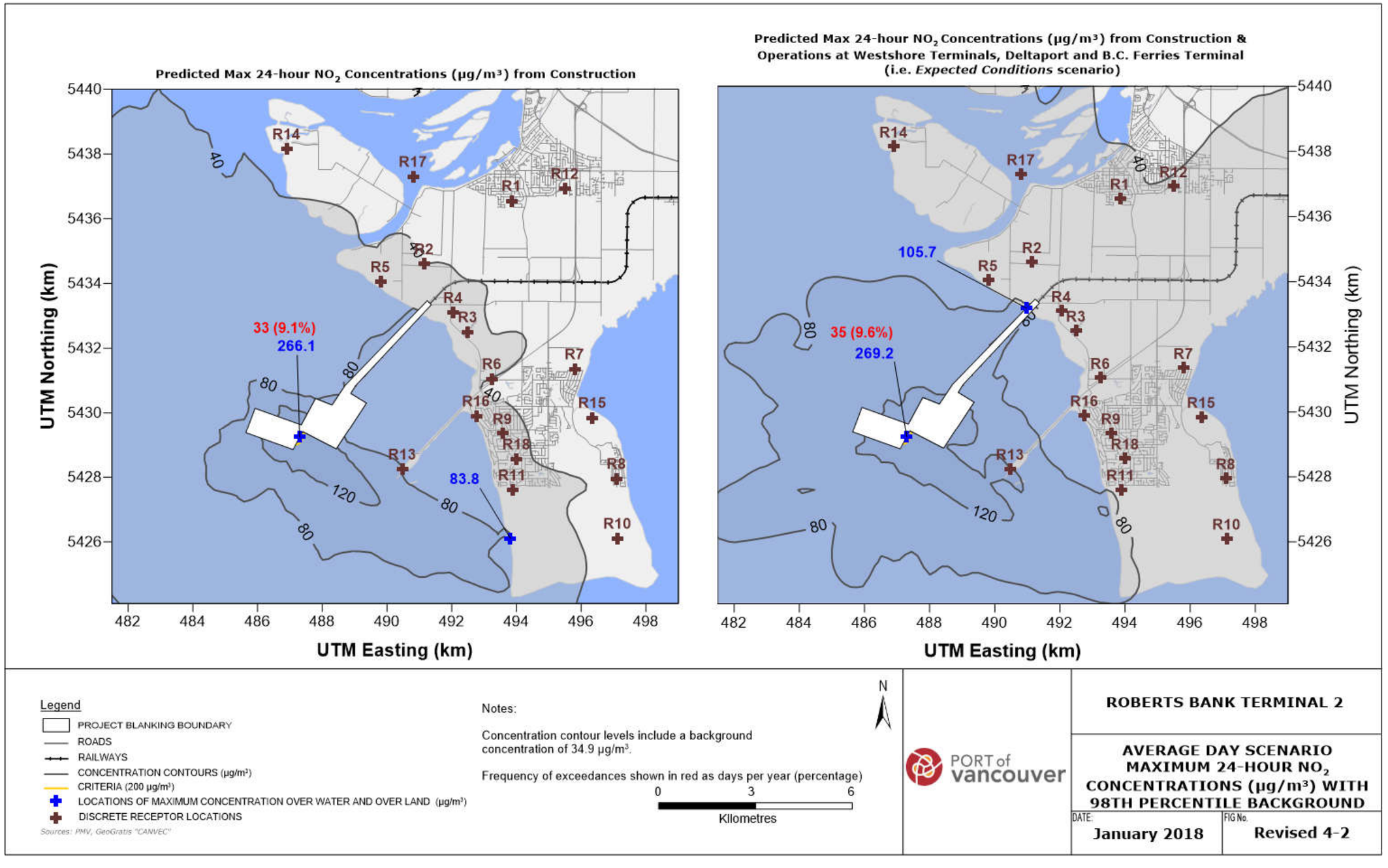


Figure IR6-24-A23 Construction Phase Average Day Scenario – Annual NO_2 Concentrations (µg/m³) – Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-3)

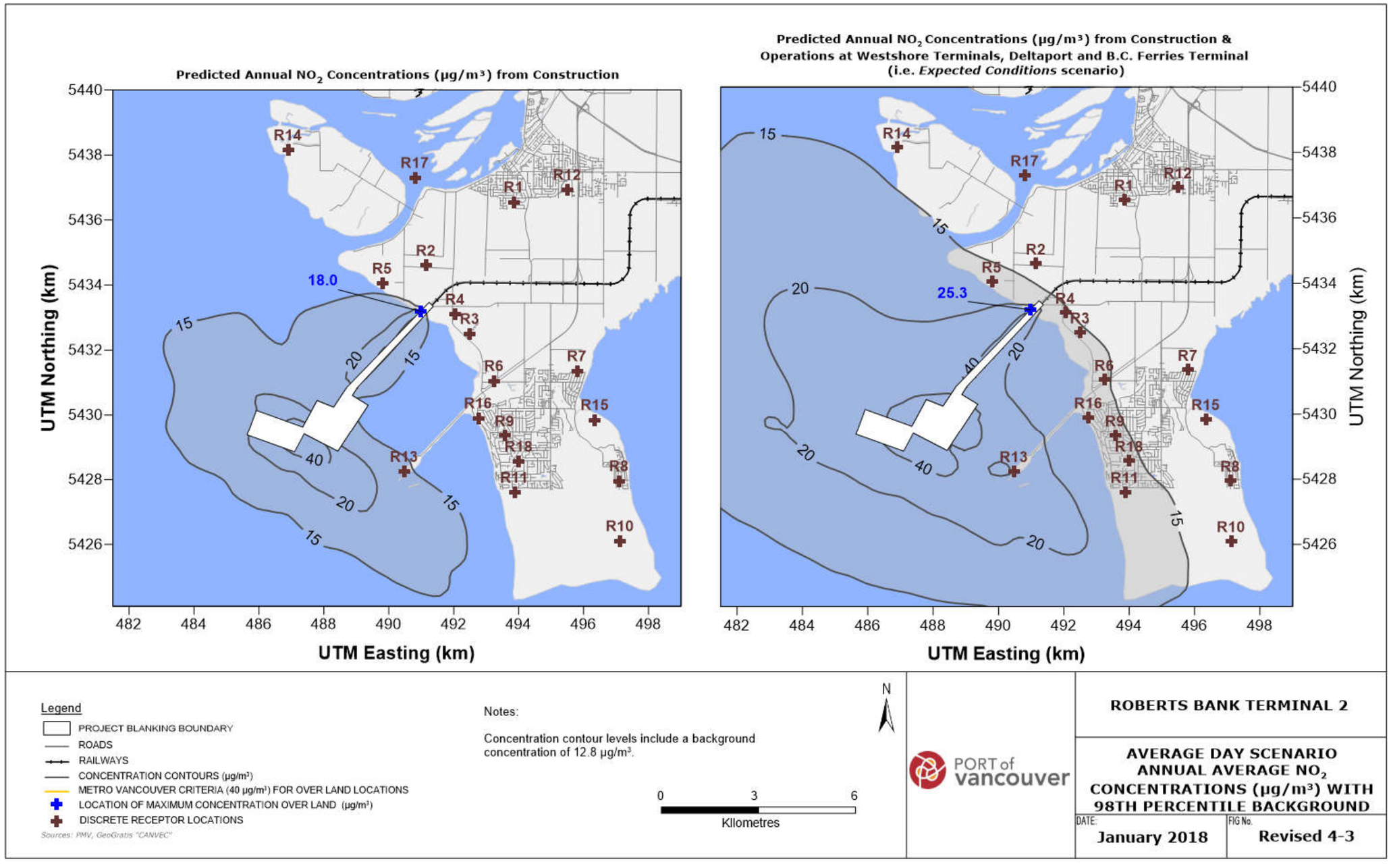


Figure IR6-24-A24 Construction Phase Average Day Scenario – Annual NO_2 Concentrations (µg/m³) – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-3)

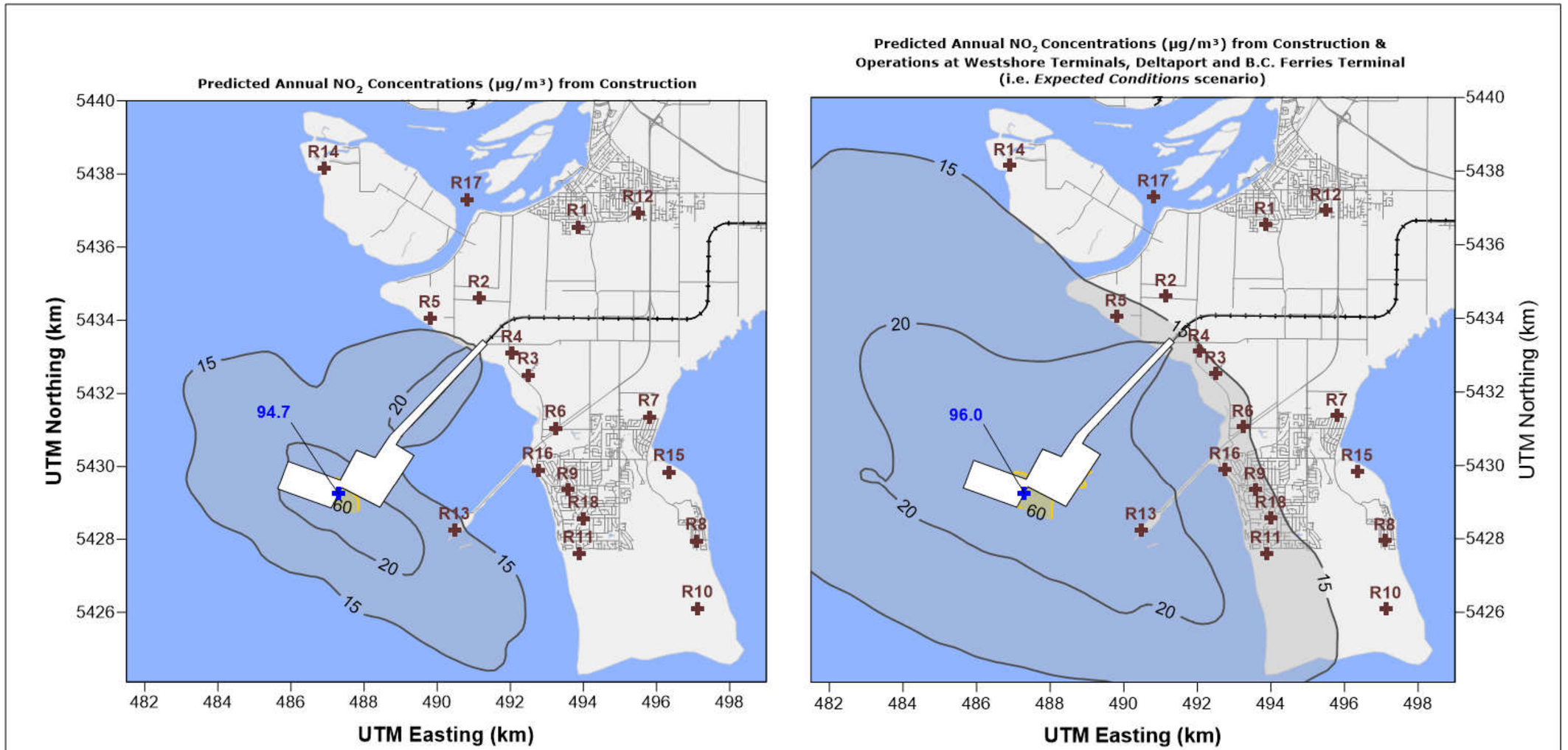


Figure IR6-24-A25 Construction Phase Average Day Scenario – Maximum 24-hour PM Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-4)

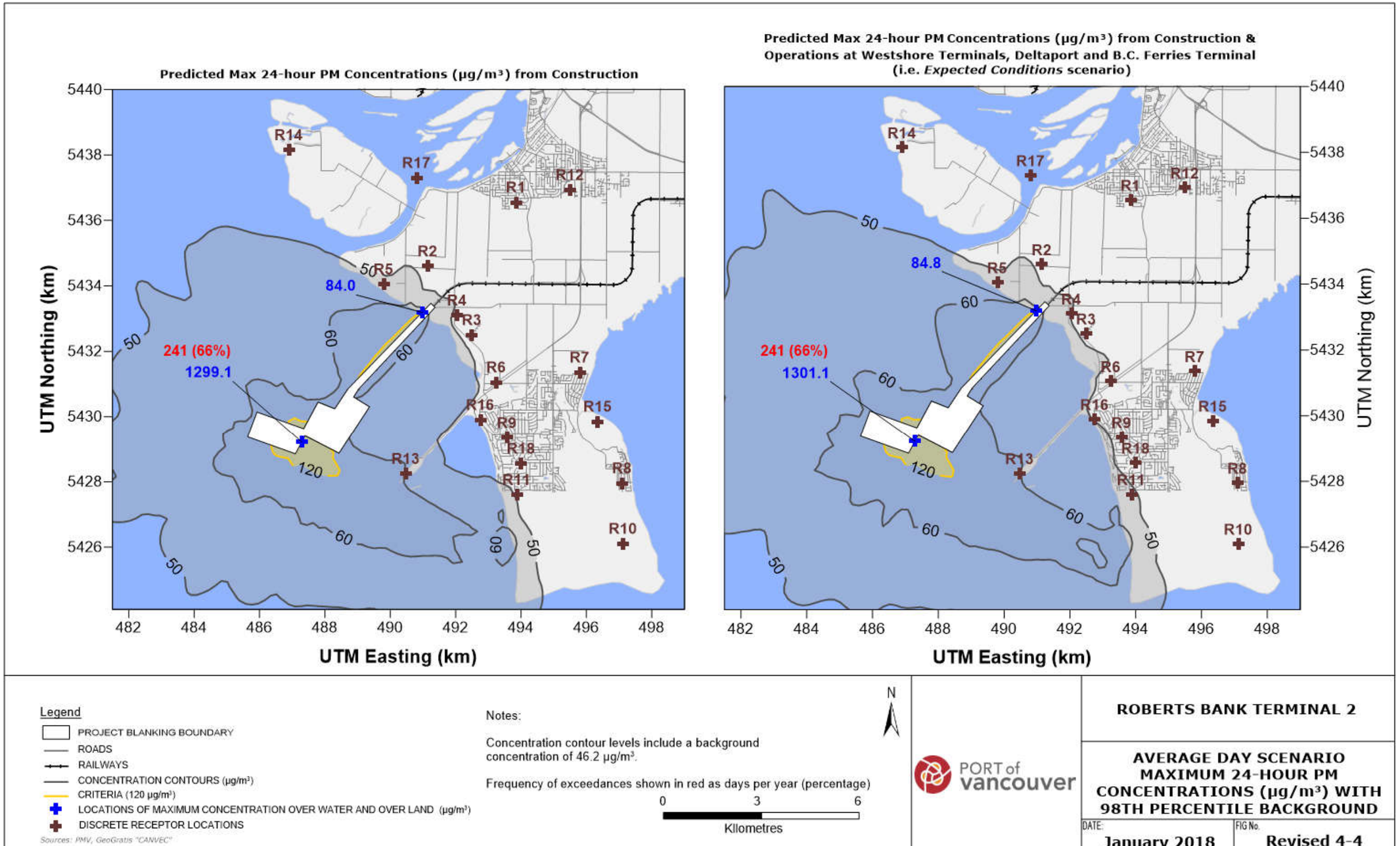


Figure IR6-24-A26 Construction Phase Average Day Scenario – Annual PM Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-5)

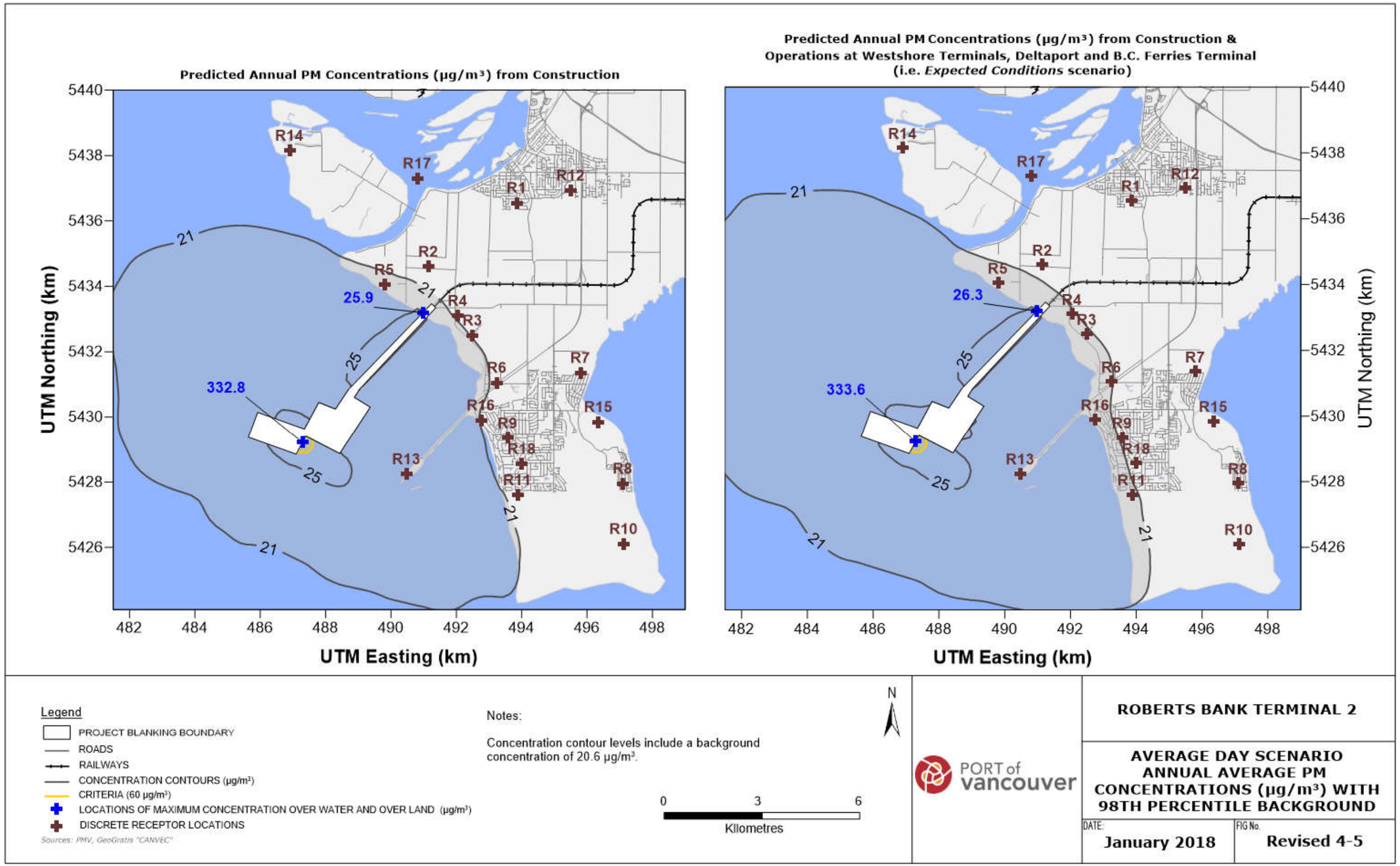


Figure IR6-24-A27 Construction Phase Average Day Scenario – Maximum 24-hour PM_{10} Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-6)

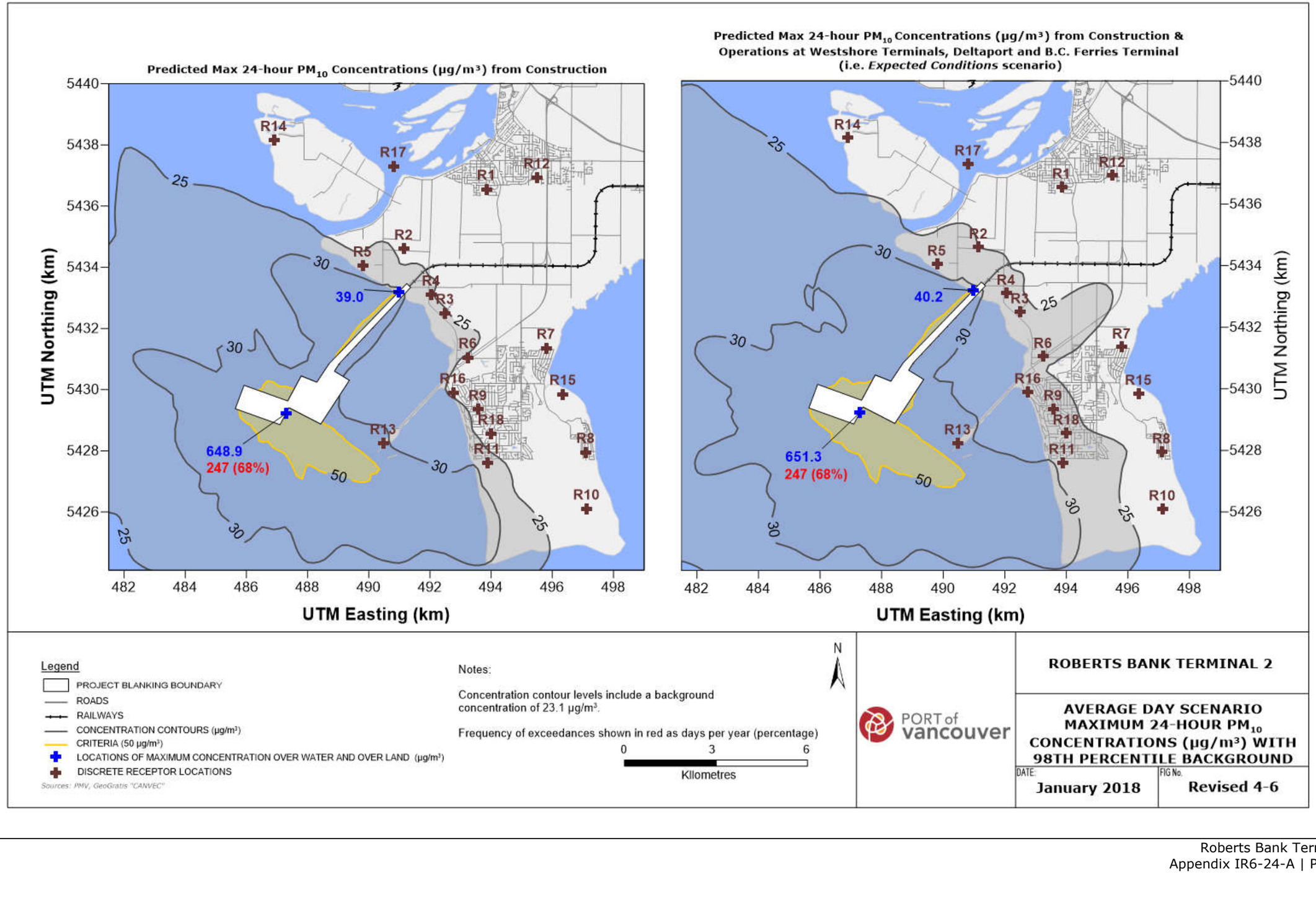


Figure IR6-24-A28 Construction Phase Average Day Scenario – Annual PM_{10} Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-7)

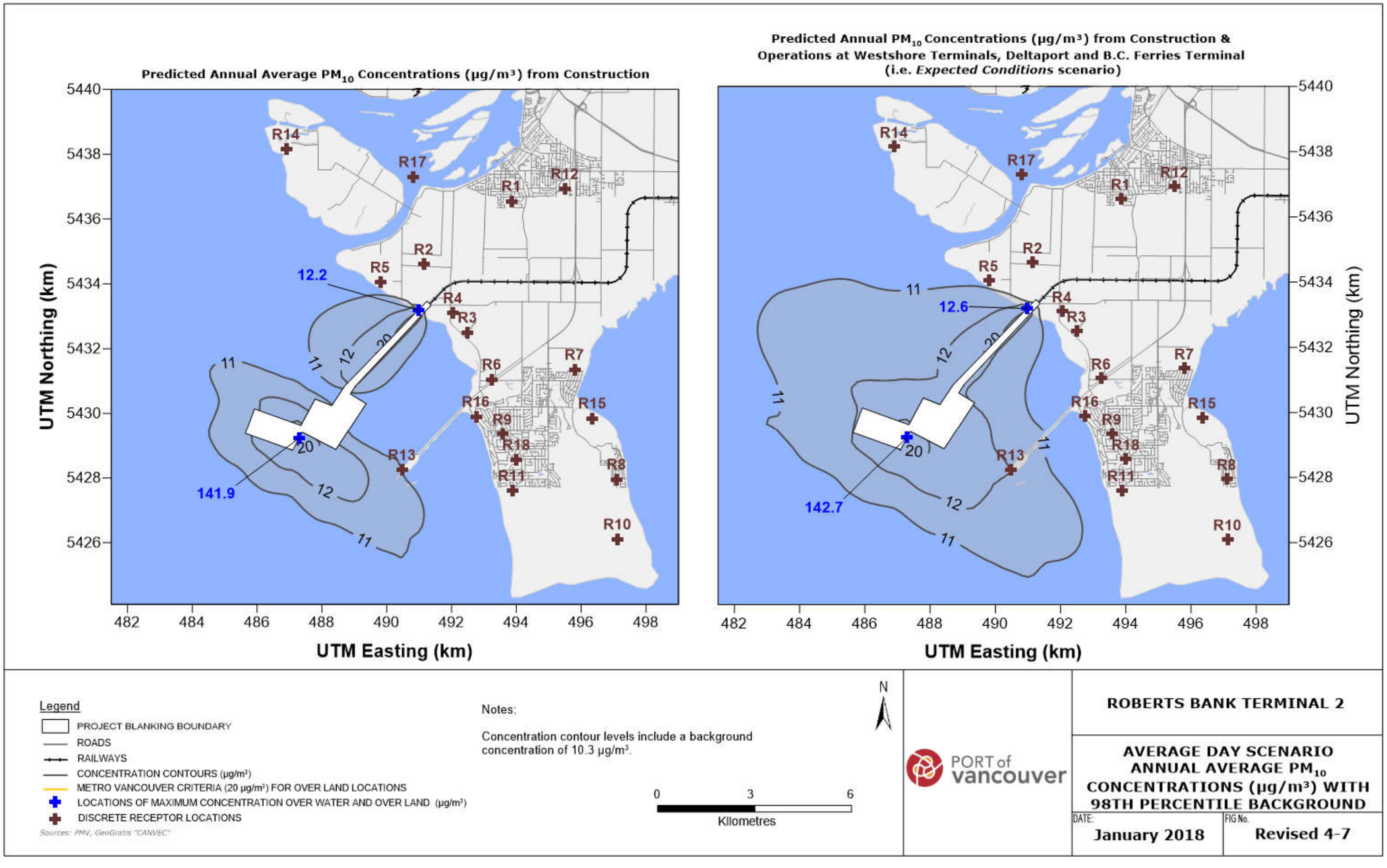


Figure IR6-24-A29 Construction Phase Average Day Scenario – Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) U.S. Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-8)

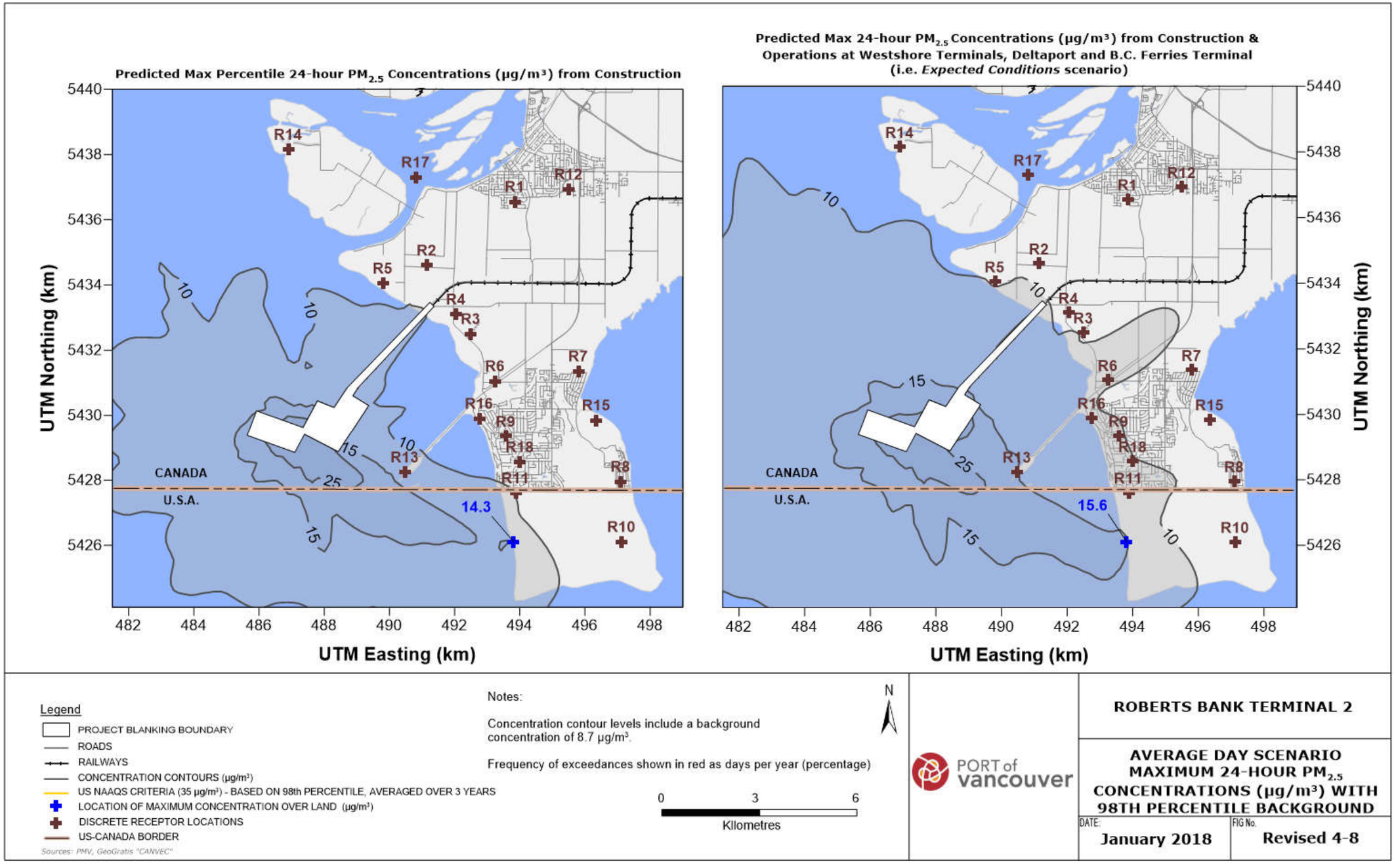


Figure IR6-24-A30 Construction Phase Average Day Scenario – 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-8)

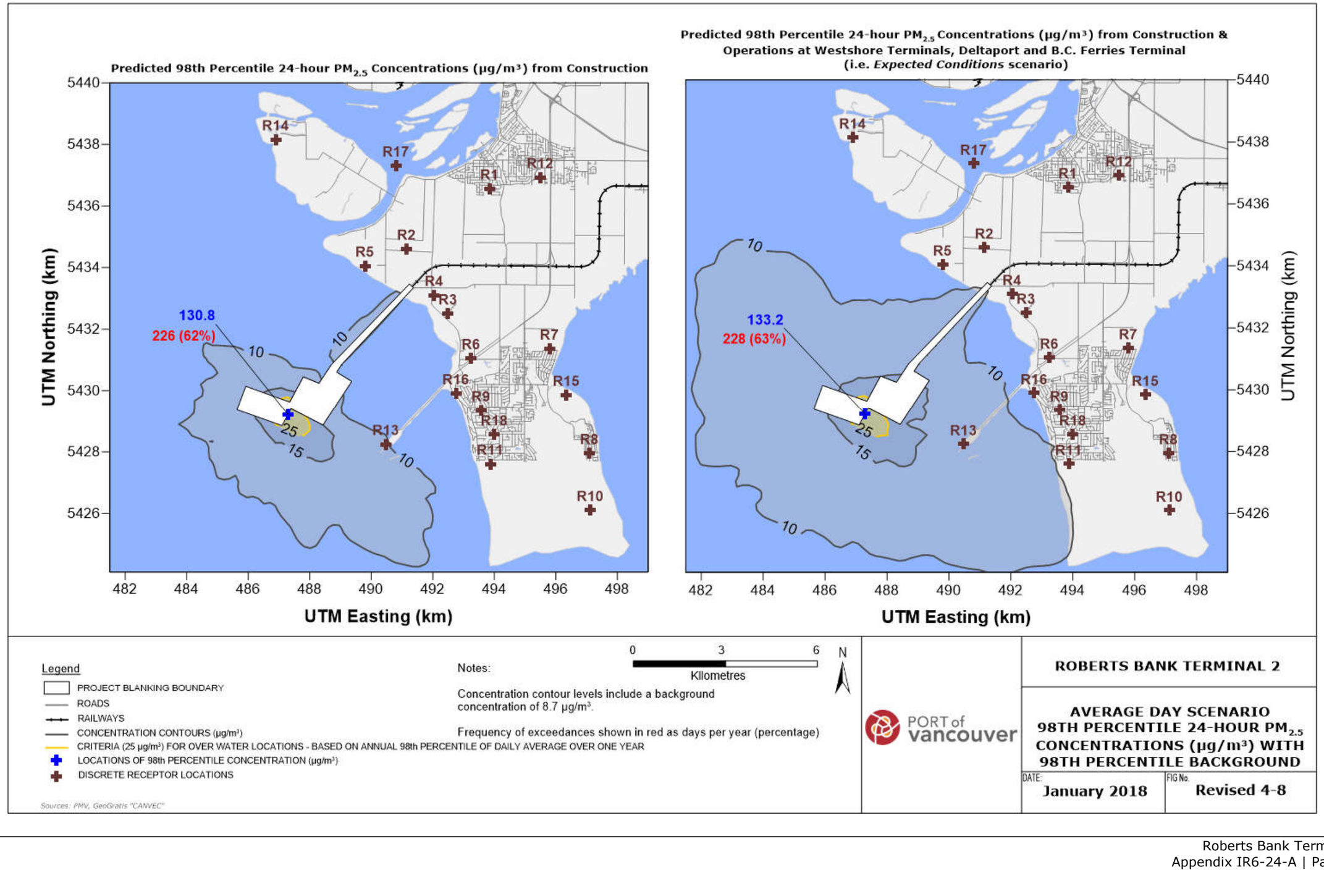


Figure IR6-24-A31 Construction Phase Average Day Scenario – Annual $PM_{2.5}$ Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-9)

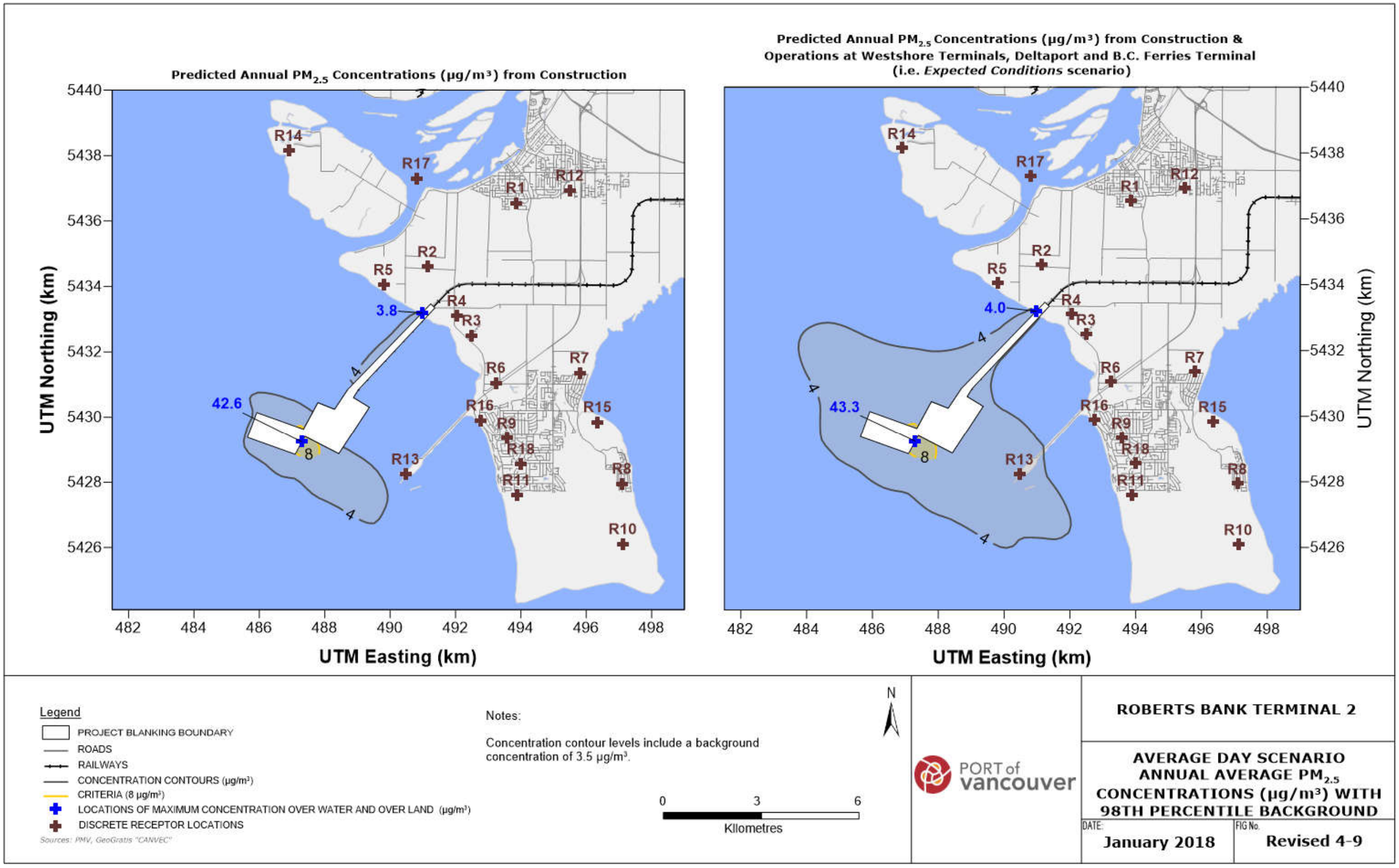


Figure IR6-24-A32 Construction Phase Peak Day Scenario – Maximum 1-hour NO_2 Concentrations (µg/m³) – Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-10)

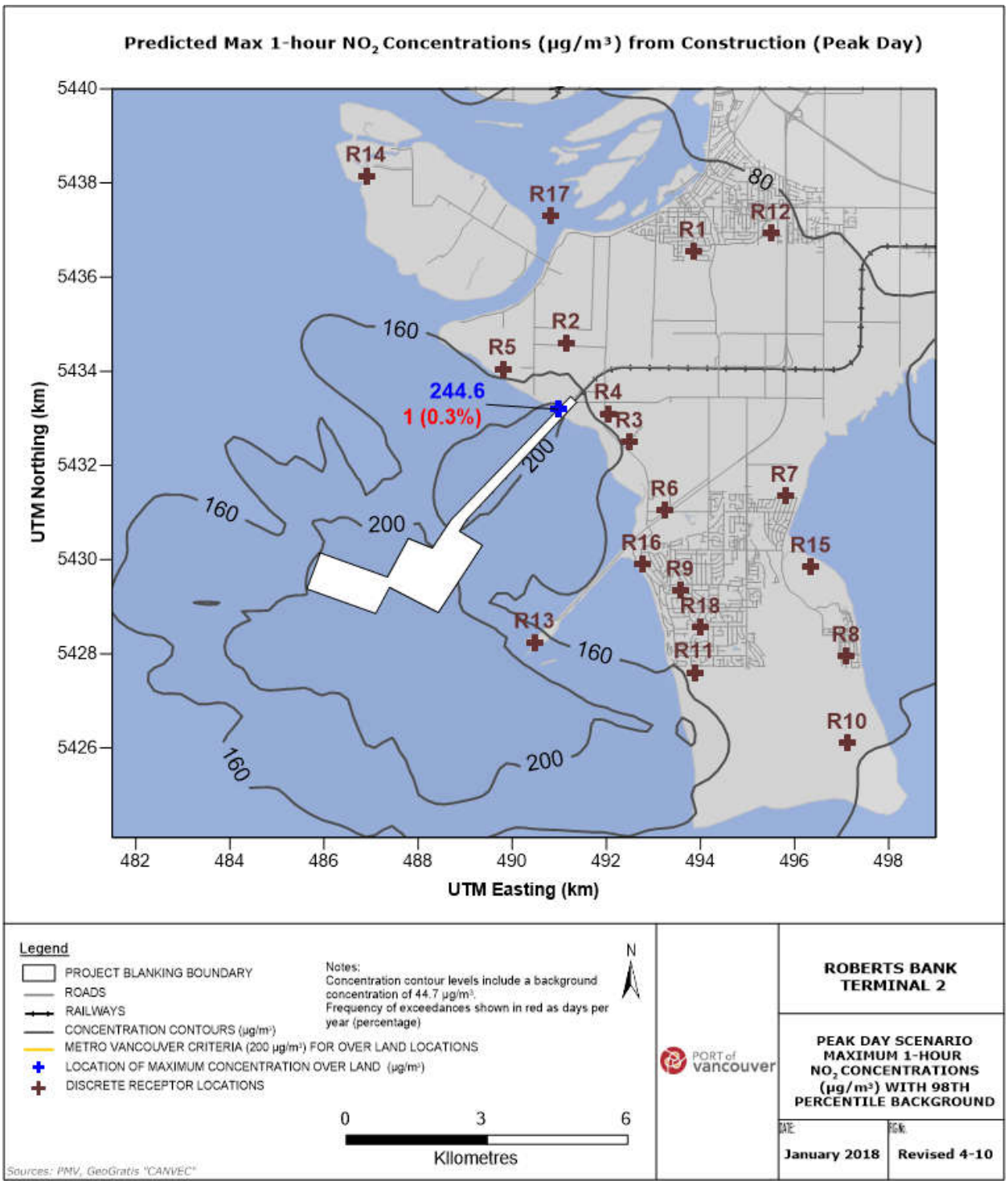


Figure IR6-24-A33 Construction Phase Peak Day Scenario – 98th Percentile 1-hour NO_2 Concentrations (µg/m³), including 98th Percentile Background – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-10)

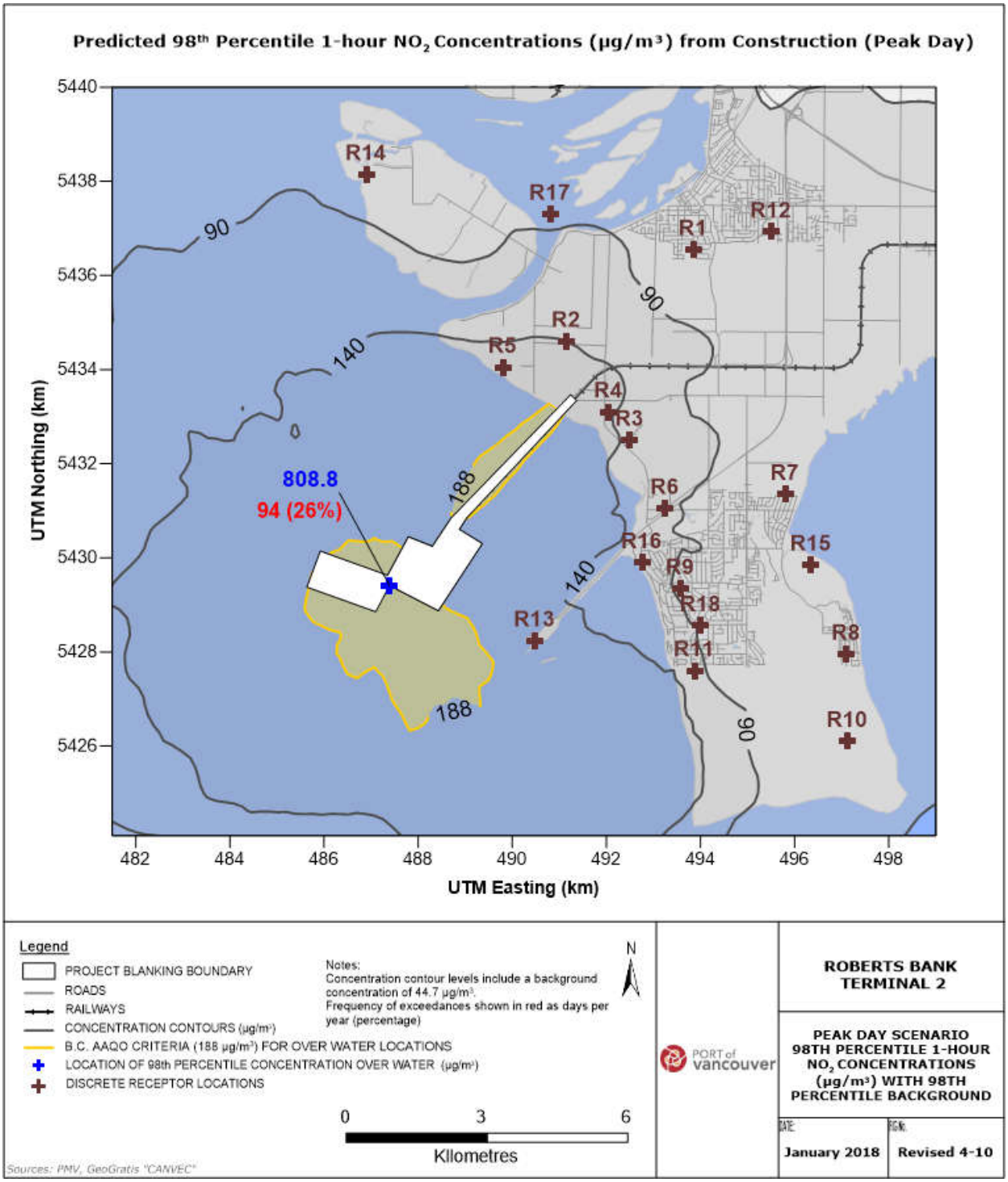


Figure IR6-24-A34 Construction Phase Peak Day Scenario – Maximum 24-hour NO_2 Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-11)

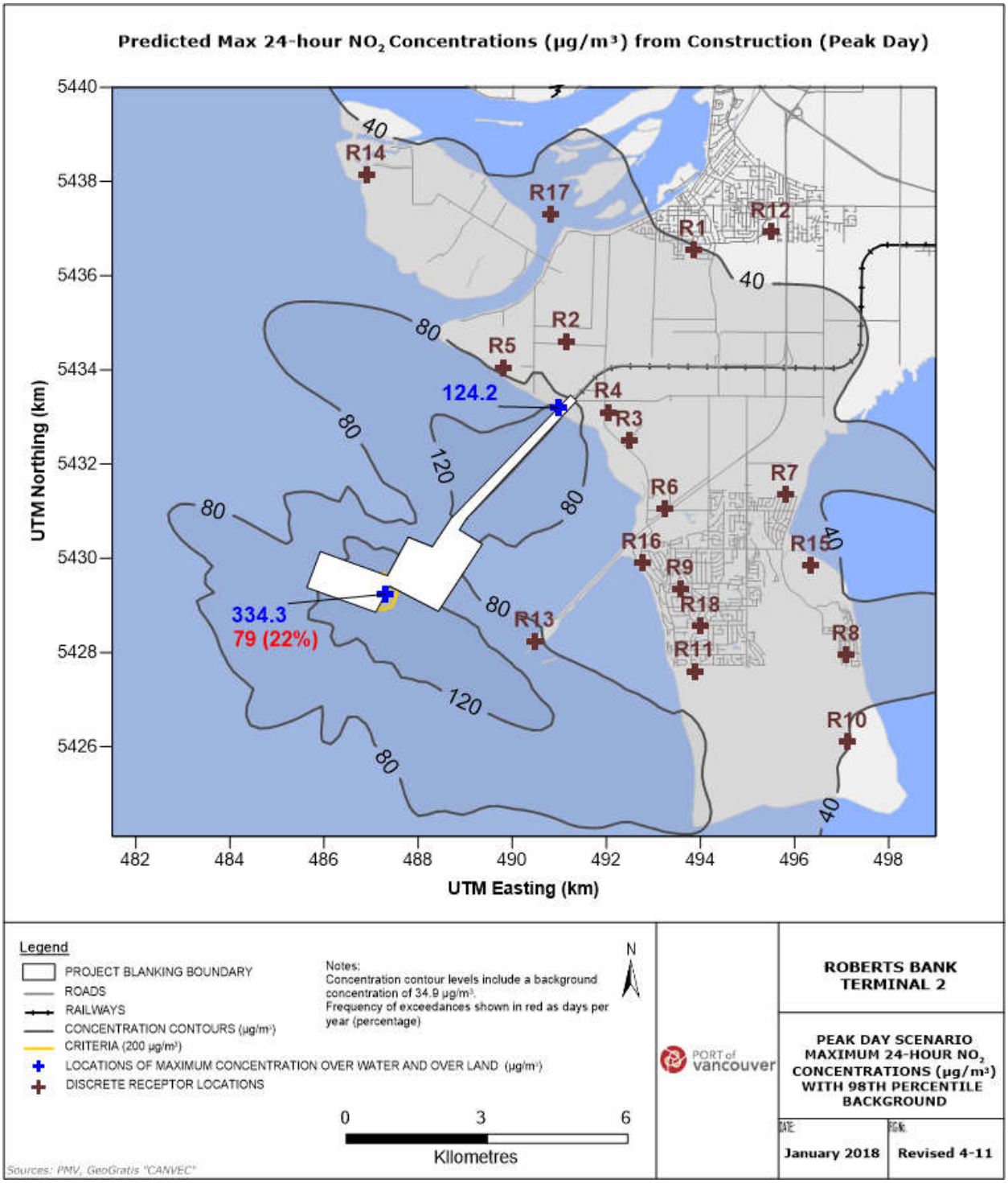


Figure IR6-24-A35 Construction Phase Peak Day Scenario – Maximum 24-hour PM Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-12)

