Information Request Package 7 from the Review Panel for the Roberts Bank Terminal 2 Project Environmental Assessment: Responses

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IR7-43 Outdoor Recreation - Crab Harvesters, Mitigation and Effects Assessment

IR7-01 Atmospheric Noise – Modelling Using Worst-Case Meteorological Conditions

Information Source(s)

EIS Volume 2: Section 9.3.12; Appendix 9.3-A, Table 3-5

TDR Upland Noise and Vibration - Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals (CEAR Doc#986)

EIS Volume 4: Section 27.6.3.2; Section 27.6.3.4

Proponent Response to Information Request Package 3 (CEAR Doc#984): Preamble to IR3-25 to IR3-46

Context

In Appendix 9.3-A of the EIS, the Proponent acknowledged that meteorological conditions such as wind speed, wind direction and temperature stratification have an important influence on noise propagation in the atmosphere. In its technical data report on the effects of meteorological conditions on sound propagation (CEAR Doc#986), the Proponent examined some of these effects, and highlighted that enhanced noise propagation can occur:

- in downwind directions;
- in light wind conditions;
- under temperature inversions; and
- under low level jets (giving sea breezes as an example).

Further, it was emphasized that sound propagating over water may undergo modest amplification.

In Appendix 9.3-A of the EIS, the Proponent indicated that it used the LfU-Bayern (1999) noise modelling approach, which only accounts for wind direction effects. As a result, noise from the proposed Project may be greater than predicted since the LfU-Bayern approach does not account for the numerous meteorological conditions that could result in enhanced noise propagation, as described in CEAR Doc#986.

Alternatively, the CONCAWE model can explicitly treat temperature inversion and other meteorological conditions. As stated by the Proponent in Section 2.3.3.4 of Appendix 9.3-A of the EIS, the CONCAWE method was not used in the model because it is based on empirical sound propagation data collected exclusively over land, and because the Pasquill Stability Categories were similarly developed in relation to ground surfaces rather than water surfaces. However, the CONCAWE model can be operated with measured or estimated temperature profile data valid for overwater surfaces.

In Section 9.3.12 of the EIS, the Proponent indicated that it is not known whether low level jets actually occur within the local study area. However, it is possible that recently published

literature may provide information such that the influence of low level jets on noise propagation could be included in the noise assessment of the Project.

Because the noise modelling is based on a meteorological data set that is limited in terms of capturing important meteorological conditions (such as temperature inversions and low level jets) and their seasonality, further information regarding the worst-case meteorological conditions and the resultant noise levels at the seven sites identified by the Proponent in the upland study area is required.

Information Request

Provide a brief summary of relevant and available literature regarding existing measurement and modelling studies of the atmospheric boundary layer in near-coastal parts of the Lower Fraser Valley that could be applied to the local study area for the proposed Project. The review should include studies that investigated sea breezes and temperature inversions.

Based on results of the literature review, construct a representative meteorological data set to be used as input to the CONCAWE model. The data set should be designed to capture a reasonable worst-case scenario for enhanced noise propagation (i.e. downwind conditions, light winds, temperature inversions, low level jets, and overwater propagation) from the Project to the seven sites located in the upland study area for the Project. The data set should also account for seasonal dependence of meteorological conditions. Provide a tabulation of the data set used to represent the worst-case scenario.

Provide an analysis of the frequency of occurrence by season of these worst-case meteorological conditions that result in enhanced sound propagation.

Run the CONCAWE model using the representative atmospheric data set to develop an assessment of worst-case noise levels at the seven noise measurement sites in the upland study area for the Project during both construction and operation. The worst-case meteorological conditions should include all worst-case conditions acting simultaneously, and all physically realistic combinations of such conditions. The Proponent is to follow the revised activities for Project construction as presented in CEAR Doc#984.

Present the results of the CONCAWE model run in tables similar to Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS that summarize L_d, L_n, L_{dn} and L_{max} at the seven noise measurement sites in the upland study area during construction and operation of the Project under different combinations of the worst-case meteorological conditions. Provide a discussion of the results to accompany these tables.

VFPA Response

Clarification

This information request asks for updated noise modelling of L_d, L_n, L_{dn}, and L_{max} at the seven noise measurement sites in the upland study area. However, these parameters (associated with continuous noise) were measured at, and predicted for, only sites 3, 4, and 5. Initial measurements of ground-borne vibration were taken at sites 1 and 2, and low frequency noise at sites 6 and 7 (as shown in Table 2-1 of EIS Appendix 9.3-A). The assessment focuses on predicted noise levels at sites 3, 4, and 5 as representative of the areas within the local assessment area (LAA) that are expected to receive the highest levels of Project-related noise in the future, as discussed in Section 9.3.6.3 of Appendix 9.3-A of the EIS. This response

provides the requested information for sites 3, 4, and 5, where the indicators L_d, L_n, and L_{dn} were assessed.

The L_{max} parameter represents the highest measured value over a designated time period and relates only to the measurements of existing conditions in Appendix 9.3-A of the EIS. Model scenarios cannot refine activity sufficiently to enable prediction of L_{max} in 1 or 10 minute increments, or link short term event data represented by L_{max} to specific meteorological conditions, so this parameter is not addressed in this response.

1. Provide a brief summary of relevant and available literature regarding existing measurement and modelling studies of the atmospheric boundary layer in near-coastal parts of the Lower Fraser Valley that could be applied to the local study area for the proposed Project. The review should include studies that investigated sea breezes and temperature inversions.

The following provides a detailed summary of relevant literature. The reference list is provided at the end of this response.

Overview – Refraction of Sound Rays in Surface Layer

In the Project region, the atmospheric boundary layer tends to be on the order of hundreds of metres high. Noticeable modifications to sound levels are only expected within the lowest 100 metres (approximately) of the atmospheric boundary layer, which is called the 'surface layer' (Stull 1988). This response will limit the discussion to the surface layer.

When sound waves travel horizontal distances of several kilometres between source and receiver, as would be the case with noise from the RBT2 terminal, the sound waves are substantially attenuated in the atmosphere due to geometric spreading and atmospheric absorption (Crocker 2007). Under these conditions, the main concern of worst-case atmospheric conditions is downward bending (refraction) of sound waves, which can limit the sound waves to the surface layer, resulting in increased noise propagation (Crocker 2007).

Sound can be generated across a broad, multidirectional wave front, or it can be very directional, depending on the nature of the sound source. The nature of spatial propagation of sound, and how sound is perceived or measured, results in only the portion of a sound wave that is on the direct path from source to receiver being heard. This is evaluated by defining or modelling sound as a 'ray' between the source and receiver of the sound. When substantial downward refraction of sound rays is occurring within the surface layer, additional rays that would otherwise propagate away from the surface will reach the receptor, resulting in amplification of the sound.

Effect of Atmospheric Conditions on Downward Refraction

Downward refraction of sound rays in the atmosphere occurs when the speed of sound propagation increases with height (Crocker 2007). The speed of sound depends on several atmospheric parameters, but only temperature and wind speed have sufficient vertical variability to cause measurably strong downward bending of sound waves within the atmospheric surface layer to cause sound amplification (Crocker 2007).

As described in Section 2.1.5 of the RBT2 Technical Data Report: Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals ('RBT2 Meteorological Report'; CEAR Document #986[1]), under conditions that enhance downward refraction and over a hard reflecting surface, such as water, a maximum reduction in attenuation of 3 decibels (dB) would be possible. For example, a sound source of 50 A-weighted decibels (dBA) that attenuates to 40 dBA at a distance over land, a neutral atmospheric surface, would attenuate to 43 dBA at the same distance over water.

Temperature Variation

Downward refraction occurs when temperatures increase substantially with height above the ground within the atmospheric surface layer (Crocker 2007). Such atmospheric conditions are called 'stable', because the colder air near the ground has higher density than the air aloft and, therefore, vertical exchange of air is suppressed. The main mechanism creating stability is nighttime cooling at the surface, particularly under cloudless conditions. Because of the stability, air further aloft cools less rapidly, creating a positive temperature gradient from the surface upwards such that sound rays are refracted downward (Stull 1988). The meteorological modelling discussed further below suggests that stable nighttime conditions are common in the entire region, including the Project site.

Refraction of sound waves can also occur at substantially higher altitude, for instance at the temperature inversion at the top of the convective boundary layer or the capping inversion that frequently occurs over mountain valleys roughly at ridge height of the surrounding mountains (Whiteman 2000, McKendy and Lundgren 2000). In the lower Fraser Valley, these conditions occur at heights of many hundreds of metres up to approximately one kilometre above the surface (van der Kamp and McKendy 2010). However, under these atmospheric conditions, the change in attenuation is negligible because of the strong attenuation over the longer vertical distance travelled by the downward bent sound rays. Furthermore, such conditions are less likely to occur at the Project site, which is located at the mouth of the Fraser River over 35 kilometres from the mountain ridges to the north and south.

Wind Speed Variation

Downward refraction of sound also occurs in the direction of wind flow when wind speeds increase substantially with height above the ground (Crocker 2007). Wind speed is always zero right on the ground. Therefore, strong winds at relatively low altitudes cause a substantial increase of wind speed from the ground up. Section 2.2.2 of the RBT2 Meteorological Report (CEAR Document #986) defines 'strong winds blowing at relatively low altitudes' as 'low level jets'. Different meteorological conditions that can cause low level jets are inertial oscillations and land-sea breezes, described in the following paragraphs.

[1] CEAR Document #986 From the Review Panel Secretariat to the Review Panel re: Roberts Bank Terminal 2 Technical Data Report - Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals.

Inertial Oscillations

Community members at Roberts Bank have reported sudden gusts of wind that amplify sound from the Roberts Bank terminals. These low-level jets are most likely inertial oscillations. Inertial oscillations are mostly expected in large flat terrain, which might explain the apparent lack of literature on inertial oscillations in the lower Fraser Valley. A mechanism explaining inertial oscillations was first proposed by Blackadar (1957), and Stull (1988) provides the mathematical description of the mechanism. The larger scale pressure differences in the atmosphere cause strong winds at higher elevation in the atmosphere. Under fair weather conditions during the daytime, turbulence from the surface heating slows down these winds throughout the entire atmospheric boundary layer. In the evening, the surface layer becomes stable and winds in the atmospheric boundary layer above the surface layer can speed up. These winds tend to oscillate in direction and speed because of Earth's rotation, which imposes a perpendicular force on the motion (except near the equator). This is similar to a pendulum performing oscillations caused by its inertia and the gravitational force acting at an angle to the motion of the pendulum.

Inertial oscillations are expected to occur in a shallow layer of strong winds on the order of about one hundred metres deep that occur detached from the surface at altitudes of up to several hundred metres above the ground. Banta et al. (2002), for example, reported observations of inertial oscillations over Kansas. Other investigations, however, have called into question the prevalence of such idealised inertial oscillations and suggested that, in practice, inertial oscillations are weak, sporadic, and often occur substantially above the surface layer, for example Lundquist (2003).

On the rare occasion when inertial oscillations occur sufficiently close to the ground and with the wind direction from the noise sources towards the receptors, they can contribute to sound level amplification. However, typically inertial oscillations occur under stable nighttime conditions and weak surface winds, when noise is already substantially less attenuated, according to the existing models, than under other meteorological conditions, regardless of the presence of inertial oscillations. Therefore, information on the frequency of such events is not required to ensure modelling of noise propagation considers worst-case meteorological conditions.

Land-sea Breezes

At nighttime, because the heat capacity is lower for solid ground than for water, the energy loss from land causes a faster drop in temperature over land than over water. That implies that near the Project site right at the water, the faster temperature drop occurs over the land surface in the lower Fraser Valley. The build-up of colder air above the land surface eventually causes a decreasing pressure gradient from land towards the water, and creates a subsequent land breeze of colder air from the lower Fraser Valley towards the Strait of Georgia (Stull 1988).

Because land breezes generally blow from the receptors on land towards the sound source over water, they are less likely to be associated with worst-case meteorological conditions for sound propagation than their daytime equivalent, the sea breeze. Sea breezes can carry

sound from a noise source over the water towards the receptors on land. While they are typically hundreds of metres deep, the wind speed maximum occurs roughly 100 metres above the ground (Steyn 1998, 2003). Hence, under sea breeze conditions, a substantial wind speed gradient exists near the surface that can amplify sound levels.

Other Temperature Gradient Effects

The lower Fraser Valley is characterised by additional land surface complexities beyond the land-sea interface (McKendry and Lundgren 2000). Additional horizontal temperature gradients and subsequent pressure gradients are caused by the following (Whiteman 2000):

- Slope flows over steep complex terrain to the north and southeast of the lower Fraser Valley;
- Valley flows in tributary valleys particularly in the north shore mountains and for the lower Fraser Valley as a whole; and
- Plain-mountain wind systems for the larger-scale terrain gradient between the Pacific Ocean and the mountains in B.C. and Washington State.

To the extent that these flows reach the Project site in Delta, they can interact with the sea or land breeze. In most cases, the interaction would be an enhancement to, but indistinguishable from, the sea or land breeze. For instance, daytime up-valley flows into the lower Fraser Valley could enhance the sea breeze at the Project site.

In summary, worst-case meteorological conditions for noise propagation are those with strongly increasing temperature and wind speed (from source towards receptor) within the surface layer. These are most likely associated with sea breezes (potentially enhanced by other complex terrain flows in the lower Fraser Valley) during the daytime. At nighttime, these conditions occur when the atmosphere is stable and larger-scale winds aloft drag air within the surface layer or cause sporadic bursts of inertial oscillations. An analysis of the frequencies of these sea-breeze and stable nighttime conditions with winds blowing from the source to the receptors is provided below.

2. Based on results of the literature review, construct a representative meteorological data set to be used as input to the CONCAWE model. The data set should be designed to capture a reasonable worst-case scenario for enhanced noise propagation (i.e. downwind conditions, light winds, temperature inversions, low level jets, and overwater propagation) from the Project to the seven sites located in the upland study area for the Project. The data set should also account for seasonal dependence of meteorological conditions. Provide a tabulation of the data set used to represent the worst-case scenario.

Overview of CONCAWE Approach

The CONCAWE model estimates sound levels under six different meteorological categories (table on page 21 in CONCAWE (1981)). The purpose of the meteorological categories is to calculate a factor, referred to as K4, which is applied to the sound-level estimates to account for meteorological influence. Category 4 has assumed zero meteorological influence. Empirical correction curves were derived for the other five categories. These curves show sound-level corrections as a function of acoustic frequency and distance from the noise source. They were

derived from field data collected for sound from petrochemical plants propagating over a land surface. Generally, meteorological categories 1 to 3 are associated with noise reductions and categories 5 to 6 are associated with sound enhancement, relative to category 4.

Available meteorological data for the field study on which the CONCAWE model was based included wind speed and direction, daytime incoming solar radiation, and cloud cover. In a first step, that data were used to identify atmospheric Pasquill stability classes from A (very unstable) to F (stable) (table on page 20 in CONCAWE (1981)). In a second step, strength and direction of the wind components relative to the downwind direction from noise source to receptor were categorised. In the third step, these wind component categories were combined with Pasquill stability classes and assigned to one of the six meteorological categories (table on page 21 in CONCAWE (1981)).

A limitation of the CONCAWE meteorological categories is that they combine meteorological observations that are associated with very different meteorological conditions into the same category. For instance, meteorological category 6 could include a variety of conditions including the following: fully developed strong sea breezes straight from the noise source to the receptor (stability class C and v>+3.0 m/s); a typical winter storm under rainy and overcast conditions (stability class D and v>+3.0 m/s); or nighttime or otherwise stable conditions with sufficiently strong onshore winds to suppress a land breeze (stability class F and v>+0.5 m/s).

Worst-case Meteorological Conditions for Sound Propagation at Roberts Bank

To estimate CONCAWE calculation input data representing Pasquill stability classes for the Project site, solar radiation observations were required. These observations were unavailable from area meteorological stations, and therefore, another approach was necessary to derive information on Pasquill stability classes. Instead, output from a CALMET model run over the Project region for the year 2011 was utilised. CALMET was run using as input 1) observations from several meteorological stations in the region and 2) output from the atmospheric mesoscale Weather Research and Forecast (WRF) model. CALMET output included Pasquill stability classes and wind speed and direction at a 2.5-km grid resolution. This output was bilinearly interpolated to the location of the noise source to provide the best representation of atmospheric conditions at the location of noise generation and for much of the over-water distance travelled towards the receptors. Wind vectors were rotated relative to the downwind direction from noise source to each receptor for each of the three main receptors sites.

For every hour of the year 2011, the wind component categories and Pasquill stability classes determined from the CALMET output were assigned to their respective meteorological categories. Finally, the frequencies of occurrence for each meteorological category were determined for each of the three receptor sites 3, 4, and 5 (Figure 2-3 in Appendix 9.3-A of the EIS) to provide all potential stability classes prior to focussing on the worst-case conditions. The results are shown in **Table IR7-01-1** below.

Table IR7-01-1 Frequencies of Occurrence of CONCAWE Meteorological Categories at Sites 3, 4, and 5 based on CALMET Output for Calendar Year 2011

Meteorological Category	Frequency of Occurrence (in %)		
	Site 3	Site 4	Site 5
1	0.7	0.9	1.1
2	17.2	18.9	25.0
3	21.2	23.8	24.0
4	19.2	17.6	16.0
5	23.0	19.6	14.3
6	18.6	19.1	19.5

The class that represents the 'worst-case' meteorological condition from a CONCAWE perspective for noise propagation is category 6. As described above, this category can represent more than the 'sea-breeze' condition, which is known to be the 'worst-case' meteorological condition from the ISO 9613 model perspective (receptor downwind of sound source).

The data set that was developed considered the location of all receptors used in the noise and vibration study. However, the EIS did not include the modelling of future noise levels at sites 1, 2, 6, or 7. Sites 1 and 2 were used to assess Project-related ground-borne vibration and sites 6 and 7 were used to assess Project-related low frequency noise. As such, the design of the data set focused on capturing meteorological conditions at sites 3, 4, and 5, as these sites represent residential locations that in the future are expected to receive the highest levels of Project noise.

3. Provide an analysis of the frequency of occurrence by season of these worst-case meteorological conditions that result in enhanced sound propagation.

A climatology of sea breezes was presented in Steyn and Faulkner (1986) based on a ten-year observational record. The statistics presented in this study can be expected to provide a good representation of current conditions. Data from Table 2.2 in Steyn and Faulkner (1986) at Vancouver International Airport (representative of the Project site) were incorporated in **Table IR7-01-2** below and used to derive a rough estimate of the overall frequency of sea breeze conditions by month and annually. Sea breezes are a daytime occurrence.

Table IR7-01-2 Frequencies of Occurrence of Sea Breezes at Vancouver International Airport based on Data Presented in Steyn and Faulkner (1986)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean frequency of occurrence (days)	3.2	4.1	6.9	7.7	9.4	8.5	11.5	11.0	8.9	8.7	3.8	2.2	-
Mean daily duration (hours)	4.9	6.7	8.1	8.6	9.0	8.3	7.9	8.3	8.9	7.2	5.5	4.1	-
Total average sea-breeze hours	15.7	27.5	55.9	66.2	84.6	70.6	90.9	91.3	79.2	62.6	20.9	9.0	674.3
Total hours per period	744	672	744	720	744	720	744	744	720	744	720	744	8760
Mean frequency of occurrence (%)	**2.1**	**4.1**	**7.5**	**9.2**	**11.4**	**9.8**	**12.2**	**12.3**	**11.0**	**8.4**	**2.9**	**1.2**	**7.7**

Relative to all hours in a given month, the frequency of sea breezes varies from a minimum of 1.2% in December to a maximum of 12.3% in August. Based on the ten-year observational data set in Steyn and Faulkner (1986) and the criteria for sea breeze identification applied by the authors, sea breezes occur in approximately 7.7% of all hours in a calendar year.

Table 2.2 in Steyn and Faulkner (1986) indicates that monthly mean sea breeze wind speeds varied between 2.5 m/s and 3.6 m/s, and the most frequent wind directions were from 210° to 240° (roughly southwesterly) at the coast. The wind component from noise source to receptors at the Project site is therefore less than +3 m/s most of the time. Because sea breezes occur under stability classes A, B, and C, according to the table on page 21 in CONCAWE (1981), sea breezes are assigned to meteorological categories 4 and 5 most of the time, and category 6 occasionally. Following the categorisation in the CONCAWE model, occasionally occurring sea breezes in category 6 are the worst-case meteorological conditions. Sea breezes occur less than 10% of the time.

Worst-case scenarios are therefore best represented by applying meteorological category 6 for every hour of the year, although in reality they occur less than 20% of the time over the course of a calendar year as shown in **Table IR7-01-1**. **Table IR7-01-3** below shows the frequency of occurrence of the six meteorological conditions further broken down by season.

Table IR7-01-3 Frequencies of Occurrence of CONCAWE Meteorological Categories at Sites 3, 4, and 5 based on CALMET Output for Calendar Year 2011 Broken Down by Season

Meteorological Category	Frequencies (in %)											
	Winter[a]			Spring[b]			Summer[c]			Fall[d]		
	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5
1	1.7	2.2	2.3	0.6	0.6	0.7	0.0	0.0	0.0	0.5	1.0	1.3
2	33.4	33.4	38.7	13.3	14.7	21.8	7.2	10.0	15.7	15.3	17.9	24.3
3	22.7	22.1	18.5	16.8	20.3	22.1	22.6	29.6	32.6	22.8	23.3	22.7
4	11.7	12.2	14.2	19.2	19.2	15.1	27.6	22.6	19.2	18.3	16.4	15.6
5	14.5	14.6	10.5	26.7	19.6	15.0	27.4	22.8	16.3	23.4	21.3	15.3
6	16.0	15.4	15.9	23.4	25.6	25.3	15.1	14.9	16.2	19.7	20.2	20.8

Notes:

a. Winter includes the months of December, January, and February
b. Spring includes the months of March, April, and May
c. Summer includes the months of June, July, and August
d. Fall includes the months of September, October, and November

4. Run the CONCAWE model using the representative atmospheric data set to develop an assessment of worst-case noise levels at the seven noise measurement sites in the upland study area for the Project during both construction and operation. The worst-case meteorological conditions should include all worst-case conditions acting simultaneously, and all physically realistic combinations of such conditions. The Proponent is to follow the revised activities for Project construction as presented in CEAR Doc#984.

Present the results of the CONCAWE model run in tables similar to Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS that summarize L_d, L_n, L_{dn} and L_{max} at the seven noise measurement sites in the upland study area during construction and operation of the Project under different combinations of the worst-case meteorological conditions. Provide a discussion of the results to accompany these tables.

Project Operation

The CadnaA model used in the EIS to forecast noise levels under future conditions with Project operation has been revised to account for the influence of meteorology on sound propagation according to the CONCAWE method (CONCAWE 1981). Sound propagation factors other than those considered by CONCAWE (e.g., distance) were still calculated according to the ISO 9613 standard (ISO 1996), as they were in the EIS. The ISO 9613 meteorological correction factor was replaced and calculated according to the CONCAWE method. The CONCAWE method was used to develop noise level predictions for the case of all sound propagation occurring under CONCAWE meteorological category 6; the category that would result in worst-case Project noise levels.

This revised approach only applies to noise from the sources in the CadnaA model that represent marine terminals and rail traffic. The EIS approach calculates road traffic noise as linear noise sources according to the NMPB-Routes 96 standard (Sétra 1997). The CONCAWE method does not include linear sources. The NMPB model does, however, allow for road traffic noise to be calculated under both neutral and downwind meteorological conditions. Conditions where downwind propagation occurs 100% of the year were used for the traffic portion of the model runs, which is equivalent to conditions included in CONCAWE meteorological class 6.

Table IR7-01-4 presents noise levels at sites 3, 4, and 5 for CONCAWE meteorological category 6 (worst-case meteorological conditions). Provided for comparison are the noise levels presented in the EIS which are for annual average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999). All noise levels are for future conditions with Project operation.

Table IR7-01-4 Noise Levels at Sites 3, 4, and 5 (Future Conditions with Project Operation) for CONCAWE Meteorological Category 6 Compared to EIS Annual Average

Site	ISO 9613 CONCAWE Meteorological Category 6			ISO 9613 EIS - LfU-Bayern Annual Average Windrose			Noise Level Differences between CONCAWE minus LfU-Bayern (EIS)		
	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)
3	57.5	54.1	61.2	52.0	51.7	58.1	5.5	2.4	3.1
4	54.3	52.2	59.0	49.5	46.5	53.5	4.8	5.7	5.5
5	56.3	55.1	61.7	52.8	49.6	56.7	3.5	5.5	5.0

Table IR7-01-4 shows that noise levels at the three sites are from 2.4 to 5.7 dBA higher for CONCAWE Meteorological Category 6 (reflecting worst-case meteorological conditions) when compared to annual average noise levels according to LfU-Bayern.

Construction Noise

The calculations of Project construction noise levels have been revised to consider sound propagation under ISO 9613 with CONCAWE meteorological category 6 (i.e., 'worst-case' meteorological conditions). Project construction noise levels are based on the Project construction activities described in Section 4.4.1 of the EIS, and detailed in Appendix 4-E and 4-F of the EIS. The VFPA will respond to the Panel under separate cover with regard to the changes to the environmental assessment that result from the changes to the RBT2 Project Description, as per the Panel's direction in letters dated July 17, 2017 (CEAR Document #995[2]) and October 3, 2017 (CEAR Document #1069[3]). However, the changes to the Project Description include removal of key noise sources, such as activity associated with the intermediate transfer pit and marine vibro-replacement; these changes would have the effect of reducing construction noise. The information provided below is therefore considered conservative in this context.

Table IR7-01-5 presents revised construction noise levels, calculated using the CONCAWE method, at sites 3, 4, and 5. The corresponding table in the EIS is Table 9.3-18. **Table IR7-01-6** compares the CONCAWE based results to the corresponding levels in Table 9.3-18 of the EIS.

[2] CEAR Document #995 From the Review Panel to the Vancouver Fraser Port Authority re: Requirements for information pertaining to changes to the Roberts Bank Terminal 2 Project.
[3] CEAR Document #1069 From the Review Panel to the Vancouver Fraser Port Authority re: Response to the Vancouver Fraser Port Authority's plan for the presentation of the revised information (See Reference Document # 1054).

Table IR7-01-5 Construction Noise Levels under CONCAWE Meteorological Category 6

Site	Annual Average Expected L_d (dBA)	Project Construction Phase L_d (dBA)		Project-related Increase (dBA)	
		Range	Avg.	Range	Avg.
3	51.9	51.9 – 58.0	54.1	0.0 – 6.1	2.2
4	48.4	48.4 – 56.3	51.7	0.0 – 7.9	3.3
5	52.3	52.3 – 53.9	53.0	0.0 – 1.6	0.7
Site	**Annual Average Expected L_n (dBA)**	**Project Construction Phase L_n (dBA)**		**Project-related Increase (dBA)**	
		Range	**Avg.**	**Range**	**Avg.**
3	51.5	51.5 – 57.9	53.3	0.0 – 6.4	1.8
4	44.5	44.5 – 55.9	48.9	0.0 – 11.4	4.4
5	48.5	48.5 – 51.3	49.6	0.0 – 2.8	1.1
Site	**Annual Average Expected L_{dn} (dBA)**	**Project Construction Phase L_{dn} (dBA)**		**Project-related Increase (dBA)**	
		Range	**Avg.**	**Range**	**Avg.**
3	58.0	58.0 – 64.3	59.9	0.0 – 6.3	1.9
4	51.7	51.7 – 62.4	55.9	0.0 – 10.7	4.2
5	55.7	55.7 – 58.1	56.8	0.0 – 2.4	1.1

Table IR7-01-6 Comparison of Project Related Increases from Construction Noise under CONCAWE Meteorological Category 6 and EIS ISO 9613 Methods

Site	CONCAWE Project-related Construction Increase L_d (dBA)		EIS Project-related Construction Increase L_d (dBA)		Noise Level Differences between CONCAWE and EIS Construction Increases L_d	
	Range	Avg.	Range	Avg.	Range Maximum	Avg.
3	0.0 – 6.1	2.2	0.0 – 1.9	0.6	4.2	1.6
4	0.0 – 7.9	3.3	0.0 – 2.6	0.9	5.3	2.4
5	0.0 – 1.6	0.7	0.0 – 0.3	0.1	1.3	0.6
Site	**CONCAWE Project-related Construction Increase L_n (dBA)**		**EIS Project-related Construction Increase L_n (dBA)**		**Noise Level Differences between CONCAWE and EIS Construction Increases L_n**	
	Range	**Avg.**	**Range**	**Avg.**	**Range**	**Avg.**
3	0.0 – 6.4	1.8	0.0 – 2.0	0.4	4.4	1.4
4	0.0 – 11.4	4.4	0.0 – 4.8	1.3	6.6	3.1
5	0.0 – 2.8	1.1	0.0 – 0.6	0.2	2.2	0.9

Site	CONCAWE Project-related Construction Increase L_{dn} (dBA)		EIS Project-related Construction Increase L_{dn} (dBA)		Noise Level Differences between CONCAWE and EIS Construction Increases L_{dn}	
	Range	Avg.	Range	Avg.	Range	Avg.
3	0.0 – 6.3	1.9	0.0 – 2.0	0.5	4.3	1.4
4	0.0 – 10.7	4.2	0.0 – 4.3	1.3	6.4	2.9
5	0.0 – 2.4	1.1	0.0 – 1.0	0.3	1.4	0.8

As shown in **Table IR7-01-6**, the CONCAWE based results show increases of up to 6.6 dBA (at site 4) relative to the noise levels in Table 9.3-18 of the EIS. The construction noise level ranges cover a five and a half-year period and the 'worst-case' sound propagation conditions (i.e., CONCAWE meteorological category 6) are forecast to occur for less than 20% of that time. Furthermore, these estimated maximum construction noise levels assume that the 'worst-case' sound propagation conditions would occur at the same time as maximum Project construction noise emissions. While there is no way to quantify this at this stage of construction planning, the variable nature of site activity is such that it is considered highly unlikely that such concurrence would happen 20% of the time.

Conclusions

Summary of Model Outputs

Recalculation of predicted noise levels using the CONCAWE method indicates that sound levels may increase by up to 5.7 dBA for the operation phase, and by up to 6.6 dBA for the construction phase, under 'worst-case' meteorological conditions, which are predicted to occur less than 20% of the time. The actual degree of sound level increases will depend on the level of site activity and the amount of ambient sound at those times when the category 6 meteorological condition occurs. The analysis presented herein applies worst-case meteorological conditions to annual average operation phase and construction phase noise levels, but actual levels will vary day-to-day and throughout the year.

Conservativism and Limitations

The predictions for sound levels, using the CONCAWE method, during the construction phase are considered highly conservative given that some noise emitting construction activities will be removed in the updated Project Description[4]. The predictions in the EIS are also considered conservative in this context.

Predictions for both the construction and operation phase are also considered conservative because the analysis for this response applied a more conservative attenuation factor than in typical CONCAWE applications. Uncertainty exists in the use of CONCAWE-based noise predictions, as the method suggests that hard surfaces, such as propagation over water or

[4] An updated Project Description will be prepared, as per the Panel's direction in letters of July 17, 2017 (CEAR Document #995) and October 3, 2017 (CEAR Document #1069).

concrete, use an arbitrary attenuation of -3 dBA (three dBA less attenuation than neutral conditions) for downwind conditions. However, the CONCAWE method does not account for partial attenuation over varying ground types. So the change in attenuation over water to land for the Project could not be evaluated using the CONCAWE method. To account for this, the calculations conducted for this CONCAWE-based exercise used the category 6 attenuation factor (or 100% downwind/sea breeze equivalent) for the entire source-to-receptor distance, which resulted in attenuation of up to -6 or -7 dBA (6 or 7 dBA less attenuation than neutral conditions) depending on distance and acoustic frequency. This is expected to result in higher sound levels than a strict application of the suggested CONCAWE factors for the applicable ground conditions.

Due to the limitations described above, using the CONCAWE method results in noise level predictions that are limited in accuracy and applicability to assessing Project-related effects from noise. The CONCAWE method has not been adopted by international standards organisations, such as CSA (Canadian Standard Organisation), ISO (International Organization for Standardization), or ANSI (American National Standards Institute). The limitations of the CONCAWE method with respect to modelling sound propagation over water, and therefore limitations in assessing Project-related effects from noise, are described in Section 2.3.3.4 of Appendix 9.3-A of the EIS.

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IR7-02 Atmospheric Noise – Transient Vessels

Information Source(s)

Marine Shipping Addendum: Section 7.4.5.1; Table 7.4-1; Figure 7.4-3; Figure 7.4-4

EIS Volume 2: Section 9.3.6.3; Table 9.3-4; Figure 9.3-4

Context

In Section 7.4.5.1 of the Marine Shipping Addendum, the Proponent stated that no data are available regarding the noise levels or frequency of container ship-related transient noise events such as from ship horns or other signals. The Proponent stated that if the rate of occurrence of transient noise events is assumed to increase in proportion to vessel movements, then such occurrences would also be expected to increase by 9 to 12%. The Proponent further indicated that the rates of occurrence of transient events are not expected to be perceptible. As described in Table 9.3-4 of the EIS, perceptibility is based on noise level increases; therefore, it is unclear how the Proponent determined whether transient events would be perceptible since there was no information provided regarding noise levels for such events.

In Section 9.3.6.3 of the EIS, the Proponent indicated that noise from ships in transit was excluded from the model because no data were available regarding their noise emissions. Some participants in the environmental assessment have expressed concern regarding the transient noise from container ships. However, the Proponent also stated that during the July noise measurement period, residents reported that one of the ships berthed at Deltaport Terminal caused higher-than-usual noise levels.

Information is required to predict the noise levels from transient noise events from container ships at receptor locations within the marine shipping area and the upland study area.

Information Request

Based on the existing Roberts Bank terminals, describe the frequency of occurrence of transient noise events from a container ship while transiting the marine shipping area and while at berth.

Provide information on the L_{max} of transient noise events from container ships, and describe the noise levels at various setback distances. Present the results in a figure similar to Figure 7.4-3 of the Marine Shipping Addendum.

Assuming neutral meteorological conditions, describe the L_{max} of transient noise events from a container ship at berth, and a container ship transiting the Marine Shipping Area at the following locations:

- sites in the upland study area as denoted by Figure 9.3-4 of the EIS; and

- on land within the local study area as described in Table 7.4-1 of the Marine Shipping Addendum.

Provide a figure similar to Figure 7.4-4 of the Marine Shipping Addendum that identifies the following contour lines along the shipping routes for Segments A and B:

- perceptibility of noise level increases due to transient noise events from a container ship; and
- outdoor noise level of 60 dBA Lmax.

VFPA Response

Based on the existing Roberts Bank terminals, describe the frequency of occurrence of transient noise events from a container ship while transiting the marine shipping area and while at berth.

Clarification

Transient noise events from container ships include the following:

- Ship pass-bys – Although engine noise from container ships is continuous while in transit, the noise may be received as transient at a stationary noise receptor, as the passing ship approaches, passes by, and recedes from the receptor;
- Ship horn soundings – short blasts of a ship's horn under certain navigational circumstances; and
- Ship anchor movements – metal-on-metal noise as the chain from the ship's anchor passes through an opening in the ship's hull while the anchor is being lowered or raised.

For the purposes of this response, ship pass-bys are the only relevant transient noise from container ships. The rationale for exclusion of ship horns and anchorage activities as part of this response is provided below.

The following rules from the document *Consolidation, Collision Regulations, C.R.C., c. 146*[1] provide regulations governing the circumstances under which marine vessels are required to sound their horns:

- *Rule 34 Manoeuvring and Warning Signals – International* describes situations under which a vessel would be required to sound its horn;
- *Rule 35 Sound Signals in Restricted Visibility – International* describes various types of horn sounding procedures for vessels when they are moving or at anchorage in or near an area of restricted visibility;
- *Rule 36 Signals to Attract Attention*; and
- *Rule 37 Distress Signals*.

[1] http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._1416/

As most ship-to-ship communication is done over VHF (very high frequency) radio at the discretion of the vessel master and as required by Canadian Coast Guard vessel traffic services requirements (under Radio Aids to Navigation), none of the circumstances described in these rules are expected to occur regularly or predictably as part of RBT2 Project operation (approaching or departing the berth), or marine shipping associated with the Project (ships in transit outside of VFPA jurisdiction). While certain situations may arise occasionally, such as restricted visibility (due to fog, mist, or falling snow), that will require container ships to sound their horns to avoid collisions when approaching or departing the berth, these activities are not considered to be part of normal berthing operations of RBT2 so were not included in the scope of assessment of effects of the Project, or in this response. Similarly, as described in Section 4.4.2.1 of the EIS, there are no plans or foreseen terminal operating requirements for off-terminal anchoring of container ships waiting for a berth at the new marine terminal. Additional information on anchorage is provided in the response to IR5-01 (CEAR Document #1078[2]), which clarifies that neither the construction phase nor the operation phase of RBT2 will require new anchorages.

Frequency of Occurrence of Transient Noise Events

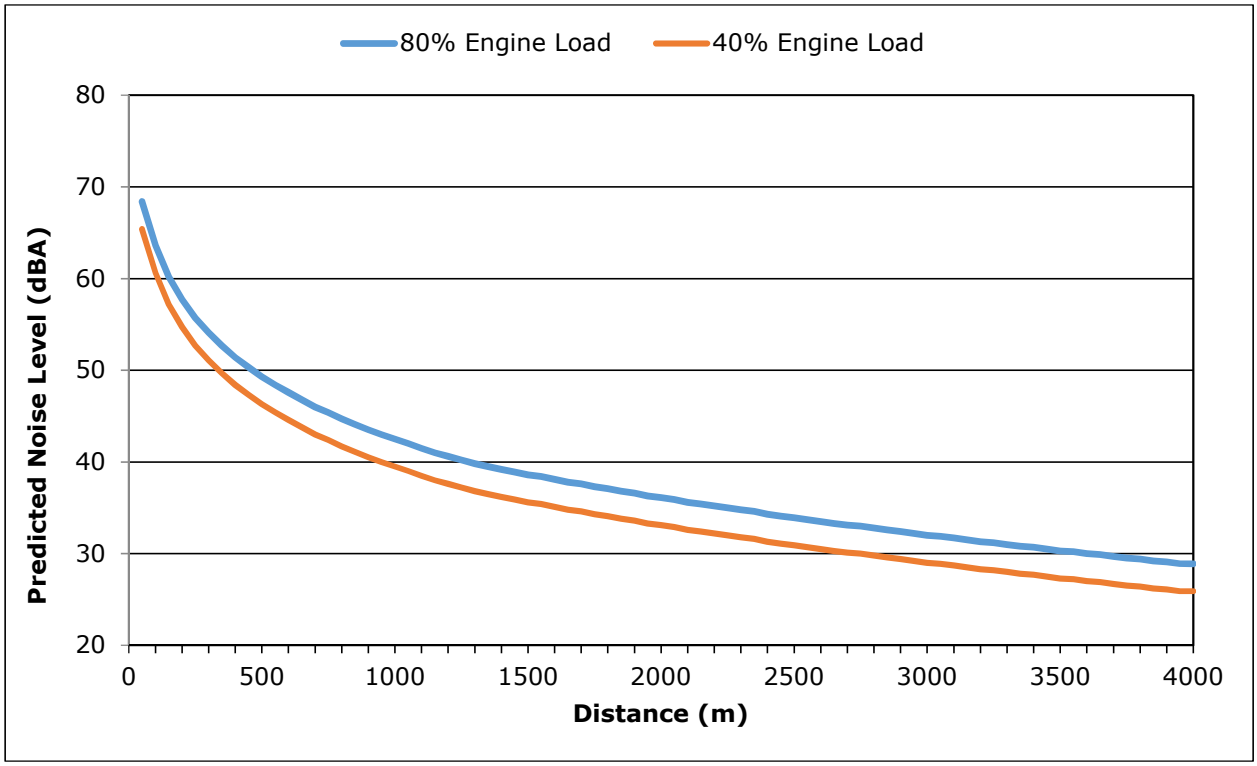
As described in Section 4.4.2.1 of the EIS, the RBT2 Project is estimated to receive 260 container ship calls per year when the terminal reaches its 2.4 million vessel TEU (twenty-foot equivalent) design capacity. This will result in 520 Project-associated container ship movements per year (one call equals two movements—one inbound and one outbound), or on average approximately three pass-bys, and associated noise, every two days at a given receptor point along the shipping route. As explained below, whether or not the noise from a vessel pass-by is perceptible at a receptor point depends on the setback distance from the noise source.

Provide information on the L_{max} of transient noise events from container ships, and describe the noise levels at various setback distances. Present the results in a figure similar to Figure 7.4-3 of the Marine Shipping Addendum.

Figure 7.4-3 of the Marine Shipping Addendum (reproduced as **Figure IR7-02-1** below for ease of reference) provides L_{max} levels for container ship pass-bys at various setback distances at 40% and 80% engine load. Given that no additional sources of transient noise were identified in response to this information request, no modifications to the figure were necessary.

[2] CEAR Document #1078 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR4-33, IR5-01, IR5-12, IR5-15, IR5-16, IR5-23, IR5-24, IR5-32, IR5-33, IR5-34, IR5-35, IR5-36, IR6-26, IR7-03, and IR7-05 (See Reference Documents #946, #975, #991, and #1000).

Figure IR7-02-1 Container Ship Maximum Pass-by Noise Levels at Various Setback Distances (Figure 7.4-3 of the Marine Shipping Addendum)



Assuming neutral meteorological conditions, describe the L_{max} of transient noise events from a container ship at berth, and a container ship transiting the Marine Shipping Area at the following locations: sites in the upland study area as denoted by Figure 9.3-4 of the EIS; and on land within the local study area as described in Table 7.4-1 of the Marine Shipping Addendum.

As discussed in the Section 7.3 of the Marine Shipping Addendum, container ship pass-bys are not expected to be audible beyond 4 km from the source. Consequently, under neutral meteorological conditions container ship pass-bys are not expected to be audible at sites 3, 4, and 5 as they are set back more than 5.5 km from the container ship arrival and departure routes, shown on Figure 4-1 of the Marine Shipping Addendum.

Provide a figure similar to Figure 7.4-4 of the Marine Shipping Addendum that identifies the following contour lines along the shipping routes for Segments A and B: perceptibility of noise level increases due to transient noise events from a container ship; and outdoor noise level of 60 dBA Lmax.

Figure 7.4-4 of the Marine Shipping Addendum provides sound level contour lines showing the setback distances at which container ship noise pass-bys in Segment B (where vessel engine load is assumed to be at 40%) are estimated to result in maximum ship noise levels of 35 and 45 dBA (A-weighted decibels). These sound contour lines correspond to estimated background noise levels for the daytime (7:00 a.m. to 10:00 p.m., 45 dBA) and nighttime (10:00 p.m. to 7:00 a.m., 35 dBA) in the local study area of the atmospheric noise effects

assessment (Section 7.4 of the Marine Shipping Addendum). As such, these contour lines provide estimates of the approximate setback distances at which maximum noise levels during container ship pass-bys would be perceptible (i.e., distinguishable from background noise).

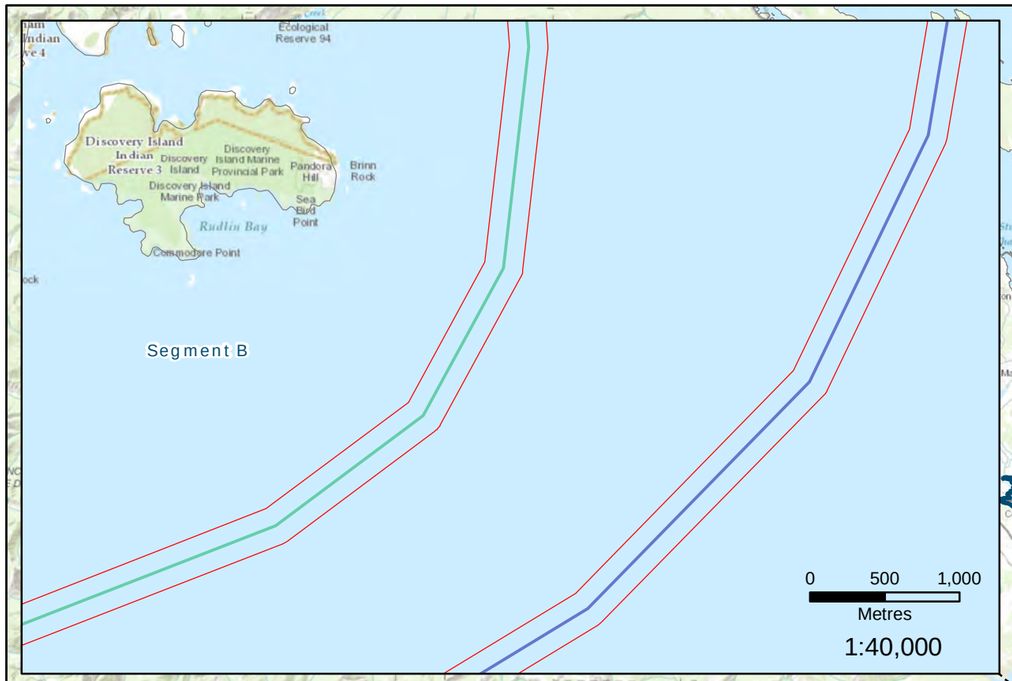
Figure IR7-02-A1 in **Appendix IR7-02-A** updates EIS Figure 7.4-4 to provide a contour line corresponding to the setback distance at which the maximum noise levels during container ship pass-bys in Segments A and B, under 40% engine load, would reach 60 dBA. The setback distance is approximately 130 m from the source, and not anticipated to overlap with land, or areas with land-based receptors, at any point along the shipping routes in Segments A or B, as shown on Figure IR7-02-A1 in **Appendix IR7-02-A**. In Segments C, D, E, F, and G, land is further from the shipping lanes than in Segments A or B; therefore, the 60 dBA maximum noise level from ship pass-bys is also not anticipated to interact with land-based receptors in these areas.

Appendices

Appendix IR7-02-A Supporting Figure

APPENDIX IR7-02-A
SUPPORTING FIGURE

Path: O:\1200\12466\EIS_INFORMATION_REQUESTS\IR7_2\mxd\IR7_2_A1_VesselPassbyNoise_60dBA_MSA_171107.mxd



Segment A
Segment B
Segment C
Segment D
Segment E
Segment F
Segment G
Galiano Island
Mayne Island
North Pender Island
Saturna Island
South Pender Island
Moresby Island
Boundary Passage
Haro Strait
Rosario Strait
Middle Channel
Juan de Fuca Strait
Victoria
CANADA
UNITED STATES

Legend

- BOUNDARY OF PROJECT AREA
- MARINE SHIPPING AREA AND SEGMENTS
- VESSEL PASS-BY NOISE LEVEL - 60 DBA
- PILOT STATION
- RBT2 ASSOCIATED INBOUND SHIPPING ROUTE
- RBT2 ASSOCIATED OUTBOUND SHIPPING ROUTE
- U.S.A.-CANADA BORDER

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N

PORT METRO vancouver

ROBERTS BANK TERMINAL 2

VESSEL PASS-BY NOISE LEVEL
OF 60 DBA IN MARINE SHIPPING
AREA SEGMENTS A AND B

DATE: 11/07/2017

FIG No. IR7-02-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.

IR7-03 Atmospheric Noise – Rail Traffic

Information Source(s)

EIS Volume 2: Appendix 9.3-A

CEAR Doc#651

Context

Appendix 9.3-A of the EIS stated that no results are presented for locomotive pass-bys or train movements at site 4 or 5 as these transient noise events were not at measurable levels at these sites. However, in its submission to the Review Panel (CEAR Doc#651), Tsawwassen First Nation reported that its members experience transient train noise in the community. Further information is required to determine whether the transient noise produced by locomotive pass-bys and train movements can be detected at sites 4 or 5.

Information Request

Provide supporting evidence that the transient noise produced by locomotive pass-bys and train movements is not measurable at sites 4 and 5 in the upland study area.

VFPA Response

Transient and impulsive noise events due to rail activity in the local study area include locomotive pass-bys, wheel-rail interactions, and train shunting. Impulsive noise levels, including from train shunting, are presented for site 4 in Table 3-4 of Appendix 9.3-A of the EIS. Other transient rail events, including locomotive pass-bys and wheel rail interactions, may be distinguishable from other existing sounds on Tsawwassen First Nation Lands. However, analysis of the measured data at sites 4 and 5 indicates the noise levels created by these events are not clearly identifiable relative to ambient noise levels.

Influence of Setback Distance on the Characteristics of Train Pass-by Events

The closest residences on Tsawwassen First Nation Lands to the Roberts Bank Rail Corridor (RBRC) are located on Falcon Way and are set back approximately 1,400 m from the RBRC. The closest residence to the RBRC that is not on Tsawwassen First Nation Lands is located at site 3 (3044 41 B St.). This residence is set back approximately 240 m from the RBRC. Train pass-by noise levels at site 3 were documented in Appendix 9.3-A of the EIS.

Figure IR7-03-1 shows a time history at site 3 of the noise levels created by a typical train pass-by event. The noise level data were collected during the August 2013 baseline noise monitoring and include the passage of a locomotive and attached cars.

Figure IR7-03-1 Noise Level Time History of a Train Pass-by Event

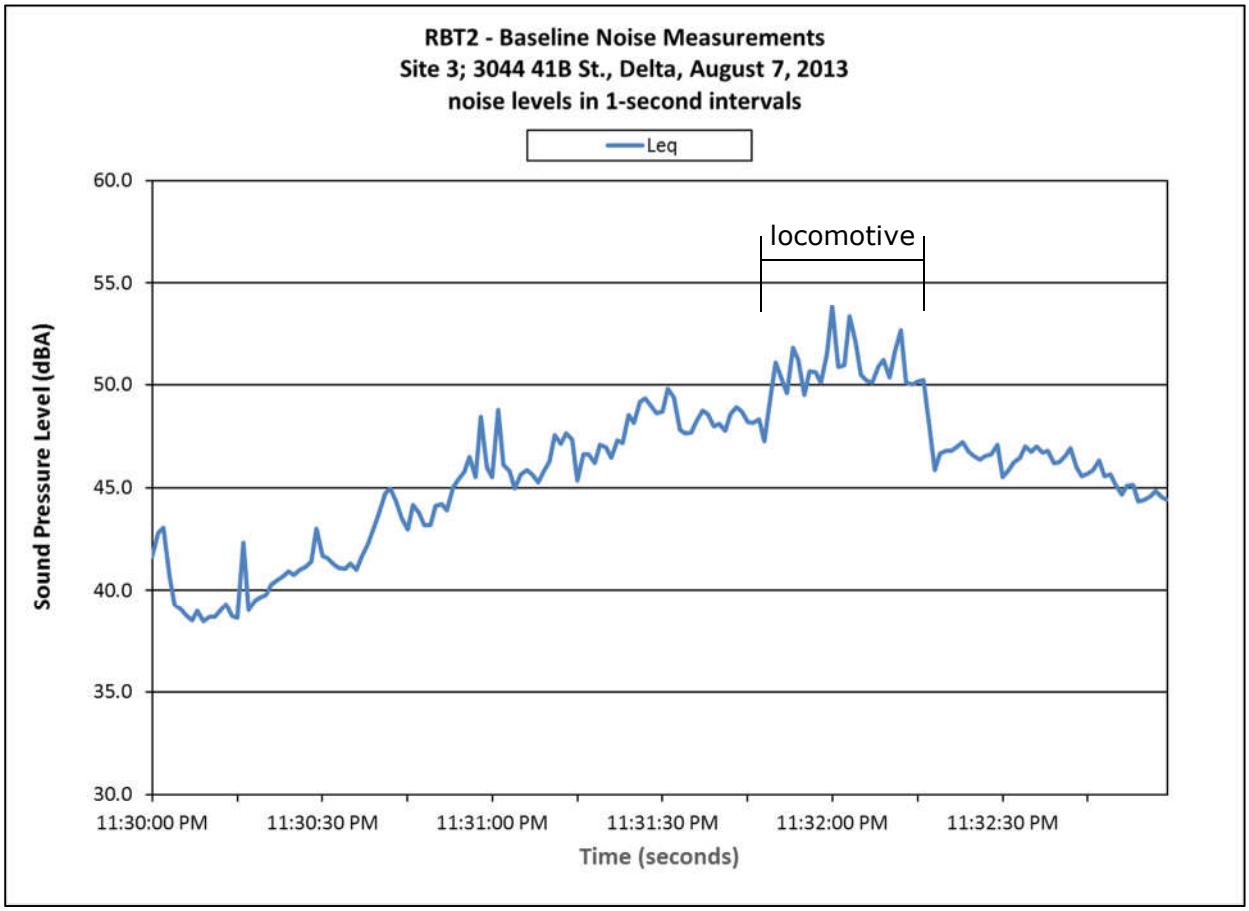


Figure IR7-03-1 shows that during a train pass-by, the noise level steadily increases until it reaches a maximum level when the locomotive passes by the microphone. Afterwards, the noise level decreases. The degree to which a train pass-by event is measurable relative to ambient noise levels depends on both the magnitude of the noise level increase and the rate at which the increase occurs. Both the magnitude of the noise level increase, and the rate at which it occurs, are functions of the setback distance of the measurement position from the train. At greater setback distances, both the magnitude of the noise level increase, and the rate at which it occurs, would diminish.

Figure IR7-03-2 illustrates the relationship between setback distance and pass-by events. This figure was generated using an idealised scenario within the Cadna software. In this scenario, pass-by sound levels were calculated at setback distances of 240 m (representing site 3) and 1,400 m (representing Falcon Way residences) from the RBRC. Noise levels were then calculated at a sampling rate of $1/10^{th}$ of a second as a locomotive travelled by at 50 km/hour.

Figure IR7-03-2 Train Pass-by at 240 m and 1,400 m Setbacks

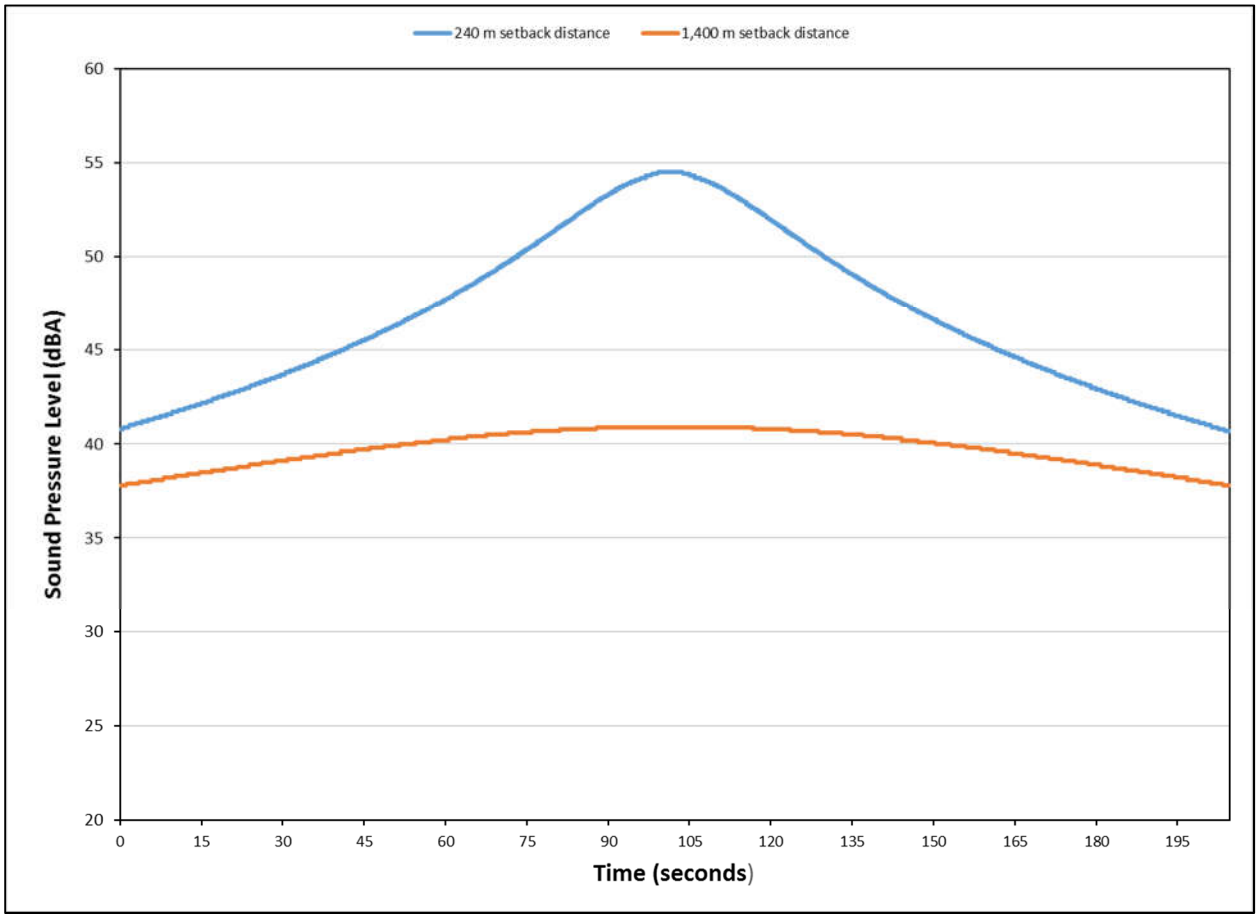


Figure IR7-03-2 shows that a train pass-by would be much more distinguishable as an isolated event at a setback distance of 240 m than it would be at a setback distance of 1,400 m.

The ambient noise environment on Tsawwassen First Nation Lands includes noise from the natural environment, local development, idling locomotives on the RBRC, locomotives and traffic on the causeway, plus general low-frequency noise emissions from the Roberts Bank terminals, and B.C. Ferries. These sources produce a quasi-continuous background noise level, with similar frequency characteristics to that of locomotive noise, which would add to the difficulty of measuring the gradual rise and fall of noise levels during a locomotive pass-by on Tsawwassen First Nation Lands. As such, the approach used in the effects assessment to consider locomotive noise on Tsawwassen First Nation in the context of continuous, low-frequency noise, is considered appropriate.

The residence at site 5 is set back approximately 3,400 m from the RBRC. At this relatively large setback distance, locomotive pass-by events would be even less distinguishable as measurable isolated events.

Influence of Setback Distance on Maximum Locomotive Noise Levels

Table 3-5 of the Noise and Vibration Technical Report (EIS Appendix 9.3-A) presents the maximum noise levels (L_{max}) of 18 locomotive pass-bys as measured at site 3 (3044 41 B St.) in 2013. The locomotive pass-by L_{max} ranged from 46.2 to 62.2 dBA (A-weighted decibels) with an average value of 55.3 dBA. The greater setback distance of site 4 (Falcon Way residences) from the RBRC would be expected to result in an approximate 15.3 dBA[1] reduction in locomotive L_{max} relative to the L_{max} measured at site 3. Locomotive L_{max} at the closest residences on Tsawwassen First Nation Lands are then estimated to range from 30.9 to 46.9 dBA with an average value of 40.0 dBA. At the setback distance of site 5, the noise level from a locomotive pass-by event would be expected to range from 23 to 39 dBA.

Figure IR7-03-3 and **Figure IR7-03-4** compare the estimated range of locomotive L_{max} on Tsawwassen First Nation Lands to noise history charts at site 4. These noise history charts are from the baseline noise monitoring that was conducted for two 24-hour periods from July 22 to 23, 2013 and July 23 to 24, 2013 (EIS Appendix 9.3-A). The charts show the variation in ambient L_{max}, equivalent sound level (L_{eq}), and ninety percent exceedance level (L_{90}) in 15-minute intervals over the 24-hour monitoring periods.

[1] This reduction was conservatively estimated by assuming that geometric divergence (i.e., spherical spreading) would be the only attenuating factor during sound propagation. The attenuation is calculated according to the formula $20*\log(d_1/d_2)$ (ISO 1996) where d_1 is the setback distance of site 3 and d_2 is the setback distance of site 4.

Figure IR7-03-3 Estimated Range of Locomotive L_{max} compared to Site 4 Noise History Chart for July 22-23, 2013

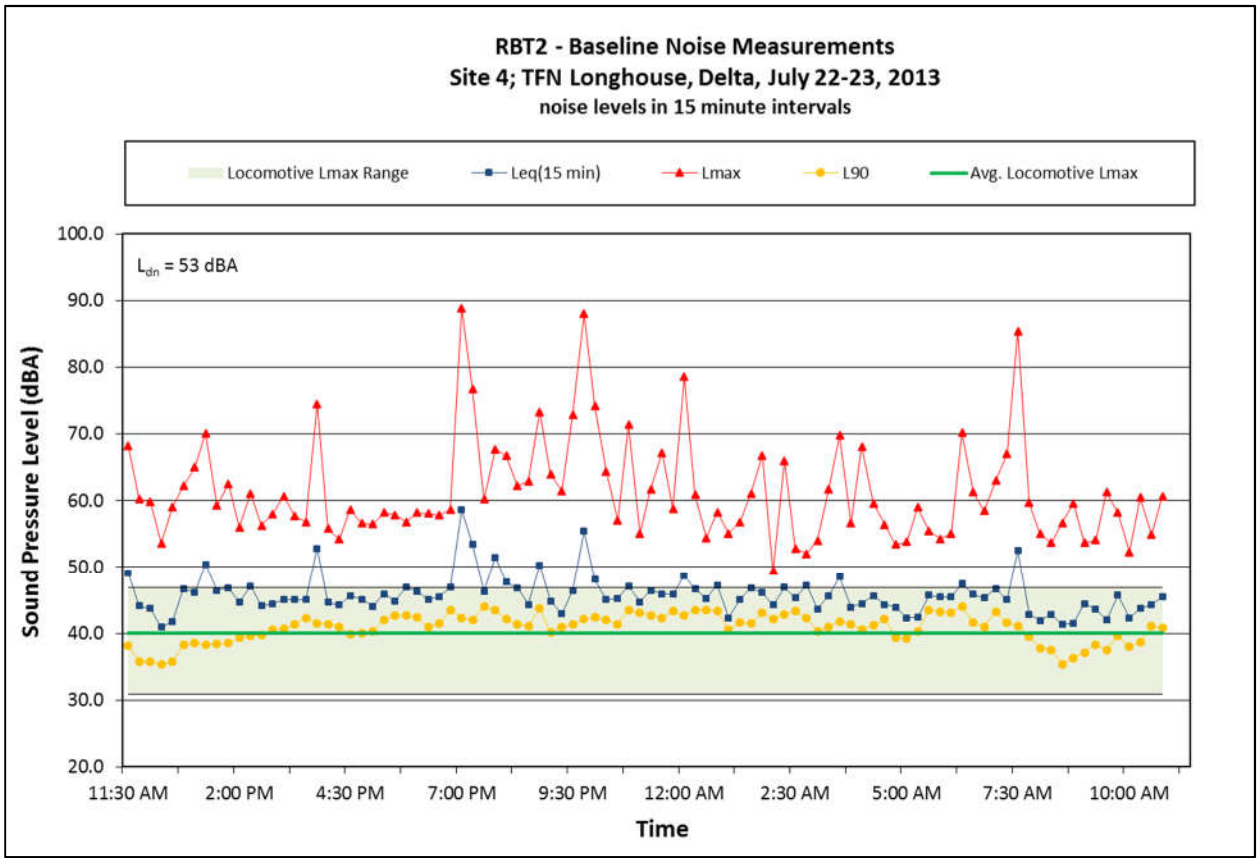
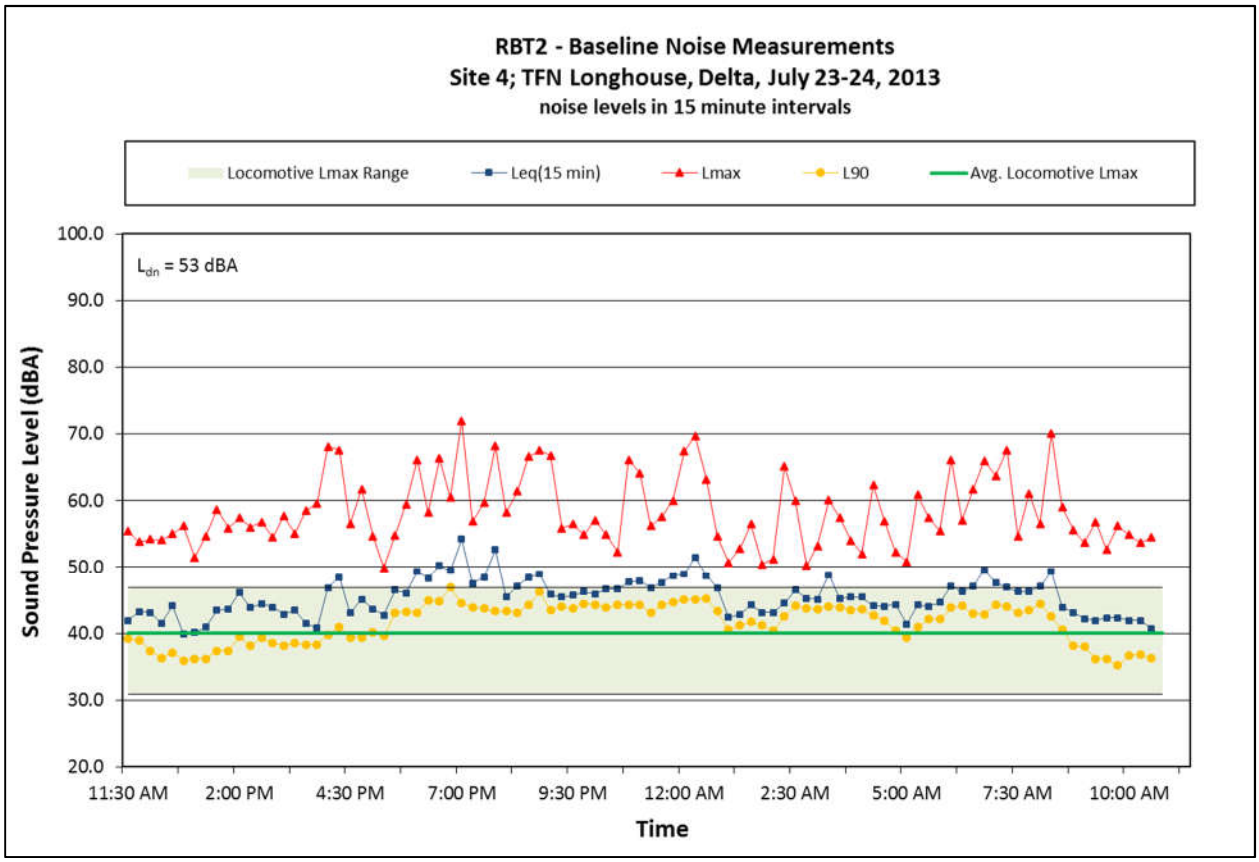


Figure IR7-03-4 Estimated Range of Locomotive L_{max} compared to Site 4 Noise History Chart for July 22-23, 2013



Figures IR7-03-3 and **IR7-03-4** show that the locomotive pass-by L_{max} levels were lower than the ambient L_{max} and that the majority of the locomotive L_{max} events were lower than the 15-minute L_{eq} at site 4. Furthermore, on average, locomotive pass-by L_{max} were often lower than the ninety-percent exceedance level. As such, while certain locomotive pass-bys may have been measurable relative to the ambient noise environment, the majority of the locomotive pass-bys would not have been. This creates an environment where train sounds may be distinguishable from other local sounds at specific moments, but the measurements themselves cannot be used to define the locomotives as the source of that sound.

While not presented in this response, the noise history charts for site 5 are provided in Appendix B of EIS Appendix 9.3-A. The estimated range of locomotive pass-by noise levels (23 to 39 dBA) are well below the L_{eq} provided in the Appendix B charts. As such, locomotive pass-by events would not be expected to create measurable noise levels at site 5. Additionally, the ambient L_{max} levels at sites 4 and 5, which were largely due to other sources of community noise, would have further contributed to making locomotive L_{max} inseparable from the measurements. While this analysis focuses on locomotive noise, measured train pass-by noise also includes noise from wheel-rail interactions. As the noise levels created by these interactions were lower in level than locomotive noise (**Figure IR7-03-3**), they would also not have tended to be measurable.

In conclusion, this analysis demonstrates that the noise levels created by locomotive pass-by events at sites 4 and 5 are not measurable relative to ambient noise levels.

References

International Standards Organization (ISO). 1996. ISO Standard 9613-2:1996 Acoustics -- Attenuation of sound during propagation outdoors, Part 2 – General method of calculation.

IR7-04 Atmospheric Noise – Baseline Low-Frequency

Information Source(s)

EIS Volume 2: Section 9.3.6.3, Table 9.3-10

Context

In Section 9.3.6.3 of the EIS, the Proponent stated that frequency spectra were measured in one-third octave bands at sites 5, 6, and 7 to investigate the degree to which low-frequency noise from the existing terminals and causeway was present. The Proponent also indicated that low-frequency noise levels at site 4 on Tsawwassen First Nation lands were estimated through comparison with noise levels measured at the other sites. The Proponent stated that although the noise survey that was carried out as part of the proposed Project reported fewer people were disturbed by low-frequency noise on Tsawwassen First Nation lands than in Ladner, there is more potential for the Project to influence low-frequency noise levels on Tsawwassen First Nation lands due to its proximity to the causeway and the proposed marine terminal. Measured baseline information for low-frequency at site 4 is required.

Information Request

Provide measurements of low-frequency noise at site 4 on Tsawwassen First Nation lands and provide a discussion on and comparison with the estimated baseline low-frequency noise levels at site 4.

Update Table 9.3-10 of the EIS to reflect the measured noise levels at site 4.

VFPA Response

Provide Measurements of Low-frequency Noise at Site 4 on Tsawwassen First Nation Lands

This response provides the results of low-frequency noise measurements conducted on Tsawwassen First Nation Lands.

Measurement Methodology

The low-frequency noise measurement instrumentation and parameters were consistent with applicable guidance as referenced in EIS Appendix 9.3-A. The low-frequency noise data was collected over two 24-hour periods (7:00 a.m. to 7:00 a.m.) on October 25-26 and October 28-29, 2017 by a VFPA permanent noise monitoring station located at the Tsawwassen First Nation Administration building (site 4A). This location is expected to have a very similar noise environment to that of site 4 (The Tsawwassen First Nation Longhouse), especially in terms of noise received from the Deltaport Terminal and vehicle traffic on Tsawwassen Drive North. Both sites are located on the western shoreline of Tsawwassen First Nation Lands and are approximately 3.8 km northeast of the Roberts Bank terminals.

During the entire October 25-26 measurement period, there were two vessels at berth at Deltaport Terminal (*UMM SALAL v .03* and *San Francisco Bridge v .29*). During the October 28-29 measurement period, there were from one to three vessels at berth. For the first hour only, there were three vessels at berth. For the majority of the period (17 hours) there were two vessels at berth, and for the remaining six hours there was just one vessel at berth. The vessel names and times at berth during the October 28-29 measurement period are shown below:

- The *ZIM Colombo v .51* was at berth October 28, 7:00 a.m. to 8:00 a.m.;
- The *UMM SALAL v .03* was at berth October 28, 7:00 a.m. to midnight, and October 29, midnight to 1:00 a.m.; and
- The *NYK APOLLO v .91* was at berth for the entire monitoring period.

The specific monitoring periods were selected based on predicted meteorological conditions and vessel call schedules. As per applicable guidance for noise measurement, the monitoring periods were scheduled to ensure the meteorological conditions were appropriate for noise measurement (i.e., no active precipitation, calm winds, and temperatures within operating specifications of noise meters). The monitoring was also scheduled to correspond with the presence of vessels that generate higher levels of noise. In the EIS, monitoring took place while a ship historically associated with noise complaints was at berth. As this ship no longer calls at Deltaport, the 2017 monitoring was scheduled while at least one larger vessel was at berth.

In addition to noise measurements, field observations were conducted for ten hours, in three segments (9:00 a.m. to 12:00 p.m., 1:00 p.m. to 3:00 p.m., and 11:00 p.m. to 4:00 a.m.) for each of the 24-hour measurement periods. The field observations were conducted to observe the composition of the noise environment to support identification of low-frequency noise sources.

During the daytime, the primary sources of low-frequency noise were observed to be activities at the Deltaport Terminal and locomotives on the Roberts Bank causeway. The field engineer also noted that a heat pump that serves the administrative building was operating. Additionally, there was construction activity taking place to the east of site 4A on parcels of land adjacent to Blue Heron Road. A review of the corresponding measurement data did not provide sufficient evidence to conclusively determine if noise from either the heat pump or construction activity were influencing low-frequency noise levels.

During the nighttime, the primary sources of low-frequency noise were observed to be activities at the Deltaport Terminal and locomotives on the Roberts Bank causeway.

Low-frequency Noise Measurement Results

Table IR7-04-1 provides the results of the low-frequency noise measurements for the October 25-26 and October 28-29 daytime measurement periods (7:00 a.m. to 10:00 p.m.). Low-frequency noise levels are presented in terms of C-weighted noise levels, and the differences between A- and C-weighted noise levels. Both locations are shown on Figure IR7-04-A1 in **Appendix IR7-04-A**. Also presented are the percentages of the

measurement period during which 1, 2, or 3 vessels were present at berth. Corresponding results for the two nighttime monitoring periods[1] (midnight to 5:00 a.m.) are provided in **Table IR7-04-2**.

Table IR7-04-1 Low-frequency Noise Measurement Results at Site 4A – Daytime

Monitoring Period	Numbers of Vessels at Berth	A-weighted Noise Level (dBA)	C-weighted Noise Level (dBC)	Difference (dBC minus dBA)
October 25-26	2	47.5	66.6	19.1
October 28-29	2-3[a]	47.2	66.2	19.0
Average	2	47.4	66.4	19.0

Note: a. Two vessels for 93% of the daytime monitoring period and three vessels for 7% of the daytime monitoring period.

The low-frequency noise levels measured for the two daytime monitoring periods are quite similar, differing only by only 0.4 dBC (**Table IR7-04-1**).

Table IR7-04-2 Low-frequency Noise Measurement Results at Site 4A – Nighttime

Monitoring Period	Numbers of Vessels at Berth	A-weighted Noise Level (dBA)	C-weighted Noise Level (dBC)	Difference (dBC minus dBA)
October 25-26	2	43.5	65.8	22.3
October 28-29	1-2[a]	41.9	61.9	20.1
Average	1	42.6	63.9	21.2

Note: a. One vessel for 80% of the nighttime monitoring period and two vessels for 20% of the nighttime monitoring period.

The low-frequency noise levels measured for the October 25-26 nighttime monitoring period were 3.9 dBC higher than the low-frequency noise levels measured for the October 28-29 nighttime monitoring period. This result is attributable to there being two vessels at berth for the entire October 25-26 nighttime monitoring period whereas there were two vessels at berth for 20% of the October 28-29 nighttime monitoring period.

Comparison of Measured and Estimated Low-frequency Noise Levels on Tsawwassen First Nation Lands

Table IR7-04-3 presents an updated version of Table 9.3-10 in the EIS (EIS Section 9.3.7.1) that includes the average nighttime (midnight to 5:00 a.m.) low-frequency noise levels measured at site 4A on Tsawwassen First Nation Lands. This table provides estimated low-

[1] While the nighttime period in noise assessments is typically considered to be 10:00 p.m. to 7:00 a.m., the EIS used a nighttime period of midnight to 5:00 a.m. to characterise low-frequency noise levels due to activity at the existing Roberts Bank terminals and on the Roberts Bank causeway. This was the time period during which these sources were expected to be most dominant in terms of overall low-frequency noise levels on Tsawwassen First Nation Lands.

frequency noise levels at site 4 and measured low-frequency noise levels at sites 4A, 5, 6, and 7. Low-frequency noise levels are represented in terms of C-weighted noise levels, and the differences between A- and C-weighted noise levels.

Table IR7-04-3 Average Nighttime Low-frequency Noise Levels at Sites 4A, 4, 5, 6, and 7

Site	A-weighted Noise Level (dBA)		C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
4A	42.6	-[a]	63.9	-[a]	21.2	-[a]
4[b]	40.0	-[a]	57.9	-[a]	17.9	-[a]
5	43.4	35.8	61.3	51.8	17.9	16.0
6	32.5	25.9	49.9	38.5	17.4	12.6
7	42.4	26.9	61.7	49.4	19.3	22.5

Notes: a. No indoor noise level data was available.
b. Outdoor levels at site 4 were estimated from levels measured at site 5. Indoor noise levels were not estimated since differences between indoor and outdoor levels are unique to each residence.

The average C-weighted noise level measured at site 4A (**Table IR7-04-3**) is 6.0 dBC higher than the estimated noise level at site 4 presented in Table 9.3-10 of the EIS. Similarly, the difference between the C- and A-weighted noise levels measured at site 4A (**Table IR7-04-1**) is 3.3 dB higher than the estimated difference at site 4 presented in EIS Table 9.3-10.

Appendices

Appendix IR7-04-A Figure IR7-04-A1 Noise Measurement Sites on Tsawwassen First Nation Lands

APPENDIX IR7-04-A

FIGURE IR7-04-A1 NOISE MEASUREMENT SITES ON TSAWWASSEN FIRST NATION LANDS

Path: O:\t1200\t1246\EIS_INFORMATION_REQUESTS\IR7_04\mxd\IR7-04-A01_NoiseMeasurementSites_TFN_180124.mxd

Roberts Bank

Tsawwassen First Nation

Site 4

Site 4A

Tsawwassen

Point Roberts (U.S.A.)

CANADA

U.S.A.

Tsawwassen First Nation Longhouse

Site 4

Tsawwassen Drive North

Tsawwassen First Nation Administration Building

Site 4A

Legend

- NOISE MEASUREMENT SITE
- BOUNDARY OF PROJECT AREA
- CANADA-U.S.A. BORDER

0 1 2

Kilometres

1:50,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

NOISE MEASUREMENT SITES ON TSAWWASSEN FIRST NATION LANDS

DATE: 02/02/2018

FIG No. IR7-04-A1

Basemap 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; Imagery Source: BING Maps Aerial

IR7-05 Atmospheric Noise - Variations in Low Frequency

Information Source(s)

EIS Volume 2: Appendix 9.3-A; Section 2.3.1.4; Table 3-8

CEAR Doc#579

Context

In Section 2.3.1.4 of Appendix 9.3-A, the Proponent presented the methodology used in the collection and assessment of low-frequency noise. The Proponent indicated that while the measurements were conducted over periods of either 24 or 48 hours, only the data from midnight to 5:00 am were analyzed. The rationale provided by the Proponent was that nighttime data were considered to be representative of low-frequency noise related to the Roberts Bank terminals because port-related noise is more prominent - and therefore more identifiable - during these hours.

As indicated by Health Canada in its submission to the Review Panel (CEAR Doc#579), this suggests that daytime low-frequency noise levels may be higher than estimated by the Proponent if other sources are present that produce low-frequency noise. A full characterization of low-frequency noise baseline conditions at sites 5, 6, and 7 in the upland study area, both at night and during the day, is required to fully assess the potential effects of the proposed Project and to validate the assumption that low-frequency noise from the existing terminals is more prominent at night than during the day.

Information Request

Provide a comparison of low-frequency noise during the day and night at sites 5, 6, and 7 in the upland study area, and discuss any differences observed.

Present the results of the daytime low-frequency noise in a table similar to that of Table 3-8 of Appendix 9.3-A of the EIS.

Confirm whether low-frequency noise in the upland study area originating from the existing Roberts Bank terminals is more prominent at night than during the day.

VFPA Response

Provide a comparison of low-frequency noise during the day and night at sites 5, 6, and 7 in the upland study area, and discuss any differences observed. Present the results of the daytime low-frequency noise in a table similar to that of Table 3-8 of Appendix 9.3-A of the EIS.

A comparison of low frequency noise (LFN) levels measured during the daytime (7:00 a.m. to 10:00 p.m.) and nighttime (midnight to 5:00 a.m.) is provided in **Table IR7-05-1** (outdoors) and **Table IR7-05-2** (indoors). The nighttime LFN levels shown in these tables correspond

to those provided in Table 3-8 of the Noise and Vibration Technical Report (EIS Appendix 9.3-A). The daytime LFN levels were extracted from the original datasets reported in EIS Appendix 9.3-A, collected July 22 to 24, 2013.

LFN levels are presented as C-weighted noise levels. The degree of influence LFN levels have on overall noise levels are presented as the difference between A- and C-weighted noise levels. The C-weighted noise levels provide the magnitude of LFN levels while the difference between A- and C-weighted noise levels provide an indication of the distinguishability of LFN levels relative to mid- and high-frequency noise levels.

Table IR7-05-1 Outdoor Low Frequency Noise Levels, Daytime versus Nighttime

Site	Outdoor A-weighted Noise Level (dBA)		Outdoor C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
5	46.3	43.4	60.5	61.3	14.2	17.9
6	38.1	32.5	49.8	49.9	11.7	17.4
7	43.0	42.4	62.6	61.7	19.6	19.3

Table IR7-05-2 Indoor Low Frequency Noise Levels, Daytime versus Nighttime

Site	Indoor A-weighted Noise Level (dBA)		Indoor C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
5	38.8	35.8	52.1	51.8	13.3	16.0
6	32.0	25.9	41.4	38.5	9.4	12.6
7	33.2	26.9	54.4	49.4	21.2	22.5

Confirm whether low-frequency noise in the upland study area originating from the existing Roberts Bank terminals is more prominent at night than during the day.

From **Table IR7-05-1**, it can be seen that there is less than 1.0 dBC difference between outdoor daytime and nighttime C-weighted noise levels at sites 5, 6, and 7. The data also show that the dBC-dBA difference is greater at night at these sites, supporting the assumption that LFN is more prominent at night. While LFN levels are somewhat higher during the daytime, LFN is more distinguishable, relative to mid- and high-frequency noise, during the nighttime. At site 7, the difference of 0.3 decibels (dB) between the daytime and nighttime dBC-dBA value, is considered negligible as it is within the ±1 dBA accuracy of the sound level meters.

According to the data shown in **Table IR7-05-2**, measured indoor C-weighted levels were up to 5 dB higher during the day; however, this result is expected to be influenced by activities taking place within the residences during the daytime. There is more uncertainty with indoor

measured levels due to the lack of control for activities in proximity to the microphone so no trends can be inferred from the result.

IR7-06 Atmospheric Noise – Low Frequency

Information Source(s)

EIS Volume 5: Section 32.2.4.7; Section 32.3.2.2

CEAR Doc#733

Context

As stated by the Proponent in Section 32.2.4.7 of the EIS, Lyackson First Nation indicated that it has experienced an irregular low-frequency noise and associated vibration while using areas at Le'eyqsun (Valdes Island), and believes the source of the noise and vibration is from the screws of large vessel traffic. In its submission to the Review Panel (CEAR Doc#733), Lyackson First Nation reiterated concerns about noise.

An update is required of the ongoing discussion between Lyackson First Nation and the Proponent regarding the source of the noise referred to in Section 32.2.4.7 of the EIS.

Information Request

Provide an update of the ongoing discussion with Lyackson First Nation regarding the source of the noise referred to in Section 32.2.4.7 of the EIS.

VFPA Response

Valdes Island is outside the VFPA's navigational jurisdiction and outside the marine shipping area as defined in the Marine Shipping Addendum (Figure 1-1 of the Marine Shipping Addendum). Valdes Island is approximately 30 km from the RBT2 Project area, and approximately 20 km from the nearest international shipping lane. While large ships may travel in proximity to Valdes Island, noise from current and future container traffic bound for Roberts Bank is not anticipated to be detectable at Valdes Island. Atmospheric noise from container ships is not expected to be audible at distances greater than 4 km (as described in Marine Shipping Addendum Section 7.4.5.1). Underwater sound levels from container ships 30 km from the terminal would be the same as sound levels from existing traffic conditions in the Strait of Georgia (as shown in Figure A-52 in Appendix 9.8-A of the EIS).

These results were discussed with Lyackson First Nation during two workshops on assessment results in 2014 (October 28, 2014, Preliminary EIS Results Workshop #3; December 10, 2014, Health & Aboriginal Rights Workshop), and in subsequent meetings regarding the EIS and Marine Shipping Addendum. When Lyackson raised the concern again in 2017, the VFPA held another meeting with Lyackson (on May 3, 2017) where further discussion regarding underwater noise and vibration occurred between Lyackson and technical specialists.

Through submission of the Marine Shipping Addendum, the VFPA has communicated with Transport Canada, Health Canada, DFO, and the Canadian Environmental Assessment Agency that Lyackson has a number of outstanding concerns related to marine shipping activities outside the VFPA's navigational jurisdiction. The VFPA participated along with these agencies in a meeting to provide Lyackson an opportunity to further discuss these concerns (October 4, 2017). The VFPA has provided Lyackson with information about how to report noise incidents to the VFPA's 24-hour community complaint line, should this assist in identifying a particular vessel entering the VFPA's jurisdiction that may be generating noise along the international shipping lanes. In the case of vessels with excessive noise within the VFPA's jurisdiction, the VFPA works with terminal operators and vessel operators to reduce noise while at berth, and to address concerns regarding vessel safety and condition while travelling through the VFPA's navigational waters.

The VFPA will continue to support efforts led by Transport Canada and others to better understand the current effects of vessels along the marine shipping route, and to determine the most likely cause of the noise experienced by Lyackson, and potential steps to address it.

IR7-08 Atmospheric Noise – Clarification, Traffic Forecasts

Information Source(s)

EIS Volume 1: Appendix 4-D

EIS Volume 2: Section 9.3.10.1; Table 9.3-23

Context

Table 9.3-23 of Section 9.3.10.1 of the EIS presented the forecast traffic and rail volumes on Deltaport Way and the Roberts Bank Rail Corridor. The Proponent indicated that the values in this table were based on Appendix 4-D of the EIS. However, it is unclear how the values for the following columns of Table 9.3-23 of the EIS were derived:

- Deltaport Way annual average daily traffic; and
- Deltaport Way percentage (%) heavy vehicles.

Information is required to determine how the values presented in Table 9.3-23 of the EIS were derived.

Information Request

Provide a description of how the information presented in Appendix 4-D of the EIS was used to derive the values presented in Table 9.3-23 of the EIS.

VFPA Response

The following two data sources were used to derive the annual average daily traffic volumes (AADT) and percentages of heavy vehicles on Deltaport Way in Table 9.3-23 of the EIS:

- Appendix 4-D of the EIS, Table 12; and
- Tsawwassen First Nation Community Development: Transportation Impact Assessment (Bunt & Associates 2011), Exhibits 5.4 and 6.4.

Table 12 of EIS Appendix 4-D provides inbound and outbound total vehicle movements (passenger/service vehicles and container trucks) for the growth scenario of 4.8 million (M) twenty-foot equivalent units (TEUs) through the existing Deltaport Terminal, and the proposed RBT2 terminal. The 4.8 M TEU scenario corresponds to future conditions with Project operation. Vehicle movements are provided for each hour of the day such that it is possible to calculate the AADT and percentage heavy vehicles that would be arriving at and departing the Roberts Bank causeway via Deltaport Way.

Exhibits 5.4 and 6.4 in Bunt & Associates (2011) provide projected AM and PM peak traffic volumes on Deltaport Way for 2031. The traffic volumes take into account the Tsawwassen

First Nation Land Use Plan which includes up to nearly 3,500 additional homes, a 1.2 million square foot shopping centre, and a 575,000 square-foot mall.

The traffic data from EIS Appendix 4-D and Bunt & Associates (2011) were combined to provide total traffic volumes on Deltaport Way for the temporal cases that are considered in EIS Table 9.3-23 (i.e., future conditions with the Project and future conditions with the Project and other reasonably foreseeable projects and activities). Data from EIS Appendix 4-D provides Project-related truck traffic for the on-causeway portion of Deltaport Way. These volumes were used in the assessment of future cumulative changes to noise levels (EIS Section 9.3.10) for the off-causeway portion of Deltaport Way, and are shown in Table 9.3-22 for 'incremental road traffic associated with RBT2'.

Annual average daily traffic projections, based on the AM/PM peak traffic data in Bunt & Associates (2011), were estimated using the formula:

$$AADT = AM\ Peak \times 8$$

References

Bunt & Associates Engineering (Bunt & Associates). 2011. Tsawwassen First Nation Community Development: Transportation Impact Assessment. Prepared for Tsawwassen First Nation.

IR7-09 Atmospheric Noise – Nighttime Shift Changes

Information Source(s)

EIS Volume 2: Appendix 9.3-A, Appendix B

CEAR Doc#651

Context

In its submission to the Review Panel (CEAR Doc#651), Tsawwassen First Nation indicated that its members have noted that the late night shift change of workers at the existing Roberts Bank terminals is particularly disruptive because passenger vehicles are higher pitched and travelling faster, resulting in transient noise spikes.

As stated in Appendix 9.3-A of the EIS, road traffic from the causeway and terminal were included as a source of noise when making predictions regarding the noise produced by the proposed Project. However, given that the Proponent relied on metrics such as L_d, L_n, and L_{dn} when describing the potential noise produced by the Project, it is unclear how peaks in terminal and causeway activity occurring at night were considered in the assessment of noise effects. Information is required to determine the effects of peak terminal activity on nighttime noise levels at the sites identified by the Proponent located in the upland study area.

Information Request

Describe the types of Project activities - such as nighttime shift changes - that are likely to occur that could result in peak nighttime noise levels.

Provide a figure similar to those in Appendix B of Appendix 9.3-A which display the L_d, $L_{eq\ (15\ minutes)}$ and L_{max} for a typical night of operations from 10:00 p.m. to 7:00 a.m. at sites 3, 4 and 5 in the upland study area. Identify the source of all peaks.

VFPA Response

Clarification

Based on the context provided for this request, the terms 'peak nighttime noise levels' and 'peaks' are interpreted to refer to the maximum noise levels reached during transient or impulsive noise events that are measurable in terms of the L_{max}. The L_{max} is the maximum RMS (root-mean square) sound pressure level that occurs, or is measured, during a particular time period.

Types of Project Activities that could Result in Transient and Impulsive Noise Events as Measured by the L_{max}

The types of Project activities that are expected to result in measurable, maximum noise levels due to transient or impulsive noise are identified in Section 9.3.9.3 of the EIS. These activities are material handling at the marine terminal and train shunting on the Roberts Bank causeway. No other Project activities are expected to result in measurable, regularly occurring transient or impulsive noise.

It is acknowledged that the nighttime shift change may create a period of time during which Project-related traffic noise is more noticeable relative to the average nighttime noise environment. However, individual vehicles driving on the Roberts Bank causeway during the nighttime shift change would not be expected to regularly cause L_{max} values at receptors that are measurably higher than average nighttime noise levels. This expectation is based on the average vehicle noise emissions provided in the U.S. Federal Highway Administration Traffic Noise Model User's Guide (U.S. FHWA 1998) and consideration of the speed limit and setback distances of receptors from the Roberts Bank causeway.

The increased noticeability of nighttime shift change traffic would be due to the character of the noise rather than to the level of the noise. Shift change traffic will produce more high-frequency noise than is generally present in the study area during nighttime hours. The traffic noise will therefore tend to stand out relative to other sources of nighttime noise. Potential human health effects from exposure to noise that is below quantitative thresholds is assessed qualitatively in the human health assessment as part of the stress and annoyance sub-component (EIS Section 27.6.4).

Transient and Impulsive Noise Events as Measured By The L_{max}

Clarification

The charts in Appendix B of EIS Appendix 9.3-A display the L_{eq}, L_{max}, and L_{90} in 15-minute intervals for sites 3, 4, and 5 for a typical night of operations at Deltaport Terminal. The L_d (daytime average equivalent sound level), requested in this information request, is not plotted on this chart because it is a single value providing an average level for the daytime period (7:00 a.m. to 10:00 p.m.)

L_{max} Source Identification

A source identification analysis similar to the one requested was conducted as part of the atmospheric noise study of the EIS to identify the L_{max} noise levels associated with port-related transient and impulsive noise events. This analysis consisted of a review of field observations, audio recordings, and measured noise levels (see Section 3.1.3 of EIS Appendix 9.3-A). The analysis of noise levels included a review of ten hours of one-second resolution noise level data at site 5, which identified 48 impulsive noise events potentially attributable to port-related activity. The overall analysis at sites 4 and 5 found that impulsive noise events related to activities such as material handling and train shunting resulted in L_{max} ranging from 42.9 to 53.8 dBA (A-weighted decibels; Table 3-4 of EIS Appendix 9.3-A). At site 3, port-related noise events were not measurable.

A similar analysis was conducted for this response to identify the sources, port-related and otherwise, of the highest L_{max} measurements for a typical night of operation. This involved a review of noise measurements in 15 minute intervals. Through this analysis, it was determined that port-related activity was not the likely the cause of many of the 15-minute L_{max} that are plotted in the noise history charts for sites 3, 4, and 5. At sites 4 and 5, over 50% of the L_{max} plotted in the noise history charts of Appendix B of EIS Appendix 9.3-A were greater than 55 dBA. Therefore, the highest 50% of the 15-minute L_{max} measured at sites 4 and 5 were higher than the 42.9 to 53.8 dBA range that was established for port-related activity, and were likely due to non-port-related activities such as aircraft.

References

U.S. Department of Transportation Federal Highway Administration (FHWA). 1998. FHWA Traffic Noise Model User's Guide.

IR7-10 Atmospheric Noise – Nighttime Levels

Information Source(s)

EIS Volume 2: Appendix 9.3-A; Table 3-11, Table 3-21, Section 4.1; Section 9.3.4; Section 9.3.9

Context

In Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS, the Proponent provided the predicted noise levels (L_d, L_n, and L_{dn}) for sites 3, 4 and 5 during construction and operation of the proposed Project. In Section 4.1 of Appendix 9.3-A of the EIS, the Proponent provided a summary of key findings for the noise assessment. However, the discussion presented in Section 4.1 of Appendix 9.3-A of the EIS regarding noise in the upland study area focused exclusively on L_{dn}. Similarly, the supporting discussion in Section 9.3.9 of the EIS also focused on L_{dn}.

As stated by the Proponent in Section 9.3.4 of the EIS, when calculating L_{dn}, all noise levels occurring between 10:00 p.m. and 7:00 a.m. are increased by 10 dBA to reflect the greater sensitivity of residential communities to noise at night. However, a discussion of the nighttime noise levels in the upland study area during both construction and operation is also required due to the importance of these noise levels when assessing the potential for sleep disturbance.

Information Request

Using the revised model outputs from Review Panel information requests IR7-01, provide a summary of key findings regarding L_n in the upland study area during both construction and operation of the proposed Project.

VFPA Response

The response to IR7-01 in CEAR Document #1104[1] provided nighttime equivalent sound levels (L_n) calculated under worst-case meteorological conditions. The calculations were carried out according to ISO 9613 (ISO 1996) with the influence of meteorology on sound propagation accounted for using the CONCAWE method (CONCAWE 1981). Please refer to IR7-01 (CEAR Document #1104) for a detailed discussion of these calculations.

Nighttime Noise Levels Under Worst-case Meteorological Conditions

Table IR7-10-1 provides nighttime equivalent noise level for Project operation at sites 3, 4, and 5, assuming worst-case meteorological conditions according to the CONCAWE method.

[1] 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).

Provided for comparison are the noise levels presented in the EIS, which are for annual-average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999).

Table IR7-10-1 Noise Levels at Sites 3, 4, and 5 for Worst-case Meteorological Conditions under the CONCAWE Model – Future Conditions with Project Operation

Site	Nighttime Equivalent Noise Level, L_n (dBA)		Worst-case (CONCAWE) L_n minus Annual-average (EIS) L_n (dBA)
	Worst-case Meteorology, CONCAWE	Annual-average Meteorology, EIS	
3	54.1	51.7	2.4
4	52.2	46.5	5.7
5	55.1	49.6	5.5

Table IR7-10-1 shows that worst-case L_n during Project operation at sites 3, 4, and 5 are predicted to be 2.4 to 5.7 dBA (A-weighted decibels) higher than the predicted annual average L_n.

Table IR7-10-2 provides L_n for Project construction at sites 3, 4, and 5 assuming worst-case meteorological conditions according to the CONCAWE method. Provided for comparison are the construction phase noise levels presented in the EIS, which are for annual-average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999).

Table IR7-10-2 Noise Levels at Sites 3, 4, and 5 for Worst-case Meteorological Conditions under the CONCAWE Model – Project Construction Phase

Site	CONCAWE - Project Construction Phase L_n (dBA)		EIS - Project Construction Phase L_n (dBA)		Noise Level Differences between CONCAWE and EIS Project Construction Phase L_n	
	Range	Average	Range	Average	Range	Average
3	51.5 – 57.9	53.3	51.5 – 53.5	51.9	0.0 – 4.4	1.4
4	44.5 – 55.9	48.9	44.5 – 49.3	45.8	0.0 – 6.6	3.1
5	48.5 – 51.3	49.6	48.5 – 49.1	48.7	0.0 – 2.2	0.9

Table IR7-10-2 indicates that, under the CONCAWE method 'worst-case' conditions, nighttime noise during the construction phase are predicted to be from 0.0 to 6.6 dBA higher, relative to the construction phase noise levels in Table 9.3-18 of the EIS. The two results are not directly comparable. The application of the CONCAWE method is limited as it cannot handle changing ground conditions and assumes that the worst-case weather condition is constant over an extended day or night period resulting in an unrealistic scenario (see IR7-01 in CEAR Document #1104 for a discussion on the limitations of the method). Table 9.3-18 of the EIS reflects annual average meteorological conditions. When the two methods are

compared, it means the L_n construction noise levels may be up to 3.1 dBA higher than annual average sound levels if CONCAWE 'worst-case' meteorological conditions were to occur.

The L_n presented in **Tables IR7-10-1** and **IR7-10-2** reflect worst-case meteorological conditions, which are forecast to occur up to 20% of the time on an annual-basis (see response to IR7-01 in CEAR Document #1104). However, given the variable nature of weather, these days or hours could occur over the course of several weeks, or be spread randomly over the year in periods of a few isolated hours at a time.

The analysis provided above demonstrates the variation in nighttime noise levels that could occur under worst-case meteorological conditions, depending on the Project construction or operation activities taking place at the same time as the worst-case meteorological conditions. While the Panel's context to this information request indicates that information on nighttime noise levels is important for the assessment of sleep disturbance, it should be clarified that the Human Health Risk Assessment for Atmospheric Noise and Vibration (EIS Appendix 27-C) relies on annual-average noise levels to evaluate noise-related risks to human health as per World Health Organization guidelines (WHO 2009). As such, it is not appropriate to use these worst-case L_n to evaluate potential noise-related health effects due to sleep disturbance, but rather the annual average L_n values (representing annual average meteorological conditions) provided herein. The annual average L_n values for Project construction and operation are also included in Section 9.3.9.3 of the EIS.

References

Bavarian Environment Agency (LfU-Bayern). 1999: Meteorologische Korrektur (C_{met}).

CONCAWE (Oil Companies' European Association for Environment, Health and Safety). 1981. The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities. Report no. 4/81, prepared by C.J. Manning. Den Haag, May 1981. Available at https://www.concawe.eu/wp-content/uploads/2017/01/rpt_81-4ocr-2004-01264-01-e.pdf. Accessed September 2017.

International Standards Organization (ISO). 1996. ISO Standard 9613-2, Acoustics-Attenuation of Sound During Propagation Outdoors, Part 2 – General Method of Calculation.

World Health Organization (WHO). 2009. Night Noise Guidelines for Europe. Hurtley, C. (Ed). Available at www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2009/ night-noise-guidelines-for-europe. Accessed September 2017.

IR7-11 Atmospheric Noise – Mitigation and Adaptive Management Measures

Information Source(s)

EIS Volume 5: Section 33; Section 33.3.6; Section 33.4.4; Section 33.5; Table 35-2

CEAR Doc#579

Context

In Section 33 of the EIS, the Proponent highlighted that a noise management plan would be used to mitigate the potential effects of noise during both construction and operation of the proposed Project. The Proponent noted that, based on final designs and the detailed construction approach of the Project, noise abatement measures and timing of specific construction activities will be planned to limit disruption to sensitive receptors. Section 33.3.6 and Section 33.4.4 of the EIS described the potential measures that could be implemented to mitigate construction and operational noise, respectively. Table 35-2 of the EIS also outlined the Proponent's commitments with respect to the mitigation of noise, as well as commitments for the mitigation of effects on other intermediate and valued components.

Numerous participants in the environmental assessment have expressed concerns regarding the potential effects of construction and operational noise from the Project. Many of the participants presented examples of noise effects based on their experience with the Deltaport Third Berth project. Although it is expected that the Proponent would use existing information to inform its assessment of environmental effects and the development of mitigation measures, it is unclear as to what degree the results of the follow-up program from the Deltaport Third Berth project were used in providing the mitigation measures for noise noted in the above paragraph.

In Section 33.5 of the EIS, the Proponent highlighted the importance of its compliance monitoring plans, as well as its long-term approach to adaptive management measures in relation to noise. Additional information from the follow-up program from the Deltaport Third Berth project should be used to provide additional detail regarding the mitigation measures to be implemented as part of the construction and operational noise management plan for the Project.

Information Request

Describe how the results of the follow-up program for the Deltaport Third Berth project were used to inform the measures described in the construction and operation noise management plan for the proposed Project.

Provide a description of any adaptive management measures for noise realized during the Deltaport Third Berth project that could be implemented as mitigation measures for the Project.

VFPA Response

Describe how the results of the follow-up program for the Deltaport Third Berth project were used to inform the measures described in the construction and operation noise management plan for the proposed Project.

The Deltaport Third Berth (DP3) Project noise management approach included implementation of noise monitoring and mitigation during construction, as well as community engagement. There was no specific follow-up program directly related to noise for the DP3 Project.

In planning for the RBT2 environmental assessment, the VFPA undertook a community feedback survey focused on noise to solicit input on the components of the noise mitigation and management plans as described in the EIS. The VFPA will develop details of these mitigation and management plans based on this information and will incorporate lessons learned from the monitoring conducted for DP3. Each of these components, and how they will inform the development of the RBT2 construction and operation noise management plans, are discussed in the sections below.

Noise Monitoring During DP3 Construction

During construction of the DP3 Project, the VFPA received complaints regarding noise from project-related dredging activities, specifically the Columbia dredge. In response to these complaints, noise monitoring was subsequently conducted by BKL Consultants Ltd. and the VFPA (VFPA 2009). The noise monitoring demonstrated that project-related dredging activities were causing an increase in noise levels. Based on results of the noise monitoring, the VFPA required the contractor to install additional silencers on the dredge equipment to mitigate noise from the dredging activities, as discussed in greater detail in the second part of the response below.

Experience gained through DP3 construction noise monitoring will inform the development of the RBT2 Construction Noise Management Plan (outlined in EIS Section 33.3.6).

Community Communications during DP3 Construction

The VFPA provided several mechanisms through which DP3 construction noise related complaints could be communicated, such as participation in the Delta Community Liaison Committee, the 24-hour Community Response Line, and the dedicated project email address. Community feedback was used to target noise monitoring and identify additional mitigation.

Feedback received during DP3 through these mechanisms will inform the development of the RBT2 Construction Noise Management Plan, as well as the Construction Communications Plan (outlined in EIS Section 33.3.16). The plan will describe how interested parties (including local residents) will be informed of the nature, location, status, and progress of construction activities.

Based on the effectiveness of the communication channels for DP3, the VFPA will carry these mechanisms forward for RBT2 including the Delta Community Liaison Committee, the 24-hour

Community Response Line, and the dedicated RBT2 Project email address (container.improvement@portvancouver.com).

Permanent Noise Monitoring Stations

Since DP3, the VFPA has made efforts to gain a better understanding of the existing noise environment and associated community concerns within its jurisdiction. Since 2013, the VFPA has implemented a long-term noise monitoring program that captures sound levels in real time[1]. The recording and analysis of the noise environment enables identification of potential areas for improvement. Permanent noise monitoring stations have been deployed in the Roberts Bank trade area since 2014 and 2015, including monitoring stations at Roberts Bank, shown in Figure IR7-11-A1 in **Appendix IR7-11-A**.

Data from continuous monitoring will inform the specific noise monitoring and noise management plans (construction and operation) as outlined in EIS Sections 27.7.2, 33.3.6, and 33.4.4.

Community Feedback Survey

In planning for RBT2, the VFPA undertook a community survey to inform scoping of RBT2 noise assessment. The survey aimed to determine the types, locations, and perceived sources of existing noise in the community (Economic Planning Group 2013). Feedback from this survey informed the scope of the assessment, modelling, and locations of the measurement program of existing noise (described in EIS Appendix 9.3-A).

Community concerns about the influence of weather conditions on the prominence of noise from the existing terminals informed the development of a study of the effects of meteorological conditions on sound propagation from Roberts Bank terminals (Wakefield Acoustics Ltd. 2014).

The learnings described above from the DP3 Project, and more recently with permanent noise monitoring and the community survey, will inform the specific measures to be included in the RBT2 construction and operation noise management plans.

Provide a description of any adaptive management measures for noise realized during the Deltaport Third Berth project that could be implemented as mitigation measures for the Project.

During DP3 construction, noise complaints during dredging activity were followed up with noise monitoring, as described above. The installation of additional silencers on dredge equipment as a mitigation measure was effective in that it reduced the noise emissions from dredging activities to acceptable levels, and resulted in reduced noise complaints. If RBT2 construction phase monitoring indicates that dredging activities are resulting in exceedances of noise level thresholds, the use of silencers could be implemented as an adaptive mitigation

[1] Real time noise monitoring accessible at https://www.portvancouver.com/port-dashboard/noise-monitoring/.

measure. The application of this specific mitigation measure, the use of silencers, depends on the dredge equipment to be used, and the distance of the noise source from receptors. Given that the intermediate transfer pit (ITP) will no longer be used as part of RBT2[2], the location of the majority of the dredging during RBT2 construction will be approximately 2 to 4 km further from land-based receptors than the dredging activity was for DP3.

Measures to adaptively mitigate noise issues identified through RBT2 construction and operation monitoring will build on learnings from the DP3 Project, and other relevant projects. Please refer to the response to IR7-12 for detailed information on additional potential measures to mitigate noise from RBT2, if monitoring were to identify exceedances of thresholds.

References

Economic Planning Group. 2013. Roberts Bank Terminal 2: Survey of Area Residents Regarding Noise and Vibration Issues. Available at http://www.robertsbankterminal2.com/environmental-assessment/technical-data-reports/. Accessed August 2017.

Vancouver Fraser Port Authority (VFPA). 2009. Pre-Operations EAC Compliance Report; Deltaport Third Berth Project. Available at https://www.portvancouver.com/wp-content/uploads/2015/03/DP3_Pre-Operations_Compliance_Report.pdf. Accessed August 2017.

Wakefield Acoustics Ltd. 2014. Roberts Bank Terminal 2 Technical Data Report; Upland Noise and Vibration – Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals. Available at http://www.robertsbankterminal2.com/environmental-assessment/technical-data-reports/. Accessed August 2017.

Appendices

Appendix IR7-11-A Supporting Figure

[2] Refer to Preamble in Support of Responses to IR4-25 to IR3-24 (General and Disposal at Sea-related Project Construction Update) in CEAR Document #984 for more information.

APPENDIX IR7-11-A
SUPPORTING FIGURE

Path: O:\1200-\1246\EIS_INFORMATION_REQUEST\SIR7_11\mxd\IR7_11_A1_PermanentNoiseMonitoringStations_171117.mxd

Canoe Passage

Roberts Bank

Inter-causeway Area

Strait of Georgia

Boundary Bay

MUSQUEAM I.R. 4

Tsawwassen First Nation

Tsawwassen

CANADA

DELTAPORT WAY

DELTAPORT TERMINAL

EXPANDED TUG BASIN

MARINE TERMINAL

DREDGE BASIN

WESTSHORE TERMINALS

B.C. FERRIES TERMINAL

Deltaport Way

Tsawwassen Golf & Country Club

Tsawwassen Town Centre Mall

Beach Grove Golf Club

Winskill Park

Boundary Bay Cemetery

Pebble Hill Park

Diefenbaker Park

Point Roberts Golf & Country Club

Legend

- PERMANENT NOISE MONITORING STATION
- BOUNDARY OF PROJECT AREA
- U.S.A.-CANADA BORDER

0 1 2

Kilometres

1:40,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

VFPA PERMANENT NOISE MONITORING STATIONS AT ROBERTS BANK

DATE: 11/17/2017

FIG No. IR7-11-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

IR7-12 Atmospheric Noise – Technical and Economic Feasibility of Mitigation Measures

Information Source(s)

CEAR Doc#579

Context

In Appendix A of its submission to the Review Panel (CEAR Doc#579), Health Canada provided a list of commonly applied construction mitigation measures and considerations for noise reductions. Although not all of these measures may be suitable for application to the proposed Project, further information is required to determine whether the measures listed in Appendix A of the Health Canada submission are technically and economically feasible measures that could be used by the Proponent to mitigate the noise from construction and operation of the Project.