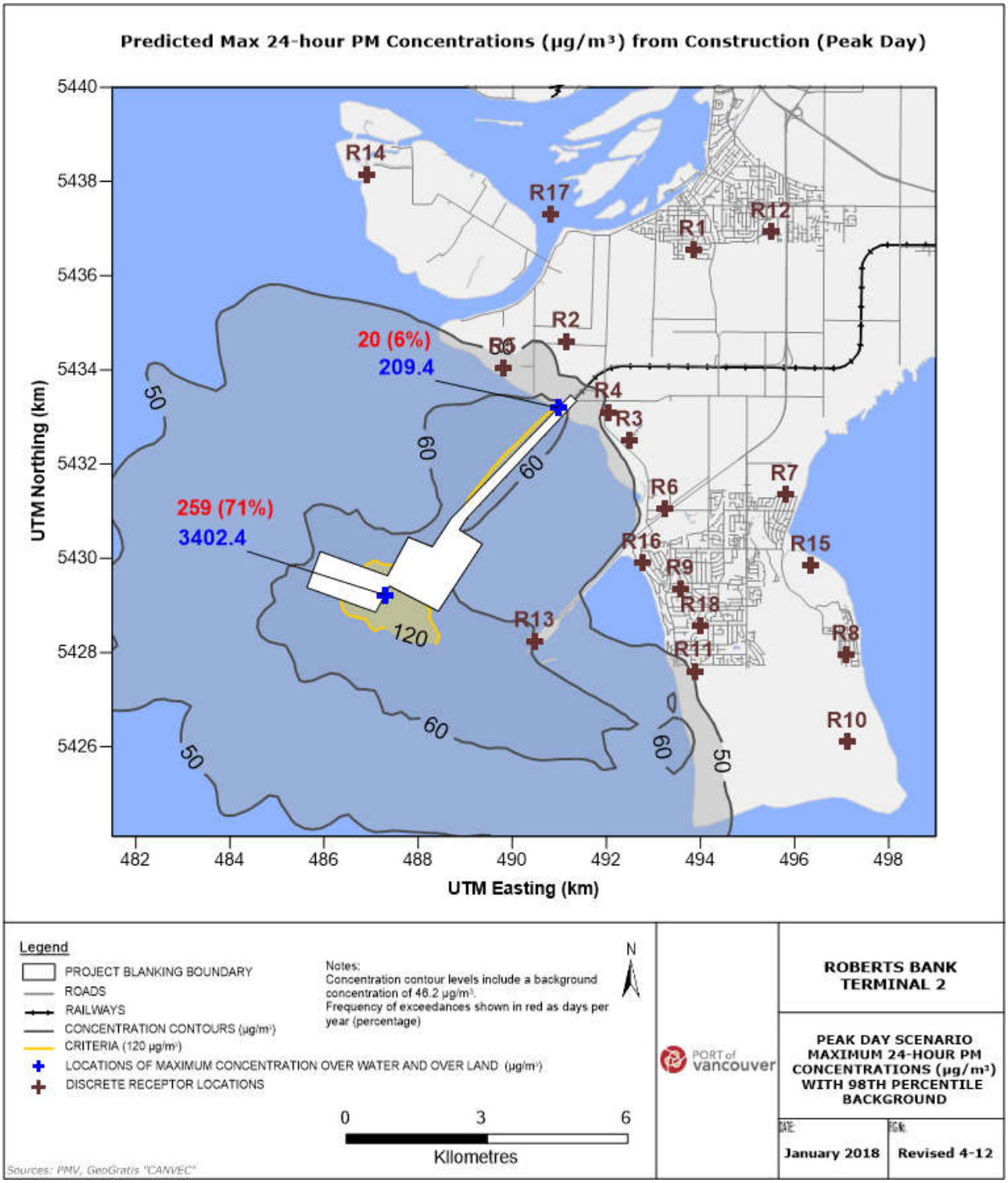


Figure IR6-24-A36 Construction Phase Peak Day Scenario – Maximum 24-hour PM_{10} Concentrations (µg/m³) – Over Land and Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-13)

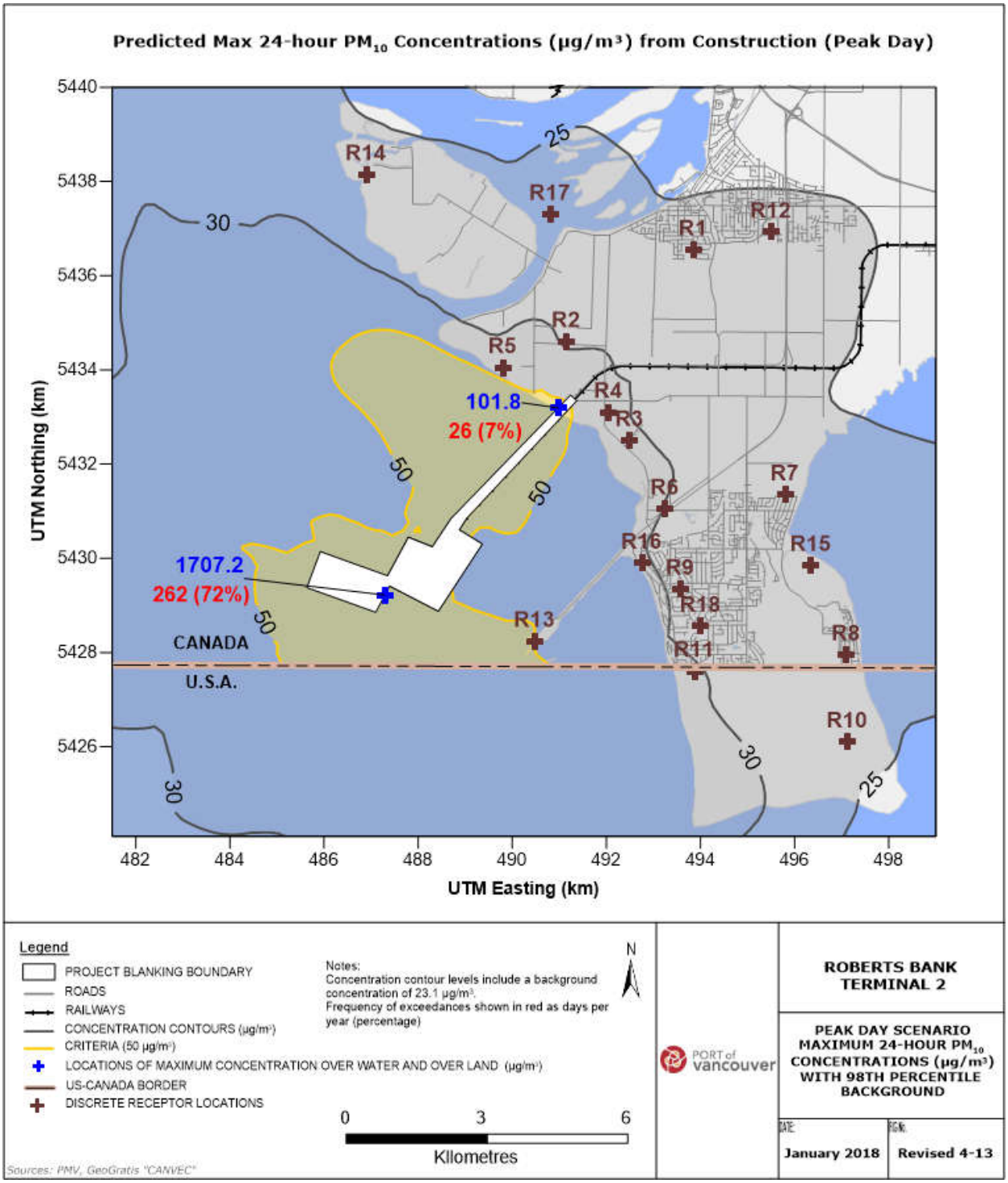


Figure IR6-24-A37 Construction Phase Peak Day Scenario – Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Land (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-14)

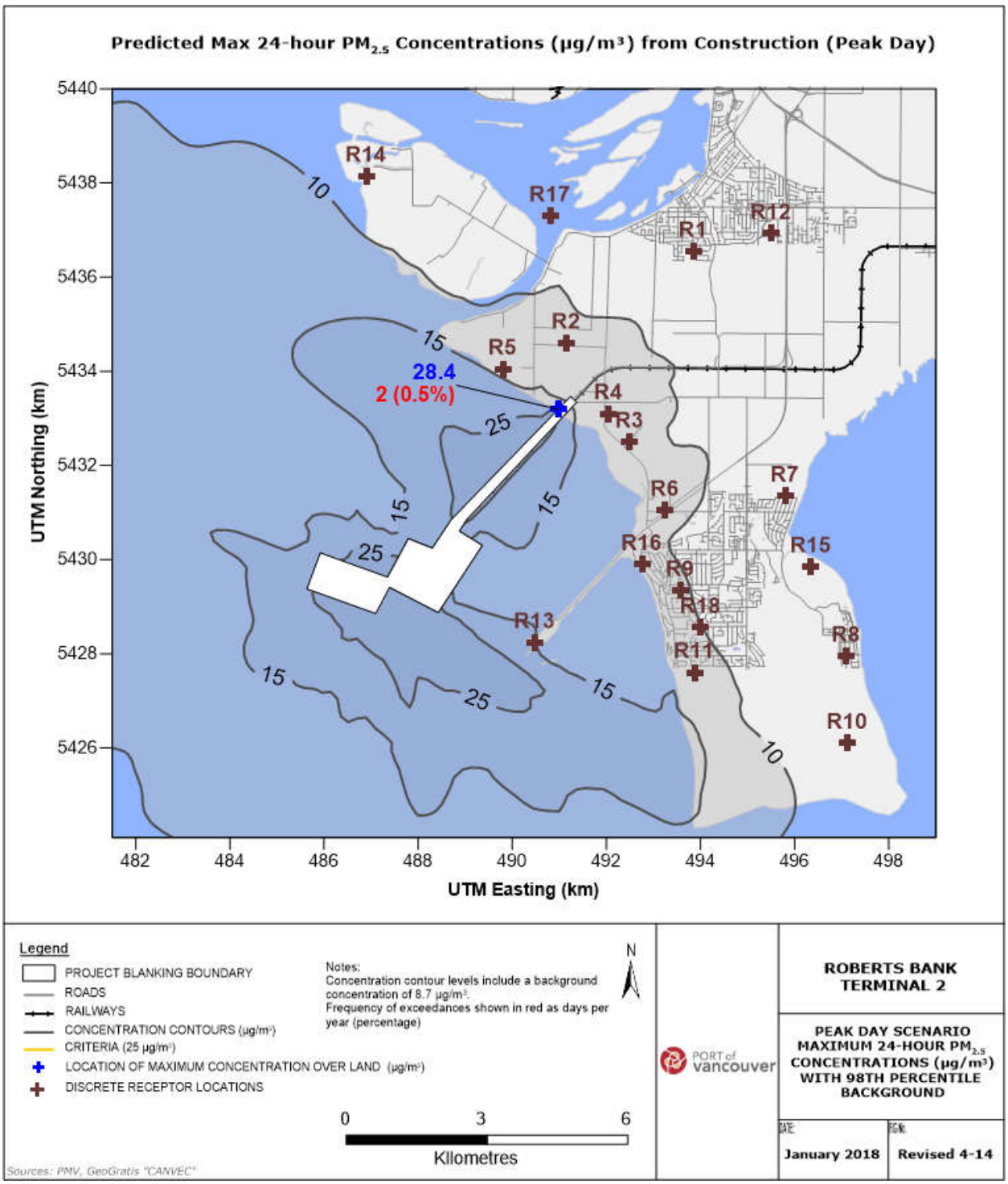


Figure IR6-24-A38 Construction Phase Peak Day Scenario – 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) – Over Water (Revised EIS Appendix 9.2-A, Appendix E, Figure 4-14)

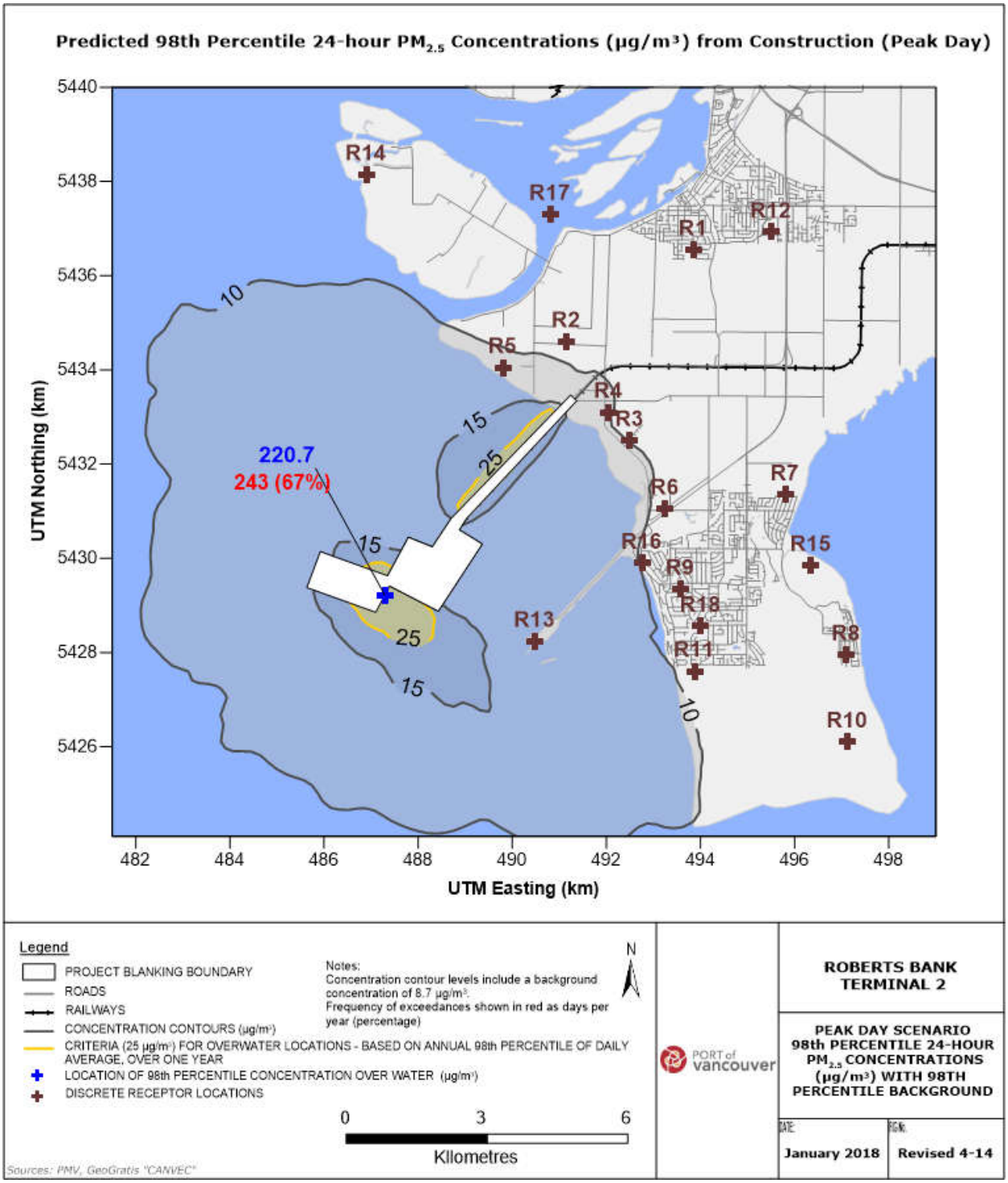


Figure IR6-24-A39 Maximum 1-hour Acrolein Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water (Revised EIS Appendix 27-A, Figure 4)

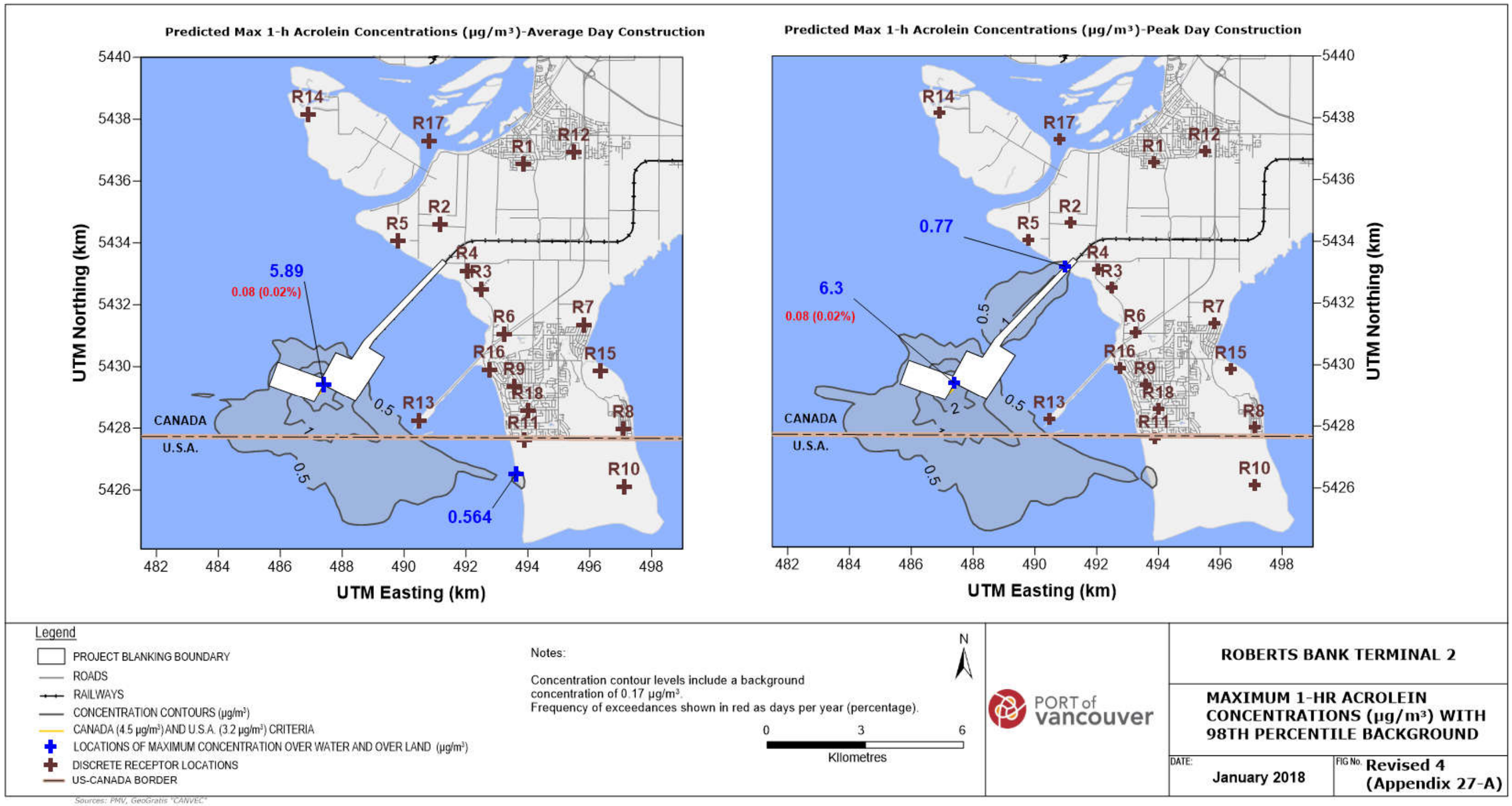


Figure IR6-24-A40 Maximum 1-hour Formaldehyde Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water (Revised EIS Appendix 27-A, Figure 5)

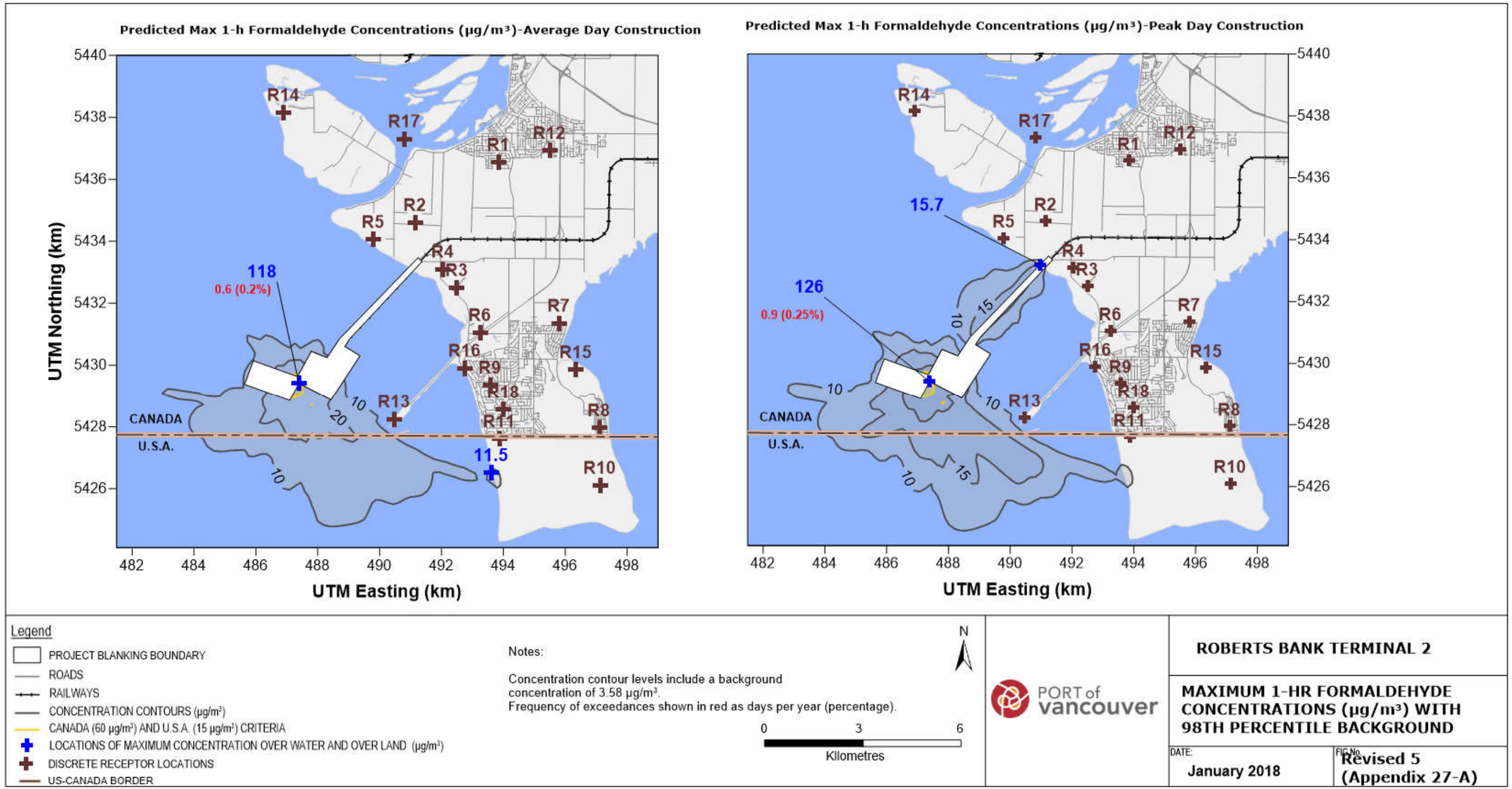


Figure IR6-24-A41 Maximum 1-hour NO_2 Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land (Revised EIS Appendix 27-A, Figure 6)

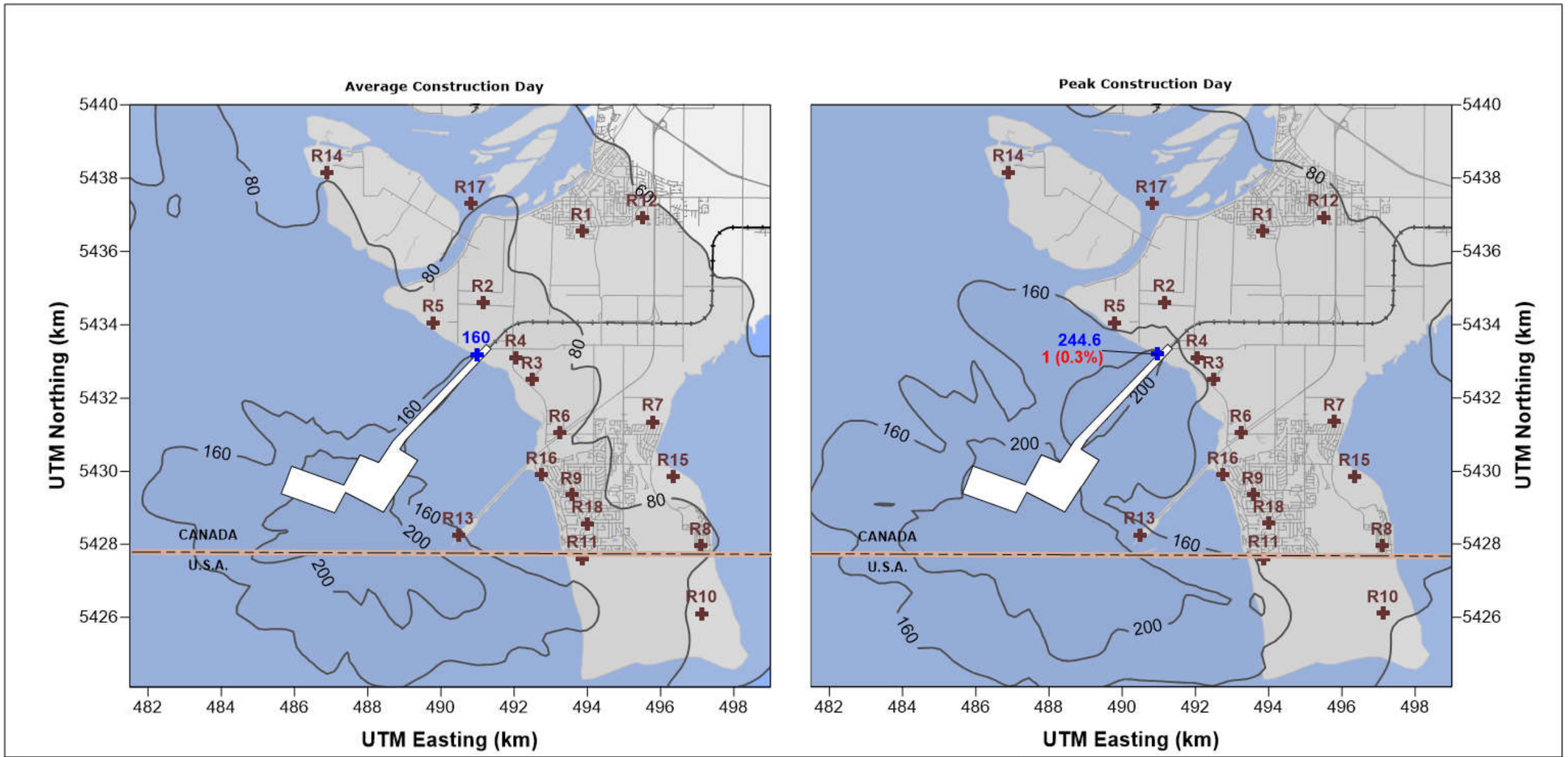


Figure IR6-24-A42 Maximum 1-hour NO_2 Concentrations (µg/m³) During an Average and Peak Construction Day – Over Water (Revised EIS Appendix 27-A, Figure 6)

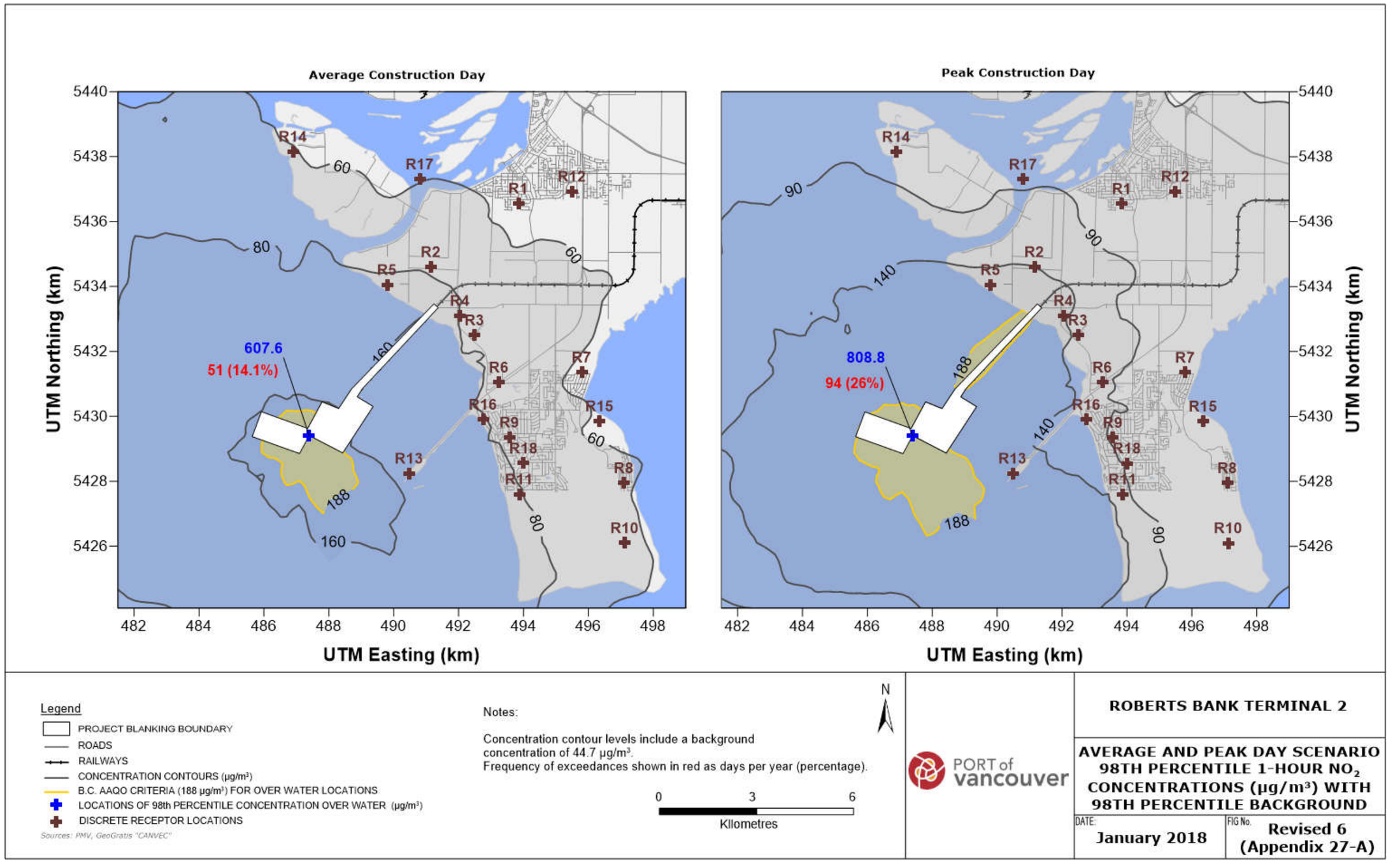


Figure IR6-24-A43 Maximum 24-hour PM_{10} Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land and Over Water (Revised EIS Appendix 27-A, Figure 7)

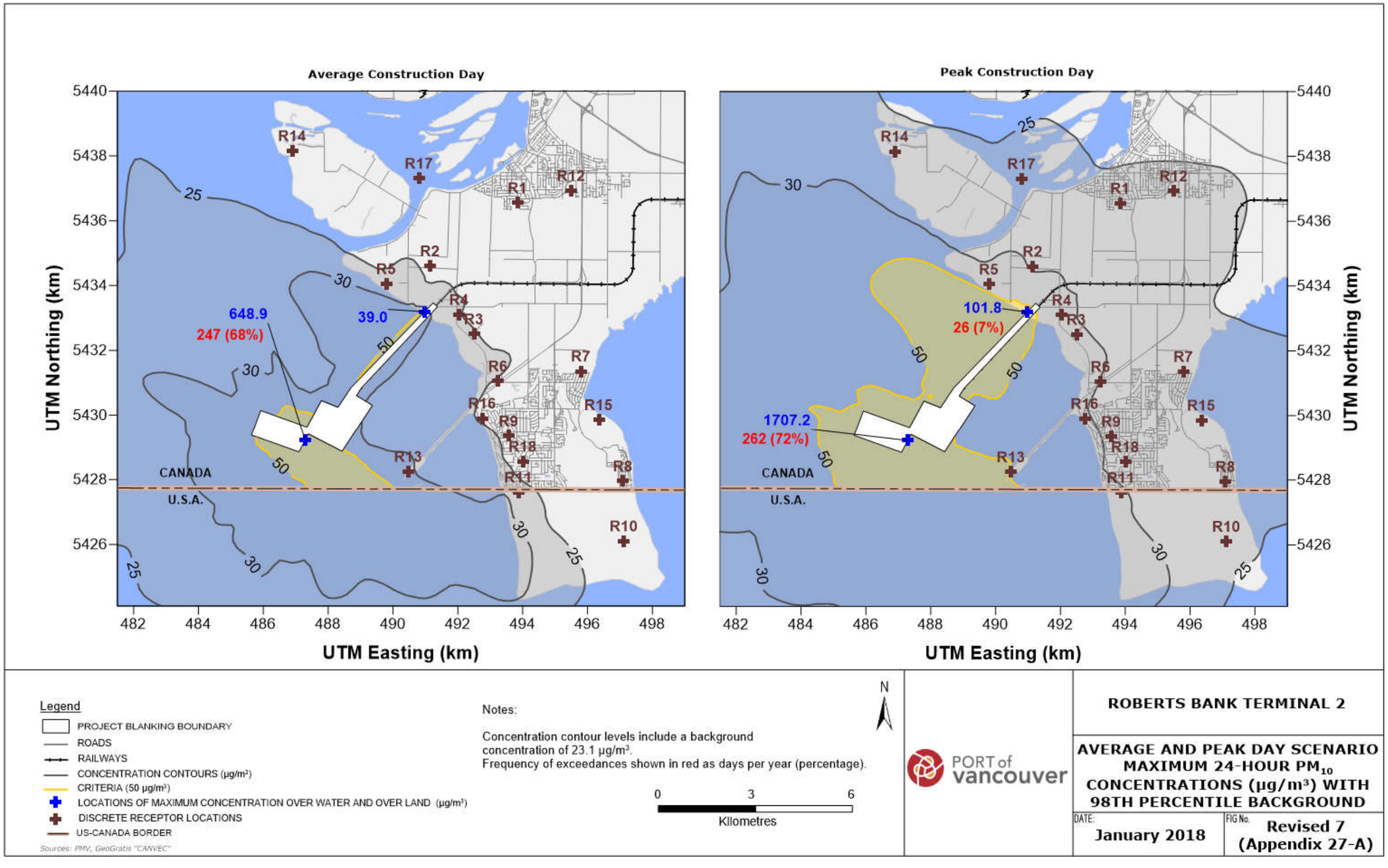


Figure IR6-24-A44 Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m³) During an Average and Peak Construction Day – Over Land (Revised EIS Appendix 27-A, Figure 8)

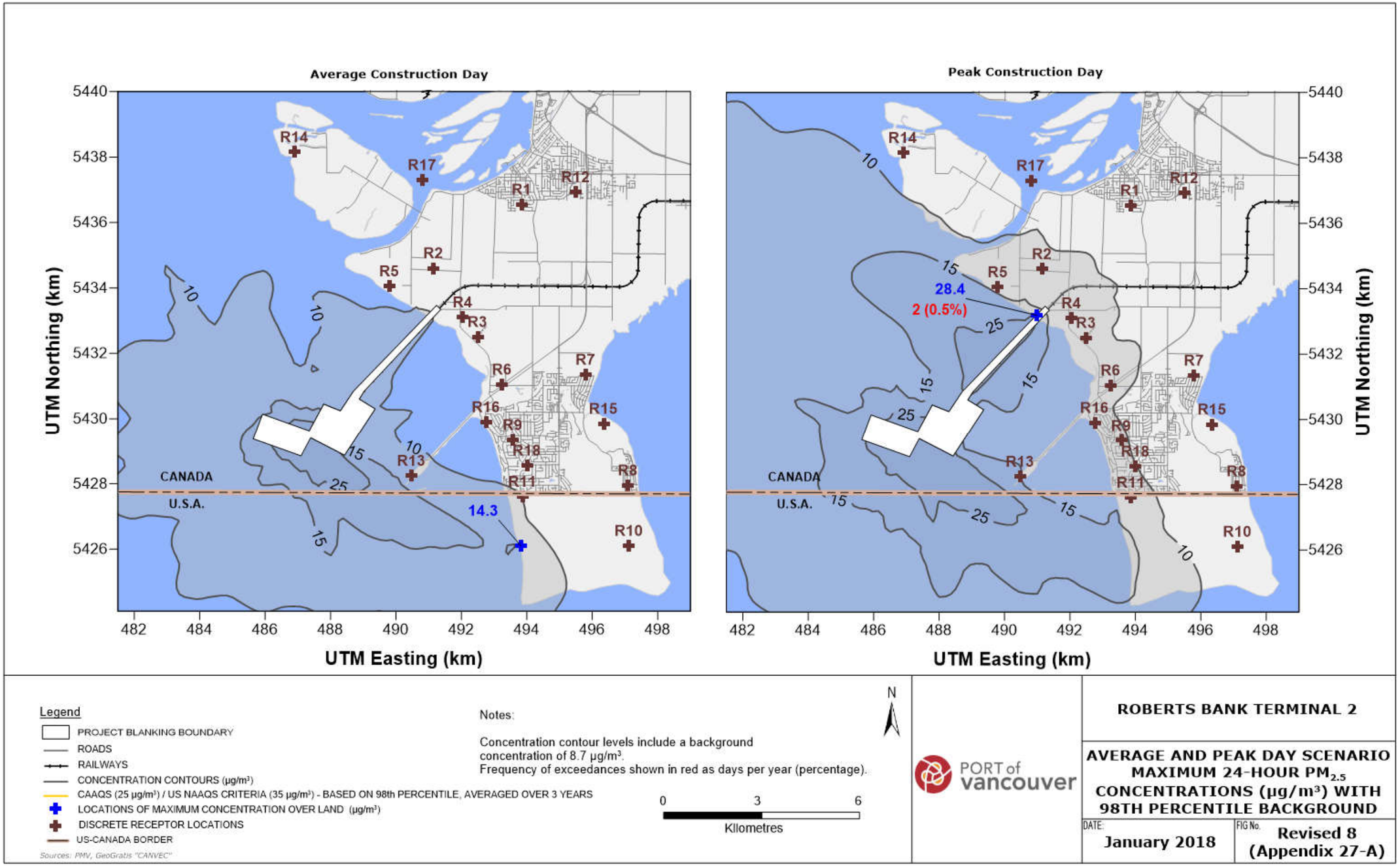
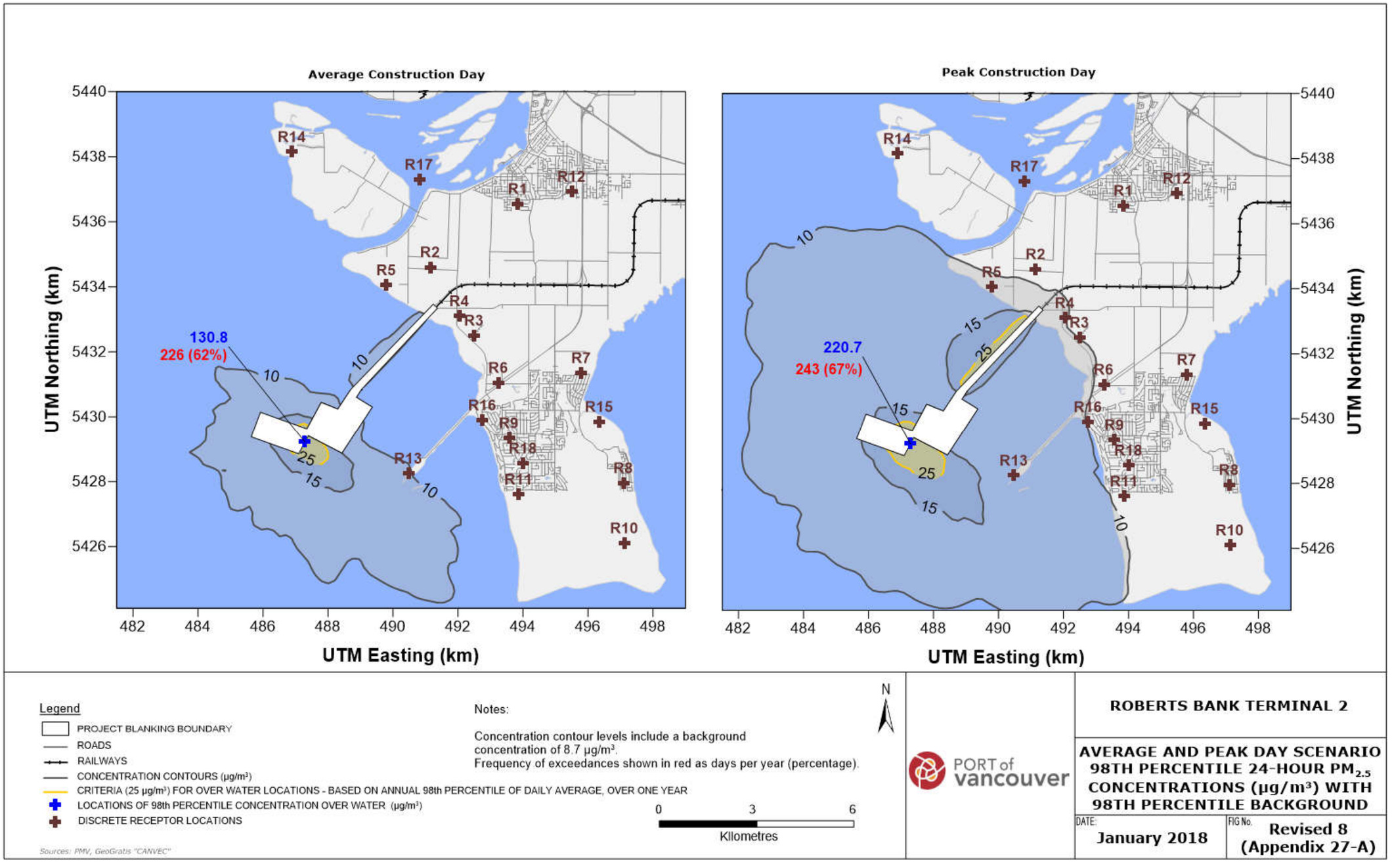


Figure IR6-24-A45 98th Percentile 24-hour $PM_{2.5}$ Concentrations (µg/m³) During an Average and Peak Construction Day – Over Water (Revised EIS Appendix 27-A, Figure 8)



IR6-25 Air Quality – Emissions from Marine Shipping

Information Source(s)

EIS Volume 2: Appendix 9.2-A: Section 4 and Figure 4-10; Appendix A, Section 2, Table 2-12; Appendix F, Figure 4-1

Context

Environment and Climate Change Canada considered that the Proponent's modelling may be predicting an exceedance of the British Columbia interim air quality limit for NO_2 under with Project future conditions 2025, even when assuming that the majority of commercial vessels were NOx Tier III. Since the effects of emissions in the EIS local study area are assessed separately from the effects of the emissions of vessels underway in the region adjacent to the local and regional study areas, additional information is required to support this assertion.

Information Request

For 2025 future conditions with the Project, present a table and isopleth plot of the results for 1-hour NO_2 for the marine emissions estimates and modelling - as combined effects with background as opposed to an incremental change due to ships underway - as presented in Appendix A and F of Appendix 9.2-A of the EIS.

VFPA Response

Emissions from vessel activities in the Strait of Georgia presented in Appendix F of EIS Appendix 9.2-A are captured by Station T39 air quality monitoring equipment and, therefore, included in the Station T39 background data that was added to the modelled predictions, as per the British Columbia Air Dispersion Modelling Guideline (B.C. MOE 2015). The assessment of ships underway evaluated potential changes in air quality due to marine vessel activities within and around the Strait of Georgia in the shipping lanes near the Project. These ships are not associated with Project operations or the operations of other terminals at Roberts Bank, as vessel activities related to the Roberts Bank terminals (i.e., manoeuvring and at berth) have been accounted for in the model predictions for existing and future conditions.

Combining the three components (i.e., modelled emissions for ships underway, background air quality levels from Station T39, and the predicted operational emissions from the marine terminals at Roberts Bank) would double count emissions from ships underway. For this reason, the requested table and isopleth plot for combined 1-hour NO_2 emissions is not provided.

As further explanation, the purpose of the ships underway assessment presented in Appendix F of EIS Appendix 9.2-A was to determine incremental emissions from vessels that do not call at Roberts Bank terminals (i.e., vessels underway in and around the Strait of Georgia). Vessels were selected to represent an average emission scenario and a hypothetical

maximum emission scenario in 2025 based on anticipated future vessel traffic[1]. The frequency of movement of all types of vessels that may transit through this area in 2025 was beyond the assessment scope[2].

Section 2.2 in Appendix F of the EIS Appendix 9.2-A provides the following information for the modelling of ships in transit in the Strait of Georgia:

1. The total number of vessel movements in 2012 was 22,488 in the Strait of Georgia near Roberts Bank;
2. The number of vessel movements was projected to increase by 13% between 2012 and 2030 to 25,412; and
3. As the future assessment year for the RBT2 Air Quality Study was 2025, vessel movements in 2025 were assumed to be similar to those projected to 2030.

Based on these assumptions, the average number of vessel movements in the Strait of Georgia near Roberts Bank in 2012 was estimated as 2.6 movements per hour (22,488 movements / 8,760 hours per year). By 2025, the average number of vessel movements was projected to increase from 2.6 to 2.9 movements per hour (i.e., 0.3 vessel movements more per hour than existing traffic levels as calculated from 25,412 movements / 8,760 hours per year). The 2.6 and 2.9 movements per hour were both rounded up to 3 movements per hour in each temporal case assessment.

Because emissions from ships in transit represent discrete, time-limited events rather than continuous sources of emissions, it is impractical to model emissions from 0.3 vessel movements (i.e., or partial vessel movements) per hour. Therefore, the modelling of future ship traffic in the Strait of Georgia assumed that an average emission scenario included four vessels in total, with three vessels in the Strait of Georgia (i.e., a 9,000 TEU (twenty-foot equivalent unit) container ship, a Vancouver Airport Fuel Facilities Corporation tanker, and a ferry) plus a tugboat towing a coal barge on the South Arm of the Fraser River. For the purposes of modelling a hypothetical maximum emission scenario, the average emission scenario was augmented by increasing the size of the container ship to 12,000 TEU, and adding a Kinder Morgan tanker and a large cruise ship (see Tables 3-4 and 3-5, Appendix F, EIS Appendix 9.2-A).

In the response to IR6-12, Figures IR6-12-2 and IR6-12-3 show that ship emissions from the existing vessel traffic in 2012 (i.e., 2.6 vessel movements per hour) are captured in the ambient air quality monitoring data at Station T39 (data which is used to define background

[1] Section 2.2 in Appendix F of EIS Appendix 9.2-A lists the types of vessels considered in the assessment of ships underway, including vessels associated with both approved and proposed future projects. The combinations of vessels considered in each scenario are described below.

[2] An accurate assessment of all vessel activity in the Strait of Georgia was not technically feasible because the potential combinations and permutations of different vessel types at different times of day, week, or month would require varying the emissions by vessel type in every hour of the year, and defining the speed and time of transit through the strait (page 3, Appendix F, EIS Appendix 9.2-A). In order to achieve a reasonable representation of potential changes in air quality due to increases in ship traffic, emissions from ships in transit through the Strait of Georgia were based on a selection of representative ships that would be expected to be present.

air quality). Since almost 90% (i.e., 2.6/2.9 vessel movements per hour) of the vessel traffic is included in the background air quality from Station T39, adding the background air quality to the modelled emissions from ships in transit would result in double-counting of these emissions.

With respect to tier-level emission standard assumptions, the NO_x emission factors listed in Attachment 1, Appendix F, EIS Appendix 9.2-A show that only the cruise ship and the Kinder Morgan tanker were assumed to meet Tier III emission standards for marine vessels in the assessment of ships in transit. While the Trans Mountain Pipeline Environmental and Socio-Economic Assessment assumed Tier II emission standards for all Kinder Morgan tankers, it is reasonable to assume that some tankers calling at the Kinder Morgan terminal would meet Tier III emission standards, since close to 90% of container ships calling at Roberts Bank in 2030 are assumed to meet Tier III NO_x emission standards. If the assessment of ships underway were to assume that all Kinder Morgan tankers met Tier II NO_x emission standards and container ships met Tier III NO_x emission standards, the results of the ships underway assessment would be similar to the results presented in Appendix F of EIS Appendix 9.2-A. For further information, refer to response to IR6-18 of CEAR Document #1125[3].

References

British Columbia Ministry of Environment (B.C. MOE). 2015. British Columbia Air Dispersion Modelling Guideline. Available at https://www.bcogc.ca/node/13339/download. Accessed November 2017.

[3] CEAR Document #1125 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-18, IR6-20, IR7-06, IR8-11, IR8-12, IR8-13, and IR8-14 (See Reference Documents #991, #1000, & #1071).

IR6-26 Air Quality - Emissions from Locomotives, Clarification

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Section 4, Table 4-4-1; Appendix A, Attachment 8, Appendix G, Table 4-1

Context

The tables providing annual emission rates for criteria air contaminants from locomotives at all terminals are found in different locations in the EIS: in Table 4-4-1(t/y); Attachment 8 of Appendix A (g/s); and Table 4-1 of Appendix G (t/y).

The rail emissions are expected to be the same or equivalent across the various tables given that they describe the same emissions in the same geographic area but are presented in different units.

Information Request

Demonstrate that emission rates given in different units in Tables 4-4-1 of Appendix 9.2-A; Attachment 8 of Appendix A and Table 4-1 of Appendix G of Appendix 9.2-A. are consistent across tables, and equal for the same sources.

VFPA Response

The VFPA confirms that emission rates given in different units in Tables 4-4-1 of EIS Appendix 9.2-A; Attachment 8 of Appendix A and Table 4-1 of Appendix G of EIS Appendix 9.2-A are consistent across tables, and equal for the same sources.

The emission rates in grams per second (g/s) and in tonnes per year (t/y) are consistent for emissions provided for operating conditions along the Roberts Bank causeway and at the Roberts Bank terminals. The emissions from locomotives listed in Table 4-4-1 of EIS Appendix 9.2-A include total annual emissions (in t/y) from locomotives operating at Deltaport Terminal, Westshore Terminals, and RBT2 for existing, expected, and future conditions, as relevant (i.e., RBT2 only included in future conditions). Attachment 8 of Appendix A of EIS Appendix 9.2-A includes the maximum hourly, maximum daily, and annual average emission rates (in g/s) that were used in the air dispersion modelling analysis of locomotive emissions associated with these terminals, as relevant, for existing, expected, and future conditions.

As an example of the alignment of locomotive emissions in these tables for causeway and terminal operations, the total annual carbon monoxide emission rate for existing conditions in 2010 (see Attachment 8, page 111 of Appendix A of EIS Appendix 9.2-A) from all locomotives operating along the causeway and at Deltaport Terminal and Westshore Terminals is 0.9845 g/s (i.e., 0.8 g/s from locomotives on the causeway, 0.132 g/s from

locomotives at Deltaport Terminal and Westshore Terminals, and 0.0525 g/s for locomotives operating at the Westshore Terminal rail loop). The total annual emission rate in tonnes per year is therefore 0.9845 g/s x 3,600 s/h (seconds per hour) x 8,760 h/y (hours per year) ÷ 1,000,000 g/t = 31.05 t/y, which is the annual emission listed in Table 4-4-1 of EIS Appendix 9.2-A (i.e., 21.9 t/y from Deltaport Terminal and 9.2 t/y from Westshore Terminals).

Another example of the alignment of locomotive emissions under Future Conditions (2025) tables is provided for NO_x. In Attachment 8 (page 113 of Appendix A of EIS Appendix 9.2-A), the NO_x emission rate for the terminals is 3.298 g/s (i.e., 2.92 from the Causeway – Rail model source for the three terminals, 0.253 g/s from RBT2 Rail Work source, and 0.125 g/s from the Westshore Rail Loop source). The total annual emission rate in tonnes per year is therefore 3.298 g/s x 3,600 s/h x 8,760 h/y ÷ 1,000,000 g/t = 104.0 t/y. This equates to the rail NO_x emission in Table 4-4-1 of the EIS Appendix 9.2-A of 103.9 t/y (i.e., 45.7 t/y from RBT2, 37.7 t/y from Deltaport and 20.5 t/y from Westshore).

Table 4-1 of Appendix G of EIS Appendix 9.2-A provides total annual emissions in t/y for existing, expected, and future conditions for locomotives operating in rail yards east of the causeway that may contribute to cumulative emissions within the local study area. This table does not reflect locomotive emissions generated from operation activities along the causeway or at the terminals, and hence, the annual emission rates will be different than those provided in EIS Appendix 9.2-A (Table 4-4-1) and Attachment 8 of Appendix A. Nevertheless, as stated in Section 3.1.3 of Appendix G, the emission factors used to calculate the emissions from the locomotives operating in the rail yards east of the causeway are the same emission factors used to calculate emissions from locomotives operating on the Roberts Bank causeway and at the Roberts Bank terminals.

IR6-27 Air Quality – Future Conditions

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Section 5.2.5; Appendix F; Appendix G

Proponent Response to Additional Information Requirement of July 31, 2015 (CEAR Doc#314): IR19, Appendix 19-A

Context

Other future and foreseeable projects covered in Appendix 9.2-A, ships underway as listed in Appendix F and future rail activity identified in Appendix G have spatial plots of predicted air quality parameter concentrations presented separately for each study. Sections 5.2.4 and 5.2.5 of Appendix 9.2-A of the EIS presented predicted tabulated results from these combined studies. The results presented in Table 5-12 indicated that *cumulative future conditions* will exceed Metro Vancouver's 1-hour NO_2 objective at four of the sensitive receptor locations; exceedance is shown as well in Figure 2-3 in Appendix 19-A.

The isopleth plot for future conditions 2025 with the Project for maximum annual average NO_2 (Figure 4.12) indicated exceedance of Metro Vancouver annual objective. This was not reported in Table 5-14 since there was no discrete receptor in the area plotted.

Isopleth plots are needed that indicate the points of maximum impingements and the location of the discrete receptors where isopleth plots indicate exceedances.

Clarification is needed if future conditions 2025 with Project in Figure 4.10 represents 100^{th} percentile. The apparent discrepancy with the data results of Table 5.12 must be explained.

Information Request

Provide an isopleth plot for the *cumulative future conditions* results (including background) for the predicted maximum 1-hour NO_2 and annual average NO_2.

Provide a frequency of exceedance isopleth plot for the cumulative future conditions results, including background, for maximum predicted 1-hour NO_2 and a comparison to Metro's Vancouver 1-hour objective of 200 ug/m^3.

Provide an isopleth plot where the expected conditions and other future projects results are presented, including background, for 1-hour maximum predicted NO_2 and annual average NO_2.

Include the location of maximum points of impingement both on land and overwater, and of discrete receptors, when available, where isopleth plots indicate exceedances.

Specify if future conditions 2025 with Project in Figure 4.10 represents 100^{th} percentile and the reasons for the apparent discrepancy with the data results of Table 5.12 which presents

not only future conditions but the combination of Project-related changes in air contaminant concentrations plus changes from other certain and reasonably foreseeable projects and activities.

VFPA Response

There are five parts to this information request and some requests are responded to together if related; therefore, the order of the responses is not necessarily in the order of the requested information.

Provide an isopleth plot for the cumulative future conditions results (including background) for the predicted maximum 1-hour NO_2 and annual average NO_2.

Provide an isopleth plot where the expected conditions and other future projects results are presented, including background, for 1-hour maximum predicted NO_2 and annual average NO_2.

Include the location of maximum points of impingement both on land and overwater, and of discrete receptors, when available, where isopleth plots indicate exceedances.

Figures IR6-27-A1 to IR6-27-A2 in **Appendix IR6-27-A** present isopleth plots[1] for cumulative expected conditions (first panel) and cumulative future conditions with the Project (second panel) for 1-hour average NO_2 concentrations over land and over water, respectively[2]. These isopleth plots incorporate the updated study criteria presented in the response to IR6-23 (Table IR6-23-1), including 200 µg/m^3 for over land and 188 µg/m^3 for over water locations[3].

The isopleth plot for cumulative expected conditions includes emissions from the operation of existing terminals at Roberts Bank, rail locomotive activity associated with RBT2 east of the Roberts Bank causeway, and 98th percentile background air quality measured at Station T39 (2010 to 2012 data)[4]. The isopleth plot for cumulative future conditions with the Project includes incremental concentrations from Project operations plus cumulative expected conditions emissions. For both the cumulative expected conditions case and the cumulative future with the Project case, the maximum 1-hour average NO_2 concentrations reflect the

[1] As outlined in EIS Section 9.2.10.5 and the response to IR6-24, isopleth plots indicate the highest hourly or daily concentrations for the specific hour or day in the year that results in the maximum concentration at each grid receptor point, and should not be interpreted as an aggregate plume.
[2] For an explanation of the approach to how EIS Table 5-12 cumulative concentrations were derived and the isopleth plots provided in **Appendix IR6-27-A** were generated, refer to **Appendix IR6-27-B**.
[3] 1-hr NO_2 updated study criterion for over land locations (200 µg/m^3) is Metro Vancouver's ambient air quality objective (AAQO), with achievement based on 100th percentile concentration over one year, while the criterion for over water (188 µg/m^3 B.C. AAQO) is based on annual 98th percentile of daily 1-hour maximum, over one year.
[4] Emissions from ships in transit in the Strait of Georgia are included in the background air quality; therefore, these emissions are not included in the Column A emissions. For more information, refer to the response to IR6-12.

maximum worst-case condition 1-hour emission scenario, which is explained further in the response to IR6-15 of CEAR Document #1113[5].

Figures IR6-27-A3 to IR6-27-A4 in **Appendix IR6-27-A** present isopleth plots for cumulative expected conditions and future conditions with the Project for annual average NO_2 concentrations over land and over water, respectively. These isopleth plots incorporate the updated study criteria presented in the response to IR6-23 (Table IR6-23-1), including 40 µg/m^3 for over land and 60 µg/m^3 for over water locations[6]. Annual average NO_2 concentrations from all sources were based on average annual emission rates.

Locations in Point Roberts, Washington, which are subject to the U.S. National Ambient Air Quality Standards, were calculated in the same manner as over land locations for 1-hour and annual average NO_2 concentrations (refer to Table IR6-23-1 for more information). Therefore, the isopleths shown in Figures IR6-27-A2 and IR6-27-A4 in **Appendix IR6-27-A** are applicable to U.S. locations.

Figure IR6-27-A1 in **Appendix IR6-27-A** shows that maximum 1-hour average NO_2 concentrations for cumulative expected conditions are not predicted to exceed the Metro Vancouver ambient air quality objective (AAQO) at over land locations. For cumulative future conditions with the Project, maximum 1-hour average NO_2 concentrations are predicted to exceed the Metro Vancouver AAQO at the east end of the causeway 1.2% of the year. Predicted NO_2 concentrations along the east end of the causeway, however, are considered to be an overprediction. This is because the emissions from road and rail activities on the causeway and in the rail yards were modelled as volume sources, and the maximum point of impingement is located at the end of the volume source on the causeway (concentration shown in blue text). This location is too close to the volume source for the CALPUFF model to accurately predict dispersion from the source. Furthermore, use of the Ozone Limiting Method (OLM) assumes instantaneous conversion of emissions from sources contributing NO_x emissions rather than a gradual conversion of nitric oxide (NO) to NO_2 with advection of the emissions away from the source. The OLM has been demonstrated to over predict maximum NO_2 concentrations by up to a factor of two (Podrez 2015), as explained in Appendix C of EIS Appendix 9.2-A and in the response to IR6-22. Although the modelling suggests a potential exceedance of the NO_2 objective for cumulative future conditions with the Project, actual exceedance of the criterion is considered unlikely.

Figure IR6-27-A2 in **Appendix IR6-27-A** shows that the maximum point of impingement for 1-hour average NO_2 concentrations over water would occur near the berths at Westshore Terminals and Deltaport Terminal (concentration shown in blue text). The frequency of exceeding the updated study criterion (i.e., 188 µg/m^3) is predicted for 11 to 12 days per year or 3.2% of the year (frequency shown in red text) for both cumulative expected

[5] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).

[6] The average annual NO_2 updated study criterion for over land locations is the Metro Vancouver AAQO of 40 µg/m^3, with achievement based on 100th percentile concentration, while the criterion for over water is the B.C. AAQO of 60 µg/m^3, based on the arithmetic mean concentration.

conditions and cumulative future conditions with the Project. As with all estimated NO_2 concentrations, the concentrations and apparent exceedances indicated in Figure IR6-27-A2 (**Appendix IR6-27-A**) are subject to the same sources of over estimation described above, and actual exceedances of the criterion are considered unlikely.

The maximum predicted annual average NO_2 over land concentrations occur along the railway corridor and are 25.3 µg/m^3 and 32.2 µg/m^3 for cumulative expected conditions and cumulative future conditions with the Project (see Figure IR6-27-A3 in **Appendix IR6-27-A**), respectively, both of which are lower than the updated study criterion. Note that the content of EIS Figure 4-12 has been misinterpreted in the context to this information request; the isopleth plot for future conditions in 2025 with the Project for maximum annual average NO_2 does not indicate exceedance of Metro Vancouver annual objective.

The locations of the maximum points of impingement for cumulative expected conditions and cumulative future conditions with the Project for annual average NO_2 over water are located at the berths at the Westshore and Deltaport terminals, but the updated study criterion is not exceeded elsewhere over water (see Figure IR6-27-A4 in **Appendix IR6-27-A**).

Provide a frequency of exceedance isopleth plot for the cumulative future conditions results, including background, for maximum predicted 1-hour NO_2 and a comparison to Metro's Vancouver 1-hour objective of 200 ug/m3.

Figure IR6-27-A5 in **Appendix IR6-27-A** presents the frequency of exceedances of predicted maximum 1-hour average NO_2 concentrations for cumulative expected conditions and cumulative future conditions with the Project (i.e., the number of hours within a year when concentrations could be expected to exceed the Metro Vancouver AAQO for 1-hour NO_2 of 200 µg/m^3)[7]. As illustrated in Figure IR6-27-A5, it is predicted that this objective could be exceeded generally less than a day per year, as shown by the 1 hour and 4 hour contours, near the east end of the Roberts Bank causeway under cumulative future conditions with the Project. The duration of predicted exceedance is an overprediction based on the same concerns about overprediction discussed above.

Specify if future conditions 2025 with Project in Figure 4.10 represents 100th percentile and the reasons for the apparent discrepancy with the data results of Table 5.12 which presents not only future conditions but the combination of Project-related changes in air contaminant concentrations plus changes from other certain and reasonably foreseeable projects and activities.

Figure 4-10 illustrates existing conditions, expected conditions, and future conditions with the Project, while Table 5.12 presents the cumulative future conditions. Therefore, discrepancies

[7] Note that for the cumulative future conditions scenario, Figure IR6-27-A1 shows a 1-h maximum NO_2 concentration of 297.5 µg/m^3 over land. At this specific location, the criterion of 200 µg/m^3 is predicted to be exceeded 101 hours over a year (i.e., 4.2 days or 1.2% of the year). Figure IR6-27-A1 shows frequency, as show by the 1 and 4 hour contours, of exceeding the criterion of 200 µg/m^3 over one year.

between the two are expected and appropriate. Further explanation of the content in Figure 4-10 and Table 5.12 is provided below.

Figure 4-10 in EIS Appendix 9.2-A is entitled "Maximum 1-h NO_2 Concentrations ($\mu g/m^3$) under Existing, Expected and Future Conditions". The term 'maximum' refers to the 100th percentile concentration in each of the three scenarios presented in Figure 4-10. Predicted maximum (100th percentile) concentrations are based on a hypothetical maximum worst-case hourly emission scenario[8], which is explained in the response to IR6-15 (CEAR Document #1113), for each of the three cases: existing conditions, expected conditions, and future conditions with the Project. The isopleth plots for each case include the 98th percentile background NO_2 concentration of 44.7 $\mu g/m^3$ from Station T39[9] (as indicated in the 'Notes' section of Figure 4-10). Figure 4-10 does not present the cumulative case, but this cumulative future condition is provided in Figures IR6-27-A1 to IR6-27-A4 in **Appendix IR6-27-A**.

Table 5-12 in EIS Appendix 9.2-A tabulates the maximum (i.e., 100th percentile) predicted 1-hour average NO_2 concentrations at discrete receptors for the following conditions:

- Cumulative expected conditions from the operation of the Westshore Terminals, Deltaport Terminal, and the BC Ferries Tsawwassen Terminal plus other future projects and activities (i.e., rail locomotive emissions in rail yards and activity off the Roberts Bank causeway beyond the Project area, as outlined in EIS Appendix 9.2-B and Appendix G of EIS Appendix 9.2-A), and 98th percentile 2010 background air quality, as measured at Station T39 (Column A);
- Incremental concentrations from RBT2 operations (Column B);
- Cumulative future conditions (Column C), which includes concentrations presented in Columns A and B. It is noted under Table 5-12 that Column C concentrations are not necessarily the same as the sum of Column A and Column B concentrations, as they may not occur in the same period (e.g., 1-h, 24-h, etc.); and
- Percent cumulative change in emissions associated with cumulative future operations and rail activity, as compared with expected operations and rail activity (calculated as (Column C – Column A) / Column A.

Appendix IR6-27-B provides information to further explain the concentrations presented in Table 5-12 of EIS Appendix 9.2-A, and also provides updates to Table 5-12 that were undertaken for the purposes of generating the figures provided in **Appendix IR6-27-A**.

[8] The maximum predicted hourly NO_2 concentrations presented in EIS Section 9.2 and supporting appendices are considered to be hypothetical worst-case emission rather than examples of what might actually occur (for further explanation, refer to the responses to IR6-22 and IR6-23).

[9] The background concentration includes the contributions during 2010 from emissions from the three existing marine terminals at Roberts Bank (Westshore Terminals, Deltaport Terminal, and the BC Ferries Terminal). Emissions from these terminals, therefore, are counted twice when the background concentration is added to the modelled emissions from terminals at Roberts Bank.

References

Podrez, M. 2015. An Update to the Ambient Ratio Method for 1-h NO_2 Air Quality Standards Dispersion Modeling. Atmospheric Environment 103:163-170.

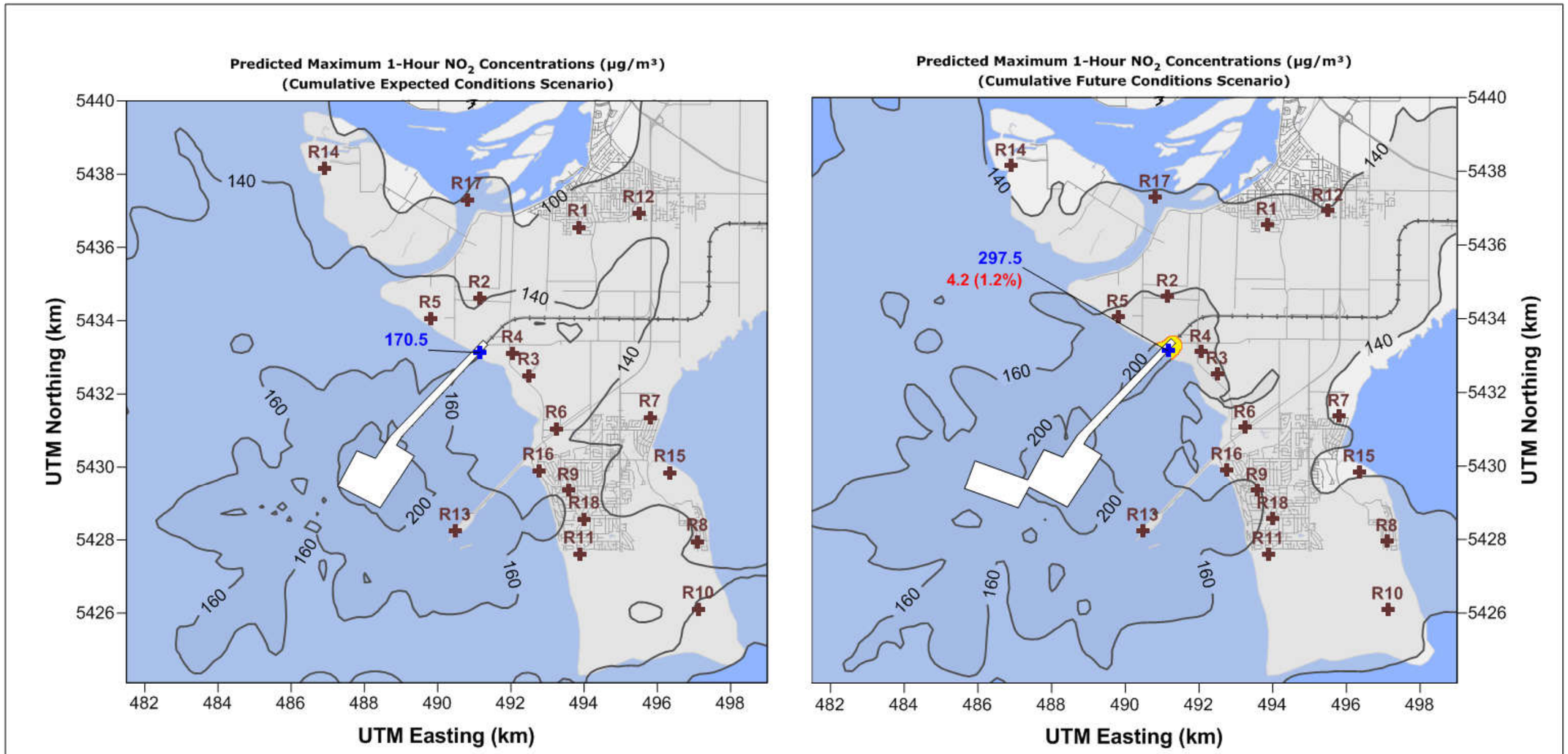
Appendices

Appendix IR6-27-A Figures of Isopleth Plots for Cumulative Future Conditions

Appendix IR6-27-B Information on Generation of Appendix IR6-27-A Figures

APPENDIX IR6-27-A
FIGURES OF ISOPLETH PLOTS FOR CUMULATIVE FUTURE CONDITIONS

Figure IR6-27-A1 Predicted Maximum 1-Hour NO_2 Concentrations (µg/m³) Over Land for Cumulative Expected Conditions and Cumulative Future Conditions with the Project



Legend

- PROJECT BLANKING BOUNDARY
- ROADS
- RAILWAYS
- CONCENTRATION CONTOURS (µg/m³)
- METRO VANCOUVER CRITERIA (200 µg/m³) FOR OVER LAND LOCATIONS
- LOCATION OF MAXIMUM CONCENTRATION OVER LAND (µg/m³)
- DISCRETE RECEPTOR LOCATIONS

Sources: PMV, GeoGratis "CANVEC"

0 3 6 Kilometres

N

Notes:

Concentration contour levels include a background concentration of 44.7 µg/m³.

Frequency of exceedances shown in red as days per year (percentage).

Cumulative expected conditions (without the Project) represents future conditions with other certain and reasonably foreseeable projects and activities, including Deltaport Terminal, Westshore Terminals and B.C. Ferries Terminal operations and rail activity.

Cumulative future conditions, including changes from RBT2 in combination with the expected conditions and other future projects and activities and rail activity.

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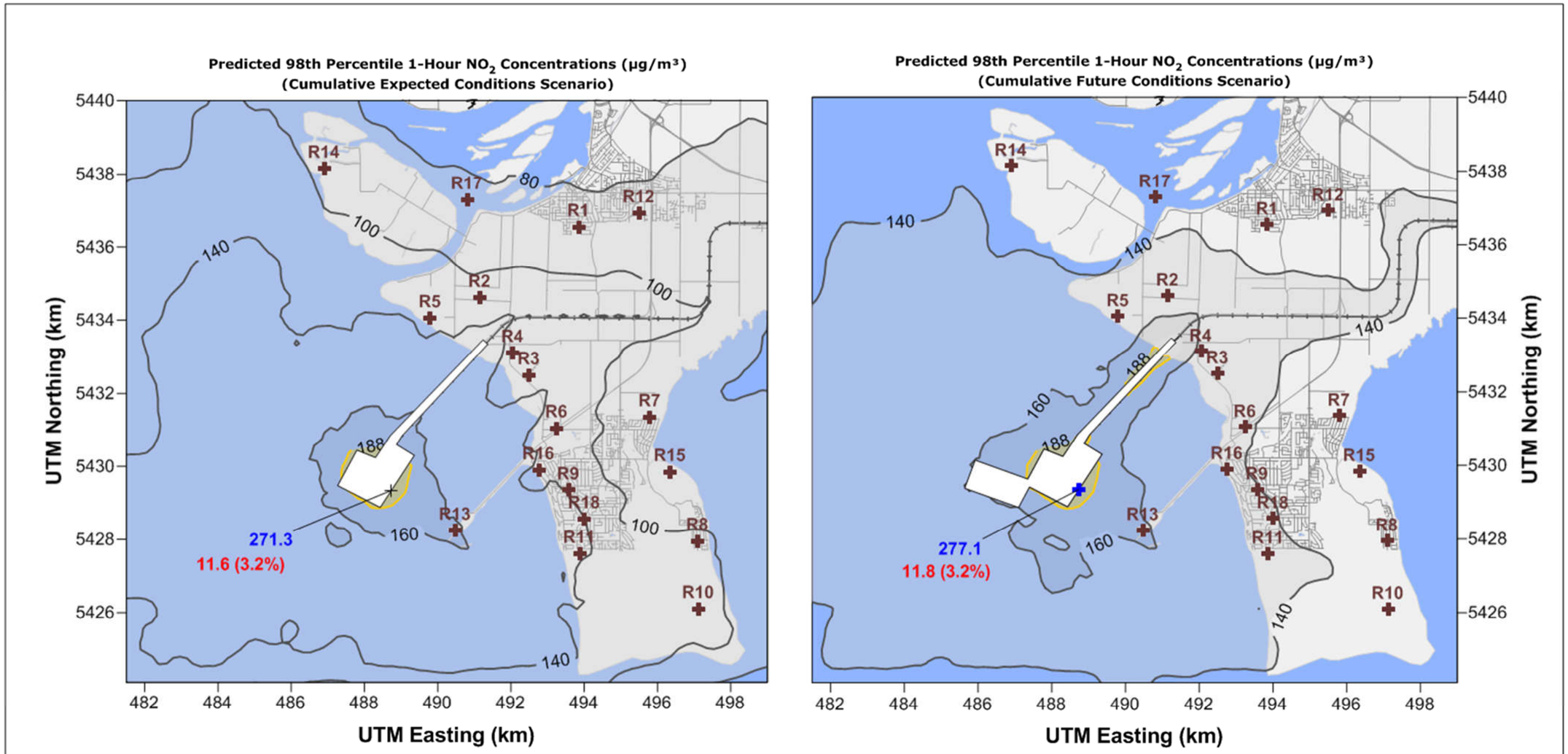
ROBERTS BANK TERMINAL 2

MAXIMUM 1-HOUR CUMULATIVE NO_2 CONCENTRATIONS (µg/m³) WITH 98TH PERCENTILE BACKGROUND

DATE: **February 2018**

FIG No. **IR6-27-A1**

Figure IR6-27-A2 Predicted 98th Percentile 1-Hour Average NO_2 Concentrations (µg/m³) Over Water for Cumulative Expected Conditions and Cumulative Future Conditions with the Project



Legend

- PROJECT BLANKING BOUNDARY
- ROADS
- RAILWAYS
- CONCENTRATION CONTOURS (µg/m³)
- B.C. AAQO CRITERIA (188 µg/m³) FOR OVER WATER LOCATIONS
- LOCATION OF MAXIMUM CONCENTRATION OVER WATER (µg/m³)
- DISCRETE RECEPTOR LOCATIONS

Sources: PMV, GeoGratis "CANVEC"

0 3 6
Kilometres

N

Notes:

Concentration contour levels include a background concentration of 44.7 µg/m^3.

Frequency of exceedances shown in red as days per year (percentage).

Cumulative expected conditions (without the Project) represents future conditions with other certain and reasonably foreseeable projects and activities, including Deltaport Terminal, Westshore Terminals and B.C. Ferries Terminal operations and rail activity.

Cumulative future conditions, including changes from RBT2 in combination with the expected conditions and other future projects and activities and rail activity.

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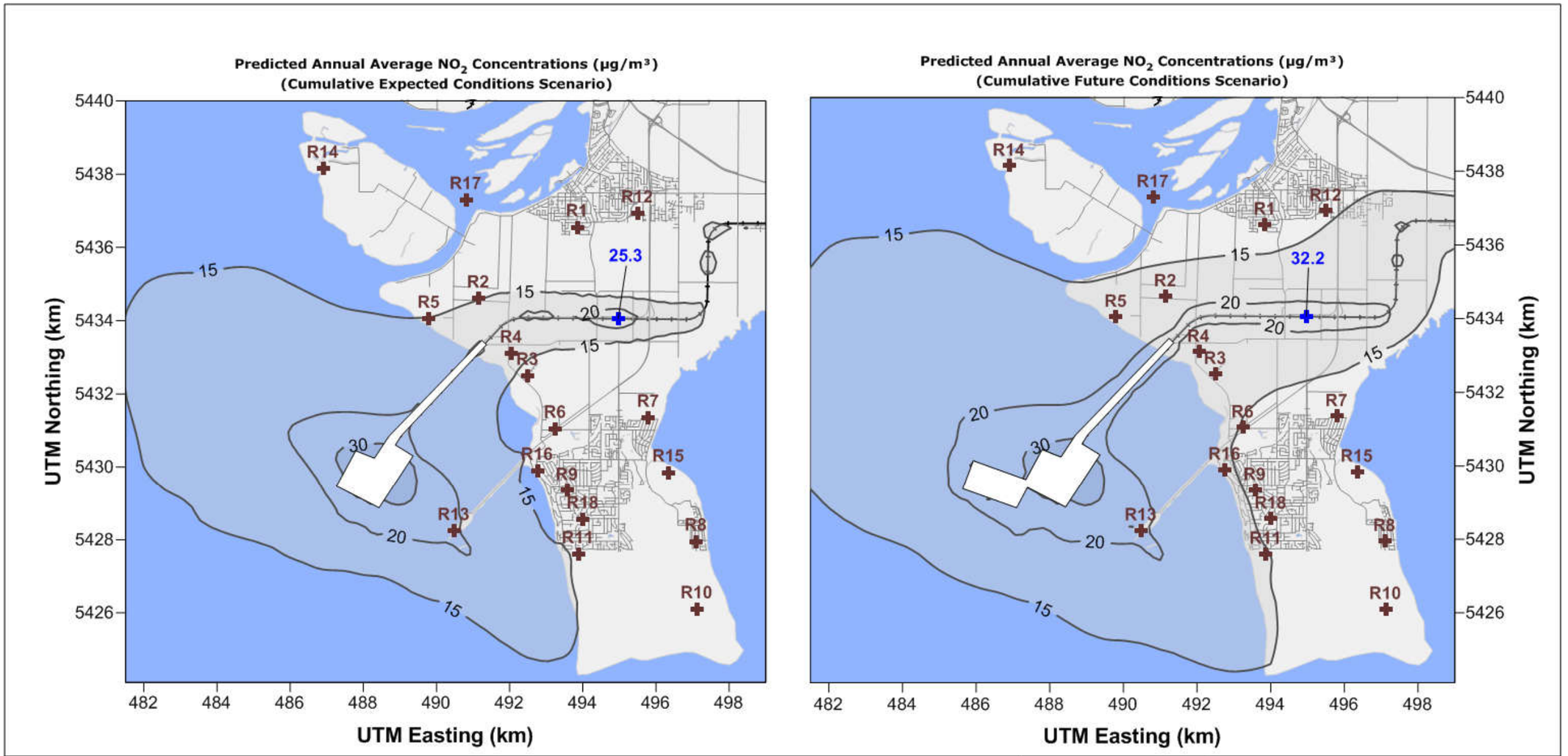
ROBERTS BANK TERMINAL 2

98TH PERCENTILE 1-HOUR CUMULATIVE NO_2 CONCENTRATIONS (µg/m³) WITH 98TH PERCENTILE BACKGROUND

DATE: **February 2018**

FIG No. **IR6-27-A2**

Figure IR6-27-A3 Predicted Average Annual NO_2 Concentrations (µg/m³) Over Land for Cumulative Expected Conditions and Cumulative Future Conditions with the Project



Legend

- PROJECT BLANKING BOUNDARY
- ROADS
- RAILWAYS
- CONCENTRATION CONTOURS (µg/m³)
- METRO VANCOUVER CRITERIA (40 µg/m³) FOR OVER LAND LOCATIONS
- LOCATION OF MAXIMUM CONCENTRATION OVER LAND (µg/m³)
- DISCRETE RECEPTOR LOCATIONS

Sources: PMV, GeoGratis "CANVEC"

0 3 6 Kilometres

1:100,000

N

Notes:
- Concentration contour levels include a background concentration of 12.8 µg/m^3.
- Cumulative expected conditions (without the Project) represents future conditions with other certain and reasonably foreseeable projects and activities, including Deltaport Terminal, Westshore Terminals and B.C. Ferries Terminal operations and rail activity.
- Cumulative future conditions, including changes from RBT2 in combination with the expected conditions and other future projects and activities and rail activity.

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ROBERTS BANK TERMINAL 2

ANNUAL AVERAGE CUMULATIVE NO_2 CONCENTRATIONS (µg/m³) WITH 98TH PERCENTILE BACKGROUND

DATE: **February 2018**

FIG No. **IR6-27-A3**

Figure IR6-27-A4 Predicted Average Annual NO_2 Concentrations (µg/m³) Over Water for Cumulative Expected Conditions and Cumulative Future Conditions with the Project

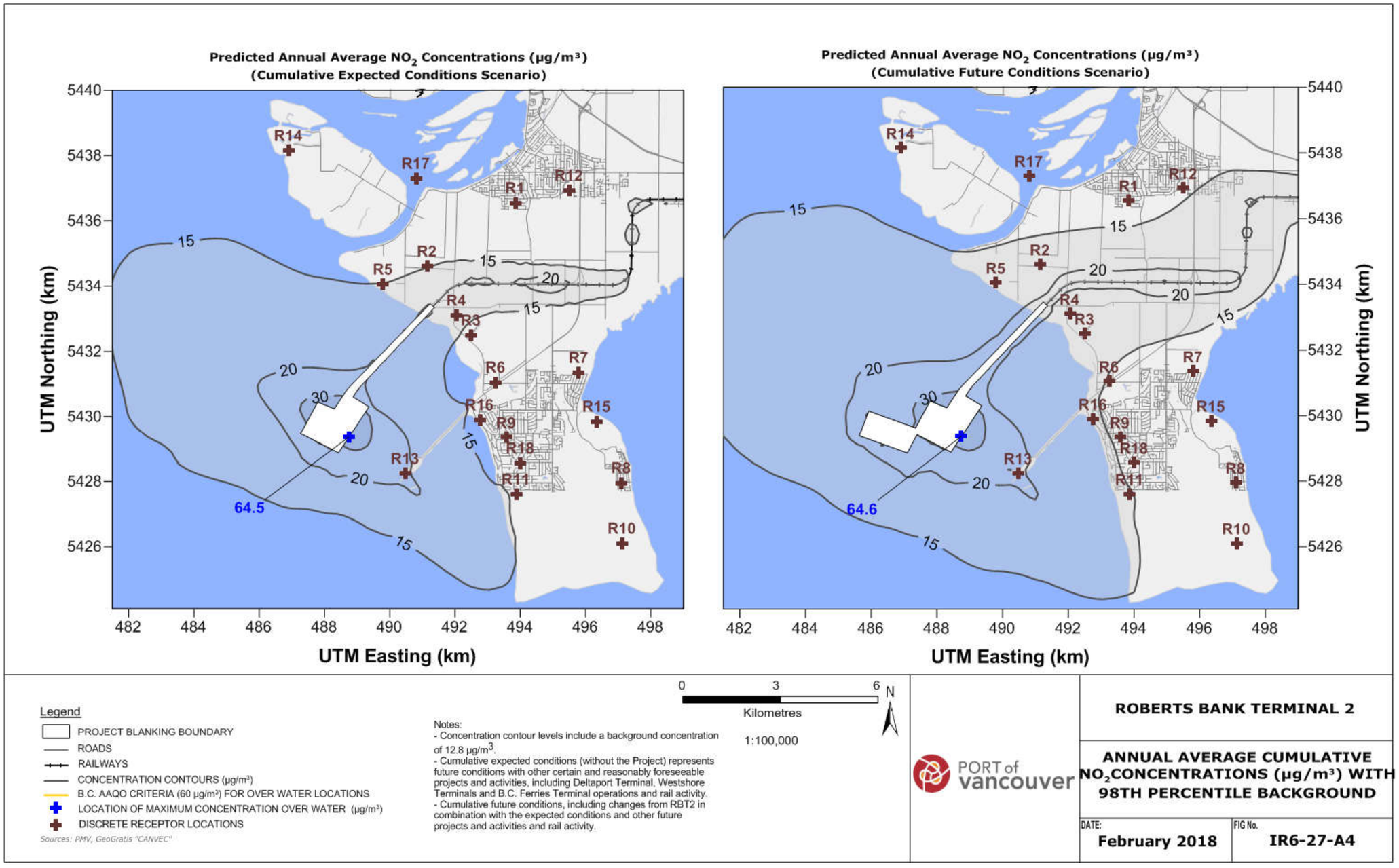
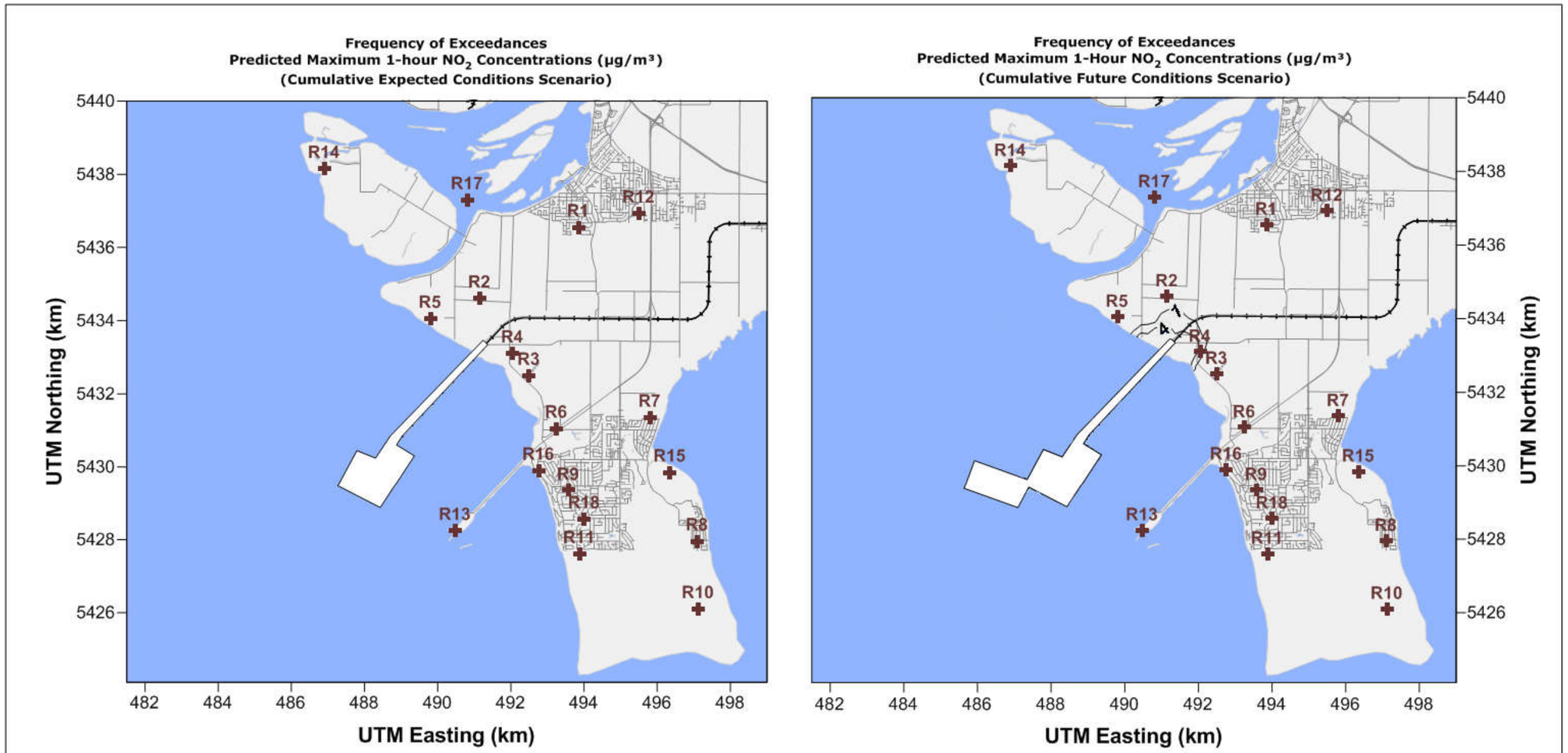


Figure IR6-27-A5 Frequency of Exceedance (contours in number of hours per year) of Predicted Maximum 1-Hour Average NO_2 Concentrations for Cumulative Expected and Cumulative Future Conditions



Legend

- PROJECT BLANKING BOUNDARY
- ROADS
- RAILWAYS
- FREQUENCY OF EXCEEDANCES CONTOURS (hours)
- METRO VANCOUVER CRITERIA (200 µg/m³) FOR OVER LAND LOCATIONS
- DISCRETE RECEPTOR LOCATIONS

Sources: PMV, GeoGratis "CANVEC"

0 3 6
Kilometres

N

Notes:

Cumulative expected conditions (without the Project) represents future conditions with other certain and reasonably foreseeable projects and activities, including Deltaport Terminal, Westshore Terminals and B.C. Ferries Terminal operations and rail activity.

Cumulative future conditions, including changes from RBT2 in combination with the expected conditions and other future projects and activities and rail activity.

PORT of vancouver

ROBERTS BANK TERMINAL 2

FREQUENCY OF EXCEEDANCES MAXIMUM 1-HOUR CUMULATIVE NO_2 CONCENTRATIONS (µg/m³) WITH 98TH PERCENTILE BACKGROUND

DATE:	FIG No.
February 2018	IR6-27-A5

APPENDIX IR6-27-B
INFORMATION ON GENERATION OF APPENDIX IR6-27-A FIGURES

Appendix IR6-27-B Information on Generation of Appendix IR6-27-A Figures

Table 5-12 in EIS Appendix 9.2-A tabulates the maximum (i.e., 100th percentile) predicted 1-hour average NO_2 concentrations at discrete receptors for the following conditions:

- Cumulative expected conditions from the operation of the Westshore Terminals, Deltaport Terminal, and the BC Ferries Tsawwassen Terminal plus other future projects and activities (i.e., rail locomotive emissions in rail yards and activity off the Roberts Bank causeway beyond the Project area, as outlined in EIS Appendix 9.2-B and Appendix G of EIS Appendix 9.2-A), and 98th percentile 2010 background air quality, as measured at Station T39 (Column A). Emissions from ships in transit in the Strait of Georgia are included in the background air quality; therefore, these emissions are not included in the Column A emissions. For more information, refer to the response to IR6-12;
- Incremental concentrations from RBT2 operations (Column B), calculated as the maximum difference in hourly predicted concentrations from expected conditions (without the Project) to future conditions with the Project;
- Cumulative future conditions (Column C), which includes emissions presented in Columns A and B. I Column C concentrations are not necessarily the same as the sum of Column A and Column B emissions, as they may not occur in the same period (e.g., 1-h, 24-h, etc.); and
- Percent cumulative change in emissions associated with cumulative future operations and rail activity, as compared with expected operations and rail activity (calculated as (Column C – Column A) / Column A.

The rail yard activity in Appendix G of EIS Appendix 9.2-A was modelled on a different modelling grid (see Figure 3-1 of Appendix G) from that which was used to model emissions from the marine terminals at Roberts Bank (see Figure 3-1 of Appendix C) in order to more accurately capture the maximum predicted contaminant concentrations nearest the two modelled rail yards. Because the modelling of the emissions from the marine terminals was conducted on a different grid from that conducted for the two rail yards, the estimated total NO_2 concentration in Column C of Table 5-12 overestimates NO_2 concentrations. This is because the maximum predicted concentrations from the two modelling runs may not coincide in time at the same grid point location. This factor was outlined in a note below Table 5-12, that stated "Future conditions concentrations are not necessarily the same as the sum of expected conditions (column [A]) and incremental RBT2 operations (column [B]) as they may not occur in the same time period (e.g., 1-h, 24-h, etc.)". The Panel referred to these overpredictions in the context to this information request, stating that cumulative future conditions (Column C) were predicted to "exceed Metro Vancouver's 1-hour NO_2 objective at four of the sensitive receptor locations".

In order to address this source of uncertainty and to generate the requested isopleth plots for this response, the emissions from the two rail yards were re-modelled using the same modelling grid used for the modelling of emissions from the marine terminals (i.e., the receptor grid shown in Figure 3-1 of EIS Appendix C). **Table IR6-27-B1** provides updated 1-hour NO_2 concentrations tabulated in Columns A and B of Table 5-12 (EIS Appendix 9.2-A) and updated percent cumulative change (Column D) based on the results of re-modelling.

Concentrations predicted for cumulative future conditions are not predicted to exceed Metro Vancouver's 1-hour NO_2 objective at all discrete receptors (i.e., concentrations at all discrete receptor locations are below the 1-hour NO_2 objective of 200 µg/m^3).

Table IR6-27-B1 Estimated Percent Cumulative Change from Expected Conditions: Predicted 1-hour NO_2 Concentrations (µg/m^3) (Updated EIS Appendix 9.2-A, Table 5-12)

Discrete Receptor	1-h NO_2			Percent Cumulative Change[d] [D]
	Expected Conditions and other future Projects/Activities[a] [A]	Incremental RBT2 Operations[b] [B]	Cumulative Future Conditions[c] [C]	
Background Concentration	44.7			
Ladner	108	56	145	34%
Farmer 1	139	75	161	16%
Tsawwassen First Nations	147	77	165	12%
Farmer 2	146	77	172	18%
Farmer 3	148	78	164	11%
Tsawwassen Beach Campsite	148	76	151	2%
Beach Grove	102	60	131	29%
Boundary Bay	136	32	143	5%
Tsawwassen	154	65	162	5%
Point Roberts 1	108	6	122	14%
Point Roberts 2	144	13	146	2%
Delta Hospital	123	33	143	16%
B.C. Ferries Terminal	171	76	171	0%
Reifel Bird Sanctuary	110	39	126	14%
Boundary Bay GVRD Park	121	31	138	13%
English Bluffs Beach	149	74	151	2%
South Arm Marsh	102	53	143	40%
Air Quality Station T39	146	48	151	3%

Notes:

a. Concentrations represent cumulative expected conditions, including emissions from Deltaport Terminal, Westshore Terminals, and BC Ferries Terminal operations, represents future conditions with other certain and reasonably foreseeable projects and activities (i.e., rail locomotive emissions in rail yards and activity off the Roberts Bank causeway beyond the Project area), and background concentrations.

b. Incremental concentrations represent the maximum difference in hourly predicted concentrations from expected conditions (without Project) to future conditions with the Project.

c. Concentrations represent cumulative future conditions, including changes from RBT2 in combination with the cumulative expected conditions. Cumulative future conditions concentrations are not necessarily the same as the sum of cumulative expected conditions (Column [A]) and incremental RBT2 operations (Column [B]) as they may not occur in the same time period (e.g., 1-h, 24-h, etc.)

d. The percent cumulative change associated with cumulative future operations and rail activity, as compared with expected operations and rail activity; Column [D] = (Column [C]-Column [A])/Column [A].

IR6-28 Air Quality – NO_2 Exceedances During Construction

Information Source(s)

EIS Volume 2: Section 9.2; Appendix 9.2-A, Appendix E, Section 4.4, Figures 4-10, 4-13 and 4-14

Context

The Proponent, in Section 9.2 of the EIS, concluded that the construction activities were predicted to cause a small increase in air contaminants concentrations, primarily in areas over water and in the vicinity of the construction works. The construction phase assessment in Appendix E did show areas of NO_2, PM_{10} and $PM_{2.5}$ where the limit of the criteria was attained or where there was an exceedance over water (Figures 4-10, 4-13 and 4-14) for peak day scenarios. There were also areas where the criteria limits were attained for NO_2 and PM_{10} overland (Figures 4-10 and 4-13), including on Tsawwassen First Nation lands and Point Roberts.