Information Request

In a table, summarize whether the measures presented in Appendix A of CEAR Doc#579 are technically and economically feasible measures that could be implemented to mitigate the noise from construction and/or operation of the proposed Project, and provide supporting rationale. Indicate whether the measures would be suitable to mitigate continuous noise, transient and impulsive noise, and/or low-frequency noise.

VFPA Response

Context for Mitigation Evaluation

The noise mitigation measures included in the Health Canada submission (CEAR Document #579[1]) have been evaluated at a preliminary level for technical and economic feasibility. In some cases, more detailed technical evaluation would be required before implementation. Further evaluation would be focused on verifying technical and economic feasibility, as well as potential effectiveness and appropriateness in terms of mitigating the specific RBT2-related sources and types of noise. A summary of the preliminary evaluation is provided in Table IR7-12-A1 of **Appendix IR7-12-A**.

Environmental Management Plans

Most of the measures in the Health Canada submission are specific practices that could be included as part of construction and operation environmental management plans (EMPs). The

[1] CEAR Document #579 From Health Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project (NOTE: Updated October 18, 2016).

EMPs where similar practices are proposed in the EIS as mitigation for noise and noise-related effects on human health (EIS Section 27.7.2) are referred to throughout Table IR7-12-A1 (**Appendix IR7-12-A**), and are listed below:

Construction environmental management plans:

- Construction Compliance Monitoring Plan (EIS Section 33.3.1);
- Noise Management Plan (EIS Section 33.3.6);
- Land and Marine Traffic Management Plan (EIS Section 33.3.9); and
- Communications Plan (EIS Section 33.3.16).

Operation environmental management plans:

- Operation Compliance Monitoring Plan (EIS Section 33.4.1); and
- Noise Management Plan (EIS Section 33.4.4).

Adaptive Management Measures

Noise levels in the local study area will be monitored before and during construction, and during operation as part of the construction and operation monitoring plans and the RBT2 Follow-up Program (EIS Section 33.5). If unanticipated effects are identified, additional mitigation measures may be implemented to further reduce noise levels, as an adaptive management strategy. Some of the measures in Table IR7-12-A1 (**Appendix IR7-12-A**), if confirmed to be technically and economically feasible upon further evaluation, may be considered as adaptive management mitigation measures to be undertaken if monitoring identifies exceedances related to RBT2 construction or operations activities.

Project-specific Context

Several entries in Table IR7-12-A1 (**Appendix IR7-12-A**) refer to measures that would be relevant for projects with construction or operation activities taking place immediately adjacent to, or in near proximity to, neighbouring residences. In the case of RBT2, the nearest residents range in proximity from approximately one kilometre away from construction works at the east end of the causeway, to over five kilometres away from construction and operation activities at the terminal.

Overview of Mitigation Evaluation Table

The details of the Health Canada submission, *Appendix A. Commonly Applied Construction Noise Mitigation Measures and Considerations for Noise Reduction* (CEAR Document #579), are included in their entirety in Table IR7-12-A1 (**Appendix IR7-12-A**) as 67 separate entries. Where entries consist of general comments with no specific measures for evaluation, these are noted as such. As an initial filter, each specific measure was reviewed for applicability to the RBT2 Project. For those that do not apply, a rationale is provided, and the measures are not evaluated further. For those measures that are applicable to the Project, information is provided on the phase (construction, operation, or both) in which the measures would apply, and the type of noise (continuous, transient, impulsive, or low-frequency noise)

that could potentially be mitigated by the measure. If a similar measure is included in the EIS, this is also noted within the table.

A preliminary and high-level indication of the technical and economic feasibility is provided for each applicable measure. Based on preliminary evaluation, a suggested measure is indicated as 'technically feasible' if the specific technology proposed (if any) is available and applicable, and fits with local site characteristics, Project design, and construction schedule. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

Appendices

Appendix IR7-12-A Supporting Table

APPENDIX IR7-12-A
SUPPORTING TABLE

Table IR7-12-A1 Evaluation of Noise Mitigation Measures

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
General Mitigation Measures							
1	Include in tenders, employment contracts, subcontractor agreements and work method statements clauses that assure the minimisation of noise and compliance with directions from management to minimise noise.	Yes – General comment, no specific measure to evaluate	--	--	--	--	--
2	Give preference to the use of quieter technology or other mitigation measures rather than lengthening construction duration (i.e., it is not recommended to lower noise by having fewer pieces of equipment running at a time thereby leading to extended construction duration).	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	Yes
3	Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways that minimise noise.	Yes – For evaluation	Construction and Operation	Similar measure included in outline for RBT2 Construction and Operation Noise Management Plans in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
4	Ensure that site managers periodically check the site, nearby residences and other sensitive receptors for noise problems so that solutions can be quickly applied.	Yes – For evaluation	Construction and Operation	Similar measure included in outline for RBT2 Construction and Operation Compliance Monitoring Plans in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Compliance Monitoring Plans	Yes
5	Avoid the use of radios and stereos outdoors and the overuse of public address systems where neighbours can be affected.	Yes – For evaluation	Construction	--	Continuous, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
6	Avoid shouting, and minimise talking loudly and slamming vehicle doors.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
7	Keep truck drivers informed of designated vehicle routes, parking locations, acceptable delivery hours and other relevant practices (e.g., minimising the use of engine brakes and periods of engine idling).	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan, and/or Land and Marine Traffic Management Plan	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Nighttime Mitigation Measures							
8	Avoid the use of equipment that generates impulsive noise.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan, specific to pile driving activity	Yes
9	Minimise the need for reversing alarms.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
10	Avoid dropping materials from a height.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Minimisation of dropping materials from heights could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
11	Avoid metal-to-metal contact on equipment.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	*Construction:* Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan *Operation:* No – Primary Project activities involve metal-to-metal contact (e.g., rail movements, container handling and stacking)	Yes – For construction
12	If possible, schedule truck movements to avoid residential streets.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan and/or Land and Marine Traffic Management Plan	Yes
13	Avoid mobile plant clustering near residences and other sensitive receptors.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan.	Yes
14	Ensure that periods of respite are provided in the case of unavoidable maximum noise level events.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Further evaluation required

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Consultation and Notification							
15	Provide related information [about noise] that is frank, and does not attempt to understate the likely noise level; respect commitments.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Communications Plan in EIS	N/A	Yes – Measure could be included in the final RBT2 construction Communications Plan	Yes
Notification Before and During Construction							
16	Provide advance notification to people concerning construction duration, defining activities that are expected to be noisy and their expected duration, what noise mitigation measures are being applied, and when noisy periods will occur.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Communications Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – To be implemented as specified in the final RBT2 construction Communications Plan	Yes
17	For nighttime work, receptors may be informed in two stages: two weeks prior to construction and then two days before commencement.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic to be included as part of construction Communications Plan; to be adapted specific to Project construction plan	Yes
18	Provide information to neighbours before and during construction through media such as letterbox drops, meetings, or individual consultation. In some areas, the need to provide notification in languages other than English may be considered. A website may also be established for the project.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in construction Communications Plan	Yes
19	Use a site information board at the front of the site with contact details, hours of operation, and regular information updates.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Communications Plan	Yes
20	Facilitate contact with people to ensure that everyone can see that the site manager understands potential issues, that a planned approach is in place, and that there is an ongoing commitment to minimise noise.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in construction Communications Plan.	Yes
Plant and Equipment							
21	In terms of both cost and results, controlling noise at the source is one of the most effective methods of minimising the noise impacts from any construction activities.	Yes – General comment, no specific measure to evaluate	--	--	--	--	--

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Quieter Methods							
22	Examine and implement, where feasible and reasonable, alternatives to rock-breaking work methods such as hydraulic splitters for rock and concrete, hydraulic jaw crushers, chemical rock and concrete splitting, and controlled blasting such as penetrating cone fracture.	No – Rock materials will be transported to site by barge from local quarries. No rock splitting or blasting activities on site at RBT2	N/A	N/A	N/A	N/A	N/A
23	Consider alternatives to diesel and gasoline engines and pneumatic units such as hydraulic or electric-controlled units where feasible and reasonable. When there is no electricity supply, consider using an electrical generator located away from residences.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
24	Examine and implement, where feasible and reasonable, alternatives to transporting excavated material from underground tunnelling offsite at nighttime (i.e., stockpile material in an acoustically treated shed during the night and load out the following day).	No – No underground tunnelling as part of RBT2 construction plan	N/A	N/A	N/A	N/A	N/A
25	Examine and implement, where feasible and reasonable, alternatives to pile driving using a diesel hammer, such as hydraulic hammer, hydraulic press-in, or vibratory pile driver.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Underwater Noise Management Plan in EIS **Note:** As per Appendix IR12-A (Summary of Proposed Mitigation and Related Effectiveness; CEAR Document #314), the Underwater Noise Management Plan for construction will include use of vibratory hammer instead of impact pile driving when practical.	Impulsive/transient	Yes – Measure could be included in the Underwater Noise Management Plan	Yes
26	To reduce the impact of backup alarms, examine and consider implementing, where feasible and reasonable, ambient sensitive backup alarms, signal workers, turning circles, and side loading/unloading trucks.	Yes – For evaluation	Operation	Similar measure included in outline for RBT2 Operation Noise Management Plan in EIS	Impulsive/transient	Yes – Measure could be included in Operation Noise Management Plan	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Quieter Equipment							
27	Examine different types of machines that perform the same function and compare the noise level data to select the least noisy machine (i.e., rubber-wheeled tractors can be less noisy than steel-tracked tractors).	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
28	Pneumatic equipment is traditionally a problem. Consider selecting super-silenced compressors, silenced jackhammers, and damped bits where possible.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
29	When renting (or purchasing) equipment, select quieter pieces of plant and construction equipment where feasible and reasonable. As well, select the most effective mufflers, enclosures, and low-noise tool bits and blades. Always seek the manufacturer's advice before making modifications to any equipment to reduce noise.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Further evaluation required
30	Reduce throttle settings and turn off equipment when it is not being used.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise	Yes – Measure could be included in Construction Noise Management Plan	Yes
31	Examine and consider implementing, where feasible and reasonable, the option of reducing noise from metal chutes and bins by placing damping material in the bin.	No – Chutes and bins are typically associated with demolition work and will not be used in RBT2 construction	N/A	N/A	N/A	N/A	N/A
Equipment Maintenance							
32	Regularly inspect and maintain equipment to ensure that it is in good working order, including the condition of mufflers.	Yes – For evaluation	Operation	Similar measure included in outline for RBT2 Operation Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Operation Noise Management Plan	Yes
33	For machines with enclosures, verify that doors and door seals are in good working order and that the doors close properly against the seals.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
34	Return any leased equipment that is causing noise that is not typical for the equipment. The increased noise may indicate the need for repair.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
35	Ensure that air lines on pneumatic equipment do not leak.	Yes – For evaluation	Construction and Operation	--	Continuous	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
Site Mitigation Measures							
36	Barriers and acoustic sheds are most suited to long-term fixed works as in these cases, the associated cost is typically outweighed by the overall time savings.	General comment – No specific measure for evaluation (specific measures re: barriers are evaluated in #43 to #48 and #62 to #67)	--	--	--	--	--
Equipment Location							
37	Place as much distance as possible between the equipment and residences and other sensitive receptors.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	Yes
38	Restrict areas in which mobile plants can operate so that they are away from residences and other sensitive receptors at particular times.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Yes
39	Locate site vehicle entrances away from residences and other sensitive receptors.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	No – The Project is accessible to vehicles only by the Roberts Bank causeway. Alternative vehicle entrances not available or possible, due to geographic characteristics of site	No – Not economically feasible to construct alternative entrances
40	Carry out noisy fabrication work at another site (e.g., within enclosed factory premises) and then transport products to the Project site.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Majority of metal fabrication (e.g., steelwork for buildings and equipment) will be completed offsite	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Alternatives to Reversing Alarms							
41	Avoid the use of reversing alarms by designing the site layout to avoid reversing, such as by including drive-through for parking and deliveries.	No – Container trucks are not required to have back up alarms and generally do not have them.	N/A	N/A	N/A	N/A	N/A
42	When applicable legislation permits, consider less annoying alternatives to the typical 'beeper' alarms. Examples include smart alarms that are adjustable in volume depending on the ambient level of noise, and multi-frequency alarms that emit noise over a wide range of frequencies.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
Maximise Shielding							
43	Re-use existing structures rather than demolishing and reconstructing.	No – No demolition involved in RBT2 construction	N/A	N/A	N/A	N/A	N/A
44	Use full enclosures, such as large sheds, with good seals fitted to doors to control noise from nighttime work.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Yes
45	Use temporary site buildings and material stockpiles as noise barriers.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Project design includes temporary site buildings, and pre-load stockpiles on causeway and terminal at various stages; when situated between noise sources and receptors, noise shielding may occur	Yes
46	Schedule the construction of permanent walls so that they can be used as noise barriers as early as possible.	No – Buildings on terminal will be constructed near end of construction phase	N/A	N/A	N/A	N/A	N/A
47	Use natural landform as a noise barrier. Place fixed equipment in cuttings or behind earth berms.	No – Project site is flat/over water	N/A	N/A	N/A	N/A	N/A
48	Take note of large reflecting surfaces on- and offsite that might increase noise levels, and avoid placing noise-producing equipment in locations where reflected noise will increase noise exposure or reduce the effectiveness of mitigation measures.	No – Measure applies to vertical surfaces; the only vertical surfaces will be between the noise sources and receptors, and would act as barriers versus reflecting noise toward receptors	N/A	N/A	N/A	N/A	N/A

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Work Scheduling							
49	Schedule noisy work during periods when people are least affected.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management plan, specific to pile driving activity	Yes
Provide Respite Periods							
50	Consult with schools to ensure that noise-generating construction works in the vicinity are not scheduled to occur during examination periods, unless other acceptable arrangements (such as relocation) can be made.	No – No schools located in areas where construction or operation noise is predicted to exceed thresholds for learning environments.	N/A	N/A	N/A	N/A	N/A
51	When night work near residences cannot be feasibly or reasonably avoided, restrict the number of nights per week and/or per calendar month that the work is undertaken.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be considered as adaptive measure in Follow-up Program	Further evaluation required
Schedule Activities to Minimise Noise Impacts							
52	Organise work to be undertaken during the recommended standard hours where possible.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	No – Would effectively double duration of construction for in-water works, and increase environmental effects	No – Would cause significant delays to overall construction phase
53	If the construction site is in the vicinity of a sports venue, consider scheduling work to avoid times when there are special events.	No – No sports venues located in the vicinity of construction	N/A	N/A	N/A	N/A	N/A
54	When work outside the recommended standard hours is planned, avoid scheduling it on Sundays or public holidays.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	No – Would cause significant delays to overall construction phase
55	Schedule work when neighbours are not present (e.g., commercial neighbours, college students, and school students may not be present outside business hours or on weekends).	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	No – Would effectively double duration of construction for in-water works, and increase environmental effects	No – Would cause significant delays to overall construction phase
56	Schedule noisy activities around times of high background noise (i.e., when local road traffic or other local noise sources are active) where possible to provide masking or to reduce the amount that the construction noise intrudes above the background noise.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan, specific to pile driving activity	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Deliveries and Access							
57	Nominate an offsite truck parking area away from residences for trucks arriving prior to gates opening and schedule deliveries only during specified periods.	Yes – To be evaluated	Construction	--	Continuous, low-frequency noise, impulsive/transient	Further evaluation required – Measure to be considered further in the detailed design stage of the Project	Further evaluation required
58	Optimise the number of vehicle trips to and from the site. Movements can be organised to amalgamate loads rather than using a number of vehicles with smaller loads.	Yes – Construction plan is based on assumption of full loads for all truck trips	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure addressed by Project design	Yes
59	Designate access routes to the site through consultation with potentially noise-affected residences and other sensitive receptors, and inform drivers of nominated vehicle routes.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Land and Marine Traffic Management Plan in EIS	Low-frequency noise, impulsive/transient	Yes – Measure could be included in Land and Marine Traffic Management Plan	Yes
60	Provide onsite parking for staff and onsite truck waiting areas away from residences and other sensitive receptors.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	*Construction:* Further evaluation required – Measure to be considered further in the detailed design stage of the Project *Operation:* Yes – Onsite employee parking included in terminal design	Further evaluation required
61	Truck waiting areas may require walls or other barriers to minimise noise.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	*Construction:* Yes – Measure (temporary barriers) could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program *Operation:* Further evaluation required – Measure (permanent barriers) to be considered further in the detailed design stage of the Project	*Construction:* Yes *Operation:* Further evaluation required

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Noise Transmission Path							
62	Physical methods to reduce the transmission of noise between construction locations and residences or other sensitive receptors are generally suited to construction projects in which there is long-term noise exposure.	General comment – no specific measure for evaluation (see #63-67)	--	--	--	--	--
63	Reduce the line-of-sight noise transmission to residences and other sensitive receptors using temporary noise barriers.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure (temporary barriers) could be considered as adaptive measure in Follow-up Program	Yes
64	Temporary noise barriers can be constructed from boarding (plywood boards, panels of steel sheeting, or compressed fibre cement board) with no gaps between the panels at the site boundary.	Barrier materials to be considered as part of #63.	N/A	N/A	N/A	N/A	N/A
65	Stockpiles and shipping containers can be effective noise barriers.	Yes – For evaluation	Operation	--	Continuous, low-frequency noise, impulsive/transient	No – Orientation of terminal does not allow for stacking containers between noise sources and receptors	No – Re-design of terminal would be required
66	Erect temporary noise barriers before work commences to reduce noise from construction as soon as possible.	Timing of barriers to be considered as part of #63	N/A	N/A	N/A	N/A	N/A
67	Where high-rise dwellings adjoin the construction site, the height of a barrier may not be sufficient to effectively shield the upper levels of the residential building from construction noise. Find out whether this is a consideration for the Project and examine alternative mitigation measures where needed.	No – No high-rise dwellings adjacent to construction site.	N/A	N/A	N/A	N/A	N/A

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

Preamble for IR7-13 to IR7-23 Wave Environment Information Requests

The technical approach adopted to conduct the wave environment effects assessment that was included in Section 7.2 and Appendices 7.1 and 7.2 of the Marine Shipping Addendum was informed by the Updated Guidelines for the Preparation of an Environmental Impact Statement for the Roberts Bank Terminal 2 Project (Updated EISG, 2015). Specifically, the following guidance appears in section 17, under the introductory heading "Anticipated Level of Effort":

> *"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."*

Incorporating the expected technical scope of assessment specified in the Updated EISG, the objective of the wave environment effects assessment was to evaluate the contribution of waves generated by RBT2-associated vessels to the existing wind-generated wave climate. The adopted study methodology is similar to the approach taken to assess wake from ships for the Kitimat LNG Export Terminal Project near Kitimat, B.C. (Moffatt and Nichol (2011) report, appended to IR7-17 as Appendix IR7-17-A) and the Woodfibre LNG Project near Squamish, B.C. (Moffatt and Nichol 2014). The Moffatt and Nichol (2011) report (Appendix IR7-17-A) forms the basis for the wake assessment for the Trans Mountain Expansion Project. Fisheries and Oceans Canada (DFO) reviewed the application submitted to the National Energy Board (NEB) pertaining to the Trans Mountain Expansion Project and described the wake assessment approach as "quantitative" (DFO 2014). The Marine Shipping Addendum expands on the methodology presented in the Moffatt and Nichol (2011) report (Appendix IR7-17-A) by considering vessel speed and water depth at 4 km intervals along the shipping route, rather than assuming an average across a segment.

The following series of statements regarding wake interactions with the existing wave environment summarises the logical approach to assessing wake for the wave environment effects assessment:

a) The wave environment in the marine shipping area, including Segments A to C, is dominated by wind-generated waves, and Segment D is dominated by both wind-generated waves and swell from the Pacific Ocean;
b) Waves generated by passing vessels contribute to the existing wave environment;
c) The shorelines within the marine shipping area are exposed to wind-generated waves arriving from open water on an ongoing, long-term basis;

d) Shorelines that are exposed to waves contributed by vessels transiting in the international shipping lanes are also exposed to wind-generated waves on an ongoing basis;
e) Waves arriving from open water are likely to interact with the shoreline in a variety of ways, including shoaling, reflection, and refraction, as the water depth decreases in the near-shore environment; and
f) Project-associated marine traffic is not expected to change how waves arriving from open water will interact with shorelines in the marine shipping area.

Detailed investigations of the nearshore wave interactions (i.e., shoaling, reflection, and refraction) were not assessed since these processes are occurring in relation to the existing wave climate and are unaffected by Project-associated vessels.

The information included above is referred to or expanded upon in the responses to the wave environment information requests (IR7-13 to IR7-23) that follow. A common theme across these eleven information requests is around uncertainty in the wave assessment results. The VFPA has demonstrated in the following responses that the approach taken is appropriate to the level of detail required in the investigation and that the results can be relied upon for the purposes of the wave environment assessment.

References

Fisheries and Oceans Canada (DFO). 2014. Hearing Order OH-001-2014: Trans Mountain Pipeline ULC (Trans Mountain) Application for the Trans Mountain Expansion Project (OH-001-2014). Written evidence submitted by Fisheries and Oceans Canada (Intervenor). 38 pp.

Moffatt and Nichol. 2011. Vessel Wake Study (DRAFT). Report prepared by Moffatt & Nichol for KM LNG Operating General Partnership, Vancouver, BC. 18 pp. Provided as Appendix IR7-17-A in the response to IR7-17.

Moffat and Nichol. 2014. Woodfibre LNG - Vessel Wake Assessment. Available at https://www.woodfibrelng.ca/wp-content/uploads/2014/08/Moffatt-and-Nichol-wake-study.pdf. Accessed October 2017.

IR7-13 Wave Environment – Numerical Wave Model

Information Source(s)

Marine Shipping Addendum: Appendix 7.2-A, Figure 1

Context

In Appendix 7.2-A of the Marine Shipping Addendum, the Proponent modelled wind-driven waves using local meteorology for the year 2012 as input to the numerical wave model described by Donelan *et al* (2012).

The Proponent did not discuss the strengths, weaknesses and sources of uncertainty associated with this numerical wave model.

Information Request

Justify the choice of the Donelan *et al* (2012) numerical wave model to model wind-driven waves in the Deepwater Wave Model Domain shown in Figure 1 of Appendix 7.2-A of the Marine Shipping Addendum.

Provide a discussion of the strengths, weaknesses and sources of uncertainty of the Donelan *et al* (2012) numerical wave model and its use in the proposed Project assessment.

VFPA Response

Justify the choice of the Donelan* et al *(2012) numerical wave model to model wind-driven waves in the Deepwater Wave Model Domain shown in Figure 1 of Appendix 7.2-A of the Marine Shipping Addendum.

The Donelan et al. (2012) model, referred to by the paper's authors as the University of Miami Wave Model (or UMWM), calculates the wave spectrum in deep water in response to a calculated wind stress field. The model's predictive results were compared to a number of field datasets and the model was found to perform well (Donelan et al. 2012). The UMWM calculates wave interactions with the sea bed, which includes the processes of shoaling and diffraction, but it does not include diffraction around breakwaters, reflection from boundaries, or triad interactions in the surf zone (aspects that are not relevant to this study, as described in the *Preamble in Support of Responses to IR7-13 to IR7-23*). In contrast to other widely-used wave models, such as SWAN (Simulating WAves Nearshore; Booij et al. 1999), that incorporate the near-shore shallow-water interactions, the UMWM is more computationally efficient and does not require detailed shoreline bathymetry as input.

The justification for the use of the UMWM is described below:

a) The model is demonstrated to perform well in the deep water environment as compared to field datasets (Donelan et al. 2012; Marine Shipping Addendum Appendix 7.2-A), and is a reliable method to provide the required analysis, as outlined in the Updated EIS Guidelines; and
b) The model is computationally efficient, allowing for the development of a long-term (12 month) representation of the wave environment in the marine shipping area.

Provide a discussion of the strengths, weaknesses and sources of uncertainty of the Donelan* et al *(2012) numerical wave model and its use in the proposed Project assessment.

Model Strengths

The UMWM was developed to provide full atmosphere-wave-ocean coupling that is computationally efficient and robust. Greater computational efficiency means that large areas of ocean can be modelled with relatively high spatial and temporal resolution. With respect to the wave environment assessment for Project-associated vessels, computational efficiency and robustness were important considerations in the choice of model.

Additional strengths of the UMWM, as outlined in Donelan et al. (2012), are that the model can take advantage of parallel processing, meaning that the work of solving the equations can be parsed between multiple computer processors to compute the solution in parts simultaneously, allowing for a more extensive modelling study. In addition, its design follows the standard of the Earth System Modelling Framework (ESMF), which makes it suitable for coupling to atmosphere and ocean circulation models.

Model Weaknesses

The main weakness of the UMWM is that it is not intended to represent near-shore shallow-water wave transformations. This weakness is largely irrelevant to the wave environment assessment, as the approach considers the wake from passing Project-associated ships in the context of the existing wind-generated wave climate and, therefore, does not rely on an assessment of wave transformation in the near-shore environment.

Sources of Uncertainty

Uncertainty with respect to a numerical model and its application to a physical environment is typically considered as relating to a) the natural variability of the phenomenon or environment that is being represented, b) internal simplifications in the model, and c) the parameters specified in the model. These uncertainties are inherent to all models and are not unique to the UMWM and are further explained below.

a) With respect to natural variability, the marine shipping area is a relatively complex environment with numerous islands and a tortuous shoreline, and winds that vary in speed and direction on an ongoing basis. As is the case for all models, the UMWM represents the natural variability in a necessarily simplified form. Within the model, for instance, winds are specified based on measured data at various locations and between these locations the winds are interpolated, as outlined in the response to

IR7-14. It is likely that localised effects of wind direction being affected by topography are not perfectly represented in all areas of the model domain. The use of hourly wind data to describe a phenomenon that naturally varies on the scale of minutes is another example of a necessary simplification that is incorporated.

b) With respect to model simplifications, the code that describes the interactions between the wind field and the ocean surface to generate waves is, by necessity, a generalisation (albeit a sophisticated generalisation) of the real-world phenomena. As described in Donelan et al. (2012), the model represents real-world measurements of open water waves fairly well, but the match is imperfect, partly because the code cannot capture the full complexity of the natural system.
c) With respect to model parameters, the UMWM requires that parameters that describe eddy diffusivity and the characteristics of the wave spectrum are specified by the operator. These are chosen based on existing science, professional judgement, and knowledge of the system being modelled.

For uncertainty associated with the model results that arises from the above items, validation of results reduces the inherent uncertainty. For the validation of the wave environment assessment UMWM results, Appendix 7.2-A of the Marine Shipping Addendum presents a comparison of modelled and observed waves at the Halibut Bank and New Dungeness wave monitoring stations, and at the Roberts Bank AWAC measurement location. These three sites represent the known locations where waves were measured in the marine shipping area during 2012 (see Marine Shipping Addendum Appendix 7.2-A, Figure 2), the year upon which the assessment is based.

The validation process summarised above and expanded upon in the response to IR7-15 demonstrates that the UMWM reproduces the existing wind-driven wave environment in the study area well, and that the uncertainties associated with the use of the UMWM do not undermine the VFPA's confidence in the results.

References

Booij, N., R. C. Ris, and L. H. Holthuijsen. 1999. A Third-generation Wave Model for Coastal Regions: 1. Model Description and Validation. Journal of Geophysical Research: Oceans, 104(C4), 7649–7666. doi:10.1029/98JC02622.

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-14 Wave Environment – Wind Model

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2

Review Panel Information Request IR6-04 (CEAR Doc#991): Air Quality Modelling

Context

Detailed three-dimensional wind field modelling was performed as part of the air quality assessment. Those wind fields are based on models that are far more sophisticated than the two-dimensional wind field model used in the wave assessment.

However, the Proponent did not describe the process whereby two-dimensional, time varying wind fields required as input by the numerical wave model, were generated from various available wind record stations.

A comparison of the modelled wind fields used in the wave assessment modelling with the modelled wind fields used in the air quality assessment modelling would increase confidence in the wave assessment modelling.

Information Request

Describe the process whereby two-dimensional, time varying wind fields required as input by the wave assessment numerical model, was generated from various available wind record stations.

In regions where the modelling domains overlap, compare wind fields used in the wave assessment modelling with those generated by the NMM-WRF-CALMET meteorological modelling system used in the revised air quality assessment of the proposed Project to determine how well the two wind-fields match. Comment on the confidence that the wind fields used in the wave assessment modelling are appropriate.

VFPA Response

Describe the process whereby two-dimensional, time varying wind fields required as input by the wave assessment numerical model, was generated from various available wind record stations.

The University of Miami Wave Model (UMWM), described by Donelan et al. (2012), calculates waves generated by an applied wind stress. As described in Appendix 7.2-A of the Marine Shipping Addendum (MSA), a two-dimensional, time-dependent wind field was generated based on the following wind record stations (locations are shown in MSA Appendix 7.2-A, Figure 2):

- Pam Rocks – Meteorological Service of Canada (MSC) Station 10459NN;

- Halibut Bank wave buoy – Environment Canada Station 46146;
- Sand Heads – MSC Station 1107010;
- Cherry Point wind station – National Oceanic and Atmospheric Administration (NOAA) Station CHYW1;
- Smith Island wind station – NOAA Station SISW1;
- New Dungeness wave buoy – NOAA Station 46088; and
- Neah Bay wave buoy – NOAA Station 46087.

Within the deep water model domain, a 1 km x 1 km grid of the Strait of Georgia and Juan de Fuca Strait was generated using data from existing hydrographic charts. Wind speed and direction were interpolated between the available wind record from these stations using an inverse distance weighting interpolation technique (spatial varying), which is a standard accepted approach used in wave models. For the time-varying component, a linear interpolation between spatial-varying fields was applied. In both cases, the interpolations were incorporated into the model code to produce deep water waves.

In regions where the modelling domains overlap, compare wind fields used in the wave assessment modelling with those generated by the NMM-WRF-CALMET meteorological modelling system used in the revised air quality assessment of the proposed Project to determine how well the two wind-fields match. Comment on the confidence that the wind fields used in the wave assessment modelling are appropriate.

As noted in the Panel's context to this information request, detailed three-dimensional wind field modelling using the Weather Research Forecast Non-hydrostatic Mesoscale Model (WRF-NMM) was performed as part of the RBT2 Air Quality Study (EIS Appendix 9.2-A).

The three-dimensional wind field used in the air quality assessment incorporated a vertical component, while the two-dimensional wind field applied to the wave modelling does not. Source functions were developed based on wind speed and direction at 10 m elevation for the wave modelling, while WRF-NMM incorporated atmospheric conditions at various elevations in the atmosphere as input. Although there is spatial overlap for the UMWM and WRF-NMM modelling domains, the air quality assessment modelling was based on 2010 wind field data while the wave environment assessment was based on 2012[1]. Since there is no temporal scale overlap, the requested comparison of wind fields cannot be provided.

Nevertheless, with respect to the appropriateness of the wind fields used in the wave assessment modelling, since actual wind field data from seven wind record stations within and proximal to the marine shipping area was used as input, and the method of interpolation is a proven and accepted numerical method, the VFPA is confident that the wind fields incorporated in the UMWM reasonably reflect wind field conditions in the marine shipping

[1] The assessment of air quality provided in EIS Section 9.2 incorporated meteorological data from 2010, as this year had highest frequency of calms for the five year period (2008 to 2012) of data reviewed from the Vancouver International Airport, thus providing for the most conservative assessment. The assessment of the wave environment provided in MSA Section 7.2 incorporated 2012 field data, as this data was available from the coastal geomorphology assessment (EIS Section 9.5).

area, and that the use of the UMWM is appropriate to meet the requirements of the wave environment assessment study, as outlined in the response to IR7-13.

References

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-15 Wave Environment – Baseline, Wind-driven Wave Climate

Information Source(s)

Marine Shipping Addendum: Appendix 7.2-A, Figures 4 and 5

Context

In Appendix 7.2-A of the Marine Shipping Addendum, the Proponent modelled wind-driven waves using local meteorology as input. The modelled waves were then evaluated by comparison with wave buoy data collected at Halibut Bank and New Dungeness, as well as wave data from an AWAC (Acoustic Wave and Current Profiler) station near Roberts Bank.

The model evaluation was presented in the form of wave height time series scatterplots (Figures 4 and 5 of Appendix 7.2-A). The Proponent stated that the scatterplots indicated that the model simulated the wave environment at these three sites reasonably well. However, based on the scatterplots, it appears that the model may have underestimated the height of extreme waves.

More information on the ability of the wave model to realistically simulate the wind-driven wave environment in the Salish Sea is required.

Information Request

Provide scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and AWAC Roberts Bank for all months of a year using available data.

Calculate root mean square error, mean bias error and slope of best fit line for each scatterplot.

Based on this analysis, discuss the ability of the wave model to accurately simulate the wave environment in the Salish Sea.

VFPA Response

Provide scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and AWAC Roberts Bank for all months of a year using available data.

In response to the Panel's request, the VFPA has provided scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and the AWAC Roberts Bank site for all months of a year using available data. It was assumed that a quartile signifies one of four groups into which equal numbers of a population are divided according to the distribution of values. Available wave information data is from hourly observations at Halibut Bank, New Dungeness, and at the Roberts Bank AWAC

station. **Table IR7-15-1** provides a summary of the assignment into quartiles of the observed wave height data at each station.

Table IR7-15-1 Summary of Observed Data at Halibut Bank, New Dungeness, and the Roberts Bank AWAC Station

Station	Number of Observations[a]	Wave Height Range (m)			
		1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Halibut Bank	8,784	0.53 – 3.15	0.31 – 0.53	0.15 – 0.31	0 – 0.15
New Dungeness	8,784	0.55 – 2.71	0.31 – 0.55	0.18 – 0.31	0 – 0.18
Roberts Bank AWAC	1,104	0.33 – 1.63	0.21 – 0.33	0.14 – 0.21	0 – 0.14

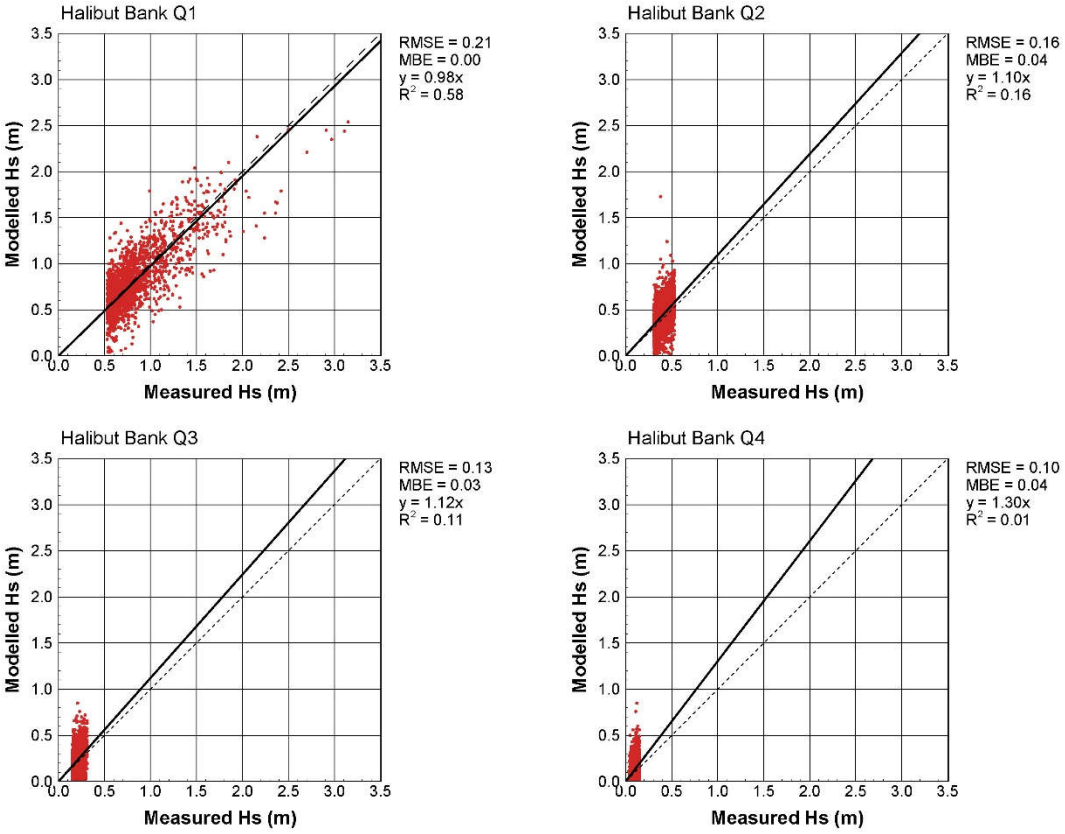
Note: a. 2012 was a leap year containing 366 days or 8,784 hours. The Roberts Bank AWAC station was operational for only part of the year.

Comparisons of modelled and measured significant wave heights for 2012 at Halibut Bank, New Dungeness, and AWAC Roberts Bank are provided in **Figures IR7-15-1** to **IR7-15-3**, respectively. The plots are generated by comparing hourly predictions of modelled wave heights to measured wave heights.

Calculate root mean square error, mean bias error and slope of best fit line for each scatterplot

The root mean square error (RMSE), mean bias error (MBE), slope of best fit line, and the corresponding R squared values are also shown on each plot. The RMSE represents the standard deviation of the aggregated differences between the modelled and observed wave heights and can be used to describe the accuracy of the model to predict the measured values. The MBE describes the direction of the error bias and its value is related to magnitude of values under investigation. A negative MBE occurs when the modelled values are smaller in value than the observed waves. Similarly, the slope of the best fit line is a measure of bias in the model predictions. A slope of 1 demonstrates that there is no bias, while a slope with a steepness greater than 1 indicates that the model is overpredicting the values, while a slope less than 1 indicates under prediction of wave heights. The R squared value is a statistical measure of how close the data are to the fitted regression line. An R squared value of 0% indicates that the model explains none of the variability in the observed values, while an R squared value of 100% indicates that the model explains all of the variability.

Figure IR7-15-1 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom) – Halibut Bank



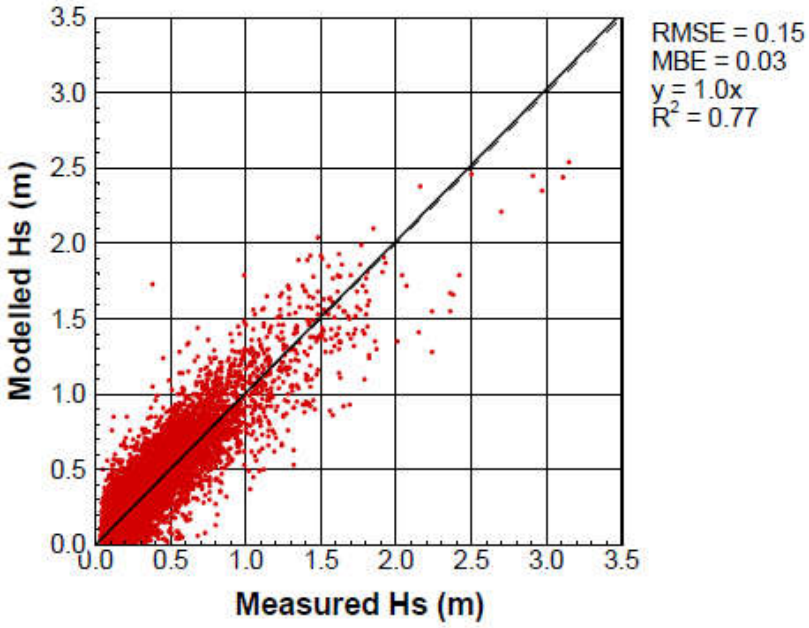


Figure IR7-15-2 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom) – New Dungeness

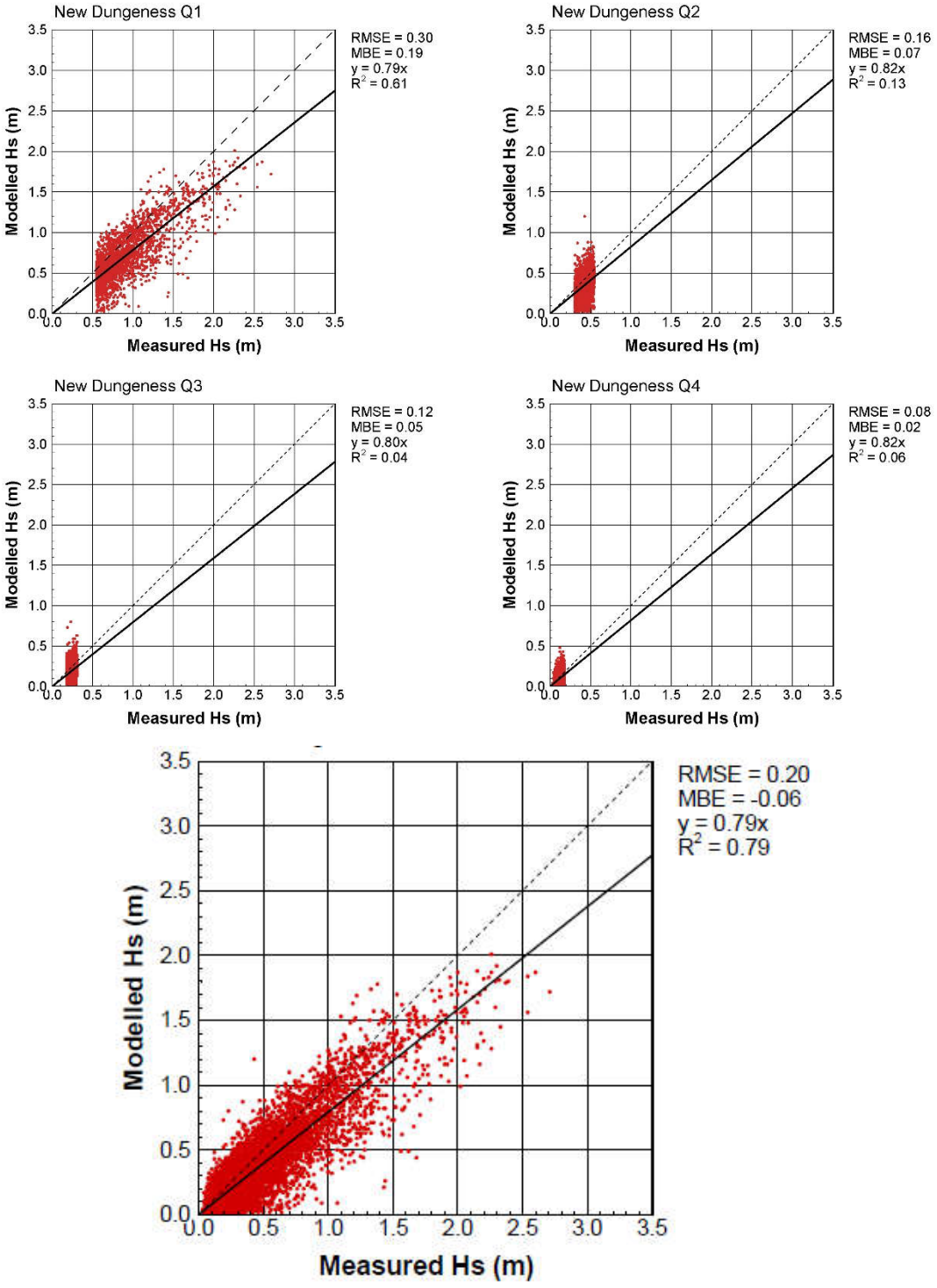
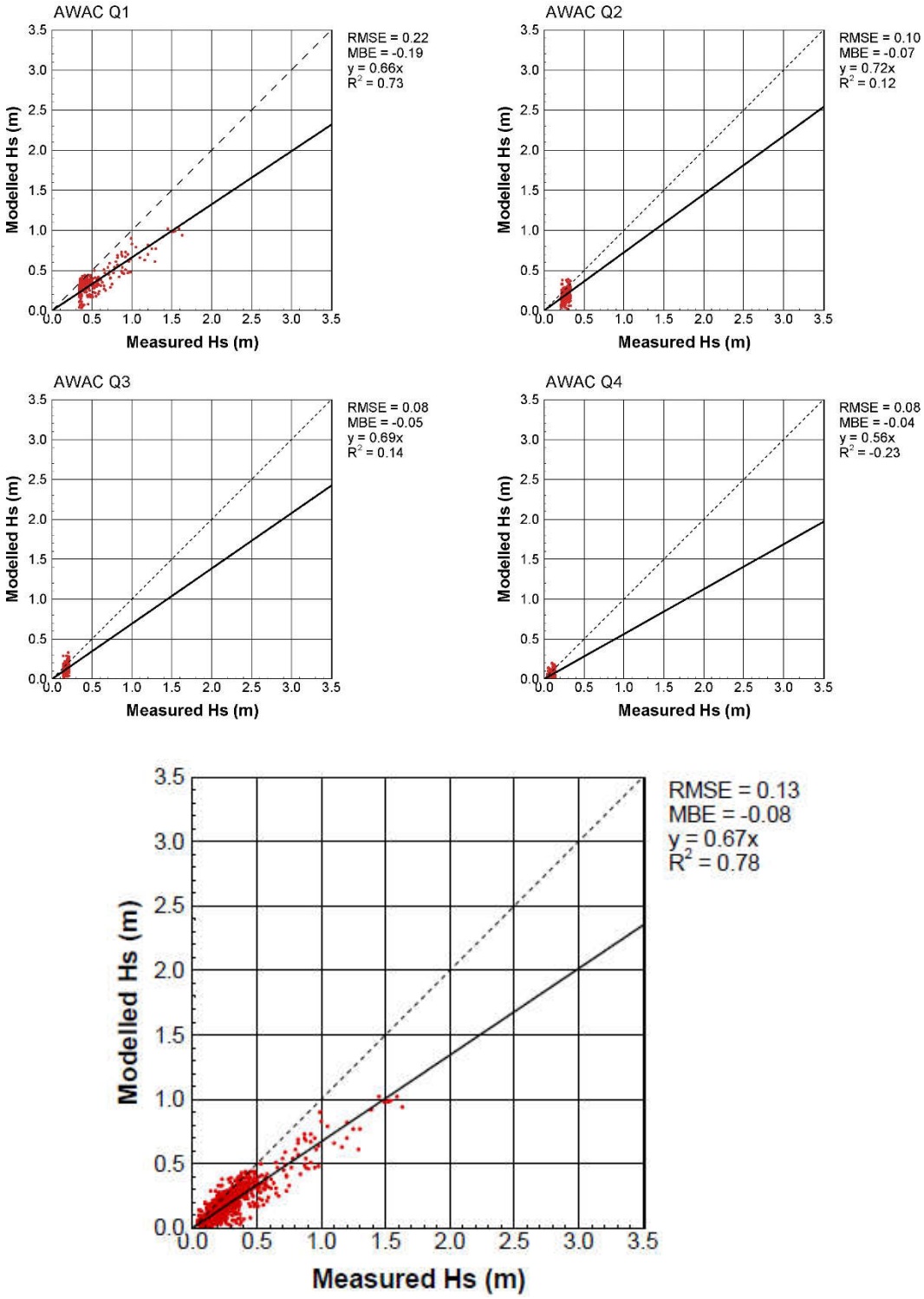


Figure IR7-15-3 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom)– AWAC Roberts Bank



Based on this analysis, discuss the ability of the wave model to accurately simulate the wave environment in the Salish Sea.

As stated in the response to IR7-13, a model, no matter how sophisticated, is a generalised representation of real-world phenomena that occurs as a result of highly complex physical interactions. Differences between observed and modelled predictions of wave heights are related to items such as time-based discrepancies (e.g., the time delay between waves responding to wind), direction discrepancies (e.g., the interpolation of wind direction between stations), and existing sea state (e.g., waves entering from outside the model domain).

The results indicate good agreement between modelled and measured wave heights at the Halibut Bank station. It is noted there is better performance demonstrated for the larger wave heights, and relatively poor performance demonstrated for the smallest wave heights. For instance, the R squared value calculated on the aggregated sample of wave heights is 0.77, but it is only 0.01 for the smallest quartile of wave heights.

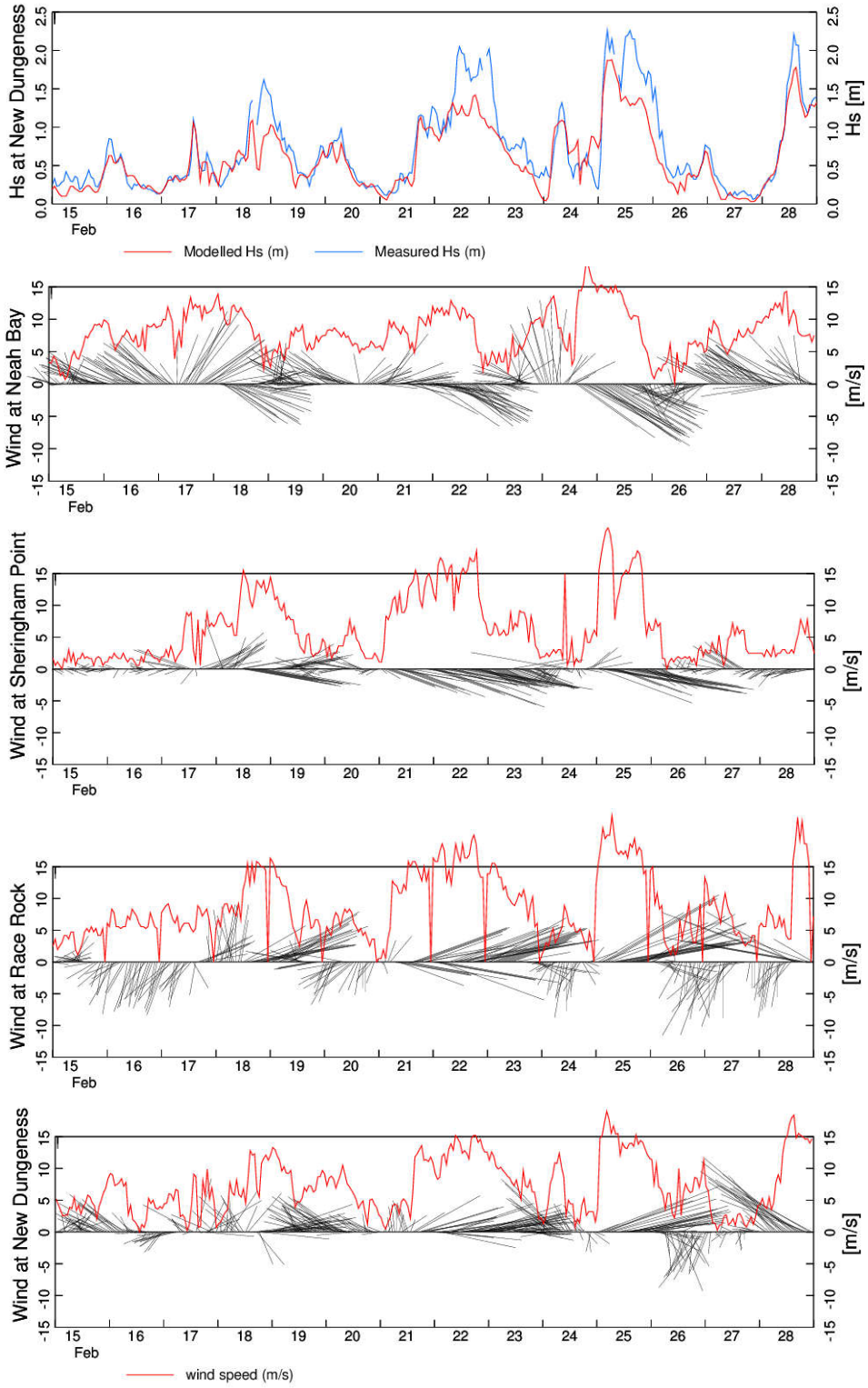
As expected, the deep water model, which does not account for nearshore wave transformation processes, underestimates the wave climate at the AWAC at Roberts Bank, where the shoaling effect across the delta front can be prominent. Nevertheless, the R squared value of the aggregated sample is 0.78.

The model underestimates the wave climate at the New Dungeness station, which is situated in a location where Juan de Fuca Strait, Haro Strait, and Puget Sound meet. The spatial and temporal wind fields used as energy inputs for the wave model were developed using a simple spatially varying interpolation method and with limited meteorological stations. The resulting wind fields may not be fully representative of the exact wind distribution along Juan de Fuca Strait and Haro Strait. The available meteorological stations with hourly wind data in Juan de Fuca Strait are shown in **Figure IR7-15-4**. Time-series of measured (blue line) and modelled (red line) wave heights at New Dungeness and measured winds from available meteorological stations for the period between February 15 and February 28, 2012 are shown in **Figure IR7-15-5**. The top panel in **Figure IR7-15-5** shows an increase in wave heights from 1.5 m to 2 m in the afternoon of February 22, 2012. However, no marked increased in wind speeds were measured at Neah Bay, Sheringham Point, Race Rock, or New Dungeness. Thus, in addition to the uncertainties with spatially varying wind fields, there could be other processes, possibly relating to atmospheric pressure, that contribute to the wave climate at New Dungeness.

The comparison of modelled and observed wave heights at Halibut Bank, AWAC Roberts Bank, and New Dungeness indicate that the deep water model underestimates the wave climates in Juan de Fuca Strait and in the nearshore region. Since the outputs from the deep water model are used as baseline wind climate conditions to assess changes from Project-associated vessel wakes, the underestimation of the wind-driven waves by the model will result in a more conservative assessment of the relative influence on wake-generated waves, as outlined in the response to IR7-13. The UMWM meets or exceeds the performance requirements to simulate the wave environment in the Salish Sea for the purposes of the assessing marine shipping associated with the Project.

Figure IR7-15-4 Available Meteorological Stations in Juan de Fuca Strait

Figure IR7-15-5 Time Series of Measured Winds, Waves, and Modelled Waves – New Dungeness



Note: The stick plots (black lines) indicate the direction to which the wind is blowing and the wind speed is indicted by the length of the stick, as scaled to the y-axis.

IR7-16 Wave Environment – Baseline, Wind-driven and Wake-driven Wave Climate

Information Source(s)

Marine Shipping Addendum: Section 7.2.4; Section 7.2.6; Appendix 7.2-A

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-1

Context

In Section 7.2.4 and Appendix 7.2-A of the Marine Shipping Addendum, the Proponent assessed the existing wave environment as consisting only of waves generated by wind action over water.

The analysis omits waves generated by the vessels of all sizes that pass through the marine shipping assessment area.

The analysis omits waves generated in the open ocean that pass through Strait of Juan De Fuca and enter the marine shipping assessment area.

Information Request

Discuss the potential consequences of using a numerical model that comprises only wind-generated waves and could underestimate the wave environment, in terms of the size and frequency of occurrence of waves, because it does not include vessel wake or ocean swell.

VFPA Response

As described in the response to IR7-13, the wave environment effects assessment utilised the University of Miami Wave Model (UMWM; Donelan et al. 2012) to characterise the existing wave climate. The model calculates waves based only on local winds and, therefore, the characterisation of the existing wave climate omits ocean swell and waves from passing vessels. Additional information on these elements of the wave climate is provided below.

Ocean Swell

Swell refers to waves generated in the open ocean in response to winds outside the local area. As stated in the Panel's context to this information request, swell generated in the open ocean is understood to pass through Juan de Fuca Strait and enter the marine shipping area. Because these waves are generated by winds outside the UMWM domain, they are not represented by the model. Swell is a relatively unimportant component of the existing wave climate in the marine shipping area, except in Juan de Fuca Strait (Segments C and D, and the southern part of Segment B). Omitting ocean swell that passes through Juan de Fuca Strait results in a more conservative assessment, as outlined below.

Figure 5 in Appendix 7.2-A of the Marine Shipping Addendum (MSA) shows modelled and measured wave heights for 2012 at Halibut Bank and the AWAC stations located in the Strait of Georgia, and at the New Dungeness station located at the east end of Juan de Fuca Strait (for station locations refer to Figure 2 in MSA Appendix 7.2-A). The New Dungeness station is exposed to swell passing through Juan de Fuca Strait, while the other stations are not exposed to swell because of the presence of the southern Gulf Islands.

There is good agreement between observed and modelled waves at Halibut Bank and AWAC stations. Because the Strait of Georgia and Haro Strait are dominated by wind-generated waves, the consequences of the model not representing ocean swell will not affect the assessment results in Segment A and the northern part of Segment B.

For Juan de Fuca Strait, the model often under predicts wave heights at New Dungeness (see Figure 5 and the response to IR7-15), particularly during the largest wave events, and it is likely that this discrepancy results from the fact that ocean swell (generated by non-local winds) is not included in the model. This discrepancy is further illustrated by comparing the wave roses presented in Figure 6 (observed waves at New Dungeness) and Figure 7 (modelled waves at New Dungeness) in Appendix 7.2-A of the MSA. The modelled results show almost no waves coming from the west, the direction from which swell would be expected. As outlined in MSA Appendix 7.1-A, further refinement of the model results that are under predicting conditions in Segments C and D and the southern part of Segment B during large wave events is unlikely to affect the assessment results. This is because the vessel-generated waves are only observed during calmer sea conditions. Additional information describing measured versus observed wave heights at these stations is provided in the response to IR7-15.

Vessel Wake

As summarised in Table 4-2 of the MSA and the response to IR4-04 (CEAR Document #1051[1]), there were 8,896 vessel movements through Segment B of the marine shipping area in 2012 (includes vessels of all types that carry the Automatic Identification System—see MSA Section 4.1.1 for a description). Waves from these passing vessels are not included in the characterisation of the existing wave climate calculated by the UMWM.

As shown in MSA Appendix 7.2-B: Figure 1, wake-generated waves vary in size depending on vessel type, vessel speed, and water depth. For the range of vessels considered in this wave environment study, wake height would be expected to be as high as 15 cm at an offset distance of 1 km from the sailing line when the vessel is travelling at 15.5 knots in water depth of 167 m. In water depth of 50 m, wake height would be expected to be as high as 22 cm at the same offset distance. Wake height is, therefore, well within the range of natural waves.

[1] CEAR Document #1051 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 4 (See Reference Document #946).

Potential Consequences of Using the UMWM That Does Not Include Vessel Wake or Ocean Swell.

The potential consequences of not including waves from passing vessels or waves generated in the open ocean outside the UMWM domain in the characterisation of the existing wave climate include the following:

- The magnitude and frequency of waves are likely under-represented in Juan de Fuca Strait, particularly during the largest wave events; and
- Periods of calm are likely overestimated in all areas of the marine shipping area, but particularly in the southern portion.

The potential consequences of under-representing the frequency and magnitude of waves is that wake-generated waves from Project-associated vessels will be more frequently predicted as being larger than the existing wind-generated waves by comparison. The consequence of overestimating periods of calm is that the chance of Project-associated vessel wake being present during periods of calm is actually smaller than that calculated. In both cases, the outcome results in a conservative assessment, and hence, the conclusions of the assessment that Project-associated wake-generated waves are expected to increase the number of vessel-generated waves by 6% in Segment B is over-predicted in relation to the existing wind-wave climate.

References

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-17 Wave Environment – Numerical Modelling of Vessel Wake-driven Waves: Vessel Wake Study

Information Source(s)

Marine Shipping Addendum: Section 7.2.2.2; Appendix 7.2-B

Context

In Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum, the Proponent stated that the PIANC (1987) wake model was used, following the methodology presented in a draft vessel wake study prepared by Moffatt and Nichol (2011) for the proposed Kinder Morgan LNG project at Kitimat, British Columbia.

However, the Proponent does not provide a rationale for the application of the PIANC model in the assessment to calculate the height of the secondary waves in the marine shipping area.

Information Request

Provide the 2011 vessel wake study by Moffatt and Nichol that was cited In Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum.

Provide a description and explanation of the specific circumstances under which the vessel wake study by Moffatt and Nichol (2011) is relevant to the calculation of the height of secondary waves in the marine shipping area and describe the limitations of this application.

VFPA Response

Provide the 2011 vessel wake study by Moffatt and Nichol that was cited in Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum.

The Moffatt and Nichol (2011) Vessel Wake Study (the Study) report is provided in **Appendix IR7-17-A**. As indicated in Section 7.2 of the Marine Shipping Addendum (MSA), this draft report was prepared for the proposed Kitimat LNG Export Terminal as part of the TERMPOL Review Process[1].

[1] The TERMPOL Review Process, overseen by Transport Canada, is a technical review of marine terminal systems and transshipment sites that focuses on a design vessel's selected route in waters under Canadian jurisdiction to its berth at a proposed marine terminal or transshipment site, as well as the process of cargo handling between vessels, or off-loading from vessel to shore or vice-versa, including single point mooring facilities.

Provide a description and explanation of the specific circumstances under which the vessel wake study by Moffatt and Nichol (2011) is relevant to the calculation of the height of secondary waves in the marine shipping area and describe the limitations of this application.

Relevance of Moffatt and Nichol (2011) Vessel Wake Study to Calculation of Height of Secondary Waves

The Study is relevant to the calculation of the height of secondary wake-generated waves in the marine shipping area on the basis that the two study areas have a similar range of water depths and consider similar types of vessels. Given that the height of secondary waves are mainly influenced by these two variables, in addition to vessel speed, the application of the Study is therefore relevant to the Marine Shipping Addendum. This reasoning is further expanded upon below.

The Study involved the assessment of secondary wake-generated waves in Douglas Channel, B.C., a relatively narrow but deep channel. The Study used the PIANC (1987) formula to calculate the height of secondary waves at various offset distances from a transiting vessel. The Study report documented a logical methodology for assessing ship wake for navigation considerations and presented the theoretical background of the method.

Channel dimensions referring to 'deep' and 'narrow' are relative. As discussed in the response to IR7-18, the PIANC (1987) formula was developed for vessel waves in deep water conditions when the Froude number of the form F_h is less than 0.7. The average water depth in Segment B of the navigation channel varies between 44 m and 320 m. At an average speed of 15.5 knots for container vessels transiting through this segment, the maximum Froude number F_h is 0.38 and satisfies the deep water condition. The average channel width that was assessed in the Study was 2.3 km, which is narrower than the distance to shore from the international shipping routes for some areas of Segments A and C, and all of Segment D in the marine shipping area, but similar to the distance to shore from the shipping route in Zones 1, 2, and 3 of Segment B (the segment in which shoreline interactions from wake-generated waves were assessed in MSA Section 7.1). Refer to the response provided in IR7-22 for information on calculating wake-generated waves for wider channels in deep water.

Limitations of the PIANC (1987) Formula

The limitations of the PIANC (1987) formula, which was developed to assess secondary wake-generated waves, are described below with respect to the distance from the sailing line and vessel speed.

PIANC (1987) presents the formula in reference to designing shoreline erosion protection structures in inland waterways. As such, its application has mainly been used as a tool for predicting waves within a relatively short offset distance from the sailing line (e.g., within 2.5 km and less, as described above). While there have been a number of studies that have compared observed wake to predicted wake (e.g., Verhey and Bogaerts 1989), no studies could be identified that provide definitive limits to the application of the PIANC (1987) formula.

Kriebel and Seelig (2005) compared PIANC-based results to the results for an alternate equation for calculating ship wake, which used a unified Froude number that combines the channel depth-based and vessel length-based forms. A similar comparison, which was provided in the response to IR4-02 of CEAR Document #1051[2], demonstrated that the PIANC (1987) formula estimated higher wake heights at most locations within Segment B, as compared to wake heights determined via the Kriebel and Seelig (2005) formula. These results are consistent with the Study that concluded that "Given that the channel cross section is very much greater than the vessel cross section, the calculation of wave heights is relatively insensitive to the actual channel dimensions used." In other words, once the channel cross section (width) is much greater than the width of the vessel, vessel speed and vessel shape are the major determinants for wake height.

The PIANC (1987) formula is potentially limited by the range of observed values under which it was developed, a limitation identified in a number of wake prediction models reviewed by Sorensen (1997). For vessel speeds that exceed the range of observed values that were used to develop the formula, the wake height predictions may not be accurate. While the specific limitations were not quantified, some insight was included in Kriebel and Seelig (2005), which compared observed versus predicted waves using the PIANC (1987) formula for vessel speeds ranging from 7 knots to 10 knots. A more detailed discussion of the specific limitations with respect to vessel speed and wave attenuation as a function of distance from the sailing line is included in the response to IR7-22.

References

Kriebel, D. and W. M. Seelig. 2005. An Empirical Model for Ship-generated Waves. Proceedings from the Fifth International Symposium on Ocean Wave Measurement and Analysis. Available at http://adac.uaa.alaska.edu/css/images/pdf/online_course/presentation/Ship%20waves%20slides%20-%20Kriebel%20and%20Seelig%202005.pdf. Accessed October 2017.

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World Association for Waterborne Transport Infrastructure (PIANC). 1987. Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways. Report of Working Group 4 of the Permanent Technical Committee - Permanent International Association of Navigation Congress.

[2] CEAR Document #1051 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 4 (See Reference Document #946).

Appendices

Appendix IR7-17-A Moffatt and Nichol (2011) Vessel Wake Study

APPENDIX IR7-17-A
MOFFATT AND NICHOL (2011) VESSEL WAKE STUDY

VESSEL WAKE STUDY

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VESSEL WAKE STUDY

May 5th, 2011

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1. INTRODUCTION

In 2006 Moffatt & Nichol prepared a comprehensive Metocean (meteorological and oceanographic) study for Douglas Channel to support the preliminary engineering design of the Kitimat LNG terminal. The 2006 study was intended primarily to provide design information related to wind, wave and current forces on the jetty structures within Bish Cove. Further metocean analysis was planned for the detailed design phase, as well as to support the TERMPOL review process which considers navigational issues not only within Bish Cove, but also more generally along the planned navigational route.

This report documents additional analysis on vessel wakes expected along Douglas Channel caused by tugs and LNG carriers en route to and from the terminal. Since vessel wakes and their impacts are of relevance to navigation, this report was intended to form part of the studies comprising the TERMPOL submittal. Although the TERMPOL process is only in its early stages, this report is being released earlier than planned to support discussions related to the NEB hearing process.

Revision 1 of this report is considered a draft in progress and is subject to revision following further analysis and internal review.

2. VESSEL-GENERATED WAVES

The following description of the characteristics of ship-generated environmental effects in narrow channels is adapted from several sources, including the Permanent International Association of Navigation Congresses PIANC (1987), Sorensen (1997), Schiereck (2001) and previous Moffatt & Nichol reports (2003).

Two main types of waves are generated by moving vessels:

- Primary wave (or drawdown wave); and,
- Secondary waves caused by discontinuities in the hull profile.

Primary waves are often minor in wide, deep channels, therefore, this study will focus primarily on secondary wave generation and attenuation at selected distances away from the vessel for both LNG carriers and escort tugs.

2.1 PRIMARY WAVE (DRAWDOWN)

From a hydrodynamic point of view, flow near a moving ship is similar to flow around a fixed body such as bridge abutment. As the ship moves, water flows past the vessel hull in the opposite direction of travel. This flow is known as the return current. The velocity head of the water flowing past the vessel causes the water level along the vessel's length to fall in order to maintain the total head (energy) constant. Therefore the water level around the vessel is lowered. This water level depression is sometimes referred to as the primary wave (Figure 2.1).

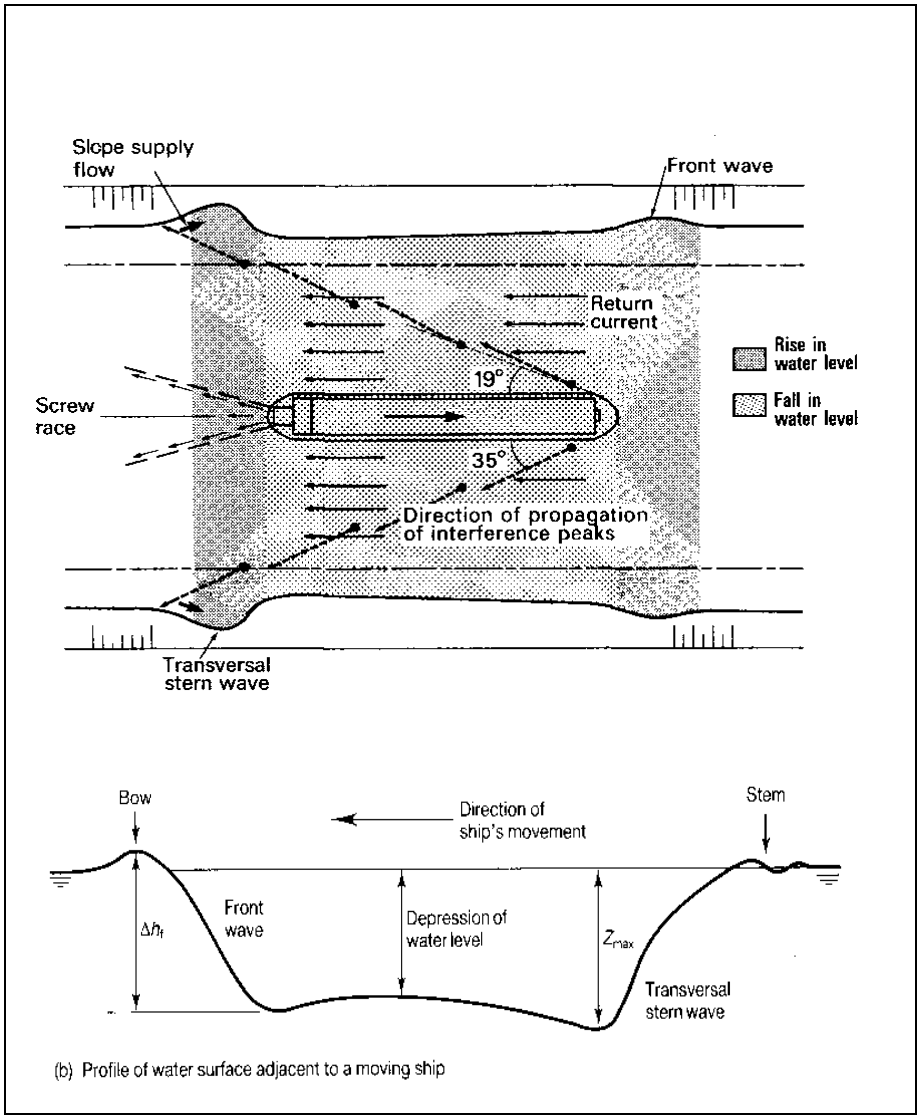


Figure 2.1: Primary Wave Components of Ship Induced Water Motions *(Source: PIANC 1987)*

The transition between the undisturbed water level in front of the vessel and the water level depression takes the form of sloping water surface referred to as the front wave. The water surface immediately ahead of the vessel is elevated by the approaching ship, so the total height of the front wave is slightly greater than the water level depression.

The transversal stern wave is the transition between the water level depression and the normal water level behind the ship.

The combination of water level depression, front wave and transversal stern wave, referred to as drawdown, acts like a long solitary wave with a length similar to that of the ship. Therefore, drawdown is generally not easily observed in the field, other than in the case of

relatively large vessels sailing in confined channels. Drawdown does not break at the shoreline as normal waves, instead, it is more like a tidal pulse, rising and falling as the vessel passes.

2.2 SECONDARY WAVES

When responding to the sharp rise and fall in the water surface at the bow and the stern, inertia causes the water surface to lag behind its equilibrium position and produces a surface oscillation. In turn this produces a pattern of free surface waves, called secondary waves that propagate from the vessel (Figure 2.2 and Figure 2.3). The pattern spreads out from the vessel with decreasing wave amplitudes due to diffraction. The pattern consists of symmetrical sets of diverging waves that move obliquely out from the sailing line and a single set of transverse waves that move in the direction of the sailing line. The transverse and diverging waves meet to form cusps, also called interference peaks, along a pair of lines that form an angle of 19.5 degrees with the sailing line. The highest waves in the pattern are found along this cusp locus line. A similar pattern of waves, but typically with much lower amplitudes, is generated at the vessel stern and superimposed on the pattern generated out from the bow. These secondary waves are the ones that are generally visible in the field and even on aerial photographs. Secondary waves are always “short” and act like normal waves which means, that the general linear wave theory relations for wavelength, celerity, etc. are valid. These waves may also break as they approach the bank shoreline and the breaker type (i.e., spilling, plunging, or surging) is dictated by the same slope and wavelength relationships as for other normal waves.

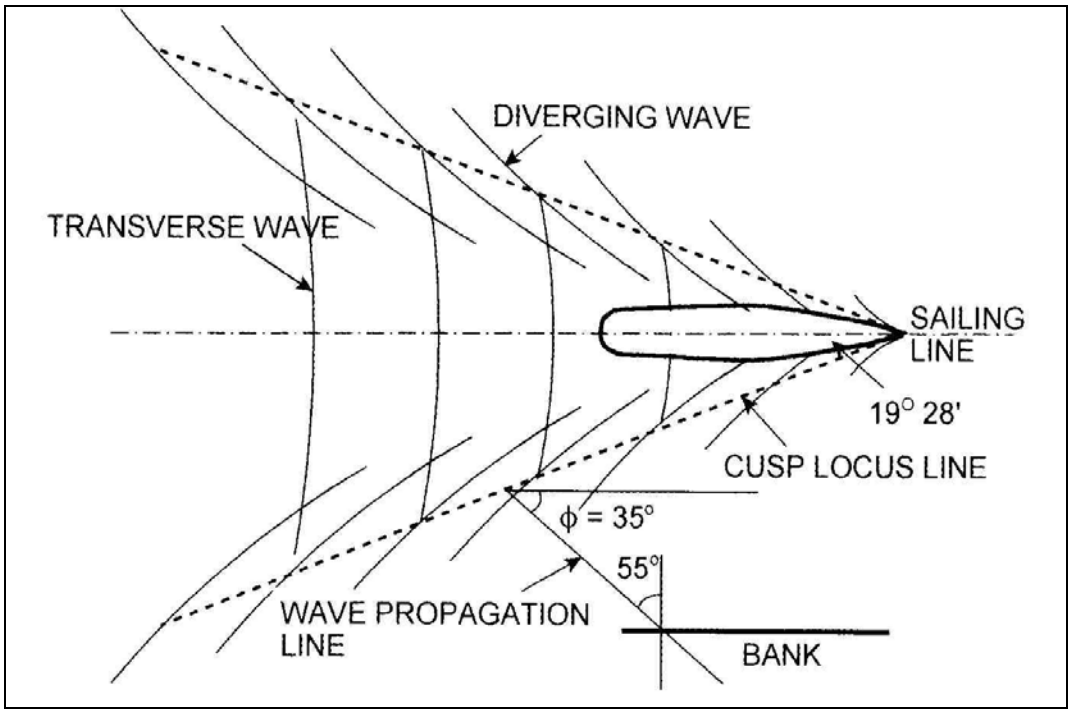


Figure 2.2: Secondary Wave Pattern *(Source: Schierech, 2001)*

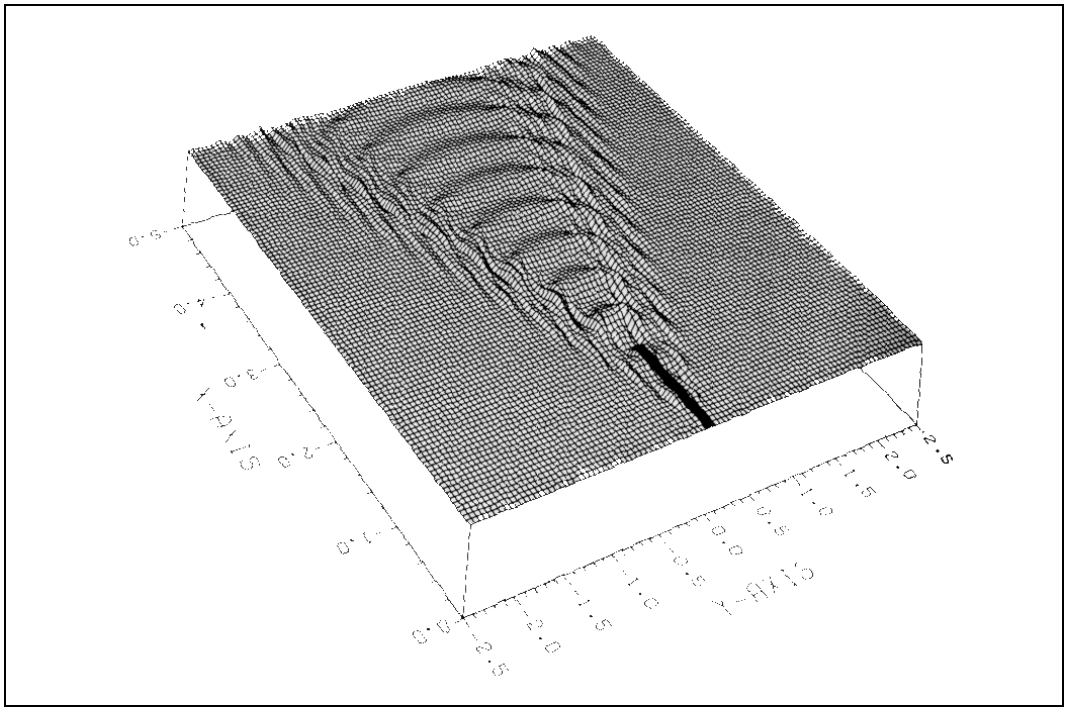


Figure 2.3: Isometric View of Secondary Wave Pattern *(Source: Faltinsen, 1990)*

3. ASSUMPTIONS

The empirical equations used to generate primary and secondary wave heights rely on a number of parameters. The assumptions made for each of the parameters are discussed in this section. With the exception of the type of vessel and cross-sectional area of the hull, hull form geometric description is not significant when using empirical formulas to determine primary and secondary wave heights. Furthermore, where the channel cross section is large relative to the vessel hull cross section, and the water depth is large relative to the vessel draft, the calculated wave heights are relatively insensitive to the actual hull dimensions. Therefore the results of this study are considered applicable to the entire range of LNG vessels expected to call at the Kitimat LNG terminal (i.e. 125,000 m^3 to 215,000 m^3 capacity).

Vessel speed (v_s) is the forward speed of the vessel, and greater velocity results in a larger wake. The at-sea service speed of today's typical LNG carriers can range up to 19 knots; however it is likely that once the vessels approach the coast (and especially once they are within relatively confined waterways) the speed would be reduced. Typical escort tug speeds range between 8 to 12 knots. Vessel speeds within Douglas channel, Wright Sound, and Principe Channel are expected to be no more than approximately 10-12 knots. The actual vessel transit speed profiles will be examined in greater detail during the Termpol studies. For the purposes of this study, vessel speeds up to 16 knots were considered for both tankers and tugs, although it is recognized that the actual vessel speed profile within Douglas Channel will be considerably less (10-12 knots) so these calculations are conservative.

A vessel cross-sectional area of 600 m^2 was assumed based on the largest LNG vessel anticipated for this project (i.e. a 215,000 m^3 Qflex vessel) having dimensions of:

- Maximum beam width of 50.0 m; and,
- Draft equal to 12.0 m.

Based on the navigation charts of Douglas Channel, the channel depth (h) is generally more than 200 fathoms (365 m). Approximately 23 kilometers from the head of the channel, depth steadily decreases from 200 fathoms to approximately 120 fathoms (220m) near the Kitimat LNG terminal. The channel continues to shoal to approximately 50 fathoms (90 m) near Kitimat. It is assumed that vessels will be slowing as they near the Kitimat LNG terminal and speeds will be well less than the maximum escort speed of 12 knots.

The southern part of Douglas Channel between Money Point and Kitkiata Inlet is generally between 3 and 4 km wide. The middle part of Douglas Channel between Kitkiata Inlet and the northern end of Maitland Island is somewhat narrower, averaging 2 to 3 km, with the

narrowest point opposite of Emilia Island measuring approximately 1.4 km wide. The northern part of the channel (i.e. Kitimat Arm, closest to Bish Cove) varies between 1.7 km and 3.6 km wide.

For the purposes of this study an average width of 2.3 km was used with an average depth of 365 m, which provides a channel cross-sectional area of approximately 850,000 m^2. Given that the channel cross section is very much greater than the vessel cross section, the calculation of wave heights is relatively insensitive to the actual channel dimensions used.

4. CALCULATED WAVE HEIGHTS

This section focuses on prediction and analysis of ship generated drawdown, return current and secondary waves (interference peaks).

4.1 PRIMARY WAVE HEIGHT AND RETURN CURRENT

The theoretical effects of a ship transiting a narrow channel can be derived from the Bernoulli equation (Schiereck, 2001). The primary wave height (z) and return current (u_r) are defined as follows:

$$\frac{v_s^2}{gh} = \frac{2z/h}{(1 - A_s/A_c - z/h)^{-2} - 1}$$

$$\frac{u_r}{\sqrt{gh}} = \left[\frac{1}{1 - A_s/A_c - z/h} - 1\right]\frac{v_s}{\sqrt{gh}}$$

Where:

h = Channel depth

A_s = Cross sectional area of ship

A_c = Cross sectional area of channel

g = Gravitational constant

Previous studies using these equations have correlated well with field-measured data (i.e. “Arthur Kill Ship Wave Study” Moffatt & Nichol, 2003).

A calculation using a vessel speed of 16 knots and the channel cross-sectional area (1400m wide x 220 m deep) results in a primary wave height z of 0.015 m and a return current u_r of 0.017 m/s. These values reflect the large size of the channel cross-sectional area compared to the ship cross-sectional area. For sensitivity analysis the calculation was repeated using a much shallower channel depth of 36 m (This is representative of an isolated shoal at Dixon Island Narrows, although the majority of the channel is in fact much deeper). Using the shallower depth, the values for primary wave height and return current increase to 0.105 m and 0.124 m/s respectively. Given the small magnitude of these values, further study of primary waves is not considered to be warranted.

4.2 SECONDARY WAVE HEIGHT

A PIANC working group report on the design of canal revetments gives the following equation for secondary waves (interference peaks) generated by vessels in inland waterways (PIANC 1987).

Secondary wave height (H) is defined as:

$$H = h * \alpha_1 * \left(\frac{S}{h}\right)^{-0.33} * F_h{}^4$$

Where: F_h = Froude number, $F_h = \frac{V_s}{\sqrt{gh}}$

S = Distance between vessel's side and the point of interest

α_1 = Coefficient depending on vessel type

h = Channel depth

V_s = Vessel speed

The associated period (T) of the secondary wave is defined by:

$$T = 0.82 * V_s * \frac{2\pi}{g}$$

For a given vessel size and α_1 shape, maximum water level depression and concomitant wave heights increase with increasing Froude number. The Froude number increases with increasing vessel speed but decreases with increasing channel depth. For a given Froude number and channel dimensions, wave heights generally increase with vessel size.

Verhey and Bogaerts (1989) give values for the α_1 coefficient based on laboratory and field tests in deep water (i.e., F_h less than< 0.7 for large tankers). The coefficient α_1 has values of:

- 1.0 for tugs, patrol boats, and loaded conventional inland motor boats;
- 0.5 for empty European barges; and,
- 0.35 for empty conventional motor vessels.

Schiereck (2001) recommends a value of 1.2 as a reasonable upper limit of the available experimental data.

For this study, the coefficient α_1 was taken to be 0.7 for tankers and 1.0 for tugs. Because of the larger value of the coefficient α_1 for tugs, secondary waves for tugs will be larger than the tankers. During escort operations, the vessels will be traveling at the same speed and the secondary waves generated by the tugs and tankers will not combine, because the sources of wave generation remain separated by a constant distance. The overall effect from a reference point some distance away from the vessels will be a longer duration of incoming waves (Figure 4.1).

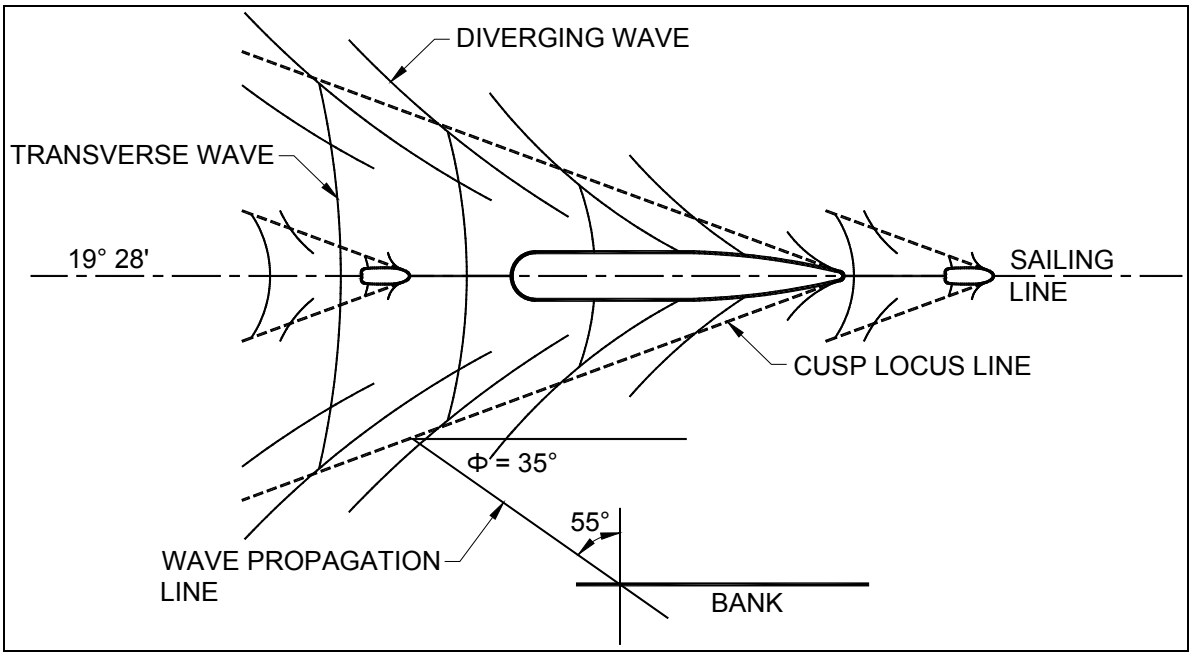


Figure 4.1: Secondary Wave Pattern for Multiple Vessels with Same Velocity *(Source: Schierech, 2001)*

Secondary wave heights for a tanker, for a range of velocities and distances from the vessel, are presented in Figure 4.2. At a distance of 10 m from the vessel hull and a speed of 16 knots, the secondary wave height is approximately 0.3 m, decaying to a height of approximately 0.08 m at distances of 1000 to 1500 m from the vessel (typical distances from the centerline of Douglas Channel to the shoreline). At the assumed maximum escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are less than 0.02 m.

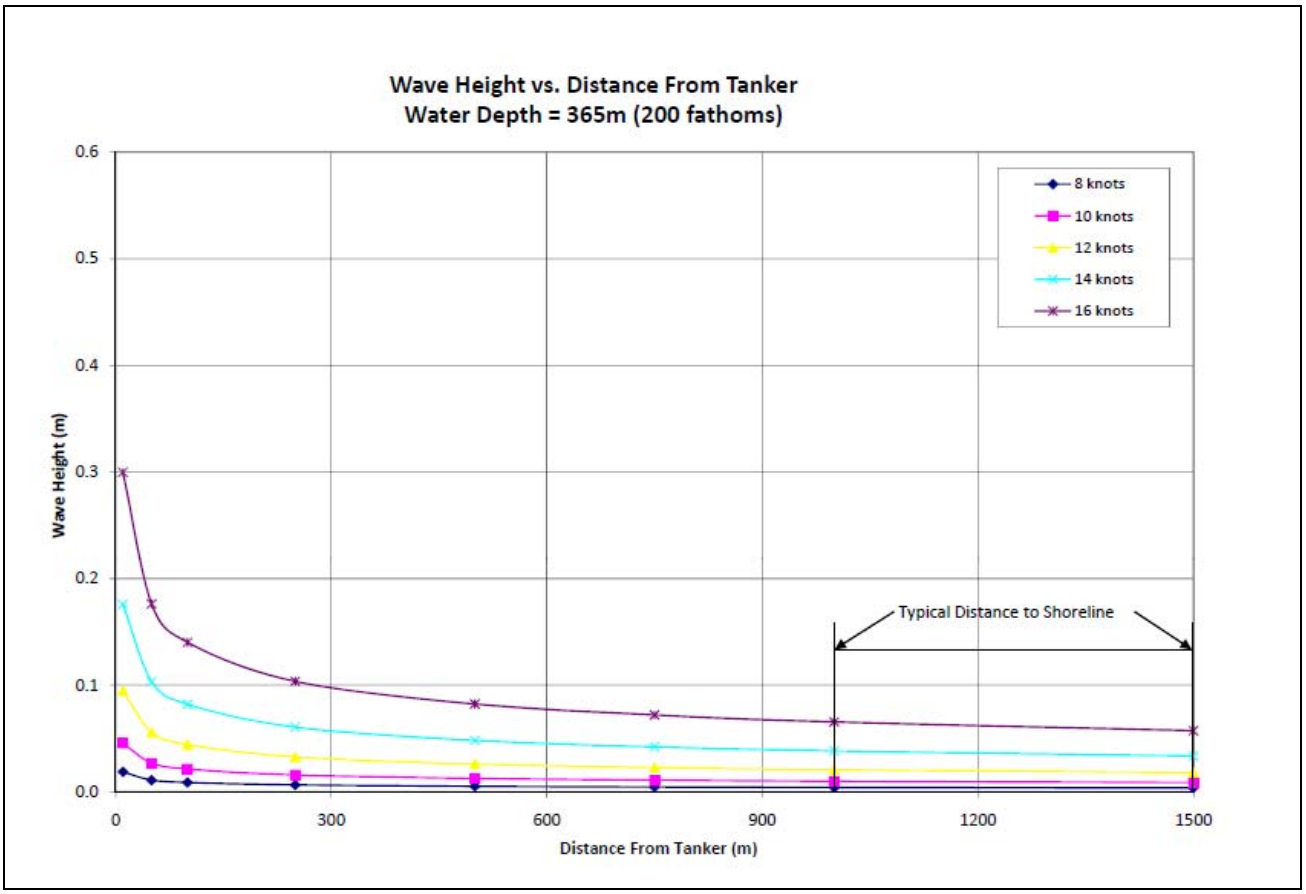


Figure 4.2: Secondary Wave Heights – Tankers, 200 fathoms

A sensitivity case was run for a water depth of 100 fathoms, and the results indicate that the generated wave heights are somewhat higher, as shown in Figure 4.3. At the assumed maximum escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are approximately 0.03 m.

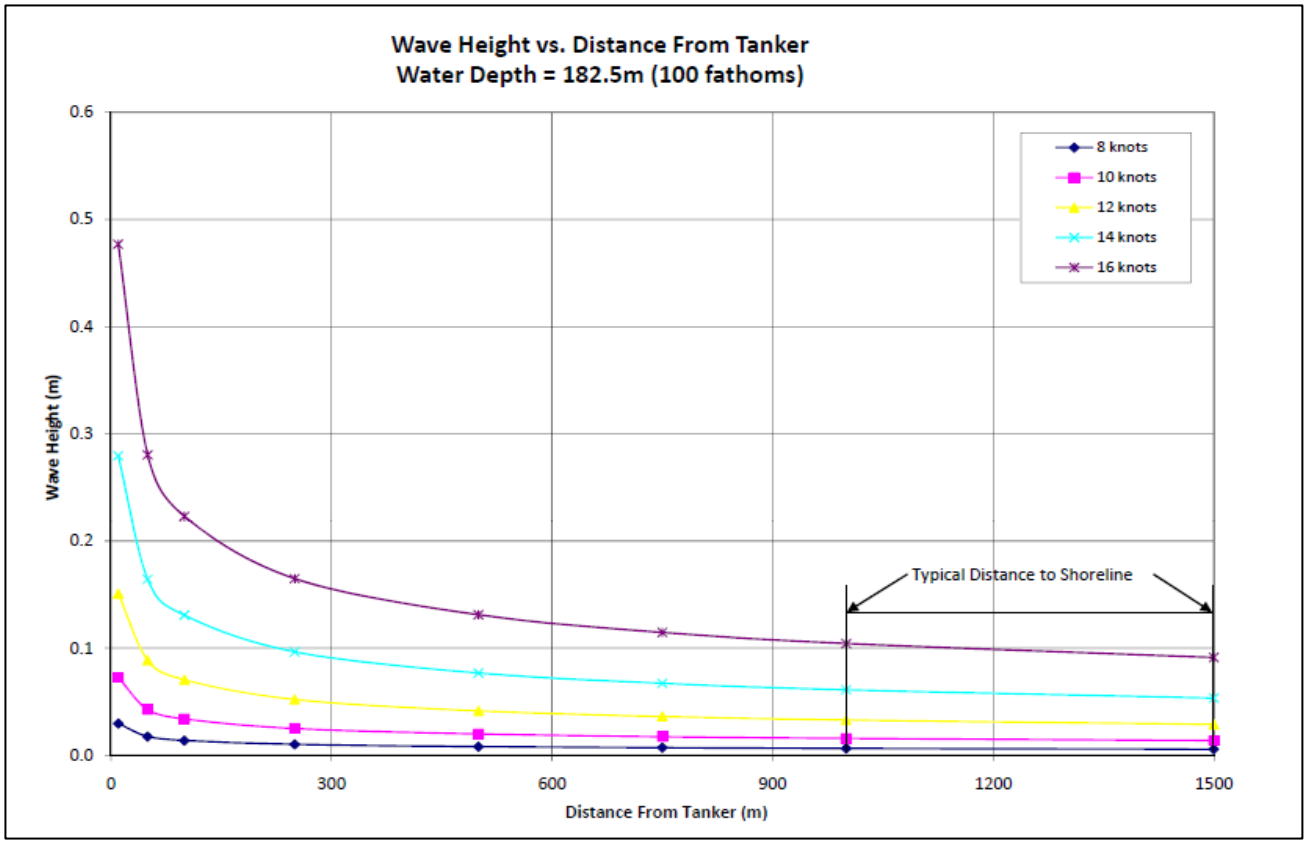


Figure 4.3: Secondary Wave Heights – Tankers – 100 fathoms

Secondary wave heights for the escort tug, for a range of velocities and distances from the vessel, are shown in Figure 4.4. At a distance of 10 m from the tug hull and a speed of 16 knots, the secondary wave height is approximately 0.43 m, decaying to a height of approximately 0.1 m at distances of 1000 – 1500 m from the vessel (typical distances from the centerline of Douglas Channel to the shoreline). At the assumed escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are approximately 0.03 m for the escort tug.

The wave heights quoted above for tugs are based on using a α_1 coefficient of 1.0. A sensitivity case was run for the escort tug condition using the reasonable upper limit of the α1 coefficient of 1.2 and a velocity of 16 knots. At distances of 1000 to 1500 m from the vessel, secondary wave heights are 20% greater, but are still less than 0.12 m. These wave heights represent the upper bound of expected wave heights near the shoreline.

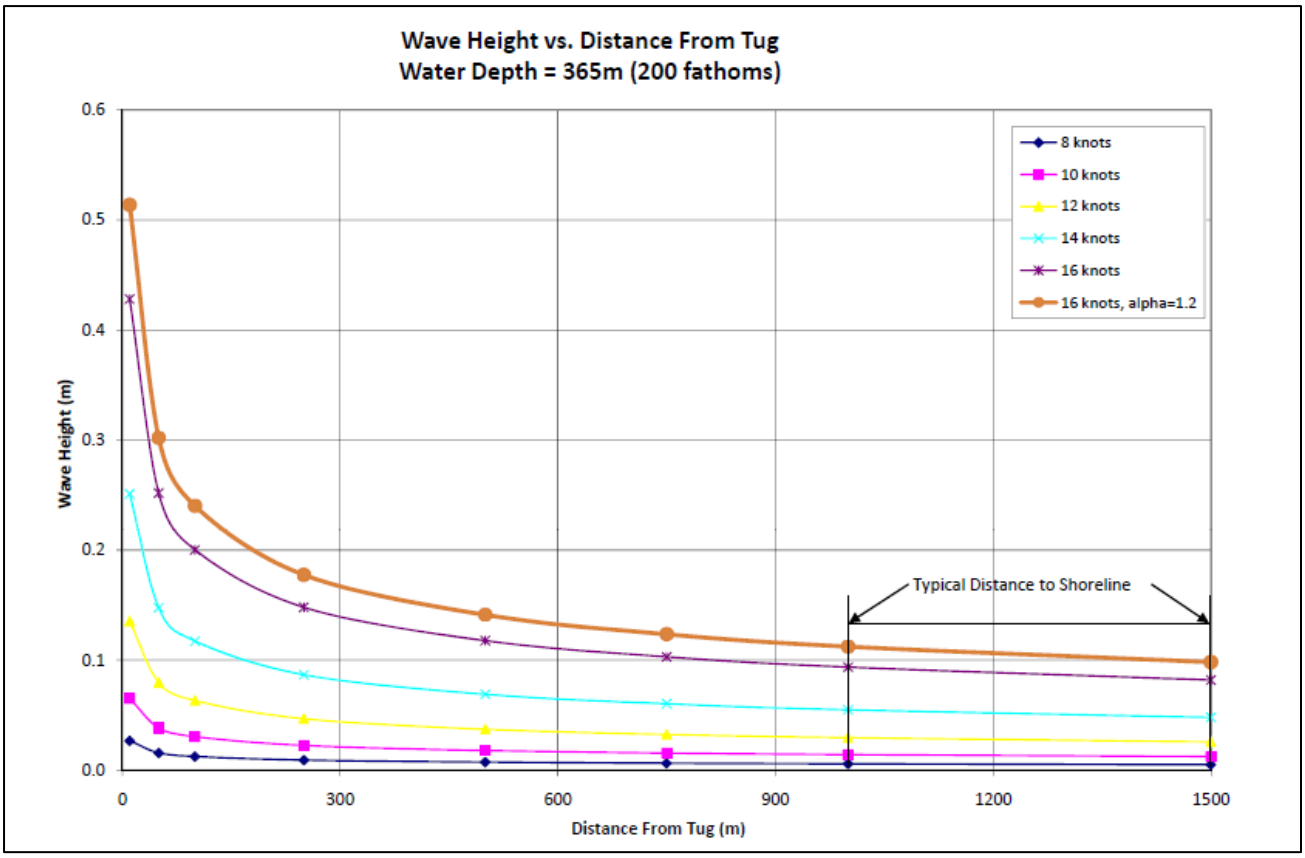


Figure 4.4: Calculated Escort Tug Secondary Wave Heights

Wave period, length and height for selected distances from the escort tug versus vessel speed are presented in Table 4.1. For the LNG tankers, wave period and wave length are the same, with smaller wave heights. At expected escort velocities of 12 knots, the secondary wave period is 3.2 seconds, decreasing to 2.2 seconds at a vessel speed of 8 knots.

Table 4.1: Vessel Speed versus Wave Period, Wavelength and Wave Height

Vessel Speed (knots)	Secondary Wave Period (s)	Wave Length (m)	Wave Height at Distance from Tug (m)				
			10 m	100 m	500 m	1000 m	1500 m
16	4.3	29.2	0.43	0.20	0.12	0.09	0.08
14	3.8	22.3	0.25	0.12	0.07	0.05	0.05
12	3.2	16.4	0.14	0.06	0.04	0.03	0.03
10	2.7	11.4	0.07	0.03	0.02	0.01	0.01
8	2.2	7.3	0.03	0.01	0.01	0.01	0.01

The wake heights predicted above are for calm water conditions. Winds, currents and ambient waves can potentially affect wake heights if they are aligned (and especially if they are in opposing directions). However, vessel waves would tend to be moving across the axis of the

channel, while winds and currents would tend to be moving along the channel. Interactions between wakes, winds, currents and ambient waves are therefore not expected to be significant.

The potential impact of ship and tug wakes can be assessed in qualitative terms by comparing the wave heights to naturally occurring ambient waves. For example, wind and wave data have been recorded for more than 20 years at the Nanakwa Shoal ocean data buoy, located in Douglas Channel approximately 10 km from the Bish Cove site. Analysis of these data indicates that ambient wave conditions exceed 0.1 m in height approximately 68% of the time, and exceed 0.2 m 39% of the time, both calculated on a long term, year round basis. During storm events, the waves in Douglas Channel of course can be much larger. For example, during the period 1988 through 2005, the maximum annual significant wave heights recorded at the Nanakwa Shoal buoy averaged 0.8m, with the overall maximum significant waves measured at 1.47m in 1996. The calculated wake heights are clearly quite small relative not only to storm conditions but also to average ambient wave conditions in Douglas Channel, and are therefore considered to be insignificant in terms of their potential for increased shoreline erosion or impact on other vessels.

5. SUMMARY OF FINDINGS

The findings of this study are summarized as follows:

- Because of the relatively deep and open channel, predicted primary wave heights caused by tankers and escort tug traffic are low, i.e. 0.025 m.
- At normal escort speeds between 8 and 12 knots, secondary waves caused by tankers and tugs are small at distances that correspond to the distance between the center of the channel and shoreline, generally well less than 0.1m.
- At a typical maximum speed for an escort tug of 16 knots, secondary wave heights at 1000 m from the tug are about 0.1 m.
- These wave heights are small compared to the naturally occurring wind-generated waves within Douglas Channel, and so are not expected to have a significant effect on shoreline erosion or other marine traffic operating in the area.

6. REFERENCES

1) Faltinsen, O.M. Sea Loads on Ships and Offshore Structures. Cambridge University Press. 1990.

2) Moffatt & Nichol. "Arthur Kill Ship Wave Study". 2003.

3) Permanent International Association of Navigation Congress (PIANC), Supplement to Bulletin No.57. "Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways". Report of Working Group 4 of the Permanent Technical Committee I. 1987.

4) Schiereck, G.J. Introduction to Bed, Bank and Shore Protection. Delft University Press. 2001.

5) Sorensen, R.M. "Prediction of Vessel-Generated Waves with Reference to Vessels Common to the Upper Mississippi River System". Prepared for US Army Corps of Engineers. 1997.

6) Verhey, H.J. and Bogaerts, M.P. "Ship Waves and the Stability of Armour Layers Protecting Slopes". Proceedings of the 9th International Harbor Congress, Antwerp, Belgium. 1989.

ABBREVIATIONS

α_1 ..... Coefficient Depending on Vessel Type
A_s ..... Cross-Sectional Area of Ship
A_c ..... Cross-Sectional Area of Channel
F_h ..... Froude Number
m/s ..... Metre Per Second
g ..... Gravitational Constant
h ..... Channel Depth
H ..... Secondary Wave Height
PIANC ..... Permanent International Association of Navigation Congresses
s ..... Second
S..... Distance between Vessel's Side and Point of Interest
T..... Period
u_r ..... Return Current
v_s or V_s ..... Vessel Speed
w ..... Channel Width
z ..... Primary Wave Height

GLOSSARY

Cross-sectional Area: The ratio of the immersed area of the midship section of a vessel to the area of the circumscribing rectangle, the width of which is the beam, B, at the waterline and the depth of which is the draft, T, for which the ratio is calculated.

Cusp Locus Line: The line formed by the peaks of convergence of diverging waves and transverse waves.

Diverging Wave: A pattern of diverging waves that moves obliquely out from the sailing line of the vessel.

Drawdown: The combination of water level lowering around a vessel caused by vessel speed, front wave and transversal stern wave.

Fetch-limited: Generated waves limited by the length of the fetch as opposed to the strength or duration of the wind.

Froude Number: A dimensionless number used to quantify the resistance of an object

	moving through water and compare objects of different sizes.
Hydrodynamic;	The study of fluid motions.
Interference Peak:	A peak caused by the convergence of peaks of non-co-linear waves.
Revetments:	Structures placed on banks or cliffs in such a way as to absorb the energy of incoming waves. They are usually built to preserve the existing uses of the shoreline and to protect the slope.
Sailing Line:	The path of the vessel.
Transverse Wave:	Vessel-generated waves perpendicular to the sailing line.
Transversal stern Wave:	The transition between the water level depression and the normal water level behind the vessel.
Wave Propagation Line:	The path of a wave.

IR7-18 Wave Environment – Numerical Modelling of Vessel Wake-driven Waves: Additional Details

Information Source(s)

Marine Shipping Addendum: Figure 4-4; Section 7.2.4.2; Section 7.2.7; Appendix 7.2-A; Appendix 7.2-B, Figure 1

Context

The uncertainty and reliability analysis provided by the Proponent in Section 7.2.7 of the Marine Shipping Addendum does not address the uncertainty arising from the use of the PIANC (1987) model of vessel wake, rather than measured vessel waves.

In Appendix 7.2-B of the Marine Shipping Addendum, the Proponent appears to have determined a vessel Froude number based on water depth, as is appropriate for vessels in shallow water (as defined by the depth to draft ratio). Waters along the vessel track in Zones 1, 2 and 3 are deep (as defined by the depth to draft ratio). In deep water applications, the Froude number must be based on vessel length.

In Figure 1 of Appendix 7.2-B, the Proponent provided wave heights for four vessel types (Empty Conventional Motor Vessels, Empty European Barges, Vessels and Tugs and Patrol Boats), but did not provide results for the classes of container vessels that would use the proposed Project terminal.

An analysis of the magnitude of uncertainty in vessel wake-driven waves is needed.

Information Request

Confirm that secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights, rather than secondary waves caused by discontinuities in the hull profile as asserted in the Marine Shipping Addendum.

Confirm that "H" in the PIANC (1987) secondary wave formula (as presented in Marine Shipping Addendum Appendix 7.2-B) is wave height, and that "h" is the channel depth.

Justify the appropriateness of using the Froude number for shallow water calculations in the PIANC (1987) model. If this is deemed inappropriate, use the deep-water form in all wave calculations and present revised tables and figures, as appropriate.

Reproduce the plots in Appendix 7.2-B, Figure 1, but plot dimensionless wave height against dimensionless cross-track distance. The plot for various vessel types should include vessels that will use RBT2, using examples from Marine Shipping Addendum Figure 4-4. Wherever appropriate, include measured wave height from actual or model vessels.

Provide an assessment of maximum probable error in secondary wave height at shorelines as calculated by the PIANC (1987) model for waves in Zones 1, 2 and 3.

Reassess the conclusion that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

Specify at what shoreline locations vessel wake would be distinguishable from the spectrum of wind-generated waves during calm conditions.

VFPA Response

Confirm that secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights, rather than secondary waves caused by discontinuities in the hull profile as asserted in the Marine Shipping Addendum.

The VFPA confirms that secondary wake-generated waves are caused by discontinuities in the hull profile, as asserted in the Marine Shipping Addendum (MSA), and can also be described as resulting of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights. Further explanation is provided below.

Secondary wake-generated waves, the focus of the wave environmental effects assessment provided in MSA Section 7.2, are caused by discontinuities in the hull profile, as opposed to primary waves, which are related to the drawdown effect when a ship hull displaces water in a relatively narrow and shallow channel. This simplified definition, which was also used in the Moffatt and Nicholl (2011) Vessel Wake Study (Appendix IR7-17-A of the response to IR7-17), was used in the wave environment effects assessment to provide an accessible language description to differentiate the two main types of waves rather than to provide a technical description of the mechanism of wave generation by a vessel. Similar language is also included in PIANC (1987): "Secondary ship waves are generated particularly at the bow and stern of the ship and at any other discontinuities along the hull of the vessel."

Various sources from the scientific and technical literature provide a more complete technical description of secondary waves. For instance, PIANC (1987) expands upon the above definition as follows: "The waves comprise transverse and diverging waves, which together form interference peaks…". Moffatt and Nicholl (2014) provide the following explanation of wave formation from a vessel:

> *"As the vessel displaces water during its passage a varying pressure distribution develops along the hull of the vessel producing an increased pressure at the bow and stern and a pressure drop along the midsection. The associated pressure gradients produce waves that propagate out from the bow and the stern of the vessel.*
>
> *The waves emanating from the bow are commonly named bow wake and follow a diverging pattern along the path of the vessel as they propagate out from the sailing line. A series of transverse waves, stern waves, propagate along the sailing line in the direction opposite to the vessel transit.*
>
> *The stern waves are typically smaller than the bow wake. The largest wave heights are encountered where the transverse waves and the diverging waves intersect,*

which occurs along the cusp locus line, which has been found to form an angle of 19.28° relative to the sailing line."

Based on the information provided above, the alternative definition of secondary waves stated in the information request, namely that "secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights" is, therefore, also technically correct.

Confirm that "H" in the PIANC (1987) secondary wave formula (as presented in Marine Shipping Addendum Appendix 7.2-B) is wave height, and that "h" is the channel depth.

The VFPA confirms that "H" in the PIANC (1987) formula refers to wave height and that "h" is the channel depth.

The following form of the PIANC (1987) formula was presented in MSA Appendix 7.2-B:

$$H = h * \alpha_1 * \left(\frac{s}{h}\right)^{-0.33} * F_h^4$$

It was incorrectly stated that 'H' refers to channel depth. In fact 'H' refers to the calculated wave height. Channel depth is represented by the term 'h'. The error was likely caused by automatic capitalisation in the word processing program.