As stated by the Proponent in Section 4.4 of Appendix E, exceedances are unlikely to occur for particulate matter because they are only predicted for certain meteorological conditions and would only occur if the meteorological conditions were to coincide with the peak construction activity. Clarification is needed as to the mitigation measures to be applied should such a scenario occur.

Information Request

Propose mitigation measures to prevent poor air quality when NO_2, PM_{10} and $PM_{2.5}$ on peak construction days would coincide with a day that has unfavorable meteorological conditions. Specify the meteorological conditions, and where they will be measured.

Discuss mitigation measures that could be imposed to avoid reaching or exceeding NO_2, $PM_{2.5}$ and PM_{10} air quality objectives, such as reducing the number of activities in any given day, or reducing certain activities. Detail how the mitigation measures could be implemented.

VFPA Response

In order to respond to this information request, background information is provided below on the assessment of peak construction activity provided in Appendix E of EIS Appendix 9.2-A, as well as contextual information on the meteorological conditions that are anticipated to contribute to maximum concentrations that could lead to exceedances of NO_2, $PM_{2.5}$, and PM_{10} air quality objectives. Requested information on proposed mitigation measures to avoid reaching or exceeding NO_2, $PM_{2.5}$, and PM_{10} air quality objectives and implementation of such measures is provided subsequently.

Background Information and Context

A conservative approach was taken for predicting potential changes to air quality resulting from RBT2 construction activities, as described in Appendix E of EIS Appendix 9.2-A (for example, the use of conservative equipment ages, equipment deterioration factors, and engine emission factors). This is because activity-related information available at the time of commencement of the RBT2 Air Quality Study (RBT2 Study) was preliminary, and it was understood that the timing of the various construction activities may differ (Section 2.2 in Appendix E of EIS Appendix 9.2-A).

The VFPA is committed to implementing specific measures during construction, which will be included in the Air Quality and Dust Control Plan (EIS Section 33.3.3). These measures will be designed to minimise the potential for exceedances of applicable air quality objectives. Relevant regulatory agencies, organisations, and Aboriginal groups will be consulted during the development of the Air Quality and Dust Control Plan to ensure it addresses regulatory requirements and standards. Additional information on the Air Quality and Dust Control Plan is provided in the responses below.

Peak Day Construction Scenario

The peak day construction activity was defined based on anticipated construction work that could potentially occur during a two-day period on June 8 to 9, 2022, as depicted in Figure 2-1 in Appendix E of EIS Appendix 9.2-A. This representative period was chosen because it was expected to have the maximum number of pieces of equipment operating simultaneously in a 24-hour period. Although peak day construction activity was modelled as occurring on any day of the year, the results should not be misinterpreted to mean that peak day construction activity would occur on every day of the year. Consequently, the estimated frequency of occurrence for maximum predicted concentrations at the maximum point of impingement (MPOI) for the peak day construction scenario on an annual basis is unrealistic because the duration of such activity would be limited to only a few days during the entire construction phase. Furthermore, peak day construction activities were modelled as if they occurred on a 24-hour basis, every day of the year. Actual construction activity is expected to be limited to shorter periods of the day; therefore, the assessment of peak day construction activity presented in Appendix E of EIS Appendix 9.2-A overestimates actual potential changes in air quality due to such construction activity.

Overprediction of 1-hour Average NO_2 Concentrations

The prediction of 1-hour average NO_2 concentrations is subject to the same caveats expressed in the response to IR6-22 concerning the use of the Ozone Limiting Method (OLM). The OLM, and other methods of converting NO_x emissions to ambient NO_2 concentrations, have been shown to overestimate NO_2 concentrations by a factor of 1.7 to 2.0 in method validation studies (Podrez 2013, 2015). Moreover, the MPOI for 1-hour average NO_2 concentrations from construction activity are predicted to occur adjacent to the construction activity emission sources. The OLM assumes instantaneous conversion of NO to NO_2 when in fact this conversion actually occurs gradually in the atmosphere as the emission plume is transported

away from the source. For these reasons, the MPOI concentrations over land and over water overestimate NO_2 concentrations that would be expected to occur.

Overprediction of 24-hour Average PM_{10} and $PM_{2.5}$ Concentrations

Similarly, the maximum 24-hour average PM_{10} and $PM_{2.5}$ concentrations predicted in the RBT2 Study for peak day construction activity are subject to the uncertainties described in Section 5.3 in Appendix E of EIS Appendix 9.2-A. Actual maximum predicted PM_{10} and $PM_{2.5}$ concentrations from construction activity may be overestimated by up to an order of magnitude (i.e., predicted concentrations may be ten times higher than the concentrations expected to occur).

Description of Meteorological Conditions

The isopleth plot figures (**Figures IR6-28-1** through **IR6-28-7**) provided below incorporate the updated study criteria for over land and over water locations presented in Table IR6-23-1 in the response to IR6-23. As outlined in EIS Section 9.2.10.5 and the response to IR6-22, isopleth plots indicate the highest hourly or daily concentrations for the specific hour or day in the year that results in the maximum concentration at each grid receptor point and should not be interpreted as an aggregate plume.

1-hour NO_2 MPOI Over Land

The highest 1-hour average incremental NO_2 concentration predicted over land for the peak day construction scenario is 199.9 µg/m^3 under light wind (0.5 m/s) from the west-southwest, moderately stable conditions, and a low mixing height of 50 m. The MPOI occurs at the east end of the causeway, immediately adjacent to and downwind from the emission sources on the causeway (**Figure IR6-28-1**). This NO_2 concentration is predicted to occur in late summer during nighttime (2:00 a.m.) and is subject to the assumption that such peak construction activity would occur during these hours, which is not likely, rather than daytime hours.

If the duration of peak day construction activity were to be extended to every day of the year, the frequency that the maximum NO_2 concentration (when added to the background level of 44.7 µg/m^3) would exceed updated study criteria[1] at the location of the MPOI over land would be 24 hours in a year (shown as 1 day or 0.3% of the year in **Figure IR6-28-1**). Most of these concentrations are predicted to occur between May and October as isolated hourly events. However, as the peak day construction activity is not expected to occur every day of the year, the actual probability would be much lower than 24 hours in a year, if ever, as explained further below.

The wind rose plot at the 1-hour average NO_2 MPOI over land shows that light west-southwest winds occur less than 1% of the time (**Figure IR6-28-2**). Moderately stable meteorological conditions with light west-southwest winds, which led to the highest predicted NO_2 concentrations over land, are predicted to occur 0.07% of the time. Given the low probability

[1] Metro Vancouver ambient air quality objective (AAQO) of 200 µg/m^3.

of these meteorological conditions occurring simultaneously with infrequently occurring peak day construction activity (i.e., limited to a few days in the year), plus the over-prediction inherent to the application of the OLM, renders the actual attainment of this level of maximum NO_2 concentration unlikely.

Figure IR6-28-1 Maximum Predicted 1-hour NO_2 Concentrations Over Land – Peak Day Construction Activity

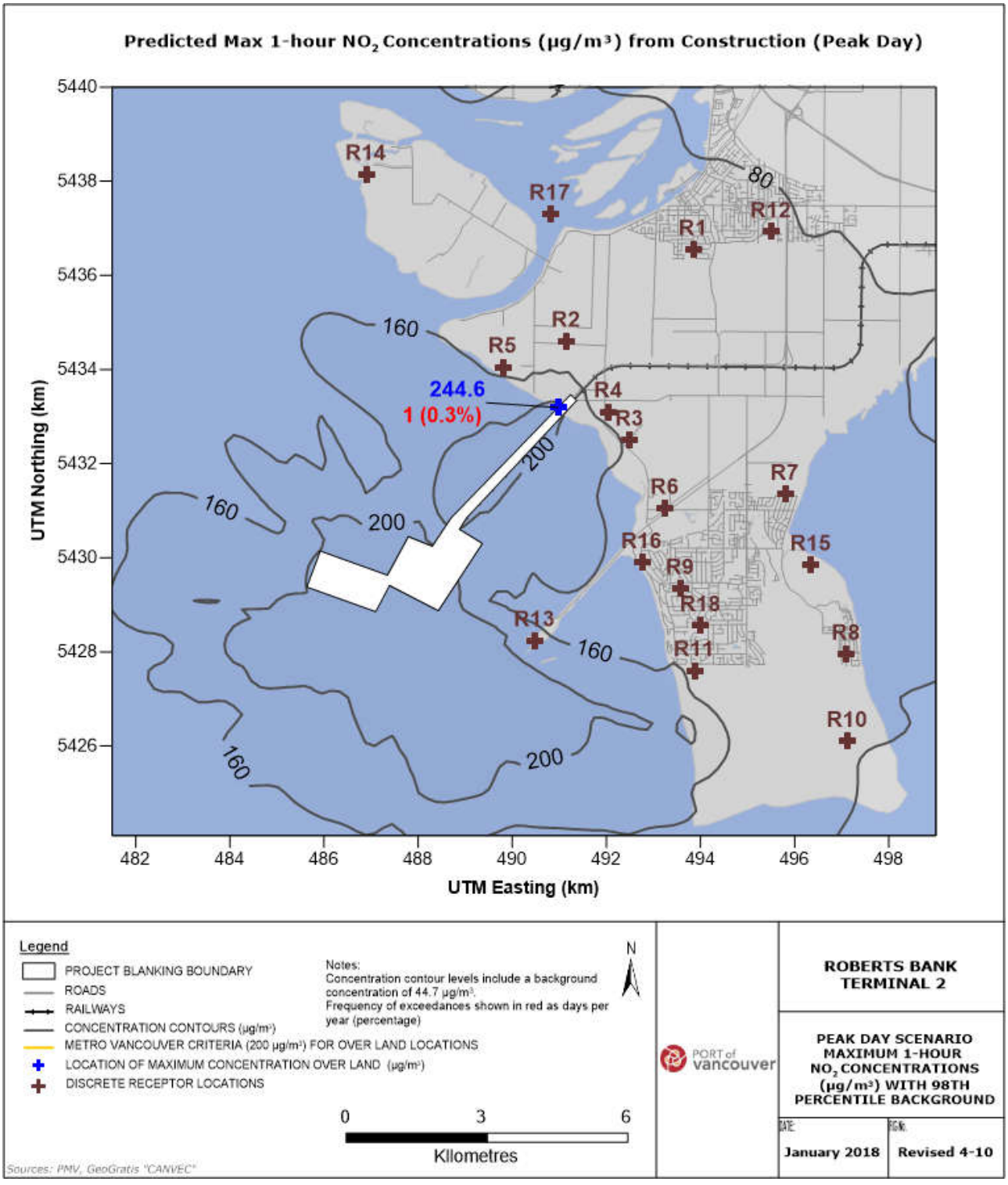
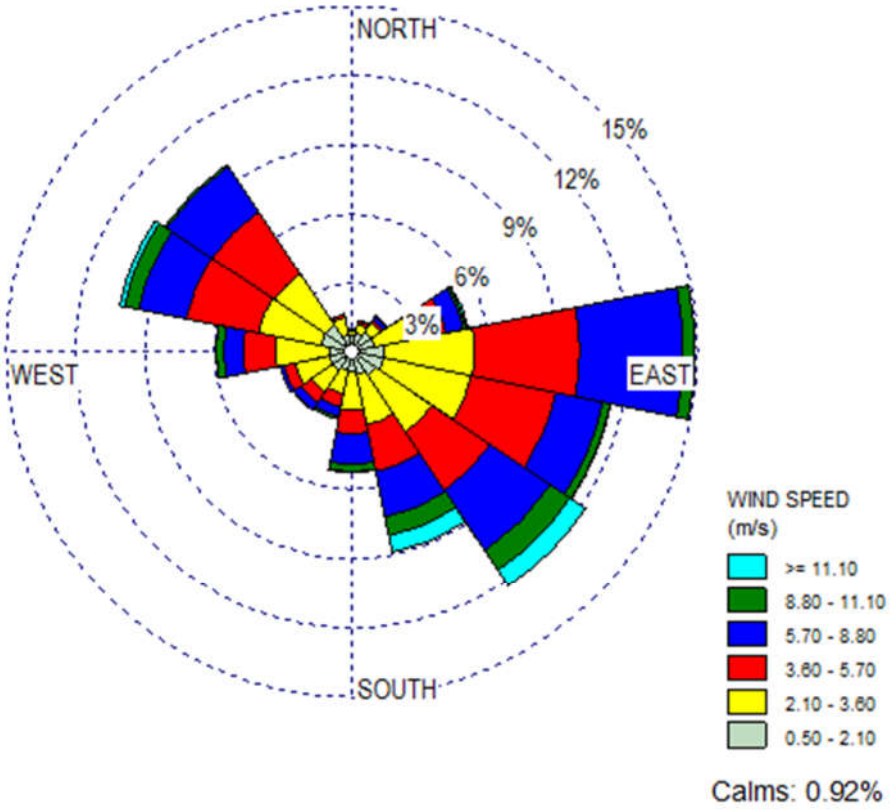


Figure IR6-28-2 Wind Rose for Over Land MPOI Location at East End of the Causeway



1-hour NO_2 MPOI Over Water

The highest 98th percentile 1-hour average incremental NO_2 concentration predicted over water for the peak day construction activity scenario is 764.1 µg/m^3 and occurs under calm wind (0.2 m/s) from the northwest, moderately stable conditions, and a low mixing height of 51.4 m. This concentration is predicted to occur on October 16 in the evening (11:00 p.m.) at the RBT2 terminal, adjacent to and immediately downwind of emission sources at the terminal (**Figure IR6-28-3**). The caveats concerning the conservatism of the OLM and the proximity of the MPOI location to the sources of emissions discussed above (for the MPOI over land) also apply to the MPOI over water. It should also be noted that, at this location, there is no public access and air quality at this location that would be subject to workplace exposure criteria set by WorkSafeBC of 1 ppm (i.e., 1,910 µg/m^3).

If the peak day construction activity were to be extended to every day of the year, the frequency of NO_2 concentrations exceeding the update study criteria[2] at the location of the

[2] B.C. AAQO of 188 µg/m^3.

MPOI over water is estimated to occur 26% of the time (i.e., 2,260 hours or 94 days per year as shown on **Figure IR6-28-3**). Most of these concentrations are predicted to occur between April and October, as isolated events lasting less than a day (only three events were predicted to last more than 24 hours, with the longest duration occurring for 39 hours). However, maximum concentrations (inclusive of the background concentration) would not exceed the WorkSafeBC exposure limit for worker health and safety.

The wind rose plot at the location of the NO_2 MPOI over water shows that calm conditions from the northwest occur less than 1% of the time (**Figure IR6-28-4**). Moderately stable meteorological conditions with calms, which led to the highest predicted NO_2 concentrations over water, are predicted to occur 0.05% of the time. Therefore, the combined probability that the peak day construction activity would coincide with these meteorological conditions to produce the maximum predicted NO_2 concentration over water is very low.

Figure IR6-28-3 Predicted 98th Percentile 1-hour Average NO_2 Concentrations Over Water – Peak Day Construction Activity

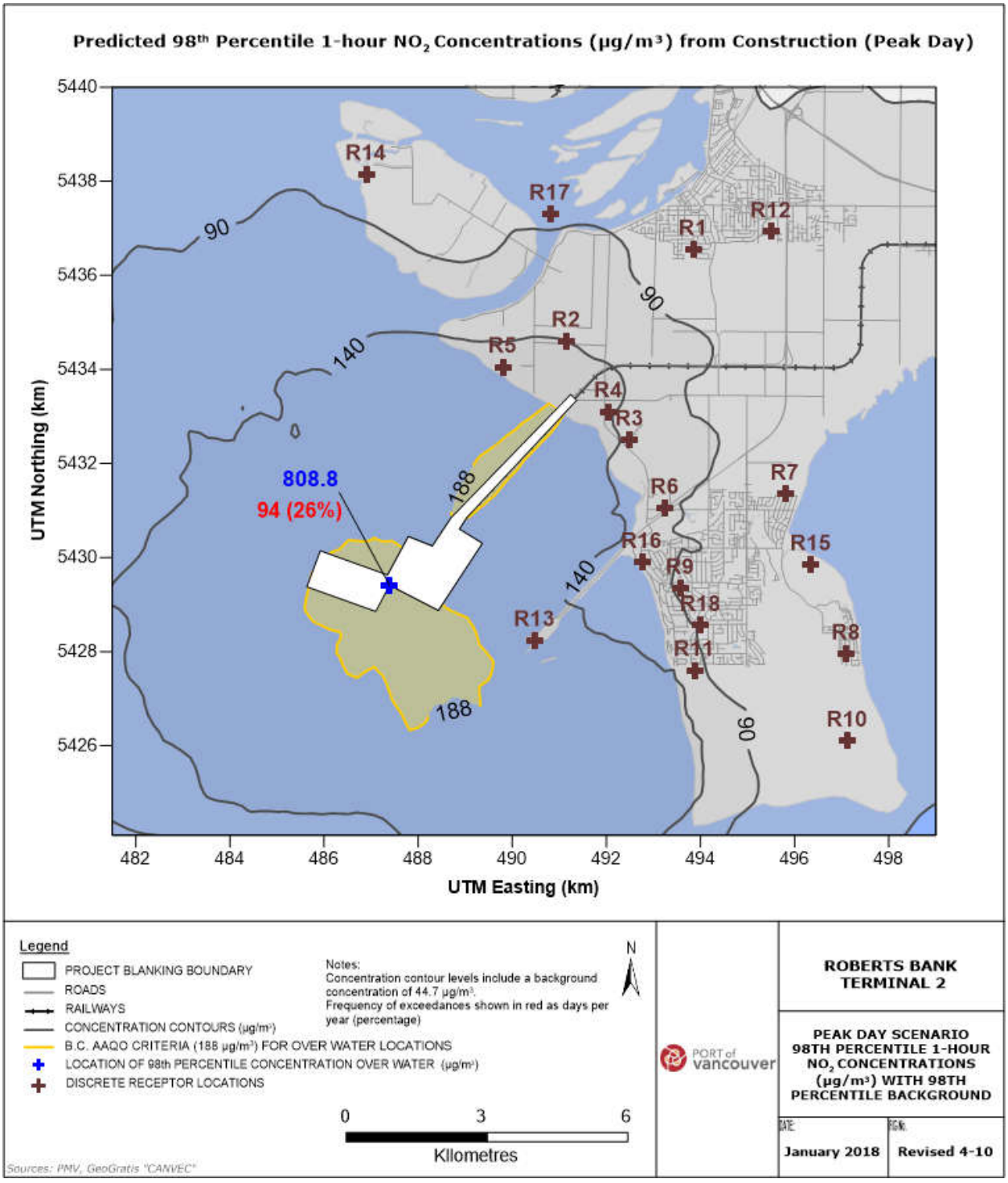
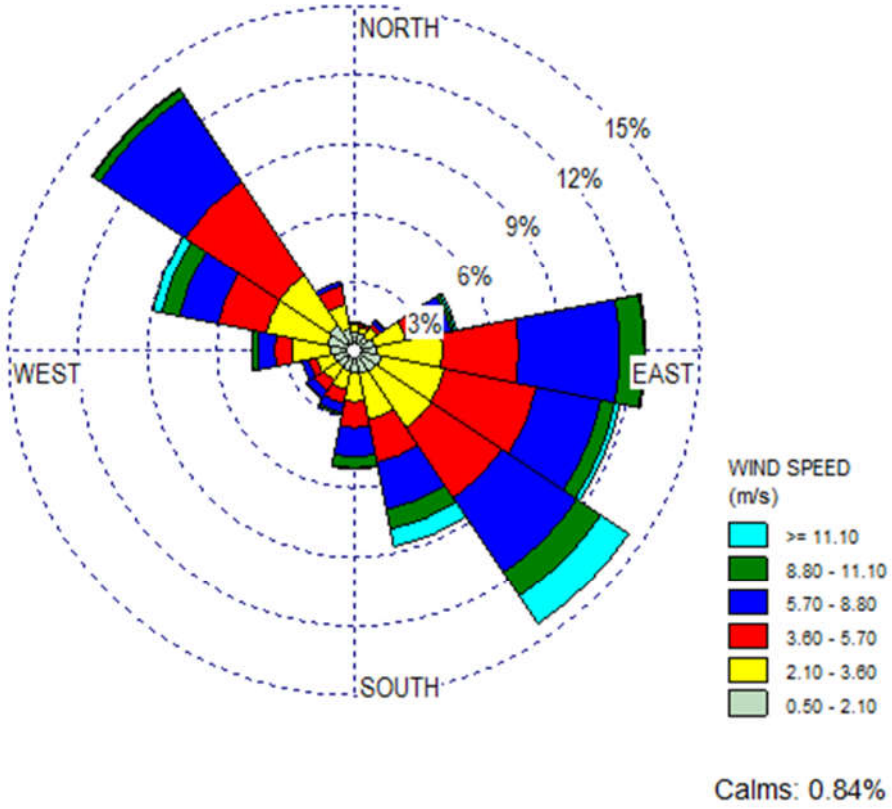


Figure IR6-28-4 Wind Rose at Over Water MPOI Location at RBT2 Terminal



24-hour PM_{10} MPOI Over Water and Over Land

The highest 24-hour rolling average incremental PM_{10} concentration predicted over land for the peak day construction activity scenario is 78.7 µg/m^3 and occurs right at the end of the causeway (**Figure IR6-28-5**), similar to the location of the MPOI for 1-hour average NO_2 concentration. This concentration is predicted to occur on September 11 at 4:00 a.m., under light wind (1.4 m/s) from the northeast, moderately stable conditions, and a low mixing height of approximately 54 m. If the level of peak day construction activity is reduced at nighttime, the concentration during these meteorological conditions would be expected to be lower. Furthermore, considering the order-of-magnitude uncertainty for PM_{10} emissions discussed in Section 5.3 in Appendix E of the EIS Appendix 9.2-A, the maximum predicted PM_{10} concentration over land and the 98th percentile background concentration of 23.1 µg/m^3 (total of 101.8 µg/m^3, as shown in **Figure IR6-28-5**) is likely to be below the updated study criteria[3] at all times during Project construction.

[3] Metro Vancouver AAQO of 50 µg/m^3.

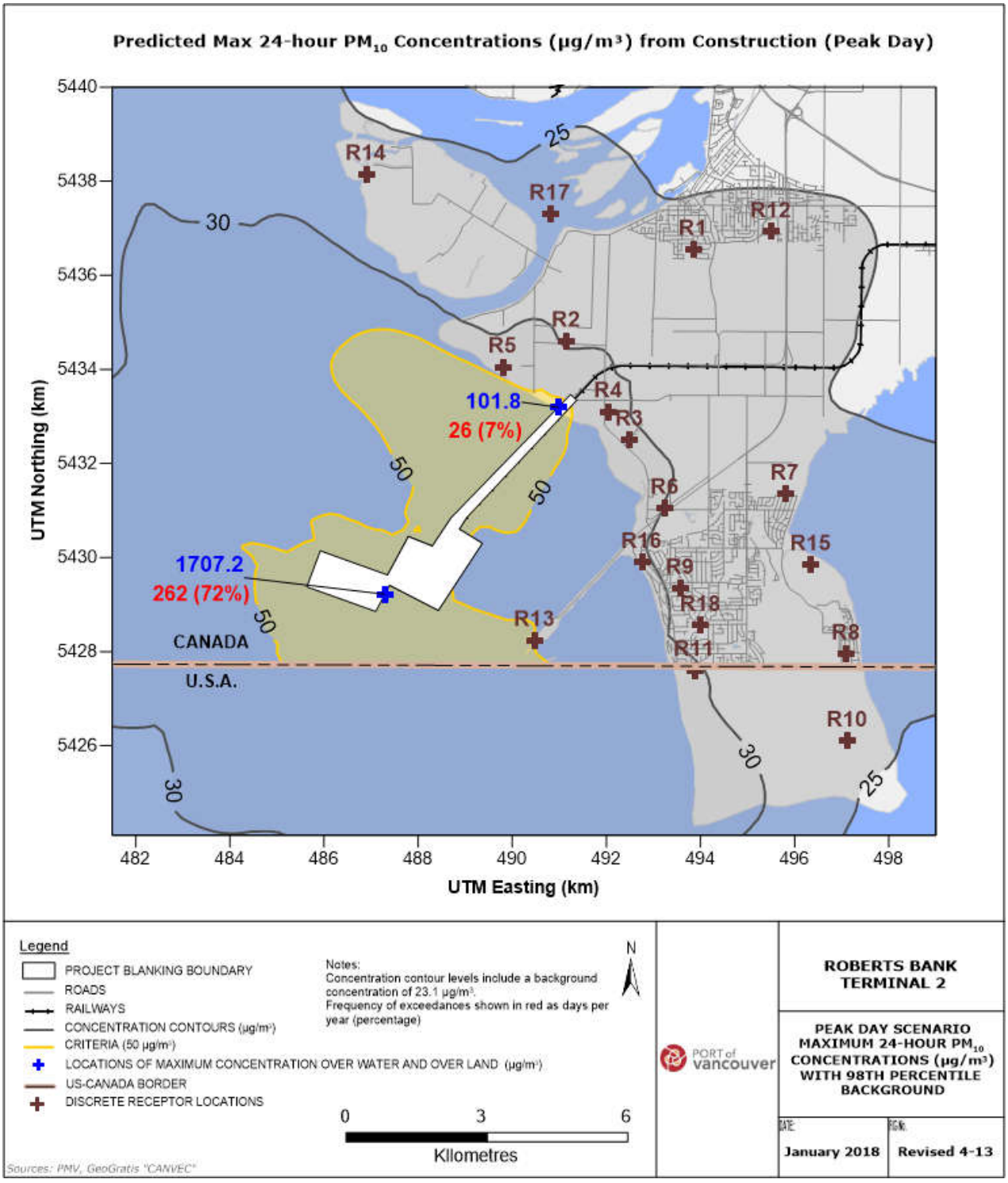
The wind rose plot at the location of the 24-hour PM_{10} MPOI over land shows that light northeast winds occur infrequently (less than 1% of the time) (**Figure IR6-28-2**). If the duration of peak day construction activity were to extend over the entire year, the frequency of PM_{10} concentrations exceeding the updated study criteria (50 µg/m^3) at the location of the MPOI over land is predicted to occur approximately 7% of the time (or 627 hours in a year). Most of these concentrations are predicted to occur between May and October lasting several hours per day, which would not necessarily mean that the 24-hour average would exceed the 50 µg/m^3 criterion (i.e., only a few events were predicted to last more than 24 hours, with the longest duration occurring for 25 hours). Given the limited duration of anticipated peak day construction activity during the year and the uncertainty associated with PM_{10} emissions (discussed in Section 5.3 in Appendix E of the EIS Appendix 9.2-A), the PM_{10} criterion is unlikely to be exceeded during the construction phase.

The highest 24-hour rolling average incremental PM_{10} concentration predicted over water for the peak day construction activity scenario is 1,684 µg/m^3 under westerly winds with a speed of 4.7 m/s, neutral stability conditions, and mixing height of 594 m (predicted to occur on April 19 at 9:00 p.m.). This concentration is predicted to occur adjacent to the RBT2 terminal and downwind of the emission sources at the terminal (**Figure IR6-28-5**). As there is no public access at this location, the relevant air quality exposure criterion for total or respirable particulate matter[4] at this location is the WorkSafeBC time-weighted average (TWA) over an 8-hour workday of 3 mg/m^3 (i.e., 3,000 µg/m^3) (WorkSafeBC 2017). The maximum predicted concentration inclusive of the 98th percentile background concentration is 1,707.2 µg/m^3, which is well below the TWA criterion, without consideration of the order-of-magnitude overprediction. For Point Roberts, Washington, the maximum predicted 24-hour average PM_{10} concentrations shown in **Figure IR6-28-5** (concentrations around 30 µg/m^3) do not exceed the U.S. National Ambient Air Quality Standard (NAAQS) of 150 µg/m^3.

Figure IR6-28-4 shows the wind rose plot at the 24-hour PM_{10} MPOI over water. Meteorological conditions that led to the highest predicted PM_{10} concentrations over water are predicted to occur infrequently (i.e., 0.4% of the time). If the peak day construction activity were to extend to every day of the year, the frequency of PM_{10} concentrations exceeding the updated study criteria[5] at the location of the MPOI over water is predicted to occur approximately 72% of the time (i.e., 6,281 hours, or 262 days in a year as shown in **Figure IR6-28-5**), but no exceedances are predicted when considering the WorkSafeBC TWA criterion of 3,000 µg/m^3.

[4] Respirable generally is assumed to refer to $PM_{2.5}$ but is applied to PM_{10} for contextual purposes in this response.
[5] B.C. AAQO of 50 µg/m^3.

Figure IR6-28-5 Maximum Predicted 24-hour Average PM_{10} Concentrations – Peak Day Construction Activity



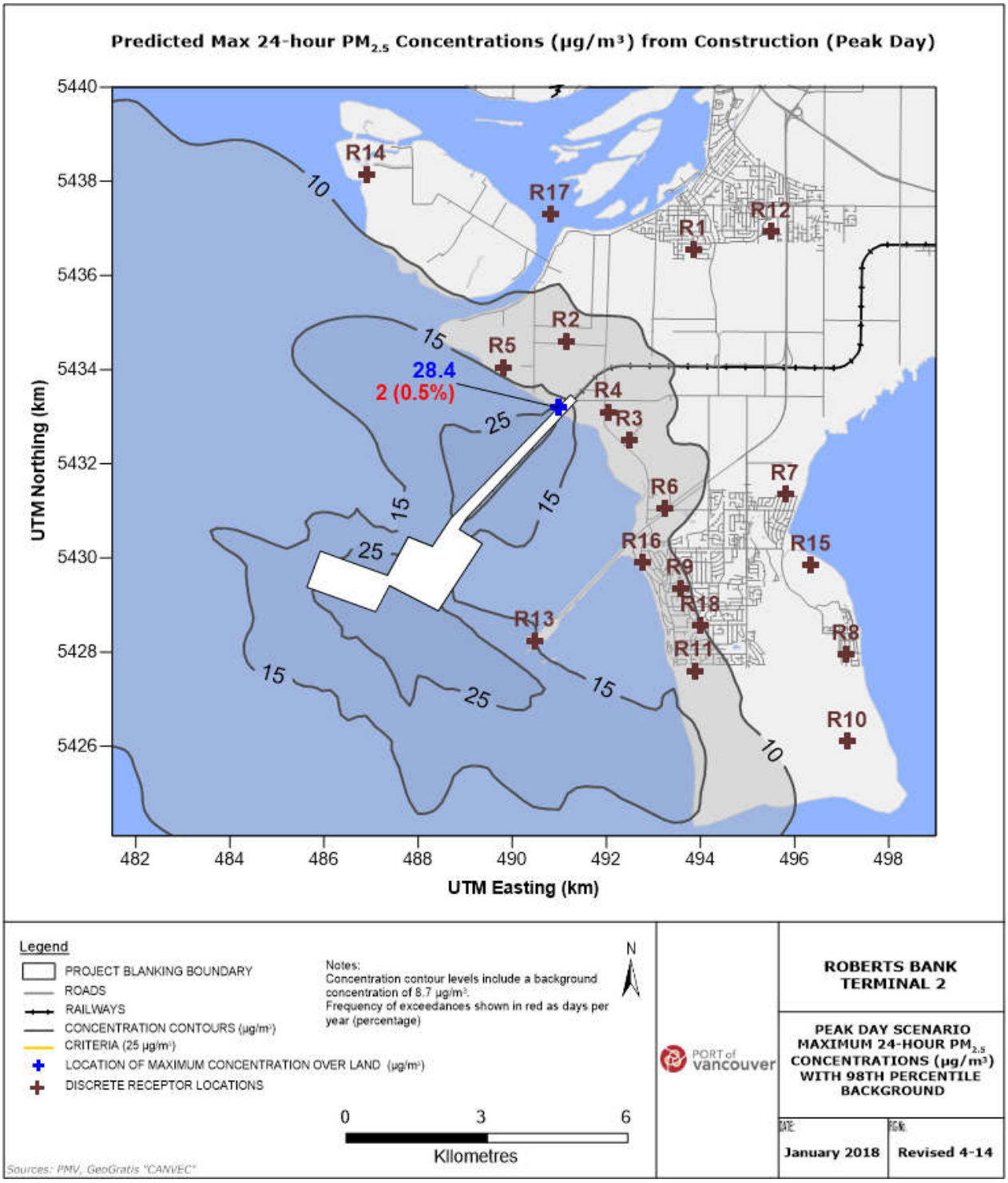
24-hour $PM_{2.5}$ MPOI Over Land

The highest 24-hour rolling average incremental $PM_{2.5}$ concentration predicted over land for the peak day construction activity scenario is 19.7 µg/m^3 and occurs at the end of the causeway (**Figure IR6-28-6**), similar to the location for the 24-hour PM_{10} MPOI. This concentration is predicted to occur on September 11 at 4:00 a.m., under light (i.e., wind speed of 1.4 m/s) north-easterly winds, moderately stable conditions, and a low mixing height of approximately 54 m. The wind rose plot at the location of maximum 24-hour $PM_{2.5}$ concentration predicted over land shows a very low frequency (<1%) of north-easterly winds (**Figure IR6-28-2**).

If the peak day construction activity were to be extended to the entire year and occur 24 hours a day, the frequency with which the predicted $PM_{2.5}$ concentrations (including background of 8.7 µg/m^3) would exceed the updated study criteria[6] at the location of the MPOI over land is predicted to be approximately 0.5% of the time (or 47 hours in a year, shown as 2 days in **Figure IR6-28-6**), in August, September, and beginning of October, mostly during the evening, nighttime, and early morning hours. However, as peak day construction activity will not occur all year long, the actual frequency of exceeding the criteria would depend on the low probability of the activity occurring during a brief period of a few days coinciding with the meteorological conditions suitable to produce the highest predicted concentrations.

[6] Metro Vancouver AAQO of 25 µg/m^3.

Figure IR6-28-6 Maximum Predicted 24-hour Average $PM_{2.5}$ Concentrations Over Land – Peak Day Construction Activity



24-hour $PM_{2.5}$ MPOI Over Water

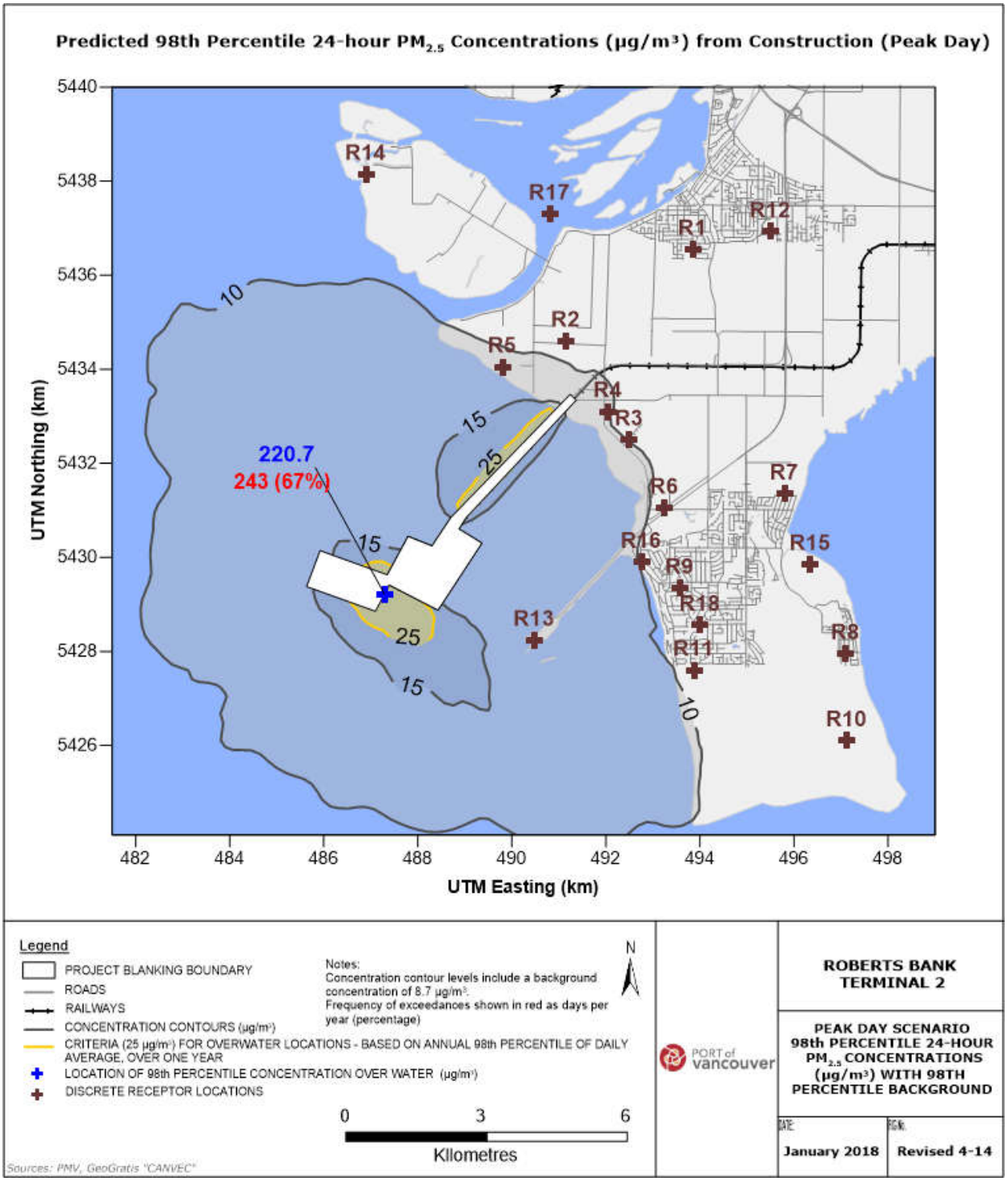
The highest 98th percentile 24-hour average incremental $PM_{2.5}$ concentration predicted over water for the peak day construction activity scenario is 212 µg/m^3 under light west-

southwesterly winds (i.e., average wind speed of 1.6 m/s), moderately unstable conditions, and average mixing height of 185 m. This concentration is predicted to occur on August 20 (24-hour averaging period) at the RBT2 terminal (**Figure IR6-28-7**). The meteorological conditions that led to the highest predicted $PM_{2.5}$ concentrations over water are predicted to occur infrequently (i.e., 0.24% of the time), and therefore, the meteorological conditions that could produce this concentration would be quite limited. The maximum predicted $PM_{2.5}$ concentration at the MPOI over water location (inclusive of the 98th percentile concentration of 8.7 µg/m^3) is well below the WorkSafeBC TWA limit of 3,000 µg/m^3 for worker health and safety.

If the duration of peak day construction activity were to extend to the entire year, the frequency of $PM_{2.5}$ concentrations that would exceed the updated study criterion[7] at the location of MPOI over water is predicted to occur approximately 67% of the time (or 243 days in a year as shown in **Figure IR6-28-7**), mostly from May to September. However, as the location of the MPOI is not accessible to the general public, the relevant criterion for exposure is the WorkSafeBC TWA which is not predicted to be exceeded.

[7] B.C. AAQO of 25 µg/m^3.

Figure IR6-28-7 Predicted 98th Percentile 24-hour Average $PM_{2.5}$ Concentrations Over Water – Peak Day Construction Activity



Propose mitigation measures to prevent poor air quality when NO_2, PM_{10} and $PM_{2.5}$ on peak construction days would coincide with a day that has unfavorable meteorological conditions. Specify the meteorological conditions, and where they will be measured.

As described above, the probability of unfavorable meteorological conditions coinciding with peak construction days is expected to be very low. Exceedances of updated study criteria (shown in Table IR6-23-1 in the response to IR6-23) are expected to occur infrequently, if ever, during the construction period.

As outlined in EIS Section 33.3 and EIS Table 33-1, an Air Quality and Dust Control Plan will be developed as part of the Construction Environmental Management Plan prior to the commencement of any construction activities in consultation with agencies including the Canadian Environmental Assessment Agency, Environment Canada and Climate Change, the B.C. Ministry of Environment and Climate Change Strategy, Metro Vancouver, and/or Health Canada, as well as organisations and Aboriginal groups, as relevant. The Air Quality and Dust Control Plan will specify measures and adaptive management measures to address potential elevated air quality concentrations on peak construction days and will consider the possibility of unfavourable meteorological conditions coinciding with such days[8].

Discuss mitigation measures that could be imposed to avoid reaching or exceeding NO_2, $PM_{2.5}$ and PM_{10} air quality objectives, such as reducing the number of activities in any given day, or reducing certain activities. Detail how the mitigation measures could be implemented.

To verify that updated study criteria are met, the VFPA will conduct air quality monitoring in accordance with the Construction Compliance Monitoring Plan (EIS Section 33.3.1), which will be informed by the requirements outlined in the Air Quality and Dust Control Plan. Should air quality observations reach set trigger values, adaptive management measures will be implemented. Adaptive management measures, such as reducing construction activity levels, will be specified in the Construction Compliance Monitoring Plan.

References

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Podrez, M. 2015. An Update to the Ambient Ratio Method for 1-h NO_2 Air Quality Standards Dispersion Modeling. Atmospheric Environment 103:163-170.

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[8] For examples of measures that may be included in the Air Quality and Dust Control Plan, see Best Practices for the Reduction of Air Emissions from Construction and Demolition Activities prepared for Environment Canada (2005; available at http://www.bv.transports.gouv.qc.ca/mono/1173259.pdf).

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IR6-29 Air Quality – Contaminant Emission Reduction: Reducing Marine-source NO_x

Information Source(s)

EIS Volume 2: Appendix 9.2-A: Section 4, Figure 4-10; Appendix A: Section 2.5.1, Table 2-12, Section 5.2, Attachments 8 and 9; Appendix F: Figure 4-1

Proponent Response to Additional Information Requirement of July 31, 2015 (CEAR Doc#314): IR19, Appendix 19-A, Table 2-1

Context

In Figure 4-10 of Appendix 9.2-A, 1-hour NO_2 concentrations, near the causeway under 'Project conditions in 2025', is shown to be close to Metro Vancouver's ambient air quality limit of 200 ug/m^3 and exceeding the British Columbia interim air quality objective of 188 ug/m^3 reported in Table 2-1 of Appendix 19-A.

Table 2-12 indicated that a Tier III engine is five times less polluting than a Tier I engine. The Proponent assumed that 82% of the 2025 fleet would meet the highest NOx standard of Tier III engines.

If the concentrations of NOx are close to or exceed regional air quality limits with the currently assumed proportion of vessels operating with NOx Tier III engines, information is required regarding additional mitigation measures that the Proponent will propose to reduce marine-source NOx.

Although the major annual contribution for NOx from the proposed Project will be from ships, Table 4-4-1 of Appendix 9.2-A indicated that the major annual contribution of NOx for future conditions is from Deltaport Terminal cargo handling equipment. Additional information is needed regarding measures that will or may be implemented to reduce NOx emissions at the Deltaport Terminal.

Information Request

Provide information on additional mitigation measures for reducing marine-source NOx of the proposed Project.

Provide information as to any discussion and/or agreements that have occurred or are planned with Deltaport Terminal to reduce NOx emissions from cargo handling equipment at that terminal.

VFPA Response

Clarification

As a point of clarification to the Panel's context provided above, the maximum predicted 1-hour average NO_2 concentrations (presented in Figure 4-10 of EIS Appendix 9.2-A) that

appear to approach the Metro Vancouver and exceed the B.C. ambient air quality objectives on the causeway are more closely related to NO_x emissions from switcher locomotives operating on the causeway, than to emissions from ships and cargo handling equipment at the three marine terminals. Elevated NO_2 concentrations predicted for switcher locomotives on the causeway is related to the use of the Ozone Limiting Method for the conversion from NO_x to NO_2.

As discussed in the response to IR6-22, the use of the 98th percentile ozone level in the RBT2 Air Quality Study resulted in over-prediction of NO_2 concentrations by more than double what was observed. As an example, the maximum predicted 1-hour average NO_2 concentration was 163 µg/m^3 at Station T39[1] for existing conditions while the maximum observed concentration was 78 µg/m^3 for winds blowing from the direction of the existing Roberts Bank terminals[2]. Thus, the maximum predicted 1-hour average NO_2 concentrations for existing conditions was higher by a factor of approximately two compared to observed concentrations at Station T39. The response to IR6-22 also notes that using the 100th percentile of observed ozone concentrations at Station T39 would have resulted in an over-prediction of NO_2 concentrations by a factor of 2.0 to 2.9. Therefore, due to the Ozone Limiting Method used in the assessment of NO_2 and the resulting conservative predictions, 1-hour average NO_2 concentrations near the causeway during future conditions with the Project are not expected to be close to Metro Vancouver's ambient air quality limit of 200 µg/m^3 or the B.C. interim air quality objective of 188 µg/m^3.

In addition, the modelling of marine source emissions considered a conservative scenario for future conditions with the Project, as described in the response to IR6-15 (CEAR Document #1113[3]). All three RBT2 berths were assumed to be occupied 100% of the time, in addition to a container ship arriving at RBT2 and a container ship departing the Deltaport Terminal simultaneously. Past activity levels, derived from the record of berth occupancy and ship arrival/departure at the Deltaport Terminal during the period 2005 to 2012, indicate that there were no ship arrivals on 43% of the days during that period, and there was approximately a 22% probability of having two ships arriving at the terminal on the same day when there was already a ship at berth. Therefore, having one ship arriving and another departing in the same hour plus all berths occupied was a highly conservative scenario. The emission scenario also conservatively assumes no use of shore power by vessels at berth. Consequently, the predicted concentrations shown in Figure 4-10 of EIS Appendix 9.2-A[4] (inclusive of the background concentration) referred to in the context of this information request are considered highly conservative, and not indicative of what levels are expected to

[1] The maximum predicted concentration of 163 µg/m^3 for existing conditions included the model prediction of 118.6 µg/m^3 plus the Station T39 background concentration of 44.7 µg/m^3, as shown in Table 4-4 of EIS Appendix 9.2-A.
[2] Additional explanation is provided in EIS Appendix 9.2-A, Section 4.2.1.
[3] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).
[4] Note that Figure 4-10 of EIS Appendix 9.2-A has been updated in the response to IR6-24.

realistically be in the future during Project operations. Therefore, NO_2 concentrations are not expected to be close to or exceed the Metro Vancouver or B.C. ambient air quality objectives.

Provide information on additional mitigation measures for reducing marine-source NOx of the proposed Project.

Predicted marine-source NO_x emissions are expected to improve in the future at Roberts Bank due to VFPA port-wide initiatives (described below), as well as the ongoing fleet turnover of BC Ferries to LNG (liquified natural gas) powered vessels. The switch to LNG for the ferry vessels is expected to reduce NO_x emissions by 90% from the emission rates used in the RBT2 Air Quality Study for operations at the ferry terminal (see IR6-13 of CEAR Document #1134[5]). These considerations were not factored into the RBT2 Air Quality Study, and hence the assessment of future conditions (both with and without the Project) is conservative. Beyond 2025 (the year selected to conservatively represent the operation phase), additional NO_x emission reductions are anticipated with, for example, fleet turnover of marine vessels (as described in IR6-18 of CEAR Document #1125[6]). Vessels built after 2016 must meet more stringent emission standards (i.e., Tier III requirements) mandated by the International Maritime Organization (IMO) for vessels operating in the North American Emission Control Area (ECA).

Port-wide Initiatives and Shore Power

Reductions in marine source NO_x will be further supported through the use of shore power at the third berth at the existing Deltaport Terminal, as well as at all three berths at RBT2, as detailed in the response to IR6-19 (CEAR Document #1113). As stated in that response, the VFPA promotes the use of shore power, and recognises cleaner ships through its EcoAction Program (VFPA 2017). Ships obtain a discount on harbour dues of up to 47% for going beyond regulated requirements by implementing voluntary emission reduction measures and other environmental practices, including implementing vessel and engine technologies (such as shore power), using cleaner fuels, and participating in energy efficiency programs. This EcoAction Program provides resources and incentives to operations across the VFPA jurisdiction, and will apply to RBT2.

Projected Fleet Turnover and IMO Regulations

The IMO has mandated increasingly stringent requirements in the ECA. These standards dramatically reduce air pollution from ships and deliver substantial air quality benefits. In 2020, emissions from ships operating in the ECA are expected to decrease annually by 320,000 metric tons for NO_x, 90,000 metric tons for $PM_{2.5}$, and 920,000 tons for SO_x (i.e.,

[5] CEAR Document #1134 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-20, IR5-30, IR5-31, IR6-13, IR7-12, IR7-37 & IR7-41. (See Reference Documents #975, #991, & #1000).
[6] CEAR Document#1125 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-18, IR6-20, IR7-06, IR8-11, IR8-12, IR8-13, and IR8-14 (See Reference Documents #991, #1000, & #1071).

23%, 74%, and 86%, respectively), as determined from predicted levels in 2020 without ECA[7].

As indicated in the EIS and in the response to IR6-18 (CEAR Document #1125), fleet turnover of container vessels to newer ships, and use of low sulphur fuels, will reduce NO_x emissions from container vessels calling on RBT2. For example, based on the relationship depicted in Figure IR6-18-2 (CEAR Document #1125), 82% of container ships at Roberts Bank would meet IMO Tier III NO_x emission standards by 2028, 13 years after the introduction of Tier III requirements for ships built in 2016 and thereafter.