Justify the appropriateness of using the Froude number for shallow water calculations in the PIANC (1987) model. If this is deemed inappropriate, use the deep-water form in all wave calculations and present revised tables and figures, as appropriate.

As clarification, the Froude number, as calculated specifically for this wave environment assessment and presented in MSA Appendix 7.2-A, satisfies the deep water condition and is, therefore, appropriate for application in the marine shipping area. The justification for the appropriateness for the deep water condition is provided below.

The PIANC (1987) formula presented above contains the term F_h, the Froude number:

$$F_h = \frac{V_s}{\sqrt{gh}}$$

Where,

h = channel depth

V_s = vessel speed

g = acceleration due to the earth's gravity

The PIANC (1987) was developed for vessel waves in deep water conditions when the Froude number of the form F_h is less than 0.7. For example, the average water depth in Segment B of the navigation channel varies between 44 m and 320 m. With an average speed of

15.5 knots for a container vessel transiting through Segment B (as stated in MSA Table 4-5), the maximum Froude number F_h is 0.38, which satisfies the deep water condition.

An alternative form of the Froude number (F_L) utilising ship length, Ls, instead of channel depth, h, was also considered in developing the formula for vessel wake height. It was found, however, that the ship's length and the block coefficient do not have a large influence on secondary waves (Schiereck 1993). The two length variables that were found to have greater effect on the height of vessel wake are vessel draught, d, and entrance length, L_e. Entrance length, a measure of the curvature of the bow, is defined as the distance from the vessel's bow to the commencement of the parallel mid-body section. These vessel characteristics have a greater effect because discontinuities in the ship's hull are responsible for the emission of pressure waves. The influence of vessel geometry on vessel wake is represented by coefficients α_1 and α_2 which are defined as follows:

$$\alpha_1 = \alpha_2 * \left(\frac{d}{Le}\right)$$

Where,

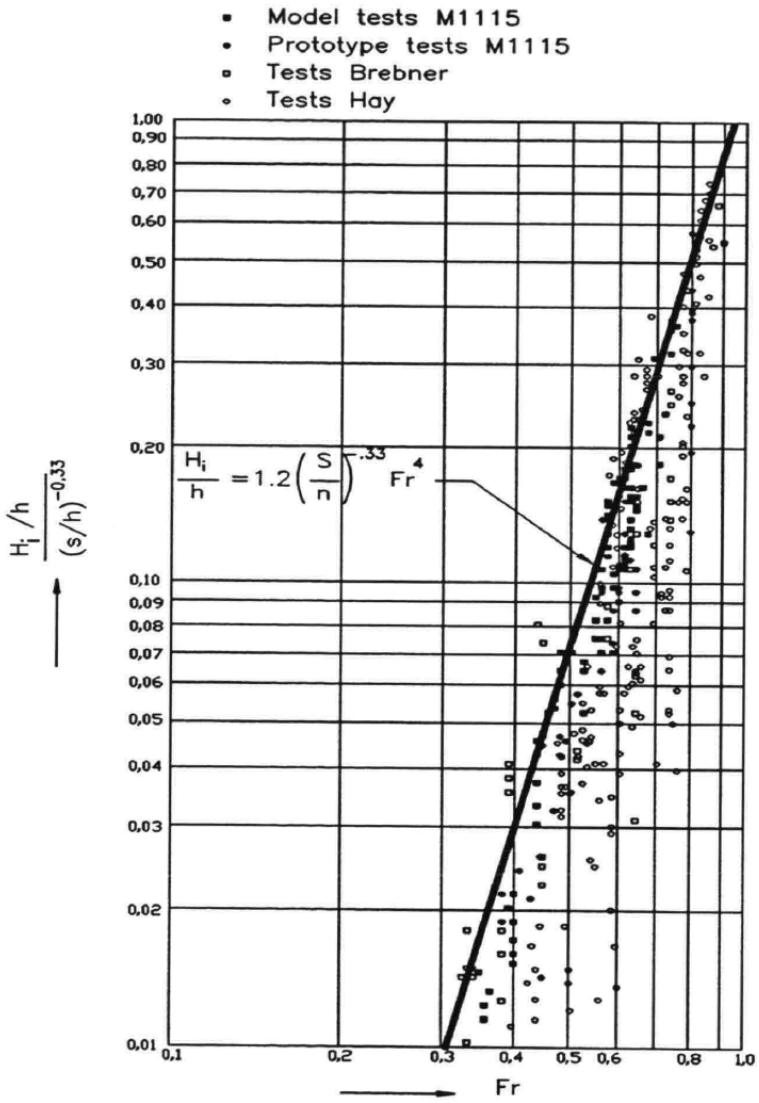
d = vessel draught

L_e = entrance length

α_2 varies between 1.5 and 4.0. The large variation is because the coefficient covers all types of vessels, from ocean going carriers to barges and small crafts. When no experiment or field data is available, a conservative value of 4.0 is recommended (Schiereck 1993).

Figure IR7-18-1, reproduced from Schiereck 1993, illustrates the relationship between calculated wake heights based on the PIANC (1987) formula and field data from hundreds of wake-generated wave measurements. The solid line is derived using the equation with α_1 value of 1.2. The figure shows that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit for estimating wake height. Therefore, when a vessel's entrance length is unknown, a safe upper limit of the α_1 value of 1.2 is recommended (Schiereck 1993)

Figure IR7-18-1 Relationship of Calculated Wake Height Using PIANC (1987) Formula with Field Wake Height Measurements



Source: Schiereck 1993.
Note: Solid line is derived using the PIANC (1987) formula with α_1 value of 1.2.

The following α_1 coefficient values were published in Verhey and Bogaerts (1989):

- α_1 = 1.0, for tugs, patrol boat, and loaded conventional inland motor vessels;
- α_1 = 0.5, for empty European barges (wave heights produced by loaded barges are relatively small and can be neglected); and
- α_1 = 0.35, for empty conventional motor vessels.

Ocean-going vessels such as tankers and container ships are not expected to generate wakes greater than those generated by tugs. For the wave environment effects assessment, an α_1 value of 0.7 for container ships was adopted. As a comparison, an α_1 value between 0.24 and

0.64 was estimated for liquified natural gas carriers associated with the Woodfibre Project (Moffatt and Nichol 2014).

Based on the above information, the method used to calculate ship wake through Segment B relies on an appropriate Froude number, as applied to the PIANC (1987) formula.

Reproduce the plots in Appendix 7.2-B, Figure 1, but plot dimensionless wave height against dimensionless cross- track distance. The plot for various vessel types should include vessels that will use RBT2, using examples from Marine Shipping Addendum Figure 4-4. Wherever appropriate, include measured wave height from actual or model vessels.

The plots presented in Figure 1 of MSA Appendix 7.2-B are reproduced in **Figure IR7-18-2** using dimensionless wave height against dimensionless cross-track distance as requested. The vessel wake is normalised in the form of gH/Vs^2. The dimensionless cross-track distance is normalised in the form of s/Ls, where Ls is ship length.

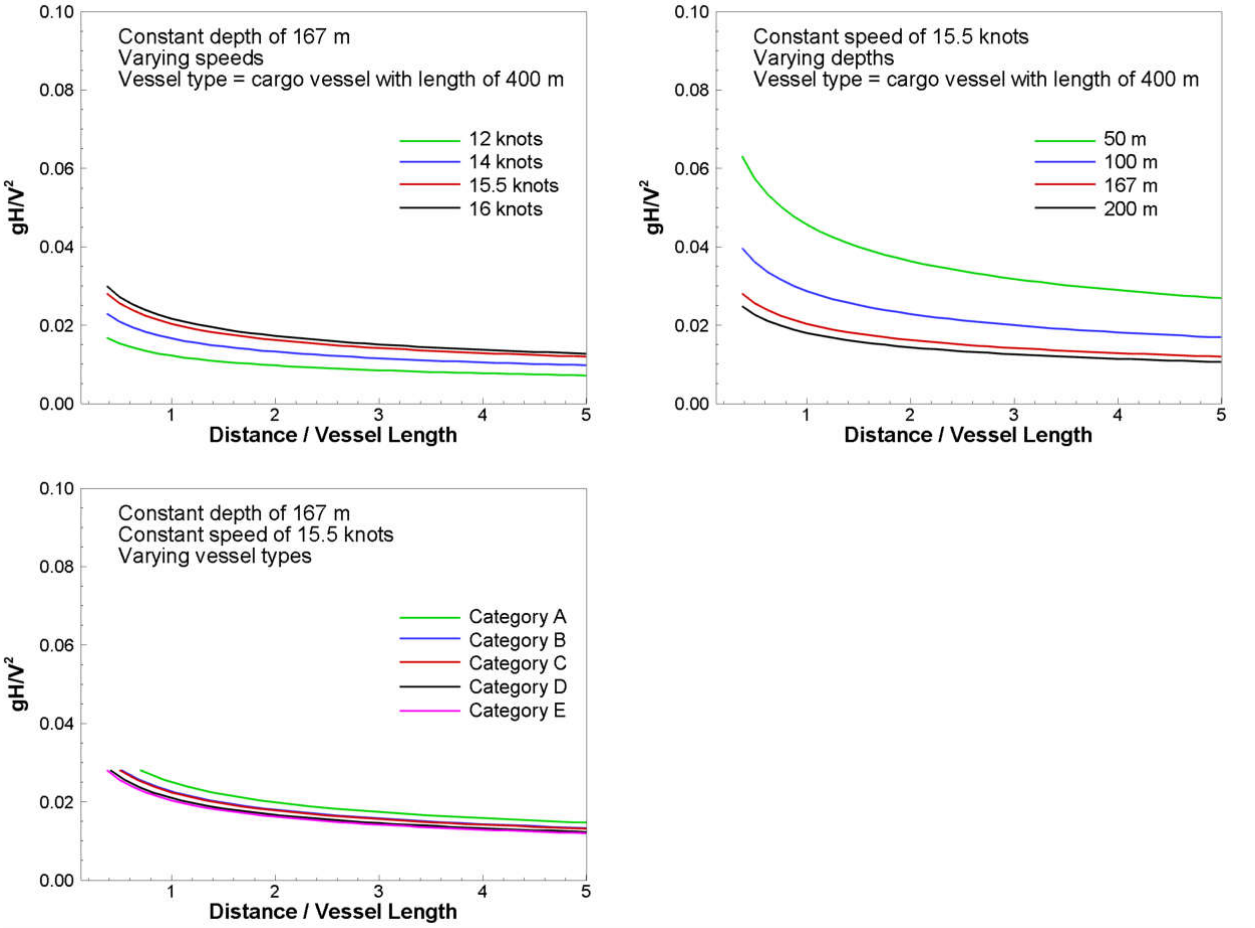
The following ship length information was used along with an α_1 value of 0.7 for the plots of the various vessel categories listed in MSA Figure 4-4:

- Category A – 215 m length for a 2,500 twenty-foot equivalent unit (TEU) vessel;
- Category B – 290 m length for a 3,400 to 4,500 TEU vessel;
- Category C – 300 m length for a 6,000 to 8,000 TEU vessel;
- Category D – 366 m length for a 12,500 vessel; and
- Category E – 400 m length for a 18,000 TEU vessel.

It is not possible to estimate wake for the region immediately beside the ship hull using the PIANC (1987) formula (vessel wake approaches infinity). There is generally insufficient dispersion within one boat length to clearly define the periods of the key waves within this nearfield range[1]. The minimum length shown in MSA Figure 4-4 is 137 m for a 500 to 800 TEU container ship. The distance away from the vessel used to generate the **Figure IR7-18-2** plots ranged between 150 m and 2,000 m.

[1] It is also dangerous for other vessels to operate this close to a large ship, and therefore, nearfield vessel wakes (<150 m) are not considered to be an assessment concern.

Figure IR7-18-2 Dimensionless Wave Height versus Dimensionless Cross-track Distance Plots

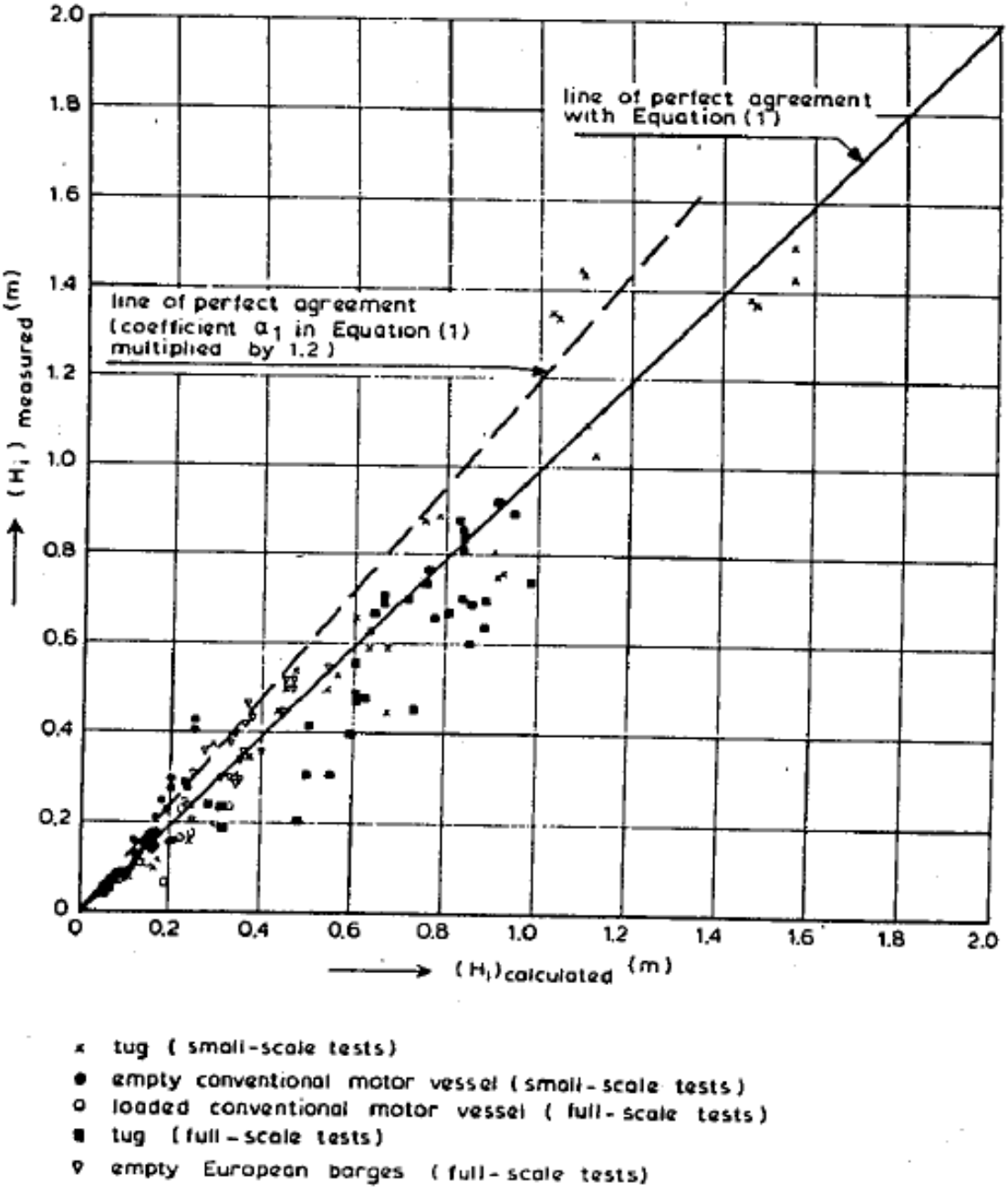


Provide an assessment of maximum probable error in secondary wave height at shorelines as calculated by the PIANC (1987) model for waves in Zones 1, 2 and 3.

No digital experimental or field data from published literature is readily available to evaluate the requested maximum probable error for each specific vessel type assessed. **Figure IR7-18-3** shows the comparison by Verhey and Bogaerts (1989) of measured and calculated wave heights for a range of vessel types. The solid line in the figure represents the line of perfect agreement using the PIANC (1987) formula with α_1 value of 1.0. The dashed line represents the line of perfect agreement with α_1 value of 1.2.

Similar to the results shown above in **Figure IR7-18-1**, these results show that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit as compared to the available field data. The maximum vessel wake reaching near the shoreline before breaking in Segment B is estimated to be 0.12 m. **Figure IR7-18-3** shows small deviations between measured and calculated vessel wakes when the wake values are less than 0.2 m.

Figure IR7-18-3 Comparison Between Measured and Calculated Wave Heights

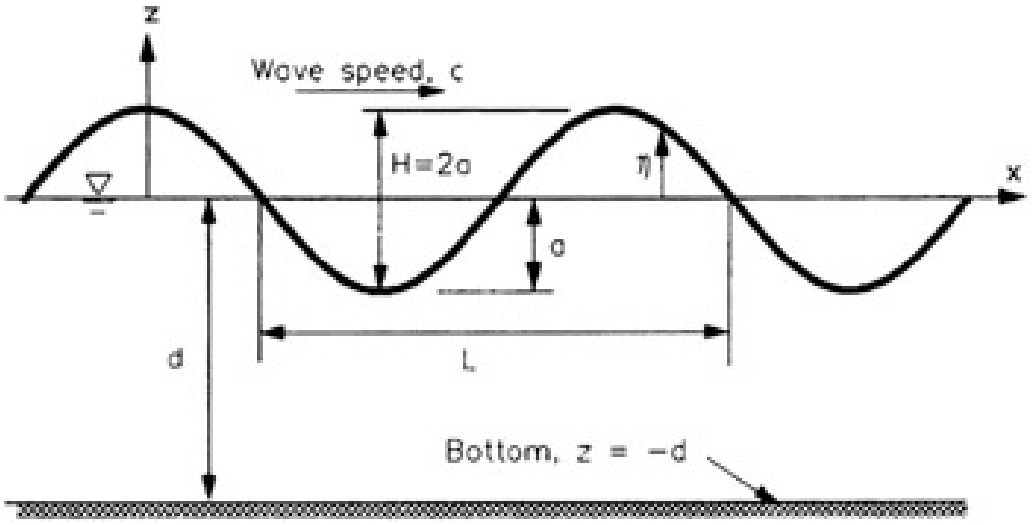


Source: Verhey and Bogaerts (1989).
Notes: Solid line represents the line of perfect agreement using the PIANC (1987) formula with α_1 value of 1.0. Dashed line represents the line of perfect agreement with α_1 value of 1.2.

Reassess the conclusion that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

Waves are generally described in terms of wave height (distance between trough and crest), wavelength (distance between wave crests), and wave period (time between wave crests). as illustrated in **Figure IR7-18-4**.

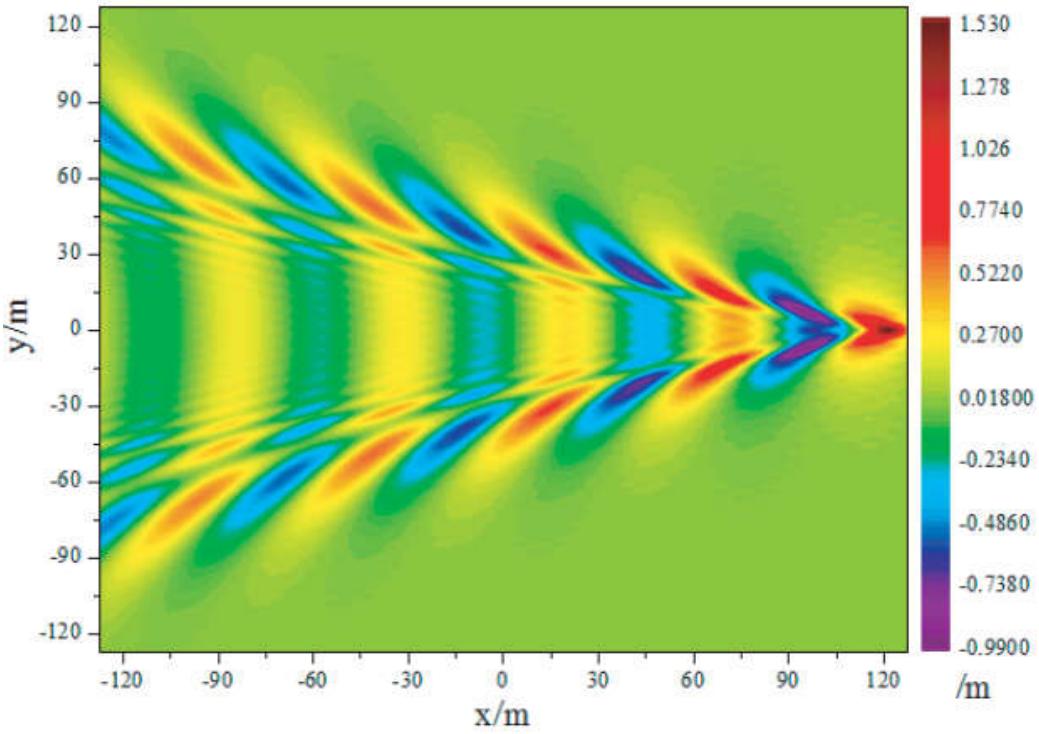
Figure IR7-18-4 Components of a Wave, including Wave Height, Wavelength, and Wave Period



While vessel wakes and wind-generated waves have different sources, a simple wind generated wave exhibits similar characteristics to a vessel wake-generated wave that has travelled away from the vessel. Although steeper and sharper waves are often observed closer to the line of travel of the vessel, waves several vessel lengths away follow the classic wave theory shown in **Figure IR7-18-4**, thereby providing a good basis for comparison of waves generated by vessel wake and wind-generated waves.

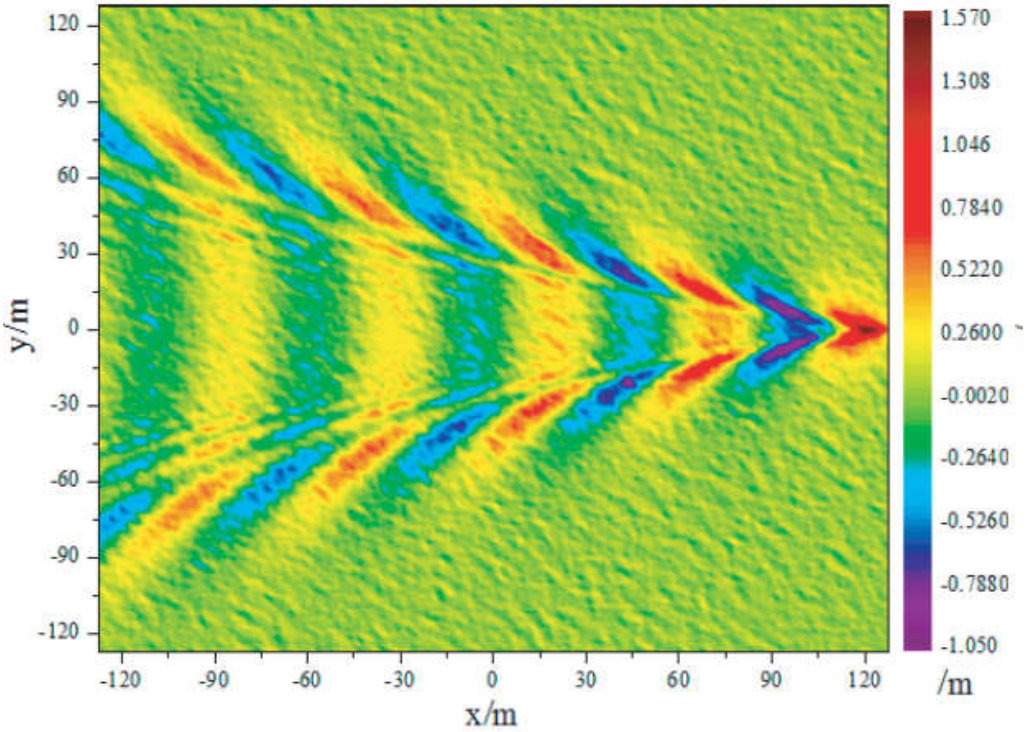
Figure IR7-18-5 shows a modelled vessel wake by Wang et al. (2016) from a ship with dimensions of 52 m length by 5.9 m beam and 3.5 m draught travelling at 9 m/s (or 17 knots). **Figures IR7-18-6** and **IR7-18-7** show modelled vessel wake on the sea surface with wind speed of 3 m/s and 5 m/s, respectively. Since wind waves and vessel wake exhibit similar characteristics, direct superposition of the ship wake on the sea surface is performed. The figures show that the effect of the wind waves on the vessel wake is significant and that the vessel wakes are indistinguishable from wind waves away from the source (**Figure IR7-18-7**).

Figure IR7-18-5 Simulated Vessel Wake for a Vessel Travelling at 9 m/s



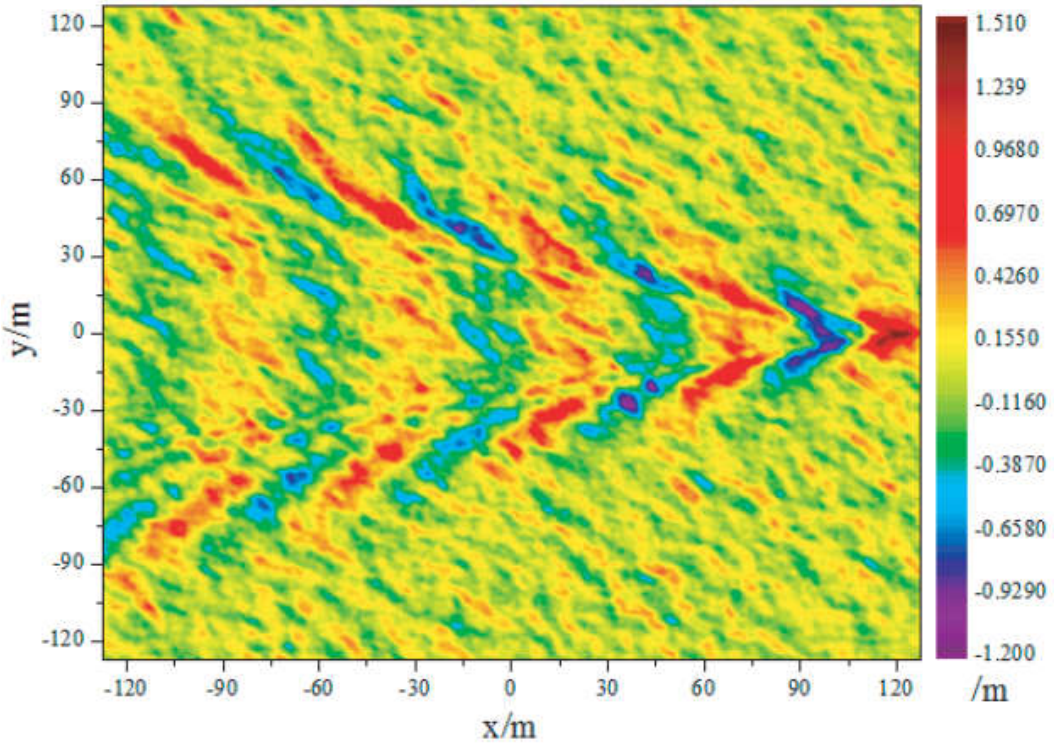
Source: Wang et al. 2016.

Figure 7-18-6 Simulated Vessel Wake for a Vessel Travelling at 9 m/s and Wind Speed of 3 m/s



Source: Wang et al. 2016.

Figure 7-18-7 Simulated Vessel Wake for a Vessel Travelling at 9 m/s and Wind Speed of 5 m/s



Source: Wang et al. 2016.

In the RBT2 wave environment assessment, wake was considered in the context of the existing wind-generated wake climate. At most shoreline locations in Segment B Zones 1, 2, and 3, which are predicted to receive wake waves exceeding 10 cm in height, the wake-generated wave was predicted to be between 10 cm and 12.5 cm (as summarised in MSA Table 7.2-5). The second most probable wake-generated wave height, by shoreline length, is between 12.5 cm and 15 cm. It is unlikely that at shoreline locations any difference would be observed between a wave that is 12.5 cm in height from a wave that is 15 cm in height. Therefore, the generalised statement that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations is valid.

Specify at what shoreline locations vessel wake would be distinguishable from the spectrum of wind-generated waves during calm conditions.

As described in MSA Section 7.2.2.2, calm conditions were defined as waves with height less than 10 cm (WMO 2015). MSA Figure 7.2-2 showed locations where wake-related waves greater than 10 cm were predicted to intersect with a shoreline within Zones 1, 2, and 3. It follows that wake height of 10 cm or greater would theoretically be distinguishable from the spectrum of wind-generated waves during calm conditions at the locations indicated in Figure 7.2-2. MSA Table 7.2-5 summarised shoreline lengths in each zone expected to be exposed to wake of various heights as well as the probability that a 'natural wave' (e.g., wind-generated wave) would occur with a height equalling or exceeding the wake-generated wave.

The inverse of this probability defines the probability that a natural wave would be smaller than the wake-generated wave, or the probability that a wake-generated wave would be distinguishable from the wind-generated wave. The inverse probabilities are presented in **Table IR7-18-1**, which is modified from Table 7.2-5 of the MSA.

Table IR7-18-1 Probability that Vessel-generated Waves Would be Distinguishable from Natural Waves by Length of Shoreline and Wake Height in each Zone (modified from Table 7.2-5 of the MSA)

Zone	Wake Height Range (cm)	Shoreline Length (km)	Probability That a Vessel-generated Wave Would be Distinguishable from Natural Waves (%)
1	10 – 12.5 12.5 – 15 15 – 20 20 – 25	1.73 1.14 0.53 *none*	40%
2	10 – 12.5 12.5 – 15 15 – 20 20 – 25	1.26 0.31 0.20 *none*	46%
3	10 – 12.5 12.5 – 15 15 – 20 20 – 25	21.34 15.34 14.96 3.86	25%
	≥25	0.28	64%

References

Moffatt and Nichol. 2011. Vessel Wake Study (DRAFT). Report prepared by Moffatt & Nichol for KM LNG Operating General Partnership, Vancouver, BC. 18 pp. Provided as Appendix IR7-17-A in the response to IR7-17.

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IR7-19 Wave Environment – Wake Waves by Vessel Type

Information Source(s)

Marine Shipping Addendum: Table 4-4; Section 7.2.4.2; Appendix 7.2-B, Figure 1

Context

The Proponent assumed that wake waves generated by all vessels (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels) through Segment B are similar to wake waves generated by the representative container ship presented in Table 4-4 of the Marine Shipping Addendum.

Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum showed that the vessel wake heights at near range vary from approximately 0.14 metres for empty conventional motor vessels to 0.38 metres for tugs and patrol boats - all travelling at 15.5 knots.

Additional information is required regarding the relationship between wake wave heights and vessel type.

Information Request

Confirm wake wave height values for near range for the four vessel types in Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum.

To all panels of Figure 1 of Appendix 7.2-B, add curves for representative container ships and representatives of all classes of vessels passing through Segment B (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels).

Reassess the assumption that wake waves generated by all vessels are the same.

VFPA Response

Context

The Marine Shipping Addendum (MSA) includes a vessel wake evaluation (MSA Section 7.2) to assess the contribution of RBT2-associated vessel wake to the existing wind-driven wave climate. Figure 1 in Appendix 7.2-B of the MSA presents three plots of wake height for varying input parameters: i) vessel speed, ii) water depth, and iii) hull coefficient. As described in the response to IR7-13, the focus of the MSA vessel wake evaluation is to assess vessel wake interactions at shorelines within the marine shipping area where wake exceeding 10 cm in height may arrive from deep water. Figure 1 of MSA Appendix 7.2-B is therefore included as part of a sensitivity analysis, to demonstrate the relatively small variation in wake height at distances of 1,000 m and greater when the input parameters are varied within a reasonable range of values. As stated in Section 7.2.4.2 of the MSA, the assumption that wake characteristics of all vessels will be similar to that of the representative container ship

described in Table 4-4 of the MSA was made based on the relatively small variation in wake height at the typical offset distances to shorelines from the vessel routes that were assessed.

The questions posed in this information request refer to 'near range' values of wake height. Near range is inferred to mean an offset distance of between 150 m and 500 m. An explanation for why wake height at offset distances of less than 150 m is not considered is included in the response to IR7-18.

Confirm wake wave height values for near range for the four vessel types in Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum.

The vessel wake evaluation was conducted using the PIANC (1987) formula. The equation to determine vessel wake height (H) is as follows:

$$H = h * \alpha_1 * \left(\frac{s}{h}\right)^{-0.33} * F_h^4$$

Where,

s = Distance between the vessel and the point of interest
α_1 = Coefficient depending on vessel type
h = Channel depth
F_h = *Froude number,* $F_h = \frac{V_s}{\sqrt{gh}}$
V_s = Vessel speed

The influence of vessel geometry on vessel wake is represented by coefficient α_1, which was varied between 0.35 and 1.0 in Figure 1 of MSA Appendix 7.2-B. The following α_1 coefficient values are published in Verhey and Bogaerts (1989):

α_1 = 1.0 for tugs, patrol boat and loaded conventional inland motor vessels;
α_1 = 0.5 for empty European barges (wave heights produced by loaded barges are relatively small and can be neglected); and
α_1 = 0.35 for empty conventional motor vessels.

Tankers, cargo or carrier vessels, and container ships (large ocean-going vessels) are not expected to generate wakes greater than that from the tugs. For the MSA vessel wake evaluation, α_1 value of 0.7 for large ocean-going vessels was adopted.

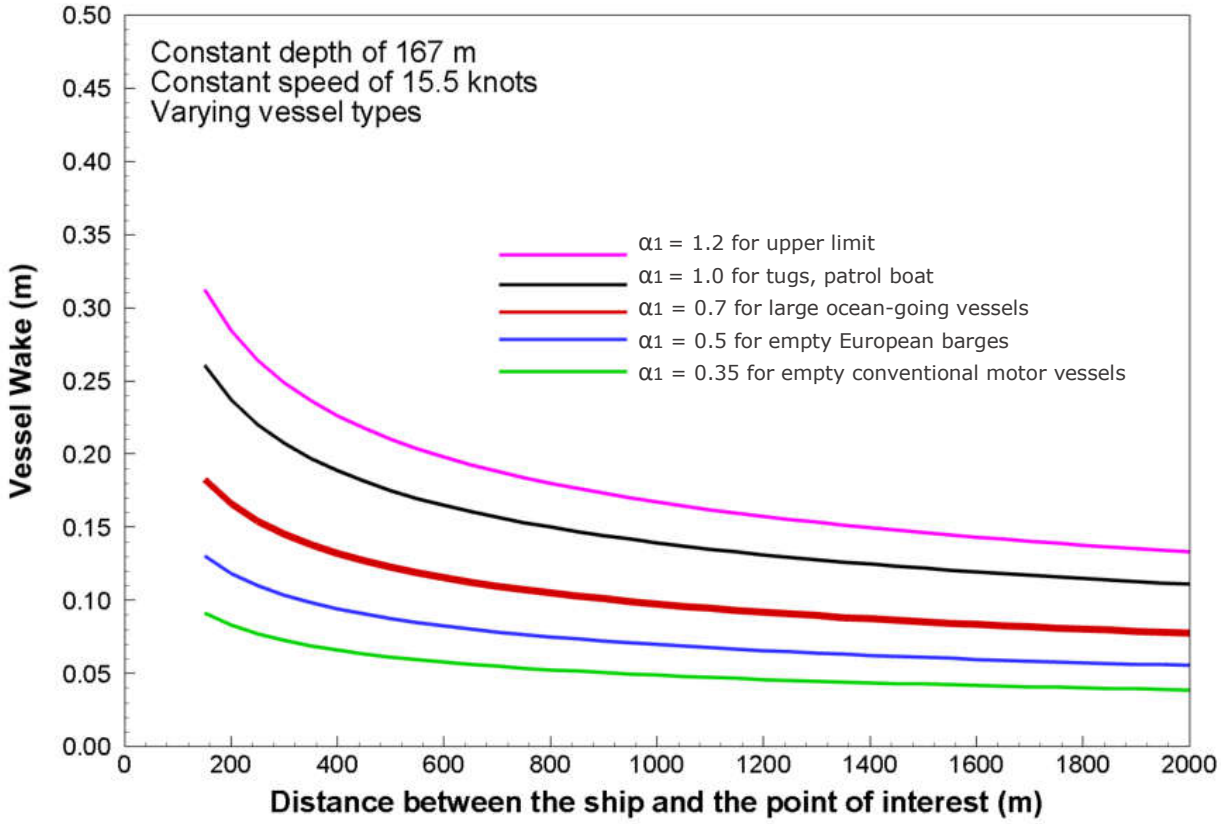
The relation of the PIANC (1987) formula with data from hundreds of field measurements originally published in Schiereck (1993) is shown in Figure IR7-18-1 in the response to IR7-18. The solid line is derived using the equation with α_1 value of 1.2. The figure shows that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit.

Figure 1 of MSA Appendix 7.2-B is reproduced in **Figure IR7-19-1** below with two additional curves: 1) upper limit using of α_1 value of 1.2, and 2) large ocean-going vessels using of α_1

value of 0.7. The value of sailing distance away from the vessel used to generate the plots ranges between 150 m and 2,000 m. (A discussion of the minimum distance from the sailing line that the formula is valid is included in the response to IR7-18.)

The results show that at 150 m away from the vessel track, the calculated vessel wake varies between 0.09 m and 0.31 m for the various vessel types assessed. At an offset distance of 500 m, the vessel wake varies between 0.06 m and 0.21 m. Within this offset distance range, the representative container vessel wake height is at approximately the mid-point in the wake height range. These values are consistent with the values presented in Figure 1 of MSA Appendix 7.2-B.

Figure IR7-19-1 Vessel Wake Height Variation as a Function of Hull Coefficient



To all panels of Figure 1 of Appendix 7.2-B, add curves for representative container ships and representatives of all classes of vessels passing through Segment B (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels).

Per the information request, **Figure IR7-19-1** includes curves for container ships and representatives of all classes of vessels passing through Segment B. The information request is for all panels of Figure 1 of EIS Appendix 7.2-B to be similarly updated; however, the other two panels of Figure 1 show variation in wake height by vessel speed (between 12 knots and

16 knots), and in water depth (between 50 m and 200 m), respectively. It is not practical to include more than a single vessel type in each of these additional panels.

Reassess the assumption that wake waves generated by all vessels are the same.

As stated in Section 7.2.4.2 of the MSA, and reiterated above, the assumption that wake characteristics of all vessels will be similar to that of the representative container ship that was the focus of the MSA was made based on the relatively small variation in wake height at the typical offset distances to shorelines from the vessel routes that were assessed. This assumption is valid in the context of the MSA because the receptor shoreline was the focus of the assessment.

In the context of this information request, which seeks clarification about wake heights in the 'near range', the assumption is less valid, given the slightly larger variation in wake height at 150 m offset distance from the sailing line (e.g., between 0.09 m and 0.31 m). Near range wake heights were not considered in the MSA (discussed further in the responses to IR7-21, IR7-22, and IR7-23), as the international shipping lanes are located more than 150 m from shore.

References

Schiereck, G. J. 1993. Introduction to Bed, Bank, Shore Protection: Engineering the Interface of Soil and Water. TU Delft, Department Hydraulic Engineering.

Verhey, H. J. and M. P. Bogaerts. 1989. Ship Waves and the Stability of Armour Layers Protecting Slopes. Delft Hydraulics Publication No. 428 (pp. 12). Paper presented at the 9th International Harbour Congress, Antwerp, Belgium, 20-24 June 1989.

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IR7-20 Wave Environment – Modelling Ship Wake Waves

Information Source(s)

Marine Shipping Addendum: Section 7.2.4.1; Appendix 7.2-A, Figure 7.2-1

Context

In Section 7.2.4.1 of the Marine Shipping Addendum, the Proponent clarified that modifications to the wave climate caused by interactions with the shoreline and seabed were not described, nor were they the subject of this assessment.

The Proponent did not address wave shoaling, reflection and refraction, which primarily occur at shorelines. The wave environment assessment was focused on shorelines through the three zones of assessment which were selected because they include shorelines.

Information is needed on the wave environment in the nearshore zone where shoaling, reflection and refraction are important processes.

Information Request

Using information provided in response to Review Panel information request IR7-18, provide an assessment to determine if wave shoaling, wave reflection and wave refraction are likely to be important along shorelines in Zones 1, 2 and 3 of the marine shipping local study area.

Provide a prediction of the likely magnitude of waves breaking on shorelines where shoaling, reflection and refraction that is likely to occur in Zones 1, 2 and 3.

Assess whether nonlinear wave effects such as shoaling, reflection and refraction are likely to contribute to the production of wave heights greater than that which may be expected solely from the proportion of additional vessel traffic.

VFPA Response

The three components of this information request are responded to by describing the characteristics of shoaling, wave reflection, and wave refraction, as opposed to responding to each component separately. As described in the response to IR7-18 (and illustrated in Figure IR7-18-4), wave characteristics include wave height (distance between trough and crest), wavelength (distance between wave crests), and wave period (time between wave crests). Wind-generated waves and vessel wake-generated waves exhibit similar characteristics for a given wave height. Wave shoaling, reflection, and refraction may be important along various shoreline segments within Zones 1, 2, and 3, but waves generated by passing ships are not expected to differ from waves generated by winds. Hence, as outlined in Section 7.2.4.1 of the Marine Shipping Addendum (MSA), modifications to the wave climate caused by interactions with the shoreline and seabed were not assessed.

Clarification as to the scope of the wave environment assessment is provided in the *Preamble for IR7-13 to I7R-23 Wave Environment Information Requests*, which includes the rationale for assessing the contribution of ship wake to the existing wind-generated wave climate. Waves, whether generated by wind or from ship wake, are expected to interact with the shoreline in Zones 1, 2, and 3 of Segment B in similar ways given similar wave characteristics.

In order to respond to this information request, the behaviour of waves generated by ship wake was compared to that of wind-generated waves. The wave period for a vessel travelling at 15.5 knots (the average speed of ships transiting through Segment B) was calculated to be 4.2 seconds. The vast majority of wind-generated waves in the open Strait of Georgia and Juan de Fuca Strait have periods in the range of 2 to 4 seconds (Thomson 1981). The wave period generated by ship wake, therefore, is predicted to be at the upper end of the natural wind-generated wave climate range. The behaviour of waves with periods ranging from 2 to 4.2 seconds with respect to shoaling, refraction, and reflection are compared below.

Wave Shoaling

Wave shoaling occurs as a wave enters shallower water and begins to interact with the bed. The wave speed and wave length decrease in shallow water resulting in an increase in wave height. The wave shoaling coefficient, which describes the ratio of the wave height at a particular point versus the original deep water wave height, depends on water depth and the incident wave period. **Figure IR7-20-1** shows the shoaling coefficient calculated for waves with period of 2, 3, 4, and 4.2 seconds. The figure shows that the shoaling coefficient increases from 1.06 when the wave period is 2 seconds to 1.43 when the wave period is 4.2 seconds.

Figure IR7-20-1 Shoaling Coefficients for Four Wave Periods (2, 3, 4, and 4.2 Seconds)

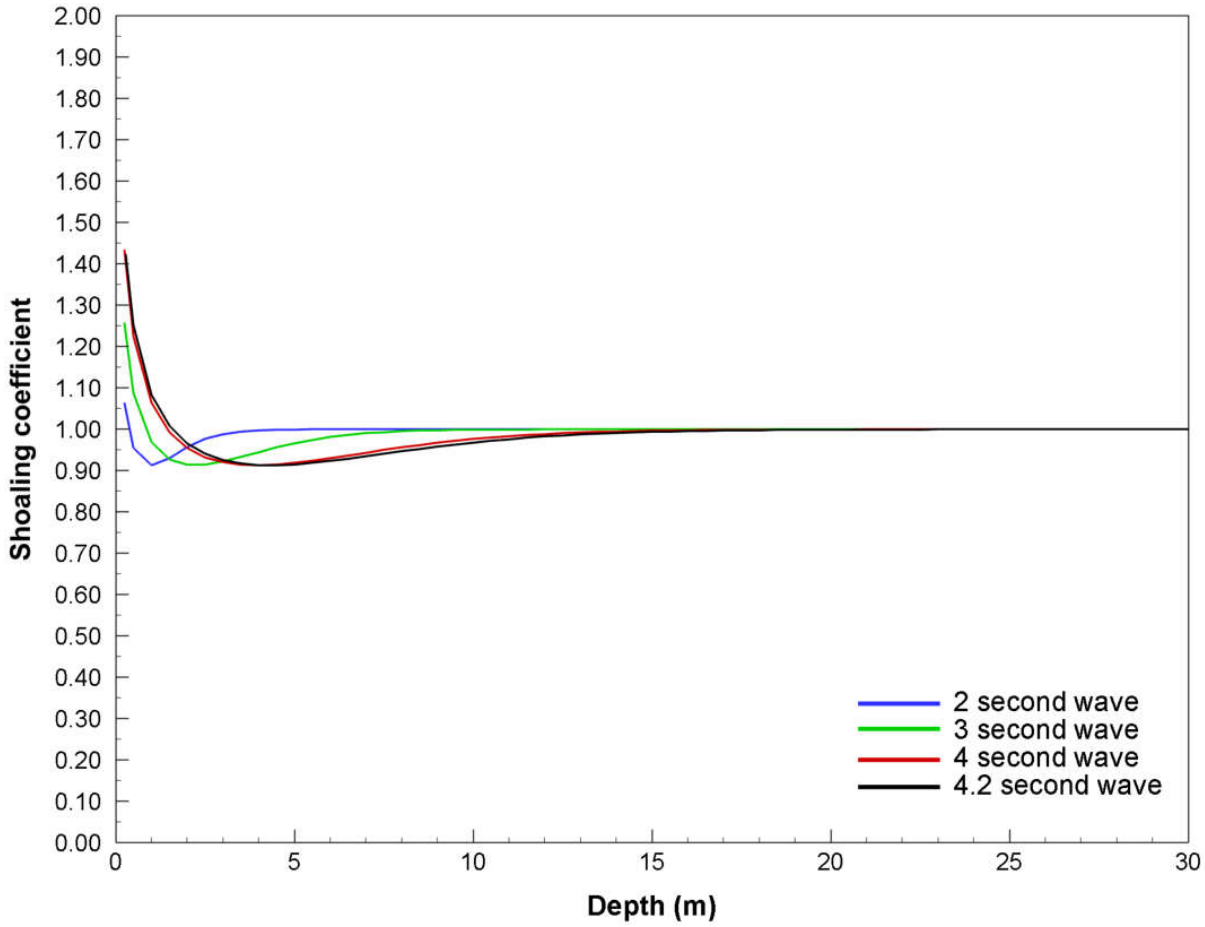


Table 7.2-5 of the MSA showed that 99.5% of the shorelines in Zones 1, 2, and 3 (total length of 60.95 km) were predicted to receive wake waves equal to or less than 0.25 m, and 39.9% are predicted to receive wake waves equal to or less than 0.125 m. **Table IR7-20-1** summarises the calculated nearshore wake-generated wave heights predicted for RBT2-associated vessels (i.e., vessel wakes) and wind-generated waves equal to or less than 0.25 m (for four wave height categories and four wave periods) in Juan de Fuca Strait (i.e., Zone 3 in Segment B, which experiences the largest wave heights of the three zones). The largest difference between shoaled wind-generated wave heights and shoaled vessel wakes is 0.10 m (i.e., when comparing a 2 second to 4.2 second wave period for an incident wave of 0.25 m). For a 0.125 m incident wave, the difference between these wave periods is 0.06 m.

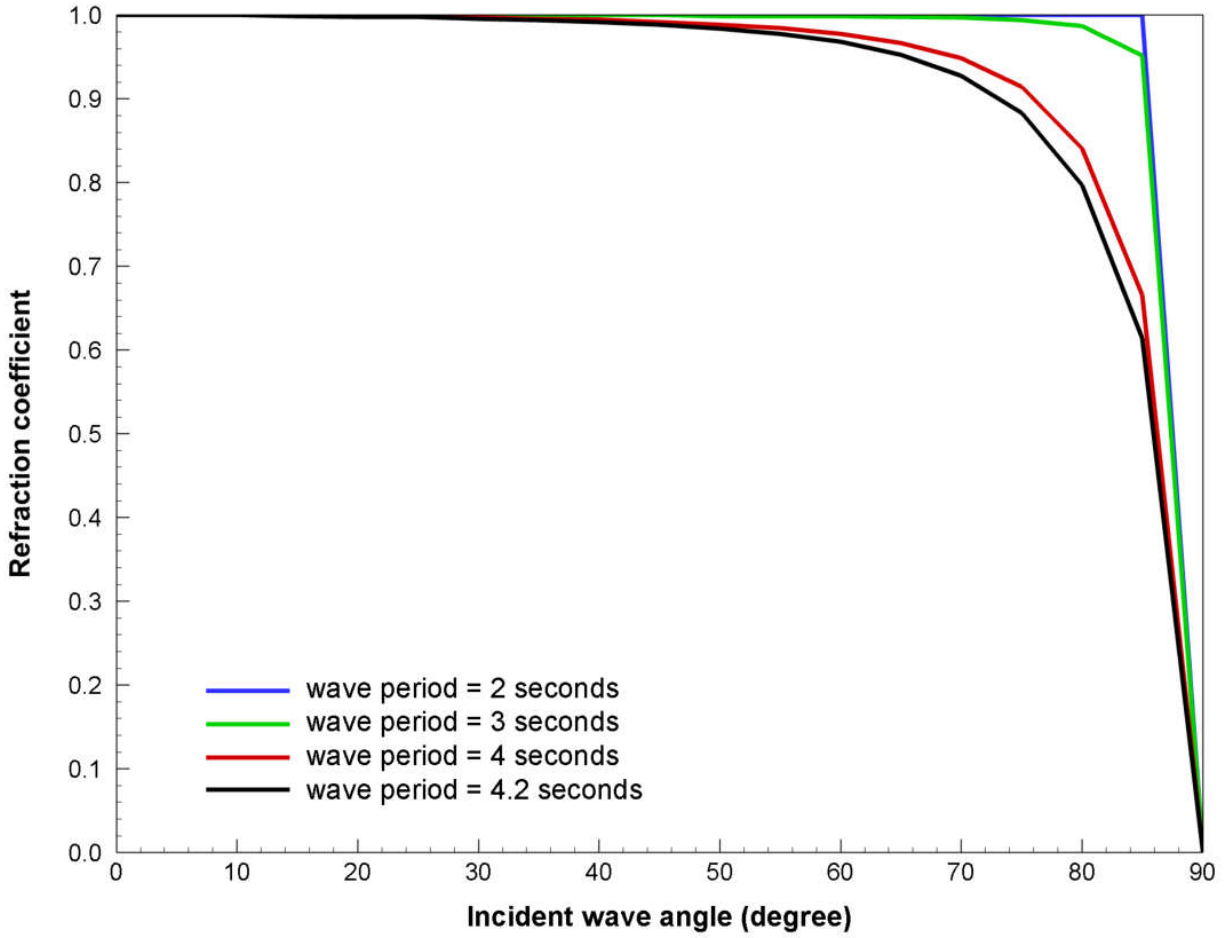
Table IR7-20-1 Nearshore Wave Heights due to Shoaling for Four Wave Periods and Four Deepwater Incident Wave Heights

Wave Type	Wave Period (s)	Deepwater Wave Height (m)	Nearshore Wave Height (m)
Vessel wake	4.2	0.125	0.21
Wind wave	4.0		0.21
	3.0		0.18
	2.0		0.15
Vessel wake	4.2	0.15	0.24
Wind wave	4.0		0.24
	3.0		0.21
	2.0		0.17
Vessel wake	4.2	0.20	0.30
Wind wave	4.0		0.29
	3.0		0.26
	2.0		0.22
Vessel wake	4.2	0.25	0.36
Wind wave	4.0		0.35
	3.0		0.31
	2.0		0.26

Wave Refraction

Wave refraction occurs when a wave approaches the shore at an angle. During refraction, the wave crests bend to align themselves with the bottom contours and the wave direction becomes more perpendicular to the shore. Wave refraction is considered as a separate process, independent of wave breaking. **Figure IR7-20-2** shows the refraction coefficient versus incident wave angle for four different wave periods at 10 m water depth. The figure shows that wave attenuation does not occur when incident waves are perpendicular to the shoreline. When the incident waves are parallel to the shoreline, waves do not reach the shoreline and the refraction coefficient is 0. The figure also shows that the refraction effect is greater for waves with longer wave periods than waves with shorter wave periods. Since the refraction effect would tend to reduce wave heights, omitting this effect from the wave environment assessment results in a conservative prediction of the height of wake arriving at the nearshore environment (i.e., larger waves would be predicted without taking the refraction effect into consideration).

Figure IR7-20-2 Refraction Coefficients for Four Wave Periods (2, 3, 4, and 4.2 Seconds)



Wave Reflection

Wave reflection occurs when an incident wave bounces back from an obstacle it encounters with some or little loss of energy. The effect is not related to breaking waves on the shoreline. The amount of wave energy reflected from a shoreline is a function of the material on the shore, the shoreline slope angle, the size and porosity of the shoreline structure, and the properties of the incoming waves (e.g., wave height and wave period) (U.S. Army Corps of Engineers 2002). Reflected waves can cause interference with incoming waves, resulting in standing waves. These are common in coastal areas where waves reflect off seawalls. The wave height of the standing wave is twice that of the incident wave. For instance, a standing wave height of 0.50 m can be expected in a coastal region with seawall structures with an incident wave of 0.25 m.

Summary

Based on the above explanations, the following is concluded:

- Shoaling could result in larger shoaled vessel wake waves than shoaled wind-generated waves, as shown in **Table 7-20-1**. Based on the largest wake-generated waves (0.25 m high waves, as shown in MSA Figure 7.2-2) that are expected to arrive at shorelines within Segment B, the largest wave height difference when compared to wind-generated waves is 10 cm, and the smallest wave height difference is 6 cm (comparing 0.125 m waves);
- The refraction effect would tend to reduce incident wave heights; therefore, the results of the wave environment assessment, which did not consider this effect, were conservatively predicted. Refraction is not related to breaking waves; and
- Reflection could result in standing waves in coastal regions with seawall structures. The effect would be the same for vessel wake-generated waves and wind-generated waves of similar wave heights. The effect is not related to wave breaking.

In general, the approach used to assess wake-generated waves in deep water without the consideration of near-shore changes to waves as a result of shoaling, refraction, and reflection was conservative. The shoaling effect has the potential to result in slightly higher breaking waves (between 6 cm to 10 cm higher) when comparing the slightly longer wave period of ship-generated wake (4.2 seconds) as opposed to wind-generated waves (2 to 4 seconds). Only shoaling results in breaking waves (i.e., refraction and reflection are unrelated to this process).

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IR7-21 Wave Environment – Calm Conditions

Information Source(s)

Marine Shipping Addendum: Section 7.2.2; Section 7.2.5.2

Context

In Section 7.2.2 of the Marine Shipping Addendum, the Proponent stated that a wake of 10 centimetres or less in height is considered to be well within the range of natural conditions. The Proponent also stated that a wake of 10 centimetres or less in height is considered to be within the range of calm conditions as defined by the Douglas Scale.

In Section 7.2.5.2 of the Marine Shipping Addendum, the Proponent stated that wake-generated waves would be well within the range of natural conditions and would not be perceptible except during calm conditions, and that vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations in the marine shipping local assessment area.

However, the Proponent also stated that Zone 1 (near Saturna Island), Zone 2, (near Stuart Island), and Zone 3, (near Discovery Island), would experience wind-generated waves smaller than 10 centimetres 40%, 46%, and 26% of the time, respectively.

An assessment of wake wave effects during calm conditions is required.

Information Request

Using information provided in response to Review Panel information request IR7-18, provide a re-assessment of the effects of vessel wake-driven waves impacting shorelines in Zones 1, 2 and 3 of the marine shipping local study area during calm conditions.

Provide an assessment of the effects of vessel wake-driven waves on private, commercial and government dock installations in the three zones during calm conditions.

Provide an assessment of the effects of vessel wake-driven waves on small-craft boating activities at sea between shipping routes and the shore in the three zones during calm conditions.

Provide an assessment of seasonal differences in the frequency of calm conditions in the three zones, and explain how these seasonal differences could affect the three types of effects detailed above.

VFPA Response

Background and Supporting Information

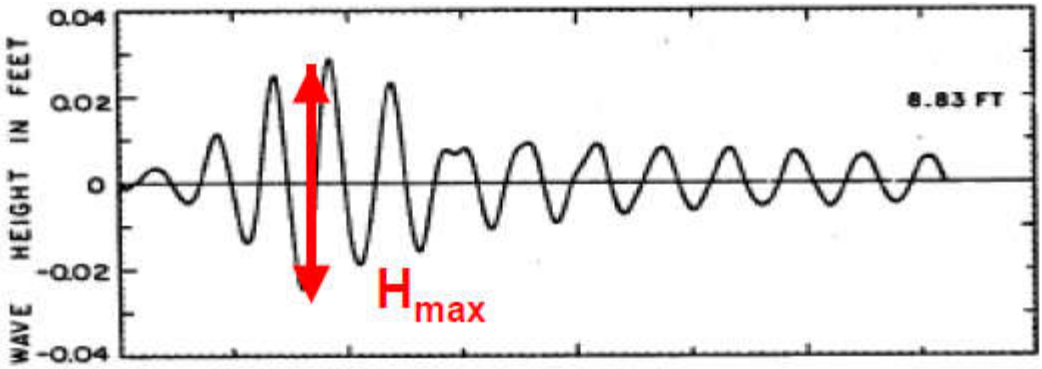
Information provided in the response to IR7-18 that is pertinent to this response includes the following:

- A discussion of the characteristics of vessel wake-generated waves compared to wind-generated waves;
- Clarification about shoreline locations in Zones 1, 2, and 3 where wake-generated waves would be distinguishable from wind-generated waves; and
- The following conclusions: 1) that for a given wave height, vessel wake waves are indistinguishable from wind-generated waves; and 2) that vessel-generated waves would be distinguishable from wind-generated waves at shoreline locations within Zones 1, 2, and 3, as defined by information in the Marine Shipping Addendum (MSA).

As further information, vessel-generated waves (i.e., those distinguished from wind-generated waves) could be determined by using the inverse of the values presented in the column labelled "Probability of Occurrence of Natural Wave of Similar or Larger Height (%)" in Table 7.2-5 of the MSA. For instance, wake-generated waves of 0.10 m to 0.20 m originating from Project-associated vessels are predicted to arrive at shorelines within Zone 1 and the probability of natural waves of 0.10 m or larger occurring in Zone 1 is 60%; therefore, there is a 40% probability that wake-generated waves of 0.10 m to 0.20 m would occur during calm conditions. This concept has been acknowledged in the Panel's context in this information request.

Another way to consider the effects of wake-generated waves in the context of the existing wind-generated wave environment is with regards to the number of waves that are generated by Project-associated vessels. As shown in **Figure IR7-21-1**, and referenced in Kriebel et al. (2003), a ship typically generates three main wake-waves, with one dominant (as indicated by the red arrow), as well as a series of minor interference waves.

Figure IR7-21-1 Example Wave Record from a Transiting Vessel



Source: Kriebel et al. 2003.

Project-associated vessel movements are expected to total 520 movements annually by 2030. Assuming that each vessel movement generates five waves (i.e., two waves before and after

the dominant wave) to be conservative, a total of 2,600 waves would be generated by Project-associated vessels in a year. A wind event that generates waves that are similar to wake-generated waves, which have a wave period of about 4 seconds (refer to the response to IR7-20 for more information), would create 900 waves in an hour. Thus, the additional waves experienced annually along the shoreline due to Project-associated vessels are slightly less than that of a three-hour wind event.

Incorporating the probability of calm periods for Zones 1, 2, and 3 from MSA Tables 7.2-2, 7.2-3, and 7.2-4, respectively, **Table IR7-21-1** summarises the occurrence of the assumed three hours of equivalent wake-generated waves occurring during calm periods in each zone as total number of hours and as percentage of the total hours of calm. The percentage of calm hours that would experience vessel-generated wake from Project-associated vessels is 0.034% for the three zones.

Table IR7-21-1 Characterisation of Calm Conditions at Zones 1, 2, and 3

	Zone 1	Zone 2	Zone 3
Percentage of Calm Conditions[a]	40%	46%	25%
Total Number of Calm Hours (based on conditions in 2012)[b]	3,504	4,030	2,190
Hours of the Assumed 3-hour Wake-Generated Wave Event Occurring During Calm Period[c]	1.20 h	1.38 h	0.75 h
Percentage of Time that the Equivalent Wake-Generated Wave Event Would Occur During Calm Period[d]	0.034%	0.034%	0.034%

Notes:

a. From MSA Tables 7.2-2, 7.2-3, and 7.2-4 for Zones 1, 2, and 3, respectively.
b. Calculated from 'Percentage of Calm Conditions' x 8,760 hours annually.
c. Calculated from 'Percentage of Calm Conditions' x 3 hours (duration to generate 2,600 waves with a 4 second wave period).
d. Calculated from 'Hours of the Assumed 3-hour Wake-Generated Wave Event Occurring During Calm Period' ÷ 'Total Number of Calm Hours'.

The information presented above is included in the responses to the requests below.

Using information provided in response to Review Panel information request IR7-18, provide a re-assessment of the effects of vessel wake-driven waves impacting shorelines in Zones 1, 2 and 3 of the marine shipping local study area during calm conditions.

The response to IR7-18 concluded that except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

From the point of view of physical processes at a shoreline, wake-generated waves arriving at a shoreline during calm periods have the same interaction as waves arriving during non-calm periods. A re-assessment is not provided, as the delivery of wake-generated waves from Project-associated vessels to the shoreline under calm conditions can be considered as a probability of occurrence. Although the probability slightly increases from Project-associated vessels (0.034% during calm conditions, as shown in **Table 7-21-1**), wake-generated waves

from Project-associated vessels will not result in a change to the shorelines in Zones 1, 2, and 3 due to the similarity of interaction at the shoreline from wake-generated and wind-generated waves

Provide an assessment of the effects of vessel wake-driven waves on private, commercial and government dock installations in the three zones during calm conditions.

Table 7.2-5 of the MSA showed that 99.5% of the shoreline in Zones 1, 2, and 3 are predicted to receive wake waves equal to or smaller than 0.25 m. The maximum wave height recorded at the New Dungeness wave buoy in 2012 was 2.7 m. The maximum 2012 hindcast wave heights at Zones 1, 2, and 3 were 1.2 m, 1.1 m, and 2.2 m respectively. Given the natural wave climate in Segment B, it is expected that any private, commercial, or government dock installations are constructed to withstand wind generated waves greater than 0.25 m. Therefore, the vessel wakes from Project-associated vessels are not expected have a physical effect on the docks during calm conditions.

Guidance concerning acceptable wave heights for small craft for both service/offloading and mooring areas at private, commercial, and government dock installations is provided in Fisheries and Ocean Canada's Harbour Accommodations Guidelines (PWGSC 2015). The smallest allowable threshold significant wave height for the smallest vessel class (0 to 10.7 m in length) is 0.3 m, which is higher than the largest wake-generated wave predicted to arrive at a shoreline in Zones 1, 2, and 3. The allowable frequency of occurrence for the threshold wave is 1.0% to 2.5% as compared to the percentage of calm hours that Project-associated vessel wake will arrive at a shoreline in Zones 1, 2, and 3, which is 0.034%[1] (**Table IR7-21-1**).

Provide an assessment of the effects of vessel wake-driven waves on small-craft boating activities at sea between shipping routes and the shore in the three zones during calm conditions.

Figure 7.2-2 of the MSA shows the extent of wake-generated waves from Project-associated vessels travelling along shipping routes in Segment B for waves in five height categories: 10 to 12.5 cm, 12.5 to 15 cm, 15 cm to 20 cm, 20 to 25 cm, and greater than 25 cm. Since the focus of the wave environment assessment was to assess wake arriving at shorelines within the marine shipping area, MSA Figure 7.2-2 does not describe wake height in proximity to the vessel; however, this can be calculated using the PIANC (1987) formula. The height of vessel wake calculated at a distance of 150 m away from Project-associated vessels travelling at 15.5 knots in Segment B is 0.47 m. In adhering to applicable regulations under the *Canadian Shipping Act, 2001*, including Collison Regulations with respect to vessel distance and overtaking vessels, it is assumed that Project-associated vessels and small craft vessels would not be within 150 m each other. Based on this information, it can be inferred that small-craft

[1] The value presented in **Table IR7-21-1** describes wake-generated waves from Project-associated vessels as a percentage of time that calm conditions occur, and includes waves smaller than the threshold significant wave height.

operating at sea between shipping routes and the shore in Zones 1, 2, and 3 could encounter waves from Project-associated vessels of 0.1 m to 0.47 m during calm conditions.

Small vessels, as defined under various Transport Canada regulations, include pleasure craft, passenger vessels (non-pleasure craft), and fishing vessels. For instance, small commercial (non-pleasure craft) vessels fall into two main categories: 0-15 gross tons and 15-150 gross tons (Transport Canada 2011), and the Safe Boating Guide for pleasure craft (Transport Canada 2014) considers a number of classes of vessels from human-powered paddleboats and sit-on-top kayaks, to sail and power boats exceeding 24 m. Construction and design standards applicable to boats built or sold in Canada dictate environmental operating limits (such as wind force and wave height) for small craft stability and buoyancy. For small commercial vessels, Transport Canada references International Standard Organization (ISO) Standard 12217, which specifies the wave height environmental limits for vessels in four design categories as exceeding 4 m, up to 4 m, up to 2 m, and 0.5 m (Transport Canada 2015).

The magnitude of wake height described above is already a feature of the environment for small-craft operators in Segment B (Haro Strait) because of transiting vessels of all sizes, including ferries, which generate larger waves due to their hull characteristics and higher transit speed during calm conditions. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazard for small-craft operators in the three zones during calm conditions.

Provide an assessment of seasonal differences in the frequency of calm conditions in the three zones, and explain how these seasonal differences could affect the three types of effects detailed above.

Table IR7-21-2 provides the frequency of calm conditions (i.e., conditions with waves less than 0.10 m) based on hindcast wave data in each zone by season. The results show that the wave climate in Segment B is not uniform throughout the year, with calm conditions occurring more frequently in summer and autumn than during spring and winter. The largest difference in seasonal calmness and the annual calmness is 21 percentage points, which occurred for winter at Zone 1. This means that compared to the annual percentage of time that calm conditions occur, wake-generated waves are less likely to occur during calm conditions in winter than in other seasons.

Table IR7-21-2 Percentage of Calm Conditions in Zones 1, 2, and 3 by Season and Annually

Period	Zone 1	Zone 2	Zone 3
Winter (December - February)	19%	26%	11%
Spring (March – May)	37%	45%	23%
Summer (June – August)	58%	55%	24%
Autumn (September – November)	45%	56%	43%
Annual	40%	46%	26%

As noted above, from a physical perspective, wake-generated waves arriving at shorelines in Zones 1, 2, and 3 during calm conditions have the same shoreline interaction as waves arriving during non-calm conditions. Considered on a seasonal basis, the assumed three hours of equivalent wake-generated waves described above translates to the equivalent of an average of an additional 45 minutes of wind-generated waves per season.

Seasonal differences in percentage of calm conditions, therefore, are not expected to affect shorelines, or coastal structures such as private, commercial, and government docks, that are designed to sustain larger wind-generated waves that are already a regular feature in the region.

Seasonal differences in percentage of calm conditions are not expected to introduce new navigational hazards for small-craft operators in Zones 1, 2, and 3 because transiting vessels of all sizes including ferries, which have the potential to generate relatively large waves due to their hull characteristics and transit speed (see response to IR7-23 for a discussion of ferry wake in Segment B), are already present.

During the summer and autumn months, human interactions with wake-generated waves from Project-associated vessels during calm conditions will be slightly higher.

References

Kriebel, D., W. M. Seelig, and C. Judge. 2003. Development of a Unified Description of Ship-Generated Waves (and some other recent work). Available at http://www.pianc.us/docs/portland2003/passingshipswkshp.pdf. Accessed November 2017.

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IR7-22 Wave Environment – Open Water

Information Source(s)

Marine Shipping Addendum: Section 9.5.5.1; Table 9.5-35; Section 7.2; Section 7.2.4.2

CEAR Doc#384

Context

As reiterated in Section 9.5.5.1 of the Marine Shipping Addendum, vessel wake from the proposed Project-associated vessels is not expected to be distinguishable from wave action on vessels engaged in commercial or recreation activities, except in calm conditions, given that vessel-related wake is within the wave-height spectrum of wind-generated waves.

In Section 7.2.4.2 of the Marine Shipping Addendum, the Proponent stated that the assessment did not describe the height of wake at the point of wave generation in open water as this assessment focused on wake-generated waves in the nearshore environment.

However, in Section 7.2 of the Marine Shipping Addendum, the Proponent stated that surface waves interact with objects in the water, the shoreline and the seabed and can move shoreline and seabed sediments, dislodge plants and animals, and move floating objects, such as boats. The Proponent also noted that potential change is anticipated if vessel wake is generated during periods of calm such that people would be affected by unexpected waves.

Indigenous groups expressed concerns about the potential environmental effects of vessel wake on their traditional activities.

Information Request

Provide a prediction of the changes that the proposed Project-related marine shipping may have on the wave environment during calm conditions in open water at various points and various distances from the shore throughout the marine shipping area.

Assess the effects of waves generated by Project-associated vessels during calm conditions on small craft engaged in activities in open water at various points and various distances from shore throughout the marine shipping area, including fishing activities in the vicinity of Swiftsure Bank.

VFPA Response

Provide a prediction of the changes that the proposed Project-related marine shipping may have on the wave environment during calm conditions in open water at various points and various distances from the shore throughout the marine shipping area.

The incidence of calm conditions at various locations within the marine shipping area is presented in Marine Shipping Addendum (MSA) Section 7.2.4.1, which reports that calm conditions occurred in Zones 1, 2, and 3 of Segment B for 40%, 46%, and 25% of the time, respectively, based on the deep water wave model results for 2012 wind conditions[1]. The results for Zone 3 likely underestimate the wave climate because the deep water wave model does not account for ocean swell (as explained in the response to IR7-16), which is indicated to be a feature of the wave climate in this area based on observations at the nearby New Dungeness wave buoy (situated southeast of Zone 3). Figure 6 of MSA Appendix 7.2-A presents observed data at the New Dungeness wave buoy that shows calm conditions occur 0% of the time (see MSA Figure 7.2-1). Wave conditions at the New Dungeness station are considered to be representative of conditions in Segment C and the eastern portion of Segment D.

Wave conditions in the western portion of Segment D are recorded at the National Oceanic and Atmospheric Administration (NOAA) Neah Bay wave buoy near Swiftsure Bank (**Figure IR7-22-1**).

[1] For marine shipping area segment locations, refer to MSA Figure 1-1, and for the location of zones assessed within the wave environment assessment, refer to MSA Figure 7.2-1.

Figure IR7-22-1 NOAA Station 46087 Neah Bay Wave Buoy Location

A summary of observed waves for 2012 at Neah Bay is presented in **Table IR7-22-1**. The maximum observed wave height was 7.68 m and the smallest observed wave was 0.32 m; there were no calm periods.

Table IR7-22-1 Summary of Observed Wave Heights at NOAA Station 46087 Neah Bay in 2012

Wave Height (m)	Percentile Exceedance (%)
7.68	0.0%
3.27	10.0%
2.67	20.0%
2.32	30.0%
1.98	40.0%
1.67	50.0%
1.42	60.0%
1.20	70.0%
1.00	80.0%
0.88	86.2%
0.78	90.0%
0.37	99.7%
0.32	100.0%

Calm conditions in Segment A have not been characterised because the expected wake-generated wave heights for Project-associated vessels manoeuvring in Segment A at an average speed of 9 knots (kn) (MSA Table 4-5) are less than 10 cm[2] and would, therefore, not be detectable during calm periods.

Although the information request asks for an assessment of Project-associated vessels in calm conditions, information is presented regardless of sea state, since the height of vessel wake is not dependent on the existing sea state (i.e., the requested wake height predictions and associated effects are not specific to calm conditions).

Contribution of Wake from Project-associated Vessels

As described in MSA Section 7.2, Project-associated vessels transiting within the marine shipping area will create waves (vessel wake) that will emanate from the ship while in motion through the water. Vessel wake was assessed in the context of the wind-generated wave climate, with a focus on the height of wake-generated waves arriving at shorelines within the marine shipping area. Since only shorelines within Segment B were predicted to be exposed to wake-generated waves in excess of 10 cm, wake-generated waves from Project-associated vessels were only presented for Segment B (as shown in MSA Figure 7.2-2).

MSA Figure 7.2-2 provides a graphical representation of the distribution of Project-associated wake-generated waves in Segment B at various distances from the sailing line, including in open water at various points and various distances from the shore. As described in the response to IR7-21, MSA Figure 7.2-2 does not describe wake height in proximity to the vessel. The rationale for why vessel wake calculations are limited to 150 m from the vessel sailing line is included in the response to IR7-18. The height of vessel wake calculated at a distance of 150 m away from Project-related vessels travelling at 15.5 knots in Segment B is 0.47 m.

Since wake height predictions were not previously presented for Segments A, C, and D, predictions are provided in **Table IR7-22-2** for offset distances of 150 m to 2,000 m, in various increments. These predictions were made using the PIANC (1987) equation, which was also the basis for the calculations presented in the MSA. The calculations are based on the average vessel speed and minimum channel depth for each segment. The average speed used in the analysis is based on 2012 AIS (Automatic Identification System) data for representative container vessels in the 8,000 to 10,000 TEU (twenty-foot equivalent unit) range (MSA Table 4-5). Minimum channel depth is used because vessel wake is inversely proportional to depth. A more conservative result is obtained by using the minimum channel depth in each segment rather than the average depth.

Wake height at offset distances greater than 2,000 m are not provided, as the PIANC (1987) equation has not been verified against field data collected at large offset distances. The results for Segments A and C show that wake heights are predicted to be smaller than 10 cm at an offset distance of 2,000 m. The wake height predicted in Segment D at 2,000 m offset

[2] Wave heights of 10 cm or less are considered to be representative of 'calm conditions'.

distance from the sailing line is 0.37 m, which is only slightly larger than the smallest wave observed at the Neah Bay wave buoy, a wave height that is exceeded 99.7% of the time based on the results shown in **Table IR7-22-1**.

Table IR7-22-2 Wave Height at Various Distances from the Container Vessel Sailing Line

Segment	Average Vessel Speed (kn)[a]	Channel Depth (m)	Wake Height (m) at Distance from the Sailing Line					
			150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
A	9.0	106	0.03	0.02	0.02	0.02	0.01	0.01
B[b]	15.5	41	0.47	0.37	0.31	0.25	0.22	0.20
C	15.0	117	0.20	0.16	0.14	0.11	0.10	0.09
D	20.0	73	0.88	0.70	0.59	0.47	0.41	0.37

Notes: a. Data from MSA Table 4-5.
b. Information for Segment B is also illustrated in MSA Figure 7.2-2.

Assess the effects of waves generated by Project- associated vessels during calm conditions on small craft engaged in activities in open water at various points and various distances from shore throughout the marine shipping area, including fishing activities in the vicinity of Swiftsure Bank.

The response to IR7-21 provides a discussion of the definition of small vessels, including the stability criteria for various categories of small commercial vessels. A discussion of the effects of waves generated by Project-associated vessels is provided below for each marine shipping area segment.

Segment A

In Segment A (southern Strait of Georgia), the estimated Project-associated vessel wave heights are predicted to be equal to or less than 0.03 m due to the slow vessel speed observed in this segment (**Table IR7-22-2**). Thus, the vessel wake from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in the southern Strait of Georgia during calm conditions.

Segment B

In Segment B (Haro Strait), the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.20 m and 0.47 m (**Table IR7-22-2**). As discussed in IR7-21, the magnitude of wake height described above is already a feature of the environment for small-craft operators in Segment B because of transiting vessels of all sizes, including ferries, which generate larger waves due to their hull characteristics and higher transit speed during calm conditions. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in Haro Strait during calm conditions.

Segment C

In Segment C (inner portion of Juan de Fuca Strait), the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.09 m and 0.20 m (**Table IR7-22-2**). While the vessel speed in Segment C is similar to the vessel speed in Segment B, the estimated vessel wake heights are smaller in Segment C due to increased channel depth (41 m in Segment B compared to 117 m in Segment C). Similar to the findings on the vessel wake heights in Segment B, the magnitude of wake height estimated in Segment C is already a feature of the environment for small-craft operators and additional Project-associated wake-generated waves are not expected to introduce new navigational hazards for small-craft operators in the inner portion of Juan de Fuca Strait, since calm conditions do not occur in this area (based on observed conditions at the New Dungeness wave buoy, as shown in Figure 6 of MSA Appendix 7.2-A).

Segment D

In Segment D (Juan de Fuca Strait), although there are no calm conditions, the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.37 m and 0.88 m. Predicted vessel wake heights are greater in this segment compared to the other three segments due to higher vessel speed (**Table IR7-22-1**). Unlike Segments A, B, and the northern portion of Segment C, Segment D is directly exposed to the Pacific Ocean and the wave climate includes both sea and swell waves. The results in **Table IR7-22-2** show that based on the percentile exceedance values generated using 2012 wave measurements, measured waves exceeded 0.37 m 99.7% of the time, and exceeded 0.88 m 86.2% of the time. The smallest wave measurement from the dataset was 0.32 m. That is, no calm condition (wave height less than 0.1 m) occurred in 2012 at Neah Bay. The magnitude of Project-associated vessel wave height described above is already a feature of the environment for small-craft operators in Segment D because of the existing energetic wave climate. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in Juan de Fuca Strait.

Swiftsure Bank is located outside of the entrance to Juan de Fuca Strait, west of NOAA Station 46087 Neah Bay wave buoy (**Figure IR7-22-1**). The wave climate at Swiftsure Bank is expected to be similar to that at observed at Neah Bay. As with Segment D, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators at Swiftsure Bank, including operators undertaking fishing activities, because of the existing energetic wave climate.

References

World Association for Waterborne Transport Infrastructure (PIANC). 1987. Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways. Report of Working Group 4 of the Permanent Technical Committee - Permanent International Association of Navigation Congress.

IR7-23 Wave Environment – Interaction of Vessel Waves

Information Source(s)

Marine Shipping Addendum: Section 7.2.6

Context

In Section 7.2.6 of the Marine Shipping Addendum, the Proponent considered wake-driven waves from single vessels in isolation, and did not address the potential interaction of waves from more than one vessel. Specifically, the assessment did not consider the worst-case scenario of wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively and thus generating high wave conditions both at the shoreline and in open water.

An assessment of a worst-case scenario resulting from the interaction of multiple vessel wakes in calm conditions is needed.

Information Request

Assess the maximum possible wave amplitude at the shoreline and in open water due to wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively under calm conditions.

Reassess the potential effects of marine shipping associated with the proposed Project on the wave environment due to the maximum possible wave height under calm conditions.

VFPA Response

Assess the maximum possible wave amplitude at the shoreline and in open water due to wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively under calm conditions.

Information is provided in the following sections on wave interactions and vessel movements and interactions to characterise Project-related and non-Project-related vessel wake interactions. Note that the information request refers to the wave amplitude; however, since the Marine Shipping Addendum (MSA) wave environment assessment presents results in terms of the wave height, this response presents the assessment results in terms of wave height for consistency and ease of comparison purposes.

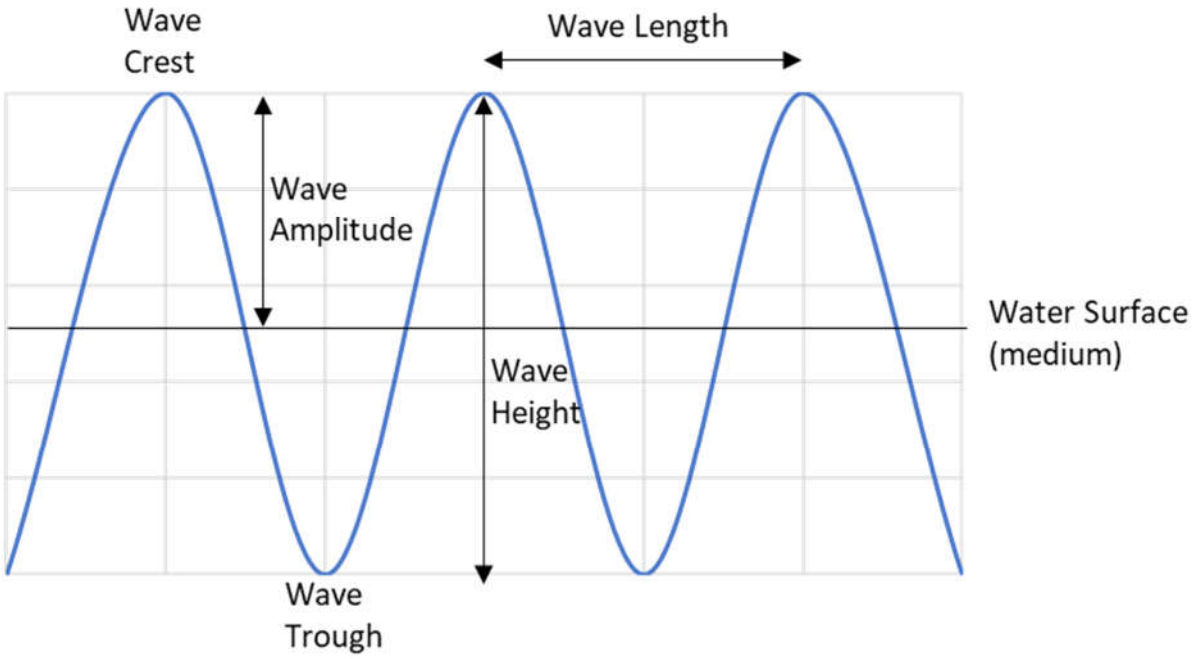
Theoretical Wave to Wave Interactions

Wave theory describes the interactions of waves in open water travelling along a medium such as water. Wave dimensions and characteristics pertinent to this response are shown in **Figure IR7-23-1**. Waves can occupy the same physical location along a medium through a process of interference, which can lead to a constructive or destructive result. In the simplest

case, when wave peaks align, there is constructive interference and the amplitude of each wave is additive (e.g., two waves of amplitude 1 will create a single wave of amplitude 2 at the time that the two waves overlap). The converse is also true, that when a wave peak and a wave trough overlap, there is destructive interference and the amplitudes are subtractive.

The two waves do not merge, but remain independent and the energy of each wave is preserved. Therefore, the constructive (or destructive) interference occurs only for the period of time that the waves occupy the same position along the water surface, which for the Panel's context for this information request considered the 'worst-case scenario'. For waves travelling towards each other from opposite directions, the constructive interference lasts only for the moment of co-occurrence of the waves. For waves travelling in the same direction, constructive interference will appear to last longer as the relative velocities are much less, though this situation also depends on the two waves having different velocities and, therefore, most likely different amplitudes.

Figure IR7-23-1 Wave Dimensions and Characteristics



Vessel Movements and Interactions

Table 4-2 and Section 7.2.5.2 of the MSA summarise vessel movements through Segment B (Haro Strait) of the marine shipping area. Approximately three vessel movements every two days, or 520 vessel movements per year, are projected to be associated with RBT2. Compared with the 8,896 vessel movements of all types that transit Segment B under existing conditions, the Project is expected to represent less than a 6% increase in vessel traffic (or 4% if compared to projected future traffic levels). When compared to the passage of cargo

vessels, which are more directly comparable in terms of the size of wake-related waves, the increase is expected to be 12% over existing cargo vessel movements.

The above consideration of the number of vessel movements provides context for understanding the likelihood of wake-related wave-to-wave interactions from two or more vessels. Ocean-going commercial vessels moving through Segment B travel along established international shipping lanes. Given the physical constraints of the shipping transit corridor and the requirements for safe navigation, it is assumed for the purposes of this assessment that vessels do not pass while transiting on the same inbound or outbound lane. Therefore, waves from different vessels will interact between the shipping lanes as vessels pass each other going in opposite directions.

Interactions between wake-generated waves originating from more than two vessels could occur in principle, if two vessels pass each other going in opposite directions while a third vessel crosses the shipping route. However, in order to maintain a safe navigation distance (assumed for the purposes of this assessment to be a minimum of 500 m or approximately two vessel lengths, as operators are expected to navigate to maintain a safe distance away from other vessels), the interaction of wake-generated waves from more than two vessels that could result in a measurably larger wave is unlikely.

The potential interactions of waves from multiple vessels is dependent on the proximity of the vessels, as well as vessel hull characteristics, vessel speed, and water depth.

Passing Project-associated Vessels

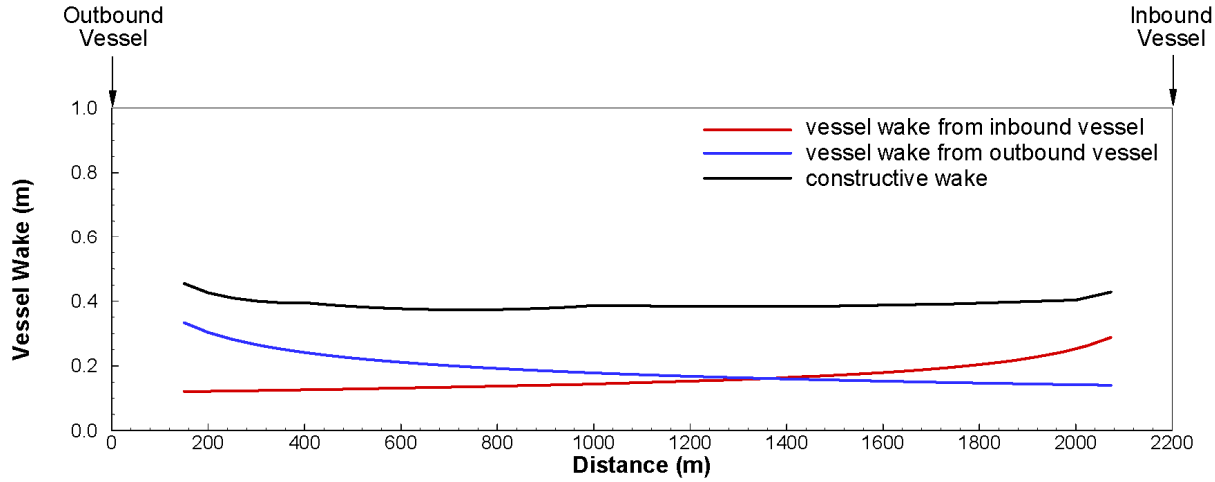
Figure 7.2-2 of the MSA shows the predicted extents of wake-generated waves of various heights in Segment B for both inbound and outbound vessels. This figure can be used to visualise the potential interaction of wakes from two Project-associated vessels travelling in opposite directions, by considering the case that two vessels are passing each other at any particular location (offset by the separation zone between the two shipping lanes). When an inbound vessel and outbound vessel pass, constructive wave interference could occur in the region between the two navigation paths. In some areas, such as in Zone 2, there is no overlap with the zones of wake exceeding 10 cm generated by the two vessels and, therefore, no potential for constructive interference.

Based on the results presented in MSA Figure 7.2-2, the maximum possible wave height at the shoreline and in open water due to wake-driven waves from two Project-associated vessels could be expected to occur near Discovery Island (Zone 3). Due to shallower water depths in Zone 3, wake-generated waves are predicted to be larger and the area of influence of wake exceeding 10 cm larger and, therefore, the area where wake-to-wake interactions can occur would also be larger. **Figure IR7-23-2** shows the vessel wakes generated from an inbound Project-associated vessel (red line) and an outbound Project-associated vessel (blue line) as well as constructive wake-generated waves (black line) near Discovery Island. The maximum constructive vessel wake height due to two passing Project-associated container ships is 0.45 m and occurs near the vessels (i.e., 150 m away from the vessels). For this analysis, it is assumed that a vessel in proximity to the passing container ships with the potential to experience this maximum constructive vessel wake are a minimum distance of

500 m away. The maximum constructive vessel wake 500 m away from two passing Project-associated container vessels is 0.38 m.

Constructive wave interference from Project-associated container ships is not expected to occur outside the region between inbound and outbound shipping lanes. This is because vessel wakes from the inbound and outbound vessels propagate in the open water at the same, or similar, speed and the wakes will not catch up to each other. Thus, the wave height at the shoreline due to vessel wakes is not altered when considering interactions from multiple Project-associated vessels.

Figure IR7-23-2 Height of Constructive Wake-generated Waves Resulting from Two RBT2-associated Vessels Passing in Opposite Directions near Discovery Island (Zone 3)

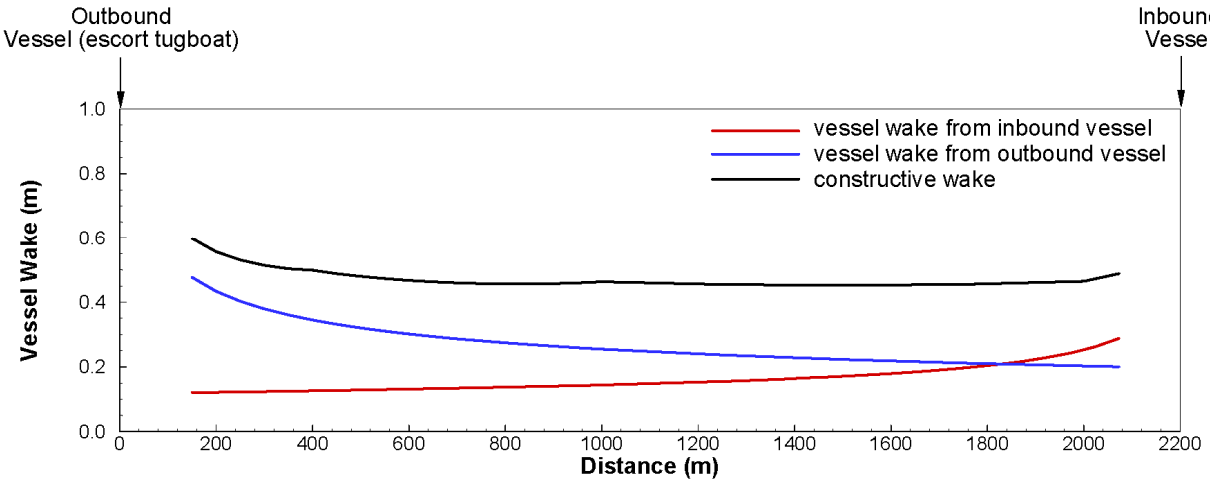


Note: The x-axis is relative to the distance from the outbound vessel (blue line). The distance from the inbound vessel is the reverse, with distance being 0 m at the 2,200 m mark and 2,000 m at the 150 m mark.

Passing Project-associated and non-Project-associated Vessels

As discussed in the response to IR7-18, of all the non-Project-associated vessels transiting within the marine shipping area Segment B, the escort tugboat is expected to generate the largest vessel wake. The vessel geometry coefficient used in the PIANC (1987) formula for tugboat was 1.0, about 43% greater than the coefficient used for Project-associated vessels. **Figure IR7-23-3** shows the vessel wakes generated from an inbound Project-associated vessel (red line) and an outbound escort tugboat (blue line) alongside an oil tanker travelling at the same speed as Project-associated vessel, as well as the constructive wave generated (black line) near Discovery Island in Zone 3. The maximum constructive vessel wake height due to Project-associated container ship and an escort tug passing in opposite directions is 0.60 m and occurs near the escort tugboat. The maximum constructive vessel wake 500 m away (assumed to be the safe operating distance from vessel operating in the international shipping lanes) from the escort tugboat is 0.48 m.

Figure IR7-23-3 Height of Constructive Wake-generated Waves Resulting from a RBT2-associated Vessel and Non-Project-associated Vessel (Escort Tug) Passing in Opposite Directions near Discovery Island



Note: The x-axis is relative to the distance from the outbound vessel (blue line). The distance from the inbound vessel is the reverse, with distance being 0 m at the 2,200 m mark and 2,000 m at the 150 m mark.

Project-associated Vessel and Ferries

Two ferry routes are within Segment B: 1) Victoria – Port Angeles and 2) Sidney – Friday Harbor. These routes are approximately perpendicular to the inbound and outbound shipping lanes. Therefore, the vessel wakes generated from Project-associated vessels travel approximately perpendicular to the vessel wakes generated from the ferries. Following good marine practice, Project-associated vessels and the ferries are expected to navigate a reasonable distance apart near the intercept point. For this analysis, it is assumed that the two transiting vessels are a minimum distance of 500 m apart.

Estimated ferry vessel wake heights at various distances from the ferry route using the PIANC (1987) formula are summarised in **Table IR7-23-1**. A vessel geometry coefficient of 1.0 was assumed for the ferry and the assumed vessel speed was based on sources available online (Wikipedia 2017a and 2017b).

Table IR7-23-1 Wave Height (m) at Various Distances from the Sailing Line – Ferry

Route	Ferry Name	Length (m)	Speed (kn)	Depth (m)	Wake Height (m) at Distance from the Sailing Line		
					500 m	750 m	1,000 m
Victoria – Port Angeles	*MV COHO*	104	15	93	0.23	0.20	0.18
Sidney – Friday Harbor	*MV Tillikum*	94.5	13	234	0.07	0.06	0.05

Constructive interference wake-generated waves from a Project-associated container ship and a Victoria-Port Angeles ferry are summarised in **Table IR7-23-2**. Constructive interference wake-generated waves from a Project-associated container ship and a Sidney-Friday Harbor ferry are summarised in **Table IR7-23-3**. The maximum constructive interference wave height is predicted to be 0.50 m 150 m away from a Project-associated vessel. At the assumed safe navigation distance of 500 m, the maximum constructive vessel wake, from **Table IR7-23-2** and **Table IR7-23-3**, is 0.41 m. Since the vessel wake-generated waves from a Project-associated vessel and a ferry in Segment B travel approximately perpendicular to one another, they are expected to reach different shorelines. Thus, a constructive interference wave from these two vessel wakes at the respective receptor shoreline will not occur.

Table IR7-23-2 Wave Height at Various Distances from the Sailing Line – Victoria to Port Angeles

Scenario	Wake Height (m) at Distance from the Sailing Line					
	150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
Project-associated vessel wake	0.27	0.21	0.18	0.14	0.13	0.11
Project-associated vessel wake combined with wake from ferry travelling 500 m away	0.50	0.44	0.41	0.37	0.36	0.34

Table IR7-23-3 Wave Height at Various Distances from the Sailing Line – Sidney to Friday Harbor

Scenario	Wake Height (m) at Distance from the Sailing Line					
	150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
Project-associated vessel wake	0.15	0.12	0.10	0.08	0.07	0.06
Project-associated vessel wake combined with wake from ferry travelling 500 m away	0.22	0.19	0.17	0.15	0.14	0.13

Reassess the potential effects of marine shipping associated with the proposed Project on the wave environment due to the maximum possible wave height under calm conditions.

As stated in the response to IR7-22, the height of vessel wake is not dependent on the existing sea state; therefore, wake height predictions are not required to be made specifically for calm conditions. Also, as stated in the response to IR7-21, the physical interactions of wake-generated waves in the marine shipping area is the same regardless of the existing sea state.

The interaction of wake-generated waves from multiple vessels is not expected to result in larger waves at the receptor shorelines in Segment B as compared to the predictions previously presented in the MSA based on wake-generated waves from a single vessel. The wake-generated waves previously predicted to interact with shorelines are well within the range of the existing wind-generated wave climate. As described in the response to IR7-21, assuming that Project-associated vessel movements generate 2,600 waves in a year, the number of wake-generated waves is slightly less than the number of waves generated in a three hour wind event (i.e., 2,700 waves, assuming that 900 waves are generated per hour with a wave period of 4 seconds). In terms of physical processes at the shoreline, a reassessment of the effects of marine shipping associated with the Project on the wave environment is not required.

The information presented in this response indicates that interactions with wake-generated waves from multiple vessels can be larger in open water than a wake-generated wave from a single vessel, as predicted in the MSA. The magnitude of wake height described above is already a feature of the environment for operators of vessels in Segment B because of transiting vessels of all sizes. Thus, constructive wave interference from multiple vessels—both Project-associated and non-Project-associated—bypassing each other are not expected to introduce new navigational hazards for vessels operating in Segment B during calm conditions, assuming that operators of vessels observe good navigation practices.

References

Wikipedia. 2017a. MV Coho. Wikipedia article describing the MV Coho. Available at https://en.wikipedia.org/wiki/MV_Coho. Accessed November 2017.

Wikipedia. 2017b. MV Tillikum. Wikipedia article describing the MV Tillikum. Available at https://en.wikipedia.org/wiki/MV_Tillikum. Accessed November 2017.

World Association for Waterborne Transport Infrastructure (PIANC). 1987. Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways. Report of Working Group 4 of the Permanent Technical Committee - Permanent International Association of Navigation Congress.

IR7-32 Marine Commercial Use – Crab Harvesting, Clarification

Information Source(s)

EIS Volume 4: Appendix 21-A, Table 21-A3, Table 21-A4

Context

The Proponent, in Appendix 21-A of the EIS, presented crab license, harvest and landed value data. There are discrepancies in the data provided in Appendix 21-A. For example, in Table 21-A4 the Proponent reported crab values of $585,763 and $394, 536 in Pacific Fisheries Management Area (PFMA) sub area 29-7 for 2007 and 2008 respectively. In Table 21-A3, it was reported that only one crab vessel fished in PFMA sub-area 29-7 in 2007 and that no crab vessels fished the area in 2008 indicating errors within these Tables.

Information Request

Update and reconcile any discrepancies in crab license, harvest and crab landed value data reported in Appendix Table 21-A of the EIS.

Present the data in tabular format and graphically.

VFPA Response

Revisions to EIS Appendix 21-A to correct one error and to clarify crab license harvest and crab landed value data have been made and are reflected in Tables IR7-32-A1 to IR7-32-A4. Two additional tables, titled IR7-32-A5 and IR7-32-A6, are included in addition to those in EIS Appendix 21-A to further clarify the crab data reporting. All tables are presented in **Appendix IR7-32-A**.

The revisions and clarifications to EIS Appendix 21-A do not alter the conclusions pertaining to Project effects on commercial crab harvesting, as specified in EIS Section 21.7.

Revisions reflect the following:

- There is one numerical error correction noted in Table IR7-32-A1 (revised Table 21-A1) in red font. No other numerical errors are noted in EIS Appendix 21-A tables.
- As indicated in EIS Section 21.3.3, DFO uses different methods to collect crab harvest and crab harvest value data. With the exception of crab landed value data, all catch data reported in EIS Section 21.5 (and EIS Appendix 21-A) were derived from logbooks, which are generally recognised as the most accurate data source (DFO 2009). EIS Section 21.3.3 also indicates that crab landed value data (as reflected in Table 21-A4) are drawn from fish slips, which are the primary source of information on catch value. Further clarification has been provided in the title of each of the revised Appendix 21-A tables (see **Appendix IR7-32-A**) to indicate the data source; data

from logbooks is included in Table 21-A2 and 21-A3, and data from fish slips is included in Table 21-A4.

- The crab landed value data received from DFO during preparation of the EIS from fish slips also included corresponding data on crab harvest (kg) and vessel counts associated with crab landed value data. This data is presented in **Appendix IR7-32-A**, Tables IR7-32-A5 and IR7-32-A6. The crab harvest (kg) data from logbooks (Table 21-A2 of EIS Appendix 21-A, and Table IR7-32-A2 in **Appendix IR7-32-A**) and crab vessel count data from logbooks (Table 21-A3 of EIS Appendix 21-A and Table IR7-32-A3 in **Appendix IR7-32-A**) varies from crab harvest (kg) and vessel count data as reported in the fish slip data.
- When considering crab harvest (kg), crab vessel counts, and crab value ($) data from fish slip data, Pacific Fishery Management Area (PFMA) sub-area 29-7 reported four crab vessels in 2007 and five vessels in 2008, with a crab harvest of 106,861 kg in 2007 and 67,464 kg in 2008, which is reflective of the specified $585,762 and $394,536 crab harvest values for 2007 and 2008, respectively.
- Further clarification has been provided within table cells, and as a note, where confidential data does not meet criteria for public release (identified by DFO as less than three vessels reporting for the time period and area), or where there was no actual data reported (Tables IR7-32-A2 and IR7-32-A4, or revised Tables 21-A2 and 21-A4, respectively).
- Tabular data in each revised EIS Appendix 21-A table (as reflected in Tables IR7-32-A1 to IR7-32-A4) and in the two additional tables (Tables IR7-32-A5 and IR7-32-A6) in **Appendix IR7-32-A** is also shown graphically below each table.

References

Fisheries and Oceans Canada (DFO). 2009. Revisions to the Official DFO Commercial Pacific Salmon Catch Estimates for 1996 to 2004. Available at http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2009/2009_031_e.pdf. Accessed October 2017.

Appendices

Appendix IR7-32-A Revised EIS Appendix 21-A Tables and Graphic Representation of Tabular Data

APPENDIX IR7-32-A
REVISED EIS APPENDIX 21-A TABLES AND GRAPHIC REPRESENTATION OF TABULAR DATA

APPENDIX IR7-32-A: REVISED EIS APPENDIX 21-A TABLES AND GRAPHIC REPRESENTATION OF TABULAR DATA

Appendix IR7-32-A1 **Crab Licences for Crab Management Area I and J** (Revised Table 21-A1 in EIS Appendix 21-A)

Area		2000	2001 to 2002	2003 to 2005	2006	2007 to 2008	2009	2010 to 2012	2013 to 2015
Area I	Number	36	36	36	41	41	42	51	32
	Percentage of Total BC Licences	16.2%	16.2%	16.2%	18.5%	18.5%	18.9%	23.1%	14.5%
Area J	Number	19	19	18	22	22	21	18	20
	Percentage of Total BC Licences	8.6%	8.6%	8.1%	9.9%	9.9%	9.5%	8.1%	9.0%

Source: DFO 2014b

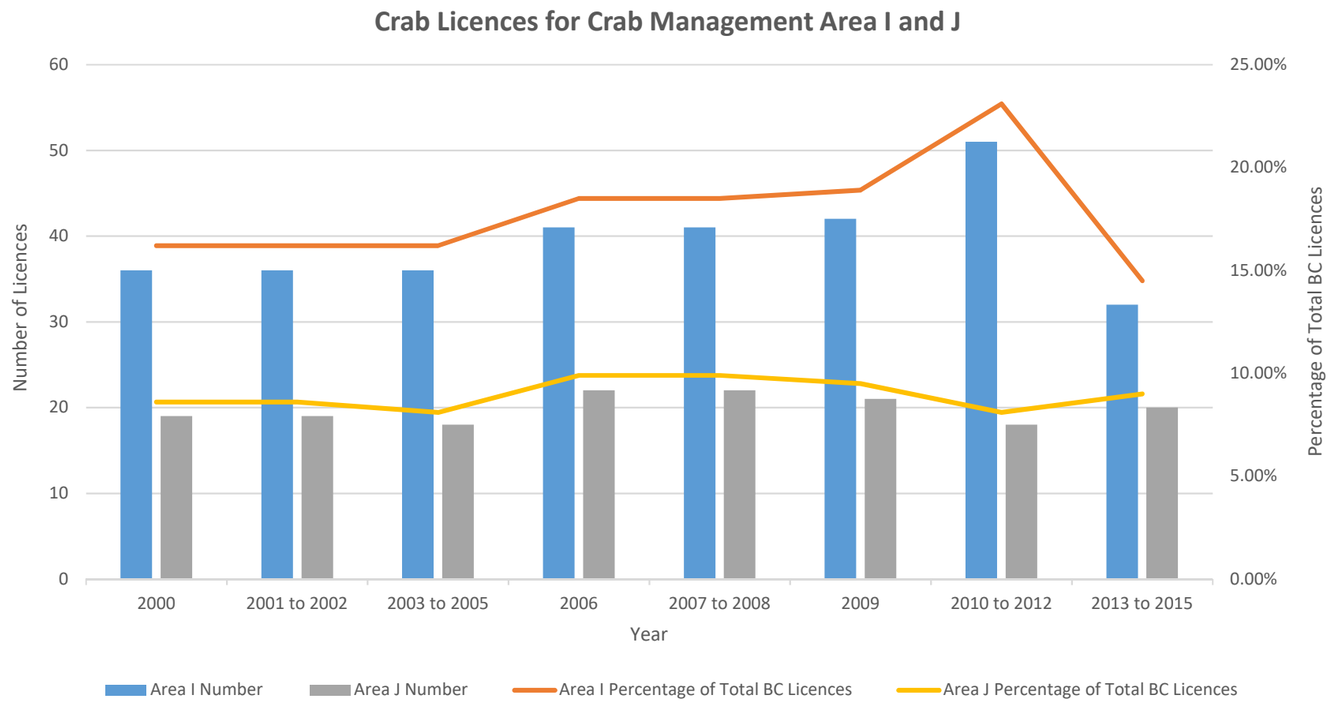


Table IR7-32-A2 Crab Harvest (kg) by Sub-area from Logbook Data (Revised Table 21-A2 in EIS Appendix 21-A)

Study Area	PFMA Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
LAA	29-6	69,874	202,080	160,621	491,547	512,623	400,355	387,471	201,243	222,019	180,432	112,035	2,940,300
	29-7	29,589	*	11,076	15,330	*	-	16,200	5,639	6,882	6,945	29,075	120,736
	29-9	38,879	19,756	48,775	78,693	104,813	65,572	69,501	25,006	*	12,705	5,638	469,338
Other RAA[a]	29-3	88,282	94,537	104,119	160,457	186,090	207029	310,426	241,075	155,955	133,397	109,780	1,791,147
	29-4	22,087	49,800	39,815	119,313	106,884	*	72,202	39,962	21,303	26,150	27,071	524587
	29-8	237,510	247,930	240,577	326,715	228,289	269,037	220,125	214,776	278,495	271,193	252,765	2,787,412
	29-10	17,564	32,077	7,980	52,825	42,283	43,061	72,444	54,131	22,195	53,095	46,746	444,401
Total		503,785	658,489	612,963	1,260,748	1,181,856	1,018,847	1,180,282	817,468	754,626	693,287	591,829	9,274,180

Source: DFO 2014c.

Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area)

- = No data reported

a. Refers to PFMA sub-areas that overlap with the regional assessment area (RAA) but do not overlap with the local assessment area (LAA).

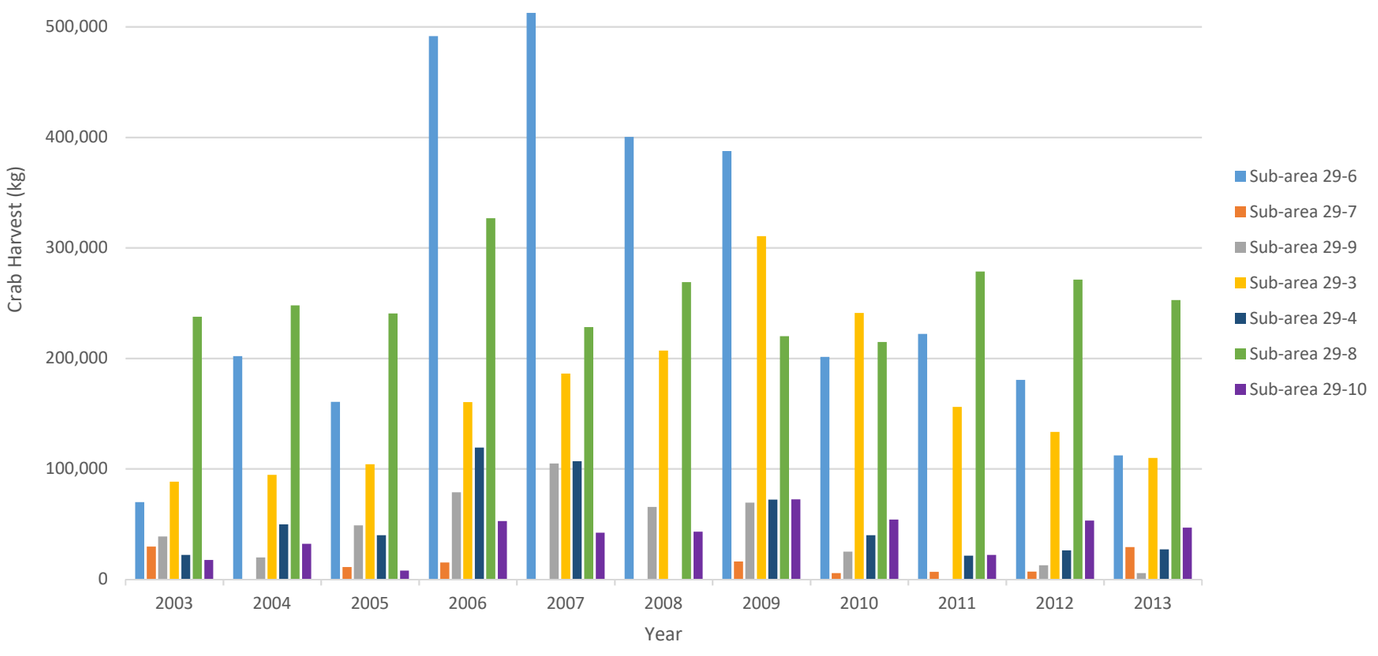


Table IR7-32-A3 Crab Vessel Count by Sub-area from Logbook Data (Revised Table 21-A3 in EIS Appendix 21-A)

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	9	15	14	19	20	20	20	28	27	21	14
LAA	29-7	4	2	4	3	1	0	3	3	3	6	5
LAA	29-9	6	4	5	6	7	7	7	13	2	10	5
Other RAA	29-3	12	11	14	10	19	20	24	29	31	31	14
Other RAA	29-4	4	9	4	7	9	2	8	8	6	7	6
Other RAA	29-8	19	18	18	21	22	22	22	18	19	18	21
Other RAA	29-10	6	7	3	5	5	6	11	14	9	18	9

Source: DFO 2014c.