Use of LNG and Low-sulphur Fuels

As stated in the response to IR6-13 (CEAR Document #1134), the RBT2 Air Quality Study assumed that all BC Ferries would be diesel-fuel powered during future conditions with the Project. As described in Section 2.8 in Appendix A of EIS Appendix 9.2-A, it was assumed that 37% of the ferry vessels would be replaced by 2025, and that these replacement vessels would operate on diesel fuel (not on LNG). Although it was understood that BC Ferries intended to convert some vessels to dual-fuel vessels (i.e., LNG or ultra-low sulphur diesel fuel), there was insufficient information at the commencement of the study on how many of the vessels would be converted or what the emission factors would be.

BC Ferries has confirmed that during the summer of 2017, two new dual-fuel Salish Class vessels replaced the existing vessels (the *Queen of Nanaimo* and the *Bowen Queen*[8]) on Route 9 (Tsawwassen – Southern Gulf Islands). BC Ferries has also confirmed that the *Queen of Alberni* operating on Route 30 and the *Queen of New Westminster* operating on Route 1 (both Spirit Class ferries) are scheduled for retirement before 2025 (BC Ferries 2017). BC Ferries will be looking to replace these vessels with ships that are dual-fuel capable, and is continuously looking for alternate technologies to reduce its footprint on the environment. The expected replacement of diesel-fuelled ferries with dual-fuel vessels operating on all three routes before 2025 will mean that future NO_x, $PM_{2.5}$, and CO_2 emissions from ferries at the Tsawwassen Terminal (both with and without the Project) are likely to be much lower than were estimated in the RBT2 Air Quality Study. The comparison provided in Table IR6-13-2 (in the response to IR6-13 of CEAR Document #1134) indicates that with the use of LNG fuel, NO_x emissions from ferries could be reduced by over 90%.

Refer to the response to IR6-34 for more information on opportunities to reduce marine-source emissions (including NO_x) through use of LNG (e.g., LNG-fuelled tugs).

A summary of potential NO_x emissions reductions from initiatives that will occur in the future (i.e., use of shore power at RBT2 and Deltaport Third Berth and the conversion of ferries to dual-fuel use) is provided below.

[7] For more information: https://westcoastcollaborative.org/files/sector-marine/the-north-american-eca-1.pdf

[8] The *Queen of Nanaimo* has been retired from the fleet and the *Bowen Queen* will continue to serve BC Ferries as a refit relief vessel until its retirement in 2021/22.

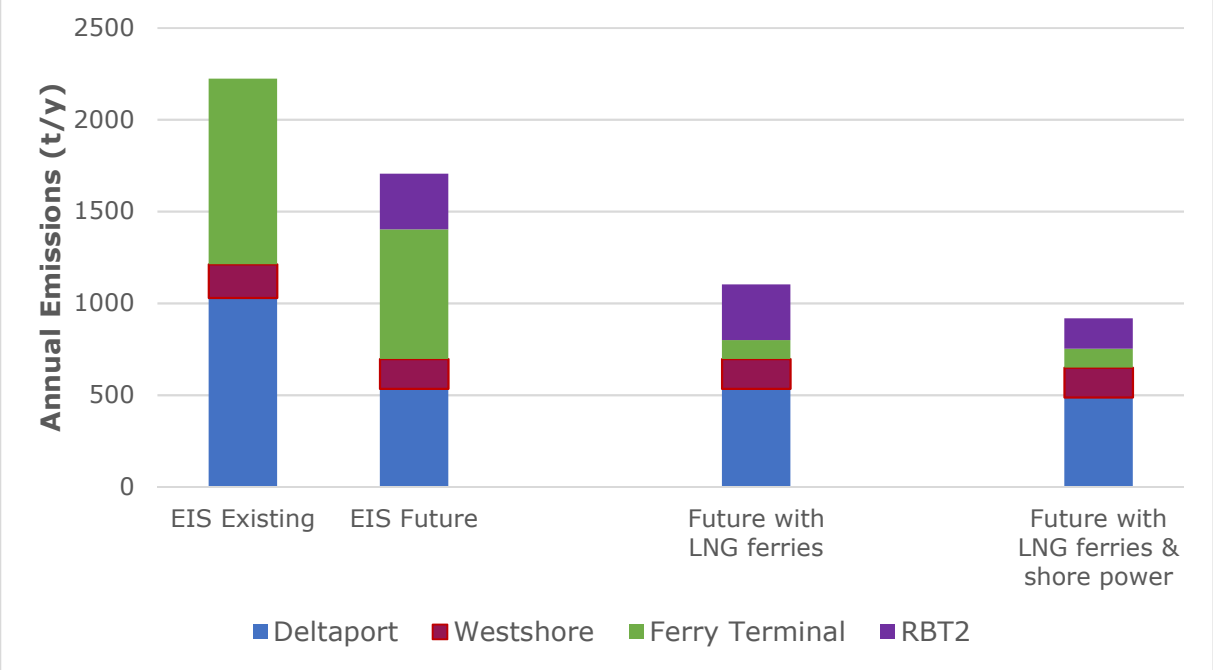
Summary of Potential NO_x Emission Reductions at Roberts Bank

Table 4-4-1 in EIS Appendix 9.2-A provided a comparison of expected changes in total annual NO_x emissions between existing conditions in 2010 and future conditions in 2025 with the Project. Total combined NO_x emissions from ships, cargo handling equipment, rail locomotives, and on-road vehicles were projected to decline from 2,223 t/y (tonnes per year) in 2010 to 1,706 t/y in 2025 with the Project, a reduction of 23% (even with the addition of NO_x emissions from RBT2). This comparison was depicted in Figure 4-1 of EIS Appendix 9.2-A, and **Figure IR6-29-1** extends that comparison to consider the following:

- The expected reductions from the conversion to dual-fuel capable ferries that operate on LNG fuel; and
- The maximum potential combined benefit of both LNG ferries and the use of shore power at the three RBT2 berths and the third berth at Deltaport.

Compared to existing conditions in 2010 with three operating Roberts Bank terminals (i.e., Deltaport Terminal, Westshore Terminals, and BC Ferries Terminal), the operation of dual-fuel capable ferries in the future (with the three existing terminals and the Project) is expected to reduce NO_x emissions by 50% (increased from the 23% reduction predicted in the RBT2 Air Quality Study). Combining the benefits of LNG-fuelled ferries with shore power use at RBT2 and Deltaport Third Berth, total NO_x emissions are anticipated to decrease by 59% from existing conditions.

Figure IR6-29-1 Annual Emissions of NO_x in Future Conditions with the Project Compared to Existing Conditions as Presented in the EIS and Considering NO_x-reducing Initiative that Will Occur in the Future



Provide information as to any discussion and/or agreements that have occurred or are planned with Deltaport Terminal to reduce NOx emissions from cargo handling equipment at that terminal.

As stated in the response to IR6-17 (CEAR Document #1140[9]), Deltaport Terminal is currently operated by Global Container Terminals Inc. (GCT). In 2014, GCT signed on as a participant to Green Marine, a voluntary environmental program for the maritime industry, specifically including GCT Deltaport[10]. In addition, GCT participates in the VFPA's Non-Road Diesel Emissions Reduction Program (NRDE), which provides incentives to terminal operators to upgrade cargo handling equipment[11]. Both programs, NRDE and Green Marine, are described further in the response to IR6-32.

Since submission of the RBT2 EIS in 2015, GCT has replaced six Tier 1 rubber-tired gantry (RTG) cranes with six Tier 4 cranes at its Deltaport terminal[12]. Specific plans pertaining to the timing of future diesel-powered equipment replacement with electric-powered equipment is not currently publicly available.

References

BC Ferries. 2017. Personal Communication. Email from M. LaRoche to VFPA December 8, 2017.

Vancouver Fraser Port Authority (VFPA). 2017. Ships: EcoAction Program. Available at https://www.portvancouver.com/environment/air-energy-climate-action/marine/. Accessed November 2017.

[9] CEAR Document #1140 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-03, IR5-21, IR6-06, IR6-07, IR6-17, and IR6-36 (See Reference Documents #975 and #991).
[10] http://globalterminals.com/gct-global-container-terminals-inc-joins-green-marine/
[11] https://www.portvancouver.com/environment/air-energy-climate-action/cargo-handling-equipment/nrde/
[12] http://globalterminals.com/gct-deltaport-grows-capacity-with-konecranes-rtgs/

IR6-30 Air Quality – Contaminant Emission Reduction: On-road Vehicles

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix A, Sections 5.1 and 6.4, Attachments 10 and 11

Context

In Section 6.4 of Appendix A of Appendix 9.2-A in the EIS, the Proponent reported the limitations of the model inputs used for on-road vehicles but stated that these limitations would not necessarily affect results and conclusions.

Environment and Climate Change Canada requested the provision of mitigation measures for the reduction of air contaminants emission from road vehicles associated with the Project during operations.

Information Request

Discuss any measures envisaged for air contaminant emission reduction for on-road vehicles associated with the Project during operations.

VFPA Response

On-road vehicles associated with the Project during operations that were considered in the RBT2 Air Quality Study included container trucks and employee and visitor vehicles (EIS Appendix 9.2-A, Appendix A). During Project operations, measures to reduce air contaminant emissions will include participation in VFPA initiatives under the Smart Fleet Trucking Strategy, including the Truck Licensing System[1]. The Smart Fleet Trucking Strategy was introduced in 2013 as a three-year action plan to achieve excellence in the local container trucking sector. The measures included in the strategy, although not described in the EIS, will apply to Project-related on-road vehicles during operations.

Through the Smart Fleet Trucking Strategy, the VFPA has outfitted all trucks with global positioning system (GPS) technology, and is using this and other data to work with trucking companies and terminal operators to continuously improve truck movement efficiency, including minimising wait times at VFPA terminal entry gates, resulting in reduced emissions. As an example, during 2014, truck turn times were reduced by 20% through industry initiatives. Specific emissions reduction measures for container trucks are described below.

The Port of Vancouver was the first port in Canada to implement stringent environmental requirements to reduce air emissions, managed through the VFPA's mandatory Truck

[1] Information on the Smart Fleet Trucking Strategy is available at https://www.portvancouver.com/truck-rail/truck/smart-fleet-trucking-strategy/.

Licensing System for the container sector. In order to gain access to VFPA facilities and property, all container trucking companies and their trucks must meet certain criteria, including minimum environmental requirements related to truck age requirement. Since January 1, 2016, any new truck requiring approval in the Truck Licensing System must be 2010 or newer. A 10-year rolling truck age requirement is expected to be introduced in the future, whereby trucks must be 10 years old or newer in any given year.

IR6-31 Air Quality – Greenhouse Gas Emissions

Information Source(s)

EIS Volume 2: Section 9.2, Tables 9.2-17, 9.2-24 and 9.2-37; Appendix 9.2-A, Table 4-4-3, Appendix E, Appendix F, Appendix G

Context

In the EIS, the Proponent provided various tables representing the expected conditions of annual greenhouse gas and black carbon emissions (Table 9.2-17), future conditions (Table 9.2-24) and a comparison of predicted changes in total annual emissions (Table 9.2-37). Table 4-4-3 of Appendix 9.2-A presented the annual emissions by terminal and activity. Other tables gave predicted emission rates for locomotives, vehicles and ships. Appendix E covered construction, Appendix F covered ships underway and Appendix G covered future rail activity.

A summary is required that presents the total annual contribution of the Project with breakdowns for construction and operation, including all sources, to assess the Project effects and its associated sources. Clarification is also needed on actual data and sources used in the preparation of Table 9.2-37.

Clarification is needed for Table 4-4-3 as to what the greenhouse gas emissions represent; whether it is for the entire trip for all vessels, for ships at berth or both.

Information Request

Provide a summary table that shows the predicted greenhouse gas emissions of the Project for existing, expected and future conditions. Include a breakdown for construction, operation and transportation sources (ships at berth, in transit, rail locomotive, vehicles).

Present predicted annual emissions from the proposed Project only, over its lifetime. Include all contributing sources such as onsite operations and transportation activities.

Present predicted annual emissions from marine shipping associated with the Project over the lifetime of the Project. Account for the entire trip for all ship movements related to the Project.

Clarify what is included in the future greenhouse gas emissions from ships shown in Table 4-4-3 (Annual Emissions for GHG and Black Carbon by Terminal and Activity) - ships at berth, ships underway or both.

In a table, place into context the total annual emissions from the Project and marine shipping associated with the Project with the total greenhouse gas emissions in the Metro Vancouver region, British Columbia and Canada as a whole.

VFPA Response

Provide a summary table that shows the predicted greenhouse gas emissions of the Project for existing, expected and future conditions. Include a breakdown for construction, operation and transportation sources (ships at berth, in transit, rail locomotive, vehicles).

Greenhouse gases (GHGs), namely carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), were presented in EIS Appendix 9.2-A and are presented in this response as CO_2 equivalents (CO_2e). N_2O and CH_4 were converted to CO_2e based on the Global Warming Potential (GWP) conversion factors for 20-year and 100-year time horizons presented in Table 1-4 in Appendix A of EIS Appendix 9.2-A.

Construction Phase GHG Emissions

Table IR6-31-1 summarises existing conditions representative of GHG emissions in 2010 and expected GHG emissions in 2025 (without the Project). **Table IR6-31-1** also summarises Project construction-related annual GHG emissions previously presented in Tables 3-14, 3-16, and 3-18 in Appendix E of EIS Appendix 9.2-A from tailpipe (i.e., construction equipment), tugs, and rail locomotives, respectively. As described in the EIS, the following assumptions were incorporated into the GHG calculations for the construction phase:

- On an average construction day, 104 pieces of equipment are anticipated to contribute to tailpipe emissions (for numbers and types of equipment, see Table 3-3 in Appendix E of Appendix 9.2-A);
- The operating assumptions for tugs included a rated engine power of 800 horsepower (hp) operating at 40% load to move 11 barges per day (i.e., 22 movements); and
- The operating assumptions for locomotives included a rated engine power of 3,000 hp, with one locomotive operating at a time on two 10-hour shifts per day.

For the construction phase, expected conditions in 2025 were assumed to be representative of 'background conditions' during the construction phase; therefore, total annual GHG emissions for future conditions during Project construction are estimated to be 321,152 t/y (tonnes per year) for the construction phase (i.e., 268,025 t/y from expected conditions plus 53,127 t/y from Project construction) based on the 20-year GWP horizon, and 321,141 t/y based on the 100-year GWP horizon.

Table IR6-31-1 Annual GHG Emissions for Existing Conditions, Expected Conditions, and Future Conditions during Project Construction

Transportation Source	Annual GHG Emissions (20-year)				Annual GHG Emissions (100-year)			
	Existing Conditions	Expected Conditions[a]	Incremental Project Construction	**Total** Future Conditions During Project Construction[c]	Existing Conditions	Expected Conditions[a]	Incremental Project Construction	**Total** Future Conditions During Project Construction[c]
Construction Equipment (Tailpipe emissions)	n/a	n/a	50,966		n/a	n/a	51,254	
Rail Locomotives			814				823	
Tugs			1,347				1,339	
Total Emissions	**210,122[b]**	**268,025[b]**	**53,127**	**321,152**	**209,892[b]**	**267,725[b]**	**53,416**	**321,141**

Notes: n/a = not applicable, as there are no Project-related emissions in existing and expected conditions.

a. Expected conditions in 2025 were assumed to be representative of 'background conditions' during the construction period.
b. For calculations of GHG emissions in existing conditions and expected conditions, refer to **Table IR6-31-2**.
c. GHG emissions under Future Conditions during Project Construction = Expected Conditions (background emissions) + Incremental Project Construction emissions.

Operation Phase GHG Emissions

Table 4-4-3 in EIS Appendix 9.2-A summarised the total GHG emissions for each terminal at Roberts Bank for three temporal cases, for both the 20-year and 100-year time horizons: existing conditions in 2010, expected conditions in 2025, and future conditions with the Project operation in 2025. **Table IR6-31-2** summarises annual GHG emissions for existing conditions, expected conditions, and future conditions during Project operation for each terminal by transportation source, as well as collectively by transportation source.

Annual GHG emissions for each temporal case include emissions from cargo handling equipment, vessels at berth and manoeuvring[1], rail locomotives, and vehicles. Assumptions are described in Appendix A of EIS Appendix 9.2-A.

Table IR6-31-2 Annual GHG Emissions for Existing Conditions, Expected Conditions, and Future Conditions during Project Operation

Temporal Case (Horizon Year)	Transportation Source	Terminal	Annual GHG Emissions by Transportation Source and Terminal (t/y CO_2e)		Total Annual GHG Emissions by Transportation Source (t/y CO_2e)	
			20-year	100-year	20-year	100-year
Existing Conditions (2010)	Cargo Handling Equipment	Deltaport	106,000	106,000	108,920	108,920
		Westshore	2,920	2,920		
	Rail Locomotives	Deltaport	2,420	2,450	7,560	7,630
		Westshore	5,140	5,180		
	Ships	Deltaport	22,400	22,300	83,300	83,000
		Westshore	12,600	12,600		
		BC Ferries	48,300	48,100		
	Vehicles	Deltaport	6,270	6,270	10,342	10,342
		Westshore	112	112		
		BC Ferries	3,960	3,960		
				Total	**210,122**	**209,892**
Expected Conditions (2025)	Cargo Handling Equipment	Deltaport	149,000	149,000	152,860	152,860
		Westshore	3,860	3,860		
	Rail Locomotives	Deltaport	1,950	1,960	5,150	5,180
		Westshore	3,200	3,220		
	Ships	Deltaport	35,300	35,200	97,100	96,800
		Westshore	13,500	13,500		
		BC Ferries	48,300	48,100		
	Vehicles	Deltaport	9,450	9,430	12,915	12,885

[1] The calculation of GHG emissions from vessels includes emissions while vessels are berthed and while approaching or departing the terminal, plus the emissions from tugs used to support these activities. Note that vessels are not considered to be transiting within VFPA jurisdiction, as the vessel trajectory away or towards the international shipping lanes has been considered as 'manoeuvring'.

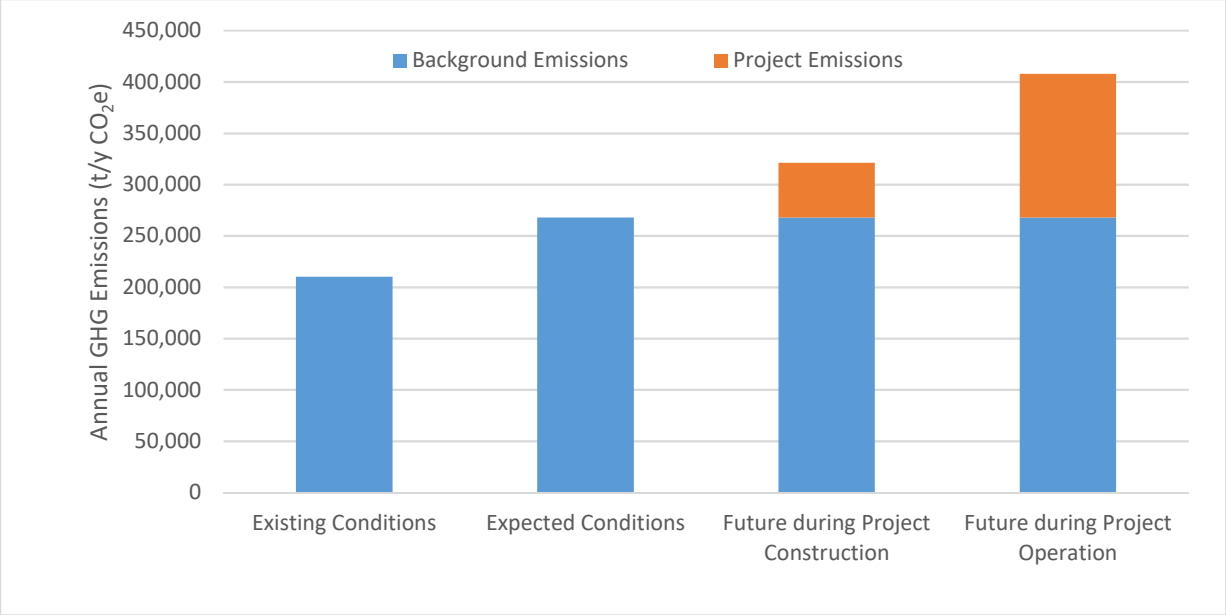
Temporal Case (Horizon Year)	Transportation Source	Terminal	Annual GHG Emissions by Transportation Source and Terminal (t/y CO_2e)		Total Annual GHG Emissions by Transportation Source (t/y CO_2e)	
			20-year	100-year	20-year	100-year
		Westshore	145	145		
		BC Ferries	3,320	3,310		
				Total	**268,025**	**267,725**
Future Conditions with Project Operation (2025)	Cargo Handling Equipment	RBT2	94,600	94,500	247,460	247,360
		Deltaport	149,000	149,000		
		Westshore	3,860	3,860		
	Rail Locomotives	RBT2	2,670	2,690	7,820	7,870
		Deltaport	1,950	1,960		
		Westshore	3,200	3,220		
	Ships	RBT2	32,500	32,400	128,000	127,600
		Deltaport	33,700	33,600		
		Westshore	13,500	13,500		
		BC Ferries	48,300	48,100		
	Vehicles	RBT2	11,600	11,600	24,515	24,485
		Deltaport	9,450	9,430		
		Westshore	145	145		
		BC Ferries	3,320	3,310		
				Total	**407,795**	**407,315**

Present predicted annual emissions from the proposed Project only, over its lifetime. Include all contributing sources such as on-site operations and transportation activities.

Figure IR6-31-1 illustrates annual GHG emissions from terminals at Roberts Bank, as t/y CO_2e, for existing conditions, expected conditions, and future conditions during both Project construction and operation based on the 20-year time horizon[2].

[2] As the total emissions for the 20-year and 100-year time horizons are similar, as presented in **Tables IR6-31-1** and **IR6-31-2**, only the 20-year time horizon emissions are presented in **Figure IR6-31-1**.

Figure IR6-31-1 Annual GHG Emissions from Roberts Bank Terminals for Existing Conditions, Expected Conditions, and Future Conditions with Project (during Project Construction and Operation)



Total Project-related GHG emissions (20-year GWP horizon) estimated for the 5.5-year construction phase are approximately 300,000 t, or 16.6% of the total estimated GHG emissions from terminals at Roberts Bank (see **Table IR6-31-1**) over the same period.

For the operation phase, 2025 was selected as the 'horizon year' to represent the worst-case emission scenario year within the operation phase. With ongoing fleet turnover and efficiency improvements (e.g., changes in technology such as more fuel-efficient equipment and electrification, changes to other lower-emitting fuels such as liquified natural gas for vessels and other types of equipment, use of shore power for vessels, decreases in vessel calls due to increasing vessel sizes, and efficiencies in management of materials), overall annual emissions would be lower in subsequent years. Cumulative total GHG emissions over the lifetime of the Project, therefore, have not been estimated on an annual basis as the high degree of uncertainty associated with the timing and magnitude of changing factors would render any prediction of annual GHG emissions over the Project lifetime (anticipated to be at least 75 years) unreliable. In other words, quantitatively estimating GHG on an annual basis for the entire life of the Project cannot be completed to a degree of accuracy that would be considered informative.

Present predicted annual emissions from marine shipping associated with the Project over the lifetime of the Project. Account for the entire trip for all ship movements related to the Project.

Annual GHG emissions assessed for RBT2-associated vessels in transit within the marine shipping area are presented in Marine Shipping Addendum (MSA) Table 7.1-16 by marine shipping area segment (i.e., Segments A to D) and as total emissions, which are estimated

to be 128,516 t/y. Compared to total annual GHG emissions from large marine vessels[3] (not all sources of GHGs within the marine shipping area) under cumulative conditions (MSA Table 7.1-21), Project-associated vessel emissions account for 6.1% of total emissions generated from large marine vessels (the contribution of Project-associated vessel emissions by segment are illustrated in MSA Figure 7.1-10).

For the purposes of assessing changes in air quality due to Project-associated vessels, it was assumed that Project-associated vessels transit directly from Segments A through D or vice versa, but this is not typically the case. A container vessel typically stops at multiple ports of call in the Pacific Northwest Region on the same trip (refer to IR1-05 (CEAR Document #897[4]) for more information), and therefore, emissions from ships destined for or departing from RBT2 are not solely associated with the Project for the length of their journey. For this reason, and the high degree of inaccuracy associated with generating a quantitative estimate of GHG emissions on an annual basis for the entire life of the Project (described above), GHG emissions from Project-associated vessels over the lifetime of the Project for the entire trip for all ship movements, has not been estimated on an annual basis.

As further information, GHG emissions from ships in transit in the marine shipping area are expected to decrease in the future. The International Marine Organization (IMO 2017), responsible for regulating the global shipping sector, mandates improved energy efficiency for ships through the Energy Efficiency Design index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP).

The EEDI requires new ships to emit fewer CO_2 per tonne mile through the following reduction levels from the average efficiency for ships built between 2000 and 2010:

- 10% reduction for ships built between 2015 and 2019;
- 20% reduction for ships built between 2020 and 2024; and
- 30% for ships built in 2025 and beyond 30% more efficient.

The SEEMP is an operational measure for new and existing ships that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner (e.g., improved voyage planning, frequent propeller cleaning, introduction of technical measures such as waste heat recovery). By 2020, up to 180 million tonnes of annual CO_2 reductions are estimated from the introduction of the EEDI for new ships and the SEEMP for all ships in operation, a figure that, by 2030, will increase to 390 million tonnes of CO_2 annually (i.e., the reductions in 2020 will be between 9% and 16%, and by 2030 between 17% and 25% compared with the 'business as usual' case). It is expected that similar reductions will be observed for Project-associated vessels in the future.

[3] Large marine vessels, including cargo or carrier vessels, tankers, and passenger ships, were included in the MSA air quality assessment, as prior to the establishment of the North American Emission Control Area, large vessels were the dominant source of emissions (SO_2) in the marine shipping area. For more information, refer to MSA Appendix 7.1-A.

[4] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

Clarify what is included in the future greenhouse gas emissions from ships shown in Table 4-4-3 (Annual Emissions for GHG and Black Carbon by Terminal and Activity) - ships at berth, ships underway or both.

Future GHG emissions from ships for Roberts Bank terminals, provided in Table 4-4-3 of EIS Appendix 9.2-A, includes ships manoeuvring (on approach to or departing from the terminal) and at berth (i.e., activities within VFPA jurisdiction). The scenario assessed, which was previously presented in tabular format in Attachment 2 (Ships Assumptions Matrix – Activity Levels) in Appendix A of EIS Appendix 9.2-A, assumed the following:

- For RBT2 in 2025, 260 vessel calls per year with 16% of the calls from <8,000 twenty-foot equivalent unit (TEU) vessels (49 hours at berth), 52% from 8,000 to 10,000 TEU vessels (60 hours at berth), and 32% from >10,000 TEU vessels (69 hours at berth);
- For Deltaport Terminal in 2010, 290 vessel calls (38.3% of the calls from <8,000 TEU vessels (49 hours at berth), 59.3% from 8,000 to 10,000 TEU vessels (60 hours at berth), and 2.4% from >10,000 TEU vessels (69 hours at berth);
- For Deltaport Terminal in 2025, 312 vessel calls (13% of the calls from <8,000 TEU vessels (49 hours at berth), 60% from 8,000 to 10,000 TEU vessels (60 hours at berth), and 27% from >10,000 TEU vessels (69 hours at berth);
- For Westshore Terminals in 2010, 246 vessel calls (51% of the calls from <100,000 dead-weight tonne (DWT) vessels and 49% from >100,000 DWT vessels—annual vessel emissions obtained from SNC Lavalin Inc. (2013);
- For RBT2, Deltaport, and Westshore vessel manoeuvring, the activity time was 2 hours per ship call and three tugs supported each activity (approach and departure);
- Two tugs berthed at all times; and
- For BC Ferries vessels, 7,617 ferry trips annually in standby mode lasting 1 hour per trip, powerdown of three ferries for six hours per night, and 2,746 ferry transits (2 hours each) on Route 30 and 4,871 on Routes 1 and 9 (negligible duration; further explanation provided in response to IR6-13 of CEAR Document #1134[5]).

In a table, place into context the total annual emissions from the Project and marine shipping associated with the Project with the total greenhouse gas emissions in the Metro Vancouver region, British Columbia and Canada as a whole.

Table IR6-31-3 provides a comparison of 2025 GHG emissions estimates (based on 20-year GWP horizon) for future conditions with Project operations and Project-associated marine shipping with 2030 GHG emissions projections publicly available for Metro Vancouver (Metro Vancouver 2013), British Columbia (ECCC 2017a), and Canada (ECCC 2017b).

[5] CEAR Document #1134 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-20, IR5-30, IR5-31, IR6-13, IR7-12, IR7-37 & IR7-41. (See Reference Documents #975, #991, & #1000).

Table IR6-31-3 Comparison of 2025 GHG Emissions for RBT2 and RBT2-associated Vessels in Transit to 2030 GHG Emissions Projections for Metro Vancouver, B.C., and Canada

	RBT2-Related GHG Emissions in 2025 (t)		Regional GHG Emission 2030 Projections (t)		
	RBT2	RBT2-associated Shipping	Metro Vancouver	British Columbia	Canada
Total Annual GHG Emissions (t/y)	140,000	129,000	24,000,000	75,000,000	742,000,000
% RBT2 of Regional Projection	--	--	0.58%	0.19%	0.02%
% RBT2-associated Shipping of Regional Projection	--	--	0.54%	0.17%	0.02%

Note: Total annual GHG emissions (t/y) for RBT2 based on information presented in **Table IR6-31-2** (and Table 4-4-3 in EIS Appendix 9.2-A), and for RBT2-associated shipping from Table 7.1-16 in the Marine Shipping Addendum.

In terms of broader context for total GHG emissions, a review of available options has indicated that the Project is the most efficient location to provide increased container capacity on the west coast of Canada (EIS Section 34.0). Situated along an established trade corridor, the Project location is well positioned to efficiently accommodate future growth in trade activity.[6,7]

It should be understood that shipments of imports and exports that are in demand will likely be shipped with or without the Project. If container vessels carrying these imports/exports do not come through Project terminal, they will be transported to their final destination through some other routing. An alternative route is likely to be less efficient than routing via the Project, and therefore the GHG emissions per TEU of imports/exports can also be assumed to be higher for the alternative.

References

Environment and Climate Change Canada (ECCC). 2017a. Canada's Greenhouse Gas Emissions Reference Case: Annex 1: Supplementary Information for Projections. Available at https://www.canada.ca/en/environment-climate-

[6] Reasons for this efficiency include deep water capable of handling large container ships; proximity to major transportation corridors for both truck and rail movement; proximity to Juan de Fuca Strait and Pacific Ocean shipping routes; and access to numerous off-dock facilities needed for efficient function of containerised trade (EIS Section 34.2).

[7] As noted in IR1-04 of CEAR Document #897), a key efficiency of the Vancouver and Prince Rupert gateways, in comparison with Seattle/Tacoma, stems from provision of on-dock facilities at Vancouver/Prince Rupert container terminals, while Seattle/Tacoma offer on-dock rail at only six of nine terminals. In addition, Vancouver and Prince Rupert offer more efficient access between port terminals and intercontinental destinations.

change/services/climate-change/publications/2016-greenhouse-gas-emissions-case/chapter-3.html#tab24. Accessed January 2018.

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IR6-32 Air Quality – Greenhouse Gas Reduction

Information Source(s)

EIS Volume 2: Section 9.2.7.1, Table 9.2-12, Table 9.2-17, Table 9.2-24; Appendix 9.2-A, Section 3.1.4

CEAR Doc#490

CEAR Doc#509

CEAR Doc#654

Context

The proposed Project has the potential to significantly increase greenhouse gas emissions in the region, as shown by a comparison of Tables 9.2-12 (existing conditions), 9.2-17 (expected conditions) and 9.2-24 (future conditions) of the EIS.

The Proponent presented two elements for the potential reduction of greenhouse gasses. - the use of shore power and its potential reduction effect as illustrated in Tables 9.2-15 and 9.2-29 of the EIS; and a Memorandum of Understanding signed in 2013 by Transport Canada and the Rail Association of Canada.

The purpose of the Memorandum of Understanding is to reduce emissions of criteria air contaminants and greenhouse gasses over the period of 2011 to 2015. Under the Memorandum, until new regulations are brought in to reduce criteria air contaminant emissions, the Rail Association of Canada was to encourage all its members to reduce Class 1 freight greenhouse gas emission intensity by six per cent from levels of 2010. In addition, as part of the SmartStart program instituted by the Canadian rail companies, idling of locomotives will be discontinued. Transport Canada, at the Panel's Orientation Session of September 2016, indicated that it was proposing *Locomotive Emissions Regulations* under the *Railway Safety Act*. These Regulations came into force June 2017. Locomotives idling time will be a maximum of 30 minutes and railway companies must have a written anti-idling policy.

The Proponent has instituted a Truck Licensing System that limits the age of trucks that are allowed to operate on port lands, or requires operators of older trucks to obtain an age exemption.

As underlined by Metro Vancouver, British Columbia and Metro Vancouver have adopted greenhouse gas reduction targets and climate action plans to reduce greenhouse gas emissions.

There is no indication of a specific plan to offset greenhouse gas emissions from construction or operation of the Project, or to contribute in meeting the Metro Vancouver's or the Province's targets.

Information Request

Given that railways are significant sources of diesel particulate matter, black carbon and other greenhouse gas emissions, describe any measures to reduce diesel particulate matter and greenhouse gas emissions from rail operations other than the Regulations in place. Clarify if electrification was considered as an emission reduction option by any of the Proponent's partners or clients.

Describe any measures to reduce greenhouse gas emissions from trucks through the use of low carbon fuels, vehicle technologies or other initiatives considered or discussed with Metro Vancouver.

Provide a plan to reduce greenhouse gas emissions from construction and operation of the Project for all emission sources.

VFPA Response

The VFPA is working with terminal operators and railway companies operating within VFPA jurisdiction to progressively reduce emissions from their operations, as it does not own or operate any cargo handling equipment (CHE), drayage trucks, or locomotives. The VFPA sets targets and objectives for emission reduction through its participation in the Northwest Ports Clean Air Strategy (NWPCAS). The objectives are developed collaboratively by the VFPA, the Port of Seattle, and the Port of Tacoma. Specific programs and initiatives are then developed by each port in partnership with terminal operators, shipping lines, and railways, where possible, to encourage the achievement of emission reductions (NWPCAS 2017).

Detailed information on the VFPA's greenhouse gas (GHG) reduction initiatives, by emission source sector, is provided in the 2015 Port Emissions Inventory Report (**Appendix IR6-32-A**). The report presents an estimate of air emissions at the Port of Vancouver in 2015, as well as an emissions backcast to 2010 and forecast to 2030. The report also includes an overview of the VFPA's initiatives to reduce emissions and encourage energy conservation at the Port of Vancouver (**Appendix IR6-32-A**). Emissions and reduction initiatives are presented by emission source sector, including marine, rail, on-road vehicles, non-road equipment, and administrative operations. Additional information on VFPA GHG reduction initiatives for each sector is also provided in the Northwest Ports Clear Air Strategy 2016 Implementation Report (NWPCAS 2017) and the Port of Vancouver 2016 Sustainability Report (VFPA 2017). Relevant information from these information sources is provided below in response to this information request.

Given that railways are significant sources of diesel particulate matter, black carbon and other greenhouse gas emissions, describe any measures to reduce diesel particulate matter and greenhouse gas emissions from rail operations other than the Regulations in place.

In the 2013 NWPCAS strategy update (NWPCAS 2013), two performance targets were established for the rail sector related to fuel efficiency and engine replacement or upgrade:

- Rail Target 1 – Switcher locomotive owners/operators participate in a fuel-efficiency program:

    - 2015 Target: By 2015, 100% of owners/operators participate in a fuel-efficiency program; and
    - 2020 Target: By 2020, 100% of owners/operators achieve performance measures of chosen program;
- Rail Target 2 – Switcher locomotive owners/operators upgrade or replace unregulated engines (engine replacement will be Tier 2 or better):
    - 2015 Target: By 2015, 10% of unregulated locomotive engines are replaced with Tier 2 or better engines; and
    - 2020 Target: By 2020, 20% of unregulated locomotive engines are replaced with Tier 2 or better engines.

To reduce rail emissions in accordance with the targets listed above, the VFPA has engaged in the initiatives described below.

Rail Fuel Efficiency Programs

To reduce rail emissions in accordance with the rail fuel efficiency target (Rail Target 1 above), the VFPA continues to work with rail operators to encourage participation in rail fuel efficiency programs. As described in the NWPCAS 2016 Implementation Report (NWPCAS 2017), a fuel-efficiency program sets goals or objectives for improving fuel-efficiency, undertakes actions that achieve those goals and objectives, and reports on progress. Examples of fuel-efficiency actions include idle-reduction policies, equipping locomotives with Automatic Engine Stop Start (AESS) technology, installing Eco-Tip fuel injectors, engaging and training employees on fuel-efficiency practices, and improving maintenance practices. Fuel-efficiency programs are a useful tool for reducing emissions from both older engines that have not yet been replaced and from newer engines.

Non-Road Diesel Emissions Program

Since 2015, the VFPA has provided fee rebates to all terminal operators conforming to the VFPA Non-Road Diesel Emissions Program. Through this program, tenants are required to register diesel-powered equipment, report on operating hours, and pay a fee for operation of older (Tier 1 and Tier 0) equipment, including switcher locomotives. Rebates are available to tenants for retiring, repowering, or installing approved emission reduction measures on equipment to achieve Tier 2 or better. To qualify for rebates, tenants must maintain a fuel-efficiency plan for non-road diesel equipment, implement an idle reduction policy, and meet opacity requirements[1].

Green Marine

Green Marine is the largest voluntary environmental certification program for the maritime industry in North America[2]. Green Marine encourages its participants (ship owners, ports, terminals, and shipyards) to achieve levels of environmental performance that exceed

[1] https://www.portvancouver.com/environment/air-energy-climate-action/cargo-handling-equipment/nrde/
[2] https://www.green-marine.org/program/

regulatory requirements in areas such as air/land/water emissions. The VFPA, Global Containers Terminals Inc. (GCT) (who operate GCT Vanterm and GCT Deltaport container terminals), and others operating in the Port of Vancouver (e.g., Westshore Terminals, Seaspan) are participants in the program. Participants must benchmark their annual environmental performance through the program's extensive self-evaluation guides, have their results verified by an accredited external auditor, and publicly report the performance levels for specific indicators, one of which is the GHG and air pollutants performance indicator. This performance indicator focuses on cutting back fuel consumption as the main means of reducing emissions. Each company is responsible for defining its own emissions-reduction strategy and demonstrating ongoing improvement. In 2016, for example, the VFPA and GCT Deltaport Terminal achieved the highest level of performance (level 5) for the GHG and air pollutants performance indicator[3].

Locomotive Engine Replacement/Upgrade

To achieve emission reductions toward the engine replacement target set by the NWPCAS (Rail Target 2 above), the VFPA continues to work with rail operators to encourage engine replacement and upgrade for equipment due for replacement. As described in the 2016 NWPCAS Implementation Report (NWPCAS 2017), of the 16 VFPA terminal owned/operated locomotives, eight are considered to be unregulated (pre-tier), one is Tier 2, and six are Tier 3 multi-gensets[4]. In addition, there are four tenant-owned/operated pushers that do the work of switcher locomotives. Pushers have smaller engines, and therefore lower emissions, than switcher locomotives. Two of these pushers are considered unregulated with the other two having Tier 1 and Tier 2 engines.

Other Initiatives to Reduce Rail Emissions

The VFPA is involved in a number of regional initiatives related to reducing rail emissions, described in the NWPCAS 2016 Implementation Report (NWPCAS 2017), including the following:

- Conducting a pilot project to collect all railcar activity data within the Vancouver Gateway. The data will inform rail network analysis and transportation planning, with the intent of ensuring continued rail efficiency through the Port of Vancouver. This information may also support the VFPA's ongoing efforts to reduce rail activity-related noise and exhaust emissions; and
- Leading a working group focused on improving rail operations on the south shore of Burrard Inlet.

[3] https://www.green-marine.org/wp-content/uploads/2017/05/2016_Performance_Report.pdf
[4] Based on discussions with representatives from BC Rail, switcher locomotives were assumed to be Tier 1 in 2025 in the RBT2 Air Quality Study (for more information refer to the response in IR6-16 of CEAR Document #1113).

Clarify if electrification was considered as an emission reduction option by any of the Proponent's partners or clients.

The emission inventory developed for the RBT2 Air Quality Study (EIS Appendix 9.2-A) to characterise emissions in 2025 (both under expected conditions and future conditions with the Project) did not assume electrification of locomotives. Electrification of switcher locomotives may be considered by rail owner/operators in an effort to achieve the NWPCAS 2020 engine replacement target, described above. However, while there are a number of tenant-owned locomotives that are lower emission Tier 3 multi-genset locomotives, the VFPA is not aware of any terminal or rail operator plans to replace diesel locomotives with electric locomotives.

Describe any measures to reduce greenhouse gas emissions from trucks through the use of low carbon fuels, vehicle technologies or other initiatives considered or discussed with Metro Vancouver.

The VFPA is working toward the following NWPCAS targets for the trucking sector:

- Truck Target 1 – Trucks meet or surpass U.S. Environmental Protection Agency (EPA) emission standards or equivalent for model year 2007:
    - 2017 Target: By the end of 2017, 100% of trucks meet or surpass 2007 U.S. EPA emission standards;
- Truck Target 2 – Ports, terminals, and truck companies have fuel-efficiency plans in place that promote continuous improvement:
    - 2015 Target: By 2015, ports have fuel-efficiency plans; and
    - 2020 Target: By 2020, ports, terminals, and 50% of truck companies have fuel-efficiency plans.

To reduce truck emissions in accordance with the targets listed above, the VFPA has implemented several programs and initiatives, which are described below.

Smart Fleet Trucking Strategy

In 2013, the VFPA introduced Smart Fleet to increase efficiency of, and reduce air emissions from, container trucks. Smart Fleet initiatives include the following[5]:

- Global positioning systems (GPS) on all port-licensed trucks, allowing the port authority to track and report on turn and wait times;
- Common data interface and a single point of entry and reservation system connecting trucking companies to all container terminal operations to effectively plan and select reservations for increased efficiencies;
- A recently revised *Truck Licensing System*, including truck age requirements (as described below);
- Identification of technology-based solutions to improve environmental sustainability including alternate low-carbon fuels and engine efficiency; and

[5] https://www.portvancouver.com/truck-rail/truck/smart-fleet-trucking-strategy/

- Collaboration with terminal operators and industry leaders, working together to improve the efficiency of port operations.

The VFPA has also extended the hours that truck gates are open to reduce congestion and improve turnaround times by spreading truck appointments over more hours of the day (VFPA 2017).

In addition, the Deltaport truck staging facility, which will improve road safety along Deltaport Way and nearby roadways, reduce port-destined truck queues along Deltaport Way and the Roberts Bank causeway, and result in less engine idling and traffic congestion, is expected to be completed by mid-2019[6].

VFPA Truck Licensing System

To reduce truck emissions toward the truck age and fuel efficiency targets listed above, the VFPA continues to implement increasingly stringent environmental requirements on container trucks accessing port terminals through the mandatory Truck Licensing System (TLS) program[7]. The VFPA does not have operational control over container trucks; therefore, the approach to achieving fuel efficiency is continuous implementation of a program that moves the fleet toward newer, cleaner models, coupled with good maintenance and limiting idling. Specific requirements for the TLS to support GHG emission reduction measures are as follows:

- A 10-year rolling truck age requirement is expected to be introduced in the future, whereby trucks must be 10 years old or newer in any given year; 10-year and older trucks need to be tested and pass 20% opacity limit; and
- All trucks are not to exceed a maximum of three consecutive minutes idling in any 60-minute period.

Provide a plan to reduce greenhouse gas emissions from construction and operation of the Project for all emission sources.

The construction and operation of RBT2 will fall under the broader VFPA GHG reduction plans and initiatives, described below. In addition, emissions will be reduced during construction through the air quality and dust control plan (outlined in EIS Section 33.3.3), which will detail requirements to limit idling and promote energy efficiency.

Regulatory Context for GHG Reduction Plans

The B.C. *Greenhouse Gas Reduction Targets Act* (*GGRTA*), in force since 2008, has set aggressive targets for reducing provincial GHGs, including the reduction of GHG emissions from 2007 levels by at least 33% by 2020 and by 80% by 2050. In addition, interim targets that are in place to guide and measure progress included a 6% reduction by 2012 and 18%

[6] https://www.portvancouver.com/development-and-permits/development/deltaport-truck-staging-facility/
[7] https://www.portvancouver.com/environment/air-energy-climate-action/container-trucking/

by 2016. The interim target for 2012 was achieved (B.C. MOE 2014), and information on progress toward the 2016 target is not yet publicly available.

Metro Vancouver has aligned its climate change goal with these provincial GHG targets. Based on an interim assessment, Metro Vancouver predicted an 8% decline in GHG emissions by 2015 (Metro Vancouver 2014), indicating that provincial and municipal 2020 targets will be challenging to meet. It is noted that long-term trends may see increases in GHG emissions due to economic and population growth factors (Metro Vancouver 2014).

Reflective of municipal trends, GHG emission intensity at the VFPA has decreased, but total emissions are increasing because of growth in trade. As stated in the 2015 Port Emissions Inventory Report (**Appendix IR6-32-A**), the intensity of port-related GHG emissions—measured as emissions per tonne of cargo—has decreased since 2010. The VFPA predicts 0.85 kg less GHG emissions will be released per tonne of cargo in 2030 than in 2015. This 11% decrease in emission intensity is due to improvements in engine and equipment efficiency. However, from 2010 to 2015, total port-related GHG emissions increased by approximately 14% due to increased trade through the port. Although the VFPA forecast shows GHG emissions steadily increasing for the foreseeable future from an increase in port throughput (**Appendix IR6-32-A**), the International Maritime Organization is currently developing a strategy for GHG emissions reduction in the shipping sector. In addition, the Government of Canada is developing a pan-Canadian framework to reduce GHG emissions that will affect the transportation sector, including ports. These regulatory initiatives will be critical to reducing total GHG emissions associated with port activities (**Appendix IR6-32-A**).

VFPA GHG Reduction Plan and Initiatives

The VFPA recognises the need for widespread cooperation to transition the transportation sector to clean, low-carbon technologies and is committed to the reduction of GHG emissions. The VFPA's approach to reducing port-related air emissions includes a comprehensive activity-based emissions inventory that enables the VFPA to estimate port-related air emissions from sources (e.g., including marine, rail, on-road vehicles, non-road equipment, and administrative operations) to assist with informing policy and programs, identifying trends, and determining priority areas for action (**Appendix IR6-32-A**).

As outlined above, the VFPA is part of the NWPCAS, which aims to reduce port-related emissions in the Georgia Basin-Puget Sound airshed. Through the NWPCAS, the VFPA has established an objective for reducing GHG emissions intensity by 15% below 2005 levels by 2020 (NWPCAS 2017). The approach to achieving this target is guided by the following goals for overall emission reduction[8]:

- Reduce port contributions to climate change through reduction in GHGs, and develop coordinated climate change adaptation plans for infrastructure and ecosystems;

[8] https://www.portvancouver.com/environment/air-energy-climate-action/

- Promote a culture of continuous improvement and energy conservation throughout the port, with a focus on transitioning industry toward renewable energy and clean technologies; and
- Collaborate with government and industry on the development of goals and objectives, performance monitoring, and progress reporting.

A summary of reduction initiatives either led by or participated in by the VFPA or its tenants for each emission source sector is provided below in **Table IR6-32-1**. While more detailed information on programs and initiatives related to rail and on-road vehicles (trucks) has been provided above, additional information for all sectors (listed in **Table IR6-32-1**) is available in the 2015 Port Emissions Inventory Report (**Appendix IR6-32-A**).