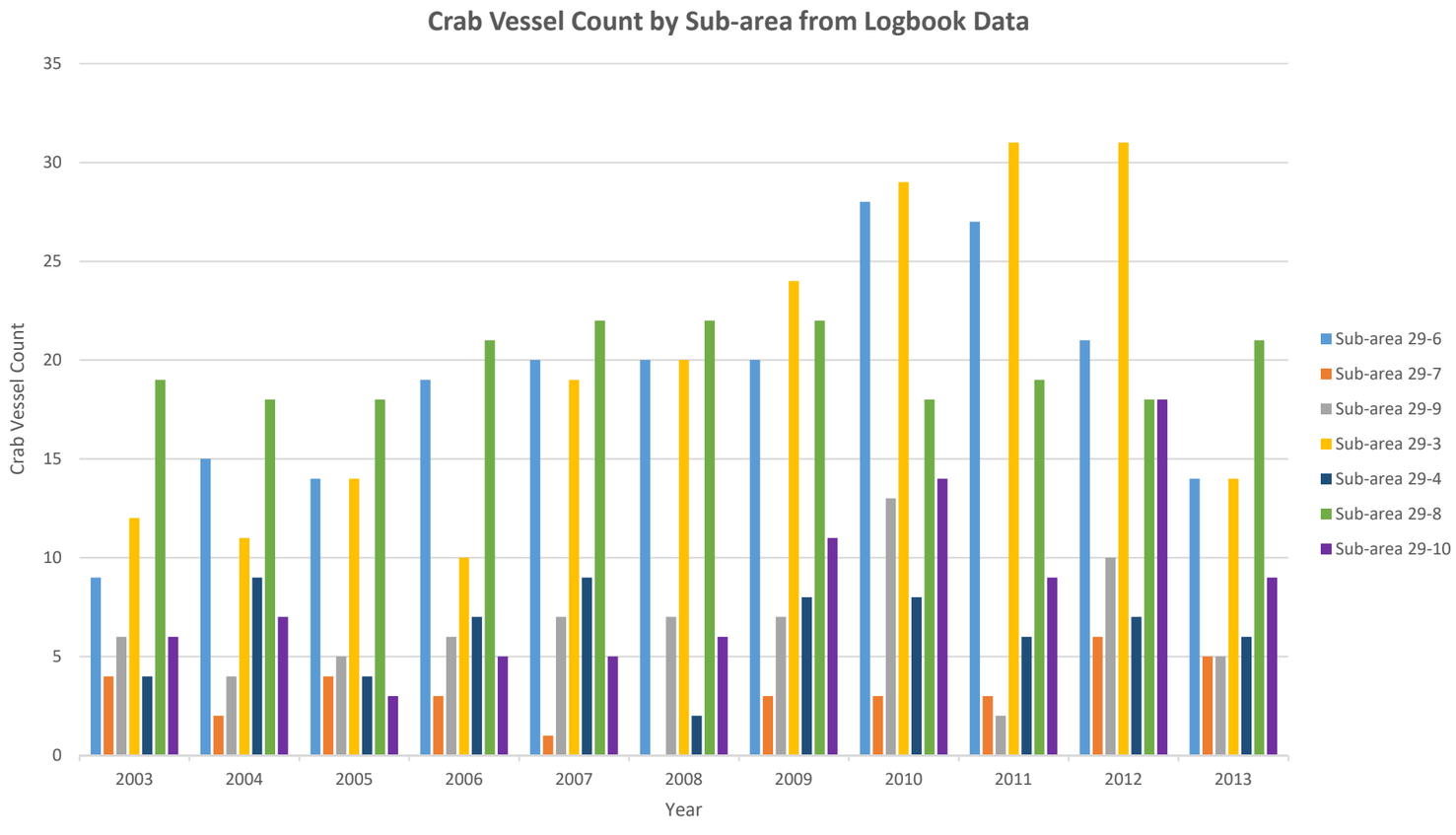
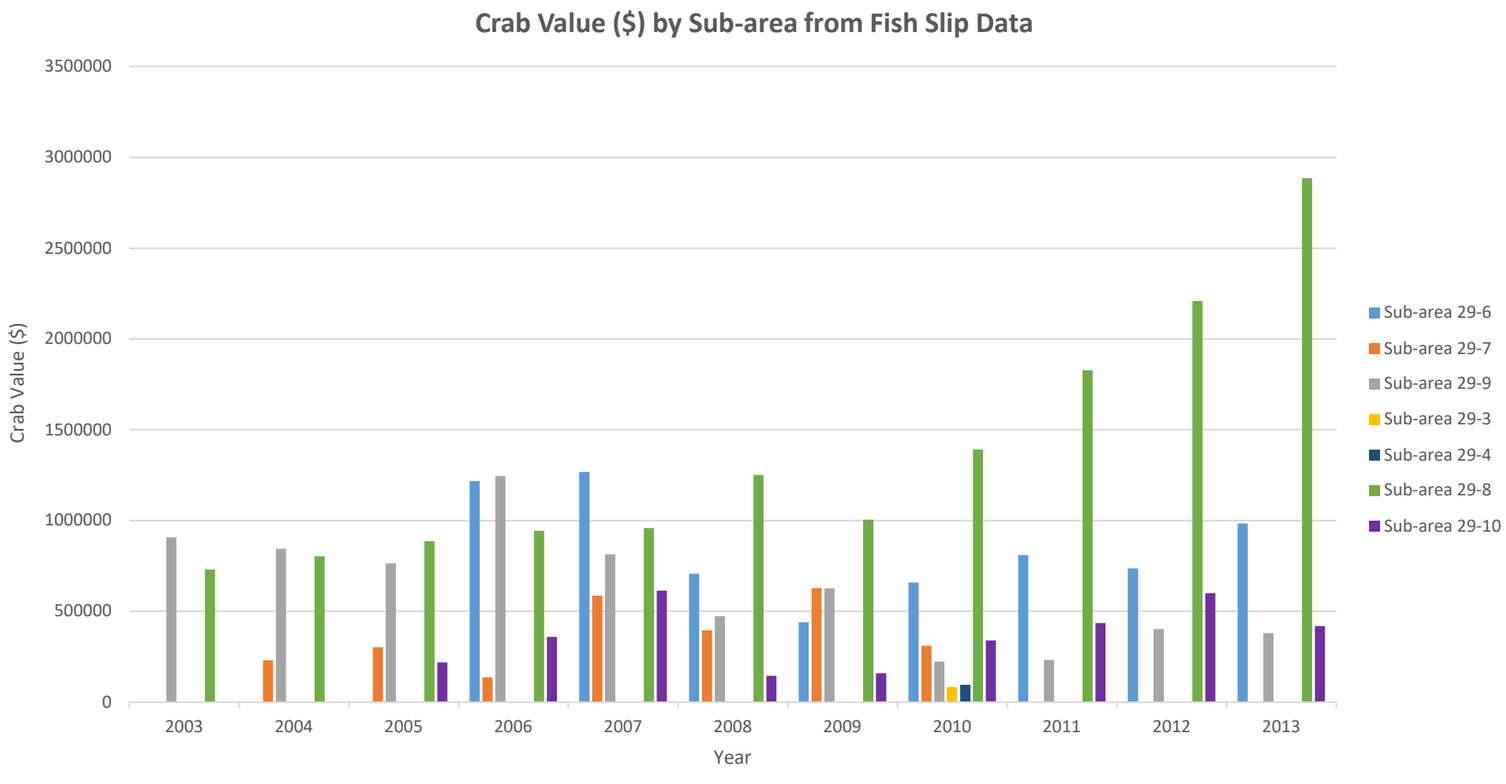


Table IR7-32-A4 Crab Value ($) by Sub-area from Fish Slip Data (Revised Table 21-A4 in EIS Appendix 21-A)

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	*	*	$1,217,157	$1,267,158	$705,650	$439,610	$657,993	$809,026	$734,928	$983,693
LAA	29-7	*	$229,379	$301,754	$136,370	$585,763	$394,536	$626,719	$310,446	*	*	
LAA	29-9	$906,528	$843,951	$763,017	$1,244,507	$813,738	$473,015	$625,893	$221,608	$231,850	$401,459	$379,065
Other RAA	29-3	-	-	*	*	*	*	*	$ 79,295	*	*	-
Other RAA	29-4	-	-	-	-	-	-	-	$94,615	-	-	-
Other RAA	29-8	$730,277	$802,959	$885,168	$943,246	$958,270	$1,250,742	$1,003,648	$1,390,596	$1,827,614	$2,208,659	$2,884,885
Other RAA	29-10	*	*	$217,968	$358,205	$612,634	$143,911	$157,884	$339,360	$434,523	$599,031	$418,522
Total		$3,128,647	$3,815,354	$3,749,936	$6,610,500	$6,539,871	$6,346,532	$7,329,578	$6,201,775	$6,739,736	$6,613,455	$6,102,069

Source: DFO 2014d.
Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area
- = No data reported



ADDITIONAL TABLES

Table IR7-32-A5 Crab Vessel Count by Sub-area from Fish Slip Data

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	1	2	6	7	7	4	6	8	9	8
	29-7	2	3	3	3	4	5	4	5	2	2	2
	29-9	11	10	9	12	13	11	11	6	5	12	8
Other - RAA	29-3	-	-	2	2	1	2	1	4	2	1	-
	29-4	-	-	-	-	-	-	-	-	-	-	-
	29-8	11	11	12	17	18	22	17	14	17	18	20
	29-10	1	1	4	4	10	5	5	9	5	16	9

Source: DFO 2014d.
Note: - = No data reported

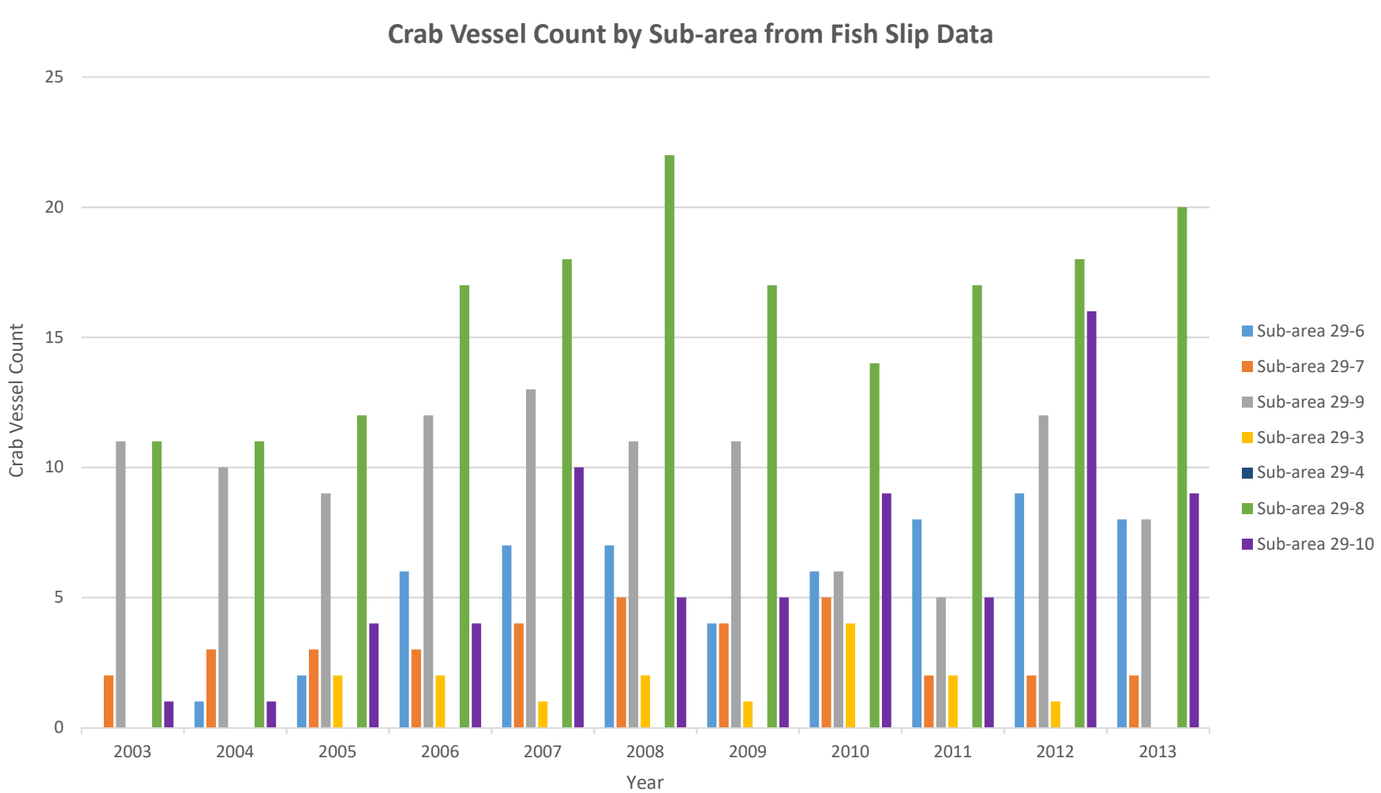


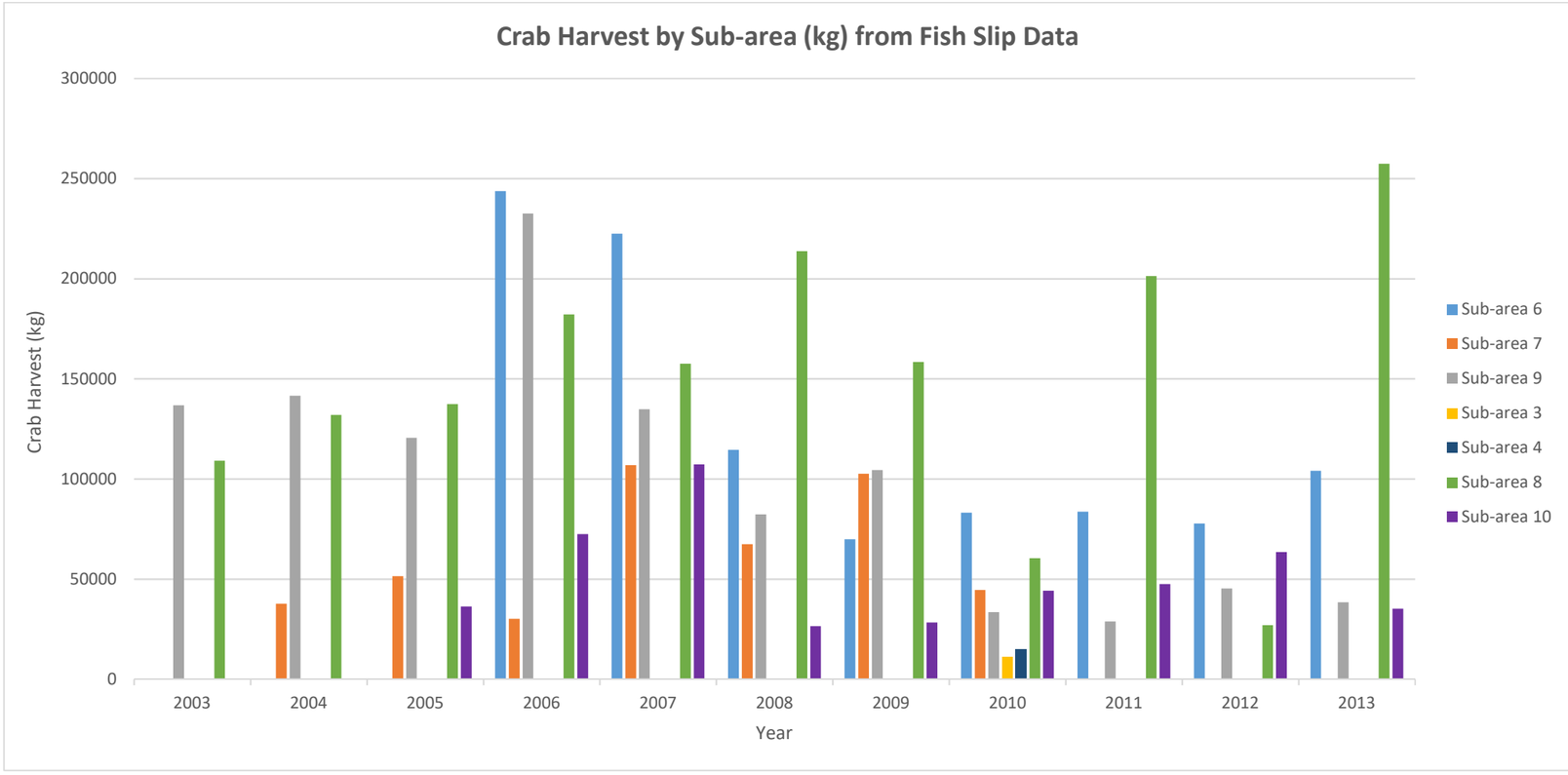
Table IR7-32-A6 Crab Harvest (kg) by Sub-area from Fish Slip Data

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	*	*	243,756	222,491	114,528	69,838	83,144	83,667	77,799	104,112
LAA	29-7	*	37,679	51,396	30,197	106,861	67,464	102,630	44,586	*	*	*
LAA	29-9	136,772	141,578	120,524	232,582	134,786	82,280	104,467	33,519	28,821	45,271	38,353
Other RAA	29-3	-	-	*	*	*	*	*	11,199	*	*	-
Other RAA	29-4	-	-	-	-	-	-	-	14,740	-	-	-
Other RAA	29-8	109,152	132,036	137,383	182,108	157,516	213,780	158,411	60,452	201,372	26,925	257,467
Other RAA	29-10	*	*	36,272	72,495	107,297	26,449	28,286	44,186	47,493	63,533	35,178

Source: DFO 2014d.

Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area)

- = No data reported



IR7-36 Outdoor Recreation – Baseline and Effects Assessment

Information Source(s)

EIS Guidelines: Section 9.1.8

EIS Volume 4: Section 24.2; Appendix 18-A; Appendix 18-B

Context

The Updated Guidelines for the Preparation of the Environmental Impact Statement stated that, with respect to Indigenous groups potentially affected by the proposed Project, the EIS will include recreational uses of the Project area.

The Proponent, in Section 24.2 of the EIS, reported that Indigenous groups were consulted in the preparation of the outdoor recreation effects assessment. Only Tsawwassen First Nation and Musqueam First Nation provided comments to the Proponent on outdoor recreation for its preparation of the EIS. This information is found in Appendices 18-A and 18-B. There was no specific information reported in the EIS about potential Project effects on outdoor recreational activities undertaken by other Indigenous groups.

Information Request

Provide information about the outdoor recreational activities of Indigenous groups - other than Tsawwassen First Nation and Musqueam First Nation - in the outdoor recreation local assessment area and the regional assessment area. For each relevant recreational activity, include information about the level of use, frequency of activity and number of users.

Evaluate any potential effects from the proposed Project on those outdoor recreational activities.

VFPA Response

Provide information about the outdoor recreational activities of Indigenous groups - other than Tsawwassen First Nation and Musqueam First Nation - in the outdoor recreation local assessment area and the regional assessment area. For each relevant recreational activity, include information about the level of use, frequency of activity and number of users.

Other than information on outdoor recreational activities carried out by Tsawwassen First Nation, no other outdoor recreation activities carried out specifically by other Aboriginal groups in the local and regional assessment areas (LAA and RAA) were identified through the preparation of the EIS or the Additional Information to the EIS – *WSÁNEĆ* Nation (AIEIS), which incorporates *WSÁNEĆ* Nation Aboriginal groups. In accordance with section 9.1.8 of the Updated EIS Guidelines, various processes were applied to obtain information on outdoor recreational activities from Aboriginal groups for the EIS and the AIEIS, as described below.

Review of Secondary Information Sources

Identification and review of available secondary sources on outdoor recreational activities within the LAA/RAA for the general Aboriginal population, as well as specific Aboriginal groups was undertaken. No specific publicly-available information on outdoor recreational activities for the Aboriginal population or specific Aboriginal groups was identified.

Interviews

Interviews were held with representatives of Tsleil-Waututh Nation to gather information on outdoor recreational activities in the LAA/RAA. No outdoor recreational activities in the LAA/RAA were identified by Tsleil-Waututh Nation representatives through these interviews.

Interviews were requested by the VFPA with all *WSÁNEĆ* groups involved in the AIEIS to gather information on marine commercial use and outdoor recreation activities as part of the AIEIS data collection program for existing conditions. Tseycum First Nation and Malahat Nation accepted the invitation for this interview. The interviews included questions regarding outdoor recreational use in the LAA/RAA. No outdoor recreational activities within the LAA/RAA were identified by Tseycum First Nation or Malahat Nation during this interview.

Written Requests for Information

Written requests for information on outdoor recreational use in the LAA were sent to Métis Nation B.C., Semiahmoo First Nation, and Lyackson First Nation. No information was received back from these Aboriginal groups on outdoor recreational activities in the LAA/RAA.

Meetings and Workshops

Meetings and workshops were held with the following Aboriginal groups to present and obtain input on initial EIS findings for the existing conditions (including outdoor recreation existing conditions), preliminary Project effects assessment results, and proposed mitigation measures (including those pertaining to outdoor recreation). **Table IR7-36-1** below summarises these engagement activities.

Table IR7-36-1 Additional Engagement Activities with Aboriginal Groups on Outdoor Recreation Activities in the LAA/RAA

Aboriginal Group	Engagement Method and Date	Engagement Summary
Tsawwassen First Nation Tsleil-Waututh Nation Musqueam First Nation Hwlitsum Stz'uminus First Nation Lyackson First Nation Cowichan Tribes Penelakut Tribes Métis Nation B.C.	EIS Working Group Meetings[1]: • May 27, 2014 • June 17, 2014	No information or input received from Aboriginal groups on outdoor recreational activities in the LAA/RAA, Project effects, or mitigation measures.
Tsawwassen First Nation Tsleil-Waututh Nation Semiahmoo First Nation Musqueam First Nation Lake Cowichan First Nation Lyackson First Nation Métis Nation B.C. Hwlitsum	EIS Technical Workshops – Valued Component Identification: • June 2014 • July 2014	
Tsawwassen First Nation Tsleil-Waututh Nation Semiahmoo First Nation Musqueam First Nation Lake Cowichan First Nation Lyackson First Nation Métis Nation B.C. Hwlitsum	EIS Technical Workshops – EIS Preliminary Results: • October 2014 (four meetings)	
Tsawwassen First Nation Musqueam First Nation	Review and comment on First Nations Community Assessments: • January 2015	
Cowichan Tribes Halalt First Nation Penelakut Tribes Stz'uminus First Nation	Technical Workshops – Review of Draft EIS: • October 2014 • November 2014	

[1] Working group meetings were also held on February 25, 2014 and April 15, 2014; however, content did not pertain directly to the outdoor recreation valued component.

Aboriginal Group	Engagement Method and Date	Engagement Summary
Tseycum First Nation Tsartlip First Nation Malahat Nation Pauquachin First Nation Tsawout First Nation	Technical Workshop – Review of Draft EIS: • November 2015	No information or input received from Aboriginal groups on outdoor recreational activities in the LAA/RAA, Project effects, or mitigation measures.
Tseycum First Nation	Elders Workshop – AIEIS: • March 2016	
Tsawout First Nation Tsartlip First Nation Tseycum First Nation Malahat Nation Pauquachin	AIEIS Issues Workshop: • July 2016	
Pauquachin First Nation Tsawout First Nation Tsartlip First Nation	Emails requesting additional input – AIEIS: • April 2016	
Pauquachin First Nation Tsartlip First Nation Tseycum First Nation	Meetings to discuss additional input – AIEIS: • February 2016 • April 2016 • June 2016	
Tsawout First Nation Malahat Nation	Email with comments on the draft AIEIS • January 2017	

As indicated in EIS Section 24.2.1 and in the response to Information Request #27 (IR-7.31.15-27 of CEAR Document #314[2]), while certain Aboriginal traditional cultural activities such as canoeing, hunting, fishing, and gathering may be viewed as having recreational benefit or attributes, these activities are pursued for traditional purposes. Descriptions of these and other traditional cultural activities by Aboriginal groups and potential Project effects on these and other cultural activities are described in EIS Section 32.2 and AIEIS Section 7.0 (and not EIS Section 24.0 (Outdoor Recreation Effects Assessment) and AIEIS Section 4.0 (Outdoor Recreation Effects Assessment)).

No outdoor recreational activities occurring in the LAA/RAA (that were not identified as pursued for traditional purposes) were identified by Aboriginal groups through implementation of secondary and primary data collection and engagement processes for EIS and AIEIS as described above (with the exception of outdoor recreation activities carried out by

[2] 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.

Tsawwassen First Nation Members as described in in EIS Sections 24.5.4.3 and 24.5.5 as well as EIS Appendix 18-A).

Evaluate any potential effects from the proposed Project on those outdoor recreational activities.

As described in the response to IR-7.31.15-27 (CEAR Document #314), based on the information received on outdoor recreational activities by Aboriginal groups, the outdoor recreation existing conditions identified in EIS Section 24.5 and AIEIS Section 4.0 are presented for, and assumed to be reflective of, the general population, which includes members of Aboriginal groups who may engage in these outdoor recreational activities in the LAA.

A minor potential effect of the Project was identified for changes in recreational crab harvesting area use, access, and displacement from the area of the Project terminal footprint and proposed expanded navigational closure areas, prohibiting recreational crab harvesting in these areas during construction and operations, as indicated in EIS Section 24.6.5.2. The identified Project effect on recreational crab harvesting would affect members of the general population who may engage in these outdoor recreational activities in the LAA. No recreational seafood harvesting activities connected with specific Aboriginal groups were identified through the above data collection and consultation and engagement process.

IR7-37 Outdoor Recreation – Baseline

Information Source(s)

EIS Guidelines: Section 9.1.7

EIS Volume 4: Section 24.5.4.1; Figure 24.1; Section 24.5.4.2

Context

The Proponent, in Section 24.5 of the EIS, reported the following types of activities on recreational trails in the local assessment area:

- Walking and running;
- Cycling; and,
- Horseback riding.

Indication was given that Brunswick Point is a popular birding location in the local assessment area and the existence of the Delta Nature Casual Birding Club, a local naturalist club, and its activities was also mentioned. There was no information provided on the use of the trail by its members or the general public. According to the Proponent, data on the levels of trail use was not available at the time of the assessment.

Information about land-based outdoor recreational activities within the local assessment area - with respect to frequency of use by activity type and the number of trail users for each activity type - is required.

Information Request

Provide information on the levels of trail use within the local assessment area, especially the Brunswick Point/Dyke-Great Blue Heron trail, including bird watching. Include data on number of users, and the frequency of each type of activity (for example, bird watching and horseback riding).

VFPA Response

The main trails identified in the local assessment area (LAA) include the Brunswick Point Trail and the Tsawwassen Outer Dyke (also referred to as Great Blue Heron Trail), as indicated in Section 24.5.4.1 of the EIS. In addition to these two trails, the Brunswick Point Trail connects to inland farm roads, and the Tsawwassen Outer Dyke connects to inland road networks, enabling users to undertake circular routings. As indicated in EIS Section 24.5.4.1, the beach area adjacent to the Tsawwassen waterfront is also used by dog walkers and for bonfires.

At the time of writing the EIS, the VFPA undertook a secondary data search of publicly available information sources on use levels at the Brunswick Point Trail and Tsawwassen Outer Dyke, as well as the Tsawwassen Beach. Information sources included local planning

documents, local user group websites and reports, City of Delta (formally the Corporation of Delta) website and municipal documents, and Tsawwassen First Nation key planning documents and reports (see EIS Section 24.11 for a full list of references). A review of public sources indicated secondary information on use levels for these trails was not available.

The City of Delta (Delta) is the owner/administrator of the Brunswick Point Trail, while Tsawwassen First Nation is the diking authority responsible for the maintenance of the Tsawwassen Sea Dike where the Tsawwassen Outer Dyke trail is located. During preparation of the EIS, the VFPA contacted Delta, and held in-person interviews with Tsawwassen First Nation representatives to inquire whether trail use information had been gathered for the Brunswick Point Trail and Tsawwassen Outer Dyke. Follow-up consultations were also held with Delta and Tsawwassen First Nation to review and obtain input on draft EIS findings, including outdoor recreation trail use. Through these engagement processes, Delta and Tsawwassen First Nation confirmed that trail use counts had not been gathered for these trails.

In August 2017, the VFPA renewed their requests to Delta and Tsawwassen First Nation inquiring if any trail use information had been gathered subsequent to the previous request in 2014. On September 6, 2017, Delta provided to the VFPA a letter written by Urban Systems on January 31, 2014 describing the potential options of improving safety related to pedestrian and bicycle crossing conditions at Deltaport Way and the sea dyke (on Tsawwassen First Nation Lands). The letter references a pedestrian count at the sea dyke at Deltaport Way that identified 400 people walking and cycling. The letter does not indicate what time of year this count was completed or over how many days the study was undertaken. Follow-up requests were made to Urban Systems to better understand the estimate; however, no response has been received to date.

Also, on August 30, 2017, Tsawwassen First Nation provided the VFPA with a copy of their Internal Roads Analysis Report which provides details around their future plans for a multi-use trail, Great Blue Heron Way, but does not include trail use or count information.

To further understand trail use in the LAA, the VFPA commissioned trail use surveys of the Brunswick Point Trail and the Tsawwassen Outer Dyke Trail in summer and fall of 2017.

Provide information on the levels of trail use within the local assessment area, especially the Brunswick Point/Dyke - Tsawwassen Outer Dyke, including bird watching. Include data on number of users, and the frequency of each type of activity (for example, bird watching and horseback riding).

Survey Results

A summer use survey (August 31 to September 2, 2017) and a winter use survey (November 18, 2017) were conducted for the Brunswick Point Trail, at the entrance to the trail. A winter use survey was conducted at the Tsawwassen Outer Dyke on November 18, 2017 at the three entrances to the trail. Both surveys were conducted during daylight hours; in summer, the duration was from 7:30 am to 7:30 pm and during the winter, survey duration was from 7:30 am to 4:30 pm. The results of the surveys are provided in **Table IR7-37-1**.

The summer survey was held on a Thursday and a Saturday to capture summer use on both a weekday and weekend. The weather on both days was sunny and warm. As summertime is the low season for bird watching on the Brunswick Point Trail, a winter survey was completed in November to capture the use associated with peak bird watching season, when raptors and waterfowl have arrived on their wintering range. The weather on the winter survey day was clear and cool, with no rain.

Table IR7-37-1 Number of Trail Users

	Summer Weekday Survey August 31, 2017 Brunswick Point Trail	Summer Weekend Survey September 2, 2017 Brunswick Point Trail	Winter Weekend Survey November 18, 2017 Brunswick Point Trail	Winter Weekend Survey November 18, 2017 Tsawwassen Outer Dyke
Total Counted (no. of people)	78	91	101	56
Number of Parties Surveyed	41	49	45	33
Average Size of Party (no. of people)[a]	1.7	1.5	1.8	1.5
Main Activity (no. of parties):				
Biking	8	9	2	4
Walking/Running	24	16	14	4
Dog Walking	7	11	14	25
Hunting	0	2	9	0
Bird Watching or Photography	0	6	5	0
Horseback Riding	0	2	0	0
Other	2	3	1	0

Note: a. Average size of party was calculated from the Number of Parties Surveyed data set (and not Total People Counted data set).

Brunswick Point Trail Survey Result Summary

The results of the summer survey at Brunswick Point indicated the most common trail uses were walking or running (44.4%) and dog walking (20.0%), followed by biking (18.9%). During the winter, walking (31.1%), dog walking (31.1%), hunting (20.0%), and bird watching or photography (11.1%) were the most popular activities. The majority of trail users interviewed during the Brunswick Point Trail summer survey indicated they use the Brunswick Point Trail at least once a week. Close to 50% of the parties interviewed for the summer survey indicated they use the trail at least once a week, and 15% indicated they use the trail every day (**Table IR7-37-2**). By comparison, 38% of parties interviewed in the winter survey on the Brunswick Point Trail indicated they use the trail at least once a week, with a

substantially higher percentage of winter trail users indicating they only use the trail a few times a year. Winter weather, combined with short timing windows for migratory bird viewing and regulated bird hunting season open dates (which are approximately early September through March), influence less frequent and more seasonally dependent trail use during the winter. In addition, some regular trail users interviewed over the summer indicated they tend to use the trail less in the winter, as they are not comfortable using the trail when hunting is occurring (**Table IR7-37-2**).

Table IR7-37-2 Frequency of Trail Use

	Summer Weekday Survey August 31, 2017 Brunswick Point Trail	**Summer Weekend Survey September 2, 2017 Brunswick Point Trail**	**Winter Weekend Survey November 18, 2017 Brunswick Point Trail**	**Winter Weekend Survey November 18, 2017 Tsawwassen Outer Dyke**
How Often User Uses Trail (no. of parties):	n = 40	n = 48	n = 45	n = 33
Daily	8	5	4	10
A few times a week	12	13	7	15
Once a week	3	2	6	1
A few times a month	4	10	4	4
Once a month	4	4	9	1
A few times a year	3	7	11	1
Today is my first visit	6	7	4	1

Bird watching is known to be a common activity on the Brunswick Point Trail, particularly during peak bird viewing season, which takes place later into the fall / early winter when snow geese and other migratory birds are migrating through the area. Five individuals interviewed during the Brunswick Point winter survey indicated bird watching was their primary activity; however, several users also noted that while their primary activity was dog walking, they were also bird watching.

Tsawwassen Outer Dyke Survey Result Summary

At the Tsawwassen Outer Dyke, dog walking was the most prevalent activity (75.8%), followed by walking or running (12.1%) and biking (12.1%). No other trail uses were observed. Based on survey responses, trail use on the Tsawwassen Outer Dyke appears to be less seasonal, with many of the trail users responding that they use the trail multiple times a week, all year round, for routine activities such as walking and dog walking. Over 75% of parties interviewed on the Tsawwassen Outer Dyke indicated they are regular trail users, accessing the trail more than once a week (**Table IR7-37-2**). Only two parties indicated they use the trail less than once a month, and the party who indicated this was their first visit

indicated they intend on accessing the trail more in the future. Nearly 80% of parties interviewed indicated they use the trail with the same frequency year-round, while the six of the remaining seven parties indicated higher trail use in the spring and summer. This is consistent with the observation of the high percentage of regular dog walkers, as dogs need to be walked year-round, regardless of the weather.

The trail survey results support land-based outdoor recreation existing conditions information as presented in Section 24.5.4 of the EIS, and do not alter the Project effects assessment results as presented in EIS Section 24.6.4.

IR7-38 Outdoor Recreation – Tsawwassen First Nation Recreational Boating, Effects and Mitigation

Information Source(s)

EIS, Volume 4: Section 24.5.5; Section 24.6.1, Table 24-5; Appendix 18-A, Section 8.1

Context

The Proponent estimated that by 2030 there would be an increase of 172 large vessels movements per year at the Roberts Bank terminals compared to 2012, in addition to the 520 movements from the proposed Project. According to the Proponent in Section 24.6.1 of the EIS, recreational boaters accessing the local assessment area via Canoe Passage may have to travel around the Project footprint, which would require more travel time and fuel, but the Project would not prevent access or use. The Proponent also reported that recreational vessels would have to change speed or direction to avoid collision when traversing the local assessment area and predicted that the Project-induced change to access and navigation for recreational use is expected to be negligible for construction and operation.

The Proponent, in Appendix 18-A of the EIS, reported that Tsawwassen First Nation have an ocean-going canoe used for ocean and river journeys. According to the Proponent, the canoe is launched from the beach on the south side of the Ferry causeway, and the team paddles to Canoe Pass for river based journeys. As reported by the Proponent, the canoe skipper must follow a path that avoids the shallow waters of Tsawwassen First Nation community as well as the busy vessel traffic. Presently, the route traverses through the footprint of the Project.

Concerns were expressed by Tsawwassen First Nation about the safety of the canoe team with the increase in vessel traffic due to the Project.

More information about the potential effects of increased vessel traffic on Tsawwassen First Nation recreational boaters (canoeing) and the proposed mitigation measures is required.

Information Request

Describe the measures, other than the proposed communication advisories, that would be applied to mitigate the effects of the proposed Project on recreational boating and provide the anticipated effectiveness of the proposed mitigation measures.

Provide an assessment of the residual effects of increased marine vessel traffic from the Project on Tsawwassen First Nation recreational boating (canoeing) after the implementation of the above mitigation measures. Include information about the safety of the users and the necessary changes to the route presently used.

If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect on Tsawwassen First Nation recreational boating (canoeing) and the likelihood that the effect would occur.

VFPA Response

Clarification

The Tsawwassen First Nation canoeing described in EIS Appendix 18-A was assessed in EIS Section 32.0 (Potential or Established Aboriginal and Treaty Rights and Related Interests, including Current Use of Lands and Resources for Traditional Purposes).

Describe the measures, other than the proposed communication advisories, that would be applied to mitigate the effects of the proposed Project on Tsawwassen First Nation canoeing and provide the anticipated effectiveness of the proposed mitigation measures.

As described in EIS Section 32.2.7, mitigation measures to address potential effects on access to Tsawwassen First Nation's preferred Current Use locations, including Tsawwassen First Nation's canoe journeys through the Project area to and from Canoe Passage, and on the canoers' safety during these journeys as a result of increased marine vessel traffic, are as follows:

- The VFPA and Tsawwassen First Nation have a Memorandum of Agreement to accommodate Tsawwassen First Nation for effects from the Project;
- The VFPA will implement the mitigation measures set out in EIS Section 26.0 that are intended to reduce potential disturbance to marine access to Tsawwassen First Nation community lease lands (i.e., Tsawwassen Water Lots identified in Appendix F-2 of the *Tsawwassen First Nation Final Agreement*) associated with Project-related vessel traffic during construction;
- The VFPA will develop a communications protocol to inform appropriate Aboriginal groups of events related to Project construction or operation that may affect Tsawwassen First Nation's ability to canoe in the project area; and
- The VFPA will develop and implement a communications mechanism that will support dialogue between the VFPA and appropriate Aboriginal groups on topics of concern that arise during the construction phase and initial operation phase, including Project status, safety issues, effectiveness of mitigation programs, and sharing of information from environmental monitoring and follow-up programs.

The combination of the existing accommodation agreement with Tsawwassen First Nation, the measures set out in EIS Section 26.0, and the communications protocol and mechanism identified above are expected to be effective at addressing planned and unforeseen events that may interfere with access to and quality of experience (e.g., safety) at marine locations for Current Use purposes (other than crab harvesting), including canoe journeys. With the implementation of these measures, residual Project-related effects on Current Use access and quality of experience were therefore predicted in EIS Section 32.2.7 to be negligible (i.e., not measurable or detectable) and were not assessed further.

Provide an assessment of the residual effects of increased marine vessel traffic from the Project on Tsawwassen First Nation canoeing after the implementation of the above mitigation measures. Include information about the safety of the users and the necessary changes to the route presently used. If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect on Tsawwassen First Nation canoeing and the likelihood that the effect would occur.

As described above (following EIS Section 32.2.7), with the application of mitigation, residual effects of the Project on Current Use access to and quality of experience at marine locations for Tsawwassen First Nation's canoe journeys were predicted to be negligible, and therefore were not assessed further.

IR7-39 Outdoor Recreation – Beach Access, Clarification

Information Source(s)

EIS Volume 4: Section 24.5.4.3; Figure 24.4

CEAR Doc #654

Context

In Section 24.5.4.3 of the EIS, the Proponent indicated that the south side of the Roberts Bank causeway (east facing, inter-causeway side), is a popular place for dog walking and bonfires. The area is used both by Tsawwassen First Nation members and the broader community.

According to Metro Vancouver in CEAR Doc #654, the public presently has access to a beach along the existing Roberts Bank causeway.

Information Request

Indicate if the public will be restricted from accessing the beach and shoreline along the causeway (east facing, inter-causeway side) during construction or operation of the proposed Project.

VFPA Response

Public access to the beach and shoreline along the causeway is not expected to be restricted during Project construction or operations.

IR7-40 Outdoor Recreation – Recreational Trail, Mitigation

Information Source(s)

EIS Volume 1: Section 4.1.2

EIS Volume 4: Section 24.5.4.1; Section 25.5.5; Appendix 18-A, Section 8.2

CEAR Doc#996: Section 7.2.3

Context

The Proponent, in Section 24.5.4.1 of the EIS, noted that the trail used for walking, running, cycling and horseback riding runs from Brunswick Point to the base of the Roberts Bank causeway, at which point the trail becomes the Great Blue Heron Way trail on Tsawwassen First Nation lands. According to the Proponent, on its western end, the Brunswick Point trail connects to River Road West allowing riders to continue onto Westham Island, Ladner or other parts of Delta.

The Tsawwassen First Nation Neighbourhood Plan (CEAR Doc#996) indicated its intention to have the Great Blue Heron Way as a multi-purpose trail on the eastern end of the trail. Tsawwassen First Nation's vision is for a safe pedestrian and bicycle route strengthening Tsawwassen First Nation's connection with other First Nations and neighbouring communities, such as Delta, the USA border, Boundary Bay and the islands accessible through the Tsawwassen Ferry Terminal. Further, it will identify cultural and heritage sites.

The Deltaport Causeway transects this trail mid-way. In order to access the second half of the trail, recreational users must cross both the Deltaport Causeway and the railroad tracks. The crossings have the required safety precautions for highway and rail rights of way. However, there is no marked crossing for recreational users. Tsawwassen First Nation expressed concerns regarding the safety of users crossing tracks at unmarked crossings and the limited visibility of incoming trains in the vicinity of the dyke trail.

In Section 4.1.2 of the EIS, the Proponent stated that the causeway widening would require a new land area of approximately 42.4 hectares, including slope and toe of slope at the seabed, for additional rail, road and utility requirements. At the east end of the causeway, rail infrastructure would extend eastward 450 m in a narrow strip of approximately one hectare on the existing British Columbia Railway right-of-way for tie-in purposes to the exiting mainline rail network via the Roberts Bank Rail Corridor.

Information is needed about the potential loss to this trail as a result of the proposed Project and the mitigation measures needed to ensure safe access between the two sections of the trail and to respect the purpose envisioned for the planned Great Blue Heron Way.

Information Request

Provide the total area (in hectares) and the length (in kilometres) of the recreational trail that will be lost due to the proposed widening of the causeway.

Provide a description of the mitigation measures that could improve the connection between the two segments of the trail; ensure the safety of present and future trail users that will be crossing the expanded causeway; and which respects the purpose of the planned Great Blue Heron Way by Tsawwassen First Nation.

VFPA Response

Clarification

The Brunswick Point Trail and the Tsawwassen Sea Dyke Trail (also referred to as Great Blue Heron Way) are not connected as the Roberts Bank causeway and British Columbia Railway (BCR) lines are situated between the two trails. Public access to the Roberts Bank causeway and the Tsawwassen Sea Dyke via Brunswick Point Trail is currently prohibited to maintain public safety and access restrictions are enforced by BCR as per the *Railway Safety Act* (1985). Individuals who choose to access the Roberts Bank causeway from the Brunswick Point trail are doing so illegally. This restriction will remain in place with the Project.

Provide the total area (in hectares) and the length (in kilometres) of the recreational trail that will be lost due to the proposed widening of the causeway.

There will be no loss in total area or in length of the Brunswick Point or Tsawwassen Sea Dyke trails due to the proposed widening of the Roberts Bank causeway.

As indicated in EIS Section 4.1.2 and illustrated in Figure 4-6 of the EIS, at the east end of the causeway, Project-related rail infrastructure would extend eastward of the shoreline for 450 m in a narrow strip of approximately one hectare on the existing BCR right-of-way. The purpose of this rail infrastructure is to tie-in the rail lines on the widened causeway to the existing mainline rail network on the Roberts Bank Rail Corridor. As described in EIS Section 4.2.2 and illustrated in Figure 4-6 of the EIS, the width of the widened causeway will vary from no change at the east end to 140 m at the S-bend of the causeway. As indicated in Figure IR7-40-A1 in **Appendix IR7-40-A**, near the area where Brunswick Point Trail ends, the proposed causeway widening would parallel the existing BCR right of way and be approximately 30 m wide. At this point, the boundary of the expanded causeway would be approximately 60 m from the gate marking the end of Brunswick Point Trail.

There will be no alteration to the causeway footprint on the south side of the causeway where the Tsawwassen Sea Dyke Trail is located. As indicated in Section 24.6.4 of the EIS, potential Project construction and operation will not displace use or prevent access to land-based outdoor recreation amenities and areas within the local assessment area, including Brunswick Point Trail and Tsawwassen Sea Dyke Trail.

Provide a description of the mitigation measures that could improve the connection between the two segments of the trail; ensure the safety of present and future trail users that will be crossing the expanded causeway; and which respects the purpose of the planned Great Blue Heron Way by Tsawwassen First Nation.

As explained above, the Project will not change the current access to, use of, or spatial footprint of the Brunswick Point Trail and Tsawwassen Sea Dyke Trail. As per the environmental assessment methodology outlined in Section 8.0 of the EIS, no project interaction and in turn, no effects to other land-based outdoor recreation sub-component of the outdoor recreation valued component (which includes land-based walking, hiking, running, and cycling activities in the local assessment area) were identified or carried forward for assessment. As mitigation measures are only required when effects are identified, mitigation is not required.

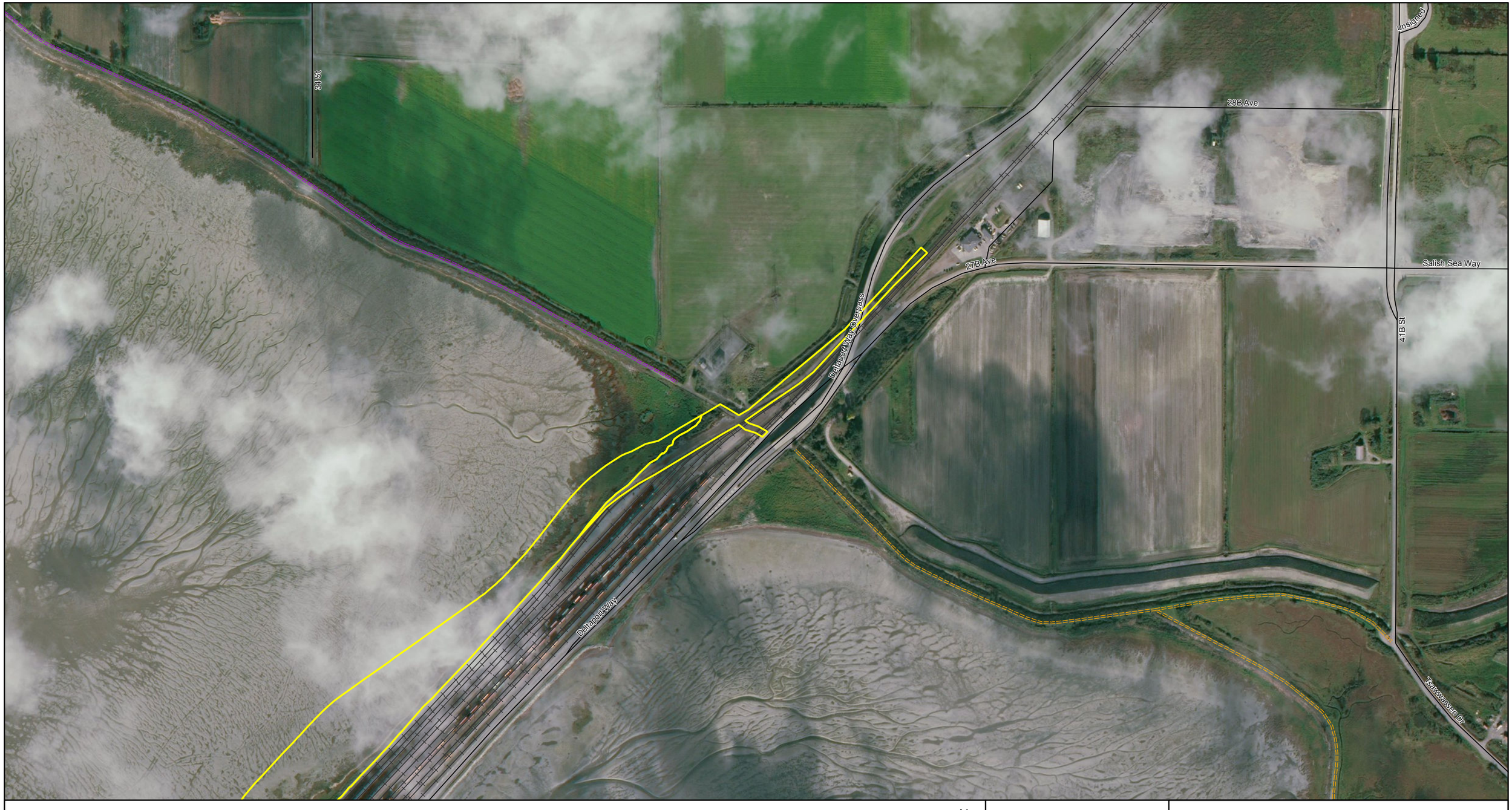
As part of the community benefit program, the VFPA welcomes further discussion on the development of a pedestrian and cyclist overpass at Deltaport Way with Tsawwassen First Nation and the City of Delta. The VFPA has indicated in a letter dated July 11, 2017 to Tsawwassen First Nation and City of Delta that it is open to further discussion on the possibility of the pedestrian and cyclist overpass, as well as other potential community benefits.

Appendices

Appendix IR7-40-A Supporting Figure

APPENDIX IR7-40-A
SUPPORTING FIGURE

Path: Y:\burnaby\CAD-GIS\Client\Vancouver_Fraser_Port_Authority\Delta\99_PROJECTS\1648389\02_PRODUCTION\MXD\Report\1648389_IR7-40-A1_Causeway.mxd



Legend

- BOUNDARY OF PROJECT AREA
- BRUNSWICK POINT TRAIL
- GREAT BLUE HERON TRAIL
- ROAD
- RAILWAY

0 80 160
Metres
1:5,000
NAD 1983 UTM Zone 10N

N

Notes:
RAILWAYS AND ROADS OBTAINED FROM DATA B.C.

PORT of vancouver

ROBERTS BANK TERMINAL 2

PROPOSED CAUSEWAY WIDENING

DATE: 12/07/2017

FIG No. IR7-40-A1

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

IR7-41 Outdoor Recreation – Tourism and Bird Watching, Effects Assessment

Information Source(s)

EIS Volume 4: Section 24.5.4.2; Section 24.6.4

CEAR Doc #558; CEAR Doc #574; CEAR Doc #581

Context

The Proponent mentioned that, due to Delta's location on the Pacific Flyway, there are a number of bird-watching opportunities in the local assessment area and the regional assessment area. The annual frequency of visitors is reported for the George C. Reifel Migratory Bird Sanctuary and for the participation in Delta Nature Casual Birding Club, a local naturalist club.

In Section 24.6.4 of the EIS, the Proponent reported that there would need to be an adverse population-level effect on birds, due to an adverse effect on productivity in order to have a measurable change in availability of birds for bird watching, which would affect the number of sightings. According to the Proponent, the proposed Project is not anticipated to affect coastal bird productivity at the population level; as a result, no effect on availability and number of sightings is anticipated. Therefore, the assessment of effects of the Project on tourism and birding activities was not conducted.

According to Environment and Climate Change Canada in CEAR Doc #581, there is a risk of significant adverse environmental effects to biofilm and consequently to migratory shorebirds - the Western Sandpiper in particular - and, in this instance, the Department would consider species-level impacts to migratory birds to be significant.

Participants in the environmental assessment have underlined the value of the regional assessment area for birds and for bird-related recreational activities. Comments have included:

- the area is an important stop-over for migratory birds;
- part of the area is a Ramsar site designated as a Wetland of international importance;
- the Western Hemisphere Shorebird Reserve Network considers the Fraser River Estuary as a site of hemispheric importance;
- the estuarine, marine and terrestrial environments around Delta are recognized nationally and internationally for their ecological significance for a wide variety of shore birds; and
- the area is a significant tourist draw because of the unique environment.

Information Request

Provide an assessment of the potential effects of the proposed Project on tourism and bird watching activities (for example, educational school visits, birding-club visits) in terms of a

reduction in the quality of the environmental setting and the potential loss of opportunities for the tourism industry of the area. In the analyses, include the consideration of the Alaksen National Wildlife Area and its international designation as a Ramsar site.

VFPA Response

Clarification

In CEAR Document #581[1], Environment and Climate Change Canada (ECCC) stated there is a risk of significant adverse environmental effects to biofilm and consequently, to migratory shorebirds, in particular Western Sandpiper, based on rationale presented in CEAR Document #574[2]. While the VFPA stands by the approach taken and science presented within the EIS that forms the basis of conclusions of the assessment of effects of the Project, the VFPA considered ECCC's comments and conducted studies during the 2016 Western Sandpiper northward migration to address the concerns raised by ECCC. Results from these studies support conclusions concerning Western Sandpipers and biofilm described in the EIS—specifically that the Project is unlikely to affect the availability of Western Sandpiper prey (including biofilm) during the Western Sandpiper's northward migration. For further detail, see IR8-04 of CEAR Document #1110[3].

As stated in EIS Section 15.10.1, a significant adverse residual effect to coastal birds would be characterised as one that negatively affects food resources or associated habitats to the extent that it compromises the long-term productive potential of the local assessment area (LAA) to support coastal bird productivity. Specific to Western Sandpiper and other shorebirds, studies conducted to support the assessment of effects of the Project indicate that food resources (i.e., biofilm, meiofaunal, and macrofaunal invertebrates) within the LAA available to support shorebirds are very large and, even under worst-case scenarios of change resulting from RBT2, will not become limiting (see EIS Section 15.7.2.2). This conclusion is supported by research conducted by the VFPA in 2016 to investigate factors affecting biofilm-associated essential fatty acids (see IR8-04 of CEAR Document #1110). Therefore, conclusions in the EIS regarding the ability of biofilm in the LAA to support Western Sandpiper populations with the Project remain unchanged after consideration of the results of additional studies in 2016.

Also, as stated in EIS Section 15.10.2, all habitats affected by the Project are anticipated to be mitigated except for subtidal soft-bottom habitat lost to the Project terminal footprint that is currently used for foraging by diving birds. The magnitude of this residual Project effect to diving birds was assessed to be low as the affected area represents 7% and 1% of the existing soft-bottom, shallow subtidal habitat within the LAA and regional assessment area (RAA),

[1] CEAR Document #581 From Environment and Climate Change Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[2] CEAR Document #574 From Environment and Climate Change Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[3] CEAR Document #1110 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Request IR8-04 (See Reference Document #1071).

respectively, and therefore, the loss of this foraging habitat would not limit diving bird productivity or the ability of the areas to support diving birds. The geographic extent was determined to be local (including Roberts Bank from the north side of the BC Ferries causeway to Canoe Passage, and from the high-water mark to -100 m chart datum (CD)), permanent, irreversible, and infrequent. Overall, the potential residual effect to productivity loss for diving birds was rated not significant indicating the ability of the LAA and RAA to support existing coastal bird populations will remain unchanged with the Project.

Provide an assessment of the potential effects of the proposed Project on tourism and bird watching activities (for example, educational school visits, birding-club visits) in terms of a reduction in the quality of the environmental setting and the potential loss of opportunities for the tourism industry of the area. In the analyses, include the consideration of the Alaksen National Wildlife Area and its international designation as a Ramsar site.

Results for the above mentioned studies used to inform potential effects to birds and biofilm and other coastal habitats support the conclusions stated in EIS Section 24.6.4 of the outdoor recreation assessment—that the Project is not anticipated to have an effect on availability of birds, number of bird sightings, or bird watching activities within the outdoor recreation LAA. The LAA was established to encompass the area within which Project effects on outdoor recreation could potentially occur, and effects are not anticipated to occur outside of the LAA. The Alaksen National Wildlife Area (ANWA) is located outside the coastal birds and outdoor recreation LAAs. As LAA boundaries are established to capture the extent of Project effect, no effects on bird watching outdoor recreation at the ANWA are anticipated.

Section 24.5.4.2 of the EIS identifies the following:

- Roberts Bank, the BC Ferries Tsawwassen Terminal, and Brunswick Point were identified as popular birding locations in the outdoor recreation LAA;
- Other identified popular locations in the outdoor recreation RAA include the George C. Reifel Migratory Bird Sanctuary (overlaps with the ANWA, which is an internationally recognised Ramsar site), Deas Island Regional Park, Boundary Bay Regional Park, Burns Bog, Serpentine Wildlife Management Area, and Point Roberts; and
- The outdoor recreation LAA overlaps the Pacific Flyway, which is a major north-south migration route for migratory birds in North and South America and an important stop-over for migratory birds.

Iona Beach Regional Park (located outside of the outdoor recreation RAA and LAA) is also a popular area for bird watchers.

EIS Section 15.5.3 further identifies the Fraser River estuary has been designated a site of hemispheric importance and that the marine and terrestrial environments around Delta are recognised for their ecological significance for a variety of shorebirds.

The VFPA acknowledges the unique environment and bird population supports bird tourism in the area. Given the assessment results as presented above, the Project is not anticipated to adversely affect availability of birds nor bird watching opportunity for bird tourism in the area.

The information request asks for an assessment of the potential effects of the proposed Project on tourism and bird watching activities in terms of a reduction in the *quality of the environmental setting* (italics added) and the potential loss of opportunities for the tourism industry of the area. As defined in EIS Section 24.6, the outdoor recreation valued component 'quality of environmental setting' pathway considered changes in noise and visual resources conditions, and effects on character of the environmental setting for bird watching (for clarification, this is a different pathway from the 'resource availability and presence' pathway, which, as indicated in EIS Section 24.6, considered Project effects on availability of birds and effects on bird watching activities, as addressed in the above section of this response). Potential effects of the proposed Project on reduction in the quality of the environmental setting and effects on outdoor recreation—including bird watching—is described in EIS Section 24.6.4. Based on this effects analysis, the Project is not anticipated to affect the bird tourism industry in the LAA, including bird tourism associated with the ANWA (which as indicated above is not located in the Project LAA, but in the RAA).

IR7-42 Outdoor Recreation – Astronomy, Effects Assessment

Information Source(s)

EIS Volume 4: Section 24.5.4

CEAR Doc #222

Context

According to a participant (CEAR Doc #222), members of the Royal Astronomical Society of Canada use Boundary Bay as an observation site.

The effect of increased nighttime light from the proposed Project on this activity is not discussed in the outdoor recreation section of the EIS.

Information Request

Provide an assessment of the potential effects of the increased nighttime light from the proposed Project on recreational astronomy in the local assessment area and regional assessment area in terms of changes to areas used and quality of environmental setting.

VFPA Response

Clarification

Section 24.0 of the EIS describes the assessment of potential Project effects on outdoor recreation. The local assessment area (LAA) encompasses the area in which the Project is expected to interact with and potentially have an effect on outdoor recreation (EIS Section 24.3.1). The regional assessment area (RAA) provides regional context for the assessment of Project-related effects. As per this methodology (see EIS Section 8.0), potential Project effects are identified and assessed within the LAA only.

The Boundary Bay astronomical viewing site identified in CEAR Document #222[1] is located within the land-based outdoor recreation RAA, but not within the LAA and is therefore outside of the area where the Project is expected to interact with and potentially affect astronomical nighttime viewing activity. The VFPA did not receive any concerns from the Royal Astronomical Society of Canada (RASC) or the public pertaining to Project effects on astronomical recreation activity (nighttime viewing) either within the LAA or at Boundary Bay during the scoping phase of the EIS, or through presentation of draft EIS results to stakeholders and Aboriginal groups.

[1] CEAR Document #222 From Harvey Dueck to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.

Consequently, the VFPA did not include astronomical recreational activity in its assessment of the effects of the Project on outdoor recreation at the time.

While the VFPA views the assessment of outdoor recreation in Section 24.0 of the EIS to be complete, in response to the concern raised in this information request, an assessment of the potential effects of the increased nighttime light from the proposed Project on astronomical recreational activity (with a focus on Boundary Bay viewing location) has being carried out. The results of this additional work are presented below.

Provide an assessment of the potential effects of the increased nighttime light from the proposed Project on recreational astronomy in the local assessment area and regional assessment area in terms of changes to areas used and quality of environmental setting.

In order to collect information on the recreational astronomy activities identified in this request, an interview was held with the President of the Vancouver Centre of the RASC (Suzanna Nagy, personal communication, 13 September 2017). The interview was held to confirm astronomy viewing locations in the outdoor recreation LAA and RAA, including Boundary Bay, and to discuss the Boundary Bay viewing location's use characteristics (including seasonal variations, number of users, and use trends) by the RASC. The RASC representative confirmed that some recreational astronomy currently takes place at Boundary Bay, on the Boundary Bay dyke near the parking area at the end of 72 Street in Delta, as indicated on the RASC website (http://rasc-vancouver.com/observing/observing-sites/boundary-bay/). The RASC indicated that September to November and March to May are the times with the highest number of viewers at this location. When conditions are favourable, daily viewing numbers can range from 5-6 to 40-50 people, with larger number of viewers being present during a celestial event, such as a comet.

According to the RASC representative, recreational astronomy activity at the Boundary Bay site has generally declined over the past five years. The RASC indicated that organised RASC viewing events are no longer held at Boundary Bay due to light pollution from greenhouses built approximately five years ago. Prior to the greenhouses, Boundary Bay was the preferred location for events as it was easy to access. First choice locations for organised viewing events are now the Porteau Cove area or in Maple Ridge.

With the exception of the viewing location at Boundary Bay, no other areas in the outdoor recreation LAA or RAA were identified by the RASC as areas used for recreational astronomy by the RASC. During the September 13, 2017 communication with RASC, light pollution was identified as a general concern, and the RASC is working with local municipalities to develop 'Urban Dark Sky Preserves' in local parks to maintain darkness and viewing opportunities within urban areas.

To address this information request, additional light measurements were collected at the Boundary Bay astronomical viewing site and light modelling was conducted. The results of the modelling were assessed based on the change in nighttime viewing conditions criteria identified in Section 25.0 of the EIS, then assessed for potential effects to recreational astronomy.

Existing light measurements were conducted at the Boundary Bay astronomical viewing site (BB) (situated at 498228 m Easting, 5434105 m Northing) on the night of September 14, 2017. Measurements were collected under clear skies and taken after astronomical twilight (i.e., after 9:15 p.m.) and while the moon was set. Light trespass measurements were carried out using a Solar Light PMA2100 photometer and a PMA2131 scotopic detector. Sky quality measurements were carried out using a Unihedron Sky Quality Meter (SQM), which provides sky quality measurements in mag/arcsec^2.

The measurement results are presented in **Table IR7-42-1**.

Table IR7-42-1 Existing Light Measurement Results at Boundary Bay Astronomical Viewing Site

Site	**Existing Light Trespass** (lux)	**CIE Environmental Classification for Light Trespass**	**Existing Sky Quality** (mag/ arcsec^2)	**Existing Sky Glow** (% Brightness above Natural Dark Sky)	**CIE Zone Classification for Sky Glow**
Boundary Bay Astronomical Viewing Site (BB)	0.011	E2	19.45	566	G4

Light trespass and sky quality measured at BB were similar to other nearby points of reception (PORs) described in the EIS with similar conditions (i.e., EIS POR8, Crescent Beach).

Modelling was undertaken to predict the effect of the Project on the existing light trespass and sky glow at BB. Light trespass was modelled using the AGi32 lighting software and sky glow was modelled using a computer program based on Garstang's model (Garstang 1986, 1989); more details on the modelling methodology are presented in Section 2.4 of Appendix 9.4-A of the EIS.

Table IR7-42-2 summarises the modelling results and the CIE (Commission Internationale de L'Éclairage) classifications for light trespass and sky glow when considering the predicted changes due to the Project. The Project is not predicted to result in a change to the CIE classifications.

Table IR7-42-2 Predicted Changes in Light Trespass and Sky Glow with the Project at Boundary Bay Astronomical Viewing Site

Site	Predicted Project Light Trespass (lux)	Existing + Project Light Trespass (lux)	CIE Environmental Classification for Light Trespass	Existing + Predicted Sky Quality (mag/ arcsec^2)	Existing + Predicted Sky Glow (% Brightness above Natural Dark Sky)	CIE Zone Classification for Sky Glow
Boundary Bay Astronomical Viewing Site (BB)	0.002	0.013	E2	19.35	623	G4

No changes are predicted at BB in CIE Environmental Classification for Light Trespass and in CIE Zone Classification for Sky Glow.

Based on the above modelling results, no visible alteration to nighttime viewing conditions at BB with the Project are anticipated. Based on the predicted change in light trespass and sky glow associated with the Project at BB, and no anticipated change in nighttime viewing conditions at BB, Project effects on quality of the nighttime visual environmental setting and on outdoor recreational experience at the Boundary Bay recreational astronomy viewing site are anticipated to be negligible. Based on current understanding that the Boundary Bay viewing site is the only recreational astronomy viewing area within the LAA or RAA, Project effects on recreational astronomy viewing in other parts of the LAA or RAA are not identified. There is no change to the land-based outdoor recreation assessment results as described in EIS Section 24.6.4.

References

Garstang, R. H. 1989. Night-sky Brightness at Observatories and Sites. Publications of the Astronomical Society of the Pacific 101:306-329.

Garstang, R. H. 1986. Publications of the Astronomical Society of the Pacific 98:364-375.

Nagy, Suzanna. Royal Astronomical Society of Canada (RASC), September 13, 2017.

IR7-01 Atmospheric Noise – Modelling Using Worst-Case Meteorological Conditions

Information Source(s)

EIS Volume 2: Section 9.3.12; Appendix 9.3-A, Table 3-5

TDR Upland Noise and Vibration - Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals (CEAR Doc#986)

EIS Volume 4: Section 27.6.3.2; Section 27.6.3.4

Proponent Response to Information Request Package 3 (CEAR Doc#984): Preamble to IR3-25 to IR3-46

Context

In Appendix 9.3-A of the EIS, the Proponent acknowledged that meteorological conditions such as wind speed, wind direction and temperature stratification have an important influence on noise propagation in the atmosphere. In its technical data report on the effects of meteorological conditions on sound propagation (CEAR Doc#986), the Proponent examined some of these effects, and highlighted that enhanced noise propagation can occur:

- in downwind directions;
- in light wind conditions;
- under temperature inversions; and
- under low level jets (giving sea breezes as an example).

Further, it was emphasized that sound propagating over water may undergo modest amplification.

In Appendix 9.3-A of the EIS, the Proponent indicated that it used the LfU-Bayern (1999) noise modelling approach, which only accounts for wind direction effects. As a result, noise from the proposed Project may be greater than predicted since the LfU-Bayern approach does not account for the numerous meteorological conditions that could result in enhanced noise propagation, as described in CEAR Doc#986.

Alternatively, the CONCAWE model can explicitly treat temperature inversion and other meteorological conditions. As stated by the Proponent in Section 2.3.3.4 of Appendix 9.3-A of the EIS, the CONCAWE method was not used in the model because it is based on empirical sound propagation data collected exclusively over land, and because the Pasquill Stability Categories were similarly developed in relation to ground surfaces rather than water surfaces. However, the CONCAWE model can be operated with measured or estimated temperature profile data valid for overwater surfaces.

In Section 9.3.12 of the EIS, the Proponent indicated that it is not known whether low level jets actually occur within the local study area. However, it is possible that recently published

literature may provide information such that the influence of low level jets on noise propagation could be included in the noise assessment of the Project.

Because the noise modelling is based on a meteorological data set that is limited in terms of capturing important meteorological conditions (such as temperature inversions and low level jets) and their seasonality, further information regarding the worst-case meteorological conditions and the resultant noise levels at the seven sites identified by the Proponent in the upland study area is required.

Information Request

Provide a brief summary of relevant and available literature regarding existing measurement and modelling studies of the atmospheric boundary layer in near-coastal parts of the Lower Fraser Valley that could be applied to the local study area for the proposed Project. The review should include studies that investigated sea breezes and temperature inversions.

Based on results of the literature review, construct a representative meteorological data set to be used as input to the CONCAWE model. The data set should be designed to capture a reasonable worst-case scenario for enhanced noise propagation (i.e. downwind conditions, light winds, temperature inversions, low level jets, and overwater propagation) from the Project to the seven sites located in the upland study area for the Project. The data set should also account for seasonal dependence of meteorological conditions. Provide a tabulation of the data set used to represent the worst-case scenario.

Provide an analysis of the frequency of occurrence by season of these worst-case meteorological conditions that result in enhanced sound propagation.

Run the CONCAWE model using the representative atmospheric data set to develop an assessment of worst-case noise levels at the seven noise measurement sites in the upland study area for the Project during both construction and operation. The worst-case meteorological conditions should include all worst-case conditions acting simultaneously, and all physically realistic combinations of such conditions. The Proponent is to follow the revised activities for Project construction as presented in CEAR Doc#984.

Present the results of the CONCAWE model run in tables similar to Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS that summarize L_d, L_n, L_{dn} and L_{max} at the seven noise measurement sites in the upland study area during construction and operation of the Project under different combinations of the worst-case meteorological conditions. Provide a discussion of the results to accompany these tables.

VFPA Response

Clarification

This information request asks for updated noise modelling of L_d, L_n, L_{dn}, and L_{max} at the seven noise measurement sites in the upland study area. However, these parameters (associated with continuous noise) were measured at, and predicted for, only sites 3, 4, and 5. Initial measurements of ground-borne vibration were taken at sites 1 and 2, and low frequency noise at sites 6 and 7 (as shown in Table 2-1 of EIS Appendix 9.3-A). The assessment focuses on predicted noise levels at sites 3, 4, and 5 as representative of the areas within the local assessment area (LAA) that are expected to receive the highest levels of Project-related noise in the future, as discussed in Section 9.3.6.3 of Appendix 9.3-A of the EIS. This response

provides the requested information for sites 3, 4, and 5, where the indicators L_d, L_n, and L_{dn} were assessed.

The L_{max} parameter represents the highest measured value over a designated time period and relates only to the measurements of existing conditions in Appendix 9.3-A of the EIS. Model scenarios cannot refine activity sufficiently to enable prediction of L_{max} in 1 or 10 minute increments, or link short term event data represented by L_{max} to specific meteorological conditions, so this parameter is not addressed in this response.

1. Provide a brief summary of relevant and available literature regarding existing measurement and modelling studies of the atmospheric boundary layer in near-coastal parts of the Lower Fraser Valley that could be applied to the local study area for the proposed Project. The review should include studies that investigated sea breezes and temperature inversions.

The following provides a detailed summary of relevant literature. The reference list is provided at the end of this response.

Overview – Refraction of Sound Rays in Surface Layer

In the Project region, the atmospheric boundary layer tends to be on the order of hundreds of metres high. Noticeable modifications to sound levels are only expected within the lowest 100 metres (approximately) of the atmospheric boundary layer, which is called the 'surface layer' (Stull 1988). This response will limit the discussion to the surface layer.

When sound waves travel horizontal distances of several kilometres between source and receiver, as would be the case with noise from the RBT2 terminal, the sound waves are substantially attenuated in the atmosphere due to geometric spreading and atmospheric absorption (Crocker 2007). Under these conditions, the main concern of worst-case atmospheric conditions is downward bending (refraction) of sound waves, which can limit the sound waves to the surface layer, resulting in increased noise propagation (Crocker 2007).

Sound can be generated across a broad, multidirectional wave front, or it can be very directional, depending on the nature of the sound source. The nature of spatial propagation of sound, and how sound is perceived or measured, results in only the portion of a sound wave that is on the direct path from source to receiver being heard. This is evaluated by defining or modelling sound as a 'ray' between the source and receiver of the sound. When substantial downward refraction of sound rays is occurring within the surface layer, additional rays that would otherwise propagate away from the surface will reach the receptor, resulting in amplification of the sound.

Effect of Atmospheric Conditions on Downward Refraction

Downward refraction of sound rays in the atmosphere occurs when the speed of sound propagation increases with height (Crocker 2007). The speed of sound depends on several atmospheric parameters, but only temperature and wind speed have sufficient vertical variability to cause measurably strong downward bending of sound waves within the atmospheric surface layer to cause sound amplification (Crocker 2007).

As described in Section 2.1.5 of the RBT2 Technical Data Report: Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals ('RBT2 Meteorological Report'; CEAR Document #986[1]), under conditions that enhance downward refraction and over a hard reflecting surface, such as water, a maximum reduction in attenuation of 3 decibels (dB) would be possible. For example, a sound source of 50 A-weighted decibels (dBA) that attenuates to 40 dBA at a distance over land, a neutral atmospheric surface, would attenuate to 43 dBA at the same distance over water.

Temperature Variation

Downward refraction occurs when temperatures increase substantially with height above the ground within the atmospheric surface layer (Crocker 2007). Such atmospheric conditions are called 'stable', because the colder air near the ground has higher density than the air aloft and, therefore, vertical exchange of air is suppressed. The main mechanism creating stability is nighttime cooling at the surface, particularly under cloudless conditions. Because of the stability, air further aloft cools less rapidly, creating a positive temperature gradient from the surface upwards such that sound rays are refracted downward (Stull 1988). The meteorological modelling discussed further below suggests that stable nighttime conditions are common in the entire region, including the Project site.

Refraction of sound waves can also occur at substantially higher altitude, for instance at the temperature inversion at the top of the convective boundary layer or the capping inversion that frequently occurs over mountain valleys roughly at ridge height of the surrounding mountains (Whiteman 2000, McKendy and Lundgren 2000). In the lower Fraser Valley, these conditions occur at heights of many hundreds of metres up to approximately one kilometre above the surface (van der Kamp and McKendy 2010). However, under these atmospheric conditions, the change in attenuation is negligible because of the strong attenuation over the longer vertical distance travelled by the downward bent sound rays. Furthermore, such conditions are less likely to occur at the Project site, which is located at the mouth of the Fraser River over 35 kilometres from the mountain ridges to the north and south.

Wind Speed Variation

Downward refraction of sound also occurs in the direction of wind flow when wind speeds increase substantially with height above the ground (Crocker 2007). Wind speed is always zero right on the ground. Therefore, strong winds at relatively low altitudes cause a substantial increase of wind speed from the ground up. Section 2.2.2 of the RBT2 Meteorological Report (CEAR Document #986) defines 'strong winds blowing at relatively low altitudes' as 'low level jets'. Different meteorological conditions that can cause low level jets are inertial oscillations and land-sea breezes, described in the following paragraphs.

[1] CEAR Document #986 From the Review Panel Secretariat to the Review Panel re: Roberts Bank Terminal 2 Technical Data Report - Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals.

Inertial Oscillations

Community members at Roberts Bank have reported sudden gusts of wind that amplify sound from the Roberts Bank terminals. These low-level jets are most likely inertial oscillations. Inertial oscillations are mostly expected in large flat terrain, which might explain the apparent lack of literature on inertial oscillations in the lower Fraser Valley. A mechanism explaining inertial oscillations was first proposed by Blackadar (1957), and Stull (1988) provides the mathematical description of the mechanism. The larger scale pressure differences in the atmosphere cause strong winds at higher elevation in the atmosphere. Under fair weather conditions during the daytime, turbulence from the surface heating slows down these winds throughout the entire atmospheric boundary layer. In the evening, the surface layer becomes stable and winds in the atmospheric boundary layer above the surface layer can speed up. These winds tend to oscillate in direction and speed because of Earth's rotation, which imposes a perpendicular force on the motion (except near the equator). This is similar to a pendulum performing oscillations caused by its inertia and the gravitational force acting at an angle to the motion of the pendulum.

Inertial oscillations are expected to occur in a shallow layer of strong winds on the order of about one hundred metres deep that occur detached from the surface at altitudes of up to several hundred metres above the ground. Banta et al. (2002), for example, reported observations of inertial oscillations over Kansas. Other investigations, however, have called into question the prevalence of such idealised inertial oscillations and suggested that, in practice, inertial oscillations are weak, sporadic, and often occur substantially above the surface layer, for example Lundquist (2003).

On the rare occasion when inertial oscillations occur sufficiently close to the ground and with the wind direction from the noise sources towards the receptors, they can contribute to sound level amplification. However, typically inertial oscillations occur under stable nighttime conditions and weak surface winds, when noise is already substantially less attenuated, according to the existing models, than under other meteorological conditions, regardless of the presence of inertial oscillations. Therefore, information on the frequency of such events is not required to ensure modelling of noise propagation considers worst-case meteorological conditions.

Land-sea Breezes

At nighttime, because the heat capacity is lower for solid ground than for water, the energy loss from land causes a faster drop in temperature over land than over water. That implies that near the Project site right at the water, the faster temperature drop occurs over the land surface in the lower Fraser Valley. The build-up of colder air above the land surface eventually causes a decreasing pressure gradient from land towards the water, and creates a subsequent land breeze of colder air from the lower Fraser Valley towards the Strait of Georgia (Stull 1988).

Because land breezes generally blow from the receptors on land towards the sound source over water, they are less likely to be associated with worst-case meteorological conditions for sound propagation than their daytime equivalent, the sea breeze. Sea breezes can carry

sound from a noise source over the water towards the receptors on land. While they are typically hundreds of metres deep, the wind speed maximum occurs roughly 100 metres above the ground (Steyn 1998, 2003). Hence, under sea breeze conditions, a substantial wind speed gradient exists near the surface that can amplify sound levels.

Other Temperature Gradient Effects

The lower Fraser Valley is characterised by additional land surface complexities beyond the land-sea interface (McKendry and Lundgren 2000). Additional horizontal temperature gradients and subsequent pressure gradients are caused by the following (Whiteman 2000):

- Slope flows over steep complex terrain to the north and southeast of the lower Fraser Valley;
- Valley flows in tributary valleys particularly in the north shore mountains and for the lower Fraser Valley as a whole; and
- Plain-mountain wind systems for the larger-scale terrain gradient between the Pacific Ocean and the mountains in B.C. and Washington State.

To the extent that these flows reach the Project site in Delta, they can interact with the sea or land breeze. In most cases, the interaction would be an enhancement to, but indistinguishable from, the sea or land breeze. For instance, daytime up-valley flows into the lower Fraser Valley could enhance the sea breeze at the Project site.

In summary, worst-case meteorological conditions for noise propagation are those with strongly increasing temperature and wind speed (from source towards receptor) within the surface layer. These are most likely associated with sea breezes (potentially enhanced by other complex terrain flows in the lower Fraser Valley) during the daytime. At nighttime, these conditions occur when the atmosphere is stable and larger-scale winds aloft drag air within the surface layer or cause sporadic bursts of inertial oscillations. An analysis of the frequencies of these sea-breeze and stable nighttime conditions with winds blowing from the source to the receptors is provided below.

2. Based on results of the literature review, construct a representative meteorological data set to be used as input to the CONCAWE model. The data set should be designed to capture a reasonable worst-case scenario for enhanced noise propagation (i.e. downwind conditions, light winds, temperature inversions, low level jets, and overwater propagation) from the Project to the seven sites located in the upland study area for the Project. The data set should also account for seasonal dependence of meteorological conditions. Provide a tabulation of the data set used to represent the worst-case scenario.

Overview of CONCAWE Approach

The CONCAWE model estimates sound levels under six different meteorological categories (table on page 21 in CONCAWE (1981)). The purpose of the meteorological categories is to calculate a factor, referred to as K4, which is applied to the sound-level estimates to account for meteorological influence. Category 4 has assumed zero meteorological influence. Empirical correction curves were derived for the other five categories. These curves show sound-level corrections as a function of acoustic frequency and distance from the noise source. They were

derived from field data collected for sound from petrochemical plants propagating over a land surface. Generally, meteorological categories 1 to 3 are associated with noise reductions and categories 5 to 6 are associated with sound enhancement, relative to category 4.

Available meteorological data for the field study on which the CONCAWE model was based included wind speed and direction, daytime incoming solar radiation, and cloud cover. In a first step, that data were used to identify atmospheric Pasquill stability classes from A (very unstable) to F (stable) (table on page 20 in CONCAWE (1981)). In a second step, strength and direction of the wind components relative to the downwind direction from noise source to receptor were categorised. In the third step, these wind component categories were combined with Pasquill stability classes and assigned to one of the six meteorological categories (table on page 21 in CONCAWE (1981)).

A limitation of the CONCAWE meteorological categories is that they combine meteorological observations that are associated with very different meteorological conditions into the same category. For instance, meteorological category 6 could include a variety of conditions including the following: fully developed strong sea breezes straight from the noise source to the receptor (stability class C and v>+3.0 m/s); a typical winter storm under rainy and overcast conditions (stability class D and v>+3.0 m/s); or nighttime or otherwise stable conditions with sufficiently strong onshore winds to suppress a land breeze (stability class F and v>+0.5 m/s).

Worst-case Meteorological Conditions for Sound Propagation at Roberts Bank

To estimate CONCAWE calculation input data representing Pasquill stability classes for the Project site, solar radiation observations were required. These observations were unavailable from area meteorological stations, and therefore, another approach was necessary to derive information on Pasquill stability classes. Instead, output from a CALMET model run over the Project region for the year 2011 was utilised. CALMET was run using as input 1) observations from several meteorological stations in the region and 2) output from the atmospheric mesoscale Weather Research and Forecast (WRF) model. CALMET output included Pasquill stability classes and wind speed and direction at a 2.5-km grid resolution. This output was bilinearly interpolated to the location of the noise source to provide the best representation of atmospheric conditions at the location of noise generation and for much of the over-water distance travelled towards the receptors. Wind vectors were rotated relative to the downwind direction from noise source to each receptor for each of the three main receptors sites.

For every hour of the year 2011, the wind component categories and Pasquill stability classes determined from the CALMET output were assigned to their respective meteorological categories. Finally, the frequencies of occurrence for each meteorological category were determined for each of the three receptor sites 3, 4, and 5 (Figure 2-3 in Appendix 9.3-A of the EIS) to provide all potential stability classes prior to focussing on the worst-case conditions. The results are shown in **Table IR7-01-1** below.

Table IR7-01-1 Frequencies of Occurrence of CONCAWE Meteorological Categories at Sites 3, 4, and 5 based on CALMET Output for Calendar Year 2011

Meteorological Category	Frequency of Occurrence (in %)		
	Site 3	Site 4	Site 5
1	0.7	0.9	1.1
2	17.2	18.9	25.0
3	21.2	23.8	24.0
4	19.2	17.6	16.0
5	23.0	19.6	14.3
6	18.6	19.1	19.5

The class that represents the 'worst-case' meteorological condition from a CONCAWE perspective for noise propagation is category 6. As described above, this category can represent more than the 'sea-breeze' condition, which is known to be the 'worst-case' meteorological condition from the ISO 9613 model perspective (receptor downwind of sound source).

The data set that was developed considered the location of all receptors used in the noise and vibration study. However, the EIS did not include the modelling of future noise levels at sites 1, 2, 6, or 7. Sites 1 and 2 were used to assess Project-related ground-borne vibration and sites 6 and 7 were used to assess Project-related low frequency noise. As such, the design of the data set focused on capturing meteorological conditions at sites 3, 4, and 5, as these sites represent residential locations that in the future are expected to receive the highest levels of Project noise.

3. Provide an analysis of the frequency of occurrence by season of these worst-case meteorological conditions that result in enhanced sound propagation.

A climatology of sea breezes was presented in Steyn and Faulkner (1986) based on a ten-year observational record. The statistics presented in this study can be expected to provide a good representation of current conditions. Data from Table 2.2 in Steyn and Faulkner (1986) at Vancouver International Airport (representative of the Project site) were incorporated in **Table IR7-01-2** below and used to derive a rough estimate of the overall frequency of sea breeze conditions by month and annually. Sea breezes are a daytime occurrence.

Table IR7-01-2 Frequencies of Occurrence of Sea Breezes at Vancouver International Airport based on Data Presented in Steyn and Faulkner (1986)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean frequency of occurrence (days)	3.2	4.1	6.9	7.7	9.4	8.5	11.5	11.0	8.9	8.7	3.8	2.2	-
Mean daily duration (hours)	4.9	6.7	8.1	8.6	9.0	8.3	7.9	8.3	8.9	7.2	5.5	4.1	-
Total average sea-breeze hours	15.7	27.5	55.9	66.2	84.6	70.6	90.9	91.3	79.2	62.6	20.9	9.0	674.3
Total hours per period	744	672	744	720	744	720	744	744	720	744	720	744	8760
Mean frequency of occurrence (%)	**2.1**	**4.1**	**7.5**	**9.2**	**11.4**	**9.8**	**12.2**	**12.3**	**11.0**	**8.4**	**2.9**	**1.2**	**7.7**

Relative to all hours in a given month, the frequency of sea breezes varies from a minimum of 1.2% in December to a maximum of 12.3% in August. Based on the ten-year observational data set in Steyn and Faulkner (1986) and the criteria for sea breeze identification applied by the authors, sea breezes occur in approximately 7.7% of all hours in a calendar year.

Table 2.2 in Steyn and Faulkner (1986) indicates that monthly mean sea breeze wind speeds varied between 2.5 m/s and 3.6 m/s, and the most frequent wind directions were from 210° to 240° (roughly southwesterly) at the coast. The wind component from noise source to receptors at the Project site is therefore less than +3 m/s most of the time. Because sea breezes occur under stability classes A, B, and C, according to the table on page 21 in CONCAWE (1981), sea breezes are assigned to meteorological categories 4 and 5 most of the time, and category 6 occasionally. Following the categorisation in the CONCAWE model, occasionally occurring sea breezes in category 6 are the worst-case meteorological conditions. Sea breezes occur less than 10% of the time.

Worst-case scenarios are therefore best represented by applying meteorological category 6 for every hour of the year, although in reality they occur less than 20% of the time over the course of a calendar year as shown in **Table IR7-01-1**. **Table IR7-01-3** below shows the frequency of occurrence of the six meteorological conditions further broken down by season.

Table IR7-01-3 Frequencies of Occurrence of CONCAWE Meteorological Categories at Sites 3, 4, and 5 based on CALMET Output for Calendar Year 2011 Broken Down by Season

Meteorological Category	Frequencies (in %)											
	Winter[a]			Spring[b]			Summer[c]			Fall[d]		
	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5	Site 3	Site 4	Site 5
1	1.7	2.2	2.3	0.6	0.6	0.7	0.0	0.0	0.0	0.5	1.0	1.3
2	33.4	33.4	38.7	13.3	14.7	21.8	7.2	10.0	15.7	15.3	17.9	24.3
3	22.7	22.1	18.5	16.8	20.3	22.1	22.6	29.6	32.6	22.8	23.3	22.7
4	11.7	12.2	14.2	19.2	19.2	15.1	27.6	22.6	19.2	18.3	16.4	15.6
5	14.5	14.6	10.5	26.7	19.6	15.0	27.4	22.8	16.3	23.4	21.3	15.3
6	16.0	15.4	15.9	23.4	25.6	25.3	15.1	14.9	16.2	19.7	20.2	20.8

Notes:

a. Winter includes the months of December, January, and February
b. Spring includes the months of March, April, and May
c. Summer includes the months of June, July, and August
d. Fall includes the months of September, October, and November

4. Run the CONCAWE model using the representative atmospheric data set to develop an assessment of worst-case noise levels at the seven noise measurement sites in the upland study area for the Project during both construction and operation. The worst-case meteorological conditions should include all worst-case conditions acting simultaneously, and all physically realistic combinations of such conditions. The Proponent is to follow the revised activities for Project construction as presented in CEAR Doc#984.

Present the results of the CONCAWE model run in tables similar to Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS that summarize L_d, L_n, L_{dn} and L_{max} at the seven noise measurement sites in the upland study area during construction and operation of the Project under different combinations of the worst-case meteorological conditions. Provide a discussion of the results to accompany these tables.

Project Operation

The CadnaA model used in the EIS to forecast noise levels under future conditions with Project operation has been revised to account for the influence of meteorology on sound propagation according to the CONCAWE method (CONCAWE 1981). Sound propagation factors other than those considered by CONCAWE (e.g., distance) were still calculated according to the ISO 9613 standard (ISO 1996), as they were in the EIS. The ISO 9613 meteorological correction factor was replaced and calculated according to the CONCAWE method. The CONCAWE method was used to develop noise level predictions for the case of all sound propagation occurring under CONCAWE meteorological category 6; the category that would result in worst-case Project noise levels.

This revised approach only applies to noise from the sources in the CadnaA model that represent marine terminals and rail traffic. The EIS approach calculates road traffic noise as linear noise sources according to the NMPB-Routes 96 standard (Sétra 1997). The CONCAWE method does not include linear sources. The NMPB model does, however, allow for road traffic noise to be calculated under both neutral and downwind meteorological conditions. Conditions where downwind propagation occurs 100% of the year were used for the traffic portion of the model runs, which is equivalent to conditions included in CONCAWE meteorological class 6.

Table IR7-01-4 presents noise levels at sites 3, 4, and 5 for CONCAWE meteorological category 6 (worst-case meteorological conditions). Provided for comparison are the noise levels presented in the EIS which are for annual average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999). All noise levels are for future conditions with Project operation.

Table IR7-01-4 Noise Levels at Sites 3, 4, and 5 (Future Conditions with Project Operation) for CONCAWE Meteorological Category 6 Compared to EIS Annual Average

Site	ISO 9613 CONCAWE Meteorological Category 6			ISO 9613 EIS - LfU-Bayern Annual Average Windrose			Noise Level Differences between CONCAWE minus LfU-Bayern (EIS)		
	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)	L_d (dBA)	L_n (dBA)	L_{dn} (dBA)
3	57.5	54.1	61.2	52.0	51.7	58.1	5.5	2.4	3.1
4	54.3	52.2	59.0	49.5	46.5	53.5	4.8	5.7	5.5
5	56.3	55.1	61.7	52.8	49.6	56.7	3.5	5.5	5.0

Table IR7-01-4 shows that noise levels at the three sites are from 2.4 to 5.7 dBA higher for CONCAWE Meteorological Category 6 (reflecting worst-case meteorological conditions) when compared to annual average noise levels according to LfU-Bayern.

Construction Noise

The calculations of Project construction noise levels have been revised to consider sound propagation under ISO 9613 with CONCAWE meteorological category 6 (i.e., 'worst-case' meteorological conditions). Project construction noise levels are based on the Project construction activities described in Section 4.4.1 of the EIS, and detailed in Appendix 4-E and 4-F of the EIS. The VFPA will respond to the Panel under separate cover with regard to the changes to the environmental assessment that result from the changes to the RBT2 Project Description, as per the Panel's direction in letters dated July 17, 2017 (CEAR Document #995[2]) and October 3, 2017 (CEAR Document #1069[3]). However, the changes to the Project Description include removal of key noise sources, such as activity associated with the intermediate transfer pit and marine vibro-replacement; these changes would have the effect of reducing construction noise. The information provided below is therefore considered conservative in this context.

Table IR7-01-5 presents revised construction noise levels, calculated using the CONCAWE method, at sites 3, 4, and 5. The corresponding table in the EIS is Table 9.3-18. **Table IR7-01-6** compares the CONCAWE based results to the corresponding levels in Table 9.3-18 of the EIS.

[2] CEAR Document #995 From the Review Panel to the Vancouver Fraser Port Authority re: Requirements for information pertaining to changes to the Roberts Bank Terminal 2 Project.
[3] CEAR Document #1069 From the Review Panel to the Vancouver Fraser Port Authority re: Response to the Vancouver Fraser Port Authority's plan for the presentation of the revised information (See Reference Document # 1054).

Table IR7-01-5 Construction Noise Levels under CONCAWE Meteorological Category 6

Site	Annual Average Expected L_d (dBA)	Project Construction Phase L_d (dBA)		Project-related Increase (dBA)	
		Range	Avg.	Range	Avg.
3	51.9	51.9 – 58.0	54.1	0.0 – 6.1	2.2
4	48.4	48.4 – 56.3	51.7	0.0 – 7.9	3.3
5	52.3	52.3 – 53.9	53.0	0.0 – 1.6	0.7
Site	**Annual Average Expected L_n (dBA)**	**Project Construction Phase L_n (dBA)**		**Project-related Increase (dBA)**	
		Range	**Avg.**	**Range**	**Avg.**
3	51.5	51.5 – 57.9	53.3	0.0 – 6.4	1.8
4	44.5	44.5 – 55.9	48.9	0.0 – 11.4	4.4
5	48.5	48.5 – 51.3	49.6	0.0 – 2.8	1.1
Site	**Annual Average Expected L_{dn} (dBA)**	**Project Construction Phase L_{dn} (dBA)**		**Project-related Increase (dBA)**	
		Range	**Avg.**	**Range**	**Avg.**
3	58.0	58.0 – 64.3	59.9	0.0 – 6.3	1.9
4	51.7	51.7 – 62.4	55.9	0.0 – 10.7	4.2
5	55.7	55.7 – 58.1	56.8	0.0 – 2.4	1.1

Table IR7-01-6 Comparison of Project Related Increases from Construction Noise under CONCAWE Meteorological Category 6 and EIS ISO 9613 Methods

Site	CONCAWE Project-related Construction Increase L_d (dBA)		EIS Project-related Construction Increase L_d (dBA)		Noise Level Differences between CONCAWE and EIS Construction Increases L_d	
	Range	Avg.	Range	Avg.	Range Maximum	Avg.
3	0.0 – 6.1	2.2	0.0 – 1.9	0.6	4.2	1.6
4	0.0 – 7.9	3.3	0.0 – 2.6	0.9	5.3	2.4
5	0.0 – 1.6	0.7	0.0 – 0.3	0.1	1.3	0.6
Site	**CONCAWE Project-related Construction Increase L_n (dBA)**		**EIS Project-related Construction Increase L_n (dBA)**		**Noise Level Differences between CONCAWE and EIS Construction Increases L_n**	
	Range	**Avg.**	**Range**	**Avg.**	**Range**	**Avg.**
3	0.0 – 6.4	1.8	0.0 – 2.0	0.4	4.4	1.4
4	0.0 – 11.4	4.4	0.0 – 4.8	1.3	6.6	3.1
5	0.0 – 2.8	1.1	0.0 – 0.6	0.2	2.2	0.9

Site	CONCAWE Project-related Construction Increase L_{dn} (dBA)		EIS Project-related Construction Increase L_{dn} (dBA)		Noise Level Differences between CONCAWE and EIS Construction Increases L_{dn}	
	Range	Avg.	Range	Avg.	Range	Avg.
3	0.0 – 6.3	1.9	0.0 – 2.0	0.5	4.3	1.4
4	0.0 – 10.7	4.2	0.0 – 4.3	1.3	6.4	2.9
5	0.0 – 2.4	1.1	0.0 – 1.0	0.3	1.4	0.8

As shown in **Table IR7-01-6**, the CONCAWE based results show increases of up to 6.6 dBA (at site 4) relative to the noise levels in Table 9.3-18 of the EIS. The construction noise level ranges cover a five and a half-year period and the 'worst-case' sound propagation conditions (i.e., CONCAWE meteorological category 6) are forecast to occur for less than 20% of that time. Furthermore, these estimated maximum construction noise levels assume that the 'worst-case' sound propagation conditions would occur at the same time as maximum Project construction noise emissions. While there is no way to quantify this at this stage of construction planning, the variable nature of site activity is such that it is considered highly unlikely that such concurrence would happen 20% of the time.

Conclusions

Summary of Model Outputs

Recalculation of predicted noise levels using the CONCAWE method indicates that sound levels may increase by up to 5.7 dBA for the operation phase, and by up to 6.6 dBA for the construction phase, under 'worst-case' meteorological conditions, which are predicted to occur less than 20% of the time. The actual degree of sound level increases will depend on the level of site activity and the amount of ambient sound at those times when the category 6 meteorological condition occurs. The analysis presented herein applies worst-case meteorological conditions to annual average operation phase and construction phase noise levels, but actual levels will vary day-to-day and throughout the year.

Conservativism and Limitations

The predictions for sound levels, using the CONCAWE method, during the construction phase are considered highly conservative given that some noise emitting construction activities will be removed in the updated Project Description[4]. The predictions in the EIS are also considered conservative in this context.

Predictions for both the construction and operation phase are also considered conservative because the analysis for this response applied a more conservative attenuation factor than in typical CONCAWE applications. Uncertainty exists in the use of CONCAWE-based noise predictions, as the method suggests that hard surfaces, such as propagation over water or

[4] An updated Project Description will be prepared, as per the Panel's direction in letters of July 17, 2017 (CEAR Document #995) and October 3, 2017 (CEAR Document #1069).

concrete, use an arbitrary attenuation of -3 dBA (three dBA less attenuation than neutral conditions) for downwind conditions. However, the CONCAWE method does not account for partial attenuation over varying ground types. So the change in attenuation over water to land for the Project could not be evaluated using the CONCAWE method. To account for this, the calculations conducted for this CONCAWE-based exercise used the category 6 attenuation factor (or 100% downwind/sea breeze equivalent) for the entire source-to-receptor distance, which resulted in attenuation of up to -6 or -7 dBA (6 or 7 dBA less attenuation than neutral conditions) depending on distance and acoustic frequency. This is expected to result in higher sound levels than a strict application of the suggested CONCAWE factors for the applicable ground conditions.

Due to the limitations described above, using the CONCAWE method results in noise level predictions that are limited in accuracy and applicability to assessing Project-related effects from noise. The CONCAWE method has not been adopted by international standards organisations, such as CSA (Canadian Standard Organisation), ISO (International Organization for Standardization), or ANSI (American National Standards Institute). The limitations of the CONCAWE method with respect to modelling sound propagation over water, and therefore limitations in assessing Project-related effects from noise, are described in Section 2.3.3.4 of Appendix 9.3-A of the EIS.

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IR7-02 Atmospheric Noise – Transient Vessels

Information Source(s)

Marine Shipping Addendum: Section 7.4.5.1; Table 7.4-1; Figure 7.4-3; Figure 7.4-4

EIS Volume 2: Section 9.3.6.3; Table 9.3-4; Figure 9.3-4

Context

In Section 7.4.5.1 of the Marine Shipping Addendum, the Proponent stated that no data are available regarding the noise levels or frequency of container ship-related transient noise events such as from ship horns or other signals. The Proponent stated that if the rate of occurrence of transient noise events is assumed to increase in proportion to vessel movements, then such occurrences would also be expected to increase by 9 to 12%. The Proponent further indicated that the rates of occurrence of transient events are not expected to be perceptible. As described in Table 9.3-4 of the EIS, perceptibility is based on noise level increases; therefore, it is unclear how the Proponent determined whether transient events would be perceptible since there was no information provided regarding noise levels for such events.

In Section 9.3.6.3 of the EIS, the Proponent indicated that noise from ships in transit was excluded from the model because no data were available regarding their noise emissions. Some participants in the environmental assessment have expressed concern regarding the transient noise from container ships. However, the Proponent also stated that during the July noise measurement period, residents reported that one of the ships berthed at Deltaport Terminal caused higher-than-usual noise levels.

Information is required to predict the noise levels from transient noise events from container ships at receptor locations within the marine shipping area and the upland study area.

Information Request

Based on the existing Roberts Bank terminals, describe the frequency of occurrence of transient noise events from a container ship while transiting the marine shipping area and while at berth.

Provide information on the L_{max} of transient noise events from container ships, and describe the noise levels at various setback distances. Present the results in a figure similar to Figure 7.4-3 of the Marine Shipping Addendum.

Assuming neutral meteorological conditions, describe the L_{max} of transient noise events from a container ship at berth, and a container ship transiting the Marine Shipping Area at the following locations:

- sites in the upland study area as denoted by Figure 9.3-4 of the EIS; and

- on land within the local study area as described in Table 7.4-1 of the Marine Shipping Addendum.

Provide a figure similar to Figure 7.4-4 of the Marine Shipping Addendum that identifies the following contour lines along the shipping routes for Segments A and B:

- perceptibility of noise level increases due to transient noise events from a container ship; and
- outdoor noise level of 60 dBA Lmax.

VFPA Response

Based on the existing Roberts Bank terminals, describe the frequency of occurrence of transient noise events from a container ship while transiting the marine shipping area and while at berth.

Clarification

Transient noise events from container ships include the following:

- Ship pass-bys – Although engine noise from container ships is continuous while in transit, the noise may be received as transient at a stationary noise receptor, as the passing ship approaches, passes by, and recedes from the receptor;
- Ship horn soundings – short blasts of a ship's horn under certain navigational circumstances; and
- Ship anchor movements – metal-on-metal noise as the chain from the ship's anchor passes through an opening in the ship's hull while the anchor is being lowered or raised.

For the purposes of this response, ship pass-bys are the only relevant transient noise from container ships. The rationale for exclusion of ship horns and anchorage activities as part of this response is provided below.

The following rules from the document *Consolidation, Collision Regulations, C.R.C., c. 146*[1] provide regulations governing the circumstances under which marine vessels are required to sound their horns:

- *Rule 34 Manoeuvring and Warning Signals – International* describes situations under which a vessel would be required to sound its horn;
- *Rule 35 Sound Signals in Restricted Visibility – International* describes various types of horn sounding procedures for vessels when they are moving or at anchorage in or near an area of restricted visibility;
- *Rule 36 Signals to Attract Attention*; and
- *Rule 37 Distress Signals*.

[1] http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._1416/

As most ship-to-ship communication is done over VHF (very high frequency) radio at the discretion of the vessel master and as required by Canadian Coast Guard vessel traffic services requirements (under Radio Aids to Navigation), none of the circumstances described in these rules are expected to occur regularly or predictably as part of RBT2 Project operation (approaching or departing the berth), or marine shipping associated with the Project (ships in transit outside of VFPA jurisdiction). While certain situations may arise occasionally, such as restricted visibility (due to fog, mist, or falling snow), that will require container ships to sound their horns to avoid collisions when approaching or departing the berth, these activities are not considered to be part of normal berthing operations of RBT2 so were not included in the scope of assessment of effects of the Project, or in this response. Similarly, as described in Section 4.4.2.1 of the EIS, there are no plans or foreseen terminal operating requirements for off-terminal anchoring of container ships waiting for a berth at the new marine terminal. Additional information on anchorage is provided in the response to IR5-01 (CEAR Document #1078[2]), which clarifies that neither the construction phase nor the operation phase of RBT2 will require new anchorages.

Frequency of Occurrence of Transient Noise Events

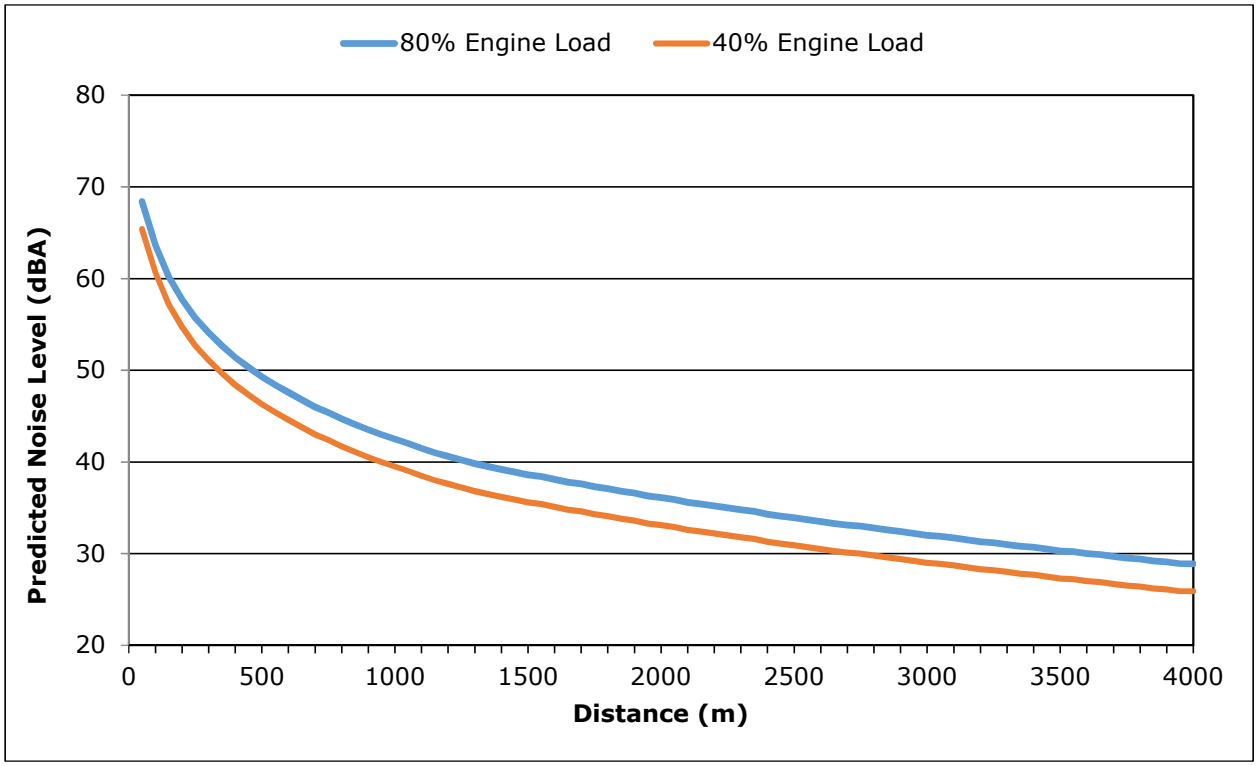
As described in Section 4.4.2.1 of the EIS, the RBT2 Project is estimated to receive 260 container ship calls per year when the terminal reaches its 2.4 million vessel TEU (twenty-foot equivalent) design capacity. This will result in 520 Project-associated container ship movements per year (one call equals two movements—one inbound and one outbound), or on average approximately three pass-bys, and associated noise, every two days at a given receptor point along the shipping route. As explained below, whether or not the noise from a vessel pass-by is perceptible at a receptor point depends on the setback distance from the noise source.

Provide information on the L_{max} of transient noise events from container ships, and describe the noise levels at various setback distances. Present the results in a figure similar to Figure 7.4-3 of the Marine Shipping Addendum.

Figure 7.4-3 of the Marine Shipping Addendum (reproduced as **Figure IR7-02-1** below for ease of reference) provides L_{max} levels for container ship pass-bys at various setback distances at 40% and 80% engine load. Given that no additional sources of transient noise were identified in response to this information request, no modifications to the figure were necessary.

[2] CEAR Document #1078 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR4-33, IR5-01, IR5-12, IR5-15, IR5-16, IR5-23, IR5-24, IR5-32, IR5-33, IR5-34, IR5-35, IR5-36, IR6-26, IR7-03, and IR7-05 (See Reference Documents #946, #975, #991, and #1000).

Figure IR7-02-1 Container Ship Maximum Pass-by Noise Levels at Various Setback Distances (Figure 7.4-3 of the Marine Shipping Addendum)



Assuming neutral meteorological conditions, describe the L_{max} of transient noise events from a container ship at berth, and a container ship transiting the Marine Shipping Area at the following locations: sites in the upland study area as denoted by Figure 9.3-4 of the EIS; and on land within the local study area as described in Table 7.4-1 of the Marine Shipping Addendum.

As discussed in the Section 7.3 of the Marine Shipping Addendum, container ship pass-bys are not expected to be audible beyond 4 km from the source. Consequently, under neutral meteorological conditions container ship pass-bys are not expected to be audible at sites 3, 4, and 5 as they are set back more than 5.5 km from the container ship arrival and departure routes, shown on Figure 4-1 of the Marine Shipping Addendum.

Provide a figure similar to Figure 7.4-4 of the Marine Shipping Addendum that identifies the following contour lines along the shipping routes for Segments A and B: perceptibility of noise level increases due to transient noise events from a container ship; and outdoor noise level of 60 dBA Lmax.

Figure 7.4-4 of the Marine Shipping Addendum provides sound level contour lines showing the setback distances at which container ship noise pass-bys in Segment B (where vessel engine load is assumed to be at 40%) are estimated to result in maximum ship noise levels of 35 and 45 dBA (A-weighted decibels). These sound contour lines correspond to estimated background noise levels for the daytime (7:00 a.m. to 10:00 p.m., 45 dBA) and nighttime (10:00 p.m. to 7:00 a.m., 35 dBA) in the local study area of the atmospheric noise effects

assessment (Section 7.4 of the Marine Shipping Addendum). As such, these contour lines provide estimates of the approximate setback distances at which maximum noise levels during container ship pass-bys would be perceptible (i.e., distinguishable from background noise).