Table IR6-32-1 Summary of GHG Emission Reduction Initiatives by Sector

Sector	Emission Reduction Initiatives

Marine Vessels
• Ocean-going vessels
• Harbour tugs
• River dredging
	• EcoAction
	  ○ Incentives for cleaner fuels, ship environmental programs, vessel and engine technology, or ship classification societies
	  ○ VFPA Blue Circle Award, for participation in third party programs (e.g., Green Marine)
	• Shore Power
	• LNG Fuel Studies and Use

Rail
• Mainline locomotives
• Switcher locomotives
	• Non-Road Diesel Emissions Program
	  ○ Fees for operation of older less-efficient equipment
	  ○ Incentives for fuel efficiency (i.e., through Green Marine Program), idle reduction, and opacity requirements
	• Fuel efficiency and engine replacement
	• Climate Smart
	  ○ Training for port tenants to measure and reduce GHG emissions

On-Road Vehicles
• Container trucks
• Other Vehicles
	• Smart Fleet Program
	  ○ Truck Licensing System Age Requirements
	  ○ GPS and scheduling efficiency measures
	  ○ Alternative fuels and engine efficiency technologies
	• Climate Smart
	  ○ Training for port tenants to measure and reduce GHG emissions

Non-Road Vehicles
• Cranes and stackers
• Loaders
• Terminal tractors
• Miscellaneous equipment
	• Non-Road Diesel Emissions Program
	  ○ Fees for operation of older less-efficient equipment
	  ○ Incentives for fuel efficiency (i.e., through Green Marine Program), idle reduction, and opacity requirements
	• Energy Action Initiative
	  ○ Support for port tenants to access BC Hydro financial incentives for energy conservation measures
	• Climate Smart
	  ○ Training for port tenants to measure and reduce GHG emissions

Sector	Emission Reduction Initiatives
Administrative Operations • Heating, electricity • Terminal lighting	• Hybrid vehicle fleet • Alternative fuels for port vehicles • Green Infrastructure Guidelines • Energy Action Initiative • Commuter Challenge • Climate Smart

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Appendices

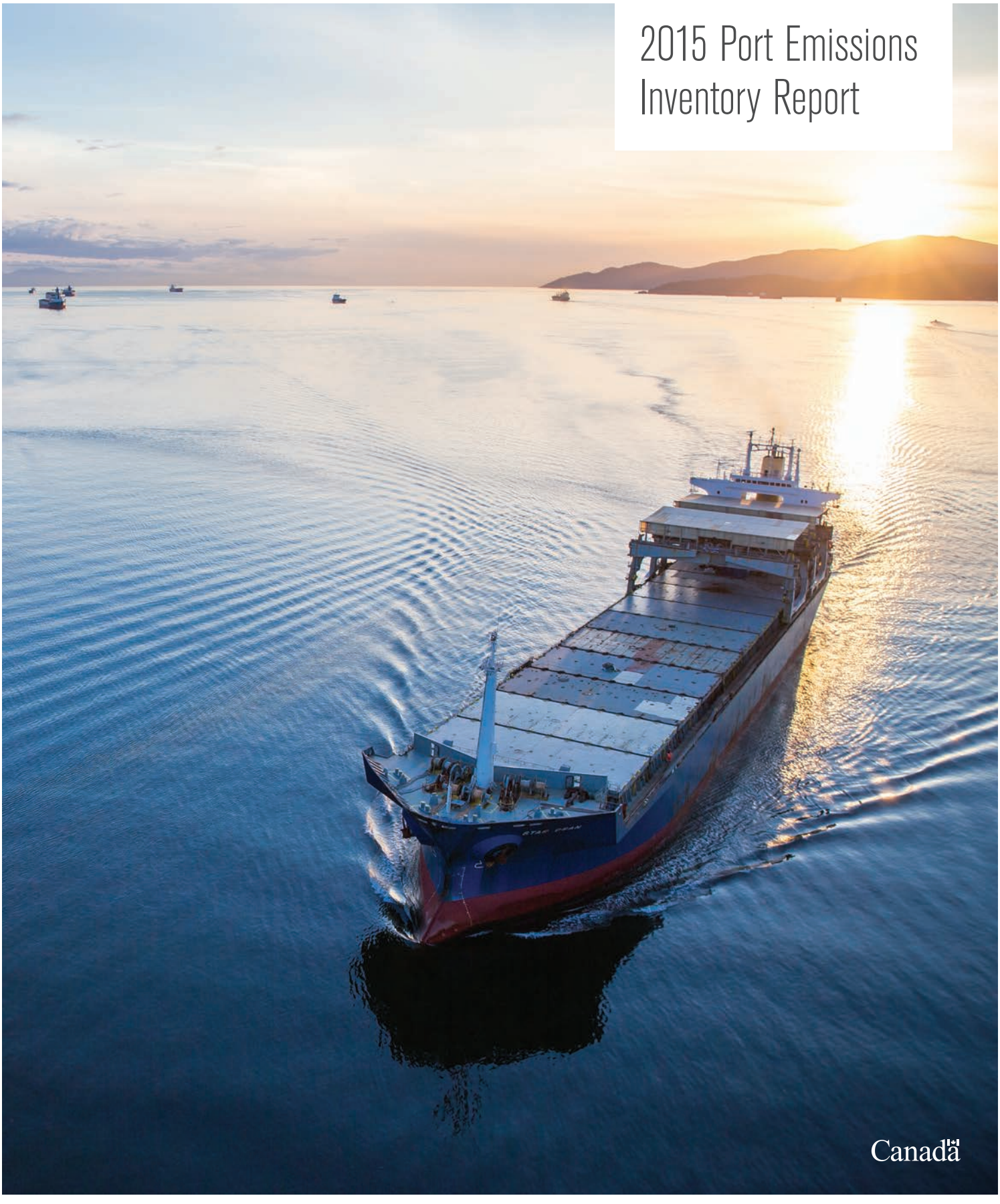
Appendix IR6-32-A 2015 Port Emissions Inventory

APPENDIX IR6-32-A

2015 PORT EMISSIONS INVENTORY

PORT of vancouver

2015 Port Emissions Inventory Report



Canada

Introduction

The 2015 Port Emissions Inventory Report presents an estimate of air emissions associated with activity at the Port of Vancouver. It provides detailed estimates of emissions by type for 2015, as well as a backcast to 2010 and forecast to 2030. The report also includes an overview of the Vancouver Fraser Port Authority's initiatives to reduce emissions and encourage energy conservation at the Port of Vancouver.

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Cautionary note regarding forward-looking statements

The information provided in this report is intended for educational and informational purposes only. While the information in this report is believed to be accurate, it is provided without warranty of any kind, whether express or implied. This report is not intended to endorse or recommend any particular product, material, or service provider, nor is it intended as a substitute for engineering, legal, or other professional advice. Such advice should be sought from qualified professionals.

Message from the President and Chief Executive Officer

2015 Port Emissions Inventory
November 2017

In 2016, we set a vision for the Port of Vancouver to be the world's most sustainable port. For us, a sustainable port delivers economic prosperity through trade, maintains a healthy environment and enables thriving communities.

Among other things, our vision means we must make business decisions that help reduce emissions associated with port activities, improve air quality, and lessen the impact of port operations on the environment and human health.

As stewards of Canada's largest port, we recognize the leadership role that we must play in facilitating emission reductions. To that end, we have worked closely with terminal operators and other port users to develop an inventory of air pollutants and greenhouse gas emissions from marine, rail, on-road, non-road and administrative activities associated with the Port of Vancouver.

I am pleased to present the 2015 Port Emissions Inventory Report, representing nearly two years of engagement, data collection, analysis and modeling. The inventory results reaffirm the significant progress that has been made toward reducing air pollutant emissions, showcasing what is possible when we all work together toward a common objective. The inventory results also show that even though greenhouse gas (GHG) emissions per tonne of cargo are decreasing, total GHG emissions are forecast to continue to increase with growth in trade. This will be an important issue for the port and transportation industry as Canada works toward meeting its climate change commitments.

Marine shipping remains among the most energy efficient methods of transporting goods and can play an important role in facilitating a transition toward a low carbon economy. I am encouraged by the industry's success in reducing sulphur oxide emissions and believe we can replicate this success if we work together to address greenhouse gas emissions.

I encourage you to read through the report to learn more about port-related air emissions, and the environmental initiatives the port authority is leading to promote emission reductions, protect air quality and reduce the port's contribution to climate change.

<Original signed by>

Robin Silvester, President and Chief Executive Officer

Acknowledgments

The 2015 port emissions inventory was completed with assistance from consultant SNC-Lavalin and port stakeholders. We would like to acknowledge the input and expertise provided by the following organizations:

- BC Marine Terminal Operators Association
- British Columbia Ministry of Environment & Climate Change Strategy
- British Columbia Ministry of Transportation and Infrastructure
- Chamber of Shipping of British Columbia
- Cruise Lines International Association – North West & Canada
- Environment and Climate Change Canada
- Metro Vancouver
- Port of Vancouver tenants
- Railway Association of Canada
- Shipping Federation of Canada
- Transport Canada

SEND US YOUR FEEDBACK

We welcome and value your feedback. Please send comments or questions to environmentalprograms@portvancouver.com

Vancouver is known for natural beauty and clean air, and it will take the collaboration and support of many stakeholders to keep it that way.

Emissions inventory

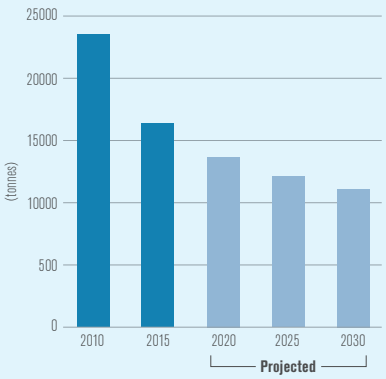
For emissions to be reduced, they must first be measured. That's why we conduct air emission inventories at the Port of Vancouver every five years, at the same time as regional and national inventories. The results identify trends so we can improve our programs and policies, and ultimately reduce emissions.

Per cent change in total emissions by source from 2010 to 2015

	Marine	Rail	On-road vehicles	Non-road equipment	Administrative operations
Air pollutants	↓36%	0%	↓31%	↓26%	↑14%
Greenhouse gas emissions	↑10%	↑17%	↑23%	↑18%	↑7%

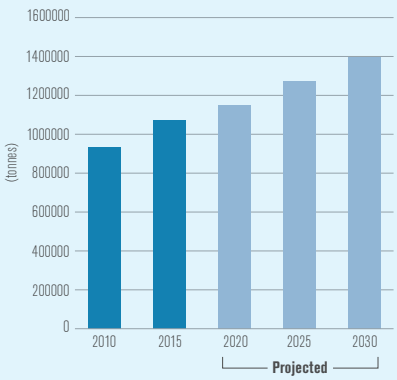
Key findings

Air pollutants



Air pollutant emissions have decreased significantly since 2010 despite growth in trade through the port – a result of stronger regulation and investment in technology.

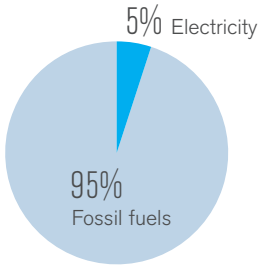
Greenhouse gas emissions



Greenhouse gas emissions per tonne of cargo have decreased, but total emissions have increased and are forecast to continue increasing with growth in trade through the port.

Challenge

Energy use



Fossil fuels make up 95% of port-related energy use. We will need to work with government and industry stakeholders to reduce port energy consumption through conservation and efficiency, and facilitate a transition to low carbon energy alternatives like hydroelectricity.

Our vision is to be the world's most sustainable port. We are working to reduce port-related air emissions that affect air quality and contribute to climate change.

Our approach

At the Vancouver Fraser Port Authority, we focus on supporting early compliance with pending environmental regulations, improving efficiency and promoting clean technology. We collaborate with government and industry stakeholders to undertake port emission inventories and enhance air quality monitoring, which enables us to track and report our progress toward achieving our vision.

Our air and energy initiatives target key port-related emission sources:

	Marine	Rail	On-road vehicles	Non-road equipment	Administrative operations
Emissions inventory Our activity-based inventory enables us to estimate port-related air emissions from a variety of sources. The inventory informs our policy and programs by helping us identify trends and priority areas for action.	✓	✓	✓	✓	✓
Northwest Ports Clean Air Strategy The strategy was developed in partnership with the ports of Seattle and Tacoma and the Northwest Seaport Alliance to reduce port-related air emissions in the Georgia Basin-Puget Sound air shed.	✓	✓	✓	✓	✓
EcoAction Program Ships can receive harbour dues discounts by meeting voluntary environmental best practices. Participation in the program grew to 612 vessel calls in 2016, representing more than 20 per cent of all vessel calls.	✓				
Shore power Since 2009, shore power at the Canada Place cruise terminal has eliminated 474 tonnes of air pollutants and 16,138 tonnes of greenhouse gases. We're installing shore power at two container terminals, to be completed in 2018.	✓				
LNG bunkering Along with other global ports, we're preparing the port for liquefied natural gas as a marine fuel, which will reduce ship air emissions.	✓				
Truck Licensing System Container trucks that access the port meet minimum environmental requirements for engine age, emission controls and idle reduction.			✓		
Non-Road Diesel Emissions Program We work with port tenants to accelerate change-over of older diesel equipment through a combination of fees and rebates.		✓		✓	
Energy Action initiative In partnership with BC Hydro, this program helps port tenants advance energy conservation measures and access financial incentives.				✓	✓
Climate Smart We offer training for port tenants to measure and reduce greenhouse gas emissions. 11 tenants participated in 2015, collectively eliminating 2,788 tonnes of CO_2e.		✓	✓	✓	✓

Learn more about our air and energy initiatives at portvancouver.com/cleanair

About us

Vancouver Fraser Port Authority

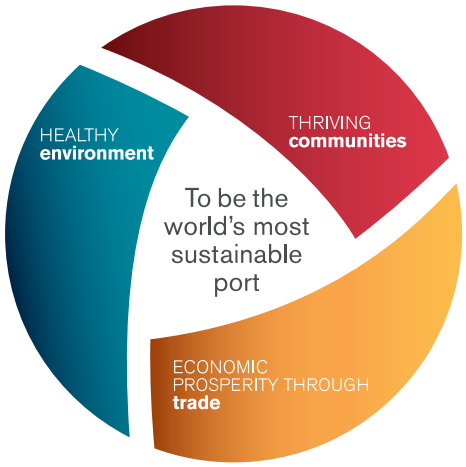
Our mission is to enable Canada's trade objectives, ensuring safety, environmental protection and consideration for local communities.

Our vision is to be the world's most sustainable port.

The Vancouver Fraser Port Authority is responsible for managing federal lands and waters at the Port of Vancouver on behalf of Canadians and in support of national trade objectives. We are a non-shareholder corporation established by the Government of Canada in January 2008, pursuant to the *Canada Marine Act,* and accountable to the federal minister of transport.

Our approach to sustainability

We believe that a sustainable port delivers economic prosperity through trade, maintains a healthy environment, and enables thriving communities, through meaningful dialogue, shared aspirations and collective accountability. To maintain a healthy environment, we are working to improve air quality and minimize greenhouse gas emissions.



Read more about our approach to sustainability at portvancouver.com/sustainability

Initiatives influencing port emissions

The below timeline shows significant milestones in our air emission programs, as well as the key regulations driving emission reductions.

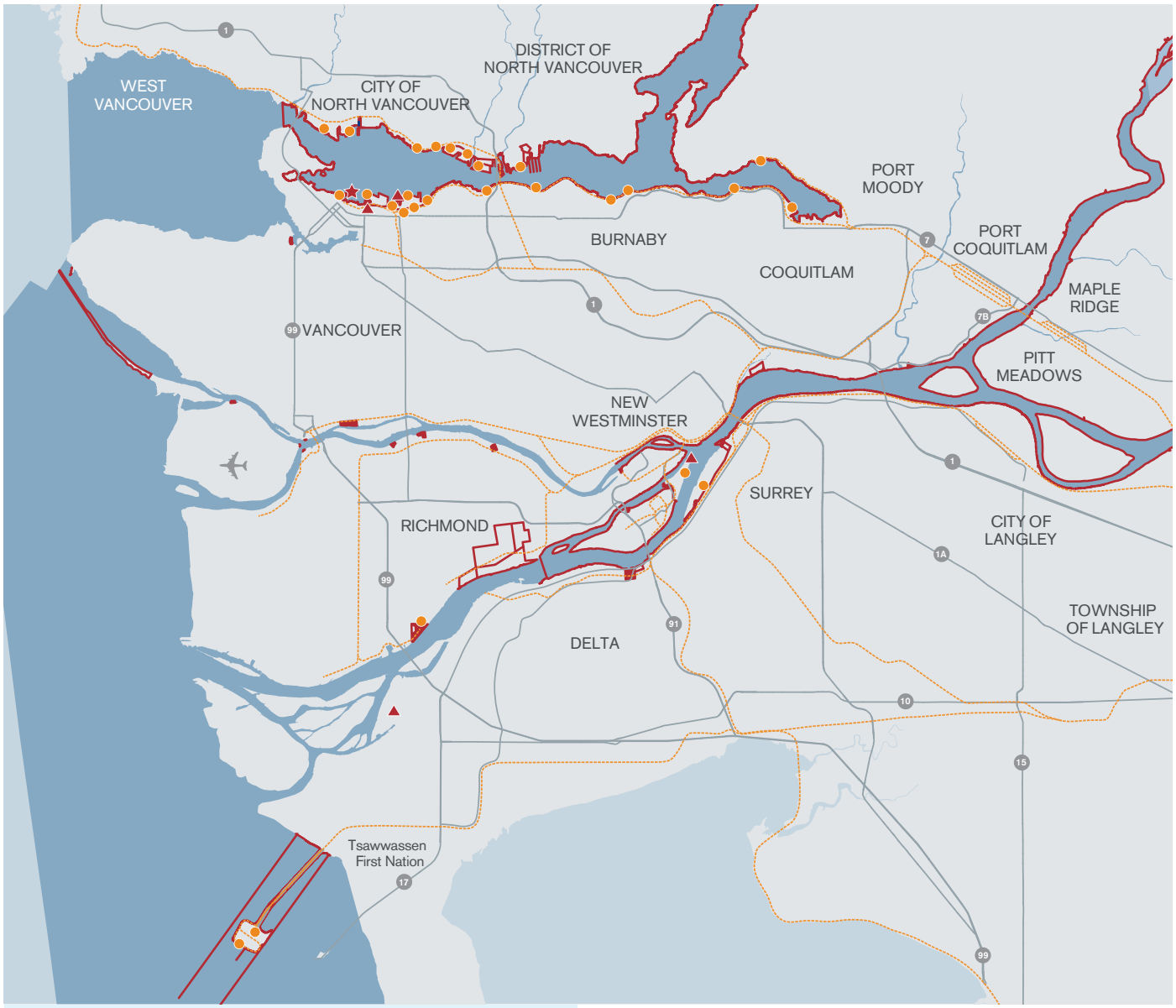
- **2005** • First port-wide emissions inventory conducted
- **2007** • EcoAction Program for ships launched
- **2007** • Northwest Ports Clean Air Strategy initiated
- **2008** • Truck Licensing System environmental requirements implemented
- **2009** • Shore power for cruise ships installed at Canada Place
  • Blue Circle Award for vessels debuted
- **2010** • Port authority operations become carbon neutral
  • Second port-wide emission inventory conducted
- **2012** • Government of Canada set diesel fuel sulphur content limit at 0.0015%
  • International Maritime Organization (IMO) set North American Emission Control Area fuel sulphur limit at 1.0%
- **2013** • Energy Action initiative launched
- **2015** • Non-road diesel emission program launched
  • IMO Emission Control Area fuel sulphur limit set at 0.1%
  • Third port-wide emissions inventory conducted
  • Climate Smart partnership established
- **2016** • IMO set nitrogen oxide emissions limit for new ships operating in Emission Control Areas

■ Port authority initiatives ■ Key regulations

Port of Vancouver

The Port of Vancouver is Canada's largest port, and the third largest in North America in terms of annual tonnes of cargo. Positioned on the southwest coast of British Columbia in Canada, the port is home to 27 major marine cargo terminals and three Class 1 railroads, offering a full range of facilities and services to the international shipping community.

The port operates across five cargo sectors: automobile, breakbulk, bulk, container and cruise. In 2016, 136 million tonnes of cargo valued at $202 billion was traded with more than 170 world economies. About 93 per cent of the cargo that moves through the port is for Canadian import and export markets, with the remainder for the United States.



Port authority
- ★ Head office
- ▲ Other facilities

Port infrastructure
- ● Port terminals
- Rail network
- Roads
- Port authority-managed federal lands
- Port authority navigational jurisdiction

Jurisdiction

The port authority's jurisdiction consists of 16,000 hectares of water, more than 1,000 hectares of land and approximately 350 kilometres of shoreline. It borders 16 municipalities and intersects the asserted and established territories and treaty lands of several Coast Salish First Nations.

2015 port emissions inventory

Port-wide emission inventories are conducted every five years. The 2015 port emissions inventory estimates air emissions from marine, rail, on-road, non-road, and administrative activities associated with the Port of Vancouver.

What's included

Air pollutants

Air pollutants affect local and regional air quality. They can directly affect human and environmental health, which can, in turn, produce secondary economic impacts, such as increased health care costs or lost work days. The following air pollutants are considered in our inventory:

• sulphur oxides (SO_X) • nitrogen oxides (NO_X)
• fine particulate matter ($PM_{2.5}$) • volatile organic compounds (VOCs) • carbon monoxide (CO) • ammonia (NH_3

Greenhouse gases

Transportation activities at ports, such as marine shipping, use of rail and non-road equipment, and trucking, are heavily dependent on fossil fuels. The use of these fuels contributes to climate change through the release of greenhouse gas emissions and black carbon. The inventory includes black carbon emissions, and the following greenhouse gases measured in terms of their carbon dioxide equivalent (CO_2e):

• carbon dioxide (CO_2) • methane (CH_4) • nitrous oxide (N_2O)

Energy usage

The sources of energy used in port activities, as well as the efficiency of energy used, influence the quantity and type of emissions. To help us gauge energy efficiency and identify clean technology options, we consider both energy sources and energy usage in our inventory.

What's not included

Emission sources not covered in this report include fugitive emissions associated with dust, vapours, and refrigerants, up/downstream emissions associated with the production or consumption of cargoes, as well as emissions associated with heavy industrial processes on or adjacent to port lands, such as chemical or cement manufacturing. These emissions are considered by the port authority in special studies and project environmental reviews, and/or by other governmental agencies, including Transport Canada, Environment and Climate Change Canada, and Metro Vancouver.

Methodology

The emissions inventory uses detailed 2015 activity data to estimate current emissions, backcast emission estimates to 2010 and forecast to 2030.

Creating the port emissions inventory

1 Determine scope

Identify the sources of emissions at the port and the geographical scope of the inventory.

2 Collect activity information

Collect, model and validate real-time activity data and operating information for each source group.

3 Apply emission factors

Apply emission factors obtained from government and industry sources to the activity data.

4 Generate emission estimates

Produce the 2015 emission estimates and conduct quality checks and analysis to inform backcast and forecast.

5 Develop backcast and forecast

Based on expected trade growth, regulatory changes, and fleet turnover, develop a backcast of emission estimates for 2010 and forecast out to 2030.

What is an emission factor?

An emission factor is the rate of emissions associated with an activity such as fuel combustion, which is dependent on factors such as engine age, technology, fuel type and operating conditions. These factors come from organizations that undertake research and/or testing to estimate the rates, including the U.S. Environmental Protection Agency, Environment and Climate Change Canada, Railway Association of Canada, and BC Hydro.

How are emission backcasts and forecasts estimated?

The backcast and forecast are created by scaling the 2015 emission estimates in consideration of factors such as:

- known regulatory changes affecting fuels and technologies.
- cargo volumes in 2010 and anticipated or assumed cargo volumes in 2020, 2025 and 2030.
- an assumption that the age distribution of equipment remains the same over time.

How accurate are the estimates?

In preparing the 2015 port emissions inventory, we formed technical advisory groups, consisting of key stakeholders in government and the shipping industry, to help us refine our approach and understand its limitations. The inventory follows best practices and is consistent with methodology used by other ports and regulatory agencies; however emissions are estimated and not directly measured. Consequently, we recognize some areas of uncertainty remain. In particular, forecasts beyond 2015 are subject to an increasingly higher degree of uncertainty related to future cargo volumes and environmental regulations.

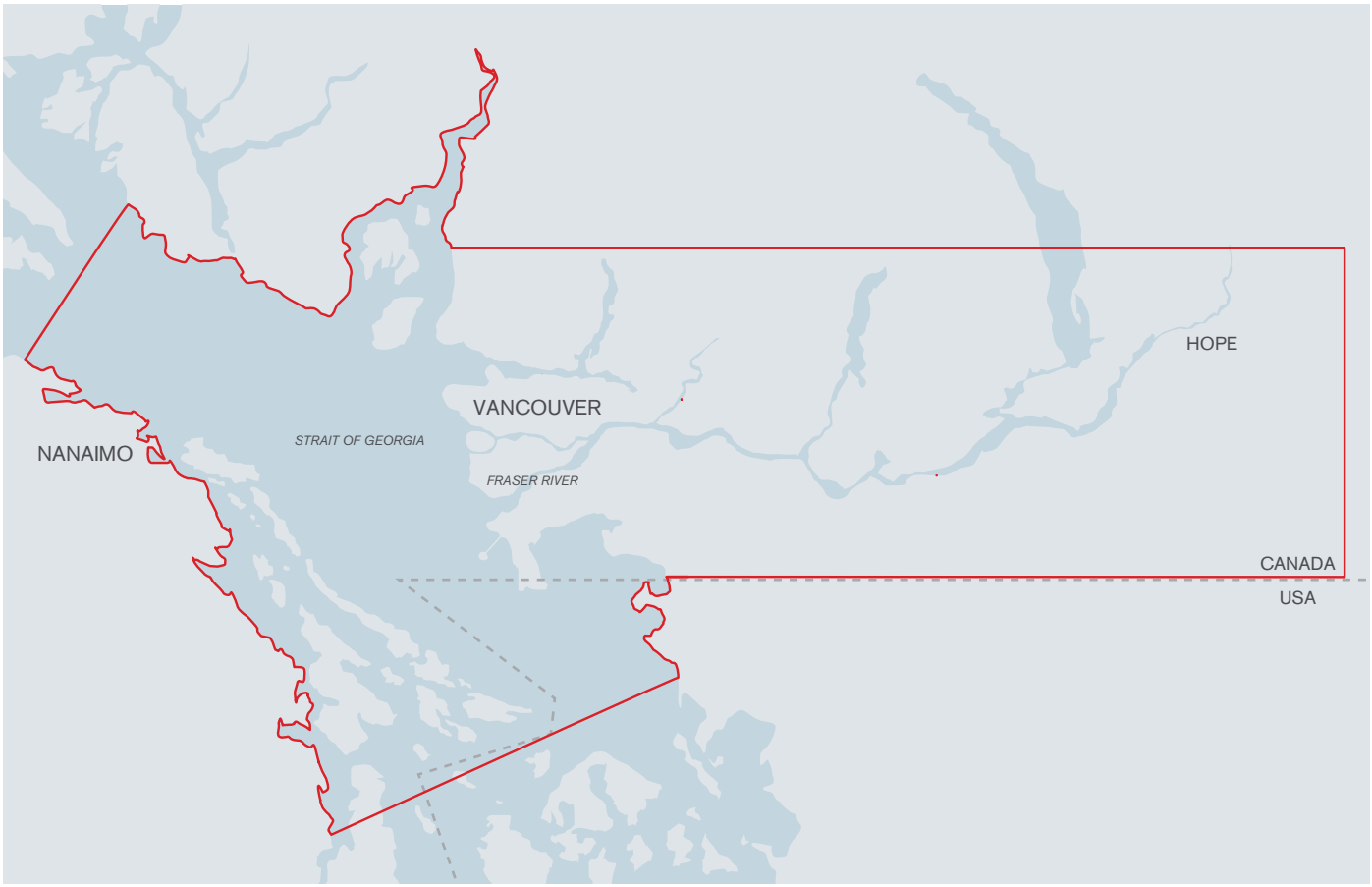
Scope

The inventory includes emissions associated with fuel and electricity used by marine and rail sectors, on-road vehicles, non-road equipment, and administrative operations.

Deep-sea terminals facilitate the movement of cargo between ship, rail, and truck transportation modes. Goods arrive and depart by sea on ocean-going vessels, facilitated by harbour tugs. Railways and trucking companies move goods to and from terminals by land. These transportation activities are operated by port tenants or other companies independent of the port authority.

Boundary

The geographic boundary of the inventory captures port-related activities in the region, both within and beyond the jurisdiction of the port authority, as shown below.



Port emissions inventory boundary

Emission sources

Marine

Ocean-going vessels

Over 3,100 ocean-going vessels call at our port every year. Using the positioning technology on board each vessel, emissions are estimated from their main engines, auxiliary engines, and boilers.

Harbour tugs

Harbour tugs escort tankers, position vessels at terminals, and tow barges and logs throughout the port. Emission estimates are based on operator records of fuel usage.

River dredging

The Fraser River is dredged to maintain the navigational channel. Emission estimates are based on fuel usage, as reported by operators.

Rail

Mainline locomotives

Three Class 1 railways and one charter railway service the port, using large locomotives to transport goods across North America. Emission estimates are based on route taken and cargo transported through the region.

Switcher locomotives

Rail cars are positioned at terminals and regional rail yards by smaller switcher locomotives, including fuel-efficient gen-set locomotives. Emission estimates are based on tenant data and quantities of cargo transported.

On-road vehicles

Container trucks

A fleet of about 1,700 port-licenced container trucks service terminals, warehouses, rail yards, and customer facilities within the region. Emission estimates are based on activity data obtained from global positioning system technology on each truck.

Other vehicles

Emissions from other vehicles moving commodities and passengers to and from port lands are estimated based on data provided by port tenants and modeling to predict vehicle routes.

Non-road equipment

Information about equipment operating on port lands is obtained through tenant questionnaires. Emission estimates are based on engine information and fuel consumption data for each piece of equipment.

Cranes and stackers

Over 320 cranes and stackers handle containers at terminals and transload facilities.

Loaders

More than 750 loaders handle dry bulk and breakbulk products, mostly at port terminals.

Terminal tractors

There are approximately 350 tractors, designed to shuttle containers, operating within terminal yards.

Miscellaneous equipment

More than 350 other pieces of equipment serve general use purposes at port facilities.

Administrative operations

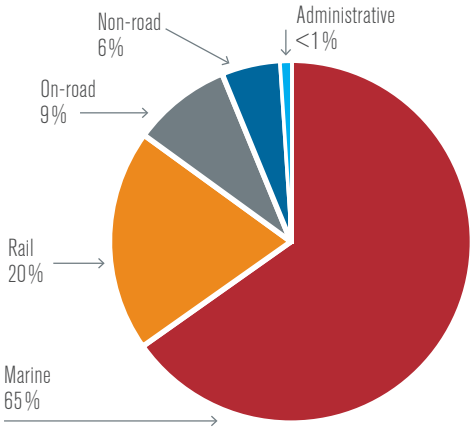
Emissions associated with heating and electricity for buildings on port lands and lighting terminals are captured through usage data and tenant questionnaires.

Results

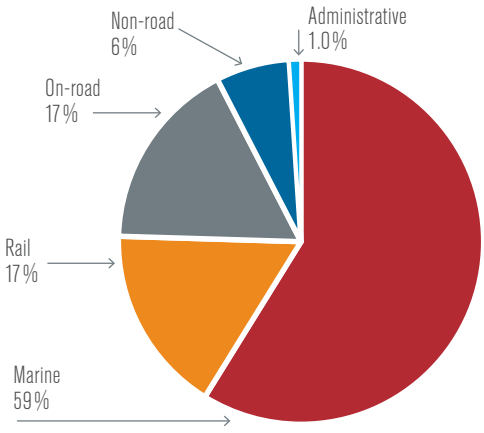
The 2015 Port Emissions Inventory Report presents an estimate of fuel combustion- and electricity-related emissions from port sources and associated activities. The results include detailed estimates of emissions by pollutant for 2015, as well as a backcast of emissions to 2010, and forecast to 2030, in five-year increments. We report both total (absolute) emissions and emissions intensity (emissions per tonne of cargo).

Port-related emissions

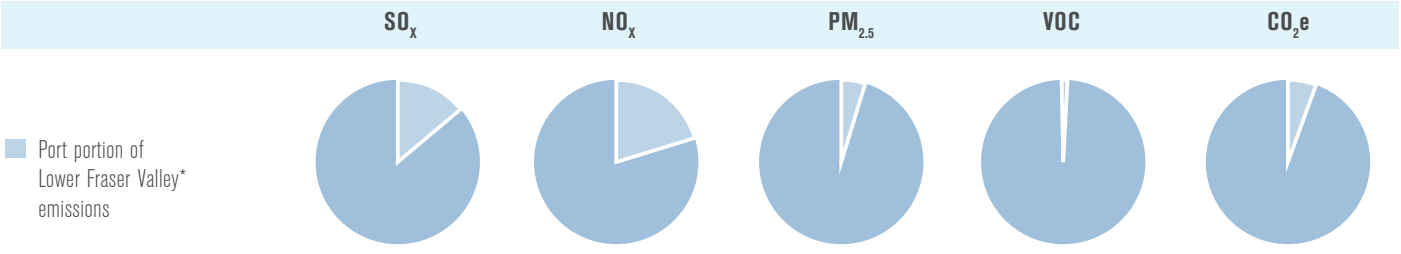
Air pollutant emissions by source, 2015



Greenhouse gas emissions by source, 2015



Emission contributions to regional, provincial and national totals by type (tonnes), 2015



	SO_x	NO_x	$PM_{2.5}$	VOC	CO_2e
Port of Vancouver	268	12,971	288	567	1,079,686
Lower Fraser Valley	1,626	50,357	5,243	65,828	17,529,390
British Columbia	60,485	276,444	80,882	164,868	60,900,000
Canada	1,054,399	1,893,775	1,620,872	1,858,662	722,000,000

* The Lower Fraser Valley includes the entire Metro Vancouver region and the southwestern portion of the Fraser Valley Regional District.

Air pollutants

Important air pollutants in the region include: sulphur oxides, nitrogen oxides, fine particulate matter and volatile organic compounds. In combination with carbon monoxide and ammonia, these pollutants collectively are smog-forming pollutants.

Between 2010 and 2015, smog-forming pollutant emissions decreased by 30 per cent, primarily as a result of regulatory changes affecting sulphur oxide and fine particulate matter emissions from marine, non-road, on-road and rail sources. Emissions are forecast to decrease by another 32 per cent by 2030 due to regulatory changes affecting nitrogen oxide emissions. Although port cargo throughput is expected to rise, these regulations will offset a corresponding rise in emissions, resulting in a significant reduction in both the total smog-forming pollutant emissions and the emissions intensity, per tonne of cargo throughput.

Pollutant

Smog-forming pollutants include sulphur oxides, nitrogen oxides, fine particulate matter, volatile organic compounds, carbon monoxide, ammonia

Source

Fuel combustion

Direct impacts

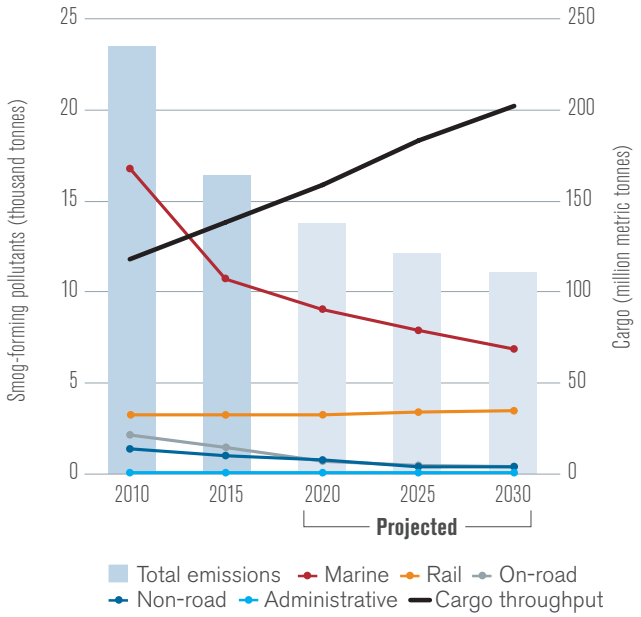
Human health: reduced respiratory system function, aggravation of asthma, increased risk of cardiovascular disease, premature death

Environmental: reduced visibility (haze), damage to vegetation, odour, acid precipitation

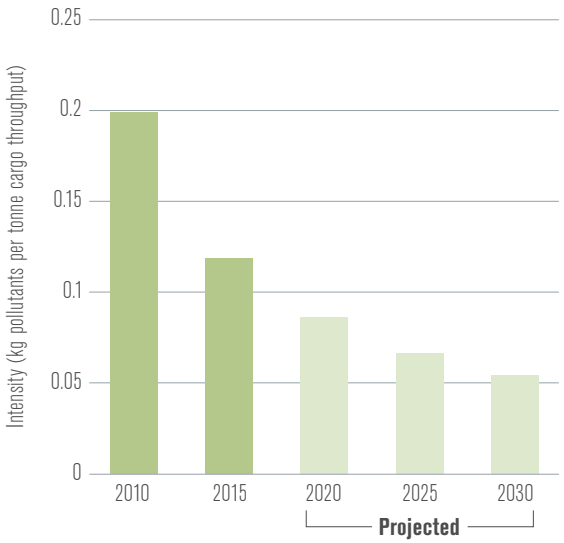
Indirect impacts

Formation of ground-level ozone and secondary particulate matter

Air pollutant emissions and cargo throughput, 2010-2030



Air pollutant emissions intensity, 2010-2030



Sulphur oxide emissions

Between 2010 and 2015, sulphur oxide (SO_X) emissions decreased dramatically, a direct result of international regulations limiting the sulphur content in ship fuel. In 2012, the International Maritime Organization, responsible for regulating the shipping sector, designated an Emission Control Area off the coast of North America, which set limits on the allowable sulphur content in marine fuel. More stringent limits were imposed in 2015. The Government of Canada enforces the Emission Control Area regulations within Canadian waters. Also contributing to the decline in sulphur oxide emissions were federal regulations, implemented between 2006 and 2014, which reduced the maximum sulphur content allowed in fuels used in on-road vehicles, off-road engines, locomotives, small stationary engines, and small domestic vessels. Our forecast suggests that in the absence of additional regulations, projected growth in trade through the Port of Vancouver is anticipated to result in small, incremental increases in SO_X emissions from 2015 to 2030.

In 2015, marine sources accounted for 99 per cent of port-related SO_X emissions at the port. This is due to the fact that marine grade fuels contain higher amounts of sulphur than fuels used for domestic land-based activities. The cargo sectors with the greatest cargo volumes – bulk and container – are associated with 49 per cent and 27 per cent respectively of total SO_X emissions at the port.

Pollutant

Sulphur oxides (SO_X) are compounds that contain sulphur and oxygen

Source

Combustion of sulphur-containing fuels

Direct impacts

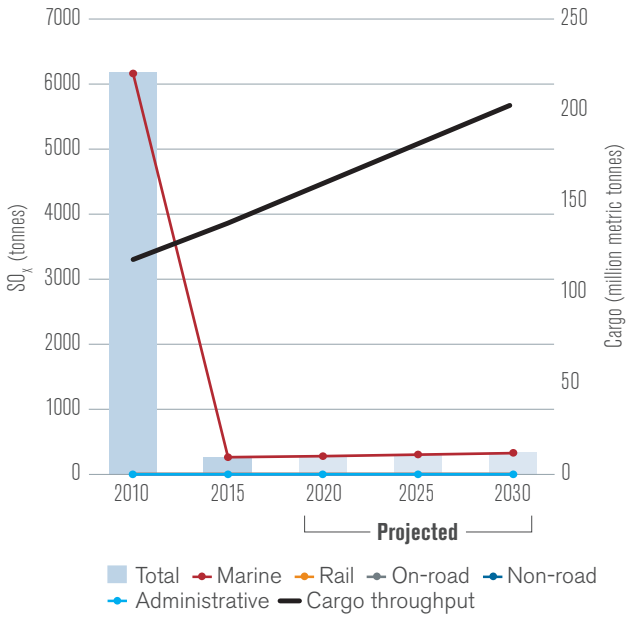
Human health: reduced respiratory system function, aggravation of asthma, increased risk of cardiovascular disease, premature death

Environmental: reduced visibility (haze), damage to vegetation, acid precipitation

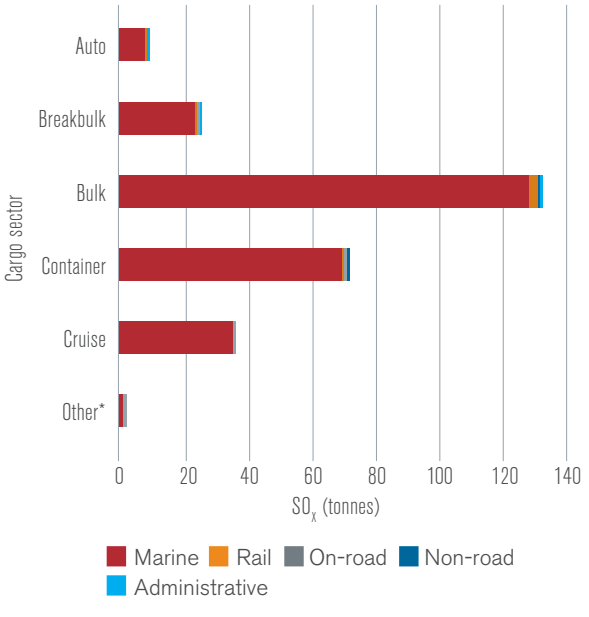
Indirect impacts

Formation of secondary particulate matter

SO_X emissions and cargo throughput, 2010-2030



SO_X emissions by cargo sector and emissions source, 2015



*Includes activities related to movement of domestic goods.

Nitrogen oxide emissions

Port-related nitrogen oxide (NO_X) emissions decreased slightly from 2010 to 2015 and are forecast to decrease by about 40 per cent by 2030 despite projected increases in cargo traded. This trend is driven by the International Maritime Organization's increasingly stringent engine emission limits for newly constructed ocean-going vessels operating in Emission Control Areas. The Government of Canada has also introduced NO_X regulations for new ship engines, vehicles and equipment, which is another factor influencing the decline.

The highest quantities of NO_X emissions are from the bulk and container sectors, which handle the most cargo. While marine activity contributes the majority of NO_X emissions at the port, the movement of bulk cargo by rail accounts for 16 per cent of total NO_X emissions. The on-road emission source for the container sector is also significant, representing about six per cent of total NO_X emissions.

Pollutant

Nitrogen oxides (NO_X) are compounds that contain nitrogen and oxygen

Source

Fuel combustion

Direct impacts

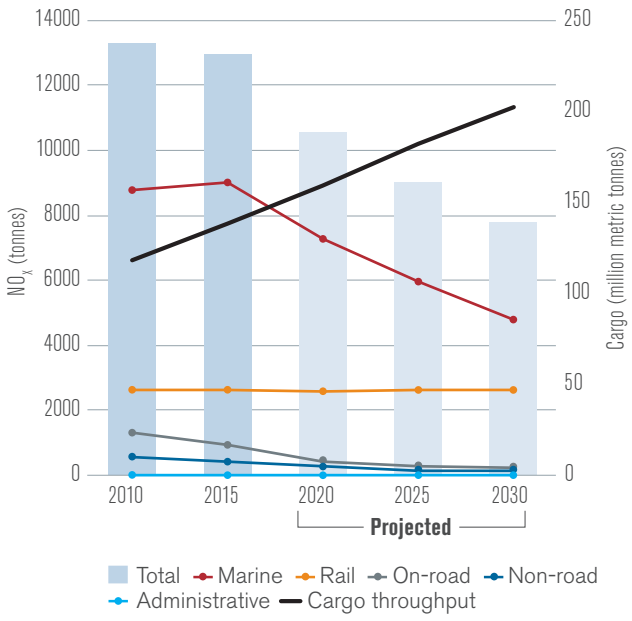
Human health: reduced respiratory system function, aggravation of asthma

Environmental: reduced visibility (haze), damage to vegetation, acid precipitation

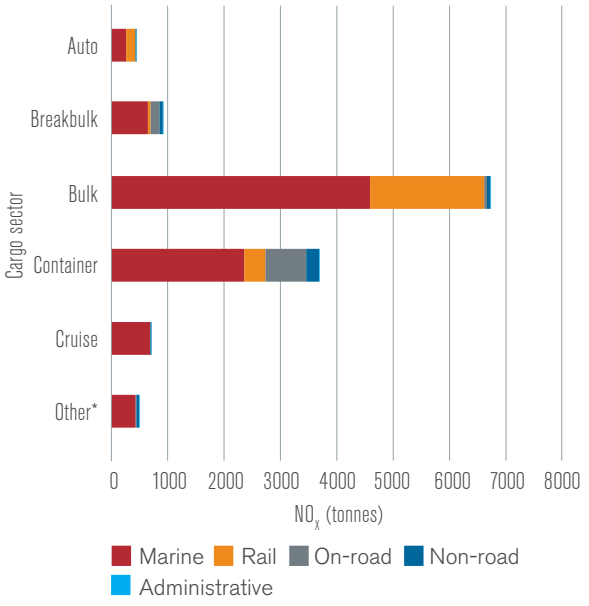
Indirect impacts

Formation of ground-level ozone

NO_X emissions and cargo throughput, 2010-2030



NO_X emissions by cargo sector and emission source, 2015



*Includes activities related to movement of domestic goods.

Fine particulate matter emissions

Port-related fine particulate matter emissions ($PM_{2.5}$) decreased by 68 per cent from 2010 to 2015 due to the International Maritime Organization's introduction of the North American Emission Control Area for marine vessels in 2012. Improvements to federal fuel sulphur and engine emission limits contributed to reductions in particulate matter from on-road and non-road sources, most notably between 2010 and 2020. As with sulphur oxide emissions, growth in trade through the port is forecast to cause total $PM_{2.5}$ emissions to increase after 2015, in the absence of new fuel or technology regulations.

Marine activity is the most significant source of $PM_{2.5}$ emissions in each cargo sector. Rail is the second largest source of $PM_{2.5}$ emissions, accounting for 25 per cent of the total in 2015. On-road vehicles and non-road equipment servicing the container sector collectively represent about 55 per cent of the container sector's contribution to $PM_{2.5}$ emissions.

Pollutant

Fine particulate matter ($PM_{2.5}$) are airborne solid or liquid particles, 2.5 microns or less in diameter

Source

Fuel combustion

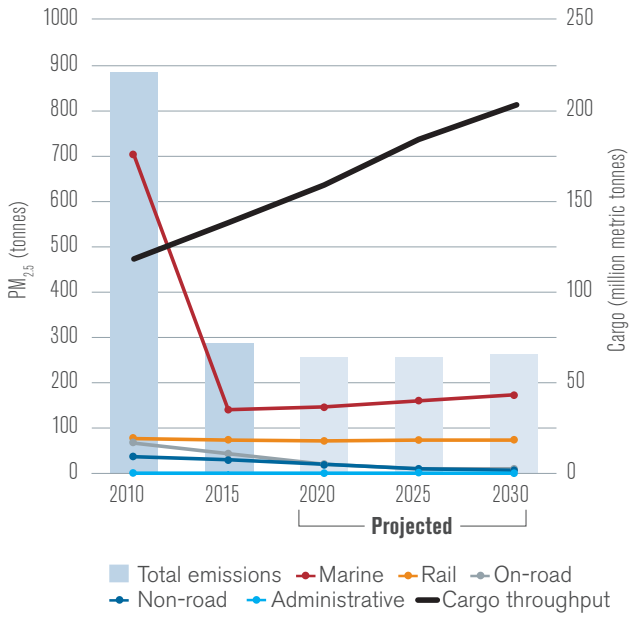
Dust generated from the movement and processing of bulk commodities[1]

Direct impacts

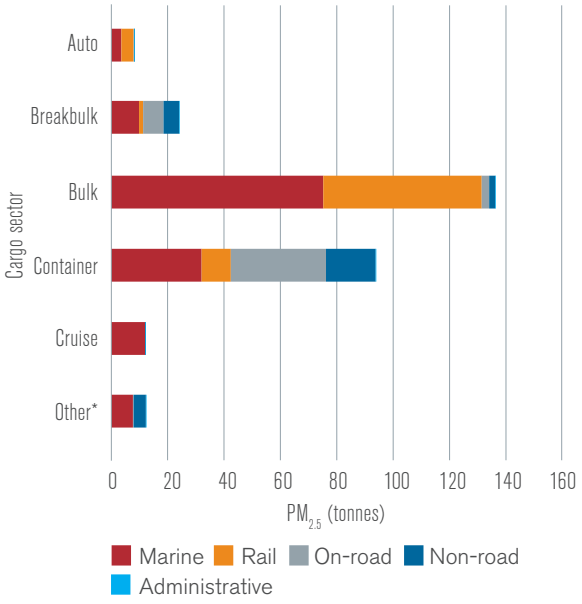
Human health: reduced respiratory and cardiovascular system function, aggravation of asthma, lung cancer, premature death

Environmental: reduced visibility (haze), damage to vegetation, acid precipitation

$PM_{2.5}$ emissions and cargo throughput, 2010-2030



$PM_{2.5}$ emissions by cargo sector and emissions source, 2015



*Includes activities related to movement of domestic goods.

[1] This report includes results of combustion- and electricity-related emissions only.

Volatile organic compound emissions

Total volatile organic compound (VOC) emissions from port activities decreased by three per cent between 2010 and 2015. Emissions are forecast to decrease another nine per cent by 2020. The short term decrease is largely driven by more stringent engine emission limits for on-road vehicles and non-road equipment. However, VOC emissions are forecast to increase after 2020, reaching nearly 2010 levels by 2030. This increase is primarily due to the expected growth in trade and vessel traffic through the port and the lack of new regulatory limits targeting VOC emissions from marine and rail engines and fuels.

The port's two largest cargo sectors, bulk and container, contribute the largest share of VOC emissions. Marine sources contribute the majority of VOC emissions for each cargo sector. Rail activity represents about 34 per cent of VOC emissions in the bulk sector, and on-road vehicles and non-road equipment being used to transport containers are collectively responsible for approximately 48 per cent of the container sector's VOC emissions.

Pollutant

Volatile organic compounds (VOCs) are gaseous chemical compounds that are primarily hydrogen- and carbon-based

Source

Fuel combustion

Evaporation of some fuels during storage and handling[2]

Direct impacts

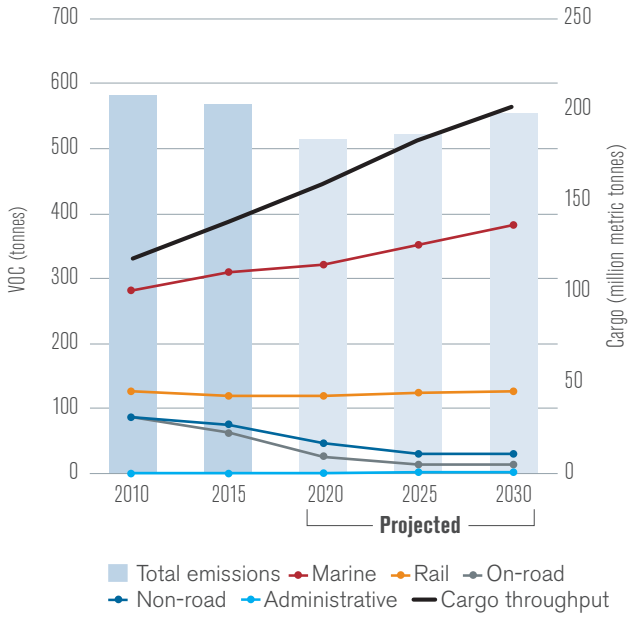
Human health: irritation of airways, headaches; nausea, damage to liver, kidney, and central nervous system, cancer

Environmental: damage to vegetation, odour

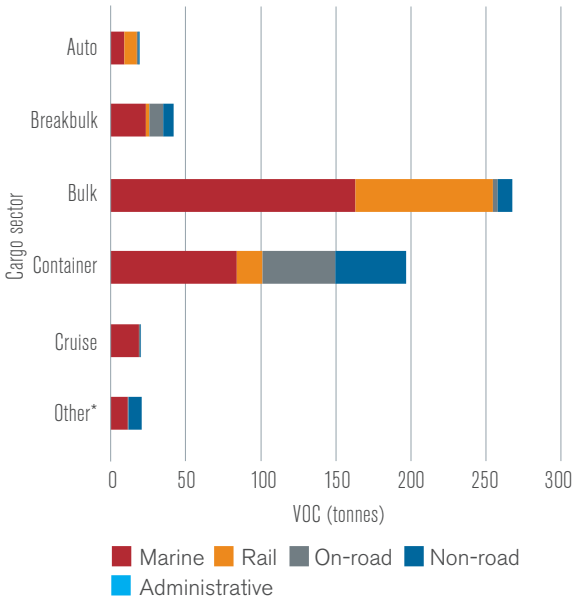
Indirect impacts

Formation of ground-level ozone

VOC emissions and cargo throughput, 2010-2030



VOC emissions by cargo sector and emission source, 2015



*Includes activities related to movement of domestic goods.

[2] This report includes results of combustion- and electricity-related emissions only.

Greenhouse gas emissions

The intensity of port-related greenhouse gas (GHG) emissions – measured as emissions per tonne of cargo – has decreased since 2010. We predict 0.85 kg less GHG emissions will be released per tonne of cargo in 2030 than in 2015. This 11 per cent decrease is due to improvements in engine and equipment efficiency.

From 2010 to 2015, total port-related GHG emissions increased by approximately 14 per cent. At the time of our analysis, no known regulations were forthcoming that would reduce total port-related GHG emissions. Consequently, our forecast shows GHG emissions steadily increasing for the foreseeable future, corresponding to an increase in cargo through the port. However, the International Maritime Organization is currently developing a strategy for GHG emissions reduction in the shipping sector. In addition, the Government of Canada is developing a pan-Canadian framework to reduce GHG emissions that will affect the transportation sector, including ports. These regulatory initiatives will be critical to reducing total GHG emissions associated with port activities.

Pollutant

Greenhouse gases (GHGs), including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)

Source

Fuel combustion

Evaporation of some fuels during storage and handling[3]

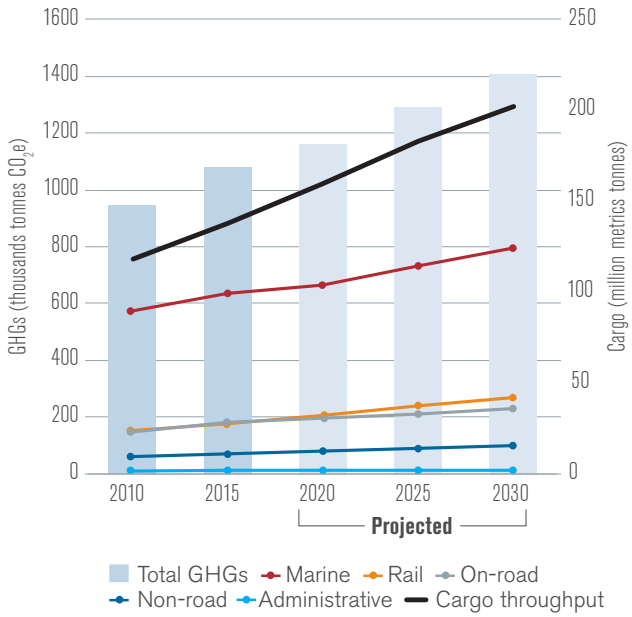
Direct impacts

Environmental: global warming, ocean acidification

Indirect impacts

Climate change and associated impacts, including sea level rise, more frequent and severe weather events (e.g. heat waves, storms, floods, droughts, forest fires), migration of disease, food and water insecurity, extinction of species

GHG emissions and cargo throughput, 2010-2030



GHG emission intensity, 2010-2030

[3] This report includes results of combustion- and electricity-related emissions only.

Black carbon emissions

Black carbon emissions decreased by 66 per cent between 2010 and 2015 as a result of fuel sulphur regulations that came into effect during this period. Black carbon emissions from ocean-going vessels declined by 79 per cent, and reductions were also achieved from on-road, non-road, rail, harbour tugs and river dredging vessel sources.

Black carbon emissions are forecast to represent 11 per cent of port carbon dioxide equivalent emissions (CO_2e) at least until 2030 on a 100-year global warming potential timeframe.

Global warming potential is a measure of the heat trapping ability of pollutants relative to carbon dioxide and is most commonly estimated based on a 100-year timeframe. Black carbon emissions, however, have a higher global warming potential in the short term, over a 20-year timeframe. This presents an opportunity to reduce the port's contribution to climate change in the short term.

In 2015, black carbon emissions represented about 40 per cent of total CO_2e emissions at a 20-year timeframe. This figure is expected to decrease nine per cent by 2030 largely due to improvements in engine emission controls.

Pollutant

Black carbon is a component of fine particulate matter

Source

Fuel combustion

Direct impacts

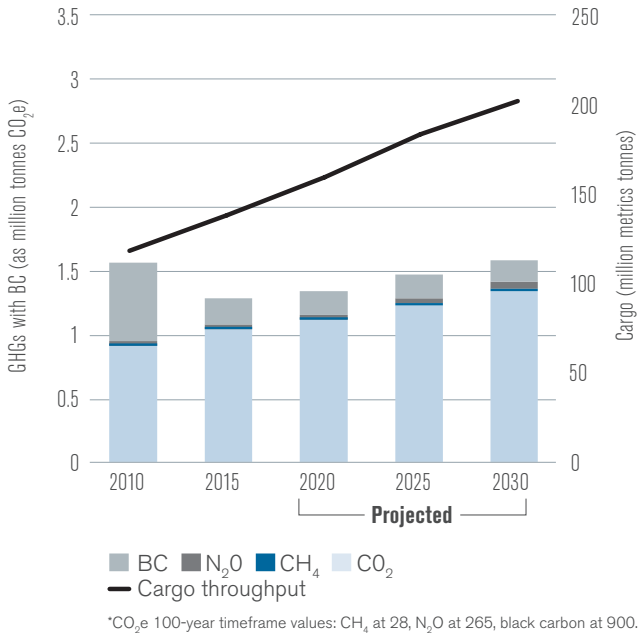
Human health: reduced respiratory and cardiovascular system function, aggravation of asthma, cardiovascular disease, lung cancer, premature death

Environmental: global warming, melting of ice and snow, reduced visibility (haze), damage to vegetation

Indirect impacts

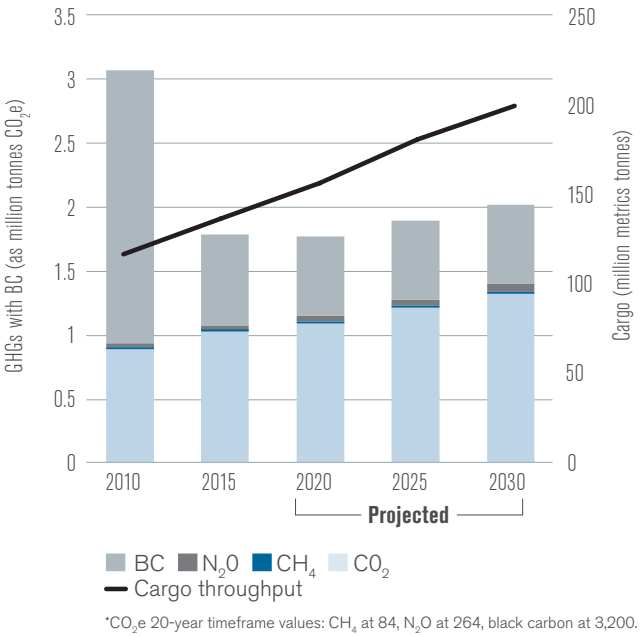
Climate change and associated impacts including sea level rise, more frequent and severe weather events (e.g. heat waves, storms, floods, droughts, forest fires), migration of disease, food and water insecurity, extinction of species

Greenhouse gases with black carbon over a 100-year timeframe, 2010-2030*



*CO_2e 100-year timeframe values: CH_4 at 28, N_2O at 265, black carbon at 900.

Greenhouse gases with black carbon over a 20-year timeframe, 2010-2030*



*CO_2e 20-year timeframe values: CH_4 at 84, N_2O at 264, black carbon at 3,200.

Energy usage

Moving cargo and people requires a lot of energy. Understanding where energy comes from and how it is used is an important part of managing air emissions. In 2015, energy used to move goods at the port was approximately 15 million gigajoules (GJ), roughly equal to the annual energy usage of over 140,000 homes in Canada. Most of this energy comes from fossil fuels that, when burned, release emissions that affect air quality and contribute to climate change.

The bulk and container sectors consume the most energy at the port because they comprise the majority of cargo handled at port terminals. Diesel, including domestic marine fuels, accounts for approximately 48 per cent of the energy used at the port, with ocean-going vessel fuel (bunker fuel) being the other major source of energy at 45 per cent. Although total energy use is forecast to increase, energy use per tonne of cargo has decreased by about three per cent since 2010. This decrease in energy usage is forecast to continue due to improvements in engine and equipment efficiency.

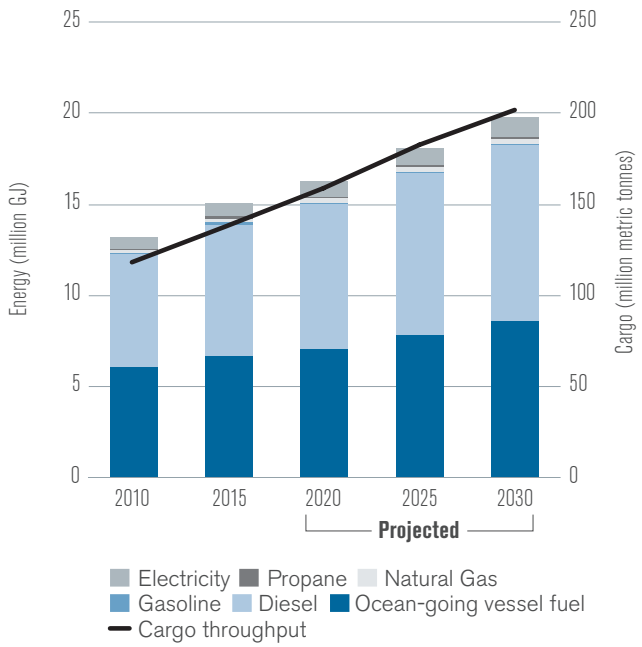
Electrification
Transitioning to low carbon fuels, or energy like hydroelectricity will reduce port greenhouse gas emissions.

Greenhouse gas emissions intensity by fuel type (CO_2e per megajoule of energy)

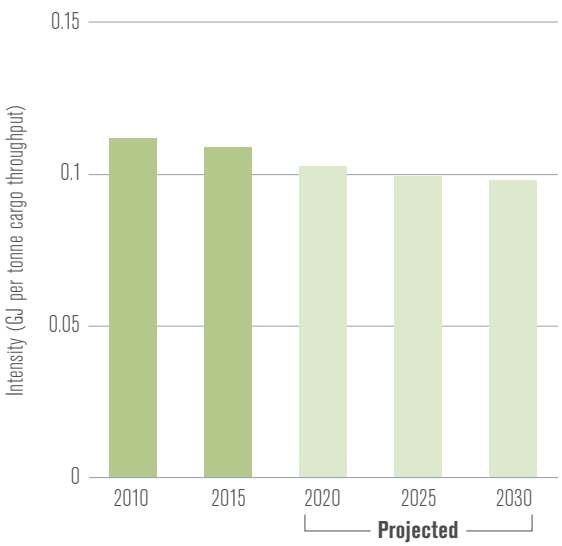
Fuel Type	g CO_2e per MJ
Ocean-going vessel fuel:	
Marine heavy fuel oil	76.01
Marine diesel oil	70.91
Marine gas oil	69.87
Diesel	70.52
Gasoline	70.44
Propane	60.33
Natural gas	57.10
BC Hydro electricity	**5.56**

· US EPA, AP-42: Compilation of Air Emission Factors, Fifth Edition, Volume 1, Appendix A; September 1985
· Environment and Climate Change Canada, National Inventory Report, 1990-2015: GHG Sources and Sinks, Part 2, Annex 5

Energy usage and cargo throughput, 2010-2030



Energy intensity, 2010-2030



Air and energy initiatives

We've implemented a number of initiatives to facilitate emission reductions and help us realize our vision of being the world's most sustainable port.

The port authority's environmental initiatives support important regulatory changes as well as complement and promote voluntary action by industry. The initiatives are specific to the unique conditions in each transportation and cargo sector at the Port of Vancouver. Since launching our first air initiatives in 2007, we have helped raise awareness among port users and reduce emissions that contribute to air pollution and climate change.

We also bring together port users, supply chain partners and other stakeholders to share information, identify opportunities, and implement solutions that improve the efficiency of cargo movements. These efficiency measures often have the added benefit of reducing air emissions through minimizing wait times and unnecessary idling or queuing.

Our environmental initiatives have received external recognition, including a 2017 award from the North American Marine Environment Protection Association.

Read more about our initiatives and performance in our 2016 Sustainability Report at portvancouver.com/sustainability-report

Northwest Ports Clean Air Strategy

We partner with the ports of Seattle and Tacoma and the Northwest Seaport Alliance to reduce port-related air emissions in the shared Georgia Basin-Puget Sound air shed. The overarching goals of the Northwest Ports Clean Air Strategy (NWPCAS), relative to a 2005 baseline, are:

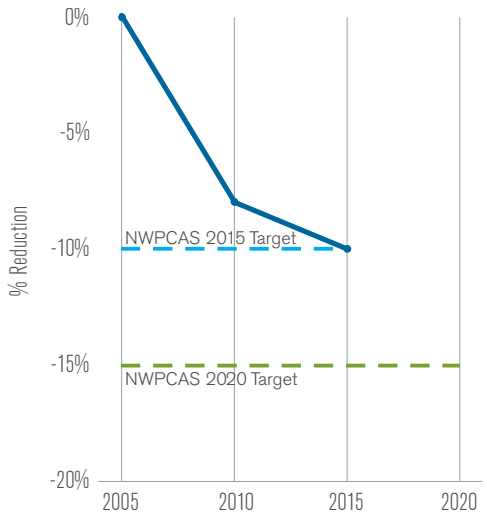
- 75 per cent reduction in diesel particulate matter[4] (DPM) emissions per tonne of cargo by 2015 and 80 per cent by 2020
- 10 per cent reduction in greenhouse gas (GHG) emissions per tonne of cargo by 2015 and 15 per cent by 2020

Based on 2015 emissions inventory data, the Port of Vancouver met the 2015 targets, achieving a 10 per cent reduction in GHG emissions and a 78 per cent reduction in DPM emissions from baseline levels.

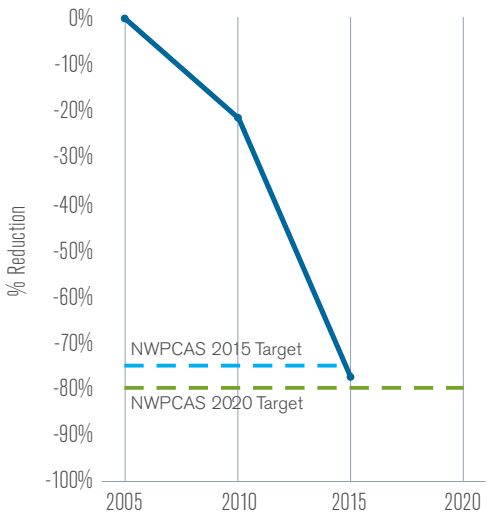
See progress toward these goals in the Northwest Ports Clean Air Strategy annual implementation reports at portvancouver.com/clean-air

The Northwest Ports Clean Air Strategy benefits from active input from Environment and Climate Change Canada, Metro Vancouver, the Puget Sound Clean Air Agency, the Washington State Department of Ecology, and the U.S. Environmental Protection Agency.

GHG emissions intensity (per tonne cargo throughput) relative to NWPCAS targets



DPM emissions intensity (per tonne cargo throughput) relative to NWPCAS targets



[4] Diesel particulate matter is a component of particulate matter, associated with the combustion of diesel fuel specifically.

Ocean-going vessels

Our approach to reducing emissions in ships includes supporting regulations, such as the International Maritime Organization North American Emission Control Area, providing incentives for positive environmental practices through our EcoAction Program, and supporting the use of shore power and cleaner fuels.

EcoAction Program

Our EcoAction Program, launched in 2007, offers discounts on harbour dues to vessels meeting voluntary environmental best practices that reduce emissions and environmental impacts. These practices include the use of cleaner fuels and technologies, and obtaining third-party environmental designations. In 2016, participation in the EcoAction Program grew to 612 vessel calls, representing 24 per cent of all eligible calls for the year. Our Blue Circle Award is given to shipping lines with the greatest proportion of participation in the EcoAction Program. In 2016, 15 shipping lines were awarded.

Shore power

Shore power enables ships at berth to shut off their diesel-powered engines and connect to the electricity grid, significantly reducing emissions that contribute to both air pollution and climate change. Since their installation in 2009, the shore power facilities at the Canada Place cruise terminal have eliminated 474 tonnes of air pollutants and 16,138 tonnes of greenhouse gases. In 2015, in partnership with the Government of Canada and with support from BC Hydro, we embarked on an initiative to develop shore power facilities at the Deltaport and Centerm container terminals. Installations are expected to be complete in 2018.

Liquefied natural gas as a marine fuel

We are working with industry and government to facilitate the use of liquefied natural gas (LNG) as a marine fuel in the Port of Vancouver. In 2016, we conducted a study that suggested the port would start seeing demand for LNG as a marine fuel as early as 2020, which would increase steadily toward 2030. The number of LNG-capable ships is expected to increase globally in response to forthcoming regulations from the International Maritime Organization on sulphur oxide and greenhouse gas emissions. LNG represents an opportunity for the shipping industry to significantly reduce air pollutants, including emissions of sulphur oxides and nitrogen oxides, as well as to achieve more modest reductions in greenhouse gas emissions. We are currently working with academic partners and the Society for Gas as a Marine Fuel to better understand the potential environmental benefits and risks associated with LNG as a marine fuel.

We're adding more ways for ships to plug in and shut off their engines, with new shore power facilities coming online at two container terminals in 2018.

Tenant operations

The port authority leases federal lands and water to over 100 industrial tenants including 27 deep-sea marine terminal operators. We work in partnership with our tenants to reduce diesel particulate matter emissions associated with cargo handling equipment through our Non-Road Diesel Emissions Program, and to promote energy conservation and greenhouse gas (GHG) reductions through our Energy Action and Climate Smart initiatives. We are also exploring low-emission technologies for cargo-handling equipment, such as electric equipment and auto-stop-start engine technology for idle reduction.

Non-Road Diesel Emissions Program

Since 2015, Port of Vancouver tenants have been required to annually register diesel-powered non-road equipment, report operating hours, and pay a fee for operation of older, higher-emission equipment. To accelerate the transition to newer, cleaner equipment, up to 80 per cent of the fee is eligible for rebate once the tenant replaces, retrofits or retires the older equipment.

Energy Action initiative

Industrial tenants at the Port of Vancouver use more than 1,600[5] gigawatt hours of electricity per year. As Canada's demand for trade grows, more energy will be needed to support port operations. Since power from BC Hydro is largely from low-emission hydroelectric sources, meeting this demand with electricity from the grid can lower GHG emissions. We partner with BC Hydro to provide port tenants with expertise in industrial energy management and access to BC Hydro's financial incentives.

Climate Smart initiative

We work with Vancouver-based social enterprise Climate Smart to provide a training program that supports our tenants in measuring and reducing GHG emissions, complementing their existing efforts. The initiative facilitates a port-focused peer group to share knowledge and practices for minimizing emissions, waste and costs. We provide funding that covers 50 per cent of the cost to participate. In 2015, 11 tenants participated, collectively eliminating 2,788 tonnes of GHG emissions from their operations within the first year, while achieving $670,000 in annual cost savings. In 2016, four new tenants joined the program and several tenants elected to repeat the training to further cut carbon and costs in their operations.

Project and environmental reviews

We require permits for all activities or developments on port lands or waters. Through our Project and Environmental Review process, we review permit applications from proponents and make a determination on the potential environmental impact. We will not authorize or allow a proposed project to proceed if it is likely to result in significant adverse environmental effects. Through this rigorous review process, we work with tenants to encourage or identify opportunities for implementing sustainable practices in their projects, including energy and emissions management.

Port tenants include 27 deep-sea marine terminals, as well as a range of facilities and services that support international and domestic shipping.

[5] Figure does not relate to energy figures presented on page 19 due to difference in scope.

Container trucks

We manage emissions from container trucks through our Truck Licensing System environmental requirements. In addition, we work with key stakeholders to improve the efficiency of operations in this sector through actions including extended gate hours, a truck reservation system and the installation of global positioning system units on trucks. Going forward, we are also collaborating with stakeholders to assess the feasibility of low-emission solutions for the trucking sector.

Truck Licensing System

All of the approximately 1,700 container trucks that access the port must enter into a Truck Licensing System agreement that includes environmental requirements for engine age, emission controls and idle reduction. Since 2008, we have phased in the requirement for trucks with engines 2006 and older to have an approved emission control device that reduces particulate matter per truck by 20 to 25 per cent. This enables interim emission reductions as we work toward the Northwest Ports Clean Air Strategy target to have all trucks meet or surpass 2007 particulate matter emission standards by 2017.

Particulate matter emissions from the more than 1,700 container trucks that access the port were reduced by 18% in 2016 as a result of our environmental requirements.

Port authority corporate emissions

We have a number of initiatives designed to reduce greenhouse gas emissions associated with the energy consumption of our own corporate operations. These include our Sort Smart waste management system, employee sustainable commuting initiatives, and lighting and temperature controls. In 2015, corporate greenhouse gas emissions totalled 1,395 tonnes. Port authority operations have been carbon neutral since 2010 through the purchase of carbon offsets.

Read more about our corporate emission reduction programs in our 2016 Sustainability report at portvancouver.com/sustainability-report

Air quality monitoring

An emissions inventory helps us understand the quantity and source of pollutants emitted, but it does not tell us the impact of these pollutants in locations where people live, work and play. For example, pollutants are dispersed by wind and can react with other components to create different pollutants. Ambient air quality monitoring helps us understand the concentration of pollutants in the air at a given location, be it from port or non-port sources. We collaborate with Metro Vancouver and other partners to monitor air quality around the port through the following initiatives:

- Metro Vancouver's T39 air quality station, located at Pebble Hill, Tsawwassen, monitors particulate matter, nitrogen oxides, ozone, sulphur dioxide, carbon monoxide and meteorology. Funded by the port authority, this station has formed part of Metro Vancouver's ambient air monitoring network since 2010 and is used in both Metro Vancouver's regional air assessments as well as our own environmental assessments.
- Tsawwassen First Nation Air Quality Monitoring Program, conducted in 2014 and 2015, included an assessment of air quality on Tsawwassen First Nation lands, compared to Metro Vancouver's T39 air quality station, as well as the contribution of coal to dustfall. The port authority led this study, with input and support from Tsawwassen First Nation, Metro Vancouver and Westshore Terminals.
- Burrard Inlet Local Air Quality Area Study Phase II monitoring began along the south shore of Burrard Inlet in 2014, focusing primarily on particulate matter and sulphur oxides. This was in follow up to the larger Phase I of the program led by Metro Vancouver. We funded the purchase, installation and a portion of the maintenance for this monitoring, which will be used to better understand the effect of port activities on air quality in Burrard Inlet.

We collaborate with Metro Vancouver to monitor air quality in our region, for example, by funding the purchase and installation of new equipment.

Glossary of terms

Term	Description
Administrative operations	Emission source group associated with heating and electricity for buildings on port lands and lighting terminals.
Backcast	Method for estimating past emission levels in 2010 by adjusting 2015 emission estimates based on the expected age of equipment operating at the port, regulatory changes, and trade volumes.
Black carbon	A component of fine particulate matter, black carbon contributes to climate change by absorbing heat from the sun which warms the air, and if deposited on snow and ice, leads to melting. Black carbon is released through incomplete combustion of fossil and bio-based fuels. Black carbon stays in the atmosphere for a much shorter time period than greenhouse gases and has a greater impact on climate change during that period.
Carbon dioxide equivalent (CO_2e)	Carbon dioxide equivalent is a standard unit of measure used to compare different types of greenhouse gas emissions and black carbon based on their global warming potential..
Cargo sector	Category of goods transported through the port, including bulk, breakbulk, container, and cruise.
Diesel particulate matter (DPM)	A component of particulate matter that comes from the combustion of diesel fuel.
Emission factor	Emission factors are representative values relating the quantity of an emission with an activity, such as fuel combustion. The most common approach for estimating emissions, the value of an emission factor depends on engine age and technology, fuel type, and operating conditions. The 2015 port emissions inventory uses Canadian and industry-specific emission factors where available, including the U.S. Environmental Protection Agency, Environment and Climate Change Canada, Railway Association of Canada, and BC Hydro.
Forecast	Method for estimating future emission levels in 5-year increments to 2030 by adjusting 2015 emission estimates based on the expected age of equipment operating at the port, regulatory changes and expected or assumed increases in cargo handled at port terminals.
Greenhouse gas (GHG)	Group of gases, including carbon dioxide, methane and nitrous oxide, that causes global warming and contributes to climate change.
Ground-level ozone	A secondary pollutant formed by the reaction of volatile organic compounds and nitrogen oxides. It is a major component of smog, can damage synthetic materials, and can impact vegetation and decrease the productivity of some crops. Exposure has been linked to pre-mature mortality.
International Maritime Organization (IMO)	A specialized agency of the United Nations, IMO is the global standard-setting and regulatory authority for the safety, security and environmental performance of international shipping.
Liquefied natural gas (LNG)	Natural gas that has been converted to liquid form in order to increase its energy density and for ease of storage or transport.

Term	Description
Marine	Emissions source group that includes ocean-going vessels, harbour tugs, and dredging vessels.
Nitrogen oxides (NO_x)	A mixture of compounds that contain nitrogen and oxygen.
Non-road equipment	Emission source group of equipment not intended for transportation on public roads, includes cranes, container stackers, loaders, terminal tractors, and forklifts.
North American Emission Control Area (ECA)	Designated by the International Maritime Organization in 2010, the Emission Control Area requires stringent emission standards for ships in waters off North American coasts. The first and second phase fuel sulfur standards began in 2012 and 2015 respectively, and stringent nitrogen oxides engine standards for new build-vessels began in 2016.
On-road vehicles	Emission source group that includes container trucks, heavy duty trucks, terminal support vehicles, and passenger transportation.
Particulate matter (PM)	A mixture of solid particles and liquid droplets in the air. Fine inhalable particles with diameters that are generally 2.5 micrometers and smaller are referred to as fine particulate matter ($PM_{2.5}$).
Rail	Emission source group that includes locomotives that move trains as part of port operations.
Shore power	The provision of shoreside electrical power to a ship at berth while its main and auxiliary engines are shut down, effectively reducing emissions.
Smog	A noxious mixture of gases and particles that often appears as a haze in the air and has been linked to a number of adverse effects on health and the environment. The two primary pollutants in smog are ground-level ozone and particulate matter.
Sulphur oxides (SO_x)	A mixture of compounds that contain sulphur and oxygen.
Throughput	The amount of cargo traded through the Port of Vancouver.
Volatile organic compound (VOC)	A group of compounds that contain primarily hydrogen and carbon.

Data tables

2015 Air pollutants (tonnes)

Cargo sector	Source	SO_x	NO_x	$PM_{2.5}$	VOC	NH_3	CO
Auto	Marine	6.973	261.349	3.469	9.068	0.479	23.955
	Rail	0.084	170.049	4.532	8.500	0.237	24.094
	On-road	0.022	2.839	0.124	0.650	0.118	10.523
	Non-road	0.002	1.281	0.014	1.208	0.002	30.076
	Administrative	0.012	0.219	0.032	0.048	0.029	0.368
Breakbulk	Marine	21.852	648.325	9.869	23.612	1.152	63.261
	Rail	0.027	46.941	1.309	2.126	0.082	7.648
	On-road	0.214	152.840	7.437	9.263	0.580	50.091
	Non-road	0.064	70.877	5.593	7.122	0.124	55.022
	Administrative	0.035	0.650	0.096	0.143	0.087	1.092
Bulk	Marine	129.644	4,591.144	75.414	163.243	9.939	537.883
	Rail	1.181	2,027.550	56.174	91.368	3.780	334.683
	On-road	0.106	50.953	2.680	3.188	0.261	16.152
	Non-road	0.102	57.121	2.312	9.842	0.131	119.482
	Administrative	0.067	1.258	0.186	0.276	0.168	2.109
Container	Marine	70.273	2,365.135	32.113	84.020	4.013	211.589
	Rail	0.211	375.096	10.391	17.253	0.634	59.924
	On-road	0.547	716.657	33.820	48.323	1.959	302.037
	Non-road	0.374	236.487	17.588	47.164	0.728	163.191
	Administrative	0.049	0.911	0.134	0.201	0.122	1.531
Cruise	Marine	35.622	696.172	11.969	18.642	3.346	50.406
	Rail	–	–	–	–	–	–
	On-road	0.039	2.263	0.084	0.884	0.219	17.906
	Non-road	0.004	0.442	0.040	0.045	0.002	0.675
	Administrative	0.013	0.247	0.036	0.054	0.033	0.414
Other	Marine	0.672	434.713	7.630	11.515	0.936	75.413
	Rail	–	–	–	–	–	–
	On-road	0.019	6.633	0.324	0.506	0.066	4.819
	Non-road	0.045	52.177	4.348	8.853	0.080	111.714
	Administrative	0.017	0.321	0.047	0.071	0.043	0.540
Total per source	Marine	265.037	8,996.837	140.464	310.101	19.865	962.507
	Rail	1.503	2,619.635	72.405	119.246	4.732	426.349
	On-road	0.947	932.186	44.468	62.815	3.202	401.528
	Non-road	0.591	418.384	29.894	74.234	1.067	480.160
	Administrative	0.193	3.606	0.532	0.793	0.483	6.054
Total emissions		268	12,971	288	567	29	2,277

Note: Summing table numbers may not equal totals due to rounding.

2015 Greenhouse gas emissions (tonnes)

Cargo sector	Source	CO_2	CH_4	N_2O	Black Carbon	CO_2e* (100 yr)	Energy consumption (annual GJ)
Auto	Marine	14,520	1.122	0.832	2.518	14,772	194,678
	Rail	9,056	0.507	3.715	3.598	10,055	131,717
	On-road	1,507	0.174	0.331	0.060	1,600	22,481
	Non-road	124	0.143	0.004	0.004	129	2,111
	Administrative	563	2.477	0.019	0.013	637	20,597
Breakbulk	Marine	44,059	3.435	2.007	7.577	44,687	589,136
	Rail	2,906	0.163	1.192	1.039	3,226	42,266
	On-road	35,928	1.890	1.497	5.696	36,378	510,609
	Non-road	7,363	0.555	2.868	4.342	8,139	111,807
	Administrative	1,805	7.387	0.065	0.038	2,029	93,447
Bulk	Marine	324,279	23.858	38.067	58.923	335,035	4,408,349
	Rail	127,164	7.114	52.168	47.293	141,188	1,849,290
	On-road	15,239	0.895	0.978	1.944	15,523	221,919
	Non-road	8,389	1.237	2.506	1.718	9,088	399,092
	Administrative	3,413	12.546	0.115	0.073	3,795	143,338
Container	Marine	137,521	10.815	4.721	23.604	139,075	1,834,088
	Rail	22,737	1.272	9.328	8.248	25,245	330,704
	On-road	124,518	5.800	0.709	26.809	124,868	1,703,788
	Non-road	43,341	4.698	16.642	13.552	47,883	698,924
	Administrative	2,656	10.052	0.096	0.053	2,963	157,867
Cruise	Marine	69,052	5.446	2.119	10.017	69,766	920,150
	Rail	–	–	–	–	–	–
	On-road	2,162	0.304	0.627	0.006	2,337	32,590
	Non-road	100	0.030	0.015	0.027	105	1,602
	Administrative	649	2.794	0.022	0.014	733	26,641
Other	Marine	28,775	1.623	11.466	6.386	31,859	416,247
	Rail	–	–	–	–	–	–
	On-road	2,240	0.159	0.219	0.229	2,302	32,781
	Non-road	4,704	0.769	1.694	3.400	5,174	68,596
	Administrative	986	3.649	0.038	0.019	1,099	68,926
Total per source	Marine	618,204	46.299	59.213	109.025	635,192	8,362,649
	Rail	161,863	9.055	66.402	60.178	179,713	2,353,977
	On-road	181,594	9.222	4.361	34.744	183,008	2,524,169
	Non-road	64,021	7.431	23.728	23.044	70,517	1,282,131
	Administrative	10,073	38.906	0.354	0.209	11,256	510,817
Total emissions		1,035,755	111	154	227	1,079,686	15,033,743

*CO_2e reported in table includes CO_2, CH_4, and N_2O, and excludes black carbon.
Note: Summing table numbers may not equal totals due to rounding.

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To enable Canada's trade objectives, ensuring safety, environmental protection and consideration for local communities.

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Our definition of a sustainable port

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IR6-33 Air Quality – GHG Reduction, Locomotives

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix A, Section 4

Context

According to Environment and Climate Change Canada, locomotives idle 85% of the time in train yards and reducing idling could significantly reduce local locomotive emissions.

Information Request

Quantify and assess the change in rail emissions that could be achieved by anti-idling technology for rail activities at Roberts Bank terminals for existing, expected and future conditions with the Project.

VFPA Response

The change in rail emissions achieved through anti-idling technology for rail activities at Roberts Bank terminals, between existing conditions in 2010 and future conditions in 2025[1], was incorporated in the RBT2 Air Quality Study (EIS Appendix 9.2-A). The assumptions for modelling of line-haul and switcher locomotive activities (based on variables such as traffic counts, idle time, speed and distance travelled, and operating hours/day) are described in Sections 4.0 and 4.2 and Attachment 5 in Appendix A of EIS Appendix 9.2-A. Emission rates for both idling and working locomotives are based on locomotive parameters, including engine power ratings, load factors, duty cycle, fuel consumption, and fleet tier mixes, as well as emission factors, and are provided in Section 4.3 and Attachment 4 in Appendix A of EIS Appendix 9.2-A.

For existing conditions, it was assumed that switcher locomotives idle 84.9% of the time based on information published in the Locomotive Emissions Monitoring Program 2010 (see Section 4.1 and Table 4-1 in Appendix A of EIS Appendix 9.2-A). At the commencement of the RBT2 Air Quality Study, BC Rail, Canadian National Railway Company, and Canadian Pacific Railway confirmed that line-haul and switcher locomotives would have anti-idling technology and be enrolled in the SmartStart Program[2] by 2017. With implementation scheduled by 2017 for these railways, 100% implementation of SmartStart technology was assumed for expected conditions and future conditions with the Project, and 0%

[1] For both expected conditions (future without the Project) and future conditions with the Project.
[2] The SmartStart Program includes the installation of SmartStart controls, which automatically shuts down locomotives when in standby mode, thus eliminating emissions that would have occurred during idling and reducing overall fuel consumption.

implementation was assumed for existing conditions in 2010 (even though some U.S. railways started implementing this technology in 2005).

For future conditions in 2025, switchers at RBT2 and Deltaport Terminal and line-haul locomotives arriving and departing from RBT2 and Westshore Terminals, were assumed to not idle due to SmartStart use[3] (as outlined in Attachment 5 in Appendix A of EIS Appendix 9.2-A). Since locomotives at Westshore Terminals cannot be shut down during unloading operations, idling for this specific activity was assumed to continue in 2025, as described in Section 4.2 in Appendix A of EIS Appendix 9.2-A.

[3] Line-haul locomotives destined for the Deltaport Terminal are set out and await their next departure in the locomotive set-out yard located (Gulf Yard) east of the Project area boundary adjacent. Therefore, only switcher locomotives operate within the Project area for the Deltaport Terminal.

IR6-34 Air Quality – GHG Emission Mitigation

Information Source(s)

EIS Volume 2: Section 9.2.8.2, Section 9.2.10.1, Table 9.2-16, Table 9.2-29

CEAR Doc#650

Context

In its submission to the Review Panel the British Columbia Ministry of Environment, Climate Action Secretariat, suggested that the Proponent consider measures for the reduction of greenhouse gas and black carbon emissions including supplying LNG fuel for ships (LNG fleets), providing a LNG Infrastructure CNG/LNG and, using electric vehicles and cargo handling equipment for the port and the inter-port transport and using an alternative marine power such as cold ironing (ship to shore power) to connect with ships.

Shore power was presented and discussed by the Proponent, and the estimated reduction of greenhouse gasses and black carbon at Deltaport and at the Project were presented in Tables 9.2-16 and 9.2-29 of the EIS.

Information Request

Present and discuss the feasibility and advantages and disadvantages of implementation of the following mitigation measures for the reduction of greenhouse gas and black carbon emissions:

- supplying LNG fuel for ships (LNG fleets); and
- providing a LNG Infrastructure CNG/LNG and, electric vehicles and cargo handling equipment for the port and the inter-port transport.

Evaluate, and present in a table, a comparison of the predicted changes in total annual emissions of greenhouse gasses and black carbon for future conditions with the Project, and for the lifetime of the Project, gained by each proposal.

VFPA Response

Present and discuss the feasibility and advantages and disadvantages of implementation of the following mitigation measures for the reduction of greenhouse gas and black carbon emissions: supplying LNG fuel for ships (LNG fleets); and providing a LNG Infrastructure CNG/LNG and, electric vehicles and cargo handling equipment for the port and the inter-port transport.

The feasibility of each of the listed mitigation measures is provided below. For those mitigation measures that are feasible, the advantages and/or disadvantages are described, and evaluated further in response to the second part of this information request.

a) Supplying LNG Fuel for Ships (LNG fleets)

Liquified natural gas (LNG) fuelled container vessel fleets are a feasible option and provide emission reduction benefits. Small container ships (e.g., 3,100 twenty-foot equivalent unit (TEU) capacity) running on LNG fuel are currently in operation[1] and larger container ships (over 20,000 TEU-capacity) are currently on order[2].

Taljegard et al. (2014) reported that natural gas-based fuels, specifically LNG and methanol, are the most probable substitute fuels likely to be adopted for use before 2030 (for more information refer to Section 6.1.6 in Appendix A of EIS Appendix 9.2-A). The shift to LNG for ocean-going vessels is not confined to container ships and the number of ships of all types operating on LNG is growing rapidly. For example, the Review of Maritime Transport 2017 published by the United Nations Conference on Trade and Development (UNCTAD 2017) states the following:

> *"While the percentage of liquefied natural gas-capable newbuildings (measured in gross tons) was relatively steady at about 2 per cent from 2002 to 2013, it rose to 5.8 per cent in 2014, 4.3 per cent in 2015 and 5.3 per cent in 2016. The trend becomes particularly evident when considering the order book. While a slight increase is expected in 2017 (to 5.7 per cent), 13.5 per cent of the gross tonnage currently on order for delivery in 2018 onwards are from liquefied natural gas-capable ships…. This is more than twice the value of 2017 and more than three times that of 2015."*

According to UNCTAD (2017), recently adopted and pending regulations on fuel quality and growing support for greenhouse gas emission regulation in the maritime sector is leading to increasing interest in the use of LNG as a propulsion fuel for marine vessels. The number of LNG-capable ships is expected to increase globally in response to forthcoming regulations from the International Maritime Organization on sulphur oxide and greenhouse gas emissions (VFPA 2017). Despite the increased interest in LNG as a fuel for ocean-going vessels, the likelihood, frequency and timing of LNG-powered container ships calling at ports in the Pacific northwest, including RBT2, is uncertain.

Container ships operate on a scheduled service to the Pacific Northwest Region from Asian home ports where they are currently fuelled for their entire transit (i.e., vessels do not bunker along the route[3]). Bunkering facilities for container ships at the existing Deltaport Terminal have not been required, nor has any bunkering facility been incorporated as part of the RBT2 Project's design[4].

As stated in the 2015 Port Emissions Inventory Report (VFPA 2017), the VFPA is working with

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[1] http://www.ship-technology.com/projects/marlin-class-lng-powered-container-ships/
[2] https://www.maritime-executive.com/article/cma-cgm-to-run-worlds-biggest-boxships-on-lng#gs.HbJGEKk
[3] Previously stated in EIS Section 4.4.2.1 and the Marine Shipping Addendum Section 4.2.2.5.
[4] The only fuelling proposed at the RBT2 terminal will be located near the maintenance and repair building to service terminal equipment that requires either gasoline or diesel fuel (EIS Appendix 4-B, Section 4.3.6).

industry and government to facilitate the use of LNG as a marine fuel in the Port of Vancouver and is monitoring LNG development activities in the region.[5,6] In 2016, the VFPA conducted a study that suggested the port would start seeing demand for LNG as a marine fuel as early as 2020, which would increase steadily toward 2030.

The use of LNG can lower emissions of NO_x by 90% and virtually eliminate SO_x and particulate matter (PM) emissions, as well as lowering greenhouse gas and black carbon emissions (Germanischer Lloyd 2011; Taljegard et al. 2014). The International Maritime Organization (IMO 2015) conducted extensive reviews of the effect of LNG on PM emissions within light-duty (passenger cars) and heavy-duty diesel engines (buses, trucks), and found that PM emissions are reduced by 88% to 99%. Since the majority of PM emissions from ultra-low sulphur diesel (ULSD) fuel use in marine engines are composed of black carbon, the IMO (2015) stated that these PM emission reductions are likely an effective proxy for reductions in black carbon emissions. The IMO (2015) also noted the following:

- Data from the U.S. Environmental Protection Agency suggest that black carbon emissions are eliminated when using LNG;
- No data has been identified on PM or black carbon emissions from LNG engines used in ships (other than Anderson et al. (2015), which was not considered in the IMO study);
- In terms of the reduction of the Global Warming Potential (GWP), the IMO stated that possible increases in fugitive emissions of methane during LNG production may counteract reductions in black carbon from LNG use in the marine shipping sector.

A semi-quantitative evaluation of potential future advantages and disadvantages with respect to exhaust emissions from LNG-powered container vessels in manoeuvring mode and while at berth is tabulated in **Table IR6-34-1**. The potential benefits of shore power as an alternative power source to both diesel and LNG while ships are at berth is also evaluated.

b) Providing a LNG Infrastructure CNG/LNG and, Electric Vehicles and Cargo Handling Equipment for the Port and the Inter-port Transport

LNG/CNG Infrastructure

As outlined above, the VFPA does not envision that compressed natural gas (CNG) or LNG infrastructure would be feasible at Roberts Bank for the fuelling of container vessels. However, for tugs that assist with the manoeuvring operations during container vessel approach, departure, berthing, and unberthing, LNG-powered tugs could be a feasible option, as discussed further below.

[5] A new facility to distribute LNG to ships in the Port of Tacoma is proposed by Puget Sound Energy. The project is currently under review by the Puget Sound Clean Air Agency and if approved to proceed, the facility will provide LNG for two Alaska-bound cargo ships and could be capable of providing LNG bunkering to ships via bunkering barges (https://www.portoftacoma.com/puget-sound-energy-lng-facility).

[6] For information on the WesPac Tilbury Marine Jetty Project to support fueling with LNG, refer to http://wespactilbury.ca/.

Tugs do not refuel at the Roberts Bank tug basin (EIS Section 4.4.2.1), but rather at the existing Chevron fuelling station in Coal Harbour, Burrard Inlet (as shown in EIS Figure 4-26). An off-site LNG fuelling station location could be used for the LNG fuelling of Project-associated tugs in the future. A semi-quantitative evaluation of potential future advantages and disadvantages with respect to exhaust emissions from LNG-powered tugs in manoeuvring mode and while at berth is tabulated below.

Alternative-fuelled Vehicles and Switcher Locomotives

For the purposes of assessing a conservative 'worst-case' scenario from operating vehicles and mobile equipment during RBT2 operations, the assumptions used for the RBT2 Air Quality Study (EIS Appendix 9.2-A) were realistic for the commencement of the operations phase in 2025 based on currently known standards. Therefore, the conclusions of the RBT2 Air Quality Study are conservative when used as a proxy to estimate emissions from operating activities in years subsequent to 2025. It is recognised that future improvements in engine and battery technology and advancements in fuels will occur throughout Project operations, resulting in continual improvements over the life of the Project.

Drayage was assessed in the RBT2 Air Quality Study as being performed by diesel fuel-powered trucks. The introduction of electrified drayage trucks is currently in early stage of development by a number of manufacturers, and may be available within a time frame of 10 years, at which time the truck operators could make purchase decisions for fleet turnover to electrified vehicles.

For the purposes of responding to this information request, it is assumed that port and inter-terminal drayage trucks will be electrified at some point in the future, but ultimately the timing of this depends on the success of electrified trucks in the marketplace (i.e., it is not at the discretion of the VFPA). It is assumed that recharging of electric-powered trucks will occur at the truck depots, not at the RBT2 terminal. A semi-quantitative evaluation of potential future benefits from the integration of CNG/LNG and electrification of drayage trucks is provided below. It is assumed that switcher locomotives supporting RBT2 operations will also be electrified at some point in the future, as battery-powered switchers are already operating in Canada[7]. Currently, the technological advances in electrified locomotive engines is not envisioned for line haul locomotives but such technology may become feasible in the future. A semi-quantitative evaluation of potential future benefits from electrification of switchers is provided in **Table IR6-34-1**.

Cargo Handling Equipment

Large cargo handling equipment for the Project will include the following electric-powered equipment (as assumed in the RBT2 Air Quality Study):

- Ship to shore (STS) cranes;
- Container yard (CY) Automatic Stacking Cranes (ASCs); and

[7] https://en.wikipedia.org/wiki/Railpower_Technologies

- Intermodal yard (IY) Rail Mounted Gantry (RMG) cranes.

To provide for a conservative air quality assessment of the operations phase, mobile equipment that will be used to transfer containers between the STS, CY, and IY areas was assumed to be diesel-fuel powered. As outlined above and in EIS Section 4.4.2.2, with advancing battery technology, mobile equipment may be electric-powered when the Project commences operation. Procurement decisions will be made by the Terminal Operator and will depend on the availability of electrical equipment at that time, as well as in the future when equipment requires replacement.

Therefore, an increase in CNG and LNG powered vehicles and equipment, as well as electric-powered vehicles and equipment, is feasible at some point in the future during the operation phase of the Project. A semi-quantitative evaluation of potential future benefits from the integration of CNG/ LNG and electrification of cargo handling equipment is provided in **Table IR6-34-1**.

Evaluate, and present in a table, a comparison of the predicted changes in total annual emissions of greenhouse gasses and black carbon for future conditions with the Project, and for the lifetime of the Project, gained by each proposal.

The use of alternative fuels and/or technologies described previously for the various transportation modes include the following:

- For container vessels and tugs – LNG;
- For drayage trucks and cargo handling equipment – electric, LNG, and CNG; and
- For switcher locomotives – electric.