Figure IR7-02-A1 in **Appendix IR7-02-A** updates EIS Figure 7.4-4 to provide a contour line corresponding to the setback distance at which the maximum noise levels during container ship pass-bys in Segments A and B, under 40% engine load, would reach 60 dBA. The setback distance is approximately 130 m from the source, and not anticipated to overlap with land, or areas with land-based receptors, at any point along the shipping routes in Segments A or B, as shown on Figure IR7-02-A1 in **Appendix IR7-02-A**. In Segments C, D, E, F, and G, land is further from the shipping lanes than in Segments A or B; therefore, the 60 dBA maximum noise level from ship pass-bys is also not anticipated to interact with land-based receptors in these areas.

Appendices

Appendix IR7-02-A Supporting Figure

APPENDIX IR7-02-A
SUPPORTING FIGURE

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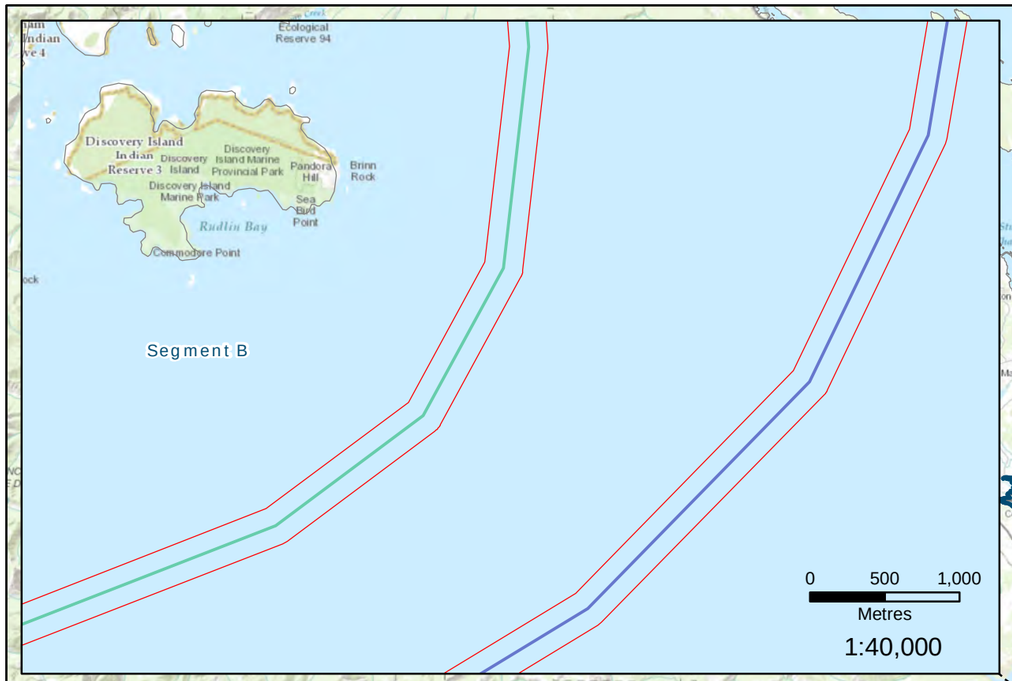

Segment A
Segment B
Segment C
Segment D
Segment E
Segment F
Segment G
Galiano Island
Mayne Island
North Pender Island
Saturna Island
South Pender Island
Moresby Island
Boundary Passage
Haro Strait
Rosario Strait
Middle Channel
Juan de Fuca Strait
Victoria
CANADA
UNITED STATES

Legend

- BOUNDARY OF PROJECT AREA
- MARINE SHIPPING AREA AND SEGMENTS
- VESSEL PASS-BY NOISE LEVEL - 60 DBA
- PILOT STATION
- RBT2 ASSOCIATED INBOUND SHIPPING ROUTE
- RBT2 ASSOCIATED OUTBOUND SHIPPING ROUTE
- U.S.A.-CANADA BORDER

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NAD 1983 UTM Zone 10N

N

PORT METRO vancouver

ROBERTS BANK TERMINAL 2

VESSEL PASS-BY NOISE LEVEL
OF 60 DBA IN MARINE SHIPPING
AREA SEGMENTS A AND B

DATE: 11/07/2017

FIG No. IR7-02-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.

IR7-03 Atmospheric Noise – Rail Traffic

Information Source(s)

EIS Volume 2: Appendix 9.3-A

CEAR Doc#651

Context

Appendix 9.3-A of the EIS stated that no results are presented for locomotive pass-bys or train movements at site 4 or 5 as these transient noise events were not at measurable levels at these sites. However, in its submission to the Review Panel (CEAR Doc#651), Tsawwassen First Nation reported that its members experience transient train noise in the community. Further information is required to determine whether the transient noise produced by locomotive pass-bys and train movements can be detected at sites 4 or 5.

Information Request

Provide supporting evidence that the transient noise produced by locomotive pass-bys and train movements is not measurable at sites 4 and 5 in the upland study area.

VFPA Response

Transient and impulsive noise events due to rail activity in the local study area include locomotive pass-bys, wheel-rail interactions, and train shunting. Impulsive noise levels, including from train shunting, are presented for site 4 in Table 3-4 of Appendix 9.3-A of the EIS. Other transient rail events, including locomotive pass-bys and wheel rail interactions, may be distinguishable from other existing sounds on Tsawwassen First Nation Lands. However, analysis of the measured data at sites 4 and 5 indicates the noise levels created by these events are not clearly identifiable relative to ambient noise levels.

Influence of Setback Distance on the Characteristics of Train Pass-by Events

The closest residences on Tsawwassen First Nation Lands to the Roberts Bank Rail Corridor (RBRC) are located on Falcon Way and are set back approximately 1,400 m from the RBRC. The closest residence to the RBRC that is not on Tsawwassen First Nation Lands is located at site 3 (3044 41 B St.). This residence is set back approximately 240 m from the RBRC. Train pass-by noise levels at site 3 were documented in Appendix 9.3-A of the EIS.

Figure IR7-03-1 shows a time history at site 3 of the noise levels created by a typical train pass-by event. The noise level data were collected during the August 2013 baseline noise monitoring and include the passage of a locomotive and attached cars.

Figure IR7-03-1 Noise Level Time History of a Train Pass-by Event

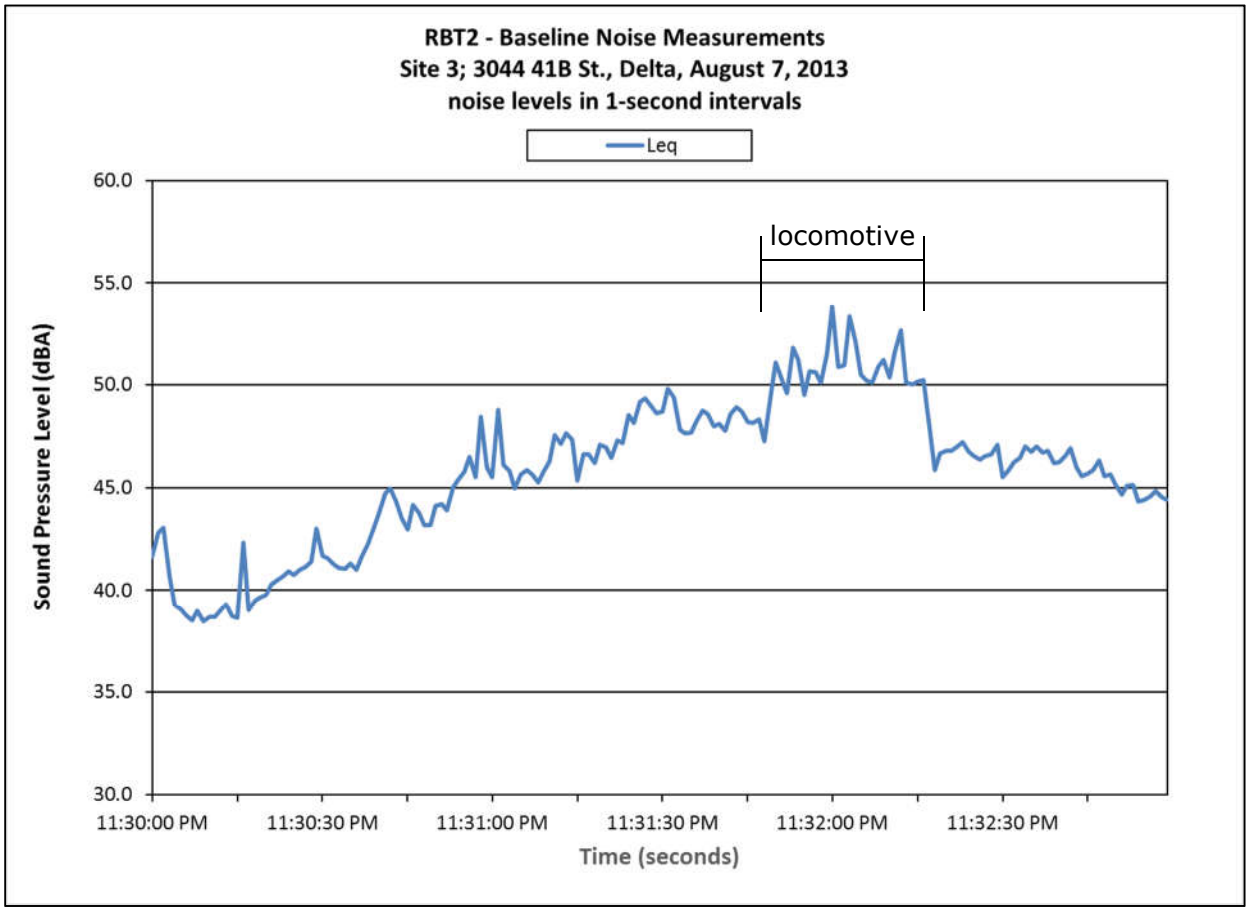


Figure IR7-03-1 shows that during a train pass-by, the noise level steadily increases until it reaches a maximum level when the locomotive passes by the microphone. Afterwards, the noise level decreases. The degree to which a train pass-by event is measurable relative to ambient noise levels depends on both the magnitude of the noise level increase and the rate at which the increase occurs. Both the magnitude of the noise level increase, and the rate at which it occurs, are functions of the setback distance of the measurement position from the train. At greater setback distances, both the magnitude of the noise level increase, and the rate at which it occurs, would diminish.

Figure IR7-03-2 illustrates the relationship between setback distance and pass-by events. This figure was generated using an idealised scenario within the Cadna software. In this scenario, pass-by sound levels were calculated at setback distances of 240 m (representing site 3) and 1,400 m (representing Falcon Way residences) from the RBRC. Noise levels were then calculated at a sampling rate of $1/10^{th}$ of a second as a locomotive travelled by at 50 km/hour.

Figure IR7-03-2 Train Pass-by at 240 m and 1,400 m Setbacks

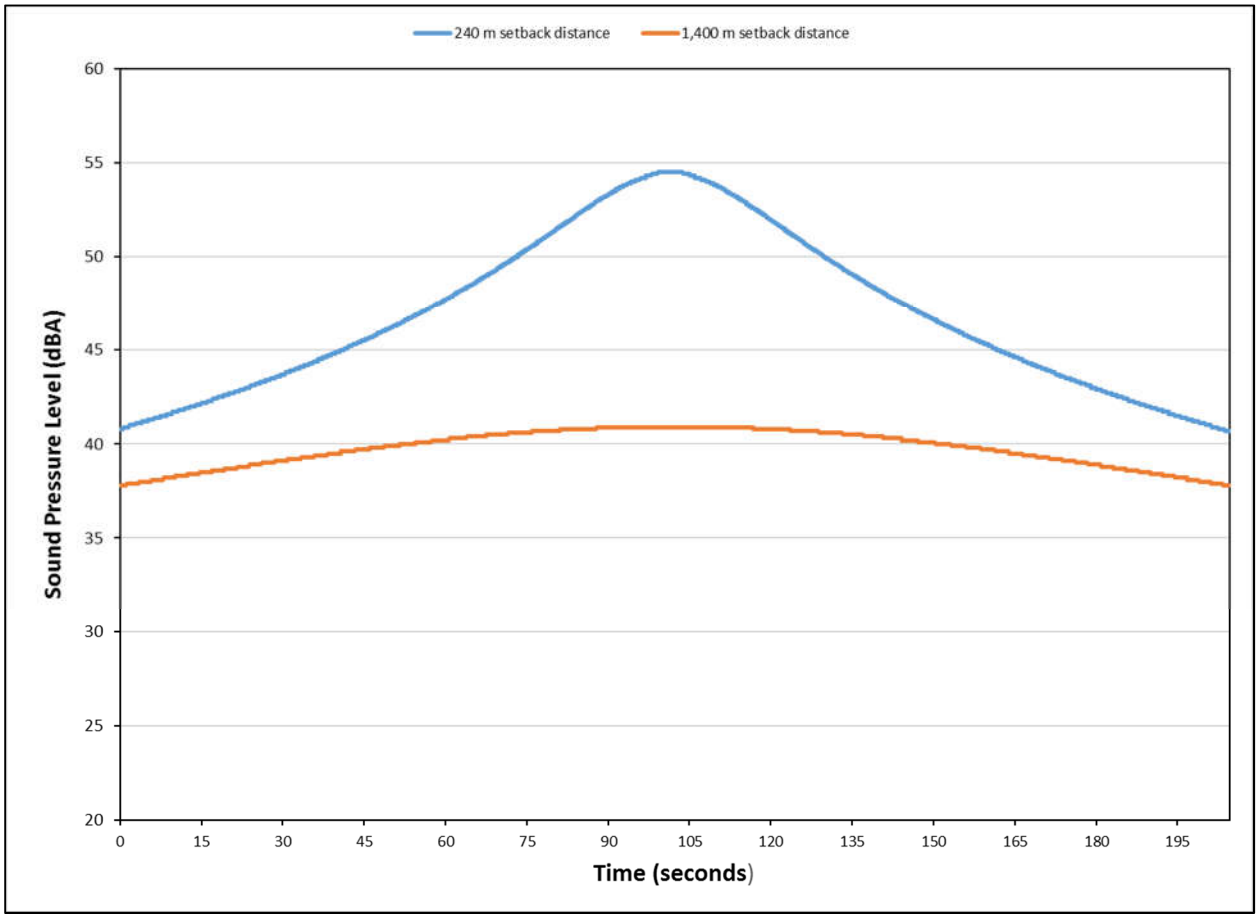


Figure IR7-03-2 shows that a train pass-by would be much more distinguishable as an isolated event at a setback distance of 240 m than it would be at a setback distance of 1,400 m.

The ambient noise environment on Tsawwassen First Nation Lands includes noise from the natural environment, local development, idling locomotives on the RBRC, locomotives and traffic on the causeway, plus general low-frequency noise emissions from the Roberts Bank terminals, and B.C. Ferries. These sources produce a quasi-continuous background noise level, with similar frequency characteristics to that of locomotive noise, which would add to the difficulty of measuring the gradual rise and fall of noise levels during a locomotive pass-by on Tsawwassen First Nation Lands. As such, the approach used in the effects assessment to consider locomotive noise on Tsawwassen First Nation in the context of continuous, low-frequency noise, is considered appropriate.

The residence at site 5 is set back approximately 3,400 m from the RBRC. At this relatively large setback distance, locomotive pass-by events would be even less distinguishable as measurable isolated events.

Influence of Setback Distance on Maximum Locomotive Noise Levels

Table 3-5 of the Noise and Vibration Technical Report (EIS Appendix 9.3-A) presents the maximum noise levels (L_{max}) of 18 locomotive pass-bys as measured at site 3 (3044 41 B St.) in 2013. The locomotive pass-by L_{max} ranged from 46.2 to 62.2 dBA (A-weighted decibels) with an average value of 55.3 dBA. The greater setback distance of site 4 (Falcon Way residences) from the RBRC would be expected to result in an approximate 15.3 dBA[1] reduction in locomotive L_{max} relative to the L_{max} measured at site 3. Locomotive L_{max} at the closest residences on Tsawwassen First Nation Lands are then estimated to range from 30.9 to 46.9 dBA with an average value of 40.0 dBA. At the setback distance of site 5, the noise level from a locomotive pass-by event would be expected to range from 23 to 39 dBA.

Figure IR7-03-3 and **Figure IR7-03-4** compare the estimated range of locomotive L_{max} on Tsawwassen First Nation Lands to noise history charts at site 4. These noise history charts are from the baseline noise monitoring that was conducted for two 24-hour periods from July 22 to 23, 2013 and July 23 to 24, 2013 (EIS Appendix 9.3-A). The charts show the variation in ambient L_{max}, equivalent sound level (L_{eq}), and ninety percent exceedance level (L_{90}) in 15-minute intervals over the 24-hour monitoring periods.

[1] This reduction was conservatively estimated by assuming that geometric divergence (i.e., spherical spreading) would be the only attenuating factor during sound propagation. The attenuation is calculated according to the formula $20*\log(d_1/d_2)$ (ISO 1996) where d_1 is the setback distance of site 3 and d_2 is the setback distance of site 4.

Figure IR7-03-3 Estimated Range of Locomotive L_{max} compared to Site 4 Noise History Chart for July 22-23, 2013

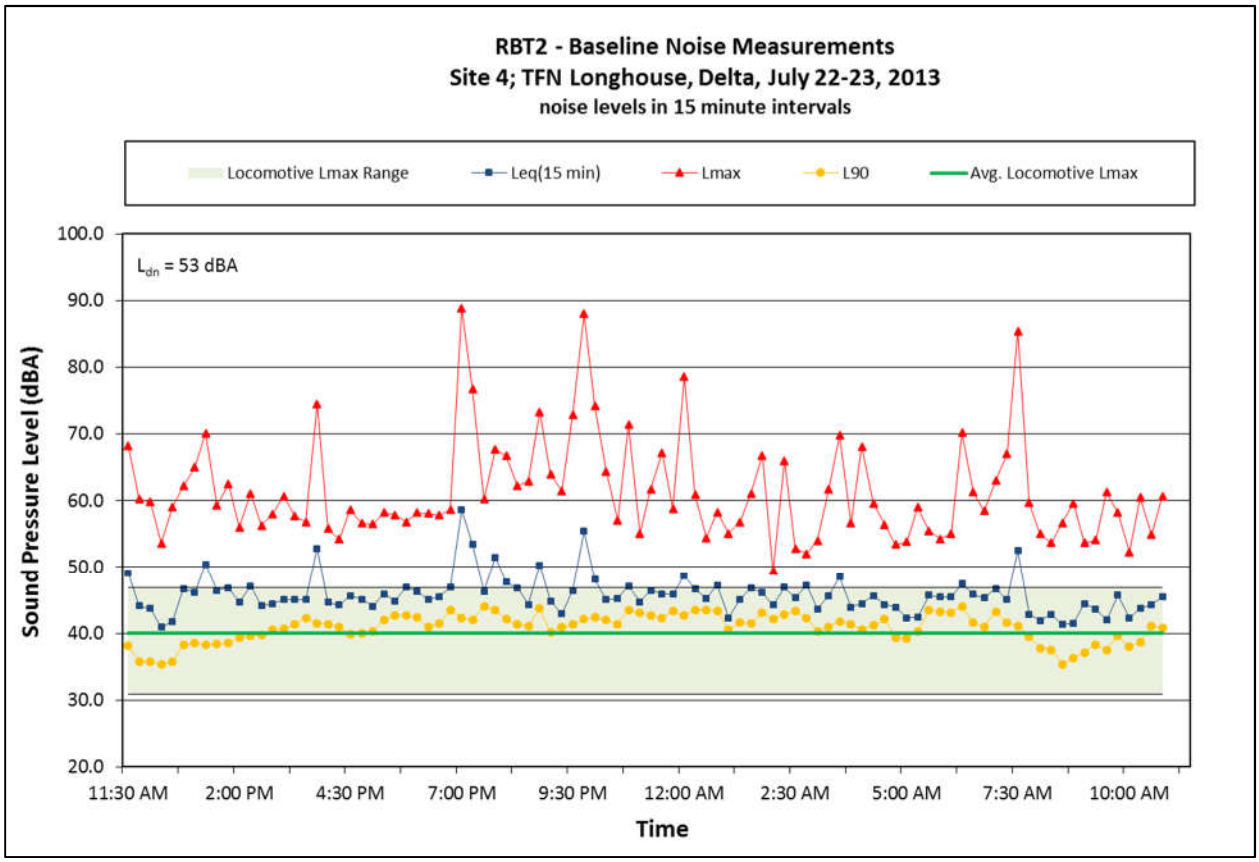
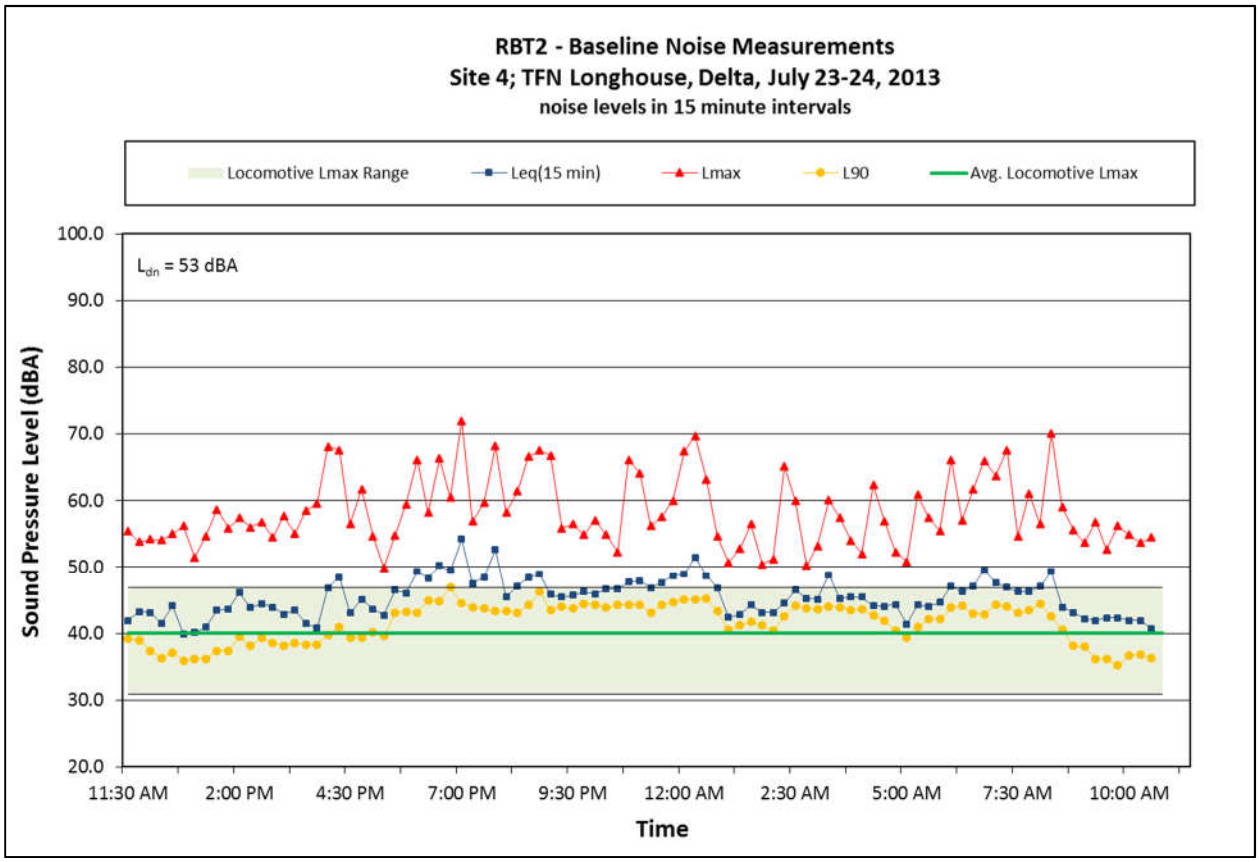


Figure IR7-03-4 Estimated Range of Locomotive L_{max} compared to Site 4 Noise History Chart for July 22-23, 2013



Figures IR7-03-3 and **IR7-03-4** show that the locomotive pass-by L_{max} levels were lower than the ambient L_{max} and that the majority of the locomotive L_{max} events were lower than the 15-minute L_{eq} at site 4. Furthermore, on average, locomotive pass-by L_{max} were often lower than the ninety-percent exceedance level. As such, while certain locomotive pass-bys may have been measurable relative to the ambient noise environment, the majority of the locomotive pass-bys would not have been. This creates an environment where train sounds may be distinguishable from other local sounds at specific moments, but the measurements themselves cannot be used to define the locomotives as the source of that sound.

While not presented in this response, the noise history charts for site 5 are provided in Appendix B of EIS Appendix 9.3-A. The estimated range of locomotive pass-by noise levels (23 to 39 dBA) are well below the L_{eq} provided in the Appendix B charts. As such, locomotive pass-by events would not be expected to create measurable noise levels at site 5. Additionally, the ambient L_{max} levels at sites 4 and 5, which were largely due to other sources of community noise, would have further contributed to making locomotive L_{max} inseparable from the measurements. While this analysis focuses on locomotive noise, measured train pass-by noise also includes noise from wheel-rail interactions. As the noise levels created by these interactions were lower in level than locomotive noise (**Figure IR7-03-3**), they would also not have tended to be measurable.

In conclusion, this analysis demonstrates that the noise levels created by locomotive pass-by events at sites 4 and 5 are not measurable relative to ambient noise levels.

References

International Standards Organization (ISO). 1996. ISO Standard 9613-2:1996 Acoustics -- Attenuation of sound during propagation outdoors, Part 2 – General method of calculation.

IR7-04 Atmospheric Noise – Baseline Low-Frequency

Information Source(s)

EIS Volume 2: Section 9.3.6.3, Table 9.3-10

Context

In Section 9.3.6.3 of the EIS, the Proponent stated that frequency spectra were measured in one-third octave bands at sites 5, 6, and 7 to investigate the degree to which low-frequency noise from the existing terminals and causeway was present. The Proponent also indicated that low-frequency noise levels at site 4 on Tsawwassen First Nation lands were estimated through comparison with noise levels measured at the other sites. The Proponent stated that although the noise survey that was carried out as part of the proposed Project reported fewer people were disturbed by low-frequency noise on Tsawwassen First Nation lands than in Ladner, there is more potential for the Project to influence low-frequency noise levels on Tsawwassen First Nation lands due to its proximity to the causeway and the proposed marine terminal. Measured baseline information for low-frequency at site 4 is required.

Information Request

Provide measurements of low-frequency noise at site 4 on Tsawwassen First Nation lands and provide a discussion on and comparison with the estimated baseline low-frequency noise levels at site 4.

Update Table 9.3-10 of the EIS to reflect the measured noise levels at site 4.

VFPA Response

Provide Measurements of Low-frequency Noise at Site 4 on Tsawwassen First Nation Lands

This response provides the results of low-frequency noise measurements conducted on Tsawwassen First Nation Lands.

Measurement Methodology

The low-frequency noise measurement instrumentation and parameters were consistent with applicable guidance as referenced in EIS Appendix 9.3-A. The low-frequency noise data was collected over two 24-hour periods (7:00 a.m. to 7:00 a.m.) on October 25-26 and October 28-29, 2017 by a VFPA permanent noise monitoring station located at the Tsawwassen First Nation Administration building (site 4A). This location is expected to have a very similar noise environment to that of site 4 (The Tsawwassen First Nation Longhouse), especially in terms of noise received from the Deltaport Terminal and vehicle traffic on Tsawwassen Drive North. Both sites are located on the western shoreline of Tsawwassen First Nation Lands and are approximately 3.8 km northeast of the Roberts Bank terminals.

During the entire October 25-26 measurement period, there were two vessels at berth at Deltaport Terminal (*UMM SALAL v .03* and *San Francisco Bridge v .29*). During the October 28-29 measurement period, there were from one to three vessels at berth. For the first hour only, there were three vessels at berth. For the majority of the period (17 hours) there were two vessels at berth, and for the remaining six hours there was just one vessel at berth. The vessel names and times at berth during the October 28-29 measurement period are shown below:

- The *ZIM Colombo v .51* was at berth October 28, 7:00 a.m. to 8:00 a.m.;
- The *UMM SALAL v .03* was at berth October 28, 7:00 a.m. to midnight, and October 29, midnight to 1:00 a.m.; and
- The *NYK APOLLO v .91* was at berth for the entire monitoring period.

The specific monitoring periods were selected based on predicted meteorological conditions and vessel call schedules. As per applicable guidance for noise measurement, the monitoring periods were scheduled to ensure the meteorological conditions were appropriate for noise measurement (i.e., no active precipitation, calm winds, and temperatures within operating specifications of noise meters). The monitoring was also scheduled to correspond with the presence of vessels that generate higher levels of noise. In the EIS, monitoring took place while a ship historically associated with noise complaints was at berth. As this ship no longer calls at Deltaport, the 2017 monitoring was scheduled while at least one larger vessel was at berth.

In addition to noise measurements, field observations were conducted for ten hours, in three segments (9:00 a.m. to 12:00 p.m., 1:00 p.m. to 3:00 p.m., and 11:00 p.m. to 4:00 a.m.) for each of the 24-hour measurement periods. The field observations were conducted to observe the composition of the noise environment to support identification of low-frequency noise sources.

During the daytime, the primary sources of low-frequency noise were observed to be activities at the Deltaport Terminal and locomotives on the Roberts Bank causeway. The field engineer also noted that a heat pump that serves the administrative building was operating. Additionally, there was construction activity taking place to the east of site 4A on parcels of land adjacent to Blue Heron Road. A review of the corresponding measurement data did not provide sufficient evidence to conclusively determine if noise from either the heat pump or construction activity were influencing low-frequency noise levels.

During the nighttime, the primary sources of low-frequency noise were observed to be activities at the Deltaport Terminal and locomotives on the Roberts Bank causeway.

Low-frequency Noise Measurement Results

Table IR7-04-1 provides the results of the low-frequency noise measurements for the October 25-26 and October 28-29 daytime measurement periods (7:00 a.m. to 10:00 p.m.). Low-frequency noise levels are presented in terms of C-weighted noise levels, and the differences between A- and C-weighted noise levels. Both locations are shown on Figure IR7-04-A1 in **Appendix IR7-04-A**. Also presented are the percentages of the

measurement period during which 1, 2, or 3 vessels were present at berth. Corresponding results for the two nighttime monitoring periods[1] (midnight to 5:00 a.m.) are provided in **Table IR7-04-2**.

Table IR7-04-1 Low-frequency Noise Measurement Results at Site 4A – Daytime

Monitoring Period	Numbers of Vessels at Berth	A-weighted Noise Level (dBA)	C-weighted Noise Level (dBC)	Difference (dBC minus dBA)
October 25-26	2	47.5	66.6	19.1
October 28-29	2-3[a]	47.2	66.2	19.0
Average	2	47.4	66.4	19.0

Note: a. Two vessels for 93% of the daytime monitoring period and three vessels for 7% of the daytime monitoring period.

The low-frequency noise levels measured for the two daytime monitoring periods are quite similar, differing only by only 0.4 dBC (**Table IR7-04-1**).

Table IR7-04-2 Low-frequency Noise Measurement Results at Site 4A – Nighttime

Monitoring Period	Numbers of Vessels at Berth	A-weighted Noise Level (dBA)	C-weighted Noise Level (dBC)	Difference (dBC minus dBA)
October 25-26	2	43.5	65.8	22.3
October 28-29	1-2[a]	41.9	61.9	20.1
Average	1	42.6	63.9	21.2

Note: a. One vessel for 80% of the nighttime monitoring period and two vessels for 20% of the nighttime monitoring period.

The low-frequency noise levels measured for the October 25-26 nighttime monitoring period were 3.9 dBC higher than the low-frequency noise levels measured for the October 28-29 nighttime monitoring period. This result is attributable to there being two vessels at berth for the entire October 25-26 nighttime monitoring period whereas there were two vessels at berth for 20% of the October 28-29 nighttime monitoring period.

Comparison of Measured and Estimated Low-frequency Noise Levels on Tsawwassen First Nation Lands

Table IR7-04-3 presents an updated version of Table 9.3-10 in the EIS (EIS Section 9.3.7.1) that includes the average nighttime (midnight to 5:00 a.m.) low-frequency noise levels measured at site 4A on Tsawwassen First Nation Lands. This table provides estimated low-

[1] While the nighttime period in noise assessments is typically considered to be 10:00 p.m. to 7:00 a.m., the EIS used a nighttime period of midnight to 5:00 a.m. to characterise low-frequency noise levels due to activity at the existing Roberts Bank terminals and on the Roberts Bank causeway. This was the time period during which these sources were expected to be most dominant in terms of overall low-frequency noise levels on Tsawwassen First Nation Lands.

frequency noise levels at site 4 and measured low-frequency noise levels at sites 4A, 5, 6, and 7. Low-frequency noise levels are represented in terms of C-weighted noise levels, and the differences between A- and C-weighted noise levels.

Table IR7-04-3 Average Nighttime Low-frequency Noise Levels at Sites 4A, 4, 5, 6, and 7

Site	A-weighted Noise Level (dBA)		C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
4A	42.6	-[a]	63.9	-[a]	21.2	-[a]
4[b]	40.0	-[a]	57.9	-[a]	17.9	-[a]
5	43.4	35.8	61.3	51.8	17.9	16.0
6	32.5	25.9	49.9	38.5	17.4	12.6
7	42.4	26.9	61.7	49.4	19.3	22.5

Notes: a. No indoor noise level data was available.
b. Outdoor levels at site 4 were estimated from levels measured at site 5. Indoor noise levels were not estimated since differences between indoor and outdoor levels are unique to each residence.

The average C-weighted noise level measured at site 4A (**Table IR7-04-3**) is 6.0 dBC higher than the estimated noise level at site 4 presented in Table 9.3-10 of the EIS. Similarly, the difference between the C- and A-weighted noise levels measured at site 4A (**Table IR7-04-1**) is 3.3 dB higher than the estimated difference at site 4 presented in EIS Table 9.3-10.

Appendices

Appendix IR7-04-A Figure IR7-04-A1 Noise Measurement Sites on Tsawwassen First Nation Lands

APPENDIX IR7-04-A

FIGURE IR7-04-A1 NOISE MEASUREMENT SITES ON TSAWWASSEN FIRST NATION LANDS

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Roberts Bank

Tsawwassen First Nation

Site 4

Site 4A

Tsawwassen

Point Roberts (U.S.A.)

CANADA

U.S.A.

Tsawwassen First Nation Longhouse

Site 4

Tsawwassen Drive North

Tsawwassen First Nation Administration Building

Site 4A

Legend

- NOISE MEASUREMENT SITE
- BOUNDARY OF PROJECT AREA
- CANADA-U.S.A. BORDER

0 1 2

Kilometres

1:50,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

NOISE MEASUREMENT SITES ON TSAWWASSEN FIRST NATION LANDS

DATE: 02/02/2018

FIG No. IR7-04-A1

Basemap 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; Imagery Source: BING Maps Aerial

IR7-05 Atmospheric Noise - Variations in Low Frequency

Information Source(s)

EIS Volume 2: Appendix 9.3-A; Section 2.3.1.4; Table 3-8

CEAR Doc#579

Context

In Section 2.3.1.4 of Appendix 9.3-A, the Proponent presented the methodology used in the collection and assessment of low-frequency noise. The Proponent indicated that while the measurements were conducted over periods of either 24 or 48 hours, only the data from midnight to 5:00 am were analyzed. The rationale provided by the Proponent was that nighttime data were considered to be representative of low-frequency noise related to the Roberts Bank terminals because port-related noise is more prominent - and therefore more identifiable - during these hours.

As indicated by Health Canada in its submission to the Review Panel (CEAR Doc#579), this suggests that daytime low-frequency noise levels may be higher than estimated by the Proponent if other sources are present that produce low-frequency noise. A full characterization of low-frequency noise baseline conditions at sites 5, 6, and 7 in the upland study area, both at night and during the day, is required to fully assess the potential effects of the proposed Project and to validate the assumption that low-frequency noise from the existing terminals is more prominent at night than during the day.

Information Request

Provide a comparison of low-frequency noise during the day and night at sites 5, 6, and 7 in the upland study area, and discuss any differences observed.

Present the results of the daytime low-frequency noise in a table similar to that of Table 3-8 of Appendix 9.3-A of the EIS.

Confirm whether low-frequency noise in the upland study area originating from the existing Roberts Bank terminals is more prominent at night than during the day.

VFPA Response

Provide a comparison of low-frequency noise during the day and night at sites 5, 6, and 7 in the upland study area, and discuss any differences observed. Present the results of the daytime low-frequency noise in a table similar to that of Table 3-8 of Appendix 9.3-A of the EIS.

A comparison of low frequency noise (LFN) levels measured during the daytime (7:00 a.m. to 10:00 p.m.) and nighttime (midnight to 5:00 a.m.) is provided in **Table IR7-05-1** (outdoors) and **Table IR7-05-2** (indoors). The nighttime LFN levels shown in these tables correspond

to those provided in Table 3-8 of the Noise and Vibration Technical Report (EIS Appendix 9.3-A). The daytime LFN levels were extracted from the original datasets reported in EIS Appendix 9.3-A, collected July 22 to 24, 2013.

LFN levels are presented as C-weighted noise levels. The degree of influence LFN levels have on overall noise levels are presented as the difference between A- and C-weighted noise levels. The C-weighted noise levels provide the magnitude of LFN levels while the difference between A- and C-weighted noise levels provide an indication of the distinguishability of LFN levels relative to mid- and high-frequency noise levels.

Table IR7-05-1 Outdoor Low Frequency Noise Levels, Daytime versus Nighttime

Site	Outdoor A-weighted Noise Level (dBA)		Outdoor C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
5	46.3	43.4	60.5	61.3	14.2	17.9
6	38.1	32.5	49.8	49.9	11.7	17.4
7	43.0	42.4	62.6	61.7	19.6	19.3

Table IR7-05-2 Indoor Low Frequency Noise Levels, Daytime versus Nighttime

Site	Indoor A-weighted Noise Level (dBA)		Indoor C-weighted Noise Level (dBC)		Difference (dBC minus dBA)	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
5	38.8	35.8	52.1	51.8	13.3	16.0
6	32.0	25.9	41.4	38.5	9.4	12.6
7	33.2	26.9	54.4	49.4	21.2	22.5

Confirm whether low-frequency noise in the upland study area originating from the existing Roberts Bank terminals is more prominent at night than during the day.

From **Table IR7-05-1**, it can be seen that there is less than 1.0 dBC difference between outdoor daytime and nighttime C-weighted noise levels at sites 5, 6, and 7. The data also show that the dBC-dBA difference is greater at night at these sites, supporting the assumption that LFN is more prominent at night. While LFN levels are somewhat higher during the daytime, LFN is more distinguishable, relative to mid- and high-frequency noise, during the nighttime. At site 7, the difference of 0.3 decibels (dB) between the daytime and nighttime dBC-dBA value, is considered negligible as it is within the ±1 dBA accuracy of the sound level meters.

According to the data shown in **Table IR7-05-2**, measured indoor C-weighted levels were up to 5 dB higher during the day; however, this result is expected to be influenced by activities taking place within the residences during the daytime. There is more uncertainty with indoor

measured levels due to the lack of control for activities in proximity to the microphone so no trends can be inferred from the result.

IR7-06 Atmospheric Noise – Low Frequency

Information Source(s)

EIS Volume 5: Section 32.2.4.7; Section 32.3.2.2

CEAR Doc#733

Context

As stated by the Proponent in Section 32.2.4.7 of the EIS, Lyackson First Nation indicated that it has experienced an irregular low-frequency noise and associated vibration while using areas at Le'eyqsun (Valdes Island), and believes the source of the noise and vibration is from the screws of large vessel traffic. In its submission to the Review Panel (CEAR Doc#733), Lyackson First Nation reiterated concerns about noise.

An update is required of the ongoing discussion between Lyackson First Nation and the Proponent regarding the source of the noise referred to in Section 32.2.4.7 of the EIS.

Information Request

Provide an update of the ongoing discussion with Lyackson First Nation regarding the source of the noise referred to in Section 32.2.4.7 of the EIS.

VFPA Response

Valdes Island is outside the VFPA's navigational jurisdiction and outside the marine shipping area as defined in the Marine Shipping Addendum (Figure 1-1 of the Marine Shipping Addendum). Valdes Island is approximately 30 km from the RBT2 Project area, and approximately 20 km from the nearest international shipping lane. While large ships may travel in proximity to Valdes Island, noise from current and future container traffic bound for Roberts Bank is not anticipated to be detectable at Valdes Island. Atmospheric noise from container ships is not expected to be audible at distances greater than 4 km (as described in Marine Shipping Addendum Section 7.4.5.1). Underwater sound levels from container ships 30 km from the terminal would be the same as sound levels from existing traffic conditions in the Strait of Georgia (as shown in Figure A-52 in Appendix 9.8-A of the EIS).

These results were discussed with Lyackson First Nation during two workshops on assessment results in 2014 (October 28, 2014, Preliminary EIS Results Workshop #3; December 10, 2014, Health & Aboriginal Rights Workshop), and in subsequent meetings regarding the EIS and Marine Shipping Addendum. When Lyackson raised the concern again in 2017, the VFPA held another meeting with Lyackson (on May 3, 2017) where further discussion regarding underwater noise and vibration occurred between Lyackson and technical specialists.

Through submission of the Marine Shipping Addendum, the VFPA has communicated with Transport Canada, Health Canada, DFO, and the Canadian Environmental Assessment Agency that Lyackson has a number of outstanding concerns related to marine shipping activities outside the VFPA's navigational jurisdiction. The VFPA participated along with these agencies in a meeting to provide Lyackson an opportunity to further discuss these concerns (October 4, 2017). The VFPA has provided Lyackson with information about how to report noise incidents to the VFPA's 24-hour community complaint line, should this assist in identifying a particular vessel entering the VFPA's jurisdiction that may be generating noise along the international shipping lanes. In the case of vessels with excessive noise within the VFPA's jurisdiction, the VFPA works with terminal operators and vessel operators to reduce noise while at berth, and to address concerns regarding vessel safety and condition while travelling through the VFPA's navigational waters.

The VFPA will continue to support efforts led by Transport Canada and others to better understand the current effects of vessels along the marine shipping route, and to determine the most likely cause of the noise experienced by Lyackson, and potential steps to address it.

IR7-07 Atmospheric Noise – Measurement of Traffic Volumes

Information Source(s)

EIS Volume 2: Appendix 9.3-A; Section 2.3.3.3, Section 4.1

Context

In Section 2.3.3.3 of Appendix 9.3-A of the EIS, the Proponent indicated that when sufficiently detailed data were not available regarding the annual average daily traffic volumes and 24-hour truck percentages for use in determining road traffic noise, that the Good Practice Guide for Strategic Noise Mapping was followed. As per this guide, the Proponent made the following assumptions regarding traffic:

- a split of 90% daytime and 10% nighttime traffic volume for 41B Street and Tsawwassen Drive North;
- application of the same values for day and night for heavy vehicle traffic for 41B Street; and
- heavy trucks account for 5% of the total volume during the day and 1% during the night at Tsawwassen Drive North.

In Section 4.1 of Appendix 9.3-A of the EIS, the Proponent stated that ground-borne vibration measurements at sites 1 to 3 showed that ambient levels were dominated by local road and rail traffic. Furthermore, the Proponent reported that heavy truck traffic was responsible for the highest vibration levels at sites 1 and 2. Additional information is required to ensure that the assumptions that were made by the Proponent and used in the modelling of noise with respect to traffic volume and heavy trucks reflect actual volumes.

Information Request

Measure actual traffic volumes on 41B Street and Tsawwassen Drive North in order to validate each assumption used in the noise model regarding traffic noise.

Where traffic volumes are found to differ by ±10% from the assumed value, discuss how this would influence the predicted noise levels (L_d, L_n, and L_{dn}) at sites located within the upland study area.

VFPA Response

Measure actual traffic volumes on 41B Street and Tsawwassen Drive North in order to validate each assumption used in the noise model regarding traffic noise.

To validate, for this response, the traffic volume assumptions used in the noise model, traffic data on 41B Street and Tsawwassen Drive North was collected in October 2017 (Stantec 2017). The traffic data considered in this response include the percentages of the total traffic volume during the daytime and nighttime (day/night traffic volume split) and percentages of heavy vehicles (%HV) in the traffic mix for the daytime (7 a.m. to 10 p.m.) and nighttime

(10 p.m. to 7 a.m.). As context for the data and analysis that follow, note that the %HV classification is considered to include semi-trailer trucks and other large vehicles with diesel engines. Vehicles such as light goods trucks and shuttle buses are not included in the %HV classification as their noise emissions are lower than those of larger diesel engine vehicles (FHWA 1998). These classifications are consistent with approach taken in the noise and vibration assessment (EIS Appendix 9.3-A).

Assumption #1: A split of 90% daytime and 10% nighttime traffic volume for 41B Street and Tsawwassen Drive North

Table IR7-07-1 presents the percentages of the total traffic volume during the daytime and nighttime based on traffic volumes measured in 2017, and compares them to the estimated values used in the noise model for the EIS.

Table IR7-07-1 Measured and Estimated Day/Night Traffic Volume Splits

Route	Day/Night Traffic Volume Split	
	Measured (2017)	Estimated (EIS)
Tsawwassen Drive North	91%/9%	90%/10%
41B St. – South of Deltaport Way and 27B Ave.	93%/7%	90%/10%
41B St. – South of Deltaport Way	91%/9%	90%/10%
41B St. – North of Deltaport Way	93%/7%	90%/10%

Table IR7-07-1 shows that the measured day/night traffic volume splits differ by increments[1] of 1% to 3% relative to the estimated values presented in the EIS. Given that the difference between the measured and estimated percentages is less than 10%, further discussion is not required.

Assumption #2: Application of the same values for day and night for heavy vehicle traffic for 41B Street

Table IR7-07-2 presents the differences between the daytime and nighttime %HV that were measured on 41B Street in 2017. These measured differences are compared to the assumption used in the assessment that the daytime and nighttime %HV were equivalent.

[1] For this response, the request to discuss "where traffic volumes are found to differ by ±10% from the assumed value" has been interpreted to mean an incremental change of 10% in traffic volumes for the unit of discussion (i.e., day vs. night, or %HV).

Table IR7-07-2 Comparison of Daytime and Nighttime Percentages of Heavy Vehicles (Measured and Estimated) for 41B Street

Route	Measured (2017)			Estimated (EIS)*		
	%HV Day	%HV Night	%HV Day vs. Night Variance	%HV Day	%HV Night	%HV Day vs. Night Variance
41B St. – South of Deltaport Way & 27B Ave.	2%	1%	1%	31%	31%	0%
41B St. – South of Deltaport Way	19%	10%	9%	31%	31%	0%
41B St. – North of Deltaport Way	11%	11%	0%	4%	4%	0%

* Estimates based on a.m. and p.m. peak hour traffic counts (CTS 2007).

Table IR7-07-02 shows the %HV for the daytime was measured to be from 0% to 9% greater than the %HV for the nighttime. As these day/night variances are all lower than 10% compared to the EIS assumption of 0% variance between day and nighttime volumes, further discussion is not required regarding this assumption.

However, the total values for daytime and nighttime %HV do vary by greater than 10% between the 2017 measured volumes and the EIS estimated values, in certain cases. Specifically, on the segments of 41B Street that are south of Deltaport Way, and south of 27B Avenue, the %HV that were measured in 2017 differ by increments of 12% to 30% relative to the values that were used in the EIS. Therefore, the influence of these differences in %HV on modelled noise levels at sites 3, 4, and 5 are considered in the second part of this response.

Assumption #3: Heavy trucks account for 5% of the total volume during the day and 1% during the night at Tsawwassen Drive North

Table IR7-07-3 presents the %HV for the daytime and nighttime on Tsawwassen Drive North that were measured in 2017, and compares them to the estimated values used in the noise model for the EIS.

Table IR7-07-3 Comparison of Daytime and Nighttime Percentages of Heavy Vehicles (Measured and Estimated) for Tsawwassen Drive North

Route	Measured (2017)		Estimated (EIS)	
	%HV Day	%HV Night	%HV Day	%HV Night
Tsawwassen Drive North	0%	0%	5%	1%

As indicated in **Table IR7-07-3**, the measured %HV for day and night on Tsawwassen Drive North were both 0%[2]. Therefore, the assumed %HV in the EIS of 5% for the day and 1% for the night vary from the 2017 measured values by 5% and 1% respectively. Given that the differences between the measured and estimated %HV on Tsawwassen Drive North are less than 10%, further discussion is not required.

Where traffic volumes are found to differ by ±10% from the assumed value, discuss how this would influence the predicted noise levels (L_d, L_n, and L_{dn}) at sites located within the upland study area.

41B Street

On the segments of 41B Street that are south of Deltaport Way and south of 27B Avenue, the %HV that were measured in 2017 differ by increments of 12% to 30% relative to the values that were assumed in the EIS (**Table IR7-07-2**). Annual average noise levels for existing conditions at sites 3, 4, and 5 (shown in EIS Figure 9.3-4) were remodelled using the 2017 values for %HV on 41B Street. The remodelling does not result in any differences in the predicted noise levels (L_d, L_n, L_{dn}) at sites 4 and 5. At site 3, remodelling resulted in a 0.1 dBA change in the L_d (from 50.2 dBA to 50.3 dBA), but no change was indicated in the L_n or L_{dn}. While there were relatively large differences between the estimated (EIS) and measured (2017) %HV values on 41B Street, traffic noise from this road has little influence on the noise levels at sites 3, 4, and 5. Noise levels at these sites are dominated by other sources of sound including traffic noise from roads in closer proximity.

References

Creative Transportation Solutions (CTS). 2007. Deltaport Way & Area Classification Counts. Prepared for Delcan.

Federal Highway Administration (FHWA). 1998. Traffic Noise Model Version 1.0, Technical Manual. Available at https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/old_versions/tnm_version_10/tech_manual/tnm03.cfm#tnma. Accessed January 2018.

Stantec Consulting Ltd. (Stantec). 2017. Roberts Bank Terminal 2 Project – Traffic Counts and Projections.

[2] Daytime %HV was rounded down from 0.2% while the nighttime %HV was 0.0%.

IR7-08 Atmospheric Noise – Clarification, Traffic Forecasts

Information Source(s)

EIS Volume 1: Appendix 4-D

EIS Volume 2: Section 9.3.10.1; Table 9.3-23

Context

Table 9.3-23 of Section 9.3.10.1 of the EIS presented the forecast traffic and rail volumes on Deltaport Way and the Roberts Bank Rail Corridor. The Proponent indicated that the values in this table were based on Appendix 4-D of the EIS. However, it is unclear how the values for the following columns of Table 9.3-23 of the EIS were derived:

- Deltaport Way annual average daily traffic; and
- Deltaport Way percentage (%) heavy vehicles.

Information is required to determine how the values presented in Table 9.3-23 of the EIS were derived.

Information Request

Provide a description of how the information presented in Appendix 4-D of the EIS was used to derive the values presented in Table 9.3-23 of the EIS.

VFPA Response

The following two data sources were used to derive the annual average daily traffic volumes (AADT) and percentages of heavy vehicles on Deltaport Way in Table 9.3-23 of the EIS:

- Appendix 4-D of the EIS, Table 12; and
- Tsawwassen First Nation Community Development: Transportation Impact Assessment (Bunt & Associates 2011), Exhibits 5.4 and 6.4.

Table 12 of EIS Appendix 4-D provides inbound and outbound total vehicle movements (passenger/service vehicles and container trucks) for the growth scenario of 4.8 million (M) twenty-foot equivalent units (TEUs) through the existing Deltaport Terminal, and the proposed RBT2 terminal. The 4.8 M TEU scenario corresponds to future conditions with Project operation. Vehicle movements are provided for each hour of the day such that it is possible to calculate the AADT and percentage heavy vehicles that would be arriving at and departing the Roberts Bank causeway via Deltaport Way.

Exhibits 5.4 and 6.4 in Bunt & Associates (2011) provide projected AM and PM peak traffic volumes on Deltaport Way for 2031. The traffic volumes take into account the Tsawwassen

First Nation Land Use Plan which includes up to nearly 3,500 additional homes, a 1.2 million square foot shopping centre, and a 575,000 square-foot mall.

The traffic data from EIS Appendix 4-D and Bunt & Associates (2011) were combined to provide total traffic volumes on Deltaport Way for the temporal cases that are considered in EIS Table 9.3-23 (i.e., future conditions with the Project and future conditions with the Project and other reasonably foreseeable projects and activities). Data from EIS Appendix 4-D provides Project-related truck traffic for the on-causeway portion of Deltaport Way. These volumes were used in the assessment of future cumulative changes to noise levels (EIS Section 9.3.10) for the off-causeway portion of Deltaport Way, and are shown in Table 9.3-22 for 'incremental road traffic associated with RBT2'.

Annual average daily traffic projections, based on the AM/PM peak traffic data in Bunt & Associates (2011), were estimated using the formula:

$$AADT = AM\ Peak \times 8$$

References

Bunt & Associates Engineering (Bunt & Associates). 2011. Tsawwassen First Nation Community Development: Transportation Impact Assessment. Prepared for Tsawwassen First Nation.

IR7-09 Atmospheric Noise – Nighttime Shift Changes

Information Source(s)

EIS Volume 2: Appendix 9.3-A, Appendix B

CEAR Doc#651

Context

In its submission to the Review Panel (CEAR Doc#651), Tsawwassen First Nation indicated that its members have noted that the late night shift change of workers at the existing Roberts Bank terminals is particularly disruptive because passenger vehicles are higher pitched and travelling faster, resulting in transient noise spikes.

As stated in Appendix 9.3-A of the EIS, road traffic from the causeway and terminal were included as a source of noise when making predictions regarding the noise produced by the proposed Project. However, given that the Proponent relied on metrics such as L_d, L_n, and L_{dn} when describing the potential noise produced by the Project, it is unclear how peaks in terminal and causeway activity occurring at night were considered in the assessment of noise effects. Information is required to determine the effects of peak terminal activity on nighttime noise levels at the sites identified by the Proponent located in the upland study area.

Information Request

Describe the types of Project activities - such as nighttime shift changes - that are likely to occur that could result in peak nighttime noise levels.

Provide a figure similar to those in Appendix B of Appendix 9.3-A which display the L_d, $L_{eq\ (15\ minutes)}$ and L_{max} for a typical night of operations from 10:00 p.m. to 7:00 a.m. at sites 3, 4 and 5 in the upland study area. Identify the source of all peaks.

VFPA Response

Clarification

Based on the context provided for this request, the terms 'peak nighttime noise levels' and 'peaks' are interpreted to refer to the maximum noise levels reached during transient or impulsive noise events that are measurable in terms of the L_{max}. The L_{max} is the maximum RMS (root-mean square) sound pressure level that occurs, or is measured, during a particular time period.

Types of Project Activities that could Result in Transient and Impulsive Noise Events as Measured by the L_{max}

The types of Project activities that are expected to result in measurable, maximum noise levels due to transient or impulsive noise are identified in Section 9.3.9.3 of the EIS. These activities are material handling at the marine terminal and train shunting on the Roberts Bank causeway. No other Project activities are expected to result in measurable, regularly occurring transient or impulsive noise.

It is acknowledged that the nighttime shift change may create a period of time during which Project-related traffic noise is more noticeable relative to the average nighttime noise environment. However, individual vehicles driving on the Roberts Bank causeway during the nighttime shift change would not be expected to regularly cause L_{max} values at receptors that are measurably higher than average nighttime noise levels. This expectation is based on the average vehicle noise emissions provided in the U.S. Federal Highway Administration Traffic Noise Model User's Guide (U.S. FHWA 1998) and consideration of the speed limit and setback distances of receptors from the Roberts Bank causeway.

The increased noticeability of nighttime shift change traffic would be due to the character of the noise rather than to the level of the noise. Shift change traffic will produce more high-frequency noise than is generally present in the study area during nighttime hours. The traffic noise will therefore tend to stand out relative to other sources of nighttime noise. Potential human health effects from exposure to noise that is below quantitative thresholds is assessed qualitatively in the human health assessment as part of the stress and annoyance sub-component (EIS Section 27.6.4).

Transient and Impulsive Noise Events as Measured By The L_{max}

Clarification

The charts in Appendix B of EIS Appendix 9.3-A display the L_{eq}, L_{max}, and L_{90} in 15-minute intervals for sites 3, 4, and 5 for a typical night of operations at Deltaport Terminal. The L_d (daytime average equivalent sound level), requested in this information request, is not plotted on this chart because it is a single value providing an average level for the daytime period (7:00 a.m. to 10:00 p.m.)

L_{max} Source Identification

A source identification analysis similar to the one requested was conducted as part of the atmospheric noise study of the EIS to identify the L_{max} noise levels associated with port-related transient and impulsive noise events. This analysis consisted of a review of field observations, audio recordings, and measured noise levels (see Section 3.1.3 of EIS Appendix 9.3-A). The analysis of noise levels included a review of ten hours of one-second resolution noise level data at site 5, which identified 48 impulsive noise events potentially attributable to port-related activity. The overall analysis at sites 4 and 5 found that impulsive noise events related to activities such as material handling and train shunting resulted in L_{max} ranging from 42.9 to 53.8 dBA (A-weighted decibels; Table 3-4 of EIS Appendix 9.3-A). At site 3, port-related noise events were not measurable.

A similar analysis was conducted for this response to identify the sources, port-related and otherwise, of the highest L_{max} measurements for a typical night of operation. This involved a review of noise measurements in 15 minute intervals. Through this analysis, it was determined that port-related activity was not the likely the cause of many of the 15-minute L_{max} that are plotted in the noise history charts for sites 3, 4, and 5. At sites 4 and 5, over 50% of the L_{max} plotted in the noise history charts of Appendix B of EIS Appendix 9.3-A were greater than 55 dBA. Therefore, the highest 50% of the 15-minute L_{max} measured at sites 4 and 5 were higher than the 42.9 to 53.8 dBA range that was established for port-related activity, and were likely due to non-port-related activities such as aircraft.

References

U.S. Department of Transportation Federal Highway Administration (FHWA). 1998. FHWA Traffic Noise Model User's Guide.

IR7-10 Atmospheric Noise – Nighttime Levels

Information Source(s)

EIS Volume 2: Appendix 9.3-A; Table 3-11, Table 3-21, Section 4.1; Section 9.3.4; Section 9.3.9

Context

In Table 3-11 and Table 3-21 of Appendix 9.3-A of the EIS, the Proponent provided the predicted noise levels (L_d, L_n, and L_{dn}) for sites 3, 4 and 5 during construction and operation of the proposed Project. In Section 4.1 of Appendix 9.3-A of the EIS, the Proponent provided a summary of key findings for the noise assessment. However, the discussion presented in Section 4.1 of Appendix 9.3-A of the EIS regarding noise in the upland study area focused exclusively on L_{dn}. Similarly, the supporting discussion in Section 9.3.9 of the EIS also focused on L_{dn}.

As stated by the Proponent in Section 9.3.4 of the EIS, when calculating L_{dn}, all noise levels occurring between 10:00 p.m. and 7:00 a.m. are increased by 10 dBA to reflect the greater sensitivity of residential communities to noise at night. However, a discussion of the nighttime noise levels in the upland study area during both construction and operation is also required due to the importance of these noise levels when assessing the potential for sleep disturbance.

Information Request

Using the revised model outputs from Review Panel information requests IR7-01, provide a summary of key findings regarding L_n in the upland study area during both construction and operation of the proposed Project.

VFPA Response

The response to IR7-01 in CEAR Document #1104[1] provided nighttime equivalent sound levels (L_n) calculated under worst-case meteorological conditions. The calculations were carried out according to ISO 9613 (ISO 1996) with the influence of meteorology on sound propagation accounted for using the CONCAWE method (CONCAWE 1981). Please refer to IR7-01 (CEAR Document #1104) for a detailed discussion of these calculations.

Nighttime Noise Levels Under Worst-case Meteorological Conditions

Table IR7-10-1 provides nighttime equivalent noise level for Project operation at sites 3, 4, and 5, assuming worst-case meteorological conditions according to the CONCAWE method.

[1] 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).

Provided for comparison are the noise levels presented in the EIS, which are for annual-average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999).

Table IR7-10-1 Noise Levels at Sites 3, 4, and 5 for Worst-case Meteorological Conditions under the CONCAWE Model – Future Conditions with Project Operation

Site	Nighttime Equivalent Noise Level, L_n (dBA)		Worst-case (CONCAWE) L_n minus Annual-average (EIS) L_n (dBA)
	Worst-case Meteorology, CONCAWE	Annual-average Meteorology, EIS	
3	54.1	51.7	2.4
4	52.2	46.5	5.7
5	55.1	49.6	5.5

Table IR7-10-1 shows that worst-case L_n during Project operation at sites 3, 4, and 5 are predicted to be 2.4 to 5.7 dBA (A-weighted decibels) higher than the predicted annual average L_n.

Table IR7-10-2 provides L_n for Project construction at sites 3, 4, and 5 assuming worst-case meteorological conditions according to the CONCAWE method. Provided for comparison are the construction phase noise levels presented in the EIS, which are for annual-average meteorological conditions according to the LfU-Bayern standard (LfU-Bayern 1999).

Table IR7-10-2 Noise Levels at Sites 3, 4, and 5 for Worst-case Meteorological Conditions under the CONCAWE Model – Project Construction Phase

Site	CONCAWE - Project Construction Phase L_n (dBA)		EIS - Project Construction Phase L_n (dBA)		Noise Level Differences between CONCAWE and EIS Project Construction Phase L_n	
	Range	Average	Range	Average	Range	Average
3	51.5 – 57.9	53.3	51.5 – 53.5	51.9	0.0 – 4.4	1.4
4	44.5 – 55.9	48.9	44.5 – 49.3	45.8	0.0 – 6.6	3.1
5	48.5 – 51.3	49.6	48.5 – 49.1	48.7	0.0 – 2.2	0.9

Table IR7-10-2 indicates that, under the CONCAWE method 'worst-case' conditions, nighttime noise during the construction phase are predicted to be from 0.0 to 6.6 dBA higher, relative to the construction phase noise levels in Table 9.3-18 of the EIS. The two results are not directly comparable. The application of the CONCAWE method is limited as it cannot handle changing ground conditions and assumes that the worst-case weather condition is constant over an extended day or night period resulting in an unrealistic scenario (see IR7-01 in CEAR Document #1104 for a discussion on the limitations of the method). Table 9.3-18 of the EIS reflects annual average meteorological conditions. When the two methods are

compared, it means the L_n construction noise levels may be up to 3.1 dBA higher than annual average sound levels if CONCAWE 'worst-case' meteorological conditions were to occur.

The L_n presented in **Tables IR7-10-1** and **IR7-10-2** reflect worst-case meteorological conditions, which are forecast to occur up to 20% of the time on an annual-basis (see response to IR7-01 in CEAR Document #1104). However, given the variable nature of weather, these days or hours could occur over the course of several weeks, or be spread randomly over the year in periods of a few isolated hours at a time.

The analysis provided above demonstrates the variation in nighttime noise levels that could occur under worst-case meteorological conditions, depending on the Project construction or operation activities taking place at the same time as the worst-case meteorological conditions. While the Panel's context to this information request indicates that information on nighttime noise levels is important for the assessment of sleep disturbance, it should be clarified that the Human Health Risk Assessment for Atmospheric Noise and Vibration (EIS Appendix 27-C) relies on annual-average noise levels to evaluate noise-related risks to human health as per World Health Organization guidelines (WHO 2009). As such, it is not appropriate to use these worst-case L_n to evaluate potential noise-related health effects due to sleep disturbance, but rather the annual average L_n values (representing annual average meteorological conditions) provided herein. The annual average L_n values for Project construction and operation are also included in Section 9.3.9.3 of the EIS.

References

Bavarian Environment Agency (LfU-Bayern). 1999: Meteorologische Korrektur (C_{met}).

CONCAWE (Oil Companies' European Association for Environment, Health and Safety). 1981. The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities. Report no. 4/81, prepared by C.J. Manning. Den Haag, May 1981. Available at https://www.concawe.eu/wp-content/uploads/2017/01/rpt_81-4ocr-2004-01264-01-e.pdf. Accessed September 2017.

International Standards Organization (ISO). 1996. ISO Standard 9613-2, Acoustics-Attenuation of Sound During Propagation Outdoors, Part 2 – General Method of Calculation.

World Health Organization (WHO). 2009. Night Noise Guidelines for Europe. Hurtley, C. (Ed). Available at www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2009/ night-noise-guidelines-for-europe. Accessed September 2017.

IR7-11 Atmospheric Noise – Mitigation and Adaptive Management Measures

Information Source(s)

EIS Volume 5: Section 33; Section 33.3.6; Section 33.4.4; Section 33.5; Table 35-2

CEAR Doc#579

Context

In Section 33 of the EIS, the Proponent highlighted that a noise management plan would be used to mitigate the potential effects of noise during both construction and operation of the proposed Project. The Proponent noted that, based on final designs and the detailed construction approach of the Project, noise abatement measures and timing of specific construction activities will be planned to limit disruption to sensitive receptors. Section 33.3.6 and Section 33.4.4 of the EIS described the potential measures that could be implemented to mitigate construction and operational noise, respectively. Table 35-2 of the EIS also outlined the Proponent's commitments with respect to the mitigation of noise, as well as commitments for the mitigation of effects on other intermediate and valued components.

Numerous participants in the environmental assessment have expressed concerns regarding the potential effects of construction and operational noise from the Project. Many of the participants presented examples of noise effects based on their experience with the Deltaport Third Berth project. Although it is expected that the Proponent would use existing information to inform its assessment of environmental effects and the development of mitigation measures, it is unclear as to what degree the results of the follow-up program from the Deltaport Third Berth project were used in providing the mitigation measures for noise noted in the above paragraph.

In Section 33.5 of the EIS, the Proponent highlighted the importance of its compliance monitoring plans, as well as its long-term approach to adaptive management measures in relation to noise. Additional information from the follow-up program from the Deltaport Third Berth project should be used to provide additional detail regarding the mitigation measures to be implemented as part of the construction and operational noise management plan for the Project.

Information Request

Describe how the results of the follow-up program for the Deltaport Third Berth project were used to inform the measures described in the construction and operation noise management plan for the proposed Project.

Provide a description of any adaptive management measures for noise realized during the Deltaport Third Berth project that could be implemented as mitigation measures for the Project.

VFPA Response

Describe how the results of the follow-up program for the Deltaport Third Berth project were used to inform the measures described in the construction and operation noise management plan for the proposed Project.

The Deltaport Third Berth (DP3) Project noise management approach included implementation of noise monitoring and mitigation during construction, as well as community engagement. There was no specific follow-up program directly related to noise for the DP3 Project.

In planning for the RBT2 environmental assessment, the VFPA undertook a community feedback survey focused on noise to solicit input on the components of the noise mitigation and management plans as described in the EIS. The VFPA will develop details of these mitigation and management plans based on this information and will incorporate lessons learned from the monitoring conducted for DP3. Each of these components, and how they will inform the development of the RBT2 construction and operation noise management plans, are discussed in the sections below.

Noise Monitoring During DP3 Construction

During construction of the DP3 Project, the VFPA received complaints regarding noise from project-related dredging activities, specifically the Columbia dredge. In response to these complaints, noise monitoring was subsequently conducted by BKL Consultants Ltd. and the VFPA (VFPA 2009). The noise monitoring demonstrated that project-related dredging activities were causing an increase in noise levels. Based on results of the noise monitoring, the VFPA required the contractor to install additional silencers on the dredge equipment to mitigate noise from the dredging activities, as discussed in greater detail in the second part of the response below.

Experience gained through DP3 construction noise monitoring will inform the development of the RBT2 Construction Noise Management Plan (outlined in EIS Section 33.3.6).

Community Communications during DP3 Construction

The VFPA provided several mechanisms through which DP3 construction noise related complaints could be communicated, such as participation in the Delta Community Liaison Committee, the 24-hour Community Response Line, and the dedicated project email address. Community feedback was used to target noise monitoring and identify additional mitigation.

Feedback received during DP3 through these mechanisms will inform the development of the RBT2 Construction Noise Management Plan, as well as the Construction Communications Plan (outlined in EIS Section 33.3.16). The plan will describe how interested parties (including local residents) will be informed of the nature, location, status, and progress of construction activities.

Based on the effectiveness of the communication channels for DP3, the VFPA will carry these mechanisms forward for RBT2 including the Delta Community Liaison Committee, the 24-hour

Community Response Line, and the dedicated RBT2 Project email address (container.improvement@portvancouver.com).

Permanent Noise Monitoring Stations

Since DP3, the VFPA has made efforts to gain a better understanding of the existing noise environment and associated community concerns within its jurisdiction. Since 2013, the VFPA has implemented a long-term noise monitoring program that captures sound levels in real time[1]. The recording and analysis of the noise environment enables identification of potential areas for improvement. Permanent noise monitoring stations have been deployed in the Roberts Bank trade area since 2014 and 2015, including monitoring stations at Roberts Bank, shown in Figure IR7-11-A1 in **Appendix IR7-11-A**.

Data from continuous monitoring will inform the specific noise monitoring and noise management plans (construction and operation) as outlined in EIS Sections 27.7.2, 33.3.6, and 33.4.4.

Community Feedback Survey

In planning for RBT2, the VFPA undertook a community survey to inform scoping of RBT2 noise assessment. The survey aimed to determine the types, locations, and perceived sources of existing noise in the community (Economic Planning Group 2013). Feedback from this survey informed the scope of the assessment, modelling, and locations of the measurement program of existing noise (described in EIS Appendix 9.3-A).

Community concerns about the influence of weather conditions on the prominence of noise from the existing terminals informed the development of a study of the effects of meteorological conditions on sound propagation from Roberts Bank terminals (Wakefield Acoustics Ltd. 2014).

The learnings described above from the DP3 Project, and more recently with permanent noise monitoring and the community survey, will inform the specific measures to be included in the RBT2 construction and operation noise management plans.

Provide a description of any adaptive management measures for noise realized during the Deltaport Third Berth project that could be implemented as mitigation measures for the Project.

During DP3 construction, noise complaints during dredging activity were followed up with noise monitoring, as described above. The installation of additional silencers on dredge equipment as a mitigation measure was effective in that it reduced the noise emissions from dredging activities to acceptable levels, and resulted in reduced noise complaints. If RBT2 construction phase monitoring indicates that dredging activities are resulting in exceedances of noise level thresholds, the use of silencers could be implemented as an adaptive mitigation

[1] Real time noise monitoring accessible at https://www.portvancouver.com/port-dashboard/noise-monitoring/.

measure. The application of this specific mitigation measure, the use of silencers, depends on the dredge equipment to be used, and the distance of the noise source from receptors. Given that the intermediate transfer pit (ITP) will no longer be used as part of RBT2[2], the location of the majority of the dredging during RBT2 construction will be approximately 2 to 4 km further from land-based receptors than the dredging activity was for DP3.

Measures to adaptively mitigate noise issues identified through RBT2 construction and operation monitoring will build on learnings from the DP3 Project, and other relevant projects. Please refer to the response to IR7-12 for detailed information on additional potential measures to mitigate noise from RBT2, if monitoring were to identify exceedances of thresholds.

References

Economic Planning Group. 2013. Roberts Bank Terminal 2: Survey of Area Residents Regarding Noise and Vibration Issues. Available at http://www.robertsbankterminal2.com/environmental-assessment/technical-data-reports/. Accessed August 2017.

Vancouver Fraser Port Authority (VFPA). 2009. Pre-Operations EAC Compliance Report; Deltaport Third Berth Project. Available at https://www.portvancouver.com/wp-content/uploads/2015/03/DP3_Pre-Operations_Compliance_Report.pdf. Accessed August 2017.

Wakefield Acoustics Ltd. 2014. Roberts Bank Terminal 2 Technical Data Report; Upland Noise and Vibration – Effects of Meteorological Conditions on Sound Propagation from Roberts Bank Terminals. Available at http://www.robertsbankterminal2.com/environmental-assessment/technical-data-reports/. Accessed August 2017.

Appendices

Appendix IR7-11-A Supporting Figure

[2] Refer to Preamble in Support of Responses to IR4-25 to IR3-24 (General and Disposal at Sea-related Project Construction Update) in CEAR Document #984 for more information.

APPENDIX IR7-11-A
SUPPORTING FIGURE

Path: O:\1200-\1246\EIS_INFORMATION_REQUEST\SIR7_11\mxd\IR7_11_A1_PermanentNoiseMonitoringStations_171117.mxd

Canoe Passage

Roberts Bank

Inter-causeway Area

Strait of Georgia

Boundary Bay

MUSQUEAM I.R. 4

Tsawwassen First Nation

Tsawwassen

CANADA

DELTAPORT WAY

DELTAPORT TERMINAL

EXPANDED TUG BASIN

MARINE TERMINAL

DREDGE BASIN

WESTSHORE TERMINALS

B.C. FERRIES TERMINAL

Deltaport Way

Tsawwassen Golf & Country Club

Tsawwassen Town Centre Mall

Beach Grove Golf Club

Winskill Park

Boundary Bay Cemetery

Pebble Hill Park

Diefenbaker Park

Point Roberts Golf & Country Club

Legend

- PERMANENT NOISE MONITORING STATION
- BOUNDARY OF PROJECT AREA
- U.S.A.-CANADA BORDER

0 1 2

Kilometres

1:40,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

VFPA PERMANENT NOISE MONITORING STATIONS AT ROBERTS BANK

DATE: 11/17/2017

FIG No. IR7-11-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

IR7-12 Atmospheric Noise – Technical and Economic Feasibility of Mitigation Measures

Information Source(s)

CEAR Doc#579

Context

In Appendix A of its submission to the Review Panel (CEAR Doc#579), Health Canada provided a list of commonly applied construction mitigation measures and considerations for noise reductions. Although not all of these measures may be suitable for application to the proposed Project, further information is required to determine whether the measures listed in Appendix A of the Health Canada submission are technically and economically feasible measures that could be used by the Proponent to mitigate the noise from construction and operation of the Project.

Information Request

In a table, summarize whether the measures presented in Appendix A of CEAR Doc#579 are technically and economically feasible measures that could be implemented to mitigate the noise from construction and/or operation of the proposed Project, and provide supporting rationale. Indicate whether the measures would be suitable to mitigate continuous noise, transient and impulsive noise, and/or low-frequency noise.

VFPA Response

Context for Mitigation Evaluation

The noise mitigation measures included in the Health Canada submission (CEAR Document #579[1]) have been evaluated at a preliminary level for technical and economic feasibility. In some cases, more detailed technical evaluation would be required before implementation. Further evaluation would be focused on verifying technical and economic feasibility, as well as potential effectiveness and appropriateness in terms of mitigating the specific RBT2-related sources and types of noise. A summary of the preliminary evaluation is provided in Table IR7-12-A1 of **Appendix IR7-12-A**.

Environmental Management Plans

Most of the measures in the Health Canada submission are specific practices that could be included as part of construction and operation environmental management plans (EMPs). The

[1] CEAR Document #579 From Health Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project (NOTE: Updated October 18, 2016).

EMPs where similar practices are proposed in the EIS as mitigation for noise and noise-related effects on human health (EIS Section 27.7.2) are referred to throughout Table IR7-12-A1 (**Appendix IR7-12-A**), and are listed below:

Construction environmental management plans:

- Construction Compliance Monitoring Plan (EIS Section 33.3.1);
- Noise Management Plan (EIS Section 33.3.6);
- Land and Marine Traffic Management Plan (EIS Section 33.3.9); and
- Communications Plan (EIS Section 33.3.16).

Operation environmental management plans:

- Operation Compliance Monitoring Plan (EIS Section 33.4.1); and
- Noise Management Plan (EIS Section 33.4.4).

Adaptive Management Measures

Noise levels in the local study area will be monitored before and during construction, and during operation as part of the construction and operation monitoring plans and the RBT2 Follow-up Program (EIS Section 33.5). If unanticipated effects are identified, additional mitigation measures may be implemented to further reduce noise levels, as an adaptive management strategy. Some of the measures in Table IR7-12-A1 (**Appendix IR7-12-A**), if confirmed to be technically and economically feasible upon further evaluation, may be considered as adaptive management mitigation measures to be undertaken if monitoring identifies exceedances related to RBT2 construction or operations activities.

Project-specific Context

Several entries in Table IR7-12-A1 (**Appendix IR7-12-A**) refer to measures that would be relevant for projects with construction or operation activities taking place immediately adjacent to, or in near proximity to, neighbouring residences. In the case of RBT2, the nearest residents range in proximity from approximately one kilometre away from construction works at the east end of the causeway, to over five kilometres away from construction and operation activities at the terminal.

Overview of Mitigation Evaluation Table

The details of the Health Canada submission, *Appendix A. Commonly Applied Construction Noise Mitigation Measures and Considerations for Noise Reduction* (CEAR Document #579), are included in their entirety in Table IR7-12-A1 (**Appendix IR7-12-A**) as 67 separate entries. Where entries consist of general comments with no specific measures for evaluation, these are noted as such. As an initial filter, each specific measure was reviewed for applicability to the RBT2 Project. For those that do not apply, a rationale is provided, and the measures are not evaluated further. For those measures that are applicable to the Project, information is provided on the phase (construction, operation, or both) in which the measures would apply, and the type of noise (continuous, transient, impulsive, or low-frequency noise)

that could potentially be mitigated by the measure. If a similar measure is included in the EIS, this is also noted within the table.

A preliminary and high-level indication of the technical and economic feasibility is provided for each applicable measure. Based on preliminary evaluation, a suggested measure is indicated as 'technically feasible' if the specific technology proposed (if any) is available and applicable, and fits with local site characteristics, Project design, and construction schedule. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

Appendices

Appendix IR7-12-A Supporting Table

APPENDIX IR7-12-A
SUPPORTING TABLE

Table IR7-12-A1 Evaluation of Noise Mitigation Measures

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
General Mitigation Measures							
1	Include in tenders, employment contracts, subcontractor agreements and work method statements clauses that assure the minimisation of noise and compliance with directions from management to minimise noise.	Yes – General comment, no specific measure to evaluate	--	--	--	--	--
2	Give preference to the use of quieter technology or other mitigation measures rather than lengthening construction duration (i.e., it is not recommended to lower noise by having fewer pieces of equipment running at a time thereby leading to extended construction duration).	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	Yes
3	Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways that minimise noise.	Yes – For evaluation	Construction and Operation	Similar measure included in outline for RBT2 Construction and Operation Noise Management Plans in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
4	Ensure that site managers periodically check the site, nearby residences and other sensitive receptors for noise problems so that solutions can be quickly applied.	Yes – For evaluation	Construction and Operation	Similar measure included in outline for RBT2 Construction and Operation Compliance Monitoring Plans in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Compliance Monitoring Plans	Yes
5	Avoid the use of radios and stereos outdoors and the overuse of public address systems where neighbours can be affected.	Yes – For evaluation	Construction	--	Continuous, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
6	Avoid shouting, and minimise talking loudly and slamming vehicle doors.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
7	Keep truck drivers informed of designated vehicle routes, parking locations, acceptable delivery hours and other relevant practices (e.g., minimising the use of engine brakes and periods of engine idling).	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan, and/or Land and Marine Traffic Management Plan	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Nighttime Mitigation Measures							
8	Avoid the use of equipment that generates impulsive noise.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan, specific to pile driving activity	Yes
9	Minimise the need for reversing alarms.	Yes – For evaluation	Construction	--	Impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan	Yes
10	Avoid dropping materials from a height.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Minimisation of dropping materials from heights could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
11	Avoid metal-to-metal contact on equipment.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	*Construction:* Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan *Operation:* No – Primary Project activities involve metal-to-metal contact (e.g., rail movements, container handling and stacking)	Yes – For construction
12	If possible, schedule truck movements to avoid residential streets.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction Noise Management Plan and/or Land and Marine Traffic Management Plan	Yes
13	Avoid mobile plant clustering near residences and other sensitive receptors.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan.	Yes
14	Ensure that periods of respite are provided in the case of unavoidable maximum noise level events.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Further evaluation required

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Consultation and Notification							
15	Provide related information [about noise] that is frank, and does not attempt to understate the likely noise level; respect commitments.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Communications Plan in EIS	N/A	Yes – Measure could be included in the final RBT2 construction Communications Plan	Yes
Notification Before and During Construction							
16	Provide advance notification to people concerning construction duration, defining activities that are expected to be noisy and their expected duration, what noise mitigation measures are being applied, and when noisy periods will occur.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Communications Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – To be implemented as specified in the final RBT2 construction Communications Plan	Yes
17	For nighttime work, receptors may be informed in two stages: two weeks prior to construction and then two days before commencement.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic to be included as part of construction Communications Plan; to be adapted specific to Project construction plan	Yes
18	Provide information to neighbours before and during construction through media such as letterbox drops, meetings, or individual consultation. In some areas, the need to provide notification in languages other than English may be considered. A website may also be established for the project.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in construction Communications Plan	Yes
19	Use a site information board at the front of the site with contact details, hours of operation, and regular information updates.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Communications Plan	Yes
20	Facilitate contact with people to ensure that everyone can see that the site manager understands potential issues, that a planned approach is in place, and that there is an ongoing commitment to minimise noise.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in construction Communications Plan.	Yes
Plant and Equipment							
21	In terms of both cost and results, controlling noise at the source is one of the most effective methods of minimising the noise impacts from any construction activities.	Yes – General comment, no specific measure to evaluate	--	--	--	--	--

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Quieter Methods							
22	Examine and implement, where feasible and reasonable, alternatives to rock-breaking work methods such as hydraulic splitters for rock and concrete, hydraulic jaw crushers, chemical rock and concrete splitting, and controlled blasting such as penetrating cone fracture.	No – Rock materials will be transported to site by barge from local quarries. No rock splitting or blasting activities on site at RBT2	N/A	N/A	N/A	N/A	N/A
23	Consider alternatives to diesel and gasoline engines and pneumatic units such as hydraulic or electric-controlled units where feasible and reasonable. When there is no electricity supply, consider using an electrical generator located away from residences.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
24	Examine and implement, where feasible and reasonable, alternatives to transporting excavated material from underground tunnelling offsite at nighttime (i.e., stockpile material in an acoustically treated shed during the night and load out the following day).	No – No underground tunnelling as part of RBT2 construction plan	N/A	N/A	N/A	N/A	N/A
25	Examine and implement, where feasible and reasonable, alternatives to pile driving using a diesel hammer, such as hydraulic hammer, hydraulic press-in, or vibratory pile driver.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Underwater Noise Management Plan in EIS **Note:** As per Appendix IR12-A (Summary of Proposed Mitigation and Related Effectiveness; CEAR Document #314), the Underwater Noise Management Plan for construction will include use of vibratory hammer instead of impact pile driving when practical.	Impulsive/transient	Yes – Measure could be included in the Underwater Noise Management Plan	Yes
26	To reduce the impact of backup alarms, examine and consider implementing, where feasible and reasonable, ambient sensitive backup alarms, signal workers, turning circles, and side loading/unloading trucks.	Yes – For evaluation	Operation	Similar measure included in outline for RBT2 Operation Noise Management Plan in EIS	Impulsive/transient	Yes – Measure could be included in Operation Noise Management Plan	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Quieter Equipment							
27	Examine different types of machines that perform the same function and compare the noise level data to select the least noisy machine (i.e., rubber-wheeled tractors can be less noisy than steel-tracked tractors).	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
28	Pneumatic equipment is traditionally a problem. Consider selecting super-silenced compressors, silenced jackhammers, and damped bits where possible.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
29	When renting (or purchasing) equipment, select quieter pieces of plant and construction equipment where feasible and reasonable. As well, select the most effective mufflers, enclosures, and low-noise tool bits and blades. Always seek the manufacturer's advice before making modifications to any equipment to reduce noise.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Further evaluation required
30	Reduce throttle settings and turn off equipment when it is not being used.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise	Yes – Measure could be included in Construction Noise Management Plan	Yes
31	Examine and consider implementing, where feasible and reasonable, the option of reducing noise from metal chutes and bins by placing damping material in the bin.	No – Chutes and bins are typically associated with demolition work and will not be used in RBT2 construction	N/A	N/A	N/A	N/A	N/A
Equipment Maintenance							
32	Regularly inspect and maintain equipment to ensure that it is in good working order, including the condition of mufflers.	Yes – For evaluation	Operation	Similar measure included in outline for RBT2 Operation Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Operation Noise Management Plan	Yes
33	For machines with enclosures, verify that doors and door seals are in good working order and that the doors close properly against the seals.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
34	Return any leased equipment that is causing noise that is not typical for the equipment. The increased noise may indicate the need for repair.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
35	Ensure that air lines on pneumatic equipment do not leak.	Yes – For evaluation	Construction and Operation	--	Continuous	Yes – Topic could be included in awareness and training measures for construction crews, as part of Construction and Operation Noise Management Plans	Yes
Site Mitigation Measures							
36	Barriers and acoustic sheds are most suited to long-term fixed works as in these cases, the associated cost is typically outweighed by the overall time savings.	General comment – No specific measure for evaluation (specific measures re: barriers are evaluated in #43 to #48 and #62 to #67)	--	--	--	--	--
Equipment Location							
37	Place as much distance as possible between the equipment and residences and other sensitive receptors.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	Yes
38	Restrict areas in which mobile plants can operate so that they are away from residences and other sensitive receptors at particular times.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Yes
39	Locate site vehicle entrances away from residences and other sensitive receptors.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	No – The Project is accessible to vehicles only by the Roberts Bank causeway. Alternative vehicle entrances not available or possible, due to geographic characteristics of site	No – Not economically feasible to construct alternative entrances
40	Carry out noisy fabrication work at another site (e.g., within enclosed factory premises) and then transport products to the Project site.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Majority of metal fabrication (e.g., steelwork for buildings and equipment) will be completed offsite	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Alternatives to Reversing Alarms							
41	Avoid the use of reversing alarms by designing the site layout to avoid reversing, such as by including drive-through for parking and deliveries.	No – Container trucks are not required to have back up alarms and generally do not have them.	N/A	N/A	N/A	N/A	N/A
42	When applicable legislation permits, consider less annoying alternatives to the typical 'beeper' alarms. Examples include smart alarms that are adjustable in volume depending on the ambient level of noise, and multi-frequency alarms that emit noise over a wide range of frequencies.	Yes – For evaluation	Construction and Operation	--	Impulsive/transient	Yes – Measure could be included in Construction and Operation Noise Management Plans	Yes
Maximise Shielding							
43	Re-use existing structures rather than demolishing and reconstructing.	No – No demolition involved in RBT2 construction	N/A	N/A	N/A	N/A	N/A
44	Use full enclosures, such as large sheds, with good seals fitted to doors to control noise from nighttime work.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program	Yes
45	Use temporary site buildings and material stockpiles as noise barriers.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Project design includes temporary site buildings, and pre-load stockpiles on causeway and terminal at various stages; when situated between noise sources and receptors, noise shielding may occur	Yes
46	Schedule the construction of permanent walls so that they can be used as noise barriers as early as possible.	No – Buildings on terminal will be constructed near end of construction phase	N/A	N/A	N/A	N/A	N/A
47	Use natural landform as a noise barrier. Place fixed equipment in cuttings or behind earth berms.	No – Project site is flat/over water	N/A	N/A	N/A	N/A	N/A
48	Take note of large reflecting surfaces on- and offsite that might increase noise levels, and avoid placing noise-producing equipment in locations where reflected noise will increase noise exposure or reduce the effectiveness of mitigation measures.	No – Measure applies to vertical surfaces; the only vertical surfaces will be between the noise sources and receptors, and would act as barriers versus reflecting noise toward receptors	N/A	N/A	N/A	N/A	N/A

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Work Scheduling							
49	Schedule noisy work during periods when people are least affected.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management plan, specific to pile driving activity	Yes
Provide Respite Periods							
50	Consult with schools to ensure that noise-generating construction works in the vicinity are not scheduled to occur during examination periods, unless other acceptable arrangements (such as relocation) can be made.	No – No schools located in areas where construction or operation noise is predicted to exceed thresholds for learning environments.	N/A	N/A	N/A	N/A	N/A
51	When night work near residences cannot be feasibly or reasonably avoided, restrict the number of nights per week and/or per calendar month that the work is undertaken.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be considered as adaptive measure in Follow-up Program	Further evaluation required
Schedule Activities to Minimise Noise Impacts							
52	Organise work to be undertaken during the recommended standard hours where possible.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	No – Would effectively double duration of construction for in-water works, and increase environmental effects	No – Would cause significant delays to overall construction phase
53	If the construction site is in the vicinity of a sports venue, consider scheduling work to avoid times when there are special events.	No – No sports venues located in the vicinity of construction	N/A	N/A	N/A	N/A	N/A
54	When work outside the recommended standard hours is planned, avoid scheduling it on Sundays or public holidays.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan	No – Would cause significant delays to overall construction phase
55	Schedule work when neighbours are not present (e.g., commercial neighbours, college students, and school students may not be present outside business hours or on weekends).	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	No – Would effectively double duration of construction for in-water works, and increase environmental effects	No – Would cause significant delays to overall construction phase
56	Schedule noisy activities around times of high background noise (i.e., when local road traffic or other local noise sources are active) where possible to provide masking or to reduce the amount that the construction noise intrudes above the background noise.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Construction Noise Management Plan in EIS	Continuous, low-frequency noise, impulsive/transient	Yes – Measure could be included in Construction Noise Management Plan, specific to pile driving activity	Yes

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Deliveries and Access							
57	Nominate an offsite truck parking area away from residences for trucks arriving prior to gates opening and schedule deliveries only during specified periods.	Yes – To be evaluated	Construction	--	Continuous, low-frequency noise, impulsive/transient	Further evaluation required – Measure to be considered further in the detailed design stage of the Project	Further evaluation required
58	Optimise the number of vehicle trips to and from the site. Movements can be organised to amalgamate loads rather than using a number of vehicles with smaller loads.	Yes – Construction plan is based on assumption of full loads for all truck trips	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure addressed by Project design	Yes
59	Designate access routes to the site through consultation with potentially noise-affected residences and other sensitive receptors, and inform drivers of nominated vehicle routes.	Yes – For evaluation	Construction	Similar measure included in outline for RBT2 Land and Marine Traffic Management Plan in EIS	Low-frequency noise, impulsive/transient	Yes – Measure could be included in Land and Marine Traffic Management Plan	Yes
60	Provide onsite parking for staff and onsite truck waiting areas away from residences and other sensitive receptors.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	*Construction:* Further evaluation required – Measure to be considered further in the detailed design stage of the Project *Operation:* Yes – Onsite employee parking included in terminal design	Further evaluation required
61	Truck waiting areas may require walls or other barriers to minimise noise.	Yes – For evaluation	Construction and Operation	--	Continuous, low-frequency noise, impulsive/transient	*Construction:* Yes – Measure (temporary barriers) could be: • Included in Construction Noise Management Plan; and/or • Considered as adaptive measure in Follow-up Program *Operation:* Further evaluation required – Measure (permanent barriers) to be considered further in the detailed design stage of the Project	*Construction:* Yes *Operation:* Further evaluation required

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

#	Suggested Measure *As provided in CEAR Document #579, Measures Adapted from New South Wales Construction Noise Guideline*	Applicable to RBT2 Project	Applicable Project Phase or Activity	Similar Measure in EIS	Noise Type	Technically Feasible	Economically Feasible[a]
Noise Transmission Path							
62	Physical methods to reduce the transmission of noise between construction locations and residences or other sensitive receptors are generally suited to construction projects in which there is long-term noise exposure.	General comment – no specific measure for evaluation (see #63-67)	--	--	--	--	--
63	Reduce the line-of-sight noise transmission to residences and other sensitive receptors using temporary noise barriers.	Yes – For evaluation	Construction	--	Continuous, low-frequency noise, impulsive/transient	Yes – Measure (temporary barriers) could be considered as adaptive measure in Follow-up Program	Yes
64	Temporary noise barriers can be constructed from boarding (plywood boards, panels of steel sheeting, or compressed fibre cement board) with no gaps between the panels at the site boundary.	Barrier materials to be considered as part of #63.	N/A	N/A	N/A	N/A	N/A
65	Stockpiles and shipping containers can be effective noise barriers.	Yes – For evaluation	Operation	--	Continuous, low-frequency noise, impulsive/transient	No – Orientation of terminal does not allow for stacking containers between noise sources and receptors	No – Re-design of terminal would be required
66	Erect temporary noise barriers before work commences to reduce noise from construction as soon as possible.	Timing of barriers to be considered as part of #63	N/A	N/A	N/A	N/A	N/A
67	Where high-rise dwellings adjoin the construction site, the height of a barrier may not be sufficient to effectively shield the upper levels of the residential building from construction noise. Find out whether this is a consideration for the Project and examine alternative mitigation measures where needed.	No – No high-rise dwellings adjacent to construction site.	N/A	N/A	N/A	N/A	N/A

Note: a. Based on preliminary evaluation, a suggested measure is indicated as 'economically feasible' if it is within the scope of the Project design and construction schedule (i.e., a costly re-design or construction delay would not be required). Consideration was also given to the total cost of implementation of each measure. However, further evaluation of each measure will be completed as part of EMP and Follow-up Program development, as well as detailed design of the Project.

Preamble for IR7-13 to IR7-23 Wave Environment Information Requests

The technical approach adopted to conduct the wave environment effects assessment that was included in Section 7.2 and Appendices 7.1 and 7.2 of the Marine Shipping Addendum was informed by the Updated Guidelines for the Preparation of an Environmental Impact Statement for the Roberts Bank Terminal 2 Project (Updated EISG, 2015). Specifically, the following guidance appears in section 17, under the introductory heading "Anticipated Level of Effort":

> *"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."*

Incorporating the expected technical scope of assessment specified in the Updated EISG, the objective of the wave environment effects assessment was to evaluate the contribution of waves generated by RBT2-associated vessels to the existing wind-generated wave climate. The adopted study methodology is similar to the approach taken to assess wake from ships for the Kitimat LNG Export Terminal Project near Kitimat, B.C. (Moffatt and Nichol (2011) report, appended to IR7-17 as Appendix IR7-17-A) and the Woodfibre LNG Project near Squamish, B.C. (Moffatt and Nichol 2014). The Moffatt and Nichol (2011) report (Appendix IR7-17-A) forms the basis for the wake assessment for the Trans Mountain Expansion Project. Fisheries and Oceans Canada (DFO) reviewed the application submitted to the National Energy Board (NEB) pertaining to the Trans Mountain Expansion Project and described the wake assessment approach as "quantitative" (DFO 2014). The Marine Shipping Addendum expands on the methodology presented in the Moffatt and Nichol (2011) report (Appendix IR7-17-A) by considering vessel speed and water depth at 4 km intervals along the shipping route, rather than assuming an average across a segment.

The following series of statements regarding wake interactions with the existing wave environment summarises the logical approach to assessing wake for the wave environment effects assessment:

a) The wave environment in the marine shipping area, including Segments A to C, is dominated by wind-generated waves, and Segment D is dominated by both wind-generated waves and swell from the Pacific Ocean;
b) Waves generated by passing vessels contribute to the existing wave environment;
c) The shorelines within the marine shipping area are exposed to wind-generated waves arriving from open water on an ongoing, long-term basis;

d) Shorelines that are exposed to waves contributed by vessels transiting in the international shipping lanes are also exposed to wind-generated waves on an ongoing basis;
e) Waves arriving from open water are likely to interact with the shoreline in a variety of ways, including shoaling, reflection, and refraction, as the water depth decreases in the near-shore environment; and
f) Project-associated marine traffic is not expected to change how waves arriving from open water will interact with shorelines in the marine shipping area.

Detailed investigations of the nearshore wave interactions (i.e., shoaling, reflection, and refraction) were not assessed since these processes are occurring in relation to the existing wave climate and are unaffected by Project-associated vessels.

The information included above is referred to or expanded upon in the responses to the wave environment information requests (IR7-13 to IR7-23) that follow. A common theme across these eleven information requests is around uncertainty in the wave assessment results. The VFPA has demonstrated in the following responses that the approach taken is appropriate to the level of detail required in the investigation and that the results can be relied upon for the purposes of the wave environment assessment.

References

Fisheries and Oceans Canada (DFO). 2014. Hearing Order OH-001-2014: Trans Mountain Pipeline ULC (Trans Mountain) Application for the Trans Mountain Expansion Project (OH-001-2014). Written evidence submitted by Fisheries and Oceans Canada (Intervenor). 38 pp.

Moffatt and Nichol. 2011. Vessel Wake Study (DRAFT). Report prepared by Moffatt & Nichol for KM LNG Operating General Partnership, Vancouver, BC. 18 pp. Provided as Appendix IR7-17-A in the response to IR7-17.

Moffat and Nichol. 2014. Woodfibre LNG - Vessel Wake Assessment. Available at https://www.woodfibrelng.ca/wp-content/uploads/2014/08/Moffatt-and-Nichol-wake-study.pdf. Accessed October 2017.

IR7-13 Wave Environment – Numerical Wave Model

Information Source(s)

Marine Shipping Addendum: Appendix 7.2-A, Figure 1

Context

In Appendix 7.2-A of the Marine Shipping Addendum, the Proponent modelled wind-driven waves using local meteorology for the year 2012 as input to the numerical wave model described by Donelan *et al* (2012).

The Proponent did not discuss the strengths, weaknesses and sources of uncertainty associated with this numerical wave model.

Information Request

Justify the choice of the Donelan *et al* (2012) numerical wave model to model wind-driven waves in the Deepwater Wave Model Domain shown in Figure 1 of Appendix 7.2-A of the Marine Shipping Addendum.

Provide a discussion of the strengths, weaknesses and sources of uncertainty of the Donelan *et al* (2012) numerical wave model and its use in the proposed Project assessment.

VFPA Response

Justify the choice of the Donelan* et al *(2012) numerical wave model to model wind-driven waves in the Deepwater Wave Model Domain shown in Figure 1 of Appendix 7.2-A of the Marine Shipping Addendum.

The Donelan et al. (2012) model, referred to by the paper's authors as the University of Miami Wave Model (or UMWM), calculates the wave spectrum in deep water in response to a calculated wind stress field. The model's predictive results were compared to a number of field datasets and the model was found to perform well (Donelan et al. 2012). The UMWM calculates wave interactions with the sea bed, which includes the processes of shoaling and diffraction, but it does not include diffraction around breakwaters, reflection from boundaries, or triad interactions in the surf zone (aspects that are not relevant to this study, as described in the *Preamble in Support of Responses to IR7-13 to IR7-23*). In contrast to other widely-used wave models, such as SWAN (Simulating WAves Nearshore; Booij et al. 1999), that incorporate the near-shore shallow-water interactions, the UMWM is more computationally efficient and does not require detailed shoreline bathymetry as input.

The justification for the use of the UMWM is described below:

a) The model is demonstrated to perform well in the deep water environment as compared to field datasets (Donelan et al. 2012; Marine Shipping Addendum Appendix 7.2-A), and is a reliable method to provide the required analysis, as outlined in the Updated EIS Guidelines; and
b) The model is computationally efficient, allowing for the development of a long-term (12 month) representation of the wave environment in the marine shipping area.

Provide a discussion of the strengths, weaknesses and sources of uncertainty of the Donelan* et al *(2012) numerical wave model and its use in the proposed Project assessment.

Model Strengths

The UMWM was developed to provide full atmosphere-wave-ocean coupling that is computationally efficient and robust. Greater computational efficiency means that large areas of ocean can be modelled with relatively high spatial and temporal resolution. With respect to the wave environment assessment for Project-associated vessels, computational efficiency and robustness were important considerations in the choice of model.

Additional strengths of the UMWM, as outlined in Donelan et al. (2012), are that the model can take advantage of parallel processing, meaning that the work of solving the equations can be parsed between multiple computer processors to compute the solution in parts simultaneously, allowing for a more extensive modelling study. In addition, its design follows the standard of the Earth System Modelling Framework (ESMF), which makes it suitable for coupling to atmosphere and ocean circulation models.

Model Weaknesses

The main weakness of the UMWM is that it is not intended to represent near-shore shallow-water wave transformations. This weakness is largely irrelevant to the wave environment assessment, as the approach considers the wake from passing Project-associated ships in the context of the existing wind-generated wave climate and, therefore, does not rely on an assessment of wave transformation in the near-shore environment.

Sources of Uncertainty

Uncertainty with respect to a numerical model and its application to a physical environment is typically considered as relating to a) the natural variability of the phenomenon or environment that is being represented, b) internal simplifications in the model, and c) the parameters specified in the model. These uncertainties are inherent to all models and are not unique to the UMWM and are further explained below.

a) With respect to natural variability, the marine shipping area is a relatively complex environment with numerous islands and a tortuous shoreline, and winds that vary in speed and direction on an ongoing basis. As is the case for all models, the UMWM represents the natural variability in a necessarily simplified form. Within the model, for instance, winds are specified based on measured data at various locations and between these locations the winds are interpolated, as outlined in the response to

IR7-14. It is likely that localised effects of wind direction being affected by topography are not perfectly represented in all areas of the model domain. The use of hourly wind data to describe a phenomenon that naturally varies on the scale of minutes is another example of a necessary simplification that is incorporated.

b) With respect to model simplifications, the code that describes the interactions between the wind field and the ocean surface to generate waves is, by necessity, a generalisation (albeit a sophisticated generalisation) of the real-world phenomena. As described in Donelan et al. (2012), the model represents real-world measurements of open water waves fairly well, but the match is imperfect, partly because the code cannot capture the full complexity of the natural system.
c) With respect to model parameters, the UMWM requires that parameters that describe eddy diffusivity and the characteristics of the wave spectrum are specified by the operator. These are chosen based on existing science, professional judgement, and knowledge of the system being modelled.

For uncertainty associated with the model results that arises from the above items, validation of results reduces the inherent uncertainty. For the validation of the wave environment assessment UMWM results, Appendix 7.2-A of the Marine Shipping Addendum presents a comparison of modelled and observed waves at the Halibut Bank and New Dungeness wave monitoring stations, and at the Roberts Bank AWAC measurement location. These three sites represent the known locations where waves were measured in the marine shipping area during 2012 (see Marine Shipping Addendum Appendix 7.2-A, Figure 2), the year upon which the assessment is based.

The validation process summarised above and expanded upon in the response to IR7-15 demonstrates that the UMWM reproduces the existing wind-driven wave environment in the study area well, and that the uncertainties associated with the use of the UMWM do not undermine the VFPA's confidence in the results.

References

Booij, N., R. C. Ris, and L. H. Holthuijsen. 1999. A Third-generation Wave Model for Coastal Regions: 1. Model Description and Validation. Journal of Geophysical Research: Oceans, 104(C4), 7649–7666. doi:10.1029/98JC02622.

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-14 Wave Environment – Wind Model

Information Source(s)

EIS Volume 2: Appendix 9.2-A, Appendix C, Section 2

Review Panel Information Request IR6-04 (CEAR Doc#991): Air Quality Modelling

Context

Detailed three-dimensional wind field modelling was performed as part of the air quality assessment. Those wind fields are based on models that are far more sophisticated than the two-dimensional wind field model used in the wave assessment.

However, the Proponent did not describe the process whereby two-dimensional, time varying wind fields required as input by the numerical wave model, were generated from various available wind record stations.

A comparison of the modelled wind fields used in the wave assessment modelling with the modelled wind fields used in the air quality assessment modelling would increase confidence in the wave assessment modelling.

Information Request

Describe the process whereby two-dimensional, time varying wind fields required as input by the wave assessment numerical model, was generated from various available wind record stations.

In regions where the modelling domains overlap, compare wind fields used in the wave assessment modelling with those generated by the NMM-WRF-CALMET meteorological modelling system used in the revised air quality assessment of the proposed Project to determine how well the two wind-fields match. Comment on the confidence that the wind fields used in the wave assessment modelling are appropriate.

VFPA Response

Describe the process whereby two-dimensional, time varying wind fields required as input by the wave assessment numerical model, was generated from various available wind record stations.

The University of Miami Wave Model (UMWM), described by Donelan et al. (2012), calculates waves generated by an applied wind stress. As described in Appendix 7.2-A of the Marine Shipping Addendum (MSA), a two-dimensional, time-dependent wind field was generated based on the following wind record stations (locations are shown in MSA Appendix 7.2-A, Figure 2):

- Pam Rocks – Meteorological Service of Canada (MSC) Station 10459NN;

- Halibut Bank wave buoy – Environment Canada Station 46146;
- Sand Heads – MSC Station 1107010;
- Cherry Point wind station – National Oceanic and Atmospheric Administration (NOAA) Station CHYW1;
- Smith Island wind station – NOAA Station SISW1;
- New Dungeness wave buoy – NOAA Station 46088; and
- Neah Bay wave buoy – NOAA Station 46087.

Within the deep water model domain, a 1 km x 1 km grid of the Strait of Georgia and Juan de Fuca Strait was generated using data from existing hydrographic charts. Wind speed and direction were interpolated between the available wind record from these stations using an inverse distance weighting interpolation technique (spatial varying), which is a standard accepted approach used in wave models. For the time-varying component, a linear interpolation between spatial-varying fields was applied. In both cases, the interpolations were incorporated into the model code to produce deep water waves.

In regions where the modelling domains overlap, compare wind fields used in the wave assessment modelling with those generated by the NMM-WRF-CALMET meteorological modelling system used in the revised air quality assessment of the proposed Project to determine how well the two wind-fields match. Comment on the confidence that the wind fields used in the wave assessment modelling are appropriate.

As noted in the Panel's context to this information request, detailed three-dimensional wind field modelling using the Weather Research Forecast Non-hydrostatic Mesoscale Model (WRF-NMM) was performed as part of the RBT2 Air Quality Study (EIS Appendix 9.2-A).

The three-dimensional wind field used in the air quality assessment incorporated a vertical component, while the two-dimensional wind field applied to the wave modelling does not. Source functions were developed based on wind speed and direction at 10 m elevation for the wave modelling, while WRF-NMM incorporated atmospheric conditions at various elevations in the atmosphere as input. Although there is spatial overlap for the UMWM and WRF-NMM modelling domains, the air quality assessment modelling was based on 2010 wind field data while the wave environment assessment was based on 2012[1]. Since there is no temporal scale overlap, the requested comparison of wind fields cannot be provided.

Nevertheless, with respect to the appropriateness of the wind fields used in the wave assessment modelling, since actual wind field data from seven wind record stations within and proximal to the marine shipping area was used as input, and the method of interpolation is a proven and accepted numerical method, the VFPA is confident that the wind fields incorporated in the UMWM reasonably reflect wind field conditions in the marine shipping

[1] The assessment of air quality provided in EIS Section 9.2 incorporated meteorological data from 2010, as this year had highest frequency of calms for the five year period (2008 to 2012) of data reviewed from the Vancouver International Airport, thus providing for the most conservative assessment. The assessment of the wave environment provided in MSA Section 7.2 incorporated 2012 field data, as this data was available from the coastal geomorphology assessment (EIS Section 9.5).

area, and that the use of the UMWM is appropriate to meet the requirements of the wave environment assessment study, as outlined in the response to IR7-13.

References

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-15 Wave Environment – Baseline, Wind-driven Wave Climate

Information Source(s)

Marine Shipping Addendum: Appendix 7.2-A, Figures 4 and 5

Context

In Appendix 7.2-A of the Marine Shipping Addendum, the Proponent modelled wind-driven waves using local meteorology as input. The modelled waves were then evaluated by comparison with wave buoy data collected at Halibut Bank and New Dungeness, as well as wave data from an AWAC (Acoustic Wave and Current Profiler) station near Roberts Bank.

The model evaluation was presented in the form of wave height time series scatterplots (Figures 4 and 5 of Appendix 7.2-A). The Proponent stated that the scatterplots indicated that the model simulated the wave environment at these three sites reasonably well. However, based on the scatterplots, it appears that the model may have underestimated the height of extreme waves.

More information on the ability of the wave model to realistically simulate the wind-driven wave environment in the Salish Sea is required.

Information Request

Provide scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and AWAC Roberts Bank for all months of a year using available data.

Calculate root mean square error, mean bias error and slope of best fit line for each scatterplot.

Based on this analysis, discuss the ability of the wave model to accurately simulate the wave environment in the Salish Sea.

VFPA Response

Provide scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and AWAC Roberts Bank for all months of a year using available data.

In response to the Panel's request, the VFPA has provided scatterplots of modelled versus measured wave heights for all four quartiles of measured wave height at Halibut Bank, New Dungeness, and the AWAC Roberts Bank site for all months of a year using available data. It was assumed that a quartile signifies one of four groups into which equal numbers of a population are divided according to the distribution of values. Available wave information data is from hourly observations at Halibut Bank, New Dungeness, and at the Roberts Bank AWAC

station. **Table IR7-15-1** provides a summary of the assignment into quartiles of the observed wave height data at each station.