Table IR6-34-1 provides a comparison (decrease or increase, as percentage change) for annual greenhouse gas (GHG), including carbon dioxide (CO_2) and methane (CH_4), and black carbon combustion exhaust emissions, between the emission scenarios assessed in 2025 for RBT2 (as per the RBT2 Air Quality Study) and alternative fuels and/or technologies for the various equipment. Emission decreases or increases are also provided on a total supply chain (i.e., Well-to-Wheel or Well-to-Wake (WtW)) basis, based on consideration of reported emission reductions. For battery-powered alternatives and for shore power, the WtW percent reduction is stated as 'n/a%' (not applicable) as the decrease cannot be estimated on a WtW basis without determining the supply of the electrical power[8].

It is not practical to estimate cumulative GHG and black carbon emission benefits over the life of the Project due to uncertainties about the introduction of these alternatives. Any such calculations over the life of the Project would be speculative and uninformative.

Supporting information and assumptions used to evaluate the increases or decreases in GHG

[8] Although more than 90% of BC Hydro's generation is produced by hydroelectric generation, at times the utility imports electricity (some power is generated by Fortis for the grid and there are inter-grid agreements with Alberta and the U.S.A.)

and black carbon emissions shown in **Table IR6-34-1** are discussed in the sections below.

Table IR6-34-1 Potential Changes in GHG and Black Carbon Emissions from Alternative Fuel and Technology Use Compared to RBT2 Exhaust Emission Predictions in 2025

Equipment	RBT2 Activity & Fuel Evaluated	Potential Alternative Fuel	Percent Change in Annual Exhaust Emissions from RBT2 Study Predictions			Percent Change in Supply Chain Emissions (WtW - CO_2e 100y)	
			Carbon Dioxide (CO_2)	Methane (CH_4)	Black Carbon	GHG	Black Carbon
Container Ships	Manoeuvring - ME & AE - low sulphur diesel	LNG	↓ 20-40%	↑ 400%	↓ ≥90%	↓ 28%	↓ ≥90%
	Manoeuvring – boilers – heavy fuel oil	None	0%	0%	0%	0%	0%
	At berth – boilers – heavy fuel oil	None	0%	0%	0%	0%	0%
	At berth – AE low sulphur diesel w/o shore power	LNG	↓ 20-40%	↑ 400%	↓ ≥90%	↓ 28%	↓ ≥90%
	At berth – AE low sulphur diesel with shore power	No change	↓ 64%	↓ 64%	↓ 11%	↓ n/a%	↓ n/a%
	At berth – AE low sulphur diesel with shore power	LNG	↓ 64%	↓ 64%	↓ 11%	↓ n/a%	↓ n/a%
Tugs	At berth & manoeuvring – low sulphur diesel	LNG	↓ 20-40%	↑ 400%	↓ ≥90%	↓ 23-28%	↓ ≥90%
Switcher Locomotives	Low sulphur-fuel diesel	Battery-powered	↓ 100%	↓ 100%	↓ 100%	↓ n/a%	↓ n/a%
Cargo Handling Equipment	Diesel	Battery-powered	↓ 100%	↓ 100%	↓ 100%	↓ n/a%	↓ n/a%
		LNG/CNG	↓ 20-40%	↑ 400%	↓ ≥90%	↓ 23%	↓ ≥90%
Drayage Trucks	Diesel	Battery-powered	↓ 100%	↓ 100%	↓ 100%	↓ n/a%	↓ n/a%

Equipment	RBT2 Activity & Fuel Evaluated	Potential Alternative Fuel	Percent Change in Annual Exhaust Emissions from RBT2 Study Predictions			Percent Change in Supply Chain Emissions (WtW - CO_2e 100y)	
			Carbon Dioxide (CO_2)	Methane (CH_4)	Black Carbon	GHG	Black Carbon
		LNG/CNG	↓ 20-40%	↑ 400%	↓ ≥90%	↓ 23%	↓ ≥90%

Notes: AE – auxiliary engine; ME – main engine; LNG = liquified natural gas; CNG = compressed natural gas; WtW = well to wheel or well to wake, depending on type of transport; n/a% – not available as supply of electricity unknown and not assumed to be 100% renewable. As there remain large uncertainties about the changes in methane emissions from the use of natural gas in dual fuel engines, the VFPA urges caution in the review of the potential reductions in GHG emissions listed above.

Assumptions Considered in the Evaluation of Potential Changes in GHG Emissions

Supporting information and assumptions used to evaluate the changes in GHG emissions shown in **Table IR6-34-1** are discussed in the section below.

With respect to the potential reduction in GHG emissions from the use of LNG in shipping, Anderson et al. (2015) reported a 40% reduction in CO_2 combustion exhaust emissions from a ferry vessel operating on LNG compared with operating on diesel fuel (refer to **Table IR6-13-2**). This value represents the upper bound estimate of potential benefits for the adoption of LNG fuel for marine vessels. Puget Sound Energy in the Port of Tacoma has claimed a 35% reduction in CO_2 emissions from LNG-fuelled ships, along with the elimination of SO_x emissions and reductions of 90% for both NO_x and diesel particulate matter emissions[9].

However, from the perspective of effects on global warming, it is more appropriate to consider GHG emissions over the entire fuel supply chain, rather than simply looking at the end-of-pipe combustion exhaust gas emissions.

The American Petroleum Institute (API 2015) provides emission factors for GHG reduction from the use of LNG that are based on GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation), which is a full life-cycle model sponsored by the Argonne National Laboratory (U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy). The model is designed to fully evaluate energy and emission impacts of advanced and new transportation fuels and their fuel cycle from Well-to-Wheel and Well-to-Wake (WtW). As such, the API emission factors do not correspond to combustion engine exhaust emission reductions that can be applied to the emission estimates presented in the RBT2 Air Quality Study.

The API 2015 report provides an estimate of about 25% WtW CO_2 emission reduction from the use of LNG as a fuel for marine vessels and a similar level of reduction from the use of LNG in locomotives and heavy-duty trucks compared to the use of diesel fuel. It has been

[9] https://www.portoftacoma.com/puget-sound-energy-lng-facility#Air%20quality

reported that methane emissions increase when using LNG in marine vessels, by as much as a factor of four to five, for combustion only emissions depending on engine load (Anderson et al. 2015), and by a factor of 20 on a WtW basis, as estimated by the API (API 2015). Since methane is a much more potent GHG than CO_2, the net benefit of ship operations using LNG fuel for GHG emission reduction may be much lower than is suggested by the measured combustion exhaust emissions.

Table IR6-34-2 lists the API emission factors for CO_2 and CH_4 (N_2O emission factors were not provided by the API), and their combined CO_2e emission factors for ocean going vessels (OGV), locomotives (Rail), and heavy-duty diesel trucks (HDDV). As summarised in **Table IR6-34-2**, the API data indicate that CO_2e emissions (i.e., CO_2 plus CH_4 combined) could be reduced by the following approximate percentages:

- For OGVs, 8.1% reduction in CO_2e by switching from bunker fuel to diesel on either a 100-year (100y) or 20-year (20y) time frame;
- For OGVs, CO_2e reductions of 23% and 28% in 20y and 100y time frames, respectively, by switching from bunker fuel to natural gas (not as a liquified form);
- For locomotives, a 32% reduction in CO_2e for either time frame by switching from diesel to natural gas; and
- For drayage trucks (HDDV), 20% to 22% reduction in CO_2e by switching from diesel to natural gas, and it is assumed that a similar reduction could apply for cargo handling equipment.

Table IR6-34-2 GHG Emission Factors by Fuel Type From the American Petroleum Institute

Equipment	Fuel Type	WtW Emission Factors (tonnes/Joule)				Percent Change in CO_2e Emissions for Current Fuel Use	
		CO_2	CH_4	CO_2e (100y)	CO_2e (20y)	100y	20y
OGV	Bunker fuel (current)	80.11	0.00434	80.2576	80.4832		
	Diesel	73.59	0.00434	73.7376	73.9632	8.1%	8.1%
	Natural gas	54.57	0.08684	57.5226	62.0382	28.3%	22.9%
Rail	Diesel (current)	80.62	0.00180	80.6812	80.7748		
	Natural gas	54.65	0.00180	54.7112	54.8048	32.2%	32.2%
	LNG	55.29	n/a	55.2900	55.2900	31.5%	31.6%
HDDV	Diesel (current)	73.75	0.00144	73.7990	73.8738		
	LNG	56.24	0.02889	57.2223	58.7245	22.5%	20.5%

Source: API 2015.

The Netherlands Organization[10] (TNO 2015) reported a 15% to 20% decrease in GHG emissions for OGVs switching from diesel to LNG, and *"a GHG reduction of 10-15%, provided that the energy consumption increase of gas engines can be limited to some 5-10%."*

According to the Natural and bio Gas Vehicle Association (NGVA 2017), the net WtW reduction of using LNG as a propulsion fuel for ocean going vessels is about 11% in total GHG emissions for 4-stroke marine engines (e.g., cruise liners, supply vessels, and tugs*)* and 21% for 2-stroke marine engines (e.g., bulkers, tankers, and container vessels). The NGVA also reported on a 6% WtW net reduction in GHG emissions for heavy-duty trucks operating on LNG and a 16% reduction in GHG emissions for trucks operating on CNG. However, the NGVA results reflect conditions for natural gas supplied to Europe from European countries (i.e., the United Kingdom, Norway, and Germany), the Middle East, North Africa, and Russia, and may not be representative of the net WtW benefits of using CNG or LNG in the Pacific Northwest region (i.e., due to differing fuel properties, extraction methods, storage practices, and transport methods to end users). For example, if LNG-fuelled container ships are refueled at their home ports in Asia, the WtW GHG emissions would be defined by the supply chain for natural gas in Asia rather than in B.C., and thus, may differ substantially from the estimated WtW GHG emissions reported by the API, the TNO, or the NGVA.

The combination of ships running on LNG plus connecting to shore power while at berth at RBT2 cannot be estimated on a WtW basis without determining the WtW GHG emissions from the LNG fuel source and the supply of the electrical power for shore power, but GHG and black carbon emissions would decrease. The same is true for any battery-powered alternative shown in **Table IR6-34-1**, as indicated by 'n/a'.

As there remain large uncertainties about the changes in methane emissions from the use of natural gas in dual fuel engines,[11] the VFPA urges caution in the review of the potential reductions in GHG emissions listed in **Table IR6-34-1**.

Assumptions Considered in the Evaluation of Black Carbon Emissions

Supporting information and assumptions used to evaluate the changes in black carbon emissions shown in **Table IR6-34-1** are discussed in the section below.

As background, the definition of the term 'black carbon' varies in published literature sources, as well as in the methods used to measure black carbon. Johnson et al. (2016) noted that published emission factors for black carbon even from ships using heavy fuel oil (HFO) and marine gas oil (MGO) is highly uncertain, varying by as much as an order of magnitude. From a climate-forcing perspective, the Commission for Environmental Cooperation (CEC 2015) defined black carbon as follows:

> *"light absorbing carbon" (LAC), comprising both light-absorbing elemental*

[10] The Netherlands Organisation for Applied Scientific Research was founded by law in 1932 and is an independent organisation regulated by public law; it is not part of any government, university, or company.
[11] Oxford Institute for Energy (Le Fevre 2017).

carbon (EC) and light-absorbing organic carbon (OC) (i.e., brown carbon). From a health perspective, BC [black carbon] *has typically been defined only as the mass of EC (i.e., the graphitic component of PM). So, BC* [black carbon] *may refer to the mass of EC only, or to the broader, optically-defined LAC."*

Black carbon from diesel engines, which makes up the vast majority of engine types operating at Roberts Bank, is dominated by elemental carbon (EC) emissions. Except for emissions from ships' boilers, black carbon emissions associated with the Project from all main and auxiliary container vessel engines, locomotives, and HDDVs would consist of EC. It is estimated that 83.4% of the black carbon emissions derived from cargo handling equipment at RBT2 would also be composed of EC.

Resulting from a series of three workshops hosted by the International Council on Clean Transportation (ICCT), in coordination with Environment and Climate Change Canada (ECCC)[12], it was agreed that the most suitable definition of black carbon for research purposes was provided by Bond et al. (2013)[13] as follows:

"BC [black carbon] *is a distinct type of carbonaceous material, formed primarily in flames, is directly emitted to the atmosphere, and has a unique combination of physical properties. Two properties in particular were considered to be useful for measurement purposes:*

- *BC* [black carbon] *strongly absorbs visible light with a mass absorption coefficient (MAC) value above 5 m^2 g^{-1} at a wavelength λ = 550 nanometers (nm) for freshly produced particles*
- *BC* [black carbon] *is refractory, with a volatilization temperature near 4000°K."*

An ICCT project on marine black carbon emissions was funded by the Climate and Clean Air Coalition (CCAC), an international cooperative partnership of over 50 country partners and more than 60 inter-governmental and non-governmental organisations to promote strategies to reduce emissions of short-lived climate pollutants, including black carbon. The ICCT noted that the IMO formally accepted the Bond et al. (2013) definition of black carbon at the Marine Environment Protection Committee (MEPC) in May 2015.

At the ICCT (2016) workshop in Vancouver, J. Yang reported that the switch in fuel sulphur content from 1.9% to 0.1% within the North American Emission Control Area (ECA) reduced black carbon emissions by 20% to 40%. Johnson et al. (2016) reported on measurement tests of black carbon emissions from ships, and noted that emissions:

"…varied from a few percent to as much as 60% less BC [black carbon] *with*

[12] Workshops hosted by the ICCT, in coordination with ECCC were held in Ottawa, Canada (2014), Utrecht, Netherlands (2015), and Vancouver, Canada (2016).

[13] The GWP reported by Bond et al. was used in estimating the CO_2e for black carbon emissions from the Project (EIS Appendix 9.2-A, Appendix A, Section 1.1.2). Therefore, the RBT2 Air Quality Study is consistent with the ICCT, ECCC, and IMO's definition of GWP for Project-related black carbon emissions.

lower sulfur fuels. The highest BC [black carbon] *reduction occurred when switching from a HFO* [heavy fuel oil] *(3.4% S) to MGO* [marine gasoil] *(0.02% S) fuel and lower reductions for a LS HFO fuel and a LS MGO fuel. These results coincide with other studies, but the magnitude in the other studies suggest factors of 10 lower BC* [black carbon] *emissions when going to MGO fuels. More research is needed to confirm these findings when switching to MGO fuels."*

By comparison, G. Lin (ICCT 2016) reported that the use of LNG fuel could reduce black carbon emissions by up to 90%, a level comparable to the results reported by Johnson et al. (2016) for the switch from HFO (<3% sulphur) to low sulphur (0.02%) MGO. The IMO (2015) also assumes that switching from HFO or marine diesel oil to LNG would result in more than a 90% reduction in black carbon emissions. Therefore, until additional sampling of emissions from ships and other types of equipment is undertaken, a 90% reduction in black carbon emissions remains the best estimate of the magnitude of potential reductions from the use of LNG as a fuel for marine vessels, cargo handling equipment, locomotives, and drayage trucks.

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IR6-35 Air Quality – Emissions from Marine Shipping, Modelling Approach

Information Source(s)

Marine Shipping Addendum: Section 7.1.4.6; Appendix 7.1-A, Section 2.3

Proponent Response to Additional Information Requirements of February 24, 2016 (CEAR Doc#391): IR8

Context

The Proponent used generic concentration-versus-distance dilution curves determined from CALPUFF modelling in Segment A to estimate ambient air quality concentrations in all other shipping segments.

The concentration-versus-distance dilution curves developed in Segment A, which is primarily open water, are not likely to capture dispersion processes in segments that pass close to islands and through narrow channels, such as Segments B, C and parts of Segment D.

Environment and Climate Change Canada is concerned that the concentration-versus-distance dilution curves only consider the effect of marine shipping emissions on ambient air quality and do not consider the influence of other local and regional air emission sources such as vehicular traffic, industry and wood burning. Application of this approach may result in an underestimation of ambient air quality concentrations for locations influenced by other air emission sources.

In its response to information requirement #8 from the Canadian Environmental Assessment Agency (CEAR Doc#391), the Proponent reported air quality monitoring data for several stations along the shipping route. However, results of air quality model output were not evaluated using data from those stations. Air quality modelling in the marine shipping area has to be evaluated by comparison with the available data.

Information Request

Provide CALPUFF dispersion modelling of air pollution from marine shipping associated with the Project along the route at a number of discrete locations in all marine shipping segments.

Compare the modelled ambient air quality concentrations (1-hour and 24-hour maxima and averages) to the monitored air quality concentrations for the Victoria Topaz and Colwood (either Royal Roads or City Hall) monitoring stations in order to evaluate the performance of the CALPUFF model.

If the modelled ambient air quality concentrations are different from those provided in the Marine Shipping Addendum, revise conclusions regarding pollution from marine shipping associated with the Project using CALPUFF modelling results.

VFPA Response

Background Information

The air quality assessment for Project-associated ships transiting in the marine shipping area presented in Marine Shipping Addendum (MSA) Section 7.1 followed a Tier 2 semi-quantitative approach. The approach was in accordance with Section 17 of the Updated EIS Guidelines, which stated the following:

- *"It is likely that a Tier 1 approach (Qualitative; description based on expert opinion and traditional and local knowledge) will be an appropriate level of detail in most cases. For select environmental effects and locations where there may be a higher risk of environmental effects, a Tier 2 approach (Semi-quantitative; measured site-specific data and existing site information) would likely be an appropriate level of detail."*
- *"To the degree possible, the proponent should maximise the use of existing material that is relevant to marine shipping activities associated with the Project which is beyond proponent's care and control and within the 12 nautical mile limit of the territorial sea. Existing material may be utilized from academic studies, work of government and non-government working groups, past or ongoing environmental assessments, Aboriginal traditional knowledge reports or any other source the proponent deems appropriate for its presentation of this material."*

During the scoping phase of the MSA air quality assessment, it was determined that there was insufficient data with which to conduct CALPUFF dispersion modelling (a Tier 3 approach to assessing effects) of existing marine shipping emissions. Two emission inventories were considered, including the following:

- The 2005 Corbett marine emission inventory, which was used for the Trans Mountain Expansion Project air quality assessment (RWDI AIR Inc. 2013). This inventory, more than ten years old, only included emissions from commercial marine traffic at a 4-km horizontal grid resolution. It was noted by RWDI AIR Inc. (2013), that the use of this data in dispersion modelling underestimated existing marine shipping emissions; and
- A 2010 marine emission inventory from Environment Canada. This inventory only included emissions from the Canadian side of the international boundary (i.e., emissions from vessels primarily transiting in the outbound shipping lane, which is in Canadian waters).

Based on the limitations of these inventories, the air quality assessment for the marine shipping area used air quality monitoring data from the study of ship plume SO_2 and NO_2 concentrations at Saturna Island (McLaren et al. 2012) and historical SO_2 monitoring data at the Canadian Air and Precipitation Monitoring (CAPMoN) site operated by Environment Canada on Saturna Island. Saturna Island is located within 2 km to 3 km from shipping lanes entering the Strait of Georgia and is sparsely populated; SO_2 levels are primarily attributable to ship emissions; therefore, SO_2 monitoring data from this location was assumed to provide a reasonable estimate of ship emission contributions at this distance from ships in transit for

the purpose of assessing Project-associated vessel emissions in the marine shipping area. The concentrations of other contaminants in vessel emissions could then be scaled to SO_2 emissions based on the ratios of emission factors for other contaminants to the SO_2 emission factors.

To extend the predicted concentrations beyond 2 km to 3 km from the shipping lanes, rates of dilution for maximum 1-hour, 24-hour, and annual average concentrations with distance (i.e., a dilution curves) for ships in transit were derived from the CALPUFF dispersion modelling analysis completed for ships underway in the Strait of Georgia (EIS Appendix 9.2-A, Appendix F). The dilution curves chosen from this CALPUFF analysis were those that would produce the highest predicted concentrations from one year of meteorological data in that analysis (i.e., worst-case). The selection of worst-case dilution curves from modelling in the Strait of Georgia (Segment A) were assumed to be representative of dilution curves (although higher concentration curves may be predicted due to use of worst-case proxy curve) along the other segments of the shipping route, including Segment B (Haro Strait and Boundary Pass) and Segments C and D (Juan de Fuca Strait), which could experience different meteorological conditions along the shipping route on an annual basis[1]. As explained below, predictions were validated against observed concentrations from monitoring stations bordering the marine shipping area.

Provide CALPUFF dispersion modelling of air pollution from marine shipping associated with the Project along the route at a number of discrete locations in all marine shipping segments.

Comparisons of the following observed and predicted concentrations from monitoring stations near the marine shipping area are presented below and summarised in **Table IR6-35-1,** taking into consideration the lack of sufficient data with which to conduct CALPUFF dispersion modelling of air pollution from marine shipping associated with the Project:

- For 1-hour and 24-hour average NO_2 and SO_2 and 24-hour average $PM_{2.5}$ concentrations:
    - Maximum observed concentrations at Christopher Point (located on the southern point of Vancouver Island)[1] in 2008;
    - Maximum predicted concentrations 7 km away from transiting Project-associated ships in Segment D[1,2] based on semi-quantitative dilution curve analysis method (MSA analysis; described above and in MSA Section 7.1); and
    - Maximum predicted concentrations at Christopher Point based on CALPUFF dispersion modelling of the 2005 Corbett marine emission inventory (RWDI AIR Inc. 2013);
- For annual average $PM_{2.5}$ concentrations:

[1] For segment locations in the marine shipping area, as well as monitoring station locations (Christopher Point, Neah Bay, Royal Roads, Victoria Topaz, Colwood (Royal Roads)), refer to Figure MSA IR8-1 in Appendix MSA IR 8-A (CEAR Document #391).
[2] Christopher Point is located at the east end of Segment D, approximately 7 km north of the shipping lanes.

- Observed concentrations at Neah Bay (located at the northwest point of the Olympic Peninsula)[1] for the 2007 to 2010 period (as estimated by Kotchenruther (2013));
- Predicted concentrations 6 km away from transiting Project-associated ships in Segment D[1,3] based on MSA analysis; and
- Predicted concentrations at Neah Bay based on CALPUFF dispersion modelling of the 2005 Corbett marine emission inventory (RWDI AIR Inc. 2013).

Comparisons between predicted and observed SO_2 levels at Saturna Island are not provided in **Table IR6-35-1** because the methodology used in the air quality marine shipping area assessment relied heavily on observed SO_2 levels at this location, and therefore, should not be used for comparison (validation) purposes.

As shown in **Table IR6-35-1** below, comparing maximum predicted to maximum observed concentrations at Christopher Point or Neah Bay, the MSA analysis (Tier 2) predictions were closer than CALPUFF dispersion modelling predictions (Tier 3) to the observed concentrations for all parameters and all averaging periods. Therefore, the MSA analysis predicted concentrations were more closely aligned with the observed concentrations, compared to the CALPUFF modelling predicted concentrations.

Based on these comparisons, the VFPA is confident that the methodology used in the MSA analysis provided a reasonable representation of contaminant concentrations due to Project-associated ships underway along the shipping route. Based on the data limitations and comparisons provided, CALPUFF dispersion modelling has not been undertaken to analyse air pollution from marine shipping associated with the Project. Further information is provided below to support the conclusion that the MSA analysis methodology provided a reasonable representation of contaminant concentrations due to ships underway along the shipping route.

Table IR6-35-1 Comparison of Predicted to Observed Concentrations at Christopher Point and Neah Bay

Parameter		Concentration (µg/m³)					
		NO_2		SO_2		$PM_{2.5}$	
		1-h	24-h	1-h	24-h	24-h	Annual
Maximum Concentrations	Observed: Christopher Point (2008)	56.4	27.5	28.0	11.7	11.4	
	Predicted: MSA Analysis for Segment D at 7 km Distance from Shipping Lanes	46.1	8.8	36.1	4.9	0.8	
	Predicted: CALPUFF Dispersion Modelling for Christopher Point[a]	75-100	5-15	<<10	<<1	<<0.5	

[3] Neah Bay is located at the western end of Segment D, approximately 6 km south of the shipping lanes (location shown in Figure MSA IR8-1 in Appendix MSA IR 8-A (CEAR Document #391)).

Parameter		Concentration (µg/m³)					
		NO_2		SO_2		$PM_{2.5}$	
		1-h	24-h	1-h	24-h	24-h	Annual
Annual Average Concentrations	Observed: Residual Fuel Oil Combustion at Neah Bay (2007-2010)[b]						0.56
	Predicted: MSA analysis for Segment D at 6 km Distance from Shipping Lanes						0.18
	Predicted: CALPUFF Dispersion Modelling at Neah Bay[a]						<<0.075

Source of data or analysis: a. RWDI AIR Inc. (2013) and b. Kotchenruther (2013).

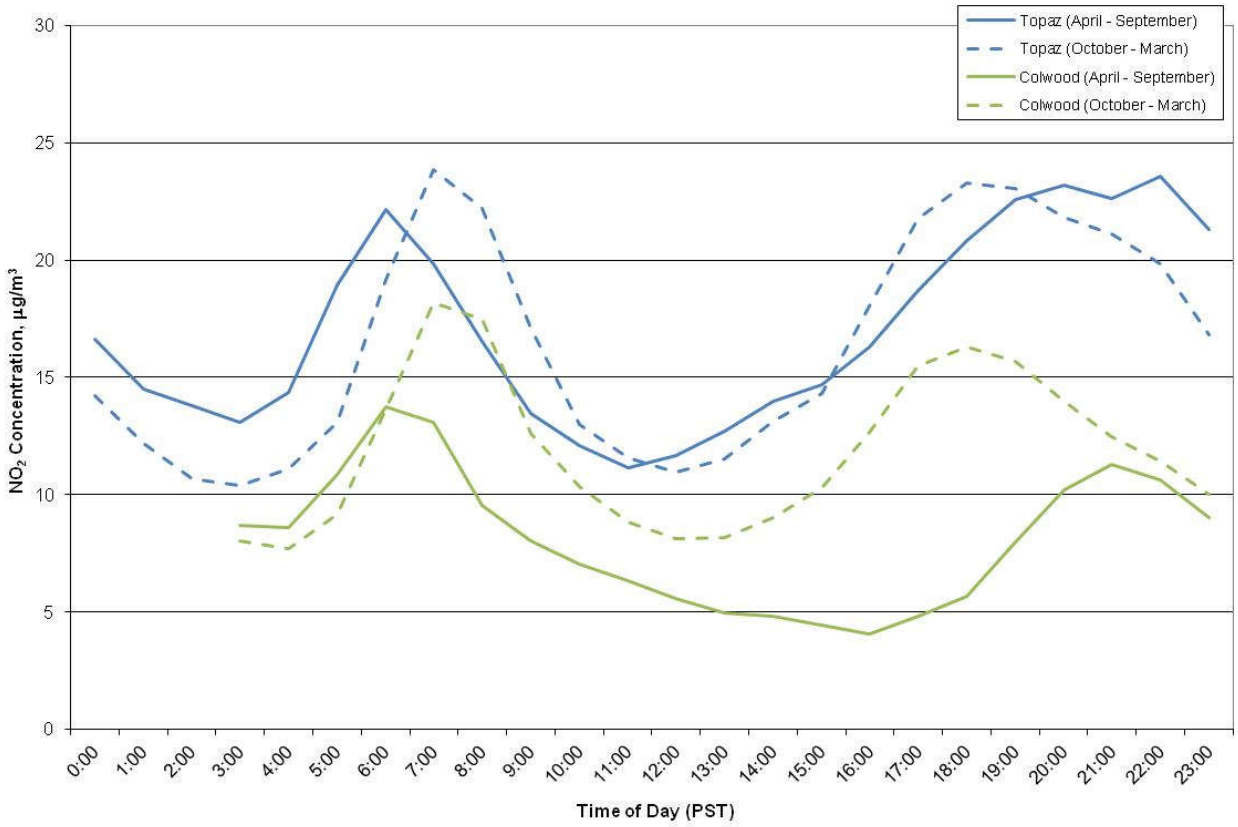
Compare the modelled ambient air quality concentrations (1-hour and 24-hour maxima and averages) to the monitored air quality concentrations for the Victoria Topaz and Colwood (either Royal Roads or City Hall) monitoring stations in order to evaluate the performance of the CALPUFF model.

Comparisons of predicted NO_2 and SO_2 concentrations, using the MSA analysis method, to observed concentrations at the Victoria Topaz and Colwood City Hall (Colwood) air quality monitoring sites[1] are provided below to illustrate that the predicted concentrations were conservative. The Victoria National Air Pollution Surveillance (NAPS) monitoring site (Victoria Topaz) is located approximately 6 km from the shipping lanes, while the monitoring station at the Colwood is located approximately 8 km from the shipping lanes.

The MSA analysis of Project-associated transiting vessels predicted maximum 1-hour average NO_2 concentrations of 47.1 µg/m^3 at Victoria Topaz and 45.6 µg/m^3 at Colwood. The observed average 98th percentile 1-hour NO_2 concentrations observed at Victoria Topaz and Colwood during peak rush hour traffic, were 56 µg/m^3 and 36 µg/m^3, respectively.

Figure IR6-35-1 shows the diurnal pattern of NO_2 concentrations, based on hourly average concentrations, at Victoria Topaz and Colwood in 2012. The double peak pattern in the morning and afternoon is consistent with emissions from on-road vehicles during rush hour traffic (SENES 2014). **Figure IR6-35-1** shows that the urban monitoring stations are highly influenced by on-road vehicle-related patterns. Emissions from ships cannot account for a large percentage of the observed levels at these two locations, as evidenced by the observed on-road vehicle-related diurnal patterns, indicating that the MSA analysis predictions in comparison to observed levels at these stations are conservative.

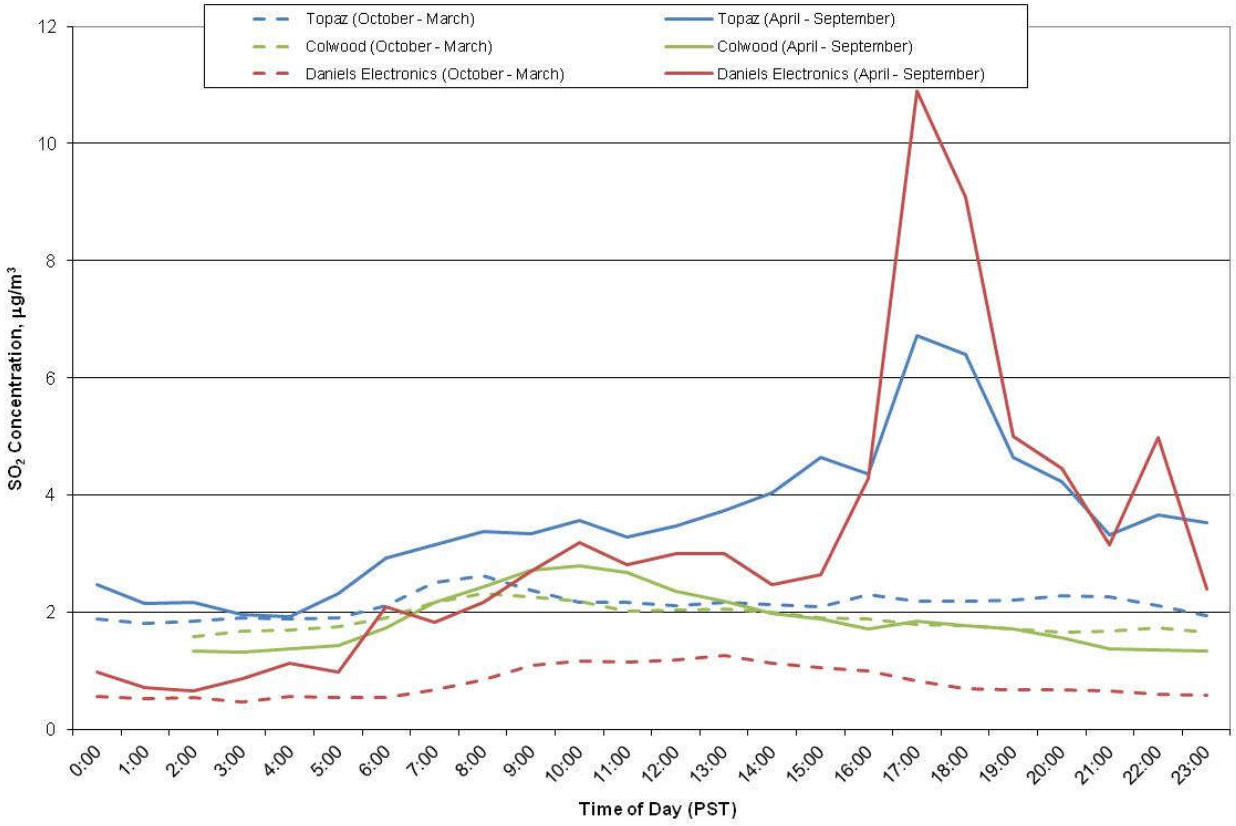
Figure IR6-35-1 Annual Average for 2012 of Diurnal Pattern on Hourly Average NO_2 Concentrations at Victoria Topaz and Colwood



Source: SENES 2014.

The conservatism in the MSA analysis is further demonstrated in the comparison to SO_2 concentrations at Victoria Topaz and Colwood. **Figure IR6-35-2** shows the diurnal pattern of hourly average SO_2 concentrations at the two sites, as well as at the Daniels Electronics monitoring site located at James Bay near the cruise ship terminal in Victoria. Both Victoria Topaz and Daniels Electronics observations are affected by cruise ship emissions from April to September, particularly in the late afternoon and evening hours when cruise ships arrive and depart. During the non-cruise season (October to March), hourly average SO_2 concentrations at all three sites in Victoria are around 2 µg/m^3. There is no evidence that cruise ship emissions affect air quality in Colwood, as stated in the 2012 annual summary of air quality in the Capital Regional District (SENES 2014).

Figure IR6-35-2 Average Annual (2012) Diurnal Pattern of Hourly Average SO_2 Concentrations at Victoria Topaz, Colwood, and James Bay (Daniels Electronics)



Source: SENES 2014.

Maximum 1-hour average SO_2 concentrations predicted from the MSA analysis were 37.9 µg/m^3 at Victoria Topaz and 34.2 µg/m^3 at Colwood. These predicted concentrations exceed the maximum observed concentration of 19 µg/m^3 at Colwood, as well as the 99th percentile concentrations at both Victoria Topaz (18 µg/m^3) and Daniels Electronics (26 µg/m^3), except during periods of highest SO_2 concentrations caused by cruise ship emissions from Victoria Topaz and Daniels Electronics.

In summary, compared to the NO_2 and SO_2 concentrations from monitoring stations in Victoria, the MSA analysis is conservative in that it over-estimates concentrations.

If the modelled ambient air quality concentrations are different from those provided in the Marine Shipping Addendum, revise conclusions regarding pollution from marine shipping associated with the Project using CALPUFF modelling results.

Comparisons of predicted concentrations from the MSA analysis to observed concentrations at Christopher Point, Neah Bay, and monitoring stations in Victoria indicate that the methodology used provided a reasonable and conservative representation of air quality emissions from Project-associated ships underway along the shipping route. Based on the data sources available to support CALPUFF dispersion modelling, it is not expected that

CALPUFF modelling would more accurately predict emission concentrations for Project-associated vessels transiting through the marine shipping area than the MSA analysis methodology that was used.

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IR6-36 Air Quality – Emissions from Marine Shipping: ECA of 0.1% Sulfur

Information Source(s)

Marine Shipping Addendum: Section 3.0; Section 7.1.4; Section 7.1.5

EIS Volume 2: Appendix 9.2-A, Section 2.5.2, Table 2-17, Appendix A

Context

According to Environment and Climate Change Canada, the North American Emission Control Area (ECA) has lead to a reduction in marine emissions of SOx and PM by requiring commercial vessels to burn fuel with no more than 0.1% sulphur or to use equivalent emission control - a requirement which came into effect on January 1, 2015. The Proponent used pre-ECA emission factors to characterize pre-Project air quality conditions, and post-ECA emission factors for with Project conditions.

Changing the emission factors for with and without Project conditions changes the emissions of those pollutants by the same order of magnitude. The result is the appearance of a reduction in marine emissions and an improvement in air quality as a result of the Project (presented in the Marine Shipping Addendum, Sections 7.1.4 and 7.1.5) when in fact, marine emissions due to the Project are predicted to increase the amount of air pollutants.

With and without Project marine emissions should be presented using the same regulatory framework and assumptions in order to accurately predict the contribution of the Project to marine emissions.

Information Request

For the Project and marine shipping associated with the Project, reassess existing conditions using emission factors for the fuel sulphur standard of the North American Emission Control Area of 0.1 % sulphur.

Re-evaluate and discuss regional SO_2 and NO_2 levels due to ship emissions assuming the same regulatory framework for 2010 and 2025 conditions with and without the Project.

VFPA Response

For the Project and marine shipping associated with the Project, reassess existing conditions using emission factors for the fuel sulphur standard of the North American Emission Control Area of 0.1 % sulphur.

Existing conditions are represented by the year 2010, which is before the North American Emission Control Area (ECA) sulphur standard came into effect. Marine source emissions in 2010 based on pre-ECA emission factors are presented in EIS Section 9.2.6 and Marine Shipping Addendum (MSA) Section 7.1.4. Quantifying emissions for existing conditions using

post-ECA emissions factors would not be representative of actual conditions and the regulatory framework that applied at that time.

Post-ECA emission factors were included in both the EIS and MSA air quality assessments in the future without the Project (expected conditions), represented by the horizon year 2025, as well as in future conditions with the Project (also in 2025). As further clarification, expected conditions represented the conditions predicted in 2025 that include the ECA sulphur standard and other expected changes (e.g., increased vessel traffic, engine technology advancements). Therefore, re-assessment is not required, as emissions from Project-associated vessels while in transit, manoeuvring, and at berth that are predicted during future conditions with the Project reflect an incremental increase compared to emissions predicted during expected conditions. For example, the incremental increases in annual emissions from transiting marine vessels associated with RBT2 are shown in MSA Tables 7.1-13 through 7.1-17. Note that these incremental emissions are discussed in the context of existing conditions (e.g., MSA Figure 7.1-10), so one can discern the influence of future technological advancements and regulatory changes, but they are not *compared to* existing conditions. The presentation of emissions as incremental increases with the Project and as a percentage of future cumulative emissions allows for the contribution of emissions from the Project and Project-associated vessels to be clearly identified in the context of changes anticipated in the future due to ECA.

Re-evaluate and discuss regional SO_2 and NO_2 levels due to ship emissions assuming the same regulatory framework for 2010 and 2025 conditions with and without the Project.

Regional ambient SO_2 and NO_2 levels due to ship emissions in 2010 are described in EIS Section 9.2.6 and MSA Section 7.1.4. These levels are based on pre-ECA emission factors. As outlined above, future conditions in 2025 incorporate post-ECA conditions and other known changes. The comparison of ambient SO_2 and NO_2 levels in future conditions with the Project and expected conditions indicates the level of increase in ambient concentrations due to increased emissions from the Project and Project-associated vessels. Therefore, a comparison of conditions assuming the same regulatory framework has been conducted with and without the Project. For more information, refer to EIS Sections 9.2.7 and 9.2.8 and MSA Section 7.1.5. Trends in regional SO_x and NO_x emission levels, which were sourced from Metro Vancouver (2013), are described below.

Regional SO_x emission levels have declined from existing conditions (2010) due largely to the implementation of the ECA. As a result, the contribution from marine vessel emissions to total SO_2 emissions in the Lower Fraser Valley is expected to decrease from approximately 43% in 2010 to approximately 10% by 2015, and remain at this level into the future, based on Metro Vancouver forecasts (Metro Vancouver 2013). Future regional SO_x emission levels are expected to be dominated by emissions from industrial sources, including primary metals industries in Whatcom County in Washington State and industrial sources such as petroleum refining and marine vessels.

Regional NO_x emission levels have declined since 1990 and are projected to continue to decline through to 2020 and then level off (Metro Vancouver 2013). Decreases in regional NO_x emissions are attributed to improved vehicle emission standards and a vehicle inspection and maintenance program (i.e., the AirCare program for light duty passenger vehicles, which

ended in 2014) (Metro Vancouver 2013, 2017). The relative contribution of marine vessels to regional NO_x emission levels in the Lower Fraser Valley is expected to increase from approximately 14% in 2010 to approximately 20% by 2020. The implementation of the requirement for ships built in 2016 and thereafter to meet Tier III NO_x emission standards under ECA will mitigate the relative increases in marine vessels emissions to regional NO_x levels and anticipated increases in marine emissions due to projected shipping growth (Metro Vancouver 2013).

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IR6-37 Air Quality – Environmental Management Plan, Operations

Information Source(s)

EIS Volume 1: Appendix 6-B

EIS Volume 5: Section 33.3.1, Section 33.3.3, Section 33.4.1

Marine Shipping Addendum: Sections 7.1.8, Section 9.1.5.1

Proponent Response to IR1-01 (CEAR Doc#897)

Context

In Section 33.3.1 of the EIS, air quality monitoring was noted as part of the construction compliance monitoring plan. The Proponent also proposed an air quality and dust control plan that would aim to prevent or reduce emissions of air contaminants during construction. Compliance monitoring parameters for air quality would be addressed as part of this plan.

In Section 33.4 of the EIS, there was no air quality component described as part of the operation compliance monitoring plan. Further, the operation health and safety and emergency response plan did not indicate measures to ensure air quality for residents or users of the marine area.

For the marine shipping area, the Proponent considered, for Segment D, that the estimated concentrations of air contaminants of potential concern due to emissions from marine vessels were expected to decline and to remain below the ambient air standards and objectives due to the implementation of the North American Emission Control Area or ECA.

Although the Proponent reported in the Marine Shipping Addendum, Section 7.1.8, that estimated average annual air concentrations of some of the trace organic contaminants (TOC) will increase, some may be reduced with the use of fuels that meet the ECA.

The annual greenhouse gas emissions from vessels in Segment D are anticipated to increase by 19 per cent under *cumulative conditions* compared to the existing ones. Six per cent of this 19 per cent will be due to vessels associated with the Project. There were no specific measures or follow-up proposed for the marine shipping area.

In Appendix 6-B of the EIS, it was also noted that the Proponent is promoting cleaner ships through an EcoAction program, which promotes emissions reduction by offering discounted harbor dues to ocean vessels that have implemented emissions reduction measures and other environmental practices.

Information Request

Report on the measures that will be implemented to ensure that air quality standards are respected during operation to protect the health of local residents and, the users of the local

study area of the proposed Project, including workers on site, fishermen, recreational users and Aboriginal groups.

Provide an outline and the basic elements of the air quality monitoring program that will be implemented during operation of the Project.

Present details of the Proponent's EcoAction program in terms of response, cooperation and success from ship operators.

VFPA Response

Clarification

Emissions in the future with the Project case for the operation phase are not predicted to approach or exceed air quality objectives or standards for any parameter except for hourly NO_2; however, as result of the Ozone Limiting Method over-predicting NO_2 concentrations by more than double, this outcome is not expected to be realised during Project operation. For further information, refer to the response to IR6-22.

Two additional reasons why observed hourly average NO_2 concentrations during Project operation are expected to be lower than the predicted concentrations are as follows:

- The RBT2 Air Quality Study did not factor in decreases in emissions from container ships using shore power while ships are berthed, as the anticipated connection rate was unknown for the three berths at RBT2 or the third berth at the Deltaport Terminal at the time of the study (refer to the response to IR6-19 of CEAR Document #1113[1] for more information); and
- The RBT2 Air Quality Study did not factor in decreases in emissions from the replacement or conversion of diesel-powered ferries to dual-fuel ferries (which operate on liquified natural gas or ultra-low sulphur diesel), as the timing of replacement/conversion was uncertain at the time of the study (refer to the response to IR6-13 of CEAR Document #1134[2] for more information).

Report on the measures that will be implemented to ensure that air quality standards are respected during operation to protect the health of local residents and, the users of the local study area of the proposed Project, including workers on site, fishermen, recreational users and Aboriginal groups.

Federal, provincial, and regional (i.e., Metro Vancouver) ambient air quality criteria apply to areas where there is public access. The standards and objectives (study criteria) selected for the RBT2 Air Quality Study (see EIS Table 9.2-4 for the original study criteria and the response

[1] CEAR Document #1113 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR6-09, IR6-15, IR6-16, IR6-19, IR7-09, IR7-10, IR7-11, and IR7-32 (See Reference Documents #991 & #1000).
[2] CEAR Document #1134 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-20, IR5-30, IR5-31, IR6-13, IR7-12, IR7-37 & IR7-41. (See Reference Documents #975, #991, & #1000).

to IR6-23 for updated study criteria[3]) for comparison to the model predictions, therefore, do not apply on or near the terminal itself, or for workers on site who would be subject to WorkSafeBC exposure limits for chemical substances[4]. Project-related emissions are not anticipated to approach the study criteria during the operation phase, including in areas frequented by local residents, fishermen, recreational users, and Aboriginal groups (for more information, refer to EIS Section 27.6.2).

Air quality objectives and standards are anticipated to be respected during the operation phase given the overprediction of emissions, as described above. Nevertheless, emission reductions are anticipated through existing ongoing VFPA port-wide initiatives. The VFPA will continue to seek opportunities to reduce NO_x emissions port-wide including during the operation phase of the Project, as described in the responses to IR6-29 and IR6-32. VFPA initiatives currently in place and those proposed to reduce marine source NO_x emissions are described in the response to IR6-29, while VFPA emission reduction initiatives targeting other combustion-related sources of NO_x (trucks, rail, cargo handling equipment) are described in the response to IR6-32. Further reductions in Project-related emissions may also be achieved through the implementation of adaptive management measures as part of the operation phase compliance monitoring program (see below).

Provide an outline and the basic elements of the air quality monitoring program that will be implemented during operation of the Project.

To verify effect predictions and demonstrate that air quality standards are being met during the operation phase, monitoring will be conducted using Station T39. Station T39 was specifically established in June 2010 to monitor air quality in relation to the operation of marine terminals at Roberts Bank, stemming from the 2005 air quality assessment conducted for the Deltaport Third Berth Project.

Station T39 has been shown to be representative of air quality levels for criteria air contaminants (i.e., CO, NO_2, SO_2, O_3, and $PM_{2.5}$) in overland areas at Roberts Bank and on Tsawwassen First Nation Lands (refer to the response to IR6-09 of CEAR Document #1113 for more information). SO_2 monitoring data over the period 2010 to 2016 has shown that ambient levels of SO_2 at Station T39 declined with the introduction of the North American Emission Control Area (ECA) for sulphur in fuel (as described in the response to IR6-12), which indicates that Station T39 provides a good measure of changes in emissions from ships operating at and in the vicinity of Roberts Bank.

[3] The response to IR6-23 provides updated study criteria, which reflects the integration of Metro Vancouver objectives with provincial and federal criteria, and any changes to the objectives or standards since the RBT2 Air Quality Study was completed.

[4] The Metro Vancouver objective for hourly NO_2 is 200 µg/m^3, while the WorkSafeBC ceiling level short-term exposure limit (STEL) for NO_2 is 1 ppm (i.e., 1,910 µg/m^3) as of June 1, 2017, more than an order of magnitude greater than either the provincial or Metro Vancouver ambient air quality objective. https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-guidelines/guidelines-part-05#EL_Table

Details of the operation phase air quality monitoring program will be provided in a sub-plan of the Operation Compliance Monitoring Plan, which will be developed and implemented by the Terminal Operator. The air quality monitoring program is anticipated to include or identify the following basic elements:

- Contaminants of potential concern to be monitored and reported on;
- Monitoring locations and equipment to obtain air quality concentrations and meteorological[5] data;
- Monitoring details, including frequency of data analysis and reporting requirements;
- Quality assurance/quality control measures; and
- Adaptive management measures to be implemented if contaminant levels approach pre-determined levels (i.e., levels to be set below the applicable ambient air quality objective to ensure that the objective is respected).

Present details of the Proponent's EcoAction program in terms of response, cooperation and success from ship operators.

The VFPA's EcoAction Program promotes emission reduction measures that exceed the current ECA requirements mandated by the IMO by offering discounted harbour due rates to vessels that have implemented emission reductions measures and other environmental practices (e.g., cleaner fuels, ship environmental programs, vessel and engine technologies, ship classification societies) (VFPA 2017b). Details of the VFPA EcoAction program regarding shore power, marine source NO_x reduction, and greenhouse gas reduction are provided in the responses to IR6-19 (CEAR Document #1113), IR6-29, and IR6-32, respectively. In 2016, 612 vessel calls (VFPA 2017c), representing 24% of all eligible calls for the year, participated in the EcoAction program.

References

Vancouver Fraser Port Authority (VFPA). 2017a. Port of Vancouver 2016 Sustainability Report. Available at https://www.portvancouver.com/about-us/sustainability/. Accessed January 2018.

Vancouver Fraser Port Authority (VFPA). 2017b. EcoAction Program. Available at https://www.portvancouver.com/wp-content/uploads/2015/05/4747-PMV-Eco-Action-Program-Brochure-Online.pdf. Accessed January 2018.

Vancouver Fraser Port Authority (VFPA). 2017c. Ships: EcoAction Program. Available at https://www.portvancouver.com/environment/air-energy-climate-action/marine/. Accessed January 2018.

[5] While Station T39 provides representative data for air quality, the meteorological data recorded at this station does not meet standard wind monitoring station siting guidelines as defined by the World Meteorological Organization, Environment and Climate Change Canada, or the United States Environmental Protection Agency (see response to IR6-05).