Table IR7-15-1 Summary of Observed Data at Halibut Bank, New Dungeness, and the Roberts Bank AWAC Station

Station	Number of Observations[a]	Wave Height Range (m)			
		1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Halibut Bank	8,784	0.53 – 3.15	0.31 – 0.53	0.15 – 0.31	0 – 0.15
New Dungeness	8,784	0.55 – 2.71	0.31 – 0.55	0.18 – 0.31	0 – 0.18
Roberts Bank AWAC	1,104	0.33 – 1.63	0.21 – 0.33	0.14 – 0.21	0 – 0.14

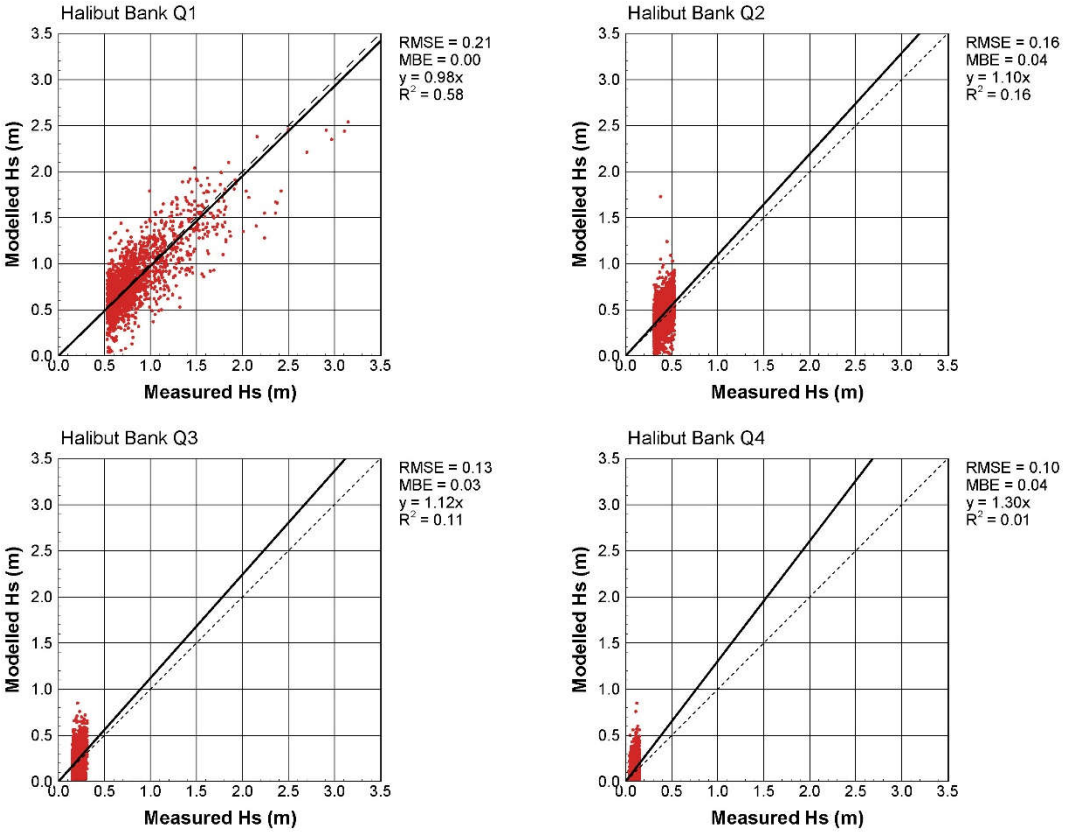
Note: a. 2012 was a leap year containing 366 days or 8,784 hours. The Roberts Bank AWAC station was operational for only part of the year.

Comparisons of modelled and measured significant wave heights for 2012 at Halibut Bank, New Dungeness, and AWAC Roberts Bank are provided in **Figures IR7-15-1** to **IR7-15-3**, respectively. The plots are generated by comparing hourly predictions of modelled wave heights to measured wave heights.

Calculate root mean square error, mean bias error and slope of best fit line for each scatterplot

The root mean square error (RMSE), mean bias error (MBE), slope of best fit line, and the corresponding R squared values are also shown on each plot. The RMSE represents the standard deviation of the aggregated differences between the modelled and observed wave heights and can be used to describe the accuracy of the model to predict the measured values. The MBE describes the direction of the error bias and its value is related to magnitude of values under investigation. A negative MBE occurs when the modelled values are smaller in value than the observed waves. Similarly, the slope of the best fit line is a measure of bias in the model predictions. A slope of 1 demonstrates that there is no bias, while a slope with a steepness greater than 1 indicates that the model is overpredicting the values, while a slope less than 1 indicates under prediction of wave heights. The R squared value is a statistical measure of how close the data are to the fitted regression line. An R squared value of 0% indicates that the model explains none of the variability in the observed values, while an R squared value of 100% indicates that the model explains all of the variability.

Figure IR7-15-1 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom) – Halibut Bank



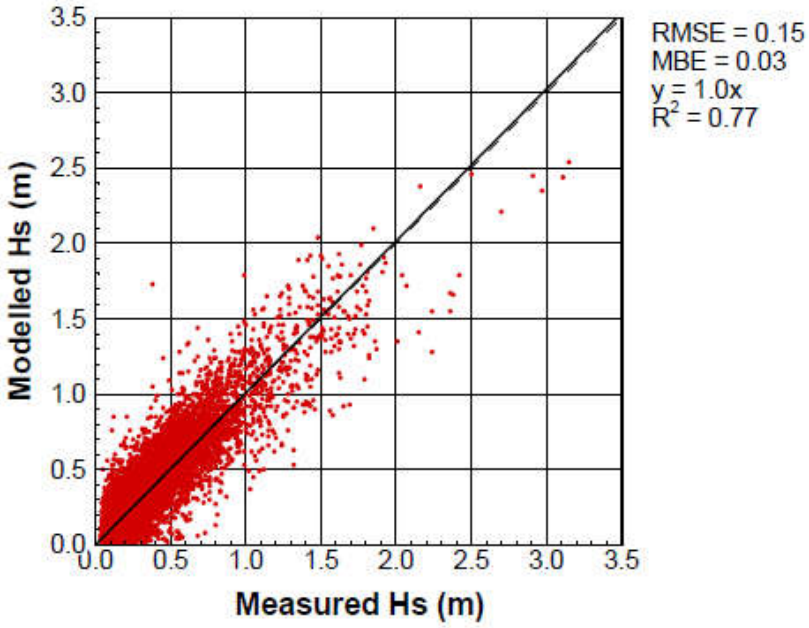


Figure IR7-15-2 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom) – New Dungeness

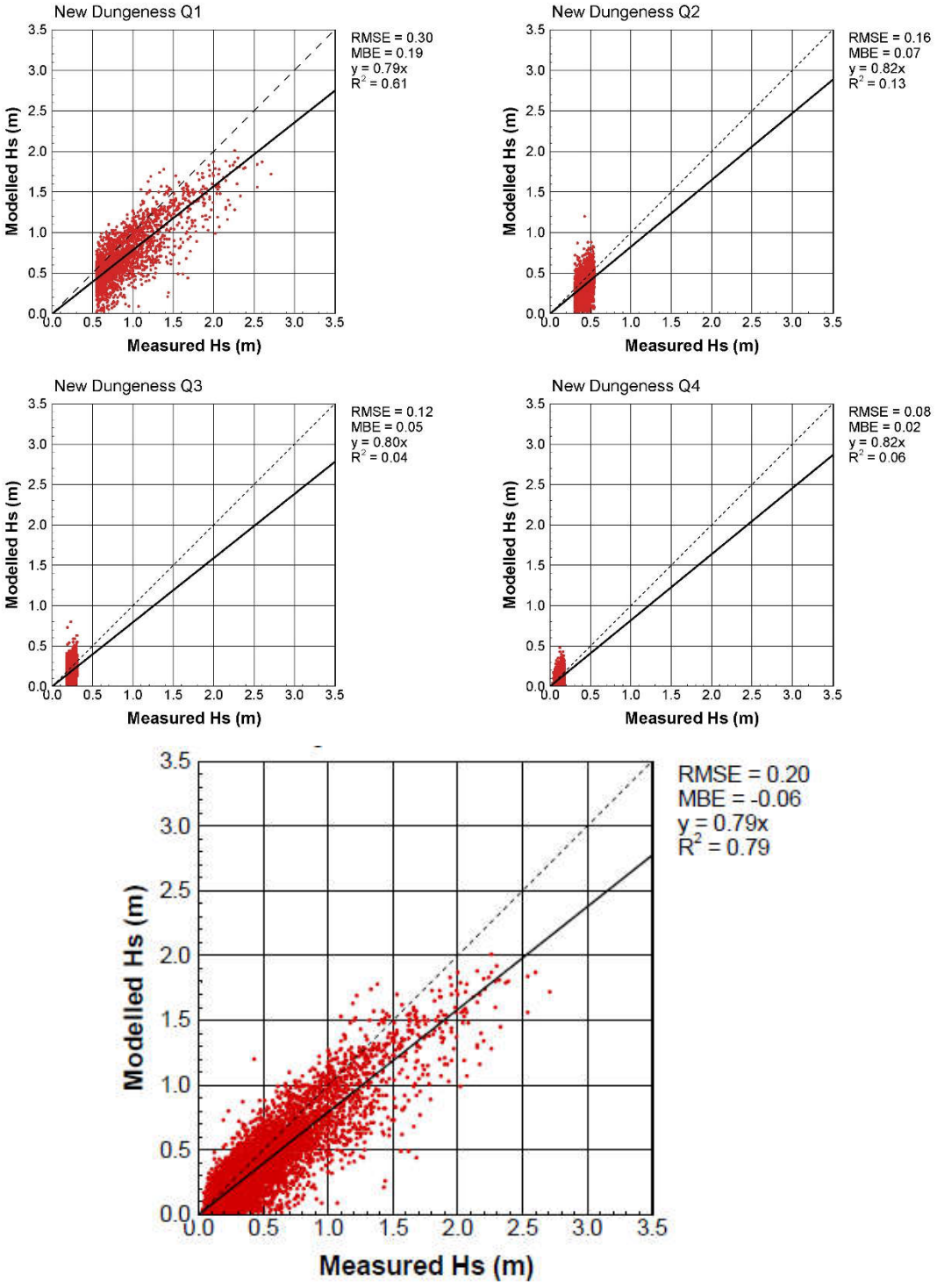
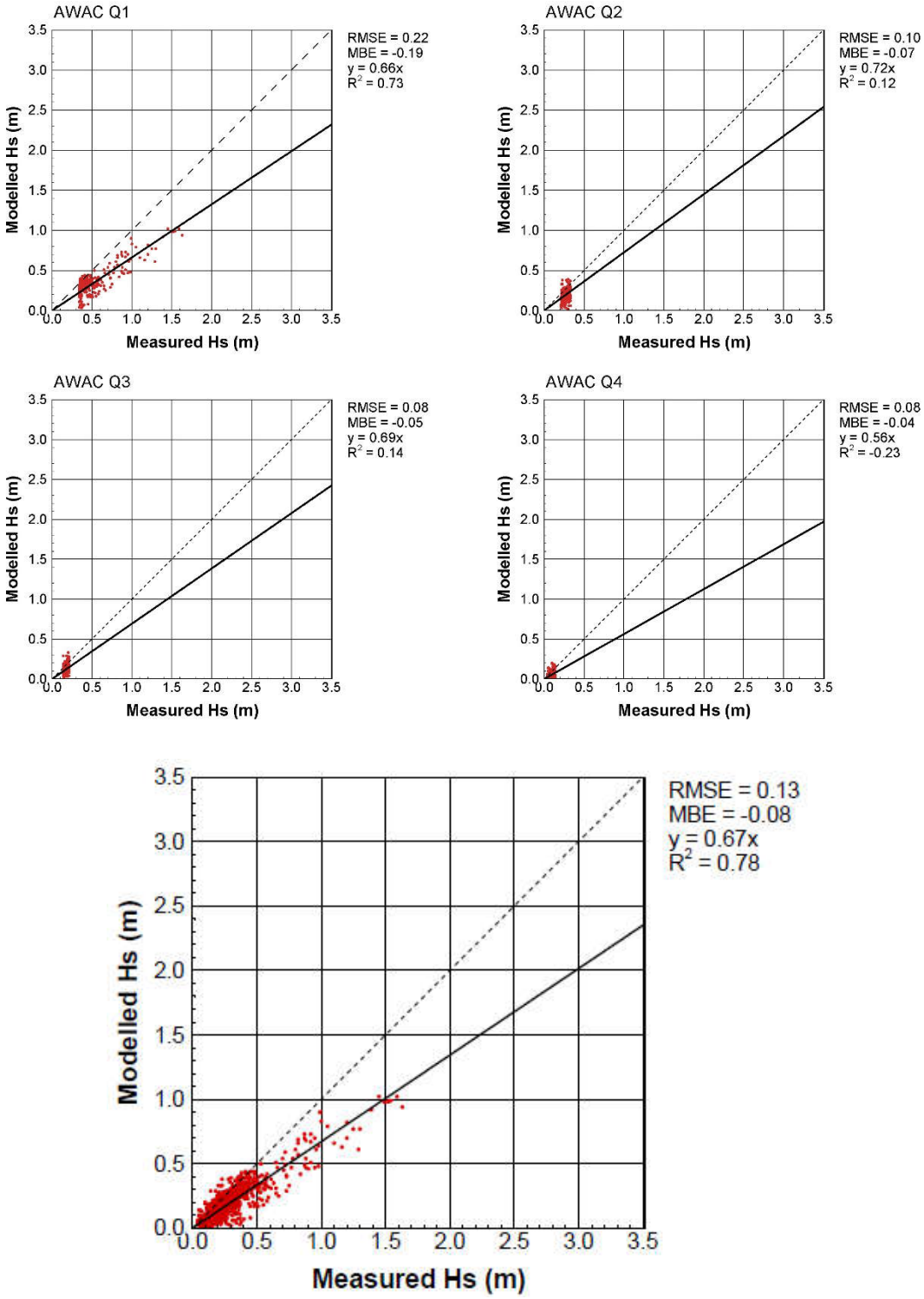


Figure IR7-15-3 Modelled versus Measured Waves by Quartile (Top) and Aggregated (Bottom)– AWAC Roberts Bank



Based on this analysis, discuss the ability of the wave model to accurately simulate the wave environment in the Salish Sea.

As stated in the response to IR7-13, a model, no matter how sophisticated, is a generalised representation of real-world phenomena that occurs as a result of highly complex physical interactions. Differences between observed and modelled predictions of wave heights are related to items such as time-based discrepancies (e.g., the time delay between waves responding to wind), direction discrepancies (e.g., the interpolation of wind direction between stations), and existing sea state (e.g., waves entering from outside the model domain).

The results indicate good agreement between modelled and measured wave heights at the Halibut Bank station. It is noted there is better performance demonstrated for the larger wave heights, and relatively poor performance demonstrated for the smallest wave heights. For instance, the R squared value calculated on the aggregated sample of wave heights is 0.77, but it is only 0.01 for the smallest quartile of wave heights.

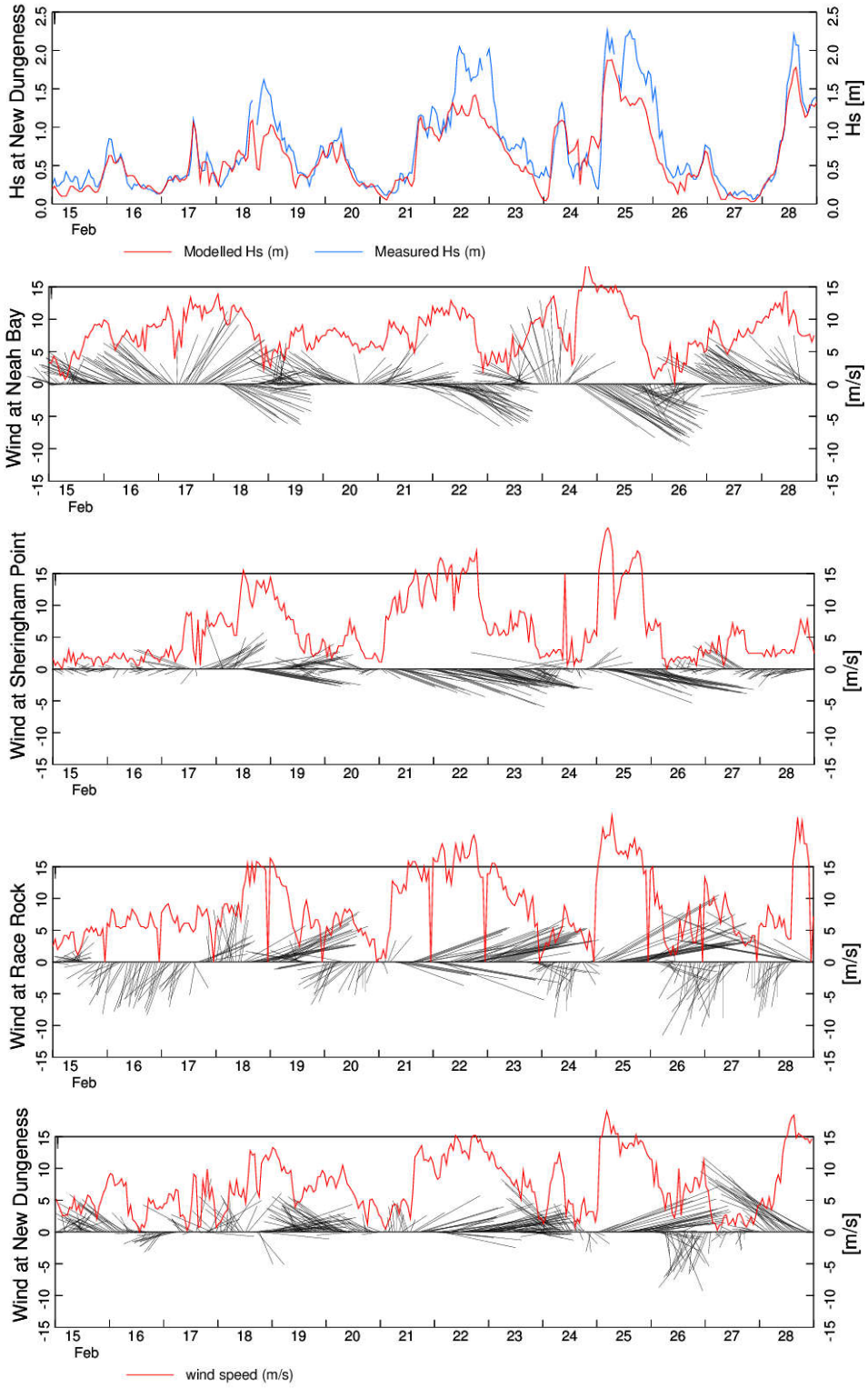
As expected, the deep water model, which does not account for nearshore wave transformation processes, underestimates the wave climate at the AWAC at Roberts Bank, where the shoaling effect across the delta front can be prominent. Nevertheless, the R squared value of the aggregated sample is 0.78.

The model underestimates the wave climate at the New Dungeness station, which is situated in a location where Juan de Fuca Strait, Haro Strait, and Puget Sound meet. The spatial and temporal wind fields used as energy inputs for the wave model were developed using a simple spatially varying interpolation method and with limited meteorological stations. The resulting wind fields may not be fully representative of the exact wind distribution along Juan de Fuca Strait and Haro Strait. The available meteorological stations with hourly wind data in Juan de Fuca Strait are shown in **Figure IR7-15-4**. Time-series of measured (blue line) and modelled (red line) wave heights at New Dungeness and measured winds from available meteorological stations for the period between February 15 and February 28, 2012 are shown in **Figure IR7-15-5**. The top panel in **Figure IR7-15-5** shows an increase in wave heights from 1.5 m to 2 m in the afternoon of February 22, 2012. However, no marked increased in wind speeds were measured at Neah Bay, Sheringham Point, Race Rock, or New Dungeness. Thus, in addition to the uncertainties with spatially varying wind fields, there could be other processes, possibly relating to atmospheric pressure, that contribute to the wave climate at New Dungeness.

The comparison of modelled and observed wave heights at Halibut Bank, AWAC Roberts Bank, and New Dungeness indicate that the deep water model underestimates the wave climates in Juan de Fuca Strait and in the nearshore region. Since the outputs from the deep water model are used as baseline wind climate conditions to assess changes from Project-associated vessel wakes, the underestimation of the wind-driven waves by the model will result in a more conservative assessment of the relative influence on wake-generated waves, as outlined in the response to IR7-13. The UMWM meets or exceeds the performance requirements to simulate the wave environment in the Salish Sea for the purposes of the assessing marine shipping associated with the Project.

Figure IR7-15-4 Available Meteorological Stations in Juan de Fuca Strait

Figure IR7-15-5 Time Series of Measured Winds, Waves, and Modelled Waves – New Dungeness



Note: The stick plots (black lines) indicate the direction to which the wind is blowing and the wind speed is indicted by the length of the stick, as scaled to the y-axis.

IR7-16 Wave Environment – Baseline, Wind-driven and Wake-driven Wave Climate

Information Source(s)

Marine Shipping Addendum: Section 7.2.4; Section 7.2.6; Appendix 7.2-A

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-1

Context

In Section 7.2.4 and Appendix 7.2-A of the Marine Shipping Addendum, the Proponent assessed the existing wave environment as consisting only of waves generated by wind action over water.

The analysis omits waves generated by the vessels of all sizes that pass through the marine shipping assessment area.

The analysis omits waves generated in the open ocean that pass through Strait of Juan De Fuca and enter the marine shipping assessment area.

Information Request

Discuss the potential consequences of using a numerical model that comprises only wind-generated waves and could underestimate the wave environment, in terms of the size and frequency of occurrence of waves, because it does not include vessel wake or ocean swell.

VFPA Response

As described in the response to IR7-13, the wave environment effects assessment utilised the University of Miami Wave Model (UMWM; Donelan et al. 2012) to characterise the existing wave climate. The model calculates waves based only on local winds and, therefore, the characterisation of the existing wave climate omits ocean swell and waves from passing vessels. Additional information on these elements of the wave climate is provided below.

Ocean Swell

Swell refers to waves generated in the open ocean in response to winds outside the local area. As stated in the Panel's context to this information request, swell generated in the open ocean is understood to pass through Juan de Fuca Strait and enter the marine shipping area. Because these waves are generated by winds outside the UMWM domain, they are not represented by the model. Swell is a relatively unimportant component of the existing wave climate in the marine shipping area, except in Juan de Fuca Strait (Segments C and D, and the southern part of Segment B). Omitting ocean swell that passes through Juan de Fuca Strait results in a more conservative assessment, as outlined below.

Figure 5 in Appendix 7.2-A of the Marine Shipping Addendum (MSA) shows modelled and measured wave heights for 2012 at Halibut Bank and the AWAC stations located in the Strait of Georgia, and at the New Dungeness station located at the east end of Juan de Fuca Strait (for station locations refer to Figure 2 in MSA Appendix 7.2-A). The New Dungeness station is exposed to swell passing through Juan de Fuca Strait, while the other stations are not exposed to swell because of the presence of the southern Gulf Islands.

There is good agreement between observed and modelled waves at Halibut Bank and AWAC stations. Because the Strait of Georgia and Haro Strait are dominated by wind-generated waves, the consequences of the model not representing ocean swell will not affect the assessment results in Segment A and the northern part of Segment B.

For Juan de Fuca Strait, the model often under predicts wave heights at New Dungeness (see Figure 5 and the response to IR7-15), particularly during the largest wave events, and it is likely that this discrepancy results from the fact that ocean swell (generated by non-local winds) is not included in the model. This discrepancy is further illustrated by comparing the wave roses presented in Figure 6 (observed waves at New Dungeness) and Figure 7 (modelled waves at New Dungeness) in Appendix 7.2-A of the MSA. The modelled results show almost no waves coming from the west, the direction from which swell would be expected. As outlined in MSA Appendix 7.1-A, further refinement of the model results that are under predicting conditions in Segments C and D and the southern part of Segment B during large wave events is unlikely to affect the assessment results. This is because the vessel-generated waves are only observed during calmer sea conditions. Additional information describing measured versus observed wave heights at these stations is provided in the response to IR7-15.

Vessel Wake

As summarised in Table 4-2 of the MSA and the response to IR4-04 (CEAR Document #1051[1]), there were 8,896 vessel movements through Segment B of the marine shipping area in 2012 (includes vessels of all types that carry the Automatic Identification System—see MSA Section 4.1.1 for a description). Waves from these passing vessels are not included in the characterisation of the existing wave climate calculated by the UMWM.

As shown in MSA Appendix 7.2-B: Figure 1, wake-generated waves vary in size depending on vessel type, vessel speed, and water depth. For the range of vessels considered in this wave environment study, wake height would be expected to be as high as 15 cm at an offset distance of 1 km from the sailing line when the vessel is travelling at 15.5 knots in water depth of 167 m. In water depth of 50 m, wake height would be expected to be as high as 22 cm at the same offset distance. Wake height is, therefore, well within the range of natural waves.

[1] CEAR Document #1051 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 4 (See Reference Document #946).

Potential Consequences of Using the UMWM That Does Not Include Vessel Wake or Ocean Swell.

The potential consequences of not including waves from passing vessels or waves generated in the open ocean outside the UMWM domain in the characterisation of the existing wave climate include the following:

- The magnitude and frequency of waves are likely under-represented in Juan de Fuca Strait, particularly during the largest wave events; and
- Periods of calm are likely overestimated in all areas of the marine shipping area, but particularly in the southern portion.

The potential consequences of under-representing the frequency and magnitude of waves is that wake-generated waves from Project-associated vessels will be more frequently predicted as being larger than the existing wind-generated waves by comparison. The consequence of overestimating periods of calm is that the chance of Project-associated vessel wake being present during periods of calm is actually smaller than that calculated. In both cases, the outcome results in a conservative assessment, and hence, the conclusions of the assessment that Project-associated wake-generated waves are expected to increase the number of vessel-generated waves by 6% in Segment B is over-predicted in relation to the existing wind-wave climate.

References

Donelan, M. A., M. Curcic, S. S. Chen, and A. K. Magnusson. 2012. Modeling Waves and Wind Stress. J. Geophys. Res., 117(C11).

IR7-17 Wave Environment – Numerical Modelling of Vessel Wake-driven Waves: Vessel Wake Study

Information Source(s)

Marine Shipping Addendum: Section 7.2.2.2; Appendix 7.2-B

Context

In Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum, the Proponent stated that the PIANC (1987) wake model was used, following the methodology presented in a draft vessel wake study prepared by Moffatt and Nichol (2011) for the proposed Kinder Morgan LNG project at Kitimat, British Columbia.

However, the Proponent does not provide a rationale for the application of the PIANC model in the assessment to calculate the height of the secondary waves in the marine shipping area.

Information Request

Provide the 2011 vessel wake study by Moffatt and Nichol that was cited In Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum.

Provide a description and explanation of the specific circumstances under which the vessel wake study by Moffatt and Nichol (2011) is relevant to the calculation of the height of secondary waves in the marine shipping area and describe the limitations of this application.

VFPA Response

Provide the 2011 vessel wake study by Moffatt and Nichol that was cited in Section 7.2.2.2 and Appendix 7.2-B of the Marine Shipping Addendum.

The Moffatt and Nichol (2011) Vessel Wake Study (the Study) report is provided in **Appendix IR7-17-A**. As indicated in Section 7.2 of the Marine Shipping Addendum (MSA), this draft report was prepared for the proposed Kitimat LNG Export Terminal as part of the TERMPOL Review Process[1].

[1] The TERMPOL Review Process, overseen by Transport Canada, is a technical review of marine terminal systems and transshipment sites that focuses on a design vessel's selected route in waters under Canadian jurisdiction to its berth at a proposed marine terminal or transshipment site, as well as the process of cargo handling between vessels, or off-loading from vessel to shore or vice-versa, including single point mooring facilities.

Provide a description and explanation of the specific circumstances under which the vessel wake study by Moffatt and Nichol (2011) is relevant to the calculation of the height of secondary waves in the marine shipping area and describe the limitations of this application.

Relevance of Moffatt and Nichol (2011) Vessel Wake Study to Calculation of Height of Secondary Waves

The Study is relevant to the calculation of the height of secondary wake-generated waves in the marine shipping area on the basis that the two study areas have a similar range of water depths and consider similar types of vessels. Given that the height of secondary waves are mainly influenced by these two variables, in addition to vessel speed, the application of the Study is therefore relevant to the Marine Shipping Addendum. This reasoning is further expanded upon below.

The Study involved the assessment of secondary wake-generated waves in Douglas Channel, B.C., a relatively narrow but deep channel. The Study used the PIANC (1987) formula to calculate the height of secondary waves at various offset distances from a transiting vessel. The Study report documented a logical methodology for assessing ship wake for navigation considerations and presented the theoretical background of the method.

Channel dimensions referring to 'deep' and 'narrow' are relative. As discussed in the response to IR7-18, the PIANC (1987) formula was developed for vessel waves in deep water conditions when the Froude number of the form F_h is less than 0.7. The average water depth in Segment B of the navigation channel varies between 44 m and 320 m. At an average speed of 15.5 knots for container vessels transiting through this segment, the maximum Froude number F_h is 0.38 and satisfies the deep water condition. The average channel width that was assessed in the Study was 2.3 km, which is narrower than the distance to shore from the international shipping routes for some areas of Segments A and C, and all of Segment D in the marine shipping area, but similar to the distance to shore from the shipping route in Zones 1, 2, and 3 of Segment B (the segment in which shoreline interactions from wake-generated waves were assessed in MSA Section 7.1). Refer to the response provided in IR7-22 for information on calculating wake-generated waves for wider channels in deep water.

Limitations of the PIANC (1987) Formula

The limitations of the PIANC (1987) formula, which was developed to assess secondary wake-generated waves, are described below with respect to the distance from the sailing line and vessel speed.

PIANC (1987) presents the formula in reference to designing shoreline erosion protection structures in inland waterways. As such, its application has mainly been used as a tool for predicting waves within a relatively short offset distance from the sailing line (e.g., within 2.5 km and less, as described above). While there have been a number of studies that have compared observed wake to predicted wake (e.g., Verhey and Bogaerts 1989), no studies could be identified that provide definitive limits to the application of the PIANC (1987) formula.

Kriebel and Seelig (2005) compared PIANC-based results to the results for an alternate equation for calculating ship wake, which used a unified Froude number that combines the channel depth-based and vessel length-based forms. A similar comparison, which was provided in the response to IR4-02 of CEAR Document #1051[2], demonstrated that the PIANC (1987) formula estimated higher wake heights at most locations within Segment B, as compared to wake heights determined via the Kriebel and Seelig (2005) formula. These results are consistent with the Study that concluded that "Given that the channel cross section is very much greater than the vessel cross section, the calculation of wave heights is relatively insensitive to the actual channel dimensions used." In other words, once the channel cross section (width) is much greater than the width of the vessel, vessel speed and vessel shape are the major determinants for wake height.

The PIANC (1987) formula is potentially limited by the range of observed values under which it was developed, a limitation identified in a number of wake prediction models reviewed by Sorensen (1997). For vessel speeds that exceed the range of observed values that were used to develop the formula, the wake height predictions may not be accurate. While the specific limitations were not quantified, some insight was included in Kriebel and Seelig (2005), which compared observed versus predicted waves using the PIANC (1987) formula for vessel speeds ranging from 7 knots to 10 knots. A more detailed discussion of the specific limitations with respect to vessel speed and wave attenuation as a function of distance from the sailing line is included in the response to IR7-22.

References

Kriebel, D. and W. M. Seelig. 2005. An Empirical Model for Ship-generated Waves. Proceedings from the Fifth International Symposium on Ocean Wave Measurement and Analysis. Available at http://adac.uaa.alaska.edu/css/images/pdf/online_course/presentation/Ship%20waves%20slides%20-%20Kriebel%20and%20Seelig%202005.pdf. Accessed October 2017.

Sorensen, R. M. 1997. Prediction of Vessel-Generated Waves with Reference to Vessels Common to the Upper Mississippi River System (ENV Report 4). Report prepared for U.S. Army Engineer District, Rock Island, St. Louis, and St. Paul, Bethlehem, PA. 30 pp.

Verhey, H. J. and M. P. Bogaerts. 1989. Ship Waves and the Stability of Armour Layers Protecting Slopes. *Delft Hydraulics Publication No. 428* (pp. 12). Paper presented at the 9th International Harbour Congress, Antwerp, Belgium, 20-24 June 1989.

World Association for Waterborne Transport Infrastructure (PIANC). 1987. Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways. Report of Working Group 4 of the Permanent Technical Committee - Permanent International Association of Navigation Congress.

[2] CEAR Document #1051 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 4 (See Reference Document #946).

Appendices

Appendix IR7-17-A Moffatt and Nichol (2011) Vessel Wake Study

APPENDIX IR7-17-A
MOFFATT AND NICHOL (2011) VESSEL WAKE STUDY

VESSEL WAKE STUDY

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VESSEL WAKE STUDY

May 5th, 2011

M&N Project No. 7333

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1. INTRODUCTION

In 2006 Moffatt & Nichol prepared a comprehensive Metocean (meteorological and oceanographic) study for Douglas Channel to support the preliminary engineering design of the Kitimat LNG terminal. The 2006 study was intended primarily to provide design information related to wind, wave and current forces on the jetty structures within Bish Cove. Further metocean analysis was planned for the detailed design phase, as well as to support the TERMPOL review process which considers navigational issues not only within Bish Cove, but also more generally along the planned navigational route.

This report documents additional analysis on vessel wakes expected along Douglas Channel caused by tugs and LNG carriers en route to and from the terminal. Since vessel wakes and their impacts are of relevance to navigation, this report was intended to form part of the studies comprising the TERMPOL submittal. Although the TERMPOL process is only in its early stages, this report is being released earlier than planned to support discussions related to the NEB hearing process.

Revision 1 of this report is considered a draft in progress and is subject to revision following further analysis and internal review.

2. VESSEL-GENERATED WAVES

The following description of the characteristics of ship-generated environmental effects in narrow channels is adapted from several sources, including the Permanent International Association of Navigation Congresses PIANC (1987), Sorensen (1997), Schiereck (2001) and previous Moffatt & Nichol reports (2003).

Two main types of waves are generated by moving vessels:

- Primary wave (or drawdown wave); and,
- Secondary waves caused by discontinuities in the hull profile.

Primary waves are often minor in wide, deep channels, therefore, this study will focus primarily on secondary wave generation and attenuation at selected distances away from the vessel for both LNG carriers and escort tugs.

2.1 PRIMARY WAVE (DRAWDOWN)

From a hydrodynamic point of view, flow near a moving ship is similar to flow around a fixed body such as bridge abutment. As the ship moves, water flows past the vessel hull in the opposite direction of travel. This flow is known as the return current. The velocity head of the water flowing past the vessel causes the water level along the vessel's length to fall in order to maintain the total head (energy) constant. Therefore the water level around the vessel is lowered. This water level depression is sometimes referred to as the primary wave (Figure 2.1).

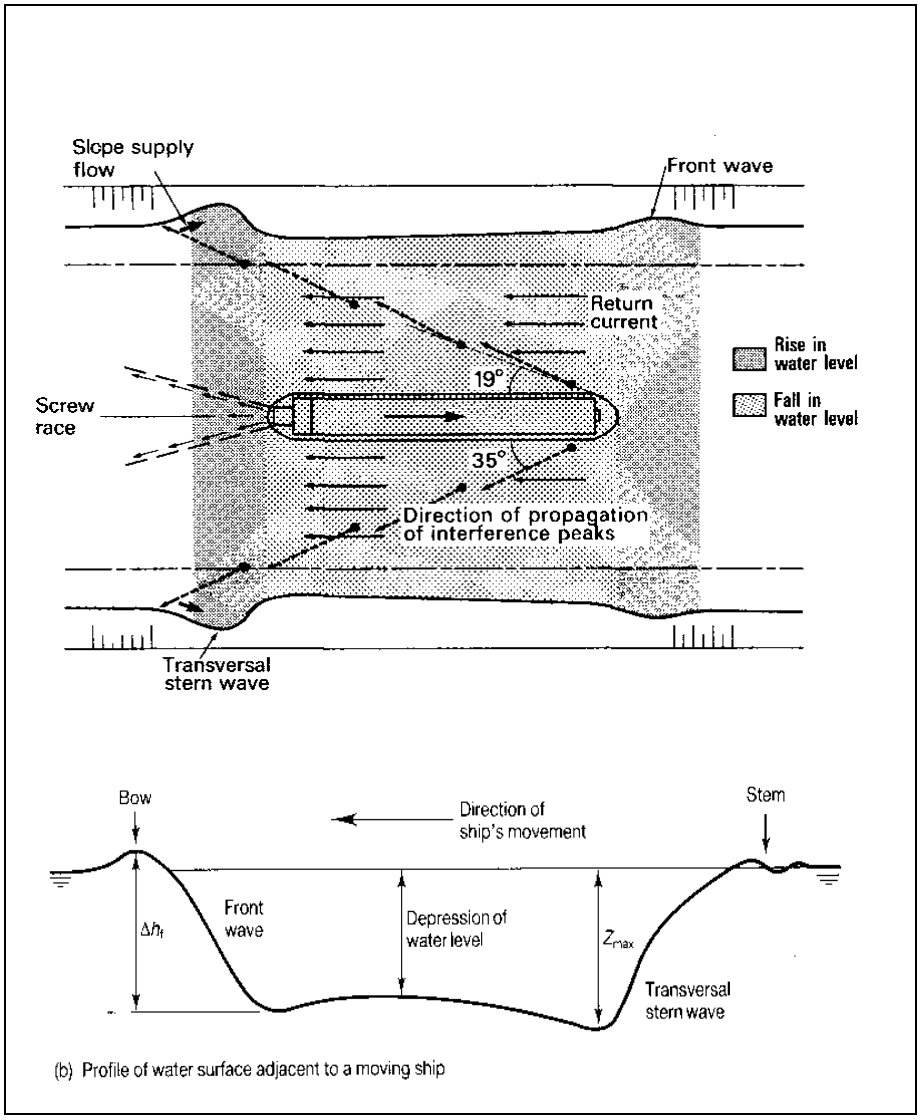

Figure 2.1: Primary Wave Components of Ship Induced Water Motions *(Source: PIANC 1987)*

The transition between the undisturbed water level in front of the vessel and the water level depression takes the form of sloping water surface referred to as the front wave. The water surface immediately ahead of the vessel is elevated by the approaching ship, so the total height of the front wave is slightly greater than the water level depression.

The transversal stern wave is the transition between the water level depression and the normal water level behind the ship.

The combination of water level depression, front wave and transversal stern wave, referred to as drawdown, acts like a long solitary wave with a length similar to that of the ship. Therefore, drawdown is generally not easily observed in the field, other than in the case of

relatively large vessels sailing in confined channels. Drawdown does not break at the shoreline as normal waves, instead, it is more like a tidal pulse, rising and falling as the vessel passes.

2.2 SECONDARY WAVES

When responding to the sharp rise and fall in the water surface at the bow and the stern, inertia causes the water surface to lag behind its equilibrium position and produces a surface oscillation. In turn this produces a pattern of free surface waves, called secondary waves that propagate from the vessel (Figure 2.2 and Figure 2.3). The pattern spreads out from the vessel with decreasing wave amplitudes due to diffraction. The pattern consists of symmetrical sets of diverging waves that move obliquely out from the sailing line and a single set of transverse waves that move in the direction of the sailing line. The transverse and diverging waves meet to form cusps, also called interference peaks, along a pair of lines that form an angle of 19.5 degrees with the sailing line. The highest waves in the pattern are found along this cusp locus line. A similar pattern of waves, but typically with much lower amplitudes, is generated at the vessel stern and superimposed on the pattern generated out from the bow. These secondary waves are the ones that are generally visible in the field and even on aerial photographs. Secondary waves are always “short” and act like normal waves which means, that the general linear wave theory relations for wavelength, celerity, etc. are valid. These waves may also break as they approach the bank shoreline and the breaker type (i.e., spilling, plunging, or surging) is dictated by the same slope and wavelength relationships as for other normal waves.

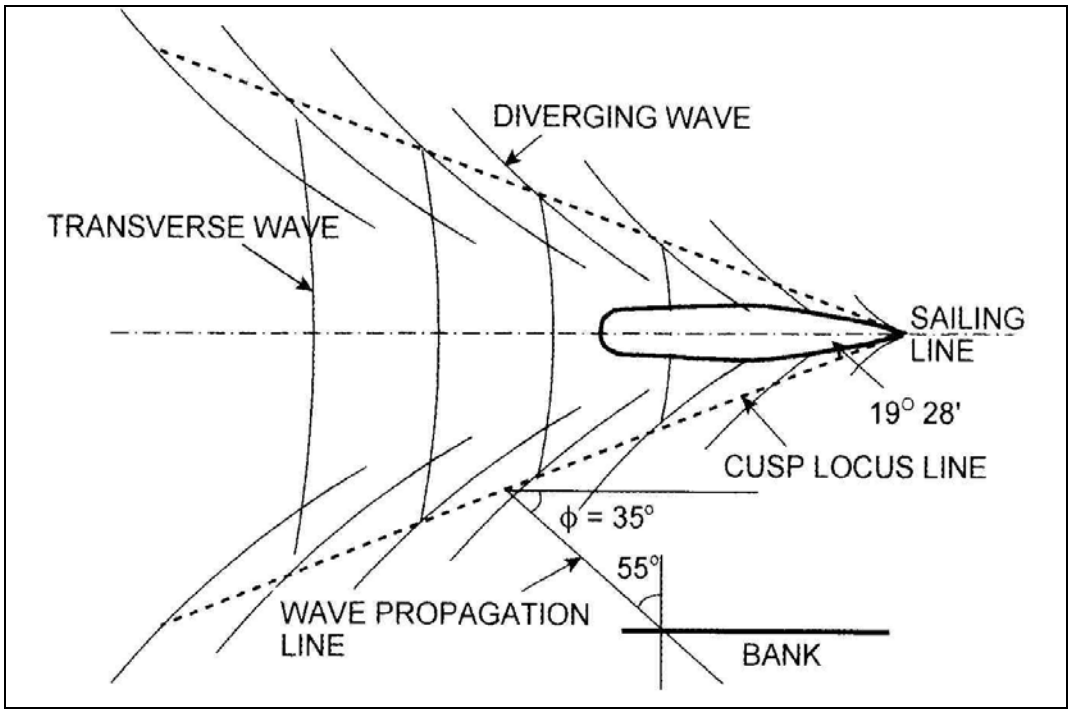

Figure 2.2: Secondary Wave Pattern *(Source: Schierech, 2001)*

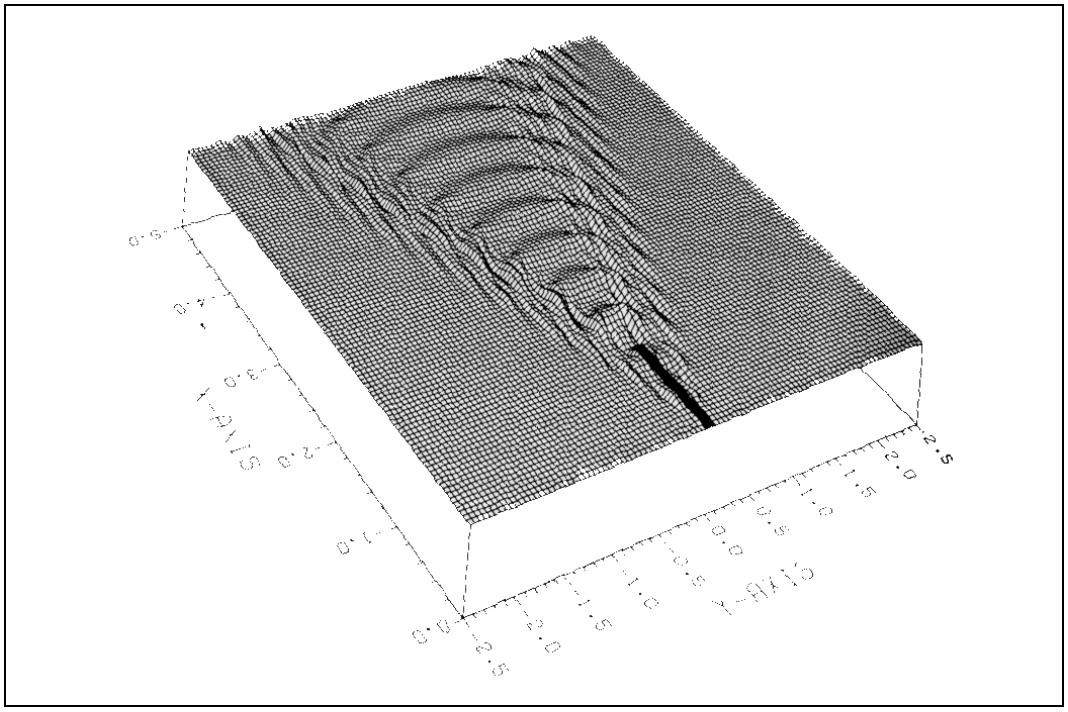

Figure 2.3: Isometric View of Secondary Wave Pattern *(Source: Faltinsen, 1990)*

3. ASSUMPTIONS

The empirical equations used to generate primary and secondary wave heights rely on a number of parameters. The assumptions made for each of the parameters are discussed in this section. With the exception of the type of vessel and cross-sectional area of the hull, hull form geometric description is not significant when using empirical formulas to determine primary and secondary wave heights. Furthermore, where the channel cross section is large relative to the vessel hull cross section, and the water depth is large relative to the vessel draft, the calculated wave heights are relatively insensitive to the actual hull dimensions. Therefore the results of this study are considered applicable to the entire range of LNG vessels expected to call at the Kitimat LNG terminal (i.e. 125,000 m^3 to 215,000 m^3 capacity).

Vessel speed (v_s) is the forward speed of the vessel, and greater velocity results in a larger wake. The at-sea service speed of today's typical LNG carriers can range up to 19 knots; however it is likely that once the vessels approach the coast (and especially once they are within relatively confined waterways) the speed would be reduced. Typical escort tug speeds range between 8 to 12 knots. Vessel speeds within Douglas channel, Wright Sound, and Principe Channel are expected to be no more than approximately 10-12 knots. The actual vessel transit speed profiles will be examined in greater detail during the Termpol studies. For the purposes of this study, vessel speeds up to 16 knots were considered for both tankers and tugs, although it is recognized that the actual vessel speed profile within Douglas Channel will be considerably less (10-12 knots) so these calculations are conservative.

A vessel cross-sectional area of 600 m^2 was assumed based on the largest LNG vessel anticipated for this project (i.e. a 215,000 m^3 Qflex vessel) having dimensions of:

- Maximum beam width of 50.0 m; and,
- Draft equal to 12.0 m.

Based on the navigation charts of Douglas Channel, the channel depth (h) is generally more than 200 fathoms (365 m). Approximately 23 kilometers from the head of the channel, depth steadily decreases from 200 fathoms to approximately 120 fathoms (220m) near the Kitimat LNG terminal. The channel continues to shoal to approximately 50 fathoms (90 m) near Kitimat. It is assumed that vessels will be slowing as they near the Kitimat LNG terminal and speeds will be well less than the maximum escort speed of 12 knots.

The southern part of Douglas Channel between Money Point and Kitkiata Inlet is generally between 3 and 4 km wide. The middle part of Douglas Channel between Kitkiata Inlet and the northern end of Maitland Island is somewhat narrower, averaging 2 to 3 km, with the

narrowest point opposite of Emilia Island measuring approximately 1.4 km wide. The northern part of the channel (i.e. Kitimat Arm, closest to Bish Cove) varies between 1.7 km and 3.6 km wide.

For the purposes of this study an average width of 2.3 km was used with an average depth of 365 m, which provides a channel cross-sectional area of approximately 850,000 m^2. Given that the channel cross section is very much greater than the vessel cross section, the calculation of wave heights is relatively insensitive to the actual channel dimensions used.

4. CALCULATED WAVE HEIGHTS

This section focuses on prediction and analysis of ship generated drawdown, return current and secondary waves (interference peaks).

4.1 PRIMARY WAVE HEIGHT AND RETURN CURRENT

The theoretical effects of a ship transiting a narrow channel can be derived from the Bernoulli equation (Schiereck, 2001). The primary wave height (z) and return current (u_r) are defined as follows:

$$\frac{v_s^2}{gh} = \frac{2z/h}{(1 - A_s/A_c - z/h)^{-2} - 1}$$

$$\frac{u_r}{\sqrt{gh}} = \left[\frac{1}{1 - A_s/A_c - z/h} - 1\right]\frac{v_s}{\sqrt{gh}}$$

Where:

h = Channel depth

A_s = Cross sectional area of ship

A_c = Cross sectional area of channel

g = Gravitational constant

Previous studies using these equations have correlated well with field-measured data (i.e. “Arthur Kill Ship Wave Study” Moffatt & Nichol, 2003).

A calculation using a vessel speed of 16 knots and the channel cross-sectional area (1400m wide x 220 m deep) results in a primary wave height z of 0.015 m and a return current u_r of 0.017 m/s. These values reflect the large size of the channel cross-sectional area compared to the ship cross-sectional area. For sensitivity analysis the calculation was repeated using a much shallower channel depth of 36 m (This is representative of an isolated shoal at Dixon Island Narrows, although the majority of the channel is in fact much deeper). Using the shallower depth, the values for primary wave height and return current increase to 0.105 m and 0.124 m/s respectively. Given the small magnitude of these values, further study of primary waves is not considered to be warranted.

4.2 SECONDARY WAVE HEIGHT

A PIANC working group report on the design of canal revetments gives the following equation for secondary waves (interference peaks) generated by vessels in inland waterways (PIANC 1987).

Secondary wave height (H) is defined as:

$$H = h * \alpha_1 * \left(\frac{S}{h}\right)^{-0.33} * F_h{}^4$$

Where: F_h = Froude number, $F_h = \frac{V_s}{\sqrt{gh}}$

S = Distance between vessel's side and the point of interest

α_1 = Coefficient depending on vessel type

h = Channel depth

V_s = Vessel speed

The associated period (T) of the secondary wave is defined by:

$$T = 0.82 * V_s * \frac{2\pi}{g}$$

For a given vessel size and α_1 shape, maximum water level depression and concomitant wave heights increase with increasing Froude number. The Froude number increases with increasing vessel speed but decreases with increasing channel depth. For a given Froude number and channel dimensions, wave heights generally increase with vessel size.

Verhey and Bogaerts (1989) give values for the α_1 coefficient based on laboratory and field tests in deep water (i.e., F_h less than< 0.7 for large tankers). The coefficient α_1 has values of:

- 1.0 for tugs, patrol boats, and loaded conventional inland motor boats;
- 0.5 for empty European barges; and,
- 0.35 for empty conventional motor vessels.

Schiereck (2001) recommends a value of 1.2 as a reasonable upper limit of the available experimental data.

For this study, the coefficient α_1 was taken to be 0.7 for tankers and 1.0 for tugs. Because of the larger value of the coefficient α_1 for tugs, secondary waves for tugs will be larger than the tankers. During escort operations, the vessels will be traveling at the same speed and the secondary waves generated by the tugs and tankers will not combine, because the sources of wave generation remain separated by a constant distance. The overall effect from a reference point some distance away from the vessels will be a longer duration of incoming waves (Figure 4.1).

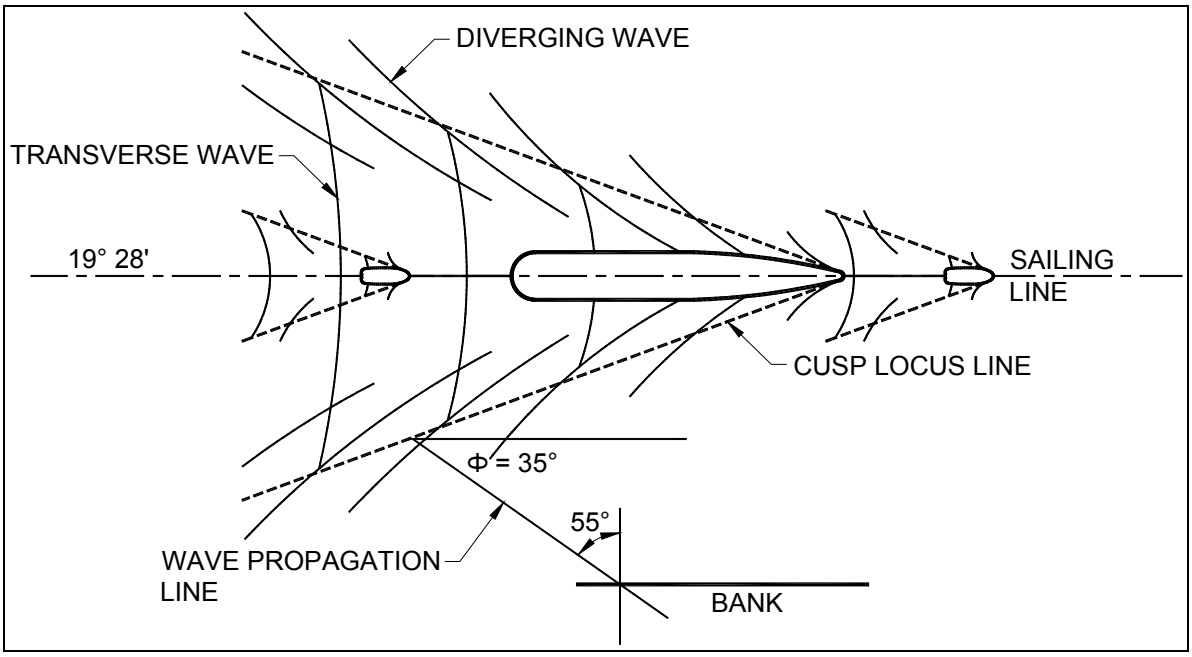

Figure 4.1: Secondary Wave Pattern for Multiple Vessels with Same Velocity *(Source: Schierech, 2001)*

Secondary wave heights for a tanker, for a range of velocities and distances from the vessel, are presented in Figure 4.2. At a distance of 10 m from the vessel hull and a speed of 16 knots, the secondary wave height is approximately 0.3 m, decaying to a height of approximately 0.08 m at distances of 1000 to 1500 m from the vessel (typical distances from the centerline of Douglas Channel to the shoreline). At the assumed maximum escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are less than 0.02 m.

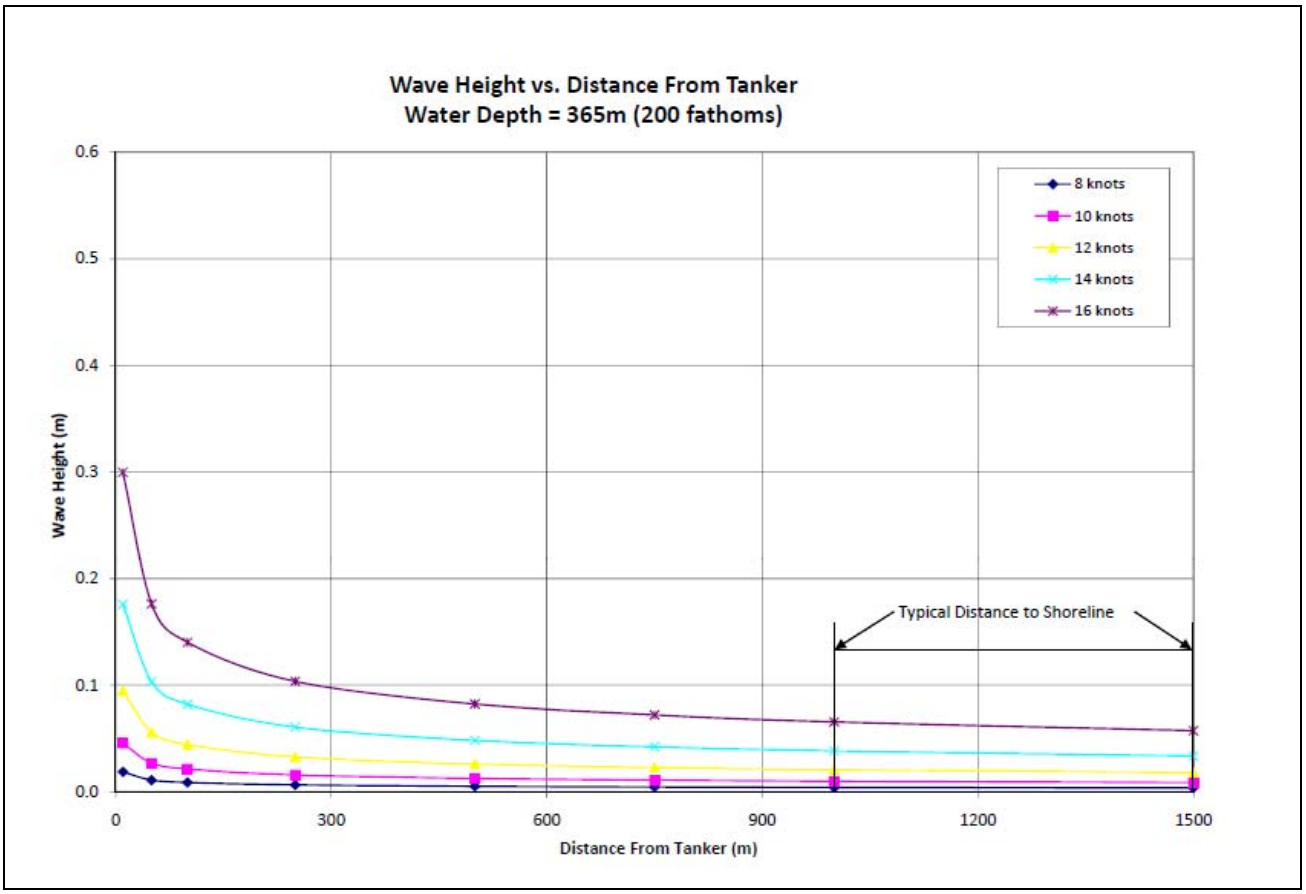

Figure 4.2: Secondary Wave Heights – Tankers, 200 fathoms

A sensitivity case was run for a water depth of 100 fathoms, and the results indicate that the generated wave heights are somewhat higher, as shown in Figure 4.3. At the assumed maximum escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are approximately 0.03 m.

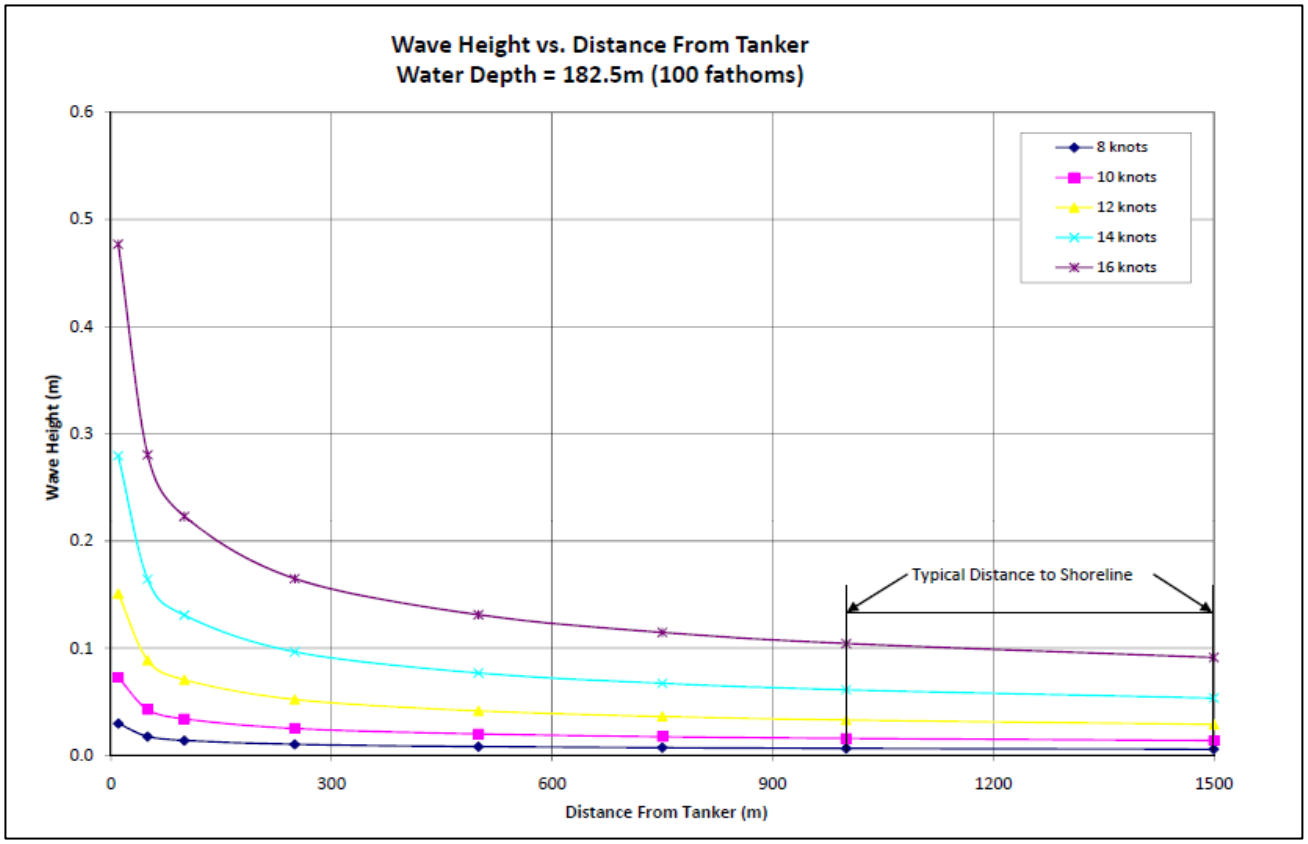

Figure 4.3: Secondary Wave Heights – Tankers – 100 fathoms

Secondary wave heights for the escort tug, for a range of velocities and distances from the vessel, are shown in Figure 4.4. At a distance of 10 m from the tug hull and a speed of 16 knots, the secondary wave height is approximately 0.43 m, decaying to a height of approximately 0.1 m at distances of 1000 – 1500 m from the vessel (typical distances from the centerline of Douglas Channel to the shoreline). At the assumed escort velocity of 12 knots, secondary wave heights at distances of 1000 to 1500 m from the vessel are approximately 0.03 m for the escort tug.

The wave heights quoted above for tugs are based on using a α_1 coefficient of 1.0. A sensitivity case was run for the escort tug condition using the reasonable upper limit of the α1 coefficient of 1.2 and a velocity of 16 knots. At distances of 1000 to 1500 m from the vessel, secondary wave heights are 20% greater, but are still less than 0.12 m. These wave heights represent the upper bound of expected wave heights near the shoreline.

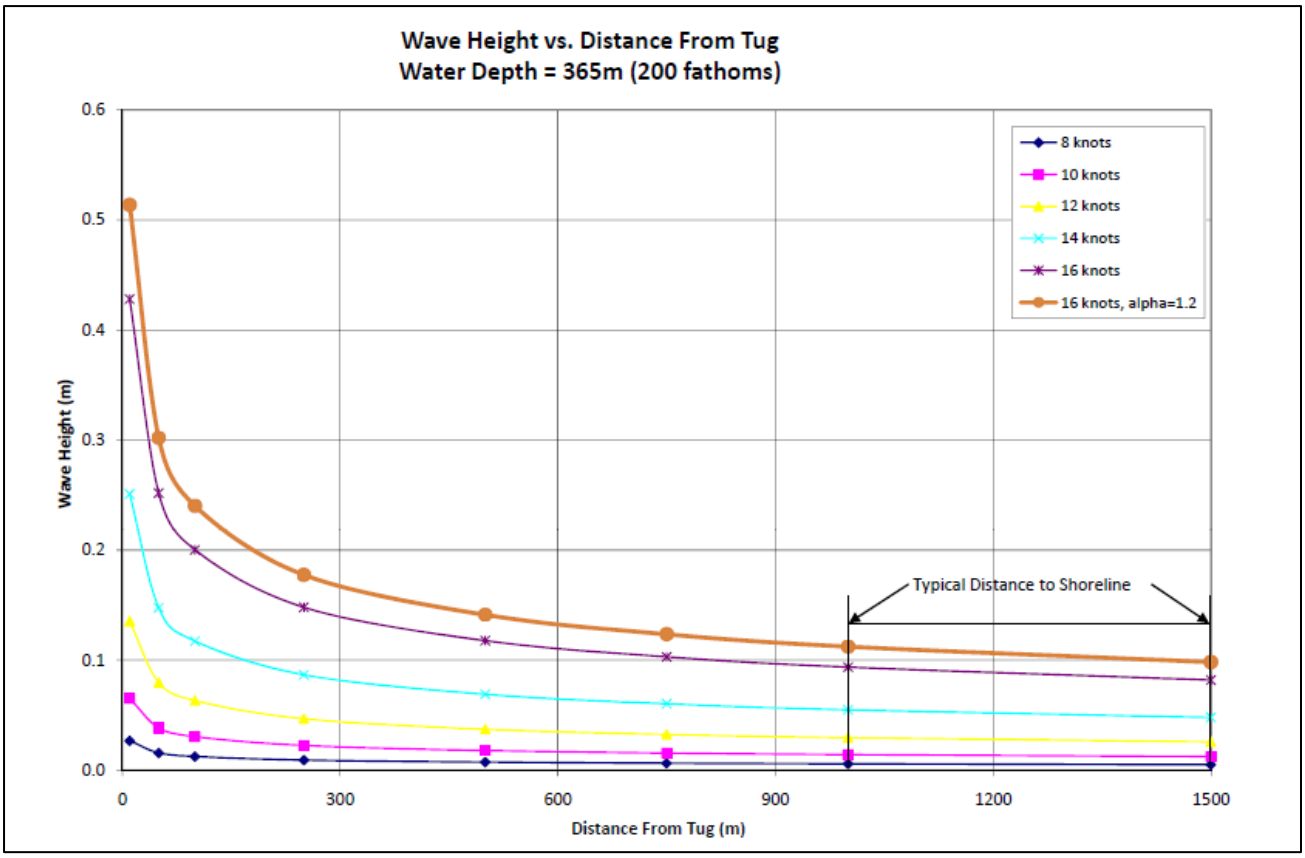

Figure 4.4: Calculated Escort Tug Secondary Wave Heights

Wave period, length and height for selected distances from the escort tug versus vessel speed are presented in Table 4.1. For the LNG tankers, wave period and wave length are the same, with smaller wave heights. At expected escort velocities of 12 knots, the secondary wave period is 3.2 seconds, decreasing to 2.2 seconds at a vessel speed of 8 knots.

Table 4.1: Vessel Speed versus Wave Period, Wavelength and Wave Height

Vessel Speed (knots)	Secondary Wave Period (s)	Wave Length (m)	Wave Height at Distance from Tug (m)				
			10 m	100 m	500 m	1000 m	1500 m
16	4.3	29.2	0.43	0.20	0.12	0.09	0.08
14	3.8	22.3	0.25	0.12	0.07	0.05	0.05
12	3.2	16.4	0.14	0.06	0.04	0.03	0.03
10	2.7	11.4	0.07	0.03	0.02	0.01	0.01
8	2.2	7.3	0.03	0.01	0.01	0.01	0.01

The wake heights predicted above are for calm water conditions. Winds, currents and ambient waves can potentially affect wake heights if they are aligned (and especially if they are in opposing directions). However, vessel waves would tend to be moving across the axis of the

channel, while winds and currents would tend to be moving along the channel. Interactions between wakes, winds, currents and ambient waves are therefore not expected to be significant.

The potential impact of ship and tug wakes can be assessed in qualitative terms by comparing the wave heights to naturally occurring ambient waves. For example, wind and wave data have been recorded for more than 20 years at the Nanakwa Shoal ocean data buoy, located in Douglas Channel approximately 10 km from the Bish Cove site. Analysis of these data indicates that ambient wave conditions exceed 0.1 m in height approximately 68% of the time, and exceed 0.2 m 39% of the time, both calculated on a long term, year round basis. During storm events, the waves in Douglas Channel of course can be much larger. For example, during the period 1988 through 2005, the maximum annual significant wave heights recorded at the Nanakwa Shoal buoy averaged 0.8m, with the overall maximum significant waves measured at 1.47m in 1996. The calculated wake heights are clearly quite small relative not only to storm conditions but also to average ambient wave conditions in Douglas Channel, and are therefore considered to be insignificant in terms of their potential for increased shoreline erosion or impact on other vessels.

5. SUMMARY OF FINDINGS

The findings of this study are summarized as follows:

- Because of the relatively deep and open channel, predicted primary wave heights caused by tankers and escort tug traffic are low, i.e. 0.025 m.
- At normal escort speeds between 8 and 12 knots, secondary waves caused by tankers and tugs are small at distances that correspond to the distance between the center of the channel and shoreline, generally well less than 0.1m.
- At a typical maximum speed for an escort tug of 16 knots, secondary wave heights at 1000 m from the tug are about 0.1 m.
- These wave heights are small compared to the naturally occurring wind-generated waves within Douglas Channel, and so are not expected to have a significant effect on shoreline erosion or other marine traffic operating in the area.

6. REFERENCES

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4) Schiereck, G.J. Introduction to Bed, Bank and Shore Protection. Delft University Press. 2001.

5) Sorensen, R.M. "Prediction of Vessel-Generated Waves with Reference to Vessels Common to the Upper Mississippi River System". Prepared for US Army Corps of Engineers. 1997.

6) Verhey, H.J. and Bogaerts, M.P. "Ship Waves and the Stability of Armour Layers Protecting Slopes". Proceedings of the 9th International Harbor Congress, Antwerp, Belgium. 1989.

ABBREVIATIONS

α_1 ..... Coefficient Depending on Vessel Type
A_s ..... Cross-Sectional Area of Ship
A_c ..... Cross-Sectional Area of Channel
F_h ..... Froude Number
m/s ..... Metre Per Second
g ..... Gravitational Constant
h ..... Channel Depth
H ..... Secondary Wave Height
PIANC ..... Permanent International Association of Navigation Congresses
s ..... Second
S..... Distance between Vessel's Side and Point of Interest
T..... Period
u_r ..... Return Current
v_s or V_s ..... Vessel Speed
w ..... Channel Width
z ..... Primary Wave Height

GLOSSARY

Cross-sectional Area: The ratio of the immersed area of the midship section of a vessel to the area of the circumscribing rectangle, the width of which is the beam, B, at the waterline and the depth of which is the draft, T, for which the ratio is calculated.

Cusp Locus Line: The line formed by the peaks of convergence of diverging waves and transverse waves.

Diverging Wave: A pattern of diverging waves that moves obliquely out from the sailing line of the vessel.

Drawdown: The combination of water level lowering around a vessel caused by vessel speed, front wave and transversal stern wave.

Fetch-limited: Generated waves limited by the length of the fetch as opposed to the strength or duration of the wind.

Froude Number: A dimensionless number used to quantify the resistance of an object

	moving through water and compare objects of different sizes.
Hydrodynamic;	The study of fluid motions.
Interference Peak:	A peak caused by the convergence of peaks of non-co-linear waves.
Revetments:	Structures placed on banks or cliffs in such a way as to absorb the energy of incoming waves. They are usually built to preserve the existing uses of the shoreline and to protect the slope.
Sailing Line:	The path of the vessel.
Transverse Wave:	Vessel-generated waves perpendicular to the sailing line.
Transversal stern Wave:	The transition between the water level depression and the normal water level behind the vessel.
Wave Propagation Line:	The path of a wave.

IR7-18 Wave Environment – Numerical Modelling of Vessel Wake-driven Waves: Additional Details

Information Source(s)

Marine Shipping Addendum: Figure 4-4; Section 7.2.4.2; Section 7.2.7; Appendix 7.2-A; Appendix 7.2-B, Figure 1

Context

The uncertainty and reliability analysis provided by the Proponent in Section 7.2.7 of the Marine Shipping Addendum does not address the uncertainty arising from the use of the PIANC (1987) model of vessel wake, rather than measured vessel waves.

In Appendix 7.2-B of the Marine Shipping Addendum, the Proponent appears to have determined a vessel Froude number based on water depth, as is appropriate for vessels in shallow water (as defined by the depth to draft ratio). Waters along the vessel track in Zones 1, 2 and 3 are deep (as defined by the depth to draft ratio). In deep water applications, the Froude number must be based on vessel length.

In Figure 1 of Appendix 7.2-B, the Proponent provided wave heights for four vessel types (Empty Conventional Motor Vessels, Empty European Barges, Vessels and Tugs and Patrol Boats), but did not provide results for the classes of container vessels that would use the proposed Project terminal.

An analysis of the magnitude of uncertainty in vessel wake-driven waves is needed.

Information Request

Confirm that secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights, rather than secondary waves caused by discontinuities in the hull profile as asserted in the Marine Shipping Addendum.

Confirm that "H" in the PIANC (1987) secondary wave formula (as presented in Marine Shipping Addendum Appendix 7.2-B) is wave height, and that "h" is the channel depth.

Justify the appropriateness of using the Froude number for shallow water calculations in the PIANC (1987) model. If this is deemed inappropriate, use the deep-water form in all wave calculations and present revised tables and figures, as appropriate.

Reproduce the plots in Appendix 7.2-B, Figure 1, but plot dimensionless wave height against dimensionless cross-track distance. The plot for various vessel types should include vessels that will use RBT2, using examples from Marine Shipping Addendum Figure 4-4. Wherever appropriate, include measured wave height from actual or model vessels.

Provide an assessment of maximum probable error in secondary wave height at shorelines as calculated by the PIANC (1987) model for waves in Zones 1, 2 and 3.

Reassess the conclusion that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

Specify at what shoreline locations vessel wake would be distinguishable from the spectrum of wind-generated waves during calm conditions.

VFPA Response

Confirm that secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights, rather than secondary waves caused by discontinuities in the hull profile as asserted in the Marine Shipping Addendum.

The VFPA confirms that secondary wake-generated waves are caused by discontinuities in the hull profile, as asserted in the Marine Shipping Addendum (MSA), and can also be described as resulting of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights. Further explanation is provided below.

Secondary wake-generated waves, the focus of the wave environmental effects assessment provided in MSA Section 7.2, are caused by discontinuities in the hull profile, as opposed to primary waves, which are related to the drawdown effect when a ship hull displaces water in a relatively narrow and shallow channel. This simplified definition, which was also used in the Moffatt and Nicholl (2011) Vessel Wake Study (Appendix IR7-17-A of the response to IR7-17), was used in the wave environment effects assessment to provide an accessible language description to differentiate the two main types of waves rather than to provide a technical description of the mechanism of wave generation by a vessel. Similar language is also included in PIANC (1987): "Secondary ship waves are generated particularly at the bow and stern of the ship and at any other discontinuities along the hull of the vessel."

Various sources from the scientific and technical literature provide a more complete technical description of secondary waves. For instance, PIANC (1987) expands upon the above definition as follows: "The waves comprise transverse and diverging waves, which together form interference peaks…". Moffatt and Nicholl (2014) provide the following explanation of wave formation from a vessel:

> *"As the vessel displaces water during its passage a varying pressure distribution develops along the hull of the vessel producing an increased pressure at the bow and stern and a pressure drop along the midsection. The associated pressure gradients produce waves that propagate out from the bow and the stern of the vessel.*
>
> *The waves emanating from the bow are commonly named bow wake and follow a diverging pattern along the path of the vessel as they propagate out from the sailing line. A series of transverse waves, stern waves, propagate along the sailing line in the direction opposite to the vessel transit.*
>
> *The stern waves are typically smaller than the bow wake. The largest wave heights are encountered where the transverse waves and the diverging waves intersect,*

which occurs along the cusp locus line, which has been found to form an angle of 19.28° relative to the sailing line."

Based on the information provided above, the alternative definition of secondary waves stated in the information request, namely that "secondary (wake-driven) waves are the result of bow waves coinciding with stern waves and forming incidental peaks with amplified wave heights" is, therefore, also technically correct.

Confirm that "H" in the PIANC (1987) secondary wave formula (as presented in Marine Shipping Addendum Appendix 7.2-B) is wave height, and that "h" is the channel depth.

The VFPA confirms that "H" in the PIANC (1987) formula refers to wave height and that "h" is the channel depth.

The following form of the PIANC (1987) formula was presented in MSA Appendix 7.2-B:

$$H = h * \alpha_1 * \left(\frac{s}{h}\right)^{-0.33} * F_h^4$$

It was incorrectly stated that 'H' refers to channel depth. In fact 'H' refers to the calculated wave height. Channel depth is represented by the term 'h'. The error was likely caused by automatic capitalisation in the word processing program.

Justify the appropriateness of using the Froude number for shallow water calculations in the PIANC (1987) model. If this is deemed inappropriate, use the deep-water form in all wave calculations and present revised tables and figures, as appropriate.

As clarification, the Froude number, as calculated specifically for this wave environment assessment and presented in MSA Appendix 7.2-A, satisfies the deep water condition and is, therefore, appropriate for application in the marine shipping area. The justification for the appropriateness for the deep water condition is provided below.

The PIANC (1987) formula presented above contains the term F_h, the Froude number:

$$F_h = \frac{V_s}{\sqrt{gh}}$$

Where,

h = channel depth

V_s = vessel speed

g = acceleration due to the earth's gravity

The PIANC (1987) was developed for vessel waves in deep water conditions when the Froude number of the form F_h is less than 0.7. For example, the average water depth in Segment B of the navigation channel varies between 44 m and 320 m. With an average speed of

15.5 knots for a container vessel transiting through Segment B (as stated in MSA Table 4-5), the maximum Froude number F_h is 0.38, which satisfies the deep water condition.

An alternative form of the Froude number (F_L) utilising ship length, Ls, instead of channel depth, h, was also considered in developing the formula for vessel wake height. It was found, however, that the ship's length and the block coefficient do not have a large influence on secondary waves (Schiereck 1993). The two length variables that were found to have greater effect on the height of vessel wake are vessel draught, d, and entrance length, L_e. Entrance length, a measure of the curvature of the bow, is defined as the distance from the vessel's bow to the commencement of the parallel mid-body section. These vessel characteristics have a greater effect because discontinuities in the ship's hull are responsible for the emission of pressure waves. The influence of vessel geometry on vessel wake is represented by coefficients α_1 and α_2 which are defined as follows:

$$\alpha_1 = \alpha_2 * \left(\frac{d}{Le}\right)$$

Where,

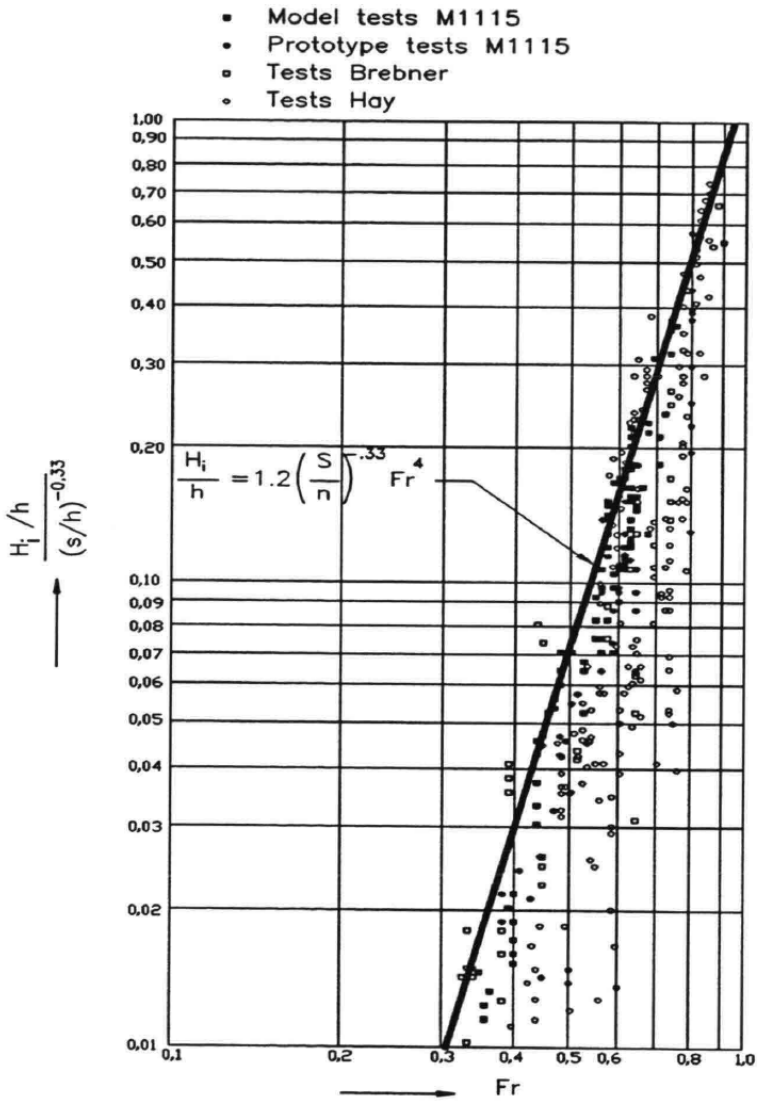
d = vessel draught

L_e = entrance length

α_2 varies between 1.5 and 4.0. The large variation is because the coefficient covers all types of vessels, from ocean going carriers to barges and small crafts. When no experiment or field data is available, a conservative value of 4.0 is recommended (Schiereck 1993).

Figure IR7-18-1, reproduced from Schiereck 1993, illustrates the relationship between calculated wake heights based on the PIANC (1987) formula and field data from hundreds of wake-generated wave measurements. The solid line is derived using the equation with α_1 value of 1.2. The figure shows that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit for estimating wake height. Therefore, when a vessel's entrance length is unknown, a safe upper limit of the α_1 value of 1.2 is recommended (Schiereck 1993)

Figure IR7-18-1 Relationship of Calculated Wake Height Using PIANC (1987) Formula with Field Wake Height Measurements



Source: Schiereck 1993.
Note: Solid line is derived using the PIANC (1987) formula with α_1 value of 1.2.

The following α_1 coefficient values were published in Verhey and Bogaerts (1989):

- α_1 = 1.0, for tugs, patrol boat, and loaded conventional inland motor vessels;
- α_1 = 0.5, for empty European barges (wave heights produced by loaded barges are relatively small and can be neglected); and
- α_1 = 0.35, for empty conventional motor vessels.

Ocean-going vessels such as tankers and container ships are not expected to generate wakes greater than those generated by tugs. For the wave environment effects assessment, an α_1 value of 0.7 for container ships was adopted. As a comparison, an α_1 value between 0.24 and

0.64 was estimated for liquified natural gas carriers associated with the Woodfibre Project (Moffatt and Nichol 2014).

Based on the above information, the method used to calculate ship wake through Segment B relies on an appropriate Froude number, as applied to the PIANC (1987) formula.

Reproduce the plots in Appendix 7.2-B, Figure 1, but plot dimensionless wave height against dimensionless cross- track distance. The plot for various vessel types should include vessels that will use RBT2, using examples from Marine Shipping Addendum Figure 4-4. Wherever appropriate, include measured wave height from actual or model vessels.

The plots presented in Figure 1 of MSA Appendix 7.2-B are reproduced in **Figure IR7-18-2** using dimensionless wave height against dimensionless cross-track distance as requested. The vessel wake is normalised in the form of gH/Vs^2. The dimensionless cross-track distance is normalised in the form of s/Ls, where Ls is ship length.

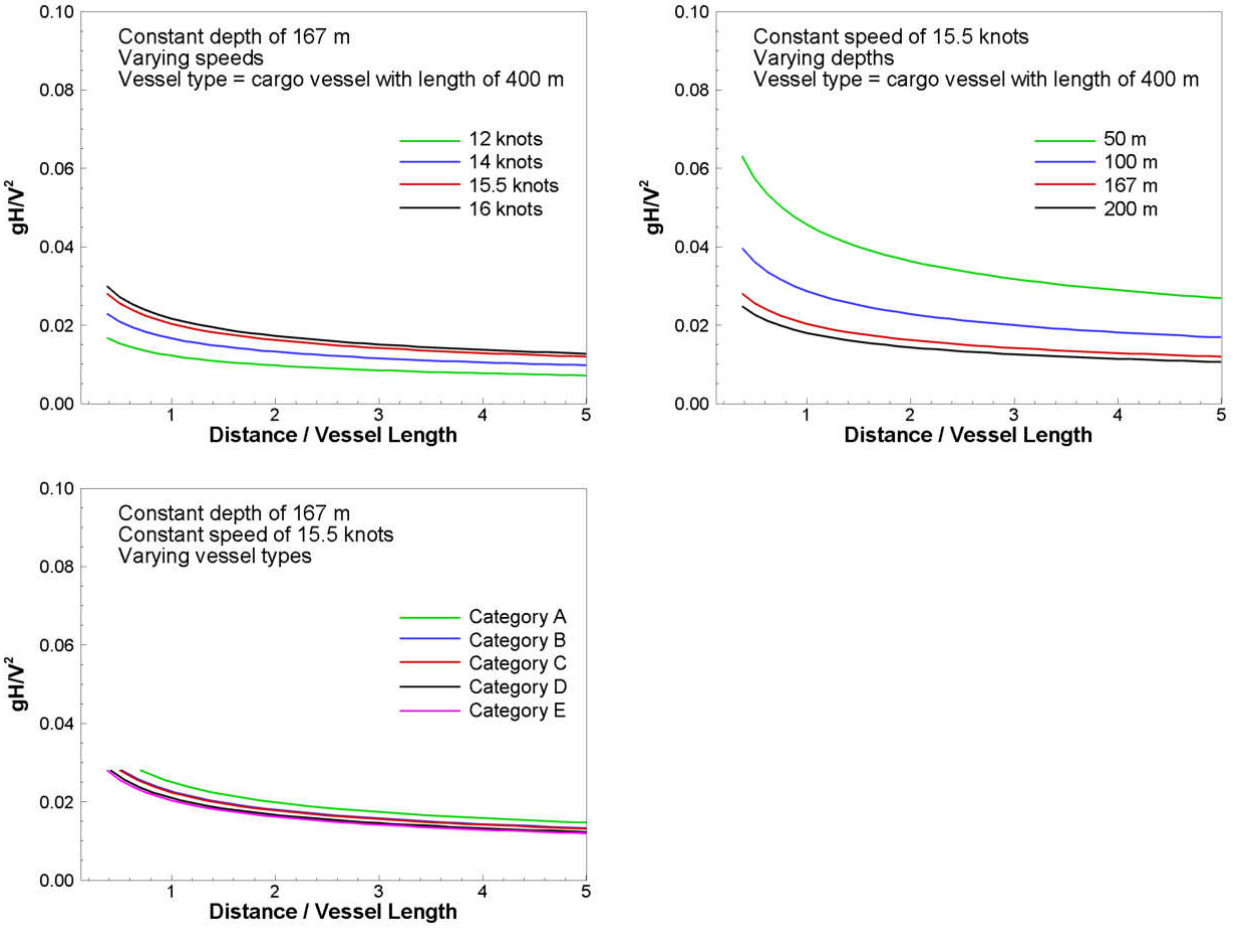
The following ship length information was used along with an α_1 value of 0.7 for the plots of the various vessel categories listed in MSA Figure 4-4:

- Category A – 215 m length for a 2,500 twenty-foot equivalent unit (TEU) vessel;
- Category B – 290 m length for a 3,400 to 4,500 TEU vessel;
- Category C – 300 m length for a 6,000 to 8,000 TEU vessel;
- Category D – 366 m length for a 12,500 vessel; and
- Category E – 400 m length for a 18,000 TEU vessel.

It is not possible to estimate wake for the region immediately beside the ship hull using the PIANC (1987) formula (vessel wake approaches infinity). There is generally insufficient dispersion within one boat length to clearly define the periods of the key waves within this nearfield range[1]. The minimum length shown in MSA Figure 4-4 is 137 m for a 500 to 800 TEU container ship. The distance away from the vessel used to generate the **Figure IR7-18-2** plots ranged between 150 m and 2,000 m.

[1] It is also dangerous for other vessels to operate this close to a large ship, and therefore, nearfield vessel wakes (<150 m) are not considered to be an assessment concern.

Figure IR7-18-2 Dimensionless Wave Height versus Dimensionless Cross-track Distance Plots

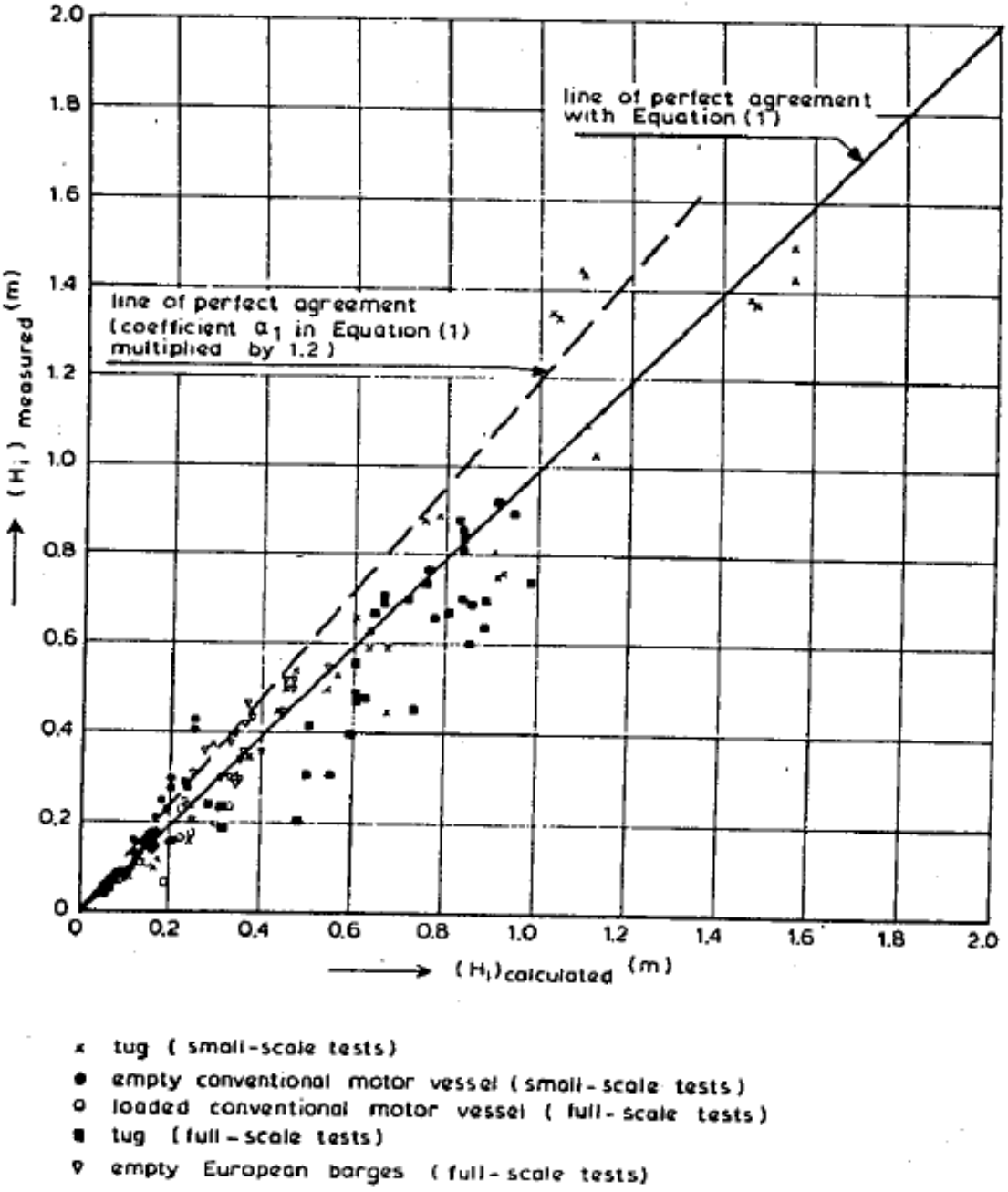


Provide an assessment of maximum probable error in secondary wave height at shorelines as calculated by the PIANC (1987) model for waves in Zones 1, 2 and 3.

No digital experimental or field data from published literature is readily available to evaluate the requested maximum probable error for each specific vessel type assessed. **Figure IR7-18-3** shows the comparison by Verhey and Bogaerts (1989) of measured and calculated wave heights for a range of vessel types. The solid line in the figure represents the line of perfect agreement using the PIANC (1987) formula with α_1 value of 1.0. The dashed line represents the line of perfect agreement with α_1 value of 1.2.

Similar to the results shown above in **Figure IR7-18-1**, these results show that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit as compared to the available field data. The maximum vessel wake reaching near the shoreline before breaking in Segment B is estimated to be 0.12 m. **Figure IR7-18-3** shows small deviations between measured and calculated vessel wakes when the wake values are less than 0.2 m.

Figure IR7-18-3 Comparison Between Measured and Calculated Wave Heights

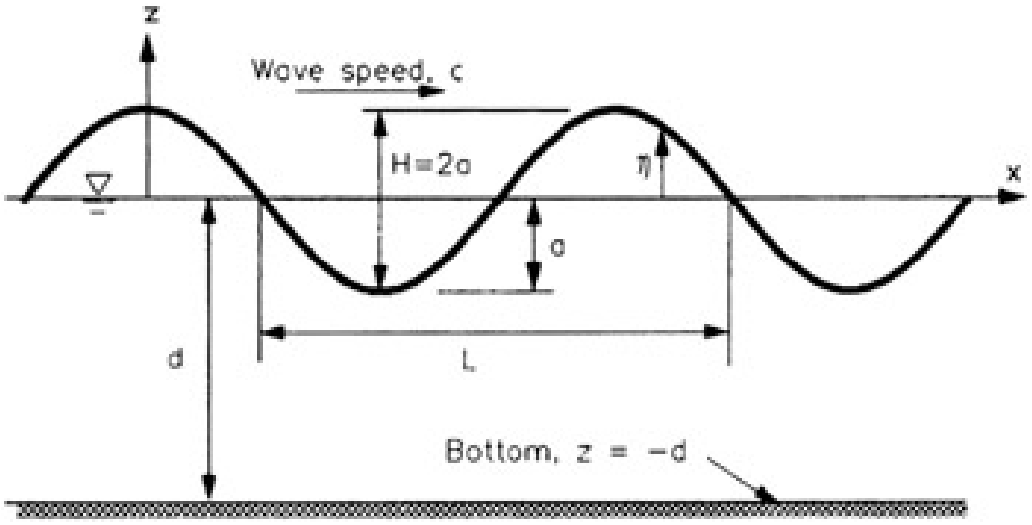


Source: Verhey and Bogaerts (1989).
Notes: Solid line represents the line of perfect agreement using the PIANC (1987) formula with α_1 value of 1.0. Dashed line represents the line of perfect agreement with α_1 value of 1.2.

Reassess the conclusion that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

Waves are generally described in terms of wave height (distance between trough and crest), wavelength (distance between wave crests), and wave period (time between wave crests). as illustrated in **Figure IR7-18-4**.

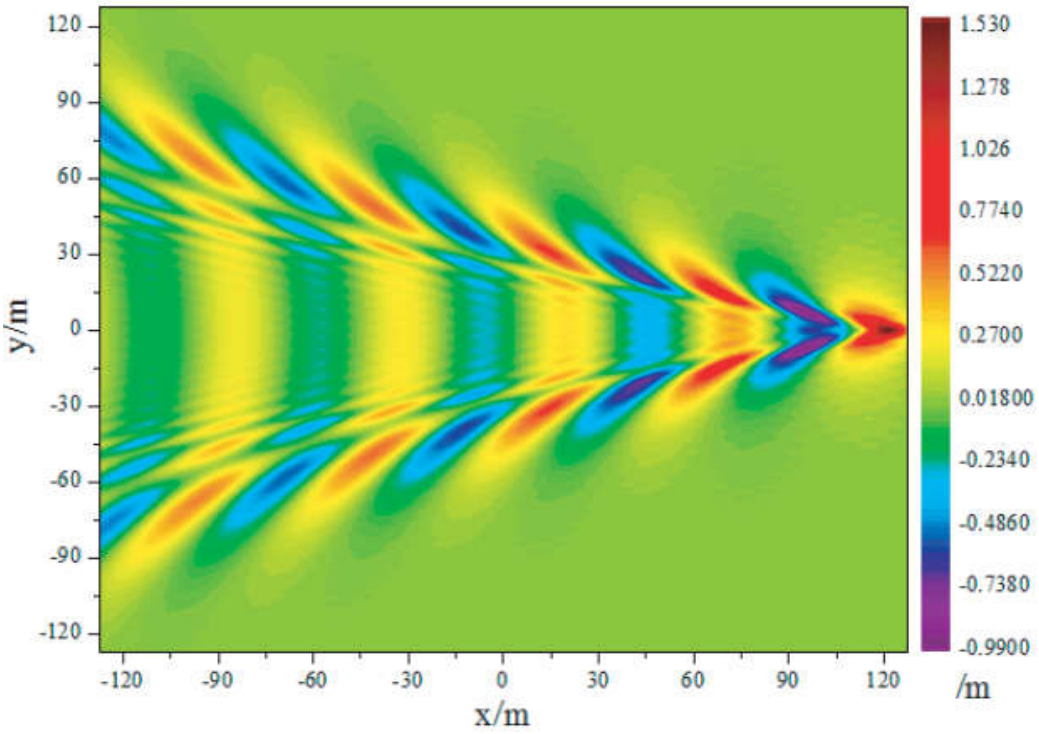
Figure IR7-18-4 Components of a Wave, including Wave Height, Wavelength, and Wave Period



While vessel wakes and wind-generated waves have different sources, a simple wind generated wave exhibits similar characteristics to a vessel wake-generated wave that has travelled away from the vessel. Although steeper and sharper waves are often observed closer to the line of travel of the vessel, waves several vessel lengths away follow the classic wave theory shown in **Figure IR7-18-4**, thereby providing a good basis for comparison of waves generated by vessel wake and wind-generated waves.

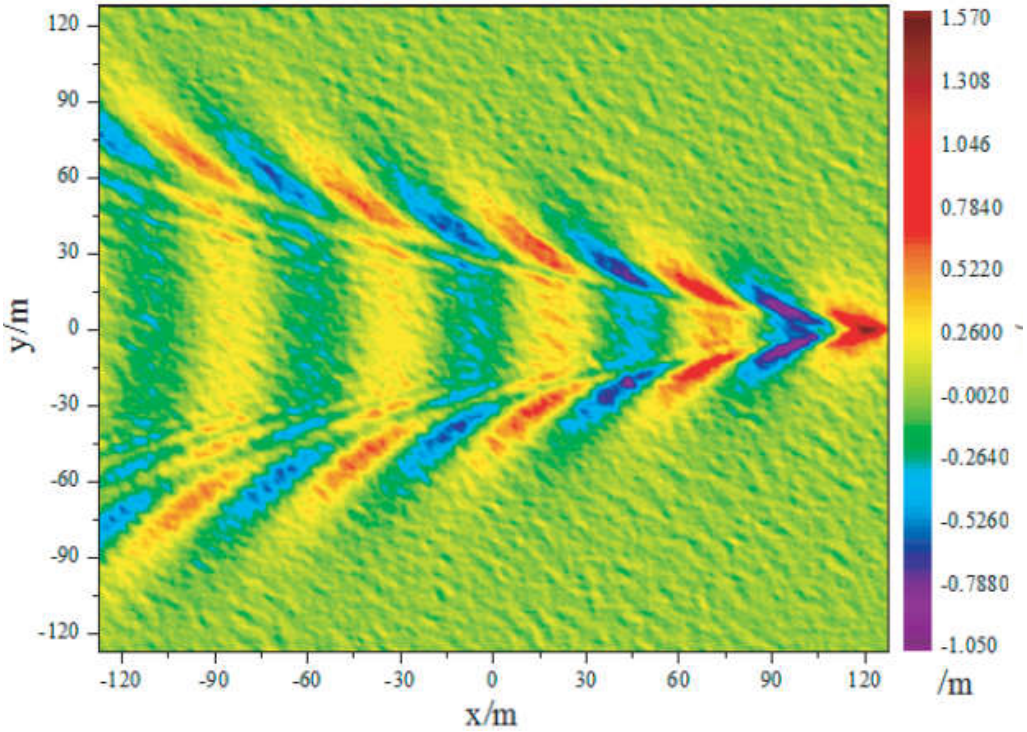
Figure IR7-18-5 shows a modelled vessel wake by Wang et al. (2016) from a ship with dimensions of 52 m length by 5.9 m beam and 3.5 m draught travelling at 9 m/s (or 17 knots). **Figures IR7-18-6** and **IR7-18-7** show modelled vessel wake on the sea surface with wind speed of 3 m/s and 5 m/s, respectively. Since wind waves and vessel wake exhibit similar characteristics, direct superposition of the ship wake on the sea surface is performed. The figures show that the effect of the wind waves on the vessel wake is significant and that the vessel wakes are indistinguishable from wind waves away from the source (**Figure IR7-18-7**).

Figure IR7-18-5 Simulated Vessel Wake for a Vessel Travelling at 9 m/s



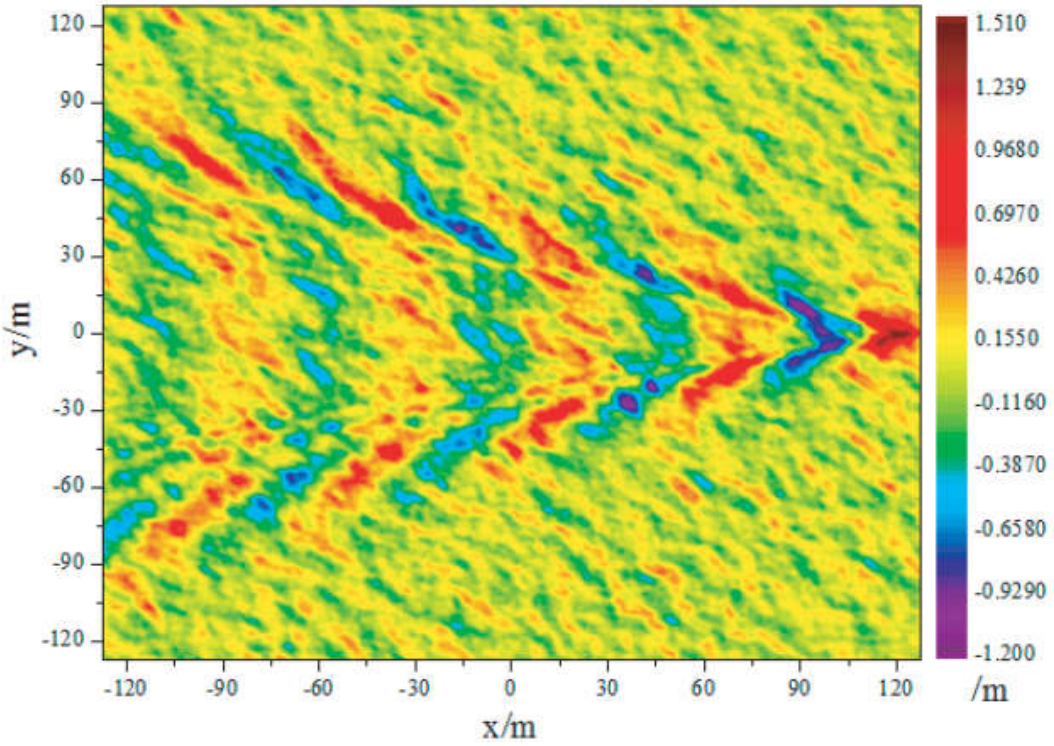
Source: Wang et al. 2016.

Figure 7-18-6 Simulated Vessel Wake for a Vessel Travelling at 9 m/s and Wind Speed of 3 m/s



Source: Wang et al. 2016.

Figure 7-18-7 Simulated Vessel Wake for a Vessel Travelling at 9 m/s and Wind Speed of 5 m/s



Source: Wang et al. 2016.

In the RBT2 wave environment assessment, wake was considered in the context of the existing wind-generated wake climate. At most shoreline locations in Segment B Zones 1, 2, and 3, which are predicted to receive wake waves exceeding 10 cm in height, the wake-generated wave was predicted to be between 10 cm and 12.5 cm (as summarised in MSA Table 7.2-5). The second most probable wake-generated wave height, by shoreline length, is between 12.5 cm and 15 cm. It is unlikely that at shoreline locations any difference would be observed between a wave that is 12.5 cm in height from a wave that is 15 cm in height. Therefore, the generalised statement that, except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations is valid.

Specify at what shoreline locations vessel wake would be distinguishable from the spectrum of wind-generated waves during calm conditions.

As described in MSA Section 7.2.2.2, calm conditions were defined as waves with height less than 10 cm (WMO 2015). MSA Figure 7.2-2 showed locations where wake-related waves greater than 10 cm were predicted to intersect with a shoreline within Zones 1, 2, and 3. It follows that wake height of 10 cm or greater would theoretically be distinguishable from the spectrum of wind-generated waves during calm conditions at the locations indicated in Figure 7.2-2. MSA Table 7.2-5 summarised shoreline lengths in each zone expected to be exposed to wake of various heights as well as the probability that a 'natural wave' (e.g., wind-generated wave) would occur with a height equalling or exceeding the wake-generated wave.

The inverse of this probability defines the probability that a natural wave would be smaller than the wake-generated wave, or the probability that a wake-generated wave would be distinguishable from the wind-generated wave. The inverse probabilities are presented in **Table IR7-18-1**, which is modified from Table 7.2-5 of the MSA.

Table IR7-18-1 Probability that Vessel-generated Waves Would be Distinguishable from Natural Waves by Length of Shoreline and Wake Height in each Zone (modified from Table 7.2-5 of the MSA)

Zone	Wake Height Range (cm)	Shoreline Length (km)	Probability That a Vessel-generated Wave Would be Distinguishable from Natural Waves (%)
1	10 – 12.5 12.5 – 15 15 – 20 20 – 25	1.73 1.14 0.53 *none*	40%
2	10 – 12.5 12.5 – 15 15 – 20 20 – 25	1.26 0.31 0.20 *none*	46%
3	10 – 12.5 12.5 – 15 15 – 20 20 – 25	21.34 15.34 14.96 3.86	25%
	≥25	0.28	64%

References

Moffatt and Nichol. 2011. Vessel Wake Study (DRAFT). Report prepared by Moffatt & Nichol for KM LNG Operating General Partnership, Vancouver, BC. 18 pp. Provided as Appendix IR7-17-A in the response to IR7-17.

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IR7-19 Wave Environment – Wake Waves by Vessel Type

Information Source(s)

Marine Shipping Addendum: Table 4-4; Section 7.2.4.2; Appendix 7.2-B, Figure 1

Context

The Proponent assumed that wake waves generated by all vessels (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels) through Segment B are similar to wake waves generated by the representative container ship presented in Table 4-4 of the Marine Shipping Addendum.

Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum showed that the vessel wake heights at near range vary from approximately 0.14 metres for empty conventional motor vessels to 0.38 metres for tugs and patrol boats - all travelling at 15.5 knots.

Additional information is required regarding the relationship between wake wave heights and vessel type.

Information Request

Confirm wake wave height values for near range for the four vessel types in Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum.

To all panels of Figure 1 of Appendix 7.2-B, add curves for representative container ships and representatives of all classes of vessels passing through Segment B (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels).

Reassess the assumption that wake waves generated by all vessels are the same.

VFPA Response

Context

The Marine Shipping Addendum (MSA) includes a vessel wake evaluation (MSA Section 7.2) to assess the contribution of RBT2-associated vessel wake to the existing wind-driven wave climate. Figure 1 in Appendix 7.2-B of the MSA presents three plots of wake height for varying input parameters: i) vessel speed, ii) water depth, and iii) hull coefficient. As described in the response to IR7-13, the focus of the MSA vessel wake evaluation is to assess vessel wake interactions at shorelines within the marine shipping area where wake exceeding 10 cm in height may arrive from deep water. Figure 1 of MSA Appendix 7.2-B is therefore included as part of a sensitivity analysis, to demonstrate the relatively small variation in wake height at distances of 1,000 m and greater when the input parameters are varied within a reasonable range of values. As stated in Section 7.2.4.2 of the MSA, the assumption that wake characteristics of all vessels will be similar to that of the representative container ship

described in Table 4-4 of the MSA was made based on the relatively small variation in wake height at the typical offset distances to shorelines from the vessel routes that were assessed.

The questions posed in this information request refer to 'near range' values of wake height. Near range is inferred to mean an offset distance of between 150 m and 500 m. An explanation for why wake height at offset distances of less than 150 m is not considered is included in the response to IR7-18.

Confirm wake wave height values for near range for the four vessel types in Figure 1 of Appendix 7.2-B of the Marine Shipping Addendum.

The vessel wake evaluation was conducted using the PIANC (1987) formula. The equation to determine vessel wake height (H) is as follows:

$$H = h * \alpha_1 * \left(\frac{s}{h}\right)^{-0.33} * F_h^4$$

Where,

s = Distance between the vessel and the point of interest
α_1 = Coefficient depending on vessel type
h = Channel depth
F_h = *Froude number,* $F_h = \frac{V_s}{\sqrt{gh}}$
V_s = Vessel speed

The influence of vessel geometry on vessel wake is represented by coefficient α_1, which was varied between 0.35 and 1.0 in Figure 1 of MSA Appendix 7.2-B. The following α_1 coefficient values are published in Verhey and Bogaerts (1989):

α_1 = 1.0 for tugs, patrol boat and loaded conventional inland motor vessels;
α_1 = 0.5 for empty European barges (wave heights produced by loaded barges are relatively small and can be neglected); and
α_1 = 0.35 for empty conventional motor vessels.

Tankers, cargo or carrier vessels, and container ships (large ocean-going vessels) are not expected to generate wakes greater than that from the tugs. For the MSA vessel wake evaluation, α_1 value of 0.7 for large ocean-going vessels was adopted.

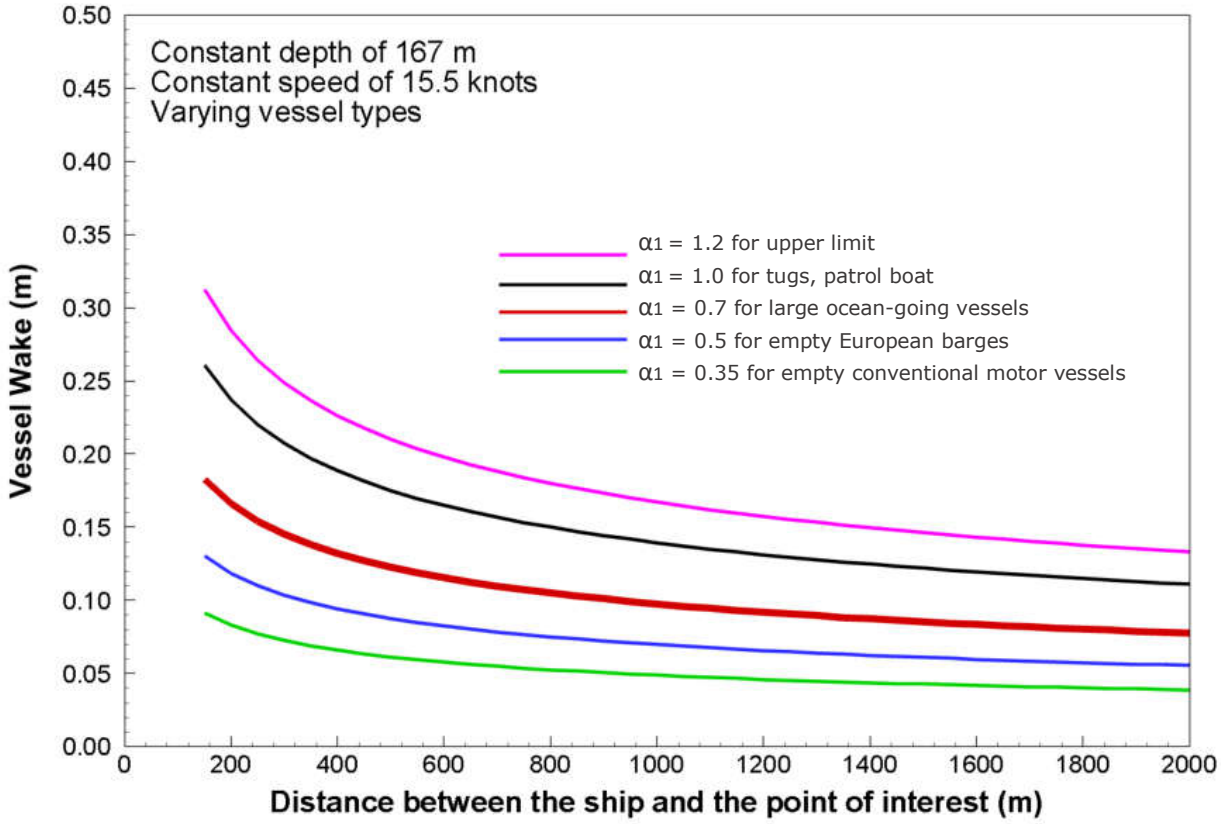
The relation of the PIANC (1987) formula with data from hundreds of field measurements originally published in Schiereck (1993) is shown in Figure IR7-18-1 in the response to IR7-18. The solid line is derived using the equation with α_1 value of 1.2. The figure shows that using α_1 value of 1.2 for the PIANC (1987) formula gives a reasonable upper limit.

Figure 1 of MSA Appendix 7.2-B is reproduced in **Figure IR7-19-1** below with two additional curves: 1) upper limit using of α_1 value of 1.2, and 2) large ocean-going vessels using of α_1

value of 0.7. The value of sailing distance away from the vessel used to generate the plots ranges between 150 m and 2,000 m. (A discussion of the minimum distance from the sailing line that the formula is valid is included in the response to IR7-18.)

The results show that at 150 m away from the vessel track, the calculated vessel wake varies between 0.09 m and 0.31 m for the various vessel types assessed. At an offset distance of 500 m, the vessel wake varies between 0.06 m and 0.21 m. Within this offset distance range, the representative container vessel wake height is at approximately the mid-point in the wake height range. These values are consistent with the values presented in Figure 1 of MSA Appendix 7.2-B.

Figure IR7-19-1 Vessel Wake Height Variation as a Function of Hull Coefficient



To all panels of Figure 1 of Appendix 7.2-B, add curves for representative container ships and representatives of all classes of vessels passing through Segment B (cargo or carrier vessels, tugs, passenger vessels, tankers, service vessels, fishing vessels and other vessels).

Per the information request, **Figure IR7-19-1** includes curves for container ships and representatives of all classes of vessels passing through Segment B. The information request is for all panels of Figure 1 of EIS Appendix 7.2-B to be similarly updated; however, the other two panels of Figure 1 show variation in wake height by vessel speed (between 12 knots and

16 knots), and in water depth (between 50 m and 200 m), respectively. It is not practical to include more than a single vessel type in each of these additional panels.

Reassess the assumption that wake waves generated by all vessels are the same.

As stated in Section 7.2.4.2 of the MSA, and reiterated above, the assumption that wake characteristics of all vessels will be similar to that of the representative container ship that was the focus of the MSA was made based on the relatively small variation in wake height at the typical offset distances to shorelines from the vessel routes that were assessed. This assumption is valid in the context of the MSA because the receptor shoreline was the focus of the assessment.

In the context of this information request, which seeks clarification about wake heights in the 'near range', the assumption is less valid, given the slightly larger variation in wake height at 150 m offset distance from the sailing line (e.g., between 0.09 m and 0.31 m). Near range wake heights were not considered in the MSA (discussed further in the responses to IR7-21, IR7-22, and IR7-23), as the international shipping lanes are located more than 150 m from shore.

References

Schiereck, G. J. 1993. Introduction to Bed, Bank, Shore Protection: Engineering the Interface of Soil and Water. TU Delft, Department Hydraulic Engineering.

Verhey, H. J. and M. P. Bogaerts. 1989. Ship Waves and the Stability of Armour Layers Protecting Slopes. Delft Hydraulics Publication No. 428 (pp. 12). Paper presented at the 9th International Harbour Congress, Antwerp, Belgium, 20-24 June 1989.

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IR7-20 Wave Environment – Modelling Ship Wake Waves

Information Source(s)

Marine Shipping Addendum: Section 7.2.4.1; Appendix 7.2-A, Figure 7.2-1

Context

In Section 7.2.4.1 of the Marine Shipping Addendum, the Proponent clarified that modifications to the wave climate caused by interactions with the shoreline and seabed were not described, nor were they the subject of this assessment.

The Proponent did not address wave shoaling, reflection and refraction, which primarily occur at shorelines. The wave environment assessment was focused on shorelines through the three zones of assessment which were selected because they include shorelines.

Information is needed on the wave environment in the nearshore zone where shoaling, reflection and refraction are important processes.

Information Request

Using information provided in response to Review Panel information request IR7-18, provide an assessment to determine if wave shoaling, wave reflection and wave refraction are likely to be important along shorelines in Zones 1, 2 and 3 of the marine shipping local study area.

Provide a prediction of the likely magnitude of waves breaking on shorelines where shoaling, reflection and refraction that is likely to occur in Zones 1, 2 and 3.

Assess whether nonlinear wave effects such as shoaling, reflection and refraction are likely to contribute to the production of wave heights greater than that which may be expected solely from the proportion of additional vessel traffic.

VFPA Response

The three components of this information request are responded to by describing the characteristics of shoaling, wave reflection, and wave refraction, as opposed to responding to each component separately. As described in the response to IR7-18 (and illustrated in Figure IR7-18-4), wave characteristics include wave height (distance between trough and crest), wavelength (distance between wave crests), and wave period (time between wave crests). Wind-generated waves and vessel wake-generated waves exhibit similar characteristics for a given wave height. Wave shoaling, reflection, and refraction may be important along various shoreline segments within Zones 1, 2, and 3, but waves generated by passing ships are not expected to differ from waves generated by winds. Hence, as outlined in Section 7.2.4.1 of the Marine Shipping Addendum (MSA), modifications to the wave climate caused by interactions with the shoreline and seabed were not assessed.

Clarification as to the scope of the wave environment assessment is provided in the *Preamble for IR7-13 to I7R-23 Wave Environment Information Requests*, which includes the rationale for assessing the contribution of ship wake to the existing wind-generated wave climate. Waves, whether generated by wind or from ship wake, are expected to interact with the shoreline in Zones 1, 2, and 3 of Segment B in similar ways given similar wave characteristics.

In order to respond to this information request, the behaviour of waves generated by ship wake was compared to that of wind-generated waves. The wave period for a vessel travelling at 15.5 knots (the average speed of ships transiting through Segment B) was calculated to be 4.2 seconds. The vast majority of wind-generated waves in the open Strait of Georgia and Juan de Fuca Strait have periods in the range of 2 to 4 seconds (Thomson 1981). The wave period generated by ship wake, therefore, is predicted to be at the upper end of the natural wind-generated wave climate range. The behaviour of waves with periods ranging from 2 to 4.2 seconds with respect to shoaling, refraction, and reflection are compared below.

Wave Shoaling

Wave shoaling occurs as a wave enters shallower water and begins to interact with the bed. The wave speed and wave length decrease in shallow water resulting in an increase in wave height. The wave shoaling coefficient, which describes the ratio of the wave height at a particular point versus the original deep water wave height, depends on water depth and the incident wave period. **Figure IR7-20-1** shows the shoaling coefficient calculated for waves with period of 2, 3, 4, and 4.2 seconds. The figure shows that the shoaling coefficient increases from 1.06 when the wave period is 2 seconds to 1.43 when the wave period is 4.2 seconds.

Figure IR7-20-1 Shoaling Coefficients for Four Wave Periods (2, 3, 4, and 4.2 Seconds)

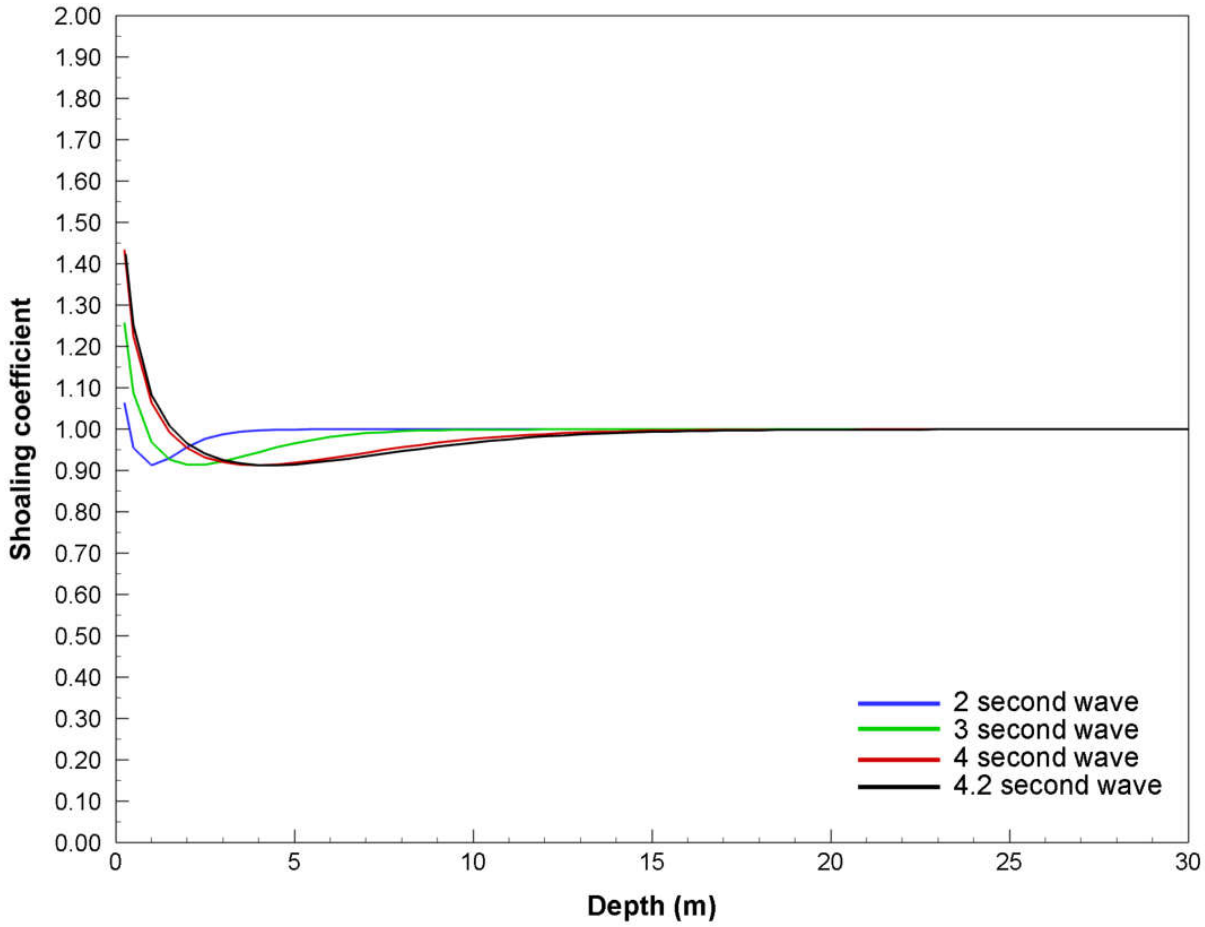


Table 7.2-5 of the MSA showed that 99.5% of the shorelines in Zones 1, 2, and 3 (total length of 60.95 km) were predicted to receive wake waves equal to or less than 0.25 m, and 39.9% are predicted to receive wake waves equal to or less than 0.125 m. **Table IR7-20-1** summarises the calculated nearshore wake-generated wave heights predicted for RBT2-associated vessels (i.e., vessel wakes) and wind-generated waves equal to or less than 0.25 m (for four wave height categories and four wave periods) in Juan de Fuca Strait (i.e., Zone 3 in Segment B, which experiences the largest wave heights of the three zones). The largest difference between shoaled wind-generated wave heights and shoaled vessel wakes is 0.10 m (i.e., when comparing a 2 second to 4.2 second wave period for an incident wave of 0.25 m). For a 0.125 m incident wave, the difference between these wave periods is 0.06 m.

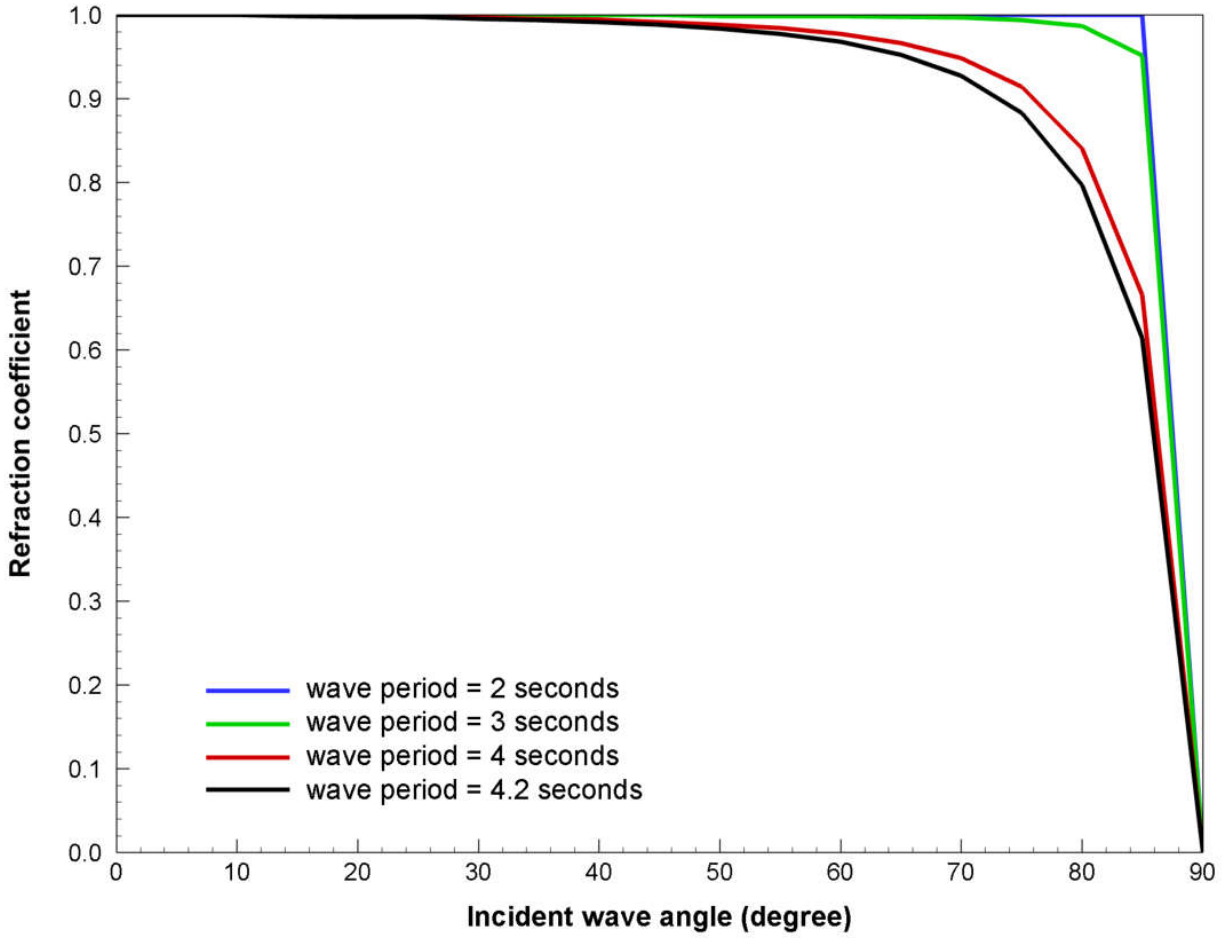
Table IR7-20-1 Nearshore Wave Heights due to Shoaling for Four Wave Periods and Four Deepwater Incident Wave Heights

Wave Type	Wave Period (s)	Deepwater Wave Height (m)	Nearshore Wave Height (m)
Vessel wake	4.2	0.125	0.21
Wind wave	4.0		0.21
	3.0		0.18
	2.0		0.15
Vessel wake	4.2	0.15	0.24
Wind wave	4.0		0.24
	3.0		0.21
	2.0		0.17
Vessel wake	4.2	0.20	0.30
Wind wave	4.0		0.29
	3.0		0.26
	2.0		0.22
Vessel wake	4.2	0.25	0.36
Wind wave	4.0		0.35
	3.0		0.31
	2.0		0.26

Wave Refraction

Wave refraction occurs when a wave approaches the shore at an angle. During refraction, the wave crests bend to align themselves with the bottom contours and the wave direction becomes more perpendicular to the shore. Wave refraction is considered as a separate process, independent of wave breaking. **Figure IR7-20-2** shows the refraction coefficient versus incident wave angle for four different wave periods at 10 m water depth. The figure shows that wave attenuation does not occur when incident waves are perpendicular to the shoreline. When the incident waves are parallel to the shoreline, waves do not reach the shoreline and the refraction coefficient is 0. The figure also shows that the refraction effect is greater for waves with longer wave periods than waves with shorter wave periods. Since the refraction effect would tend to reduce wave heights, omitting this effect from the wave environment assessment results in a conservative prediction of the height of wake arriving at the nearshore environment (i.e., larger waves would be predicted without taking the refraction effect into consideration).

Figure IR7-20-2 Refraction Coefficients for Four Wave Periods (2, 3, 4, and 4.2 Seconds)



Wave Reflection

Wave reflection occurs when an incident wave bounces back from an obstacle it encounters with some or little loss of energy. The effect is not related to breaking waves on the shoreline. The amount of wave energy reflected from a shoreline is a function of the material on the shore, the shoreline slope angle, the size and porosity of the shoreline structure, and the properties of the incoming waves (e.g., wave height and wave period) (U.S. Army Corps of Engineers 2002). Reflected waves can cause interference with incoming waves, resulting in standing waves. These are common in coastal areas where waves reflect off seawalls. The wave height of the standing wave is twice that of the incident wave. For instance, a standing wave height of 0.50 m can be expected in a coastal region with seawall structures with an incident wave of 0.25 m.

Summary

Based on the above explanations, the following is concluded:

- Shoaling could result in larger shoaled vessel wake waves than shoaled wind-generated waves, as shown in **Table 7-20-1**. Based on the largest wake-generated waves (0.25 m high waves, as shown in MSA Figure 7.2-2) that are expected to arrive at shorelines within Segment B, the largest wave height difference when compared to wind-generated waves is 10 cm, and the smallest wave height difference is 6 cm (comparing 0.125 m waves);
- The refraction effect would tend to reduce incident wave heights; therefore, the results of the wave environment assessment, which did not consider this effect, were conservatively predicted. Refraction is not related to breaking waves; and
- Reflection could result in standing waves in coastal regions with seawall structures. The effect would be the same for vessel wake-generated waves and wind-generated waves of similar wave heights. The effect is not related to wave breaking.

In general, the approach used to assess wake-generated waves in deep water without the consideration of near-shore changes to waves as a result of shoaling, refraction, and reflection was conservative. The shoaling effect has the potential to result in slightly higher breaking waves (between 6 cm to 10 cm higher) when comparing the slightly longer wave period of ship-generated wake (4.2 seconds) as opposed to wind-generated waves (2 to 4 seconds). Only shoaling results in breaking waves (i.e., refraction and reflection are unrelated to this process).

References

Thomson, R. E. 1981. Oceanography of the Britsh Columbia Coast. *Canadian special publication of Fisheries and Aquatic Sciences*, 56, 25–41. Available at http://publications.gc.ca/site/eng/9.816310/publication.html. Accessed November 2017.

U.S. Army Corps of Engineers. 2002. *Coastal Engineering Manual: Engineer Manual 1110-2-1100*. U.S. Army Corps of Engineers, Washington, D.C. (6 Volumes). Available at http://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/u43544q/636F617374616C20656E67696E656572696E67206D616E75616C/. Accessed November 2017.

IR7-21 Wave Environment – Calm Conditions

Information Source(s)

Marine Shipping Addendum: Section 7.2.2; Section 7.2.5.2

Context

In Section 7.2.2 of the Marine Shipping Addendum, the Proponent stated that a wake of 10 centimetres or less in height is considered to be well within the range of natural conditions. The Proponent also stated that a wake of 10 centimetres or less in height is considered to be within the range of calm conditions as defined by the Douglas Scale.

In Section 7.2.5.2 of the Marine Shipping Addendum, the Proponent stated that wake-generated waves would be well within the range of natural conditions and would not be perceptible except during calm conditions, and that vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations in the marine shipping local assessment area.

However, the Proponent also stated that Zone 1 (near Saturna Island), Zone 2, (near Stuart Island), and Zone 3, (near Discovery Island), would experience wind-generated waves smaller than 10 centimetres 40%, 46%, and 26% of the time, respectively.

An assessment of wake wave effects during calm conditions is required.

Information Request

Using information provided in response to Review Panel information request IR7-18, provide a re-assessment of the effects of vessel wake-driven waves impacting shorelines in Zones 1, 2 and 3 of the marine shipping local study area during calm conditions.

Provide an assessment of the effects of vessel wake-driven waves on private, commercial and government dock installations in the three zones during calm conditions.

Provide an assessment of the effects of vessel wake-driven waves on small-craft boating activities at sea between shipping routes and the shore in the three zones during calm conditions.

Provide an assessment of seasonal differences in the frequency of calm conditions in the three zones, and explain how these seasonal differences could affect the three types of effects detailed above.

VFPA Response

Background and Supporting Information

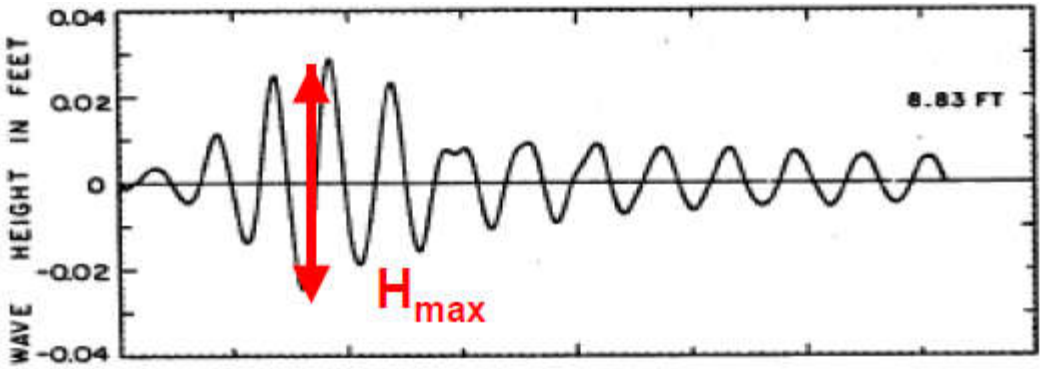
Information provided in the response to IR7-18 that is pertinent to this response includes the following:

- A discussion of the characteristics of vessel wake-generated waves compared to wind-generated waves;
- Clarification about shoreline locations in Zones 1, 2, and 3 where wake-generated waves would be distinguishable from wind-generated waves; and
- The following conclusions: 1) that for a given wave height, vessel wake waves are indistinguishable from wind-generated waves; and 2) that vessel-generated waves would be distinguishable from wind-generated waves at shoreline locations within Zones 1, 2, and 3, as defined by information in the Marine Shipping Addendum (MSA).

As further information, vessel-generated waves (i.e., those distinguished from wind-generated waves) could be determined by using the inverse of the values presented in the column labelled "Probability of Occurrence of Natural Wave of Similar or Larger Height (%)" in Table 7.2-5 of the MSA. For instance, wake-generated waves of 0.10 m to 0.20 m originating from Project-associated vessels are predicted to arrive at shorelines within Zone 1 and the probability of natural waves of 0.10 m or larger occurring in Zone 1 is 60%; therefore, there is a 40% probability that wake-generated waves of 0.10 m to 0.20 m would occur during calm conditions. This concept has been acknowledged in the Panel's context in this information request.

Another way to consider the effects of wake-generated waves in the context of the existing wind-generated wave environment is with regards to the number of waves that are generated by Project-associated vessels. As shown in **Figure IR7-21-1**, and referenced in Kriebel et al. (2003), a ship typically generates three main wake-waves, with one dominant (as indicated by the red arrow), as well as a series of minor interference waves.

Figure IR7-21-1 Example Wave Record from a Transiting Vessel



Source: Kriebel et al. 2003.

Project-associated vessel movements are expected to total 520 movements annually by 2030. Assuming that each vessel movement generates five waves (i.e., two waves before and after

the dominant wave) to be conservative, a total of 2,600 waves would be generated by Project-associated vessels in a year. A wind event that generates waves that are similar to wake-generated waves, which have a wave period of about 4 seconds (refer to the response to IR7-20 for more information), would create 900 waves in an hour. Thus, the additional waves experienced annually along the shoreline due to Project-associated vessels are slightly less than that of a three-hour wind event.

Incorporating the probability of calm periods for Zones 1, 2, and 3 from MSA Tables 7.2-2, 7.2-3, and 7.2-4, respectively, **Table IR7-21-1** summarises the occurrence of the assumed three hours of equivalent wake-generated waves occurring during calm periods in each zone as total number of hours and as percentage of the total hours of calm. The percentage of calm hours that would experience vessel-generated wake from Project-associated vessels is 0.034% for the three zones.

Table IR7-21-1 Characterisation of Calm Conditions at Zones 1, 2, and 3

	Zone 1	Zone 2	Zone 3
Percentage of Calm Conditions[a]	40%	46%	25%
Total Number of Calm Hours (based on conditions in 2012)[b]	3,504	4,030	2,190
Hours of the Assumed 3-hour Wake-Generated Wave Event Occurring During Calm Period[c]	1.20 h	1.38 h	0.75 h
Percentage of Time that the Equivalent Wake-Generated Wave Event Would Occur During Calm Period[d]	0.034%	0.034%	0.034%

Notes:

a. From MSA Tables 7.2-2, 7.2-3, and 7.2-4 for Zones 1, 2, and 3, respectively.
b. Calculated from 'Percentage of Calm Conditions' x 8,760 hours annually.
c. Calculated from 'Percentage of Calm Conditions' x 3 hours (duration to generate 2,600 waves with a 4 second wave period).
d. Calculated from 'Hours of the Assumed 3-hour Wake-Generated Wave Event Occurring During Calm Period' ÷ 'Total Number of Calm Hours'.

The information presented above is included in the responses to the requests below.

Using information provided in response to Review Panel information request IR7-18, provide a re-assessment of the effects of vessel wake-driven waves impacting shorelines in Zones 1, 2 and 3 of the marine shipping local study area during calm conditions.

The response to IR7-18 concluded that except during calm conditions, vessel wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations.

From the point of view of physical processes at a shoreline, wake-generated waves arriving at a shoreline during calm periods have the same interaction as waves arriving during non-calm periods. A re-assessment is not provided, as the delivery of wake-generated waves from Project-associated vessels to the shoreline under calm conditions can be considered as a probability of occurrence. Although the probability slightly increases from Project-associated vessels (0.034% during calm conditions, as shown in **Table 7-21-1**), wake-generated waves

from Project-associated vessels will not result in a change to the shorelines in Zones 1, 2, and 3 due to the similarity of interaction at the shoreline from wake-generated and wind-generated waves

Provide an assessment of the effects of vessel wake-driven waves on private, commercial and government dock installations in the three zones during calm conditions.

Table 7.2-5 of the MSA showed that 99.5% of the shoreline in Zones 1, 2, and 3 are predicted to receive wake waves equal to or smaller than 0.25 m. The maximum wave height recorded at the New Dungeness wave buoy in 2012 was 2.7 m. The maximum 2012 hindcast wave heights at Zones 1, 2, and 3 were 1.2 m, 1.1 m, and 2.2 m respectively. Given the natural wave climate in Segment B, it is expected that any private, commercial, or government dock installations are constructed to withstand wind generated waves greater than 0.25 m. Therefore, the vessel wakes from Project-associated vessels are not expected have a physical effect on the docks during calm conditions.

Guidance concerning acceptable wave heights for small craft for both service/offloading and mooring areas at private, commercial, and government dock installations is provided in Fisheries and Ocean Canada's Harbour Accommodations Guidelines (PWGSC 2015). The smallest allowable threshold significant wave height for the smallest vessel class (0 to 10.7 m in length) is 0.3 m, which is higher than the largest wake-generated wave predicted to arrive at a shoreline in Zones 1, 2, and 3. The allowable frequency of occurrence for the threshold wave is 1.0% to 2.5% as compared to the percentage of calm hours that Project-associated vessel wake will arrive at a shoreline in Zones 1, 2, and 3, which is 0.034%[1] (**Table IR7-21-1**).

Provide an assessment of the effects of vessel wake-driven waves on small-craft boating activities at sea between shipping routes and the shore in the three zones during calm conditions.

Figure 7.2-2 of the MSA shows the extent of wake-generated waves from Project-associated vessels travelling along shipping routes in Segment B for waves in five height categories: 10 to 12.5 cm, 12.5 to 15 cm, 15 cm to 20 cm, 20 to 25 cm, and greater than 25 cm. Since the focus of the wave environment assessment was to assess wake arriving at shorelines within the marine shipping area, MSA Figure 7.2-2 does not describe wake height in proximity to the vessel; however, this can be calculated using the PIANC (1987) formula. The height of vessel wake calculated at a distance of 150 m away from Project-associated vessels travelling at 15.5 knots in Segment B is 0.47 m. In adhering to applicable regulations under the *Canadian Shipping Act, 2001*, including Collison Regulations with respect to vessel distance and overtaking vessels, it is assumed that Project-associated vessels and small craft vessels would not be within 150 m each other. Based on this information, it can be inferred that small-craft

[1] The value presented in **Table IR7-21-1** describes wake-generated waves from Project-associated vessels as a percentage of time that calm conditions occur, and includes waves smaller than the threshold significant wave height.

operating at sea between shipping routes and the shore in Zones 1, 2, and 3 could encounter waves from Project-associated vessels of 0.1 m to 0.47 m during calm conditions.

Small vessels, as defined under various Transport Canada regulations, include pleasure craft, passenger vessels (non-pleasure craft), and fishing vessels. For instance, small commercial (non-pleasure craft) vessels fall into two main categories: 0-15 gross tons and 15-150 gross tons (Transport Canada 2011), and the Safe Boating Guide for pleasure craft (Transport Canada 2014) considers a number of classes of vessels from human-powered paddleboats and sit-on-top kayaks, to sail and power boats exceeding 24 m. Construction and design standards applicable to boats built or sold in Canada dictate environmental operating limits (such as wind force and wave height) for small craft stability and buoyancy. For small commercial vessels, Transport Canada references International Standard Organization (ISO) Standard 12217, which specifies the wave height environmental limits for vessels in four design categories as exceeding 4 m, up to 4 m, up to 2 m, and 0.5 m (Transport Canada 2015).

The magnitude of wake height described above is already a feature of the environment for small-craft operators in Segment B (Haro Strait) because of transiting vessels of all sizes, including ferries, which generate larger waves due to their hull characteristics and higher transit speed during calm conditions. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazard for small-craft operators in the three zones during calm conditions.

Provide an assessment of seasonal differences in the frequency of calm conditions in the three zones, and explain how these seasonal differences could affect the three types of effects detailed above.

Table IR7-21-2 provides the frequency of calm conditions (i.e., conditions with waves less than 0.10 m) based on hindcast wave data in each zone by season. The results show that the wave climate in Segment B is not uniform throughout the year, with calm conditions occurring more frequently in summer and autumn than during spring and winter. The largest difference in seasonal calmness and the annual calmness is 21 percentage points, which occurred for winter at Zone 1. This means that compared to the annual percentage of time that calm conditions occur, wake-generated waves are less likely to occur during calm conditions in winter than in other seasons.

Table IR7-21-2 Percentage of Calm Conditions in Zones 1, 2, and 3 by Season and Annually

Period	Zone 1	Zone 2	Zone 3
Winter (December - February)	19%	26%	11%
Spring (March – May)	37%	45%	23%
Summer (June – August)	58%	55%	24%
Autumn (September – November)	45%	56%	43%
Annual	40%	46%	26%

As noted above, from a physical perspective, wake-generated waves arriving at shorelines in Zones 1, 2, and 3 during calm conditions have the same shoreline interaction as waves arriving during non-calm conditions. Considered on a seasonal basis, the assumed three hours of equivalent wake-generated waves described above translates to the equivalent of an average of an additional 45 minutes of wind-generated waves per season.

Seasonal differences in percentage of calm conditions, therefore, are not expected to affect shorelines, or coastal structures such as private, commercial, and government docks, that are designed to sustain larger wind-generated waves that are already a regular feature in the region.

Seasonal differences in percentage of calm conditions are not expected to introduce new navigational hazards for small-craft operators in Zones 1, 2, and 3 because transiting vessels of all sizes including ferries, which have the potential to generate relatively large waves due to their hull characteristics and transit speed (see response to IR7-23 for a discussion of ferry wake in Segment B), are already present.

During the summer and autumn months, human interactions with wake-generated waves from Project-associated vessels during calm conditions will be slightly higher.

References

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IR7-22 Wave Environment – Open Water

Information Source(s)

Marine Shipping Addendum: Section 9.5.5.1; Table 9.5-35; Section 7.2; Section 7.2.4.2

CEAR Doc#384

Context

As reiterated in Section 9.5.5.1 of the Marine Shipping Addendum, vessel wake from the proposed Project-associated vessels is not expected to be distinguishable from wave action on vessels engaged in commercial or recreation activities, except in calm conditions, given that vessel-related wake is within the wave-height spectrum of wind-generated waves.

In Section 7.2.4.2 of the Marine Shipping Addendum, the Proponent stated that the assessment did not describe the height of wake at the point of wave generation in open water as this assessment focused on wake-generated waves in the nearshore environment.

However, in Section 7.2 of the Marine Shipping Addendum, the Proponent stated that surface waves interact with objects in the water, the shoreline and the seabed and can move shoreline and seabed sediments, dislodge plants and animals, and move floating objects, such as boats. The Proponent also noted that potential change is anticipated if vessel wake is generated during periods of calm such that people would be affected by unexpected waves.

Indigenous groups expressed concerns about the potential environmental effects of vessel wake on their traditional activities.

Information Request

Provide a prediction of the changes that the proposed Project-related marine shipping may have on the wave environment during calm conditions in open water at various points and various distances from the shore throughout the marine shipping area.

Assess the effects of waves generated by Project-associated vessels during calm conditions on small craft engaged in activities in open water at various points and various distances from shore throughout the marine shipping area, including fishing activities in the vicinity of Swiftsure Bank.

VFPA Response

Provide a prediction of the changes that the proposed Project-related marine shipping may have on the wave environment during calm conditions in open water at various points and various distances from the shore throughout the marine shipping area.

The incidence of calm conditions at various locations within the marine shipping area is presented in Marine Shipping Addendum (MSA) Section 7.2.4.1, which reports that calm conditions occurred in Zones 1, 2, and 3 of Segment B for 40%, 46%, and 25% of the time, respectively, based on the deep water wave model results for 2012 wind conditions[1]. The results for Zone 3 likely underestimate the wave climate because the deep water wave model does not account for ocean swell (as explained in the response to IR7-16), which is indicated to be a feature of the wave climate in this area based on observations at the nearby New Dungeness wave buoy (situated southeast of Zone 3). Figure 6 of MSA Appendix 7.2-A presents observed data at the New Dungeness wave buoy that shows calm conditions occur 0% of the time (see MSA Figure 7.2-1). Wave conditions at the New Dungeness station are considered to be representative of conditions in Segment C and the eastern portion of Segment D.

Wave conditions in the western portion of Segment D are recorded at the National Oceanic and Atmospheric Administration (NOAA) Neah Bay wave buoy near Swiftsure Bank (**Figure IR7-22-1**).

[1] For marine shipping area segment locations, refer to MSA Figure 1-1, and for the location of zones assessed within the wave environment assessment, refer to MSA Figure 7.2-1.

Figure IR7-22-1 NOAA Station 46087 Neah Bay Wave Buoy Location

A summary of observed waves for 2012 at Neah Bay is presented in **Table IR7-22-1**. The maximum observed wave height was 7.68 m and the smallest observed wave was 0.32 m; there were no calm periods.

Table IR7-22-1 Summary of Observed Wave Heights at NOAA Station 46087 Neah Bay in 2012

Wave Height (m)	Percentile Exceedance (%)
7.68	0.0%
3.27	10.0%
2.67	20.0%
2.32	30.0%
1.98	40.0%
1.67	50.0%
1.42	60.0%
1.20	70.0%
1.00	80.0%
0.88	86.2%
0.78	90.0%
0.37	99.7%
0.32	100.0%

Calm conditions in Segment A have not been characterised because the expected wake-generated wave heights for Project-associated vessels manoeuvring in Segment A at an average speed of 9 knots (kn) (MSA Table 4-5) are less than 10 cm[2] and would, therefore, not be detectable during calm periods.

Although the information request asks for an assessment of Project-associated vessels in calm conditions, information is presented regardless of sea state, since the height of vessel wake is not dependent on the existing sea state (i.e., the requested wake height predictions and associated effects are not specific to calm conditions).

Contribution of Wake from Project-associated Vessels

As described in MSA Section 7.2, Project-associated vessels transiting within the marine shipping area will create waves (vessel wake) that will emanate from the ship while in motion through the water. Vessel wake was assessed in the context of the wind-generated wave climate, with a focus on the height of wake-generated waves arriving at shorelines within the marine shipping area. Since only shorelines within Segment B were predicted to be exposed to wake-generated waves in excess of 10 cm, wake-generated waves from Project-associated vessels were only presented for Segment B (as shown in MSA Figure 7.2-2).

MSA Figure 7.2-2 provides a graphical representation of the distribution of Project-associated wake-generated waves in Segment B at various distances from the sailing line, including in open water at various points and various distances from the shore. As described in the response to IR7-21, MSA Figure 7.2-2 does not describe wake height in proximity to the vessel. The rationale for why vessel wake calculations are limited to 150 m from the vessel sailing line is included in the response to IR7-18. The height of vessel wake calculated at a distance of 150 m away from Project-related vessels travelling at 15.5 knots in Segment B is 0.47 m.

Since wake height predictions were not previously presented for Segments A, C, and D, predictions are provided in **Table IR7-22-2** for offset distances of 150 m to 2,000 m, in various increments. These predictions were made using the PIANC (1987) equation, which was also the basis for the calculations presented in the MSA. The calculations are based on the average vessel speed and minimum channel depth for each segment. The average speed used in the analysis is based on 2012 AIS (Automatic Identification System) data for representative container vessels in the 8,000 to 10,000 TEU (twenty-foot equivalent unit) range (MSA Table 4-5). Minimum channel depth is used because vessel wake is inversely proportional to depth. A more conservative result is obtained by using the minimum channel depth in each segment rather than the average depth.

Wake height at offset distances greater than 2,000 m are not provided, as the PIANC (1987) equation has not been verified against field data collected at large offset distances. The results for Segments A and C show that wake heights are predicted to be smaller than 10 cm at an offset distance of 2,000 m. The wake height predicted in Segment D at 2,000 m offset

[2] Wave heights of 10 cm or less are considered to be representative of 'calm conditions'.

distance from the sailing line is 0.37 m, which is only slightly larger than the smallest wave observed at the Neah Bay wave buoy, a wave height that is exceeded 99.7% of the time based on the results shown in **Table IR7-22-1**.

Table IR7-22-2 Wave Height at Various Distances from the Container Vessel Sailing Line

Segment	Average Vessel Speed (kn)[a]	Channel Depth (m)	Wake Height (m) at Distance from the Sailing Line					
			150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
A	9.0	106	0.03	0.02	0.02	0.02	0.01	0.01
B[b]	15.5	41	0.47	0.37	0.31	0.25	0.22	0.20
C	15.0	117	0.20	0.16	0.14	0.11	0.10	0.09
D	20.0	73	0.88	0.70	0.59	0.47	0.41	0.37

Notes: a. Data from MSA Table 4-5.
b. Information for Segment B is also illustrated in MSA Figure 7.2-2.

Assess the effects of waves generated by Project- associated vessels during calm conditions on small craft engaged in activities in open water at various points and various distances from shore throughout the marine shipping area, including fishing activities in the vicinity of Swiftsure Bank.

The response to IR7-21 provides a discussion of the definition of small vessels, including the stability criteria for various categories of small commercial vessels. A discussion of the effects of waves generated by Project-associated vessels is provided below for each marine shipping area segment.

Segment A

In Segment A (southern Strait of Georgia), the estimated Project-associated vessel wave heights are predicted to be equal to or less than 0.03 m due to the slow vessel speed observed in this segment (**Table IR7-22-2**). Thus, the vessel wake from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in the southern Strait of Georgia during calm conditions.

Segment B

In Segment B (Haro Strait), the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.20 m and 0.47 m (**Table IR7-22-2**). As discussed in IR7-21, the magnitude of wake height described above is already a feature of the environment for small-craft operators in Segment B because of transiting vessels of all sizes, including ferries, which generate larger waves due to their hull characteristics and higher transit speed during calm conditions. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in Haro Strait during calm conditions.

Segment C

In Segment C (inner portion of Juan de Fuca Strait), the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.09 m and 0.20 m (**Table IR7-22-2**). While the vessel speed in Segment C is similar to the vessel speed in Segment B, the estimated vessel wake heights are smaller in Segment C due to increased channel depth (41 m in Segment B compared to 117 m in Segment C). Similar to the findings on the vessel wake heights in Segment B, the magnitude of wake height estimated in Segment C is already a feature of the environment for small-craft operators and additional Project-associated wake-generated waves are not expected to introduce new navigational hazards for small-craft operators in the inner portion of Juan de Fuca Strait, since calm conditions do not occur in this area (based on observed conditions at the New Dungeness wave buoy, as shown in Figure 6 of MSA Appendix 7.2-A).

Segment D

In Segment D (Juan de Fuca Strait), although there are no calm conditions, the estimated Project-associated vessel wave height within 2,000 m of the sailing line ranges between 0.37 m and 0.88 m. Predicted vessel wake heights are greater in this segment compared to the other three segments due to higher vessel speed (**Table IR7-22-1**). Unlike Segments A, B, and the northern portion of Segment C, Segment D is directly exposed to the Pacific Ocean and the wave climate includes both sea and swell waves. The results in **Table IR7-22-2** show that based on the percentile exceedance values generated using 2012 wave measurements, measured waves exceeded 0.37 m 99.7% of the time, and exceeded 0.88 m 86.2% of the time. The smallest wave measurement from the dataset was 0.32 m. That is, no calm condition (wave height less than 0.1 m) occurred in 2012 at Neah Bay. The magnitude of Project-associated vessel wave height described above is already a feature of the environment for small-craft operators in Segment D because of the existing energetic wave climate. Thus, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators in Juan de Fuca Strait.

Swiftsure Bank is located outside of the entrance to Juan de Fuca Strait, west of NOAA Station 46087 Neah Bay wave buoy (**Figure IR7-22-1**). The wave climate at Swiftsure Bank is expected to be similar to that at observed at Neah Bay. As with Segment D, the vessel wakes from Project-associated vessels are not expected to introduce new navigational hazards for small-craft operators at Swiftsure Bank, including operators undertaking fishing activities, because of the existing energetic wave climate.

References

World Association for Waterborne Transport Infrastructure (PIANC). 1987. Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways. Report of Working Group 4 of the Permanent Technical Committee - Permanent International Association of Navigation Congress.

IR7-23 Wave Environment – Interaction of Vessel Waves

Information Source(s)

Marine Shipping Addendum: Section 7.2.6

Context

In Section 7.2.6 of the Marine Shipping Addendum, the Proponent considered wake-driven waves from single vessels in isolation, and did not address the potential interaction of waves from more than one vessel. Specifically, the assessment did not consider the worst-case scenario of wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively and thus generating high wave conditions both at the shoreline and in open water.

An assessment of a worst-case scenario resulting from the interaction of multiple vessel wakes in calm conditions is needed.

Information Request

Assess the maximum possible wave amplitude at the shoreline and in open water due to wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively under calm conditions.

Reassess the potential effects of marine shipping associated with the proposed Project on the wave environment due to the maximum possible wave height under calm conditions.

VFPA Response

Assess the maximum possible wave amplitude at the shoreline and in open water due to wake-driven waves from multiple vessels (both Project-related and non-Project-related) interfering constructively under calm conditions.

Information is provided in the following sections on wave interactions and vessel movements and interactions to characterise Project-related and non-Project-related vessel wake interactions. Note that the information request refers to the wave amplitude; however, since the Marine Shipping Addendum (MSA) wave environment assessment presents results in terms of the wave height, this response presents the assessment results in terms of wave height for consistency and ease of comparison purposes.

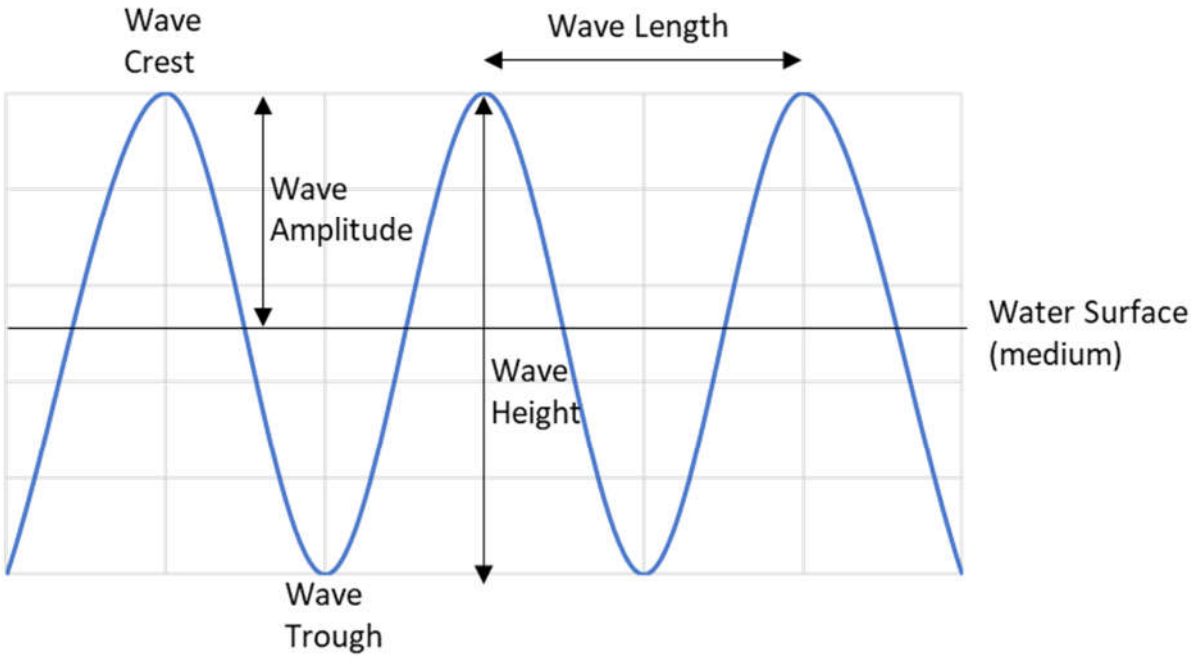
Theoretical Wave to Wave Interactions

Wave theory describes the interactions of waves in open water travelling along a medium such as water. Wave dimensions and characteristics pertinent to this response are shown in **Figure IR7-23-1**. Waves can occupy the same physical location along a medium through a process of interference, which can lead to a constructive or destructive result. In the simplest

case, when wave peaks align, there is constructive interference and the amplitude of each wave is additive (e.g., two waves of amplitude 1 will create a single wave of amplitude 2 at the time that the two waves overlap). The converse is also true, that when a wave peak and a wave trough overlap, there is destructive interference and the amplitudes are subtractive.

The two waves do not merge, but remain independent and the energy of each wave is preserved. Therefore, the constructive (or destructive) interference occurs only for the period of time that the waves occupy the same position along the water surface, which for the Panel's context for this information request considered the 'worst-case scenario'. For waves travelling towards each other from opposite directions, the constructive interference lasts only for the moment of co-occurrence of the waves. For waves travelling in the same direction, constructive interference will appear to last longer as the relative velocities are much less, though this situation also depends on the two waves having different velocities and, therefore, most likely different amplitudes.

Figure IR7-23-1 Wave Dimensions and Characteristics



Vessel Movements and Interactions

Table 4-2 and Section 7.2.5.2 of the MSA summarise vessel movements through Segment B (Haro Strait) of the marine shipping area. Approximately three vessel movements every two days, or 520 vessel movements per year, are projected to be associated with RBT2. Compared with the 8,896 vessel movements of all types that transit Segment B under existing conditions, the Project is expected to represent less than a 6% increase in vessel traffic (or 4% if compared to projected future traffic levels). When compared to the passage of cargo

vessels, which are more directly comparable in terms of the size of wake-related waves, the increase is expected to be 12% over existing cargo vessel movements.

The above consideration of the number of vessel movements provides context for understanding the likelihood of wake-related wave-to-wave interactions from two or more vessels. Ocean-going commercial vessels moving through Segment B travel along established international shipping lanes. Given the physical constraints of the shipping transit corridor and the requirements for safe navigation, it is assumed for the purposes of this assessment that vessels do not pass while transiting on the same inbound or outbound lane. Therefore, waves from different vessels will interact between the shipping lanes as vessels pass each other going in opposite directions.

Interactions between wake-generated waves originating from more than two vessels could occur in principle, if two vessels pass each other going in opposite directions while a third vessel crosses the shipping route. However, in order to maintain a safe navigation distance (assumed for the purposes of this assessment to be a minimum of 500 m or approximately two vessel lengths, as operators are expected to navigate to maintain a safe distance away from other vessels), the interaction of wake-generated waves from more than two vessels that could result in a measurably larger wave is unlikely.

The potential interactions of waves from multiple vessels is dependent on the proximity of the vessels, as well as vessel hull characteristics, vessel speed, and water depth.

Passing Project-associated Vessels

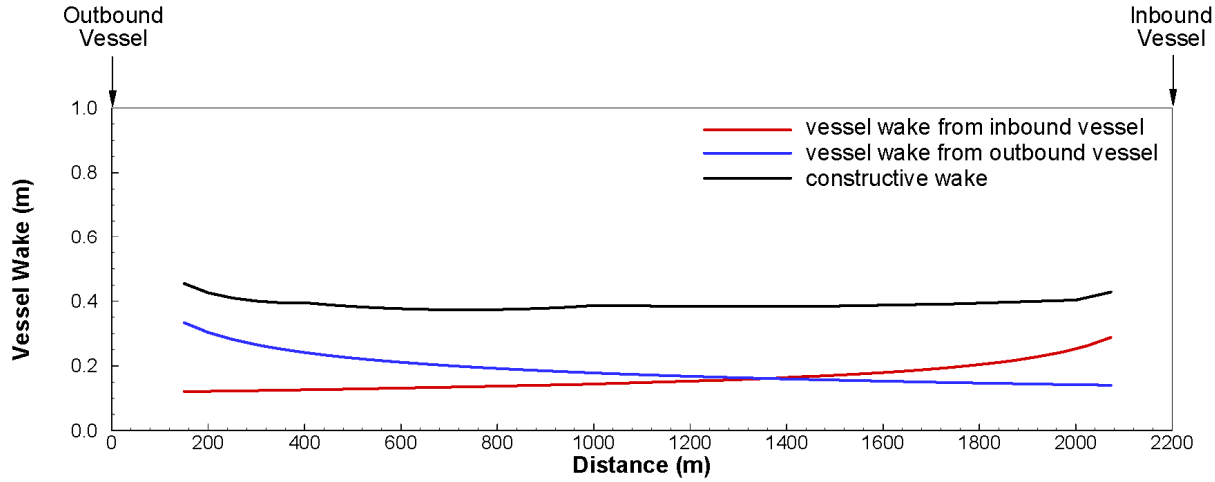
Figure 7.2-2 of the MSA shows the predicted extents of wake-generated waves of various heights in Segment B for both inbound and outbound vessels. This figure can be used to visualise the potential interaction of wakes from two Project-associated vessels travelling in opposite directions, by considering the case that two vessels are passing each other at any particular location (offset by the separation zone between the two shipping lanes). When an inbound vessel and outbound vessel pass, constructive wave interference could occur in the region between the two navigation paths. In some areas, such as in Zone 2, there is no overlap with the zones of wake exceeding 10 cm generated by the two vessels and, therefore, no potential for constructive interference.

Based on the results presented in MSA Figure 7.2-2, the maximum possible wave height at the shoreline and in open water due to wake-driven waves from two Project-associated vessels could be expected to occur near Discovery Island (Zone 3). Due to shallower water depths in Zone 3, wake-generated waves are predicted to be larger and the area of influence of wake exceeding 10 cm larger and, therefore, the area where wake-to-wake interactions can occur would also be larger. **Figure IR7-23-2** shows the vessel wakes generated from an inbound Project-associated vessel (red line) and an outbound Project-associated vessel (blue line) as well as constructive wake-generated waves (black line) near Discovery Island. The maximum constructive vessel wake height due to two passing Project-associated container ships is 0.45 m and occurs near the vessels (i.e., 150 m away from the vessels). For this analysis, it is assumed that a vessel in proximity to the passing container ships with the potential to experience this maximum constructive vessel wake are a minimum distance of

500 m away. The maximum constructive vessel wake 500 m away from two passing Project-associated container vessels is 0.38 m.

Constructive wave interference from Project-associated container ships is not expected to occur outside the region between inbound and outbound shipping lanes. This is because vessel wakes from the inbound and outbound vessels propagate in the open water at the same, or similar, speed and the wakes will not catch up to each other. Thus, the wave height at the shoreline due to vessel wakes is not altered when considering interactions from multiple Project-associated vessels.

Figure IR7-23-2 Height of Constructive Wake-generated Waves Resulting from Two RBT2-associated Vessels Passing in Opposite Directions near Discovery Island (Zone 3)

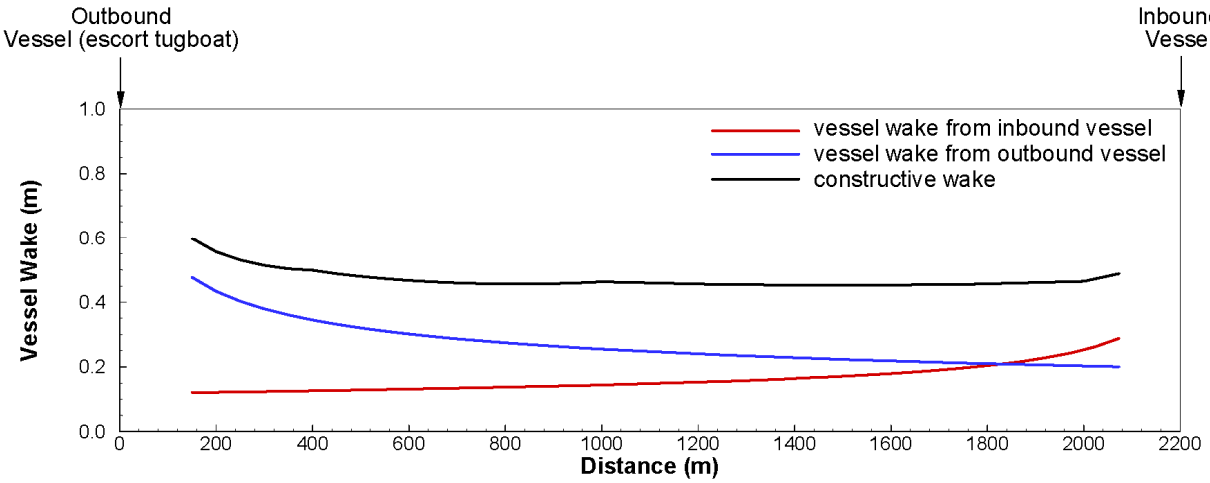


Note: The x-axis is relative to the distance from the outbound vessel (blue line). The distance from the inbound vessel is the reverse, with distance being 0 m at the 2,200 m mark and 2,000 m at the 150 m mark.

Passing Project-associated and non-Project-associated Vessels

As discussed in the response to IR7-18, of all the non-Project-associated vessels transiting within the marine shipping area Segment B, the escort tugboat is expected to generate the largest vessel wake. The vessel geometry coefficient used in the PIANC (1987) formula for tugboat was 1.0, about 43% greater than the coefficient used for Project-associated vessels. **Figure IR7-23-3** shows the vessel wakes generated from an inbound Project-associated vessel (red line) and an outbound escort tugboat (blue line) alongside an oil tanker travelling at the same speed as Project-associated vessel, as well as the constructive wave generated (black line) near Discovery Island in Zone 3. The maximum constructive vessel wake height due to Project-associated container ship and an escort tug passing in opposite directions is 0.60 m and occurs near the escort tugboat. The maximum constructive vessel wake 500 m away (assumed to be the safe operating distance from vessel operating in the international shipping lanes) from the escort tugboat is 0.48 m.

Figure IR7-23-3 Height of Constructive Wake-generated Waves Resulting from a RBT2-associated Vessel and Non-Project-associated Vessel (Escort Tug) Passing in Opposite Directions near Discovery Island



Note: The x-axis is relative to the distance from the outbound vessel (blue line). The distance from the inbound vessel is the reverse, with distance being 0 m at the 2,200 m mark and 2,000 m at the 150 m mark.

Project-associated Vessel and Ferries

Two ferry routes are within Segment B: 1) Victoria – Port Angeles and 2) Sidney – Friday Harbor. These routes are approximately perpendicular to the inbound and outbound shipping lanes. Therefore, the vessel wakes generated from Project-associated vessels travel approximately perpendicular to the vessel wakes generated from the ferries. Following good marine practice, Project-associated vessels and the ferries are expected to navigate a reasonable distance apart near the intercept point. For this analysis, it is assumed that the two transiting vessels are a minimum distance of 500 m apart.

Estimated ferry vessel wake heights at various distances from the ferry route using the PIANC (1987) formula are summarised in **Table IR7-23-1**. A vessel geometry coefficient of 1.0 was assumed for the ferry and the assumed vessel speed was based on sources available online (Wikipedia 2017a and 2017b).

Table IR7-23-1 Wave Height (m) at Various Distances from the Sailing Line – Ferry

Route	Ferry Name	Length (m)	Speed (kn)	Depth (m)	Wake Height (m) at Distance from the Sailing Line		
					500 m	750 m	1,000 m
Victoria – Port Angeles	*MV COHO*	104	15	93	0.23	0.20	0.18
Sidney – Friday Harbor	*MV Tillikum*	94.5	13	234	0.07	0.06	0.05

Constructive interference wake-generated waves from a Project-associated container ship and a Victoria-Port Angeles ferry are summarised in **Table IR7-23-2**. Constructive interference wake-generated waves from a Project-associated container ship and a Sidney-Friday Harbor ferry are summarised in **Table IR7-23-3**. The maximum constructive interference wave height is predicted to be 0.50 m 150 m away from a Project-associated vessel. At the assumed safe navigation distance of 500 m, the maximum constructive vessel wake, from **Table IR7-23-2** and **Table IR7-23-3**, is 0.41 m. Since the vessel wake-generated waves from a Project-associated vessel and a ferry in Segment B travel approximately perpendicular to one another, they are expected to reach different shorelines. Thus, a constructive interference wave from these two vessel wakes at the respective receptor shoreline will not occur.

Table IR7-23-2 Wave Height at Various Distances from the Sailing Line – Victoria to Port Angeles

Scenario	Wake Height (m) at Distance from the Sailing Line					
	150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
Project-associated vessel wake	0.27	0.21	0.18	0.14	0.13	0.11
Project-associated vessel wake combined with wake from ferry travelling 500 m away	0.50	0.44	0.41	0.37	0.36	0.34

Table IR7-23-3 Wave Height at Various Distances from the Sailing Line – Sidney to Friday Harbor

Scenario	Wake Height (m) at Distance from the Sailing Line					
	150 m	300 m	500 m	1,000 m	1,500 m	2,000 m
Project-associated vessel wake	0.15	0.12	0.10	0.08	0.07	0.06
Project-associated vessel wake combined with wake from ferry travelling 500 m away	0.22	0.19	0.17	0.15	0.14	0.13

Reassess the potential effects of marine shipping associated with the proposed Project on the wave environment due to the maximum possible wave height under calm conditions.

As stated in the response to IR7-22, the height of vessel wake is not dependent on the existing sea state; therefore, wake height predictions are not required to be made specifically for calm conditions. Also, as stated in the response to IR7-21, the physical interactions of wake-generated waves in the marine shipping area is the same regardless of the existing sea state.

The interaction of wake-generated waves from multiple vessels is not expected to result in larger waves at the receptor shorelines in Segment B as compared to the predictions previously presented in the MSA based on wake-generated waves from a single vessel. The wake-generated waves previously predicted to interact with shorelines are well within the range of the existing wind-generated wave climate. As described in the response to IR7-21, assuming that Project-associated vessel movements generate 2,600 waves in a year, the number of wake-generated waves is slightly less than the number of waves generated in a three hour wind event (i.e., 2,700 waves, assuming that 900 waves are generated per hour with a wave period of 4 seconds). In terms of physical processes at the shoreline, a reassessment of the effects of marine shipping associated with the Project on the wave environment is not required.

The information presented in this response indicates that interactions with wake-generated waves from multiple vessels can be larger in open water than a wake-generated wave from a single vessel, as predicted in the MSA. The magnitude of wake height described above is already a feature of the environment for operators of vessels in Segment B because of transiting vessels of all sizes. Thus, constructive wave interference from multiple vessels—both Project-associated and non-Project-associated—bypassing each other are not expected to introduce new navigational hazards for vessels operating in Segment B during calm conditions, assuming that operators of vessels observe good navigation practices.

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Preamble to Offsetting-related Information Requests (IR7-24 to -27, IR7-30, IR10-10, IR11-13 to -19, IR11-21) – RBT2 Offsetting Approach

Introduction

The VFPA has responded to each of the Panel's information requests on offsetting provided in Information Request Packages 7, 10, and 11 in its letters dated July 24, 2017, December 19, 2017, and April 4, 2018, respectively[1]. The following preamble was prepared to provide context and clarity to the VFPA's responses with regard to Project offsetting. The preamble presents additional background information on the VFPA's approach to offsetting as it relates to the different phases of Project development and approval, such as environmental assessment (EA) phase approval (i.e., approval under the *Canadian Environmental Assessment Act*, 2012) and post-EA phase approvals as part of Project permitting (e.g., *Fisheries Act* Authorization (FAA)). The context and clarification provided below has been organised into the following key sections:

- Overview;
- Best Available Science;
- Engagement and Collaboration;
- Long-term Commitment to Fraser River Estuary Offsetting; and
- Summary.

Briefly, the 'Offsetting Framework', as presented in Section 17.0 of the EIS, presents the initial 'Offsetting Measures' proposed to mitigate adverse effects to certain marine biophysical valued components (VCs). The EA predicted that, with mitigation (including offsetting), the Project would not result in significant residual adverse effects. The Offsetting Framework will be further developed following engagement with Indigenous groups, regulatory agencies, and key stakeholders, with the goal of agreeing on a final 'Offsetting Plan' that meets the Project's permitting phase requirements while responding to the dynamic nature of the Roberts Bank ecosystem.

Overview

RBT2 is currently in the EA phase of project approvals. As described in section 2.1 of the *Updated EIS Guidelines*, the "*Environmental assessment (EA) is a planning tool used to ensure that projects are considered in a careful and precautionary manner in order to avoid or mitigate the possible adverse effects of projects on the environment and to encourage decision makers to take actions that promote sustainable development*". In adhering to the *Updated EIS Guidelines*, the VFPA has identified technically and economically feasible measures that would mitigate adverse environmental effects of the Project. The VFPA has

[1] IR7-24 to -27, IR7-30, IR10-10, IR11-13 to -19, IR11-21.

identified mitigation to avoid, eliminate, control, or reduce potential effects of the Project on the environment, which include the proposed Offsetting Framework to offset the predicted adverse effects to certain marine biophysical VCs. The Offsetting Framework proposes Offsetting Measures developed to directly offset predicted adverse Project effects and were selected to reduce the longer-term adverse effects on ecological productivity, by targeting specific sub-components of the biophysical VCs (EIS Table 17-3). With the application of mitigation measures, including the Offsetting Framework, the VFPA has predicted no significant adverse Project-specific effects from RBT2 based on multiple lines of evidence (EIS Section 17.0).

If RBT2 is granted EA approval, the VFPA will then enter the permitting phase of the Project. This phase consists of the VFPA making applications for and subsequently obtaining approval of all regulatory permits, to ensure that aquatic habitat and productivity at Roberts Bank is protected. Such permits include a federal FAA. The permitting phase of the Project will also consider non-permit requirements, such as meeting the intent of the Federal wetland policy on Federal lands (Government of Canada 1991). As discussed below, the Offsetting Framework will continue to be developed following engagement with Indigenous groups, regulators, and key stakeholders to meet future permitting requirements.

The *Fisheries Act* requires that the Project fulfils "the sustainability and ongoing productivity of commercial, recreational and Aboriginal fisheries" objective, as per Fisheries and Oceans Canada's (DFO's) 2013 Fisheries Protection Policy Statement (DFO 2013a). It is the VFPA's expectation that the Project will be able to fulfil this objective as the VFPA progresses in further developing the Offsetting Plan as part of the FAA permitting requirements during the post-EA phase of the Project. During the EA phase, the VFPA applied DFO's hierarchical approach to standards and measures to protect fish and fish habitat (DFO 2013a,b,c) to address potential Project-related effects to the identified marine biophysical VCs. This hierarchical approach seeks to (1) avoid potential adverse effects; (2) reduce or minimise potential adverse effects that cannot be avoided, and (3) offset potential adverse effects that cannot be avoided, minimised, or reduced.

The VFPA is committed to develop RBT2 in such a way as to ensure there is no net loss of productivity for key marine biophysical VCs at Roberts Bank, including marine vegetation, invertebrates, fish, mammals, and coastal birds, or for wetlands. The goal is to sustain the immediate Project area as a productive marine ecosystem.

As part of the EA, the VFPA has developed and deployed the Roberts Bank ecosystem food-web numerical and spatial model (Roberts Bank ecosystem model) to inform the prediction of Project-related effects (described in further detail below). The Roberts Bank ecosystem model forecasts that the Project will result in an overall net increase in ecosystem productivity at Roberts Bank *prior* to mitigation. Despite this overall finding, the VFPA has developed an Offsetting Framework and five specific onsite habitat Offsetting Measures to address residual Project effects on specific marine biophysical VCs based on other lines of evidence, and by adopting a precautionary approach. Offsetting Measures are only being pursued where there are no practical measures to avoid or reduce effects. They include the enhancement and/or creation of five distinct types of productive aquatic habitat: intertidal marsh, mudflat, subtidal rock reefs, sandy gravel beach, and eelgrass.

The ecosystem-based approach of the Roberts Bank ecosystem model was also relied upon to inform the RBT2 Offsetting Framework (EIS Section 17.0). Results from this productivity modelling have been combined with multiple lines of evidence (i.e., empirical data, habitat suitability modelling, recent and historical field data, literature sources, and expert opinion) to ensure the RBT2 Offsetting Framework is scientifically robust and can address the uncertainty inherent in predicting and offsetting productivity impacts in dynamic natural systems, like that at Roberts Bank (see response to IR5-29 on multiple lines of evidence approach, CEAR Document #1185[2]).

The VFPA will be advancing its initial RBT2 Offsetting Framework and proposed Offsetting Measures into a final Offsetting Plan. The VFPA's intent is to engage with key Indigenous groups, regulators, and stakeholders to better understand their priorities, needs, and expectations when it comes to offsetting, and to evolve the existing RBT2 Offsetting Framework and Offsetting Measures. This work will identify any adjustments required to the currently proposed RBT2 Offsetting Measures in preparation for the final Offsetting Plan required for the permitting phase of the Project should the Project obtain EA approval.

Ultimately, as noted earlier, a detailed Project-specific final Offsetting Plan will be developed as part of the permitting process, pursuant to the FAA and other regulatory requirements and expectations such as Federal Policy on Wetland Conservation on Federal lands (Government of Canada 1991). This Offsetting Plan will build upon the VFPA's existing Offsetting Framework to deliver a comprehensive (based on science and Indigenous traditional knowledge) and broadly supported approach to offsetting that will ensure the productivity of the Roberts Bank ecosystem, and each of the identified marine biophysical VCs, is maintained or enhanced in the long-term. The final Offsetting Plan will also address and account for uncertainty in offsetting success and the associated time lag for the offset to become effective.

The VFPA's approach to offsetting the Project's effects on aquatic habitat and ecosystem productivity is based on the following key tenets, described further below:

1) Application of the best available science;
2) Active engagement and collaboration; and
3) The VFPA's long-term commitment to the ecological health and integrity of the Fraser River estuary.

1. Best Available Science

To predict residual Project effects and determine the Offsetting Measures required to maintain ecosystem productivity, the EIS relied upon multiple lines of scientific evidence comprising existing information, empirical data (including Project-specific field studies), numerical models (e.g., the Roberts Bank ecosystem model), and Indigenous traditional knowledge, which were examined and evaluated through expert professional judgement (IR5-29 of CEAR Document #1185).

[2] CEAR Document #1185 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-28 and IR5-29 (See Reference Document #975).

To help establish the basis for the current Offsetting Framework, the VFPA selected the Ecopath with Ecosim and Ecospace (EwE) modelling method to develop a Roberts Bank specific productivity model (the Roberts Bank ecosystem model). Ecopath is a mass balance representation of an ecosystem during a given time and is the focus of the model; Ecosim is a time dynamic simulation module for policy exploration; and Ecospace is a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas (EIS Appendix 10-A). EwE modelling is recognised by the U.S. National Oceanic and Atmospheric Administration (NOAA) as one of the top ten scientific breakthroughs in NOAA's 200-year history[3]. The primary objective of the Roberts Bank ecosystem model is to forecast changes in ecosystem productivity with and without the Project, and quantify effects, which are interpreted along with multiple lines of other scientific evidence when reaching conclusions on the amount of offsetting required.

The Roberts Bank ecosystem model employs the best available science for assessing Project effects on ecosystem productivity. This method of analysis was adopted based on the recommendations of the RBT2 Productive Capacity Technical Advisory Group (TAG), which comprised of leaders from DFO, the Canadian Wildlife Service, independent experts, and VFPA biologists and experts. The extensive expertise of the TAG was used to review key issues relevant to the evaluation of productivity, including assessment methodologies and approaches, and the selection of focal species. This expertise included in-depth knowledge of marine mammals, birds, fish, invertebrates, and marine vegetation that utilise the Roberts Bank area. The TAG process consisted, in part, of four meetings/workshops that were held between November 2012 and May 2013 to discuss suitable methods for assessing and reporting changes to productive capacity that are scientifically defensible, relevant to the regulatory process, and relevant to the Roberts Bank area. At the conclusion of the TAG process, members *"selected EwE as the preferred method and endorsed it as a conceptually sound approach to assessing changes in [Productive Capacity] at Roberts Bank resulting from the implementation of RBT2"* (see Appendix IR3-A of CEAR Document #984[4] for the Productive Capacity TAG Summary Report).

The EwE modelling software was subsequently used to create the Roberts Bank ecosystem model. Inputs used in the Roberts Bank ecosystem model were derived from a combination of recent field data, historical field data, and literature sources (EIS Appendix 10-B, #2.8 of CEAR Document #547[5]). To characterise existing conditions, the primary sources of field data were Project-specific scientific studies conducted at Roberts Bank in 2012 and 2013. The Roberts Bank ecosystem model also incorporates abiotic variables from the outputs of the hydrodynamic model for forecasting changes to species that may result from changes in waves, currents, and salinity (EIS Appendix 10-B, #2.11 of CEAR Document #547, #6.6 of

[3] https://celebrating200years.noaa.gov/breakthroughs/welcome.html
[4] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).
[5] CEAR Document #547 From the Vancouver Fraser Port Authority to the Review Panel re: Answers to preliminary technical questions submitted during the completeness phase from Fisheries and Oceans Canada, Natural Resources Canada, and Environment and Climate Change Canada, concerning the ecosystem modelling to support the Roberts Bank Terminal 2 Project environmental review (NOTE: Updated September 28th, 2016).

CEAR Document #314[6], and IR3-11 of CEAR Document #984). The model was developed by experienced practitioners and peer-reviewed by recognised experts.

The Roberts Bank ecosystem model ranks in the top 15% of all EwE models based on the extensive amount of local field data incorporated into the model (reflected in the pedigree index, or the measure of average pedigree; see CEAR Document #547 for further information). For example, it is considered to be scientifically more robust than a simpler variation of the model employed successfully by BC Hydro for its Site C hydroelectric project in northeast B.C. Moreover, external agencies and science institutions have favourably reviewed the Roberts Bank ecosystem model. For instance, the Canadian Science Advisory Secretariat (CSAS) concluded: "*Taking all these considerations into account, the model does the best job possible of comparing the biomass and productivity of the Roberts Bank ecosystem with and without the Project*" (CEAR Document #900[7]). Nevertheless, the Roberts Bank ecosystem model was subjected to multiple sensitivity analyses designed specifically to understand the uncertainty surrounding the model forecasts (EIS Appendix 10-D; #2.7, #2.13, and #2.15 of CEAR Document #547; #2.0, #7.0, and #8.0 of CEAR Document #314; and IR3-04, -09, -14, -17, -21, -22, and -23 of CEAR Document #984). Four aspects of the sensitivity were analysed: predator vulnerability, the number of abiotic factors, the variation in abiotic factors, and the variation in biotic factors. These sensitivity analyses generally demonstrate that the model is robust to sources of uncertainty in the original model inputs and settings.

The productivity approach to determining offsetting requirements and selecting Offsetting Measures was also recommended by the Productive Capacity TAG (EIS Section 7.4 and Information Request Package 3 Preamble in Support of Responses to IR3-01 to IR3-24 of CEAR Document #984), consistent with other EAs (e.g., Site C (CEA Agency 2016)), and reflects current science advice and policy (DFO 2013a,b,c; Environment Canada 2012). Moreover, the Canada's *Fisheries Act*, amended in 2012, refers to the "…*sustainability and ongoing productivity of commercial, recreational or Aboriginal (CRA) fisheries*", which is consistent with a productivity (as opposed to areal) approach to offsetting measures (Randall et al. 2013). This approach is also consistent with recent proposed amendments to Canada's *Fisheries Act* where Ministerial consideration must be made for the contribution to the productivity of relevant fisheries by the fish and fish habitat that is likely to be affected (Government of Canada 2018). Moreover, the productivity approach supports the RBT2 wetland functions assessment of wetlands on Federal lands.

Application of Best Science for RBT2 Offsetting Framework

The key driver of the VFPA's RBT2 Offsetting Framework is the principle of maximising ecological productivity through optimal offset design. This has led the VFPA to maximise

[6] 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.
[7] CEAR Document #900 From the Review Panel Secretariat to the Review Panel re: Technical Review of Roberts Bank Terminal 2 Environmental Assessment: Section 10.3 - Assessing Ecosystem Productivity - by Fisheries and Oceans Canada.

ecological value by both enhancing existing and creating new habitats with significantly higher ecological productivity than that displaced by the Project or the proposed Offsetting Measures.

The Offsetting Framework follows a set of five principles:

1) Soften the proposed hard substrate perimeter of the Project (to the extent possible) to better match substrates that are ecologically representative of the estuary;
2) Enhance or create offsetting habitat that suitably replaces aquatic habitat affected by the Project, but delivers higher ecological value or productivity;
3) Build habitat types for which there is a successful past precedent;
4) Consider physical changes arising from Project development in determining the types of habitats to be built; and
5) Include habitats that provide benefits for species of concern (e.g., forage fish) to Indigenous groups.

From these principles, a multidisciplinary team of marine biologists, coastal engineers, hydrodynamic modellers, and specialists from the VFPA's Habitat Enhancement Program identified feasible and sustainable onsite habitat offsetting concepts. Five types of onsite Offsetting Measures (i.e., Offsetting Concepts) have been proposed to date:

1) Intertidal marsh;
2) Sandy gravel beach;
3) Mudflat;
4) Subtidal rocky reef; and
5) Eelgrass.

These proposed Offsetting Measures presented in EIS Appendix 17-A are design concepts that will be refined as part of the permitting process (e.g., FAA application) post EA, should the Project obtain EA approval. As the Offsetting Framework is developed into an Offsetting Plan to meet regulatory and permitting requirements, feedback from ongoing and future engagement with regulators, Indigenous groups, and key stakeholders will be considered to further refine the concepts. These concepts would then be used to develop detailed designs for the habitat offsetting projects post EA.

Following the identification of the currently proposed RBT2 Offsetting Measures, the VFPA employed the Roberts Bank ecosystem model to estimate the net productivity resulting from the proposed Offsetting Concepts (i.e., Offsetting Measures). Essentially, the ecological value (productivity) from the existing habitat was subtracted from the ecological value (productivity) of the new habitat proposed to be built over top. The following summarises the Roberts Bank ecosystem model forecasted productivity estimates with and without the Project, as well as incorporating estimated productivity changes associated with Offsetting Measures:

- Overall, the Roberts Bank ecosystem model forecasts a positive change in productive potential for all marine biophysical VCs combined, *prior to* implementation of any Offsetting Measures (~1.5% increase compared to existing conditions, Table IR7-26-A1 in the response to IR7-26);

- The Roberts Bank ecosystem model estimates Offsetting Measures will result in a total biomass increase of 1,142 tonnes (t; 4.4%) for key representative species (Table IR7-26-A1 in the response to IR7-26); and
- While not all species require offsetting, the Roberts Bank ecosystem model estimates that most species and VCs will either experience increases to their productive potential or negligible changes (EIS Appendix 17-C; Table IR7-26-A1 in the response to IR7-26). No significant residual effects are predicted (EIS Table 17-5).

These Roberts Bank ecosystem model estimates make intuitive sense considering that the majority of the Project is located in relatively low productivity subtidal habitat in waters over 5 km away from the shoreline (note that the positioning of the terminal to the furthest practical distance offshore was an explicit design mitigation consideration to avoid effects to multiple VCs (as described in EIS Section 4.2.1 and Appendix IR13-30-A of CEAR Document #1331[8]).

2. Engagement and Collaboration

The VFPA has engaged with regulators, all levels of government, Indigenous groups, and Project stakeholders since 2011 to comprehensively evaluate environmental effects, increase benefits for local communities and all Canadians, as well as address priority issues and concerns. This commitment to proactive engagement and collaboration, as noted in IR10-11 (CEAR Document #1275[9]), continues as the Project team prepares to focus on advancing the Offsetting Framework.

As noted, the current RBT2 Offsetting Framework (EIS Section 17.0) is based on a scientific foundation with planned monitoring and adaptive management to verify and ensure that Project effects on aquatic habitat are mitigated and ecosystem productivity is sustained. The VFPA is embarking on a focused program of engagement to engage with, listen to, and identify the needs, priorities, and concerns of regulatory agencies, Indigenous groups, and key stakeholders to collaboratively identify ways in which existing proposed Offsetting Measures could or should be adjusted to meet regulatory requirements and respond to the dynamic ecology of the Roberts Bank ecosystem. This collaborative planning initiative will support the development of a final Offsetting Plan, which ensures no net loss of ecosystem productivity.

The VFPA has much experience initiating and managing collaborative processes with multiple stakeholders and Indigenous groups connected to environmental matters. The VFPA-led ECHO Program (Enhancing Cetacean Habitat and Observation Program; VFPA 2017a, 2018a) is one example of the VFPA's commitment to ongoing collaboration to address issues of mutual concern to various stakeholders. Much of the commercial vessel activity within the southern coast of B.C. transits critical habitat for the endangered southern resident killer whale

[8] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).
[9] CEAR Document #1275 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR5-01a, IR7-28, IR7-29, IR10-02, IR10-06 to IR10-09, IR10-11 to IR10-26, IR11-07, IR11-22, IR11-23, IR12-03, IR12-06, IR13-01, and IR13-19 (See Reference Documents #1000, 1130, 1179, 1206 and 1228).

(SRKW), as well as areas known to be of importance to other at-risk whales. The VFPA is committed to manage operations in a responsible and sustainable manner and takes this issue seriously and shares the concern for the endangered SRKW population. Although the geographic scope of VFPA jurisdiction is limited, it is recognised that to adequately address the cumulative threats posed by commercial vessel activities, a larger, regional-scale collaborative approach is required. In response, the VFPA-led ECHO Program was developed in 2014 as a collaborative initiative aimed at better understanding and managing the impact of shipping activities on at-risk whales throughout the southern coast of B.C. The VFPA has been instrumental in bringing together multiple partners with an interest in enhancing the health and well-being of the SRKW population. Federal organisations, Indigenous people, industry, scientific experts and research institutions, and environmental non-governmental organisations (ENGOs) have been involved to maximise program success and help ensure that mitigation and management measures developed through the program are informed by social, cultural, economic, and environmental sustainability interests. The ECHO Program has provided an invaluable forum for regional collaboration on research and voluntary mitigation approaches to benefit the recovery of the SRKW population.

On a similar theme, the New Brighton Park Shoreline Habitat Restoration Project is another example of a successful partnership among the VFPA, Vancouver Board of Parks and Recreation, with Musqueam First Nation, Squamish Nation, and Tsleil-Waututh Nation (VFPA 2017b, 2018b). This enhanced habitat provides critical refuge for juvenile salmon that migrate along the shores of Burrard Inlet as they head out to sea, and habitat for wildlife, including shorebirds, songbirds, and waterfowl. The project site was filled in by industry in the 1960s, and this project work signaled the first time in five decades that this area has been opened up (restored) to tidal influence.

It is the VFPA's intention to build on these successes and to continue engaging and consulting with regulators, Indigenous groups, and key stakeholders in developing and implementing the final Offsetting Plan for the RBT2 Project.

3. Long-term Commitment to Fraser River Estuary Offsetting

The VFPA has an enduring mandate to responsibly facilitate Canada's trade objectives, ensuring goods are moved safely, while protecting the environment and considering local communities. Accountable to the federal Minister of Transport, the VFPA manages Federal lands, water, and assets along hundreds of kilometres of shoreline, bordering 16 municipalities and intersecting the asserted and established traditional territories and treaty lands of several Coast Salish Peoples.

This expansive and long-term institutional role informs the approach the VFPA takes to its project development activities, including offsetting residual project effects for RBT2. The VFPA's mandate to protect the environment extends to preserving and enhancing the ecological health and integrity of the Fraser River estuary as part of the RBT2 Project, and ensures the organisation will be committed to the long-term efficacy of Offsetting Measures. The VFPA's environmental leadership and track record on habitat enhancement is relevant to RBT2. Examples include the following:

- Beginning in 2013, the removal of derelict structures and vessels as part of the Fraser River Improvement Initiative[10].
- In 1991, one of the VFPA's predecessor[11] port authorities, the North Fraser Harbour Commission, established an Environmental Management Plan, which included a provision for habitat banking where habitat was proactively created, restored, and enhanced. Some of the habitat created as part of this initiative remains in the VFPA's current habitat bank (see description of the Habitat Enhancement Program below).
- As part of its Habitat Enhancement Program, the VFPA currently operates the largest habitat bank in Canada, and is recognised as a leader in the development of offsetting and habitat banking (described in greater detail below). The Habitat Enhancement Program works closely with Indigenous groups, regulators such as DFO, environmental organisations such as Ducks Unlimited Canada and the Pacific Salmon Foundation, and local municipalities. Habitat projects that have been constructed as part of the Habitat Enhancement Program are the Roberts Bank Salt Marsh Restoration Project, Glenrose Tidal Marsh Project, and New Brighton Park Shoreline Habitat Restoration Project.
- The VFPA has implemented long-term monitoring and adaptive management efforts to ensure that habitat enhancement projects achieve desired outcomes (e.g., Deltaport Third Berth Adaptive Management Program).
- The VFPA has been recognised for its leadership in aquatic habitat restoration, enhancement, and creation, and overall environmental management. In 2017, the VFPA won the North American Marine Environment Protection Association (NAMPEA) award for its marine environment protection initiatives. In 2018, the VFPA received a *gold rating* under the Stewardship Centre for *B.C.'s Green Shores®* for Coastal Development program for the New Brighton Park Shoreline Habitat Restoration Project (described below) (VFPA 2018b), located in the City of Vancouver. This award, which is the highest possible achievement of project environmental goals and leadership in shoreline stewardship, is based on a number of factors, including excellence in rehabilitation of coastal habitat, innovation, and climate change adaptation. This project was also selected as a finalist for the 2018 *Environmental Managers Association of British Columbia's Environmental Management Awards*, and was a featured presentation regarding port cities and thriving environments at the 16th Annual World Conference of Cities and Ports. The VFPA was also awarded the 2018 Governance Professionals of Canada Excellence in Governance award for sustainable governance practices in the category of Best Practices in Sustainability and Environmental, Social, Governance.
- At Roberts Bank, in particular, the VFPA has successfully developed and maintained highly productive subtidal artificial reef structures on three occasions in recent decades (1983, 1993, and 2005)—in the last instance, creating highly productive aquatic

[10] https://www.portvancouver.com/marine-operations/fraser-river-maintenance/
[11] The predecessors to the VFPA were the separate Port Authorities of Fraser River, North Fraser, and Vancouver. They amalgamated into the VFPA on January 1, 2008.

habitat to offset residual project effects associated with development of the Deltaport Third Berth Project.

The VFPA's leadership in the areas of environmental stewardship, sustainability, and maintaining ecosystem productivity is exemplified by its Habitat Enhancement Program. The VFPA created the Habitat Enhancement Program in 2013 as part of a broad strategy around gateway growth, acknowledging that habitat sites may be required to offset effects from port infrastructure development. The Habitat Enhancement Program operates under a formal agreement with DFO for habitat banking. The designs of its projects are guided by coastal engineers, hydraulic engineers, wetland ecologists, and fisheries biologists that are highly experienced in the development of habitat projects within the Fraser River estuary and Burrard Inlet. Within this program, the VFPA has developed habitat projects that include a variety of habitat types such as tidal and salt marsh habitat, and rock reefs. Its habitat projects are developed through consultation and engagement with Indigenous groups, ENGOs, municipal governments, and other stakeholders, highlighting the VFPA's relationships and willingness to collaborate with a broad range of project partners. As of November 2018, the VFPA Habitat Bank has created or enhanced 13 habitat sites that would cover an area of approximately 10 hectares, and has also developed designs for over 100 hectares of additional habitat enhancement. Not only does the Habitat Enhancement Program demonstrate the VFPA's commitment to local communities and the environment, it also showcases its past experience and achievements in marine habitat enhancement.

As a long-term steward of the ecological health and integrity of the Fraser River estuary, the VFPA also views its plans for mitigating Project effects as part of a broader, decades-long commitment to ensure that Canada's marine trade can be facilitated in a way that protects the environment and supports local communities. The VFPA is committed to ensuring that any Offsetting Measures implemented or overseen by the VFPA to offset Project effects from RBT2 are monitored to confirm effectiveness. Adaptive management of offsetting habitats will be a process that will include early implementation of feasible offsets, monitoring of offsetting to confirm effectiveness, detection of action trigger thresholds indicating when performance requires remedial action, followed with corresponding action, including refinements/adjustments of offsets and the construction of additional offsets if required. This methodical approach will ensure that the habitat constructed for offsetting the Project's effects will become an effective component of the Roberts Bank ecosystem. The current RBT2 Follow-up Program considers offset habitat monitoring with Indigenous group involvement and scientific oversight (IR13-30 of CEAR Document #1331).

Summary

The VFPA is committed to developing a successful Offsetting Plan through active engagement and collaboration to ensure that ecosystem productivity is maintained. The current Offsetting Framework (EIS Section 17.0), was developed to meet the needs of the EA phase of the Project, and will evolve by the VFPA engaging with Indigenous groups, regulatory agencies, and key stakeholders to better understand priorities, needs, and expectations when it comes to offsetting.

This work will identify any refinements required to the currently proposed RBT2 Offsetting Measures in preparation for the final Offsetting Plan, to meet permitting requirements (e.g., FAA), non-permit requirements such as the intent of the federal wetland policy on Federal lands (Government of Canada 1991), and will also respond to the dynamic ecology of the Roberts Bank ecosystem. The final Offsetting Plan will build upon the existing Offsetting Framework to deliver a comprehensive and broadly supported approach to offsetting that will ensure the productivity of the Roberts Bank ecosystem, and each of the identified marine biophysical VCs, is maintained or enhanced in the long-term. The final Offsetting Plan, an FAA permit requirement, will also address and account for uncertainty in offsetting success and the associated time lag for the offset to become effective.

The VFPA has presented a responsible comprehensive approach to offsetting the anticipated impacts associated with the Project. A state of the art ecosystem productivity model was used to quantify and forecast changes in productivity with and without the Project at Roberts Bank. This model was developed using input from multiple lines of evidence (i.e., quantitative data, literature reviews, oceanographic models, etc.) and included input from experts on marine fishes, mammals, birds, invertebrates, and vegetation. The model forecasted a net increase in productivity with the Project and *prior to* any offsetting measures. Despite this overall finding, based on other lines of evidence and from a precautionary approach, the VFPA has developed an Offsetting Framework and five conceptual onsite habitat Offsetting Measures to address residual Project effects on specific marine biophysical VCs. With Offsetting Measures, the model estimated a further net increase in productivity (1,142 t). The success and effectiveness of the proposed Offsetting Measures will be monitored. The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach.

Based on the aforementioned approach to estimating, addressing, and monitoring offsetting, offsetting habitat experience, strong collaborative relationships, and past successes, the VFPA is well placed to successfully carry out the planning, engagement, and offsetting required for RBT2.

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IR7-24 Marine Fish Mitigation – Tug Basin

Information Source(s)

EIS Volume 1: Section 4.1.3

EIS Volume 3: Section 13.6.1.6; Table 13-8; Section 13.7; Appendix 10-C

Context

In Section 4.1.3 of the EIS, the Proponent described the expansion of the tug basin by 3.1 hectares which would increase the footprint from 1.4 hectares to 4.5 hectares. The basin would be dredged to a depth of -6.5 metres (chart datum) to allow for the required under-keel clearances for the anticipated new tugs. This is 0.5 metres deeper than the existing tug basin.

The Proponent, in Table 13-8 of the EIS, identified that effects from tug basin construction activities included the permanent alteration of benthic habitat and that the potential effect rating of dredging the tug basin were classified as moderate. According to the Proponent in Section 13.6.1.6 of the EIS, changes in habitat availability and utilization were attributed only to terminal placement and causeway expansion. Thereafter, in Section 13 of the EIS, there was no further reference to construction effects or permanent benthic habitat alterations within the tug basin and no offsetting was proposed in Section 13.7 of the EIS.

The Roberts Bank ecosystem model (Appendix 10-C) incorporated the productivity alterations associated with the construction of the causeway and the terminal (179 hectares) but did not account for potential effects of the proposed Project and habitat alterations within the tug basin in relation to offsetting.

Information is required regarding how the Proponent intends to mitigate the permanent alteration of benthic habitat associated with the tug basin expansion.

Information Request

Provide a description of the mitigation measures that would address the permanent alteration of benthic habitats associated with the construction of the expanded tug basin.

VFPA Response

The VFPA has considered the potential effects associated with dredging and expansion of the tug basin on the benthic habitat and surrounding marine ecosystem. Changes to habitat availability/productivity primarily associated with construction activities will result from the following: i) permanent alteration of habitats (e.g., removal of eelgrass and any non-mobile invertebrates) within the expanded area of the tug basin and ii) temporary alteration and disturbance (e.g., increased sedimentation, increase in total suspended solids (TSS) and noise) to the existing tug basin area. The EIS described potential interactions and effects

associated with dredging and expansion of the tug basin on marine vegetation (EIS Table 11-10), marine invertebrates (EIS Table 12-6), marine fish (EIS Table 13-8), marine mammals (EIS Table 14-8), coastal birds (EIS Table 15-7), and commercial, recreational, and Aboriginal (CRA) fisheries (EIS Table 16-10). Dredging and expansion of the tug basin will transform a predominantly intertidal and subtidal habitat with eelgrass, sand, and some rock to a subtidal habitat (EIS Section 11.6.1). These created subtidal habitats have different productivity to the existing intertidal and subtidal habitat, but all are wetted habitats that will continue to contribute to ecosystem productivity. Although the tug basin footprint was not quantitatively included in the Roberts Bank ecosystem model (the design was not finalised when the model was being built (EIS Appendix 10-B, Section 1.6 and IR3-02 of CEAR Document #984[1]), effects of the tug basin dredging and expansion on the marine biophysical valued components (VCs) were assessed using other lines of evidence, including but not limited to existing information, empirical data, and expert opinion (CEAR Document #1185[2]). The environmental assessment predicted, after taking mitigation into account (described herein), that changes associated with the Project (including tug basin dredging and expansion) will not result in any significant residual effects on any of the aforementioned VCs.

The environmental assessment of the tug basin dredging and expansion considered mitigation to avoid or reduce the adverse effect on all biophysical VCs during construction, and operation. Table IR7-24-A1 in **Appendix IR7-24-A** summarises potential Project-related effects to marine biophysical VCs and mitigation measures to avoid, reduce, and offset impacts on marine vegetation, marine invertebrates, marine fish, marine mammals, and coastal birds that may be affected directly or indirectly by activities associated with dredging and expansion of the tug basin.

As an example of avoidance mitigation, following submission of the Project Description in 2013, the location and layout of the tug basin expansion was evaluated and modified to minimise disturbance on marine vegetation and improve drainage in the area on an ebbing tide (EIS Sections 5.4.4 and 5.6.2). Table IR7-24-A1 (**Appendix IR7-24-A**) also outlines measures to reduce impacts of sedimentation (e.g., potential temporary increase in TSS) on water quality during construction. Related to these mitigation measures, the VFPA will develop a Dredging and Sediment Discharge Plan associated with dredging activities of the Project, including the tug basin (IR11-24 of CEAR Document #1322[3]).

Tug basin mitigation also includes measures to reduce acoustic disturbance (e.g., during dredging and construction of tug basin mooring wharves, sound level thresholds will be monitored using hydrophones and provisions for intervention in the case of non-compliance will be established). For most marine fish, limited acoustic interaction is expected. Only certain representative fish species (e.g., Pacific herring) with high auditory sensitivity would be

[1] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).
[2] CEAR Document #1185 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-28 and IR5-29 (See Reference Document #975).
[3] CEAR Document #1322 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR9-01 to IR9-04, IR10-01, IR10-27, IR10-28, IR11-06, IR11-24, IR12-08, and IR12-12 (See Reference Documents #1122, 1130, 1179, and 1206).

expected to experience any behavioural effects. For Pacific herring, avoidance behaviour is expected and Roberts Bank is not a highly used spawning area for Pacific herring (EIS Table 13-9). Moreover, Table IR7-24-A1 (**Appendix IR7-24-A**) also includes examples of avoidance/reduction of impacts to CRA fisheries, such as the timing of specific construction activities to minimise overlap with spring emergence of salmon fry. Related to this, tug basin expansion can occur during any year of the construction schedule, since the expansion activities are independent of other Project construction activities aside from re-use of the dredged material for Project infilling. Overall, it is also anticipated that there will be limited interaction with many marine animals because all mobile species will have likely avoided the tug basin area during construction activities.

The expanded tug basin, which consists of a dredged area, slope protection, and new crest protection structure, will change coastal geomorphology within the localised area immediately surrounding the tug basin (EIS Section 9.5.8.2). A mitigation measure during construction to reduce effects of a permanent habitat alteration includes the installation of crest protection rip-rap around the exposed perimeter of the expanded tug basin. These structures will protect the existing mudflats from scouring forces during tidal exchanges, thus mitigating the formation of dendritic channels (EIS Section 4.4.1.18). In addition, the rip-rap provides a stable substrate for attachment of algae (rockweed and *Ulva*) and mussels.

Offsetting Measures that were designed to benefit key functional groups/species (e.g., eelgrass, bivalves) at Roberts Bank also provide direct and indirect benefits (and/or serve as mitigation) to any effects (e.g., permanent alteration of habitats) associated with dredging and expansion of the tug basin. The approach to offsetting for RBT2 was conducted at an ecosystem-level (see the Preamble to Offsetting-related Information Requests). Thus, offsets were not designed as *like-for-like*, but rather were to be considered as a contribution to the *whole* productivity at Roberts Bank. In the case of the tug basin, it is expected that 2.7 ha of eelgrass would be removed/impacted during dredging and expansion of the tug basin (EIS Table 11-2). Using productivity estimates for eelgrass estimated from the Roberts Bank ecosystem model, the 2.7 hectare (ha) loss corresponds to a loss in productive potential of 1.31 tonnes (t) of native eelgrass (EIS Section 11.6.3.1). However, as part of the Offsetting Framework, to offset any direct or indirect effects on eelgrass, onsite eelgrass offsetting habitat will be created, corresponding to an estimated biomass increase of 8.7 t. Offsetting Measures planned for other VCs also mitigate and offset any direct or indirect subtidal impacts of dredging at the tug basin. For example, the proposed construction of onsite subtidal rock reef offsetting habitats (estimated to increase productivity by 33.2 t) will benefit kelps, lingcod, and rockfish (EIS Section 17.0, EIS Appendix 17-C). The VFPA has a successful history of creating subtidal rock reef structures at Roberts Bank (additional information in the Preamble to Offsetting-related Information Requests). With mitigation, including offsetting, the amount of change to productivity associated with tug basin expansion is estimated to be <0.1% of the total study area at Roberts Bank, too small to have a measurable or substantive effect on the ecological productivity in the assessment area.

The VFPA also committed to monitoring compliance results to assist with determining, through systematic evaluation, when additional or revised mitigation measures are required to rectify and/or enhance current mitigation measures to achieve the outcomes predicted in the EIS (as

described in the response to IR13-29 of CEAR Document #1331[4]). Moreover, the VFPA has committed to monitoring the success and effectiveness of the proposed Offsetting Measures, as part of the Project's Follow-up Program (IR13-30 of CEAR Document #1331) and future permitting requirements. The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach.

Appendices

Appendix IR7-24-A Summary of Potential Project-related Effects to Marine Biophysical Valued Components and Mitigation Measures (including offsetting) to Avoid, Reduce, and Offset Effects from Tug Basin Dredging and Expansion

[4] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).

APPENDIX IR7-24-A

SUMMARY OF POTENTIAL PROJECT-RELATED EFFECTS TO MARINE BIOPHYSICAL VALUED COMPONENTS AND MITIGATION MEASURES (INCLUDING OFFSETTING) TO AVOID, REDUCE AND OFFSET EFFECTS FROM TUG BASIN DREDGING AND EXPANSION

Table IR7-24-A1 Summary of Potential Project-related Effects to Marine Biophysical Valued Components and Mitigation Measures to Avoid, Reduce, and Offset Effects from Tug Basin Dredging and Expansion

Potential Project-related Effects to Marine Biophysical Valued Components (VCs) from Tug Basin Dredging and Expansion[1]	Applicable Mitigation Measures	Intent of Mitigation Measure	Applicable VCs	Reference
Direct mortality of marine invertebrates and marine fish from tug basin dredging and expansion. Temporary reduction in productivity of marine biophysical VCs during tug basin dredging and expansion (e.g., increased sedimentation, increase in total suspended solids (TSS)). Increased underwater noise from dredging equipment/vessels and pile driving in the existing tug basin and tug basin expansion area resulting in disturbance to marine fish, marine mammals, and coastal birds. Changes in habitat availability following tug basin dredging and expansion (e.g., changing predominantly intertidal and subtidal habitat with eelgrass, sand, and some rock to a subtidal habitat (EIS Section 11.6.1).	**Avoid**			
	Mitigation by design Alternative means assessment of tug basin location and layout to reduce adverse effects from tug basin dredging and expansion.	Minimise intertidal habitat loss. Minimise loss of continuous eelgrass habitat (selected tug basin location and layout is within patchy eelgrass habitat). Minimise potential for alteration of tidal flows and water ponding. Minimise potential for tidal channel formation.	Marine vegetation, marine invertebrates, and marine fish	EIS Sections 5.4.4 and 5.6.2
	Mitigation by design Elimination of surface disposal of tug basin dredged material.	Minimise suspension, dispersion, and deposition of sediments and direct mortality to marine invertebrate and fish (burial and entrainment) by beneficial use of dredged sediments as terminal fill material.	Marine invertebrates, marine fish	Project Construction Update (CEAR Document #1210[2])
	Mitigation by design Installation of crest protection structure around perimeter of expanded tug basin.	Avoid formation of dendritic channels in existing intertidal habitat from scouring of bed sediments during tidal exchange. Provide hard substrate (rip-rap) for attachment of algae (rockweed and *Ulva*) and mussels.	Marine vegetation, marine invertebrates, marine fish	EIS Section 4.4.1.18
	Scheduling and sequencing of construction activities Fisheries and Oceans Canada (DFO) least-risk timing window for juvenile salmon (dredging in water above -5.0 m chart datum (CD) will not occur during the fisheries sensitive window of March 1 to August 15).	Minimise productivity losses, direct mortality, and physical injury to out-migrating juvenile Pacific salmon during dredging and tug basin expansion.	Marine fish and commercial, recreational, and Aboriginal (CRA) fisheries	EIS Section 13.7.1.2 Appendix IR12-A (CEAR Document #314[3])
	Scheduling and sequencing of construction activities DFO least-risk timing window for crab (dredging in water below - 5.0 m CD will occur between April 1 and October 14).	Minimise direct mortality and physical injury to gravid Dungeness crab females (also aligns with periods when diving birds are most abundant in the area and serves as a mitigation measure for coastal birds).	Maine invertebrates, coastal birds, and CRA fisheries	EIS Section 12.7.1.2 Appendix IR12-A (CEAR Document #314)
	Reduce			
	Dredging and Sediment Discharge Management Plan Compliance checking of threshold levels for TSS/turbidity, and provisions for intervention in the case of non-compliance.	Minimise suspension, dispersion, and deposition of sediments (e.g., reduce the temporary increase in TSS levels during dredging and expansion of the tug basin).	Marine vegetation, marine invertebrates, marine fish, marine mammals, and coastal birds	EIS Section 33.0 IR11-24 (CEAR Document #1322[4])
	Underwater Noise Management Plan During piling, use of vibratory hammer instead of impact pile driving when practical.	Minimise underwater noise and over-pressure waves during dredging and expansion of the tug basin (e.g., during dredging and	Marine fish, marine mammals, and coastal birds	EIS Section 33.0 Appendix IR12-A (CEAR Document #314)

[1] See EIS Table 11-10, EIS Table 12-6, EIS Table 13-8, EIS Table 14-8, EIS Table 15-7, and EIS Table 16-10 for a complete list of potential interactions and effects to marine biophysical VCs associated with dredging and expansion of the tug basin.
[2] CEAR Document #1210 From the Vancouver Fraser Port Authority to the Review Panel re: Project Construction Update (See Reference Document #995) (NOTE: Updated June 13, 2018)
[3] 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.
[4] CEAR Document #1322 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR9-01 to IR9-04, IR10-01, IR10-27, IR10-28, IR11-06, IR11-24, IR12-08, and IR12-12 (See Reference Documents #1122, 1130, 1179, and 1206).

Potential Project-related Effects to Marine Biophysical Valued Components (VCs) from Tug Basin Dredging and Expansion[1]	Applicable Mitigation Measures	Intent of Mitigation Measure	Applicable VCs	Reference
	Hydrophone monitoring to confirm sound levels remain below thresholds and provisions for intervention in the case of non-compliance. Implementation of sound reduction or dampening methods or technologies (e.g., bubble curtains) to manage pile-driving sound levels, if required, to lower sound levels below injury and behavioural effect thresholds. Establish protective buffer zones around Project construction activities for killer whales. Marine Mammal Observers (MMOs) to visually and acoustically monitor the buffer zones and record location and behaviour of observed animals.	pile driving activities) to conduct activities under the threshold sound level that may cause harm (injury or mortality) to fish. Reduce potential marine mammal behavioural disturbance and physical injury to hearing caused by an increase in underwater noise.		IR5-49 (CEAR Document #1167[5])
	Light Management Plan Use dredge lighting shields to minimise light spilling outside the basic working footprint of the dredge. Controlling light levels and limiting light use to areas where activities are occurring, where possible.	Maintain existing marine fish habitat quality and fish productivity by minimising light trespass into marine environment. Minimise disorienting effects to birds, thereby maintaining habitat quality and minimise the potential for bird collisions	Marine invertebrates, marine fish, marine mammals, and coastal birds	EIS Section 33.0 Appendix IR12-A (CEAR Document #314) IR5-25 (CEAR Document #1153[6]) IR9-02 (CEAR Document #1322)
	Environmental Management Plan (EMP) Marine Species Salvage Plan The EMP will identify procedures for a crab and fish salvage strategy.	Bait crabs away from dredging and expansion of the tug basin activities to local area outside of Project-related disturbance area to partially mitigate construction-related mortality and physical injury.	Marine invertebrates (Dungeness crabs) and marine fish	EIS Section 33.0 Appendix IR12-A (CEAR Document #314)
	Offset			
	Onsite Offsetting Habitat Creation of eelgrass onsite offsetting habitat.	Mitigate direct or indirect effects on existing eelgrass habitat from dredging and expansion of the tug basin by creating onsite eelgrass offsetting habitat, and promote increase in bivalve shellfish (heart cockles), crab, juvenile salmon, juvenile rockfish, forage fish, and small demersal fish productivity.	Marine vegetation, marine invertebrates, marine fish, and coastal birds	EIS Section 17.0 EIS Section 35.0, Table 35-2 Appendix IR12-A (CEAR Document #314)
	Onsite Offsetting Habitat Creation of subtidal rock reef onsite offsetting habitat.	Mitigate direct effects on existing rock macroalgae habitat (i.e., rock weed on the existing tug basin crest protection structure) by creating onsite subtidal rock reef offsetting habitat, and promote increase in bivalve shellfish (bay mussel and Pacific oysters), macroalgae productivity, and reef fish productivity.	Marine vegetation, marine invertebrates, marine fish, and coastal birds	EIS Section 17.0 EIS Section 35.0, Table 35-2 Appendix IR12-A (CEAR Document #314)

[5] CEAR Document #1167 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-37, IR5-42, IR5-48, IR5-49, IR5-51, IR5-52, IR6-30 and IR8-10 (See Reference Documents #975, #991 and #1071).
[6] CEAR Document #1153 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-02, IR5-11, IR5-13, IR5-17, IR5-18, IR5-22, IR5-25, IR5-26, IR5-27, IR5-43, and IR5-44 (See Reference Document # 975).

IR7-25 Marine Fish Mitigation – On Site Offsetting Concepts: Sandy Gravel Beach

Information Source(s)

EIS Volume 3: Appendix 17-A; Appendix 17-C

Context

The Proponent, in Appendix 17-A, identified ranges in the areas for the following proposed offset concepts for the proposed Project:

- intertidal marsh - 5 to 15 hectares;
- sandy gravel beach - 4.5 to 10 hectares;
- eelgrass - up to 3 hectares;
- mudflat - 4.5 hectares; and
- rock reef - up to 2 hectares.

In Appendix 17-C of the EIS, the Proponent predicted the biomass of functional groups using the following specified areas for each onsite offsetting concept:

- 15 hectares of intertidal marsh;
- 4.5 hectares of sandy gravel beach;
- 3 hectares of eelgrass;
- 4.5 hectares of mudflat; and
- 2 hectares of rock reef.

With the exception of the sandy gravel beach offset concept, where 4.5 hectares of habitat was proposed, the Proponent, in Appendix 17-C, used the upper limits of the available proposed offset areas for the five offset habitat types.

Information Request

Given the range (4.5 to 10 hectares) of sandy gravel beach in the proposed offset concept, provide a rationale for why 4.5 hectares was used in the calculation to predict biomass of functional groups in the sandy gravel beach offset concept.

VFPA Response

The VFPA recognises that in four of the five proposed Offsetting Measures, the maximum value of proposed area was selected; however, for the proposed onsite sandy gravel beach habitat, the lower value of the potential area was adopted. As per the Offsetting Framework objectives (EIS Section 17.3.2.2), priority was given to higher productivity habitats to maximise overall productivity within the local assessment area (LAA). This approach of maximising productivity through optimal design is consistent with current science advice and policy (Bradford et al. 2016, DFO 2013, Environment Canada 2012) (further details in the Preamble to Offsetting-related Information Requests).

Rather than simply replacing *like for like*, it was determined that a more efficient strategy was to replace with more productive habitats (measured via biomass), with the goal of sustaining productivity of the ecosystem. Maximising the amount of onsite offsetting habitats that have high productive potential also maximises the probability of indirect gains by all species associated with these habitats, thus, further striving toward the VFPA's goal of sustaining productivity of the Roberts Bank ecosystem.

The onsite habitat Offsetting Concepts (i.e., Offsetting Measures) were designed by a multidisciplinary team of marine biologists, coastal engineers, hydrodynamic modellers, and specialists from the VFPA's Habitat Enhancement Program. Thus, in addition to productivity, the type and amount of habitat chosen for offsetting was based on physical characteristics (e.g., tidal height, slope, wave exposure, etc.) of the available location, with the goal of creating habitats best suited to existing and predicted conditions (additional specific details in the responses to IR11-16 and IR11-17). Consequently, the development of onsite Offsetting Measures was somewhat constrained by spatial suitability (EIS Figure 17-1). When designing Offsetting Measures, biological and ecological constraints on the focal species/groups were considered to create habitats with the best probability of success. For example, intertidal marsh vegetation thrives best in low energy, soft-substrate habitats of the high tide (> +3.5 m chart datum (CD)) and will not establish well in the mid (+1.5 to +3.0 CD) or low tide zone (<+0.5 m CD) (see response to IR7-27). Conversely, another primary producer, brown algae, rockweed (*Fucus*), thrives best in the mid to lower high tide zone of wave-exposed areas and requires a hard, stable substrate (i.e., rock, cobble, rip-rap) for attachment. For intertidal marsh vegetation and rockweed, tidal height, and substrate are key determinants of their colonisation and establishment. There is some minimal overlap in habitat conditions among intertidal marsh, sandy gravel, and mudflat; however, they have discrete differences in intertidal height and exposure. Basically, these three habitats form a continuum along an intertidal gradient. Creating sandy gravel habitats at lower tidal heights (< +0.5 m CD) in soft-bottom habitats with low wave exposure would not be successful. Thus, when combining the goals of site suitability and selecting more productive habitats, there are limits on where and the amount of onsite Offsetting Measures habitats can be located (Figure IR7-27-A1 in Appendix IR7-27-A).

Using the Roberts Bank ecosystem model, sandy gravel habitats had relatively low estimates of productive potential (13.4-15.6 tonnes per hectare (t/ha)), whereas intertidal marsh and mudflats were much higher (38.5-50 t/ha and 42.2-60.7 t/ha, respectively) (EIS Table 17-4). In the Offsetting Framework, emphasis was given to construct habitats that helped contribute to a balance of no-net-loss in overall productivity (combined with having the greatest probability of success); thus, the maximum proposed onsite offsetting area for intertidal marsh and mudflats were preferentially selected as the optimum choice. From the Offsetting Framework, the proposed onsite habitat offsetting concepts for the five habitat types result in an estimated net gain in biomass of 756 t for a total net productivity change of 1,142 t with Project and offsetting (4.4% of biomass before the Project) (Table IR7-26-A1 in Appendix IR7-26-A). Existing sandy gravel habitats were selected as habitat types over which offsetting habitats (with higher productivity) could be located and built (Table 17-C1 in EIS Appendix 17-C).

The VFPA recognises that sandy gravel beaches are also important ecologically at Roberts Bank. For example, surf smelt and Pacific sand lance, which use sandy gravel habitat, account for much of the forage fish biomass at Roberts Bank, making the development of additional sandy gravel habitat an integral component to maintaining the ongoing productivity in the Project area. Consequently, the Offsetting Framework presents construction of 4.5 ha (forecasted biomass increase of 51 t) of soft sediment beaches (to cover hard riprap structures) along the causeway and adjacent to the new terminal (Figure IR7-27-A1 in Appendix IR7-27-A). This Offsetting Measure will provide habitat for forage fish spawning and is consistent with the predominance of soft substrates in the Roberts Bank estuary. Among marine vegetation, brown algae 'rockweed' (*Fucus*) is estimated to comprise 23.37 t (45.8%) of the 51 t increase in productivity associated with the proposed onsite sandy gravel habitat (Table IR7-26-2 in the response to IR7-26). *Fucus* is a key primary producer and provides refuge habitat on these sandy gravel beaches.

The amount of sandy gravel habitat to be constructed for offsetting will be refined as the current Offsetting Framework advances into an Offsetting Plan (further details in the Preamble to Offsetting-related Information Requests). The current Offsetting Framework will evolve and adapt into a final Offsetting Plan following engagement with Indigenous groups, regulatory agencies, and key stakeholders. The final Offsetting Plan will maximise benefits for local communities plus address priority issues and concerns, while meeting permitting phase requirements responsive to the dynamic nature of the Roberts Bank ecosystem.

References

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IR7-26 Marine Fish Mitigation – On-Site Offsetting Concepts: Net Gain

Information Source(s)

EIS Volume 3: Appendix 10-D, Appendix D; Appendix 17-B; Appendix 17-C, Table 17-C

Context

The Proponent, in Appendix D of Appendix 10-D of the EIS, identified the methodology used to determine the overall amounts and types of offsetting required for the proposed Project. According to the Proponent in Appendix 17-B of the EIS, to quantify the net effect of the Project with the onsite offsetting concepts, the net gain in productivity from the onsite offsetting concepts was estimated and then subtracted from the "With Project" key run determined by the Roberts Bank ecosystem model.

Information Request

Describe how the net gain in autotrophic productivity from the onsite offsetting concepts was estimated.

Describe the assumptions for calculating the net biomass increase of heterotrophic functional groups associated with the offsetting concepts.

Describe how the areal extent of the conceptual habitat projects was integrated into the calculations and results shown in Table 17-C2 of Appendix 17-C of the EIS; Change in Biomass for Functional Groups With the Project and With Proposed Onsite Offsetting.

VFPA Response

Context

The Roberts Bank ecosystem model results (i.e., output) representing the 'without Project' conditions at Roberts Bank was used to estimate the net gains in productivity anticipated by the creation of onsite offsetting habitats. The primary objective of the Roberts Bank ecosystem model was to forecast anticipated changes in productivity between the 'with' and 'without Project' conditions (i.e., model runs). This is described in the EIS Section 10.0 and its appendices. The model results with and without the Project were interpreted as one of the lines of evidence (IR5-29 of CEAR Document #1185[1]) in the evaluation of potential adverse effects of the Project, the prediction of residual effect after accounting for mitigation, and the determination of significance of the residual effect (EIS Sections 11.0, 12.0, 13.0, and 15.0). EIS Section 17.0 described how the 'without Project' model outputs were used to provide estimates of productivity gains with the proposed onsite habitat Offsetting Concepts. A full

[1] CEAR Document #1185 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-28 and IR5-29 (See Reference Document #975).

description of the methods and approach used to estimate productivity gains is provided in the response below. The purpose of Table 17-C2 in EIS Appendix 17-C was to demonstrate the outcomes from a net productivity calculation, accounting for the productivity of the existing habitat, which is subtracted from the expected productivity gains from the offsetting habitats that will replace the existing habitats. However, the presentation of all key functional groups as listed in Table 17-C2 does not clearly communicate the broader net productivity changes when converting one habitat type to another (e.g., sandflat to eelgrass). Consequently, a revised table has been included (Table IR7-26-A1 in **Appendix IR7-26-A**) that more clearly presents the losses and gains (in biomass) per relevant functional groups (i.e., representative species) by onsite offsetting habitat type (i.e., onsite habitat Offsetting Concept).

Response

Outputs generated from the Roberts Bank ecosystem model 'without the Project' were relied upon to estimate productivity associated with onsite offsetting, including autotrophic and heterotrophic productivity. The net productivity results associated with each onsite habitat Offsetting Concept (i.e., type) are presented in a revised Table 17-C2 (Table IR7-26-A1 in **Appendix IR7-26-A**). Table IR7-26-A1 supersedes Table 17-C2 of EIS Appendix 17-C. In short, productivity estimates 'with the Project' and onsite offsetting forecasts a net gain in productivity of 1,104 tonnes (t) for autotrophic groups while a net gain of 38 t is forecasted for heterotrophic groups.

The following describes the methods by which autotrophic and heterotrophic productivity were estimated for each onsite offsetting habitat (see Appendix D of EIS Appendix 10-D for additional details on the methods described below). The net productivity results presented in Table IR7-26-A1 (**Appendix IR7-26-A**) reflect inherent assumptions of the Roberts Bank ecosystem model and also those considered and applied after the submission of the EIS, including applying a food web approach to estimating onsite offsetting productivity estimates, addressing uncertainty in 'with Project' productivity forecasts, and focusing the forecasted productivity changes on key functional groups and representative species.

Methodological Approach

The Roberts Bank ecosystem model was not rerun to estimate productivity associated with Offsetting Measures. Instead, outputs from the Roberts Bank ecosystem model were used to estimate productivity associated with each onsite habitat Offsetting Concept (i.e., Offsetting Measure). The original 'without Project' outputs from the Roberts Bank ecosystem model presented in the EIS Appendix 10-C were used to provide estimates of existing productivity of high quality habitat types (i.e., eelgrass, intertidal marsh, mudflats (with biofilm), sandy gravel beach, and rocky subtidal reef). The 'without Project' model run generated 57 model output maps illustrating spatial productivity estimates for each of the 57 functional groups considered by the Roberts Bank ecosystem model. Each model output map (i.e., productivity map) consisted of 5,468 one hectare (ha) cells that were each assigned an estimated productivity value. In the EIS, these were presented as heat maps with warmer colours corresponding to high productivity and colder colours representing low or zero productivity (EIS Appendix 10-C).

To estimate productivity for each onsite habitat Offsetting Concept, the Roberts Bank ecosystem model output without the Project (i.e., productivity map) for a habitat forming group (e.g., eelgrass) was selected. The one hectare cells best representing the habitat type (e.g., eelgrass) were selected from this productivity map. As an example, cells with the highest eelgrass productivity were identified and selected to represent productivity levels associated with eelgrass habitat. Exceedance plot analyses were conducted to determine the optimal number of representative cells to be selected to designate productivity of the different onsite habitat types (i.e., provided an estimate of what percentage of available cells to be included). The exceedance plots were constructed to identify the cells that best represented each habitat type, a threshold of 99.8 percentile was identified as optimal for representing productivity within the local assessment area. Thus, for each of the five onsite habitat Offsetting Concepts (i.e., habitat types), three to 11 cells (i.e., ~0.2% of the 5,468 cells) in the study area that have the highest productivity for the given habitat type were selected and the average productivity (i.e., biomass) value for these cells was calculated. It is important to note that for each habitat forming group (i.e., habitat type), only some of the 5,468 cells had non-zero productivity; therefore the selected cells represent the most accurate sample of a given habitat type. The location of the selected cells were used to extract productivity values for all functional groups at those cell locations providing an estimate of productivity (t/ha) for each onsite habitat Offsetting Concept as well as the existing habitat types upon which offsetting will be built over.

Food Web Approach

Appendix D of EIS Appendix 10-D detailed the food web approach adopted in the EIS to estimate ranges in productivity gains for offsetting habitats. However, the food web approach was not applied to estimating net productivity gains presented in Table 17-C2. **Table IR7-26-1** applied the habitat-specific food webs to select the relevant functional groups to consider in the productivity estimate for each onsite offsetting and existing habitat type. Moreover, the specific food web composition attributed to each onsite habitat Offsetting Concept was refined to better reflect habitat specific ecological links. A summary of the food web approach in estimating net productivity changes is provided below.

The food webs for each habitat type considered the direct trophic linkages of the functional groups from the Roberts Bank ecosystem model (i.e., Roberts Bank ecosystem model diet matrix). The food webs included functional groups that obtain at least 1% of their diet from the functional groups directly associated with the habitat type (i.e., direct trophic association). For example, the food web for eelgrass consisted of American wigeon, brant, waterfowl, and shiner perch, as each feed directly on native eelgrass. Secondly, predators of the functional groups identified to be associated indirectly with the habitat type were then included based on the diet compositions from the key run of the Roberts Bank ecosystem model (i.e., indirect trophic association). For example, great blue heron was added to the food web for eelgrass habitat because it feeds on herring. Lastly, functional groups were added that are associated with the habitat, but do not directly use it as a food source (i.e., non-trophic ecological association). For example, juvenile Chinook, chum (and other salmon), and herring are known to use eelgrass beds for refuge.

Table IR7-26-1 Food Web Functional Groups Representative of Onsite Offsetting and Existing Habitat Type

Onsite Offsetting Habitat Types				
Eelgrass	**Intertidal Marsh**	**Mudflat**	**Sandy Gravel Beach**	**Subtidal Rock Reef**
American wigeon	American wigeon	American wigeon	American wigeon	Diving waterbirds
Bald eagle	Bald eagle	Diving waterbirds	Diving waterbirds	Dogfish
Brant	Diving waterbirds	Dunlin	Great blue heron	Herring
Diving waterbirds	Dunlin	Great blue heron	Waterfowl	Large demersal fish
Great blue heron	Great blue heron	Gulls and terns	Flatfish	Lingcod
Gulls and terns	Gulls and terns	Shorebirds	Forage fish	Rockfish
Raptors	Shorebirds	Waterfowl	Herring	Shiner perch
Waterfowl	Waterfowl	Western sandpiper	Sand lance	Small demersal fish
Chinook (juvenile)	Western sandpiper	Chinook (juvenile)	Starry flounder	Dungeness crab
Chum (juvenile)	Chinook (juvenile)	Chum (juvenile)	Epifaunal grazer	Epifaunal grazers
Flatfish	Chum (juvenile)	Flatfish	Epifaunal omnivore	Epifaunal omnivores
Forage fish	Flatfish	Salmon juvenile	Bivalves	Epifaunal sessile suspension feeders
Herring	Forage fish	Small demersal fish	Macrofauna	Macrofauna
Large demersal fish	Shiner perch	Starry flounder	Meiofauna	Shrimp
Lingcod	Small demersal fish	Epifaunal grazers	Polychaetes	Brown algae (kelp/*Fucus*)
Rockfish	Starry flounder	Epifaunal omnivores	Brown algae (kelp/*Fucus*)	Red algae
Salmon juvenile	Epifaunal grazers	Bivalves	Green algae (*Ulva*)	
Pacific sand lance	Epifaunal omnivores	Macrofauna	Red algae	
Shiner perch	Bivalves	Meiofauna		
Small demersal fish	Macrofauna	Polychaetes		
Starry flounder	Meiofauna	Biofilm marine		
Dungeness crab	Polychaetes			
Epifaunal grazer	Tidal marsh species			
Epifaunal omnivore				
Bivalves				
Macrofauna				
Meiofauna				
Omnivorous & herbivorous zooplankton				

Onsite Offsetting Habitat Types				
Eelgrass	**Intertidal Marsh**	**Mudflat**	**Sandy Gravel Beach**	**Subtidal Rock Reef**
Polychaetes Shrimp Native eelgrass Red algae				

Existing Habitat Types					
Rocky intertidal	**Sandflat (intertidal)**		**Sandflat (subtidal)**		
Herring	Bald eagle	Forage fish	Diving waterbirds	Epifaunal omnivores	
Epifaunal grazers	Diving waterbirds	Starry flounder	Flatfish	Epifaunal sessile suspension feeders	
Epifaunal omnivores	Dunlin	Dungeness crab	Large demersal fish	Bivalves	
Epifaunal sessile suspension feeders	Great blue heron	Epifaunal grazers	Sand lance	Macrofauna	
Macrofauna	Gulls and terns	Epifaunal omnivores	Skate	Meiofauna	
Brown algae (kelp /*Fucus*)	Shorebirds	Bivalves	Small demersal fish	Orange sea pen	
Green algae (*Ulva*)	Waterfowl	Macrofauna	Starry flounder	Polychaetes	
Red algae	Western sandpiper	Meiofauna	Dungeness crab	Shrimp	
	Chum (juvenile)	Polychaetes			
	Flatfish				

The functional groups that were part of the food web were then selected to estimate productivity (measured in biomass) for each habitat type by extracting the biomass associated with these functional groups for the cells associated with each habitat type. Biomass values from each of the food web members (i.e., selected functional groups) associated with the relevant habitat were summed as part of the net productivity value calculations. The process was then repeated independently to attribute productivity levels to the existing habitats upon which onsite offsetting will be built over (e.g., intertidal sand, subtidal sand, mudflat). With the productivity for offsetting and existing habitat types estimated, net productivity values were calculated by discounting the gains in productivity associated with the offsetting habitat from the productivity value of the existing habitats. For example, subtidal rock reef included macrofauna (productivity value of 0.097 t/ha) as part of its food web. However, subtidal rock reef will be replacing subtidal sandflat habitat, which also had macrofauna (productivity value of 0.004 t/ha) as part of its food web. The net value of productivity for subtidal rock reef is the result of the gained productivity minus the existing productivity (i.e., 33.2 t), with the addition of two hectares of rock reef offsetting (Table IR7-26-A1 in **Appendix IR7-26-A**).

The process described above was completed for each of the offsetting habitats and selected functional groups (see **Reduction of the Number of Functional Groups** below), which included both autotrophic and heterotrophic groupings, to estimate net productivity associated with the five currently proposed onsite habitat Offsetting Concept (i.e., eelgrass, intertidal marsh, subtidal rock reef, mudflat, and sandy gravel beach). Finally, the net productivity was multiplied by the total area currently proposed for offsetting by habitat type. For example, if the net productivity of macrofauna in eelgrass was estimated as 1.4 t/ha (i.e., after discounting for existing habitat productivity estimates) and three hectares of eelgrass habitat is proposed to be built, then the total net value of macrofauna productivity is 4.2 t (Table IR7-26-A1 in **Appendix IR7-26-A**). non-trophic benefits provided by onsite offsetting habitats (e.g., structure for refuge). This may lead to underestimating (i.e., prey not gaining benefits of refuge) or overestimating (i.e., predators not being limited by lower prey availability) benefits. For example, we know that eelgrass provides protection from predators, spawning habitat, cover at low tide, sediment stabilisation, three-dimensional habitat, and indirect and direct food sources (Baldwin and Lovvorn 1994, Hemminga and Duarte 2000, Wyllie-Echeverria and Ackerman 2003), and provides habitat for juvenile salmon (*Oncorhynchus* sp.) and young-of-year Dungeness crabs (*Metacarcinus magister*) (Simenstad and Fresh 1995; Semmens 2008), foraging habitat for juvenile salmon (Fresh 2006), and spawning substrate for Pacific herring (*Clupea pallasi*) (Penttila 2007). In turn, these species interact with other species in the food web. While the model performs well at describing the current conditions and distribution of eelgrass as a species, it may underestimate when forecasting the associated productivity gains associated with non-food web ecological values. Thus, for onsite eelgrass habitat offsets, the overall productive potential is likely a conservative estimate.

Uncertainty

Appendix 10-D of the EIS describes and assesses the uncertainty associated with the estimates of productivity changes 'with the Project' generated by the Roberts Bank ecosystem model. A Monte Carlo (MC) analysis was conducted as part of the sensitivity analyses. However, this uncertainty was not applied when assessing impacts to biophysical valued

components described in the EIS[2]. For the EIS, the key run model outputs were used to estimate the amount of net productivity with offsetting. In Table IR7-26-A1 (**Appendix IR7-26-A**), the VFPA has incorporated uncertainty in estimating productivity changes with onsite offsetting by adopting the most conservative value (i.e., lower productivity estimate) between the key run or the MC median for the 'with Project' biomass estimates calculated since the submission of the EIS (IR3-09 of CEAR Document #984[3]). Thus, if any functional group had a median MC value lower than the key run, the MC value was selected. For example, shiner perch had a 'with Project' key run value of 10.6 t, whereas the MC 'with Project' value was 9.9 t. Using the lower value of 9.9 t reduced the estimated change in productivity from +1.7 t to +1.0 t. In adopting this approach, productivity estimates for 22 of the 37 functional groups presented in bold in Table IR7-26-A1 were adjusted downward.

Reduction of the Number of Functional Groups

The list of functional groups presented in Table IR7-26-A1 (**Appendix IR7-26-A**) was refined to 37 from the total of 57 functional groups incorporated to develop the Roberts Bank ecosystem model. Through the Productive Capacity Technical Advisory Group (TAG) process, recommendations were made on which species to include in the Roberts Bank ecosystem model. The recommendation was to include a number of focal species into the Roberts Bank ecosystem model. The TAG defined these as a nested set of functional groups that includes broad category, sub-category, and selected focal species. The Roberts Bank ecosystem model initially included 32 groups, which were a combination of sub-category (e.g., shorebirds) and selected focal species (e.g., western sandpiper). The list of 32 groups was expanded to 57 functional groups, by selecting an additional 25 functional groups to optimise model performance (i.e., to best represent an ecosystem) by capturing key energy flows (e.g., detritus, zooplankton), broader ecosystem components such as marine mammals, large demersal fish (e.g., greenling), epifaunal grazers (e.g., snails), jelly fish, etc., as well as culturally important species (e.g., Pacific herring).

To estimate productivity changes with the Project and onsite offsetting, the VFPA has refined the list of functional groups considered to a select 37 groups (i.e., focal species), reflecting the valued components and representative species targeted for offsetting, with direct Project interaction, with an important ecological role in the Roberts Bank ecosystem, with cultural importance, and/or recommended by the TAG. This approach considers guidance by Fisheries and Oceans Canada (DFO) to focus the assessment on a few key functional groups that are representative of the complex Roberts Bank ecosystem with a diverse array of ecological components of interest (CEAR Document #1057[4]). Table IR7-26-A1 (**Appendix IR7-26-A**) lists the key 37 functional groups considered.

[2] For the response to IR3-09 in CEAR Document #984, a Monte Carlo a sensitivity analysis was conducted, which considered wider confidence intervals and Dungeness crab harvest.
[3] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).
[4] CEAR Document #1057 From Fisheries and Oceans Canada to the Review Panel re: Response to Information Requests issued by the Review Panel on July 17, 2017 (See Reference Document #994).

Summary

The purpose of Table 17-C2 in EIS Appendix 17-C was to demonstrate how the value of existing habitat was considered in the calculations of net productivity estimates attributable to the offsetting habitats. Comments from the Panel and from DFO indicated that the presentation of Table 17**-**C2 was not clear and highlighted perceived inconsistencies with the outcomes from the proposed Offsetting Framework. The new table (Table IR7-26-A1 in **Appendix IR7-26-A**) provides updated information and shows how each proposed onsite habitat Offsetting Concept (i.e., Offsetting Measures) contributes to onsite productivity gains. The net change in biomass for each functional group was assessed based on the relative change from biomass estimates from the 'without Project' model run for the conversion from the existing habitat type to the created habitat offset. The proposed onsite habitat Offsetting Concepts have offset the forecasted productivity losses 'with the Project' for many of the functional groups. For example, for rockfish, the relevant Offsetting Measures will offset approximately three quarters of the estimated productivity losses 'with the Project'. The balance of Table IR7-26-A1 (**Appendix IR7-26-A**) shows a net gain in productivity of 1,142 t with onsite offsetting and the Project. The VFPA has committed to monitoring the success and effectiveness of the proposed Offsetting Measures, as part of the Project's Follow-up Program (IR13-30 of CEAR Document #1331[5]) and future permitting requirements. Preliminary details on the RBT2 Follow-up Program are described in the response to IR13-30 (CEAR Document #1331). The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach.

As outlined in the Preamble to Offsetting-related Information Requests, the Offsetting Framework will be refined and developed into a final Offsetting Plan following engagement with Indigenous groups, regulatory agencies, and key stakeholders, as part of the permitting phase of the Project. The final Offsetting Plan will deliver a comprehensive and broadly supported approach to offsetting that will ensure the productivity of the Roberts Bank ecosystem, and each of the identified marine biophysical valued components, is maintained or enhanced in the long term. Based on the approach to estimating, addressing, and monitoring offsetting, offsetting habitat experience, strong collaborative relationships, and past successes, the VFPA is well placed to successfully carry out the planning, engagement, and offsetting required for RBT2.

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[5] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).

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Appendices

Appendix IR7-26-A Revised Table 17-C2

APPENDIX IR7-26-A
REVISED TABLE 17-C2

Table IR7-26-A1 Change in Biomass for Functional Groups with the Project and with Proposed Onsite Habitat Offsetting Concepts, and Net Change in Productivity

Functional Group	EIS Productivity			Net Offsetting Productivity[a]							
	Without Project Biomass (t)	With Project Biomass (t)[b]	Difference (t, %)[c]	Onsite – Eelgrass (t)	Onsite – Intertidal Marsh (t)	Onsite – Sandy Gravel Beach (t)	Onsite – Mudflat (t)	Onsite – Subtidal Rock Reef (t)	Onsite Productivity Totals (t)	With Project & Onsite (t)	Net Productivity Change with Project and Onsite Biomass (t)
American wigeon	4.765	**4.363**	-0.4 -(8.4%)	0.003	0.014	0.006	0.015	-	0.04	4.40	-0.36
Bald eagle	0.120	**0.110**	-0.01 -(8.0%)	0.000	-	-	-	-	0.00	0.11	-0.01
Brant	1.088	1.031	-0.06 -(5.2%)	0.003	-0.001	0.001	-	-	0.00	1.03	-0.05
Diving waterbirds	1.506	**1.405**	-0.1 -(6.7%)	0.001	-0.001	0.002	0.001	0.001	0.00	1.41	-0.10
Dunlin	0.470	0.530	0.06 (12.7%)	-0.000	0.002	-	0.003	-	0.00	0.53	0.06
Great blue heron	0.670	**0.660**	-0.01 -(1.5%)	0.000	-0.000	0.001	0.001	-	0.00	0.66	-0.01
Gulls and terns	2.640	***2.560***	-0.08 -(2.9%)	0.000	0.001	-	0.004	-	0.01	2.57	-0.07
Raptors	0.010	0.010	0.003 (37.5%)	0.002	-	-	-	-	0.00	0.01	0.00
Shorebirds	0.050	0.040	-0.001 -(2.2%)	-0.000	0.000	-	0.000	-	0.00	0.04	-0.01
Waterfowl	16.560	***17.850***	1.29 (7.8%)	-0.004	0.696	0.014	0.097	-	0.80	18.65	2.09
Western sandpiper	0.060	0.070	0.01 (13.8%)	-0.000	0.000	-	0.001	-	0.00	0.07	0.01
Chinook (adult)	187.100	177.600	-9.5 -(5.1%)	-	-	-	-	-	-	177.60	-9.50
Chinook (juvenile)	0.660	***0.710***	0.06 (8.5%)	0.001	0.002	-	0.002	-	0.00	0.71	0.05
Chum (adult)	111.640	106.520	-5.13 -(4.6%)	-	-	-	-	-	-	106.52	-5.12
Chum (juvenile)	0.490	***0.530***	0.04 (8.0%)	0.000	-0.001	-	0.001	-	0.00	0.53	0.04
Flatfish	20.440	20.130	-0.31 -(1.5%)	0.019	-0.011	0.025	0.003	-0.001	0.04	20.17	-0.27
Forage fish	573.090	***562.240***	-10.85 -(1.9%)	0.196	0.360	0.358	-	-	0.91	563.15	-9.94
Herring	242.710	***233.350***	-9.37 -(3.9%)	0.257	-	0.250	-	0.052	0.56	233.91	-8.80
Large demersal fish	8.390	***8.080***	-0.3 -(3.6%)	0.014	-	-	-	0.000	0.01	8.09	-0.30
Lingcod	32.030	31.060	-0.98 -(3.0%)	0.005	-	-	-	2.110	2.12	33.18	1.15
Rockfish	18.480	16.840	-1.63 -(8.8%)	0.004	-	-	-	1.260	1.26	18.10	-0.38
Pacific sand lance	11.320	***11.520***	0.2 (1.8%)	0.009	-	0.013	-0.000	-0.000	0.02	11.54	0.22
Shiner perch	8.920	***9.840***	0.92 (10.3%)	0.008	0.038	0.000	-	0.000	0.05	9.89	0.97
Small demersal fish	3.950	***3.680***	-0.26 -(6.7%)	0.008	0.002	-	0.002	0.001	0.01	3.69	-0.26
Starry flounder	11.450	***11.590***	0.13 (1.2%)	0.010	0.003	0.024	0.006	-0.004	0.04	11.63	0.18

Functional Group	EIS Productivity				Net Offsetting Productivity[a]							
	Without Project Biomass (t)	With Project Biomass (t)[b]	Difference (t, %)[c]		Onsite – Eelgrass (t)	Onsite – Intertidal Marsh (t)	Onsite – Sandy Gravel Beach (t)	Onsite – Mudflat (t)	Onsite – Subtidal Rock Reef (t)	Onsite Productivity Totals (t)	With Project & Onsite (t)	Net Productivity Change with Project and Onsite Biomass (t)
Dungeness crab	252.770	***235.080***	-17.69	-(7.0%)	0.320	-	-0.120	-0.164	0.162	0.20	235.28	-17.49
Bivalves	6590.180	***5955.070***	-635.11	-(9.6%)	2.972	0.910	3.290	-0.570	-5.600	1.00	5956.07	-634.11
Macrofauna	2743.430	***3275.590***	532.16	(19.4%)	4.181	1.560	5.610	4.430	0.186	15.97	3291.56	548.13
Meiofauna	1588.640	***1733.250***	144.61	(9.1%)	-1.113	6.450	1.730	24.550	-0.001	31.62	1764.87	176.23
Orange sea pen	7.690	3.460	-4.23	-(55.0%)	-0.000	-	-0.000	-0.000	-0.000	-0.00	3.46	-4.23
Biofilm[d]	3462.530	4511.110	1048.58	(30.3%)	-	-	-	140.800	-	140.80	4651.91	1189.38
Brown algae (kelp /*Fucus*)	448.060	***394.840***	-53.22	-(11.9%)	-	-	23.370	-	35.070	58.44	453.28	5.22
Native eelgrass	304.580	***315.950***	11.37	(3.7%)	1.784	-	-	-	-	1.78	317.73	13.15
Green algae (*Ulva*)	6894.600	6311.660	-582.95	-(8.5%)	-	-	16.350	-	-	16.35	6328.01	-566.59
Non-native eelgrass	6.860	***6.760***	-0.1	-(1.4%)	-	-	-	-	-	-	6.76	-0.10
Tidal marsh species	1329.830	1664.890	335.06	(25.2%)	-	483.850	-	-	-	483.85	2148.74	818.91
Biomat	1217.130	861.010	-356.12	-(29.3%)	-	-	-	-	-	-	861.01	-356.12
TOTALS	**26104.91**	**26490.99**	**386.08**		**8.68**	**493.87**	**50.92**	**169.18**	**33.24**	**755.90**	**27246.89**	**1141.98**
Autotrophs	13663.59	14066.22	402.63	(2.9 %)	1.784	483.850	39.720	140.800	35.070	701.22	14767.44	1103.85
Heterotrophs	12441.32	12424.77	-16.55	-(0.1%)	6.895	10.024	11.204	28.382	-1.833	54.67	12479.44	38.12
Marine Birds	27.94	28.63	0.69	(2.5%)	0.004	0.711	0.024	0.122	0.001	0.86	29.49	1.55
Marine Fish	1230.67	1193.69	-36.98	-(3.0%)	0.532	0.393	0.670	0.014	3.419	5.03	1198.72	-31.95
Marine Invertebrates	11182.71	11202.45	19.74	(0.2%)	6.360	8.920	10.510	28.246	-5.253	48.78	11251.23	68.52
Marine Vegetation	13663.59	14066.22	402.63	(2.9%)	1.784	483.850	39.720	140.800	35.070	701.22	14767.44	1103.85

Notes: a. Adjusted to remove productivity estimates associated with the existing habitat upon which offsetting habitat will be built upon. Thus, negative productivity estimates represent forecasted losses when converting existing habitat to onsite offsetting habitat.
b. Numbers in bold represent functional groups for which the estimated biomass 'with the Project' has changed since the EIS to reflect model uncertainty identified by the Monte Carlo sensitivity analysis (IR3-09 of CEAR Document #984).
c. The Roberts Bank ecosystem model uncertainty of ±5% was used as one line of evidence for the effects determination in the EIS, <5% was determined to be negligible.
d. Marine and freshwater biofilm categories were combined into a single biofilm category to reflect the current understanding of this functional group (see response to IR8-04 of CEAR Document #1110[1] for additional information).

[1] CEAR Document #1110 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Request IR8-04 (See Reference Document #1071).

IR7-27 Marine Fish – On Site Offset Features

Information Source(s)

EIS Volume 3: Section 17, Section 17.3.2.2

EIS Volume 2: Appendix 9.5-A, Table 6, Figure 110

Context

The Proponent, in Section 17.3.2.2 of the EIS, reported that offsets would be created as soon as practically feasible and that the timing for construction of most onsite offsetting concepts is dependent upon completion of the proposed Project construction.

In Figure 110 and Table 6 of Appendix 9.5-A, the Proponent predicted eight zones of geomorphological changes caused by the Project footprint. The proposed offsetting concepts are located within the vicinity of seven of the eight zones.

According to Fisheries and Oceans Canada, the amount of offsetting may need to be increased when there is a time lag between the Project's environmental effects and the time it takes for the offsetting measure to become functional. The Proponent did not include a detailed description of how time lags will be considered in determining the offsetting requirements for the Project.

Information Request

Provide a schedule for the construction of offset features.

Provide a description of how the geomorphological changes from the proposed Project footprint are predicted to affect the proposed onsite habitat concepts and the timing of the construction of the offset features.

Quantify the time lags between Project construction effects to fish habitat and the development of functioning offsetting projects and analyze their implications.

VFPA Response

Provide a schedule for the construction of offset features.

Figure IR7-27-A1 in **Appendix IR7-27-A** provides the anticipated Project construction schedule (as provided in the Project Construction Update, CEAR Document #1210[1]), including a preliminary construction schedule for the proposed onsite habitat Offsetting Concepts (hereafter called the onsite offsetting construction schedule). The onsite offsetting

[1] CEAR Document #1210 From the Vancouver Fraser Port Authority to the Review Panel re: Project Construction Update (See Reference Document #995) (NOTE: Updated June 13, 2018).

construction schedule is dependent upon detailed design finalisation, Project approval, and permitting.

The timing for most onsite habitat Offsetting Concepts is dependent upon the completion of specific elements of Project construction (EIS Section 17.3.2.2). For example, onsite habitat Offsetting Concepts (i.e., Offsetting Measures) are proposed over top of, and extending seaward from, the rocky shoreline protection on the north facing side of the terminal ('terminal habitat,' Figure IR7-27-A1 in **Appendix IR7-27-A**) and along the perimeter of the widened causeway ('causeway habitat,' Figure IR7-27-A1) (e.g., sandy gravel beach, intertidal marsh, and mudflat habitats). Accounting for the Project approval and permitting timelines and the Project and offsetting construction schedules, subtidal rock reef habitats will be the first Offsetting Measure built (Figure IR7-27-A2 in **Appendix IR7-27-A**). The majority of onsite habitat offsetting construction is proposed to begin in the second half of construction Year 3 (approximately 25 months after construction start). After creation of the terminal containment dykes for land development and depending on relevant fisheries-sensitive windows, terminal onsite habitat offsetting construction can commence (e.g., sandy gravel beach, intertidal marsh, mudflat, and eelgrass transplants) in the lee of the terminal footprint (Figure IR7-27-A2). After placement of fill material in the west and east causeway containment dykes, onsite habitat offsetting construction along the causeway can commence (e.g., sandy gravel beach, intertidal marsh, and mudflat habitats). Following a period of shoreline substrate settling and stabilisation, onsite intertidal marsh offsetting habitat planting will begin in construction Year 4. The final onsite offsetting construction schedule will factor in changes that may affect the success of habitat establishment, including geomorphic changes (e.g., containment dyke effects on wave and current energies, shoreline substrate settling and stabilisation, etc.), reflect pending finalisation of detailed design, and incorporate input from Indigenous groups, regulators, and key stakeholders (this is described in greater detail for the intertidal marsh and sandy gravel beach Offsetting Concepts in the responses to IR11-16 and IR11-17, respectively).

Provide a description of how the geomorphological changes from the proposed Project footprint are predicted to affect the proposed onsite habitat concepts and the timing of the construction of the offset features.

Geomorphic changes from the proposed Project footprint have been considered in the selected locations and design of the proposed onsite habitat Offsetting Concepts (see EIS Section 17.3.2.1, including EIS Figure 17-1). As such, the proposed onsite habitat Offsetting Concepts are anticipated to benefit from geomorphic changes and are not predicted to be adversely affected. The onsite habitat Offsetting Concepts were developed by a multidisciplinary team of marine biologists, coastal engineers, hydrodynamic modellers, and specialists from the VFPA's Habitat Enhancement Program.

A new schematic (Figure IR7-27-A2 in **Appendix IR7-27-A**) is presented that indicates approximate spatial extent of potential geomorphic changes associated with the Project footprint and onsite habitat offsetting concepts. The predicted physical factors associated with the potential geomorphic changes have been summarised in **Table IR7-27-1**. In Figure IR7-27-A2, the spatial boundaries are drawn to the outer edge of the potential geomorphic changes to be conservative, but actual changes are likely to be smaller and

concentrated in the central portion of each zone (see EIS Section 9.5.8 for more detailed illustrations and descriptions of predicted geomorphic changes).

An assessment of these predicted geomorphic changes from the Project footprint (EIS Section 17.3.2.2) indicates that it is feasible to create 15 hectares (ha) of intertidal marsh: (i) in quiescent areas along the widened causeway, (ii) within the bend of the northwest section of the existing terminal, and (iii) in the elbow of the proposed terminal (Figure IR7-27-A2 of **Appendix IR7-27-A**). The intertidal marsh can be created on raised areas adjacent to the terminal and causeway at elevations between +3.0 m chart datum (CD) and +5.0 m CD (EIS Appendix 17-B, Drawing 17-B1), where wave energy is dissipated in the high intertidal (supralittoral) zone. Similarly, approximately 4.5 ha of mudflat (intended to be suitable for biofilm establishment) is proposed for (i) the quiescent zone seaward of the intertidal marsh, (ii) in the lee of pioneering intertidal marsh (within the bend of the northwest section of the existing terminal), and (iii) in the elbow of the proposed terminal (Figure IR7-27-A2; EIS Appendix 17-B, Drawing 17-B1).

The assessment also indicates that approximately 4.5 ha of sandy gravel beaches can be created in areas of predicted higher wave energy between approximately 0 m CD and +4.0 m CD at the terminal and along the causeway (Figure IR7-27-A2 in **Appendix IR7-27-A**; EIS Appendix 17-B, Drawing 17-B2). Rocky shoreline habitats are also proposed for areas of higher waves and stronger currents (Figure IR7-27-A2).

The proposed design for 2 ha of new and enhanced subtidal rock reefs adjacent to the existing artificial reefs inshore of the Westshore berth (Figure IR7-27-A2 in **Appendix IR7-27-A**; EIS Appendix 17-B, Drawing 17-B3) considered wave, currents, and potential for scour and subsidence. However, predicted geomorphic changes from the Project footprint are not anticipated to affect the existing or proposed reefs. Similarly, the predicted geomorphic changes from the Project footprint are not expected to adversely affect the existing or proposed 3 ha eelgrass transplant to the north of the proposed terminal (Figure IR7-27-A2).

The VFPA is committed to a proactive and responsive approach to manage the onsite offsetting construction schedule and in the monitoring of the onsite habitat Offsetting Concepts to ensure effectiveness (further details in the Preamble to Offsetting-related Information Requests). Specifically, the VFPA has committed to monitoring the success and effectiveness of the proposed Offsetting Measures, as part of the Project's Follow-up Program (IR13-30 of CEAR Document #1331[2]) and future permitting requirements. The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach. Pending Project approval and permitting, and applicable fisheries-sensitive windows, onsite habitat offsetting construction will be completed prior to (e.g., rock reef habitats), or as soon as possible after, Project construction.

[2] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).

Table IR7-27-1 Predicted Geomorphic Changes from the Project Footprint

Zones in Figure IR7-27-A2	Hydrodynamic Processes Affected by the Project	Gross Area	Local Changes	Potential to Trigger Wider-area Morphological Changes
1	Scour around northwest corner of terminal pad	5.8 ha	Local scour (localised decrease in tidal flat elevation, up to 1.6 m below current seabed elevation or to 2.6 m CD).	Moderate
2	Deposition along west side of terminal pad	20 ha	Deposition adjacent to scour hole (raising of seabed by ~1.0 m).	Low
3	Accelerated tidal channel	50 ha	Possible acceleration of tidal channel to the west of northwest corner scour and associated deposition in adjacent areas.	Moderate
4	Deposition off northeast corner of terminal pad	40 ha	Local deposition from combination of back-eddy, wave shadow, and increased turbidity.	Low
5	Wave shadow	70 ha	Reduction for waves in the lee of the structure.	Low
6	Wave scour	1 ha	Limited wave scour at east face of terminal.	Nil
7	Increased turbidity, reduced salinity	Not quantified	Decline in salinity, associated increase in turbidity, and increase in sedimentation.	Nil
8	Tug basin	80 m^2	Lateral adjustment of the pour-over channel.	Low

Quantify the time lags between Project construction effects to fish habitat and the development of functioning offsetting projects and analyse their implications.

Time lags between the impact from the Project and the functioning of the habitat used as an offset may contribute to a loss in fisheries productivity. Accounting for this potential loss in productivity will be a key component of the Offsetting Plan (to be developed as part of the *Fisheries Act* Authorization phase) to ensure that productivity at Roberts Bank is maintained.

The VFPA's approach to identifying and addressing productivity losses from time lags will include efforts to avoid and minimise these losses and, if required, create other increases in productivity to account for any residual losses. The quantification of any productivity losses will be performed during the development of the Offsetting Plan and the VFPA will work with appropriate regulators to meet relevant policies and legislative requirements (i.e., *Fisheries Act* Authorization). Strategies that may be implemented to address these productivity losses include the following:

1. **Avoiding productivity losses from time lags**

   By constructing offsetting habitat ahead of Project impacts, time lags can be avoided. This strategy may be applied, in part, to account for Project-related time lags as opportunities exist for the early construction of some habitat types, commencing immediately upon issuance of the *Fisheries Act* Authorization for the Project. As an example, the proposed rock reefs could be constructed ahead of Project impacts. Colonisation of rock reef fish, invertebrates, and macroalgae is known to occur over a short period of time with some instantaneous habitat function (e.g., refugia afforded by interstitial spaces). This strategy will be further explored during the development of the Offsetting Plan during permitting.

2. **Minimising productivity losses from time lags**

   Productivity losses from time lags can be substantially minimised through the implementation of effective construction and planting methods. The VFPA's Habitat Enhancement Program (see the Preamble to Offsetting-related Information Requests) has developed proven methods of construction for large-scale habitat projects. Its team of professionals have refined procedures and techniques that are used to reduce the time for habitat to become functioning. These procedures and techniques include the following:

   - Seed harvesting from local native plant stocks to ensure that seed selection incorporates local genetic variations of plant species;
   - Early propagation of plant stock to ensure healthy, established nursery stock is available for planting when required. This also provides for the opportunity to install the plants at the appropriate time of year to maximise growth;
   - Planting by trained professionals working under the guidance of professional horticulturalists to ensure proper installation of plants is achieved;
   - Planting prescriptions that are prepared by skilled wetland ecologists to ensure that appropriate plant species are selected and that planting densities are optimised; and
   - Incorporation of protective measures for young plants to counteract the negative effects of herbivory (i.e., geese grazing)

   These proven procedures and techniques provide for optimum timelines for the establishment of habitat that is used for offsetting, thus minimising productivity losses.

3. **Measures to account for productivity losses from time lags**

   Productivity losses that result from time lags that cannot be avoided or minimised must be assessed and offset. The Roberts Bank ecosystem model estimates an overall increase in ecosystem productivity over time within the study area (see response to IR7-26). This forecast provides confidence that time lag effects will be accounted for as part of Project development. Options for assessment of time lag effects, and the subsequent offsetting of these effects, include conventional methods such as net present value (NPV) calculations. NPV is a standard approach detailed in DFO guidance (Bradford 2017) on the application of time lag requirements for habitat offsetting. NPV calculations account for the changes in Project impacts and offsetting gains over time

and are part of the guidance for fish habitat compensation in Canada (Minns 2006, Clarke and Bradford 2014). The loss of NPV due to time lag is estimated as a multiplier (M_{lag}) that accounts for the discounted loss (Bradford 2017).

$$M_{lag} = (1 + r)^{t_{lag}}$$

The multiplier includes a discount rate (r) and time lag (t_{lag}), equal to the number of years that elapse between the Project impact and the full benefit of the offsetting.

As a fundamental principle used in the development of the final Offsetting Plan during permitting, the VFPA will make all reasonable efforts to avoid and minimise time tags between the potential impacts and the functioning of the offsetting measures. The quantification of any remaining losses of fisheries productivity will be performed as an inherent component of the Offsetting Plan with provision for offsetting these losses.

References

Bradford, M. J. 2017. Accounting for Uncertainty and Time Lags in Equivalency Calculations for Offsetting in Aquatic Resources Management Programs. Journal of Environmental Management 60: 588-597. doi: 10.1007/s00267-017-0892-6.

Clarke, K. D. and M. J. Bradford. 2014. A Review of Equivalency in Offsetting Policies. Fisheries and Oceans Canada. Canadian Science Advisory Secretariat. Research Document 2014/109.

Fisheries and Oceans Canada (DFO). 2013. Fisheries Protection Policy Statement. Fisheries and Oceans Canada, October 2013.

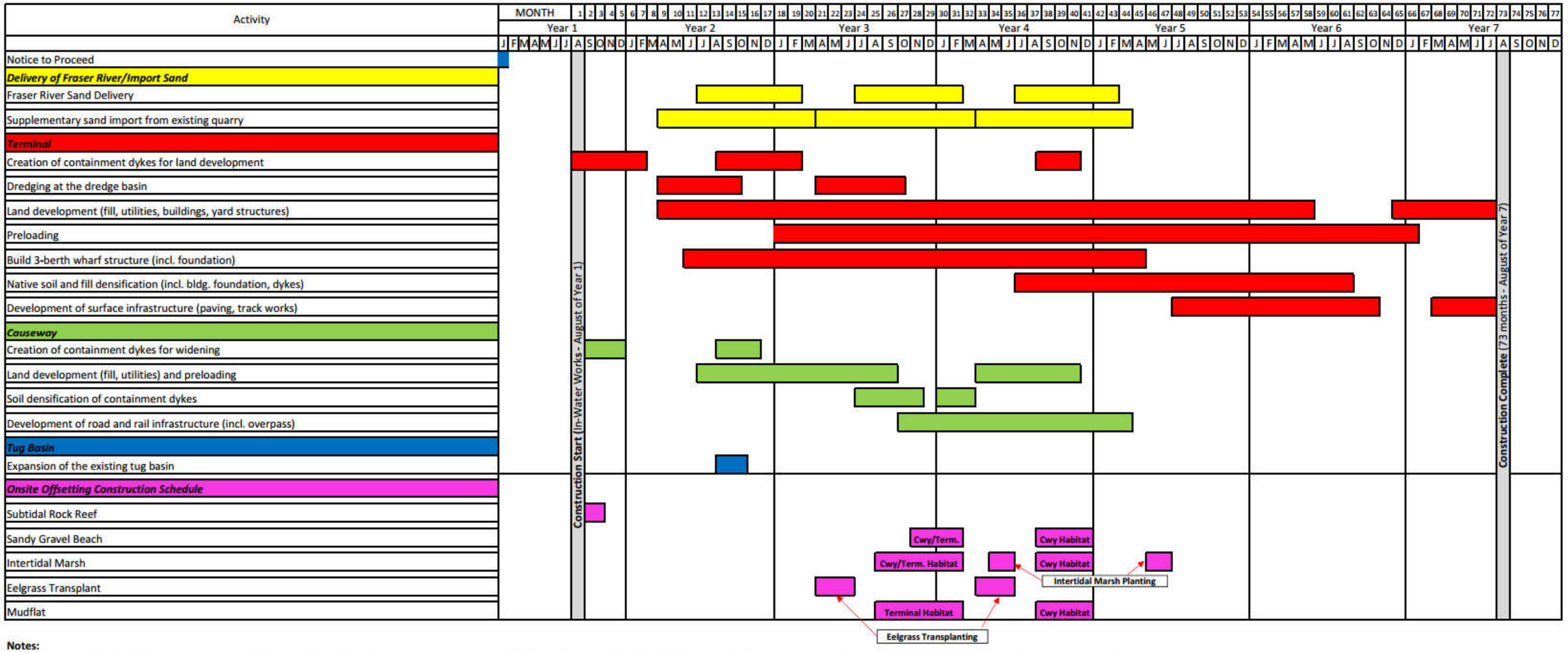
Minns, C. 2006. Compensation Ratios Needed to Offset Timing Effects of Losses and Gains and Achieve No Net Loss of Productive Capacity of Fish Habitat. Canadian Journal of Fisheries and Aquatic Sciences 63: 1172-1182.

Appendices

Appendix IR7-27-A Supporting Figures

APPENDIX IR7-27-A
SUPPORTING FIGURES

Figure IR7-27-A1 Anticipated Project Construction Schedule and Onsite Offsetting Construction Schedule



Notes:

1. The above simplified schedule is provisional and subject to change based on ongoing consultation and define refinement. The scheudle does not include TO equipment testing, commissioning, and operational system testing and training.

Path: S:\Geomatics\Projects\102738\EIS IRs\IR7_27\mxd\RBT2_IR7_27_A2_OnsiteMitigation_GeomorphAreas_181025.mxd

Roberts Bank

3

7

5

2

1

4

8

6

Legend

- BOUNDARY OF PROJECT AREA
- EXISTING INFRASTRUCTURE
- EXISTING SUBTIDAL ROCK REEF
- EXISTING RIP RAP
- EXISTING ROCKY SHORELINE
- CANADA-U.S.A. BORDER
- SCOUR (1)
- DEPOSITION (2, 4)
- ACCELERATED TIDAL CHANNEL (3)
- WAVE SHADOW (5)
- INCREASED TURBIDITY (7)
- WAVE SCOUR (6)
- TUG BASIN EXPANSION (8)

NEW ONSITE OFFSETTING HABITATS

- EELGRASS TRANSPLANT
- MUDFLAT
- SANDY GRAVEL BEACH
- SUBTIDAL ROCK REEF
- INTERTIDAL MARSH

0 0.25 0.5 Kilometres

1:18,000

NAD 1983 UTM Zone 10N

N

Note:
The Boundary of the Project Area reflects the updated Project footprint presented in the June 2018 RBT2 Project Construction Update (see CEAR Document #1210).

PORT of vancouver

ROBERTS BANK TERMINAL 2

APPROXIMATE SPATIAL EXTENT OF POTENTIAL CHANGES ASSOCIATED WITH THE PROJECT FOOTPRINT AND OVERVIEW OF PROPOSED ONSITE HABITAT CONCEPT LOCATIONS

DATE:	FIG No.
11/26/2018	IR7-27-A2

IR7-28 Marine Fish - Mitigation, Habitat Compensation

Information Source(s)

EIS Volume 3: Appendix 17-A

CEAR Doc#647

Context

According to the Proponent in Appendix 17-A of the EIS, effectiveness monitoring was conducted on the Deltaport Third Berth project intertidal (salt) marsh habitat compensation features along the south side of the causeway between 2010 and 2013. As reported by the Proponent, marsh vegetation had established on the open marsh benches, whereas the protected lagoon marshes and excavated mudflat have been less effective in allowing for natural colonization of salt marsh plant species. The Proponent also reported that the effectiveness monitoring concluded that the salt marsh compensation is not fully functional, and the biological and physical processes have not yet stabilized due to exposure to a higher wind and wave energy environment than the habitat had been designed for.

Taking the effects monitoring results from the Deltaport Third Berth project into consideration, the Proponent identified that wind and wave environments have been considered during the design of salt marsh habitats for the proposed Project.

According to Raincoast Conservation Foundation in CEAR Doc#647, recent compensation works by the Proponent have failed and the plan to create new saltmarsh habitat as an offsetting measure for the Project should be further evaluated.

Further information is needed to better understand the effectiveness of previous marsh creation projects in the local assessment area.

Information Request

Provide an evaluation of the effectiveness of past fish habitat compensation measures which relied upon intertidal marsh habitat creation within the local assessment area. Include any marsh habitat creation measures undertaken by the Proponent or other agencies.

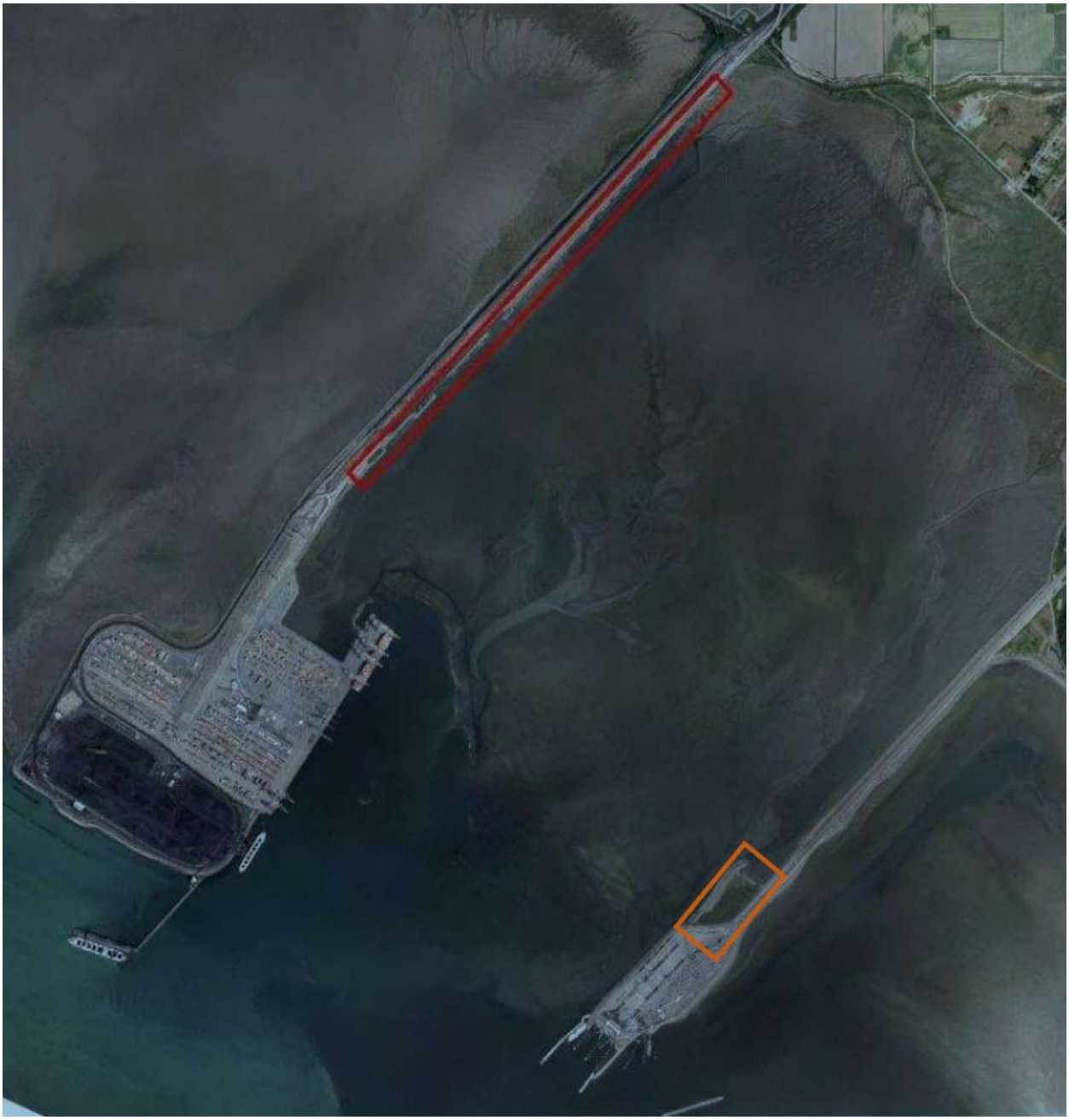
Provide an analysis of the effectiveness of intertidal marsh habitat creation as targeted mitigation for juvenile Chinook Salmon and other marine fish in the local assessment area.

VFPA Response

Provide an evaluation of the effectiveness of past fish habitat compensation measures which relied upon intertidal marsh habitat creation within the local assessment area. Include any marsh habitat creation measures undertaken by the Proponent or other agencies.

This response demonstrates that intertidal (salt) marsh habitat creation is effective when implemented with appropriate design that accounts for site-specific biophysical conditions and geomorphic constraints that influence establishment and growth of transplanted vegetation and, ultimately, determine transplant success. To that end, the response provides details regarding two intertidal marsh transplantation projects in the local assessment area (LAA) undertaken by BC Ferries in 1993 just north of the BC Ferries terminal adjacent to the causeway, and by the VFPA in 2010 as compensation for the Deltaport Third Berth Project (DP3) along the south side of the Roberts Bank causeway (see **Figure IR7-28-1**). Moreover, **Table IR7-28-1** summarises information on other successful marsh transplantation projects undertaken by the VFPA within the lower Fraser River, outside LAA boundaries. These projects demonstrate the VFPA's technical capability to undertake large-scale transplantation projects as well as commitment to long-term monitoring that allows for adaptive management and early remedial action if required to ensure transplant success.

Figure IR7-28-1 Location of Intertidal Marsh Transplants within the Local Assessment Area



Note: The red outline indicates the location of the intertidal marsh transplant undertaken by the VFPA in 2010 as part of the east causeway habitat compensation for the Deltaport Third Berth project. The orange outline indicates the location of the intertidal marsh transplant undertaken by BC Ferries in 1993 as part of compensation for the BC Ferries Terminal Expansion project.

Marsh transplantation activities are considered effective by Fisheries and Oceans Canada (DFO) if the habitat that has been created is ecologically stable, self-sustaining, and provides habitat equal in marsh productivity to that which it has been designed to replace or offset

(Pearson et al. 2005, Smokorowski et al. 2015). Success of constructed marshes is typically measured using the following criteria (Pearson et al. 2005, Smokorowski et al. 2015):

- Empirical evidence that created habitats are physically stable over time; structural integrity is typically assessed by undertaking topographic/engineering surveys and using photography; and
- Confirmation that created habitats are functioning as intended; metrics typically focus on plant survivorship, growth, and production (e.g., coverage and density expressed in %, considered by DFO as surrogates of fish productivity; for details see second part of the response).

Local Assessment Area Project #1: BC Ferries Marsh Creation

In 1993, BC Ferries undertook an intertidal marsh transplant as compensation for the expansion of the BC Ferries Tsawwassen terminal (Adams and Williams 2004, Envirowest Consultants Inc. 2015). Approximately 8,460 m^2 were transplanted in the inter-causeway area just north of the BC Ferries terminal (see **Figure IR7-28-1**), using donor plugs from existing tidal marshes south of Canoe Passage and along the north shoreline of the BC Ferries causeway (Adams and Williams 2004). The recipient site was constructed using dredge spoil contained by a large cobble berm (Adams and Williams 2004). Selection of marsh plants was experimental to determine suitability at the transplant site and included American (*Schoenoplectus americanus*[1]) and seacoast bulrush (*Bolboschoenus maritimus*), saltgrass (*Distichlis spicata*), pickleweed (*Sarcocornia pacifica*), and arrowgrass (*Triglochin maritima*) (Adams and Williams 2004).

Post-construction monitoring was undertaken for two growing seasons. Results revealed that seacoast bulrush plugs suffered 100% mortality by the end of the first growing season. However, the remaining transplanted species became established and were distributed along an elevational gradient, with pickleweed dominating higher elevations, saltgrass middle elevations, and arrowgrass lower elevations (Adams and Williams 2004). A survey undertaken in 2014 to assess the long-term development of the marsh plant community revealed that species composition comprised predominantly saltgrass and pickleweed, and was consistent with other marshes nearby at similar elevations (see Photographs 1 to 3 in **Appendix IR7-28-A** reproduced from Envirowest Consultants Inc. (2015)[2]).

Over time the constructed marsh had established successfully and transitioned (influenced by local patterns of inundation and oxygen availability) to closely resemble and function like salt marsh formed naturally nearby at the base of the BC Ferries causeway (Envirowest Consultants Inc. 2015).

[1] Scientific names of marsh plant species used in this response are as recorded in the BC Conservation Data Centre's BC Species and Ecosystems Explorer.
[2] Photographs 1 to 3 in **Appendix IR7-28-A** were reproduced from Envirowest Consultants Inc. (2015) with permission from Mark Adams, Director, Envirowest Consultants Inc.

Local Assessment Area Project #2: Deltaport Third Berth Marsh Creation

In 2010, as part of the east causeway habitat compensation for DP3, the VFPA constructed four lagoon marshes (behind barrier islands) and five open marsh benches along the south shoreline of the Roberts Bank causeway (see **Figure IR7-28-1**) to satisfy the requirements of the project's DFO *Fisheries Act* Authorization (these compensation works are referenced in the context to this information request). The habitat compensation concept had originally proposed creation of an offshore barrier island with openings at regular intervals to allow tidal cycling and channel flushing, as well as tidal access for juvenile salmon and other organisms (Williams and Millar 2006). Salt marsh transplants were proposed behind the barrier island in the tidal channel sheltered from storm waves and winds (Williams and Millar 2006). Upon request by DFO and the Canadian Wildlife Service, the habitat compensation design was modified to reduce footprint impacts on wetted habitats; the offshore barrier island was reduced in size and compensation works were limited to within the toe of the existing causeway. Wetted habitat was maximised by intermittently using sheet pile walls instead of rip rap, and smaller barrier islands were restricted in front of the lagoon marshes. Transplanted marsh species included seacoast bulrush, saltgrass, gumweed (*Grindelia stricta*), sea plantain (*Plantago maritima*), pickleweed, American bulrush, and arrowgrass (Williams and Millar 2006).

Pre-construction monitoring was undertaken in 2008 and 2009, followed by post-construction monitoring in 2010, and effectiveness monitoring for five growing seasons between 2011 and 2015 (Archipelago and Williams 2016). Consistent with the conditions laid out in the DP3 *Fisheries Act* Authorization, effectiveness monitoring included biophysical transect and GPS topographical surveys to determine physical stability of the transplant site as well as stability after events (e.g., storms), and salt marsh transect surveys to assess successful establishment of marsh plants. Fish were also sampled using beach seines to determine presence of juvenile salmon and other marine fish in the constructed habitat (Archipelago and Williams 2016).

Monitoring results revealed that the removal of the offshore barrier island from the original design led to exposure of open marsh benches to wind and waves and alongshore transport of sediment, which, in turn, resulted in erosion and lowering of elevation, increased periods of inundation, and hindered plant growth. Moreover, accumulation of debris and eelgrass wrack generated from the adjacent bed (which is approximately 850 hectares in size) rendered lagoon marshes anoxic over time, restricting plant colonisation and growth. Establishment of marsh vegetation was poor in three of four lagoon marshes and in two of five open marsh benches; pickleweed was most frequently recorded (Archipelago and Williams 2016). Overall, constructed lagoon marshes and open marsh benches were determined to not function as intended (Archipelago and Williams 2016).

In response to monitoring results and to better meet the habitat compensation goals, the VFPA consulted with DFO and several coastal geomorphologists to discuss design options for remediating the habitat. In 2017, the VFPA undertook remedial action to enhance physical characteristics of the constructed lagoon marshes and created two new barrier beach/marsh units where open marsh benches were not successful. Remedial habitat was designed to

emulate non-storm wave and tide conditions at local beaches considered natural analogues[3], protect from high waves, and allow flushing (Golder Associates 2018). Revegetation focused primarily on transplanting pickleweed and saltgrass, which dominate the upper and lower marsh, respectively, at nearby reference and donor sites (Golder Associates 2018).

Three months after planting in May 2017, the VFPA conducted a salt marsh assessment, which revealed that vegetation establishment was generally good. Plug survival exceeded 80% at five out of eight remedial locations, while at the remaining three locations, plug survival ranged from 50% to 70% (Golder Associates 2018). Some eelgrass wrack and debris were noted to enter the constructed marsh on higher tides and accumulate locally where the marsh toe is high. However, pickleweed and saltgrass were showing signs of growth and persistence under the wrack cover (Golder Associates 2018).

Effectiveness of remedial habitat creation cannot be determined yet as long-term effectiveness monitoring is scheduled to begin in September 2018. As indicated above, the remedial design relied on evidence from local natural analogues on hydrodynamic conditions, as well as proven examples of shoreline enhancement that have been constructed over the last decade. The remedial habitat is expected to perform to a standard that will meet or exceed the conditions of the DP3 *Fisheries Act* Authorization and has been endorsed by DFO. The remedial design maximises biological production along the causeway, thus the potential for performance deficiencies realised with the original habitat enhancement constructed in 2010 has been minimised and it is highly unlikely that a major rework of the habitat remediation will be required.

The south side of the Roberts Bank causeway is primarily exposed to southerly and south-easterly winds in winter that generate the largest offshore waves; in contrast, extreme wind and wave conditions on the north side of the Roberts Bank causeway, where intertidal marsh creation is proposed for RBT2, are less intense and much less frequent (see EIS Appendix 9.5-A). They resemble conditions that prevail along the north side of the BC Ferries causeway, which is considered a more appropriate natural analogue than the south side of the Roberts Bank causeway. As noted above (see LAA Project #1), intertidal marsh built north of the BC Ferries causeway was successful (Adams and Williams 2004, Envirowest Consultants Inc. 2015). Furthermore, north of the Roberts Bank causeway there is little eelgrass wrack and debris available for accumulation compared to the inter-causeway area, which along with the comparatively large reduction in wave energy, substantially increases the likelihood of a successful salt marsh planting. Thus, intertidal marsh proposed for RBT2 north of the Roberts Bank causeway is expected to be successful (see also the VFPA's forthcoming response to IR11-16 where this is explained in greater detail).

Other VFPA Marsh Creation Projects Outside the Local Assessment Area

Table IR7-28-1 summarises information on examples of brackish marsh habitats constructed by the VFPA at six sites in the lower Fraser River, outside LAA boundaries. For those marsh transplantation activities for which effectiveness monitoring revealed constraints

[3] Established stable beaches subjected to similar wave climate.

in plant establishment and growth, information on adaptive management efforts and remedial action taken by the VFPA is also provided. Based on monitoring results, and following remedial action where required, marsh habitats constructed by the VFPA (summarised in **Table IR7-28-1**) have been deemed effective by DFO, providing high-quality habitat for fish and thus performing as intended and in accordance with the conditions set out in their respective *Fisheries Act* Authorizations. Effectiveness has been attributed to the sites' physical stability and establishment of self-sustaining diverse marsh vegetation communities comprising transplanted and naturally colonising species.

In addition to marsh transplantation activities, since 2012 and as part of the Habitat Enhancement Program, the VFPA has also undertaken several salt marsh restoration projects within and outside LAA boundaries. These projects build on the VFPA's previous habitat banking efforts in the Fraser River estuary to create, restore, and enhance fish habitat to offset potential effects from future development. Salt marsh restoration was undertaken at five locations in the estuary (i.e., two sites in the inter-causeway area and three sites in Boundary Bay; Williams 2017a) and included the removal of log accumulations and excavation of narrow tidal channels to promote tidal flushing, improve drainage, and restore the function of salt marsh habitat. Post-construction monitoring has been underway annually since 2014. Results confirm that, in areas formerly covered by log accumulations, vegetation communities have established well and support dense high marsh species of grasses (e.g., saltgrass, dunegrass (*Leymus mollis*)) with localised patches of herbaceous species (e.g., yarrow (*Achillea millefolium*)), while low salt marsh vegetation is dominated by pickleweed and saltgrass. Independent of salt marsh restoration efforts, logs continue to be deposited during high tides along the toe of the dyke. Hyper-saline conditions that may develop locally in low-lying depressions of the intertidal marsh during dry, hot summers may impact vegetation survival. Overall, monitoring results indicate that restoration of salt marsh has contributed to improved fish habitat function (Williams 2017a).

Table IR7-28-1 Examples of Intertidal Marsh Transplantation Projects Undertaken by the VFPA in the Lower Fraser River from the Late 1980s to the Present

No.	Transplant Site	Project (Source)	Summary of Project Methods, Results, and Effectiveness

1a	Delta, B.C. (Fraser River Main Arm)	Glenrose Tidal Marsh Project (Glenrose Downstream) (Williams 2015a, Williams and Tranmer 2016, 2017)	• 2,194 m^2 were transplanted in 2014 at Glenrose Downstream, immediately upstream of the Alex Fraser Bridge south tower.
			• Transplanting occurred over dredge spoil from Gunderson Slough using nursery grown marsh emergent vegetation.
			• Post-construction inspection in spring 2015 revealed poor marsh establishment due to late season planting, increasing daylight tidal inundation, and geese grazing.
			• Remedial transplanting (including trial fenced enclosures to restrict geese grazing) occurred in 2015.
			• Monitoring was conducted for 3 growing seasons (2015-2017) and focused on (i) vegetation establishment (species composition/frequency of occurrence and percent coverage); and (ii) stability of constructed habitat (topographical survey and engineering assessment).
			• *Effectiveness Evaluation*: Marsh design was successful, providing ideal conditions for marsh establishment and high-quality habitat for fish and wildlife. Specifically:
			  ○ *Vegetation*:
			  – Establishment was successful over entire marsh bench.
			  – Fenced enclosures minimised geese grazing and facilitated expansion of transplanted vegetation.
			  – Some logs were observed on the marsh but get washed downstream during high winter tides.
			  – Comparable to reference marsh, plant coverage was dense (>75%) in all quadrats sampled.
			  – Plant community comprised 20 species (6 transplanted, 14 naturally recruited); the transplanted Arctic rush (*Juncus arcticus*) and Lyngbye's sedge (*Carex lyngbyei*) and the naturally recruited knotweed (*Polygonum* sp.), nodding beggarticks (*Bidens cernua*), and pond water-starwort (*Callitriche stagnalis*) were most frequently recorded.
			  ○ *Stability*: rock berm and shoreline armouring were stable; placed soils were contained; elevations of constructed marsh remained within tidal range for plant growth.

No.	Transplant Site	Project (Source)	Summary of Project Methods, Results, and Effectiveness

1b	Delta, B.C. (Fraser River Main Arm)	Glenrose Tidal Marsh Project (Glenrose Cannery) (Williams 2015a, Williams and Tranmer 2016, 2017)	• 2,820 m^2 were transplanted in 2014 at Glenrose Cannery.
			• Transplanting occurred over dredge spoil from Gunderson Slough using nursery grown marsh emergent vegetation.
			• Monitoring was conducted for 3 growing seasons (2015-2017) and focused on (i) vegetation establishment (species composition/frequency of occurrence and percent coverage); and (ii) stability of constructed habitat (topographical survey and engineering assessment).
			• *Effectiveness Evaluation*: Productivity is enhanced in the downstream portion of marsh where vegetation has established, providing high-quality habitat for fish; marsh productivity (and in turn fish habitat value) is reduced in upstream portion of marsh where vegetation cover is limited. Specifically:
			  ○ *Vegetation*:
			  – Plant establishment and coverage in downstream portion of constructed marsh was greater than upstream (where exposure to wave action is greater resulting in low soil retention and scour at the rock containment apron).
			  – Plant coverage was >50% in ~80% of downstream quadrats sampled; in contrast, plant coverage was <50% in ~87% of upstream quadrats sampled.
			  – Plant community comprised 27 species (5 transplanted, 22 naturally recruited); the transplanted Arctic rush and Lyngbye's sedge, and the naturally recruited knotweed and jointed rush (*Juncus articulatus*) were most frequently recorded.
			  – Geese grazing was evident throughout the marsh.
			  ○ *Stability*: marsh is narrow, exposed to river processes; upstream portion is exposed to wave action resulting in soil scour and substrate dominated by bare rock; downstream portion is protected characterised by net soil deposition.

1c	Delta, B.C. (Fraser River Main Arm)	Glenrose Tidal Marsh Project (Gunderson Slough Mudflat) (Williams 2015a, Williams and Tranmer 2016, 2017)	• 8,763 m^2 were transplanted in 2014 at Gunderson Slough Mudflat. • Transplanting occurred over dredge spoil from Gunderson Slough using nursery grown marsh emergent vegetation. • Post-construction inspection in spring 2015 revealed poor marsh establishment due to late season planting, increasing daylight tidal inundation, and geese grazing. • Remedial transplanting (including trial fenced enclosures to restrict geese grazing) occurred in 2015. • Monitoring was conducted for 3 growing seasons (2015-2017) and focused on (i) vegetation establishment (species composition/frequency of occurrence and percent coverage); and (ii) stability of constructed habitat (topographical survey and engineering assessment).

No.	Transplant Site	Project (Source)	Summary of Project Methods, Results, and Effectiveness
			• *Effectiveness Evaluation*: Heavy geese grazing has restricted establishment of transplanted marsh species. However, naturally recruited plant species not palatable by geese have established and are providing vegetated cover for invertebrates that in turn provide food for fish using the shoreline. Specifically: o *Vegetation*: – Plant coverage was >75% in ~50% of the quadrats sampled, attributed primarily to small, low growing, naturally recruited plants; coverage from transplanted species was dense within fenced enclosures. – Plant community comprised 17 species (5 transplanted, 12 naturally recruited); the naturally recruited pond water-starwort, European forget-me-not (*Myosotis scorpioides*), jointed rush and pigmyweed (*Crassula aquatica*) were most frequently recorded. – The lower marsh bench was colonised by benthic algae and diatoms. o *Stability*: physical processes are active as marsh design did not include an outer rock containment berm to harden the river's edge. Wave action has led to some gravel intrusion onto the lower marsh bench.
2	Vancouver, B.C. (Fraser River North Arm)	Gladstone Park and Riverfront Park Tidal Marsh Projects (Williams 2015b, 2016, 2017b)	• 5,205 m^2 and 3,620 m^2 were transplanted in 1993 along the shoreline of Gladstone-Riverside and Riverfront parks, respectively, over unvegetated mudflat adjacent to a narrow fringe marsh. • Transplantation of Lyngbye's sedge occurred on fill material placed within constructed rock containment berms and was monitored for 5 growing seasons (1993-1997). • Marsh transplants were determined by DFO to be successful as sites were stable and plant coverage was at least 80% of the total area. • The sites were approved by DFO to be deposited as intertidal brackish marsh habitat into the North Fraser Harbour Habitat Compensation Bank. In April 2013, habitat credits were transferred to the VFPA Habitat Bank. • To confirm habitat credits remain viable and habitats will continue to meet their biophysical objectives, the VFPA has been conducting annual inspections, including biological and engineering assessments. • *Effectiveness Evaluation*: Based on results from recent (2014-2017) inspections, the sites continue to support dense emergent marsh vegetation and to provide high-quality fish rearing habitat for juvenile salmon and other fish species. Specifically: • <u>Gladstone-Riverside Park:</u> o *Vegetation*:

No.	Transplant Site	Project (Source)	Summary of Project Methods, Results, and Effectiveness
			– Vegetation is denser in the upstream section of the site, which is more sheltered from vessel-generated waves than the downstream section. – A variety of brackish marsh vegetation have become established through combination of transplanting and natural colonisation. Plant community comprises Lyngbye's sedge, soft-stemmed bulrush (*Schoenoplectus tabernaemontani*), rush (*Juncus* spp.), common spike-rush (*Eleocharis palustris*), and common cattail (*Typha latifolia*). The non-native lesser cattail (*Typha angustifolia*) and purple loosestrife (*Lythrum salicaria*) were also recorded at the site. – Stranded logs were observed along most of the shoreline. ○ *Stability*: rock containment berm, which appears to be stable, and log booms moored offshore protect against erosion from vessel-generated waves. • <u>Riverfront Park:</u> ○ *Vegetation*: – A variety of brackish marsh vegetation have become established through combination of transplanting and natural colonisation. – Plant community comprises Lyngbye's sedge, common cattail, soft-stemmed bulrush, common spike-rush, and rush. The non-native lesser cattail is spreading along the outer marsh edge along the rock containment berm. Other non-native species recorded on the site include European forget-me-not, purple loosestrife, and common hound's-tongue (*Cynoglossum officinale*), observed in the marsh in 2017 for the first time). – Several large logs have become stable habitat features and add to the site's structural complexity. ○ *Stability*: rock containment berm, which appears to be stable, and log booms moored offshore protect against erosion from vessel-generated waves. Low energy conditions have allowed for sediments to accrete off the rock berm toe and form a broad mudflat.
3	Surrey, B.C. (Fraser River Main Arm)	Timberland Basin Habitat Project (Williams 2015c, 2017c)	• In 1987-1990, ~30,000 m^2 were converted into marsh (~12,000 m^2), mudflat and riparian habitat. • Habitat enhancement works were undertaken behind an existing training wall by grading and infilling the former log pond with dredged sandy silt material from the adjacent Timberland Basin channel. Riprap was placed around the perimeter of the site to retain fill material at the appropriate elevation for establishment of an intertidal marsh bench.

No.	Transplant Site	Project (Source)	Summary of Project Methods, Results, and Effectiveness

			• Experimental transplanting of Lyngbye's sedge was undertaken in 1991 with the intention to create a sedge marsh. However, the sedge was heavily grazed by geese, and the site transitioned into low marsh habitat through combination of transplanting and natural colonisation of vegetation.
			• DFO determined the site to be stable and the marsh transplant successful. DFO also approved +30,000 m^2 habitat credits to be deposited into the Timberland Basin Habitat Bank. Several parcels were extracted for habitat compensation in the 1990s and 2000s. In August 2014, the remaining 3,923 m^2 habitat credits were transferred to the VFPA Habitat Bank.
			• *Effectiveness Evaluation*: Since 2014, the VFPA have been conducting annual inspections, including biological and engineering assessments to confirm remaining habitat credits remain viable and habitat continues to meet its biophysical objectives. The site continues to provide high quality estuarine fish rearing habitat for juvenile salmon and other fish species. Specifically:
			  ○ *Vegetation*:
			  – The site supports tall, emergent marsh species in the upper elevations and shorter marsh species have colonised the former unvegetated mudflat.
			  – The upper marsh is dominated by European rush (*Juncus effusus*) and woolgrass (*Scirpus cyperinus*). Other observed species include common silverweed (*Potentilla anserine*), creeping bentgrass (*Agrostis stolonifera*), Arctic rush, and European forget-me-not. The non-native purple loosestrife and yellow iris (*Iris pseudacorus*) were also recorded at the site. Stranded logs were observed scattered in the upper marsh.
			  – The low marsh supports dense coverage of shorter species dominated by water purslane (*Ludwigia palustris*). Other observed species include water mudwort (*Limosella aquatica*), western lilaeopsis (*Lilaeopsis occidentalis*), pigmyweed, American water-plantain (*Alisma triviale*), and pond water-starwort. Invasive species recorded in the upper marsh are also spreading into the lower marsh.
			• *Stability*: rock containment berm appears to be stable and protects the site against erosion from vessel-generated waves.

Provide an analysis of the effectiveness of intertidal marsh habitat creation as targeted mitigation for juvenile Chinook Salmon and other marine fish in the local assessment area.

Transplanted marshes within (e.g., BC Ferries constructed marsh) and outside LAA boundaries (see examples in **Table IR7-28-1**) created as targeted mitigation for juvenile Chinook salmon and other marine fish are considered effective in providing the same functional attributes as naturally occurring marsh, including productive foraging and refuge opportunities for marine fish (and juvenile Chinook salmon). This is supported by results from long-term effectiveness monitoring undertaken following marsh habitat creation to satisfy the terms of the projects' respective DFO Authorizations (see summary in first part of the response). It is also supported by the literature, including a research program that was undertaken by DFO in the 1990s, which revealed that compensation marsh habitats support invertebrate fish food organisms and maintain juvenile salmon abundances at levels similar to reference marshes (Levings and Nishimura 1996, 1997, Levings 1998). Additional information is provided below.

As indicated in the first part of the response, effectiveness of intertidal marsh transplants was determined through monitoring of physical and biotic indices to evaluate, respectively, structural (substrate) stability and long-term persistence of constructed marsh. This approach is consistent with DFO guidance (DFO 2012, Smokorowski et al. 2015) and is intended to manage risk associated with aspects of the physical environment (e.g., substrate stability, risk of erosion that affects substrate elevation, length of inundation periods, etc.) that may affect establishment of marsh vegetation (Dawe et al. 2000, Adams and Williams 2004). To ascertain a successful transplant, monitoring efforts typically focus on plant survivorship and growth using metrics of primary (plant) production, such as plant coverage and density (see **Table IR7-28-1**), as these metrics are generally considered appropriate surrogates of fish productivity (DFO 2012, Smokorowski et al. 2015).

Also consistent with DFO guidance, metrics that assess secondary/tertiary (animal) productivity within constructed marshes (e.g., fish abundance and density, fish growth and condition, fish feeding rates and diet) may also be used by proponents in effectiveness monitoring (DFO 2012, Smokorowski et al. 2015). However, direct monitoring of fish productivity to evaluate efficacy of intertidal marsh transplants can be demanding in that extensive sampling and long-term data collection are required to capture inherent diversity in fish communities and natural variability in fish abundance (DFO 2012, Smokorowski et al. 2015). As a result, fish productivity metrics are rarely deployed during effectiveness monitoring and only a couple of examples were located in the literature and are summarised below.

As indicated in the first part of the response, effectiveness monitoring following construction of intertidal marsh habitats as compensation for DP3 included fish sampling using beach seines to collect information on fish presence within constructed habitats (Archipelago and Williams 2016). Juvenile chum and Chinook salmon were caught during each year of post-construction sampling (i.e., 2011, 2012, 2015) in every constructed habitat type (i.e., open marsh bench, sand/silt, gravel/sand), and fish presence was similar to references sites (Archipelago and Williams 2016). Based on these results, Archipelago and Williams (2016)

concluded that, as juvenile chum and Chinook salmon have consistently been present in the inter-causeway area since the late 1970s, the DP3 habitat compensation area continues to provide habitat for outmigrating juvenile salmon.

The efficacy of transplanted marshes to function as productive fish habitat was independently studied by DFO in 1990-1993 during a research program that was run under the auspices of the Fraser River Action Plan (Levings and Nishimura 1996, 1997). The research program focused on marsh habitat compensation projects built in the lower Fraser River (North and Main arms, Queens Reach) by proponents (other than the VFPA) between 1985 and 1991. These compensation projects, ranging from 53 m^2 to 7,000 m^2 (mean transplant area: 1,468 m^2; Levings and Nishimura 1996, 1997), were included in a 'no net loss' ledger developed for DFO by Langer et al. (1994) who concluded that net habitat gain had been achieved. Levings and Nishimura (1996, 1997) further evaluated the performance of these transplanted marshes to support invertebrate fish food organisms and maintain fish abundances by comparing them to the performance of reference marshes.

Main findings by Levings and Nishimura (1996, 1997) that demonstrate the value of constructed marshes in providing productive habitat for fish (including juvenile salmon) similar to natural marshes include the following: (a) invertebrate communities and associated densities of fish food organisms at transplanted sites were similar to reference sites; (b) species composition of fish communities using the transplanted marshes was similar to that at reference sites; (c) there was no evidence that transplanted marshes were avoided by juvenile salmon nor dominated by non-salmonids (seasonal differences in fish species composition were not investigated); and (d) sampling of marked chum fry suggested that juvenile salmon remained in the transplanted marshes at least as long as in reference habitats.

Elsewhere in the Pacific Northwest, extensive restoration activities were undertaken in the 2000s to re-establish connectivity of natural estuarine marshes that were historically dyked for agricultural purposes in Washington and Oregon states. Restoration activities focused primarily on breaching existing dykes but also included some transplanting of emergent marsh vegetation (e.g., Borde et al. 2012). Post-restoration, several studies have determined that restored estuarine marshes are equivalent to natural marsh habitats in providing ecological attributes that are important for juvenile Chinook salmon. Such ecological attributes include accessibility and use of estuarine marshes for salmon rearing (e.g., Ellings et al. 2016, Flitcroft et al. 2016, McNatt et al. 2016), provision of invertebrates as food and increased salmon foraging performance (e.g., Roegner et al. 2010), and improved salmon growth potential (e.g., David et al. 2014).

Overall, both site-specific empirical data and literature from further afield indicate that created intertidal marshes function similarly to naturally occurring marshes. Thus, constructed marsh habitat is effective as offsetting for marine fish, including juvenile Chinook salmon.

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Appendices

Appendix IR7-28-A Site Photographs, BC Ferries Transplanted Salt Marsh (Photographs Reproduced from Envirowest Consultants Inc. (2015) with Permission from Mark Adams, Director, Envirowest Consultants Inc.)

APPENDIX IR7-28-A
SITE PHOTOGRAPHS, BC FERRIES TRANSPLANTED SALT MARSH

Photograph 1 Bands of Oregon Gumweed (*Grindelia integrifolia*) on Southeast Edge of Constructed Marsh, Looking North from Roadside (August 20, 2014)

Photograph 2 Northwest Edge of Constructed Salt Marsh with Main Tidal Channel in Foreground, Looking North from Roadside (August 20, 2014)

Photograph 3 Southwest Edge of Constructed Salt Marsh with Main Tidal Channel in Left-Centre Foreground, Looking Southwest Along Grid Centerline (August 20, 2014)

IR7-29 Marine Fish – Mitigation, Offsetting (Eelgrass)

Information Source(s)

EIS Volume 3: Appendix 17-A

CEAR Doc#647

Context

The Proponent, in Appendix 17-A of the EIS, reported that following terminal construction there would be an opportunity to transplant approximately three hectares of native eelgrass within the local assessment area. Potential donor areas would be located north of the existing terminal and in the inter-causeway. The Proponent also reported that regional case studies have demonstrated that eelgrass transplants can meet or exceed the density of the donor bed within two to three years of transplanting and that an eelgrass transplant method developed in British Columbia is considered to be greater than 90% effective.

According to Raincoast Conservation Foundation in CEAR Doc#647, previous port expansion projects, including those evaluated by the Roberts Bank Environmental Review Committee (1996), developed eelgrass transplantation projects. Those efforts, however, were unsuccessful due to a poor site selection and were later rendered unnecessary by the natural expansion of eelgrass beds.

Information Request

Provide an evaluation of the effectiveness of eelgrass transplanting activities in the local assessment area. Include any eelgrass habitat creation measures undertaken by and the Proponent or other agencies.

Provide an analysis of the effectiveness of transplanted eelgrass as targeted mitigation for juvenile Chinook Salmon and other marine fish in the local assessment area.

VFPA Response

Provide an evaluation of the effectiveness of eelgrass transplanting activities in the local assessment area. Include any eelgrass habitat creation measures undertaken by and the Proponent or other agencies.

This response will demonstrate that eelgrass transplantation activities are effective, when properly implemented with appropriate design that accounts for site-specific biophysical conditions and constraints. To that end, effectiveness monitoring results are summarised in **Table IR7-29-1** for eleven eelgrass transplantation projects undertaken by the VFPA or other proponents in the local assessment area (LAA) as well as outside LAA boundaries, within the Fraser River estuary and elsewhere in B.C. Information sources used in this response include

the literature, as well as technical monitoring reports (where available) for the eelgrass transplantation projects summarised in **Table IR7-29-1**.

Eelgrass transplantation activities are considered effective[1] in B.C. if the habitat that has been created is ecologically stable and self-sustaining, and provides habitat equal in eelgrass productivity to that which it has been designed to replace. Metrics typically used to evaluate effectiveness of eelgrass transplantation projects focus on plant survivorship and growth and include the following (considered by DFO as surrogates of fish productivity; Precision Identification 2002a, Pearson et al. 2005, Smokorowski et al. 2015; also, see discussion in second part of this response):

- Mean shoot density (in number of plant shoots/m^2): mean shoot density of the transplanted eelgrass bed meets or exceeds the density of the donor bed; and
- Area of coverage (in %): target area of transplanting reaches 100% coverage.

Eelgrass transplantation projects in B.C. undertaken in the 1980s and early 1990s, including the project in the LAA referred to in the context to this information request (Project No. 1 in **Table IR7-29-1**, see below for details), employed methods developed for the Atlantic coast (described in Fonseca et al. 1982a,b). These methods experimented with site biophysical characteristics (e.g., sediment, elevation) and transplanting techniques to test how they may influence plant establishment and growth (e.g., Harrison 1990). However, projects were met with variable success as transplanting methods proved not well suited to coastal environments of the Pacific Northwest, due to notable differences in the tidal and current regimes, as well as in eelgrass types between the Pacific and Atlantic coasts (Durance 2007). For example, two sites in the LAA south of the Roberts Bank causeway totalling 57,700 m^2 were selected in the early 1980s for eelgrass transplanting as compensation for the expansion of the Westshore Terminals coal-handling port (Project No. 1 in **Table IR7-29-1**). Donor plants were harvested from the seaward edge of the adjacent natural eelgrass bed. One site was located within an erosion channel at elevation ranging from below 0.5 m chart datum (CD) to 1.1 m CD. The second site was located at a higher elevation (>1.7 m CD) landward of the leading edge of the existing natural eelgrass bed (Harrison 1990). Transplanting techniques experimented with the use of core (intact plants with sediment), sprig (unanchored bare plants), and anchored (five plant shoots anchored together in the sediment by means of 50-cm long iron rods) transplants (Harrison 1990).

Following transplanting, monitoring was undertaken for five years to determine success. To clarify, eelgrass transplanting was not "unsuccessful" as stated in the context to this information request. Rather, eelgrass survival was variable influenced primarily by site elevation (based on a review of literature, including Harrison (1990), Thom (1990), Kistritz and Gollner (1995), RBERC (1996), and Wright (2005)). Results from the first two years of monitoring revealed that at low elevation, shoot survival suffered from exposure to excessive current flow (Harrison 1990, Thom 1990, Kistritz and Gollner 1995, RBERC 1996). Following

[1] Definition of effectiveness as it pertains to eelgrass transplants is interpreted by Precision Identification (2002a), based on DFO requirements regarding effectiveness of created habitat in achieving no net loss of productive capacity (DFO 1986; see also Harper and Quigley (2005) and Smokorowski et al. (2015)).

construction of a crest protection wall along the seaward perimeter of the natural eelgrass bed, further erosion was prevented, and transplants flourished. After five years of monitoring, vegetation expanded to the extent that individual transplant plots were no longer distinguishable from surrounding vegetation (Harrison 1990, Thom 1990, Kistritz and Gollner 1995, RBERC 1996). At higher elevations, shoot survival suffered from exposure to air at low tide, as many of the plots chosen for transplant were at a level later determined to be the upper limit of expansion of the existing natural eelgrass bed.

In the mid-1990s, an eelgrass transplant method (called SAFE[2]) was developed for B.C., which accounts for site-specific biophysical conditions (i.e., salinity, sediment type, current velocity, light conditions, depth, temperature, and pH), selection of suitable plant donor stock (ecotype[3]), and use of an appropriate iron anchoring device (Durance 2007). This transplant method has been employed at over 100 sites throughout B.C. since 1994, and is considered to be greater than 90% effective (C. Durance 2014 personal communication, cited in EIS Appendix 17-A). Effectiveness is achieved typically within two to three years following transplant (Durance 2007). For example, in 2008, the British Columbia Transmission Corporation (BCTC) constructed two eelgrass beds totalling 20,900 m^2 as compensation for the Vancouver Island Transmission Reinforcement project (Project No. 4 in **Table IR7-29-1**). Both eelgrass beds are located outside LAA boundaries, but within the Fraser River estuary, in Tsawwassen, south of the BC Ferries causeway. Evaluation of the sites prior to construction of eelgrass beds suggested that eelgrass colonisation would be limited by depth, slope, and water velocity (BCTC 2007). As such, a bench was constructed prior to transplanting using Fraser River sand sourced from the VFPA's maintenance dredging program. Eelgrass donor stock was sourced from the existing eelgrass meadow adjacent to the site, and was transplanted using the SAFE method (Golder Associates 2011, 2016, Stantec 2014, C. Durance 2018 personal communication).

Post-construction compensation monitoring was undertaken for five years following transplanting. Based on topographic/stability surveys, and comparison between 2009 and 2013 depth contours, the transplant sites remained stable and entirely at elevation suitable for eelgrass growth and colonisation; thus, they were deemed to function as intended (Golder Associates 2011, 2016, Stantec 2014). Moreover, within three years of transplanting, eelgrass beds had proliferated to more than three times the original planting of eelgrass shoots. Divers noted that it was difficult to distinguish between planted and natural eelgrass at the bed margins (Golder Associates 2011, 2016, Stantec 2014, C. Durance 2018 personal communication). Therefore, transplantation was deemed effective, and the objective of no

[2] SAFE: **S**ite selected, **A**nchored with **F**e, using the appropriate **E**cotype (Durance 2007).

[3] An ecotype is a population (or subspecies or race) that is adapted to local environmental conditions. The following three ecotypes of native eelgrass (*Zostera marina*) occur in B.C. (Precision Identification 2002b):

- *typica*: characterised by narrow leaf size (width ranging from 2 to 5 mm), occurring primarily in the intertidal, and exhibiting low tolerance to currents;
- *phillipsi*: characterised by intermediate leaf size (width ranging from 4 to 15 mm), occurring primarily in depths ranging from 0 to -4 m, and exhibiting moderate tolerance to currents; and
- *latifolia*: characterised by large leaf size (width ranging from 12 to 20 mm), occurring primarily in depths ranging from -0.5 to -10 m, and exhibiting strong tolerance to currents.

net loss in productive capacity was successfully achieved (Golder 2011, 2016, Stantec 2014, C. Durance 2018 personal communication).

More recently, in 2015, the VFPA completed in the LAA a 450 m^2 eelgrass transplant in the inter-causeway area adjacent to the tug basin (Project No. 2 in **Table IR7-29-1**). The transplant was undertaken within the unvegetated footprint of a temporary barge ramp used during construction of a new tug turning basin for the Deltaport Third Berth project, and it was intended to expedite the rate at which eelgrass would re-colonise in that area. Eelgrass was harvested from adjacent donor beds and transplanting was undertaken using the SAFE method (Precision Identification 2016). Based on results from monitoring undertaken in 2016, the transplanted eelgrass multiplied and spread at an exceptionally fast rate; cover exceeded 85% (**Table IR7-29-1**), and the site resembled a natural well-established bed (Precision Identification 2016).

Additional eelgrass transplantation activities undertaken elsewhere in B.C., which employed the SAFE method, and were deemed successful, are summarised in **Table IR7-29-1**. For eelgrass transplantation activities that were not successful, information on the factors that contributed to transplant failure is provided (**Table IR7-29-1**). Overall, transplant success was noted for sites that ranged in size from as small as 140 m^2 (Whaler Bay, Galiano Island) to just over 11 hectares (within the Fraser River estuary, in Tsawwassen, south of the BC Ferries causeway). Transplant success was attributed to employment of a suitable method, selection of transplant sites with biophysical conditions optimal for eelgrass growth and colonisation, and use of eelgrass type adapted for conditions specific to each site (C. Durance 2018 personal communication).

Table IR7-29-1 Examples of Eelgrass Transplantation Projects Undertaken in the Local Assessment Area, the Fraser River Estuary, and Elsewhere in B.C. from the Early 1980s to the Present

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
Within Local Assessment Area			

1	Roberts Bank, Inter-causeway Area	Coal Port Expansion – Westshore Terminals (Harrison 1990, Thom 1990, Kistritz and Gollner 1995, RBERC 1996, Wright 2005)	• 57,700 m^2 were transplanted in 1981-1983 and were monitored for 5 years (1983-1987).
			• Transplanting was conducted south of the causeway, at a low elevation site within an erosion channel devoid of vegetation, and at a high elevation site landward of the leading edge of the existing natural eelgrass bed.
			• Donor plants were salvaged prior to dredging for coal port expansion from the seaward edge of the existing natural eelgrass bed adjacent to the transplant sites.
			• Methods included core (intact plants with sediment), sprig (unanchored bare plants), and anchored (5 shoots anchored in sediment by means of 50-cm long rebar) transplants.
			• Transplantation success was deemed variable, influenced primarily by site elevation.
			  ○ At high elevation, shoot survival suffered from exposure to air at low tide, as many of the plots chosen for transplant were at a level later determined to be the upper limit of expansion of the existing natural eelgrass bed.
			  ○ At low elevation, shoot survival initially suffered from exposure to excessive current flow. Following construction of a crest protection wall along the seaward perimeter of the natural eelgrass bed, further erosion was prevented, and transplants flourished. Following 5 years of monitoring, vegetation expanded to the extent that individual plots were no longer distinguishable from surrounding vegetation. Mean density (108 shoots/m^2) far exceeded that in areas where natural colonisation occurred (20 shoots/m^2).

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
2	Roberts Bank, Inter-causeway Area	Deltaport Third Berth Project (DP3) – Vancouver Fraser Port Authority (Precision Identification 2016)	• 450 m^2 were transplanted in 2015 to expedite eelgrass re-colonisation within the footprint of a temporary barge loading ramp used to assist with the construction of a new tug turning basin for DP3. • 4,000 shoots in total were harvested from nearby natural eelgrass beds. • The transplant site was divided in Area 1 and Area 2 on either side of the channel created following the breach of the adjacent rip rap berm to enhance water circulation in the area. • Monitoring results are available for 1 year (2016) following the transplant. • Percent cover for Area 1 and Area 2 was 95% and 85%, respectively. • Mean density (shoots/m^2) for Area 1 and Area 2 was 56 and 68, respectively, compared to a transplant density of 10. • The transplanted eelgrass multiplied and spread at an exceptionally fast rate; the transplant site resembles a natural well-established bed.
Outside Local Assessment Area – Within Fraser River Estuary			
3	Tsawwassen, South of BC Ferries Causeway	Tsawwassen Terminal Expansion – BC Ferries Corporation (Kistritz and Gollner 1995, Precision Identification 2002a)	• 114,600 m^2 were transplanted in 1991 and were monitored for 3 years (1992-1994); site was visited again in 2001. • Transplanting occurred in areas of low (-0.8 to -0.3 m), mid (-0.3 to 1.0 m), and high (1 to 1.7 m) elevation. • Transplants were primarily located at mid elevation, which was generally covered by water at low tide; transplants at high elevation were frequently exposed at low tide. • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • Eelgrass habitat in mid and low elevations of transplant bed was comparable to that in adjacent natural bed after three years following transplant. • In 1994 and 2001, mean density (shoots/m^2) of the transplant bed exceeded that of the adjacent natural bed at mid elevation (i.e., 1994: 126 > 100; 1995: 127 > 75; 2001: 102 > 92). • The transplant bed at high elevation was less productive than the natural bed, due to extension to greater elevation than the natural bed and frequent exposure at low tide.

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
4	Tsawwassen, South of BC Ferries Causeway	Vancouver Island Transmission Reinforcement – British Columbia Transmission Corporation (Golder 2011, 2016, Stantec 2014)	• 20,900 m^2 were transplanted at Roberts Bank in 2007-2008 and were monitored for 5 years (2009-2013). • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • Based on topographic/stability surveys, and comparison between 2009 and 2013 depth contours, the transplant site remained stable and entirely at elevation suitable for eelgrass growth and colonisation; thus, it was deemed to function as intended. • Post-construction monitoring in 2010 indicated that the constructed bed had proliferated to more than three times the original planting of eelgrass shoots. Divers noted that it was difficult to distinguish between planted and natural eelgrass at the bed margins.
Outside Local Assessment Area – Elsewhere in B.C.			
5	Whaler Bay, Galiano Island	Vancouver Island Transmission Reinforcement – British Columbia Transmission Corporation (Golder 2011, 2016, Stantec 2014)	• 140 m^2 were transplanted at Whaler Bay in 2007-2008 and were monitored for 5 years (2009-2013). • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • Based on topographic/stability surveys, and comparison between 2009 and 2013 depth contours, the transplant site remained stable and entirely at elevation suitable for eelgrass growth and colonisation; thus, it was deemed to function as intended. • Post-construction monitoring in 2010 indicated that the constructed bed had proliferated to more than three and half times the original planting of eelgrass shoots. Divers noted that it was difficult to distinguish between planted and natural eelgrass at the bed margins.

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
6	Nanaimo	Newcastle and Channel View Marina Development (Precision Identification 2002a)	• 5,420 m^2 were transplanted in 1994 and were monitored for 3 years (1995-1997); site was visited again in 2001. • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • By 1997, coverage in deeper sections of transplant plots increased to 70% (mean density 48 shoots/m^2). In 2001, coverage ranged from 95% to 100% (mean density 88 shoots/m^2), resembling that of robust natural populations. • Plant density in deeper sections exceeded by more than 400% plant density of the habitat affected by the project. • By 1997, and in 2001, coverage in shallower sections of transplant plots remained sparse and patchy (estimated at 10%; mean density 6 shoots/m^2), likely due to shading from adjacent structures, and donor plants marginally suitable for the elevation.
7	Protection Island, Nanaimo	Brechin Community Paddle Dock and Boathouse – City of Nanaimo (Aquaparian Environmental Consulting 2015)	• 500 m^2 and 200 m^2 were transplanted in 2008 north and south of the community paddle dock, respectively; transplants were monitored for 6 years (2009-2015). • Eelgrass site was determined suitable for transplant given substrate conditions, and presence of natural eelgrass beds nearby. • In 2009, eelgrass had survived the transplant and had started to fill in forming continuous beds; mean density was ~80 shoots/m^2, and cover was ~83%. • In 2011, eelgrass transplants had coalesced to form one single bed. Mean density ranged between 75 and 100 shoots/m^2, cover was ~97%. Beds had expanded into deeper water and growth success rates were 136% and 207% for the north and south bed, respectively. • In 2015, eelgrass cover had significantly reduced by ~95%. Substrate composition was predominantly soft silt and scattered bark waste had increased within the area of eelgrass transplants. • Failure of eelgrass transplant was attributed to log boom activity reported as close as 50 m from the dock, as well as propeller wash and substrate scour from boom boats operating nearby.

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
8	Gibsons	Gibsons Harbour Marina Development – Gibsons Small Craft Harbour Authority (Precision Identification 2002a)	• 164 m^2 (estimate) were transplanted in 1985 to compensate for eelgrass loss associated with the construction of a rip rap breakwater as part of marina development; site was monitored for one year in 1987. • Eelgrass transplant was unsuccessful as sediment comprising gravel and cobble was not conducive to eelgrass growth. • An additional 250 m^2 were transplanted in 1987-1988 along sandy benches adjacent to the original transplant site; monitoring was undertaken in 1988-1989 and site was visited again in 2001. • Monitoring revealed no eelgrass in the area of the 1985 transplant. • Within the 1987-1988 transplant site, plants appeared healthy and had multiplied to densities comparable to natural beds in areas where sediment was free of debris. • Transplant success was limited by the presence of a dense layer of bark debris from log booming activities nearby.
9	Tofino	Dredging Floatplane Dock Upgrades – Tofino Air Lines Ltd. (Precision Identification 2002a, C. Durance 2018 personal communication)	• 200 m^2 were transplanted in 1999 and were monitored for 4 years (2000-2003). • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • Eelgrass planted at low elevation reproduced quickly and merged with naturally colonising plants, with shoot density comparable to that of adjacent natural populations at similar elevations. • Transplanting of eelgrass at high elevation was generally successful, except for sections of the site in the intertidal that experienced increased foot traffic for water access at low tide. • By 2003, plant density was 402 shoots/m^2, compared to 38 shoots/m^2 recorded during the first year of monitoring. • Transplant success was attributed to suitable substrate and appropriate elevation for the selected ecotype.

No.	Transplant Site	Project – Proponent (Source)	Summary of Project Methods, Results, and Effectiveness
10	Sooke, East of Billings Spit, near Sooke River mouth	Water Main Installation (compensation for trenching on the seabed) – Silver Spray Developments (C. Durance 2018 personal communication)	• 1,008 m^2 were transplanted in 2002 and were monitored for 2 years (2003-2004). • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • Eelgrass transplanting was successful, with plant density having increased from 23 shoots/m^2 in 2003 to 41 shoots/m^2 in 2004. • Transplant success was attributed to selection of site with biophysical conditions optimal for eelgrass growth, implementation of a suitable transplant method, and use of suitable donor plant ecotype adapted for the site.
11	Klemtu	Fish Farming Operations (compensation for effects on seabed) – Marine Harvest Canada (Marine Harvest 2017, C. Durance 2018 personal communication)	• 1,950 m^2 were transplanted in 2006-2008 (2006: Trout Bay, Clothes Bay; 2007: Trout Bay, Goat Cove; 2008: Goat Cove) and were monitored for 5 years (until 2013). • As determined by DFO, the objective of no net loss in productive capacity was successfully achieved. • By 2013, areal cover of all transplant beds combined increased to 9,304 m^2. • Transplant success was attributed to selection of site with biophysical conditions optimal for eelgrass growth, implementation of a suitable transplant method, and use of suitable donor plant ecotype adapted for the site.

Provide an analysis of the effectiveness of transplanted eelgrass as targeted mitigation for juvenile Chinook Salmon and other marine fish in the local assessment area.

Eelgrass beds constructed within and outside LAA boundaries as targeted mitigation for juvenile Chinook salmon and other marine fish are considered as effective in providing productive foraging, rearing, and refuge opportunities for marine fish (including juvenile Chinook salmon) as natural eelgrass beds. This is supported by results from long-term effectiveness monitoring typically required by DFO following the creation of eelgrass habitat to determine success based on plant survivorship and growth, criteria used by DFO as surrogates of fish productivity. Additionally, the efficacy of natural (and by inference constructed) eelgrass beds to provide functional productive habitat for marine fish (including juvenile salmon) is well established in the literature. This is explained further below.

As described in the first part of the response, effectiveness of eelgrass transplantation activities in B.C. is determined through monitoring that is typically tailored to address structural stability and long-term persistence of constructed eelgrass beds (DFO 2012, Smokorowski et al. 2015). This approach is consistent with guidance from DFO and is intended to mainly manage risk associated with aspects of the physical environment (e.g., salinity, sediment type, current velocity, etc.; see first part of the response and also Durance 2007) that may influence success or failure of eelgrass transplants (DFO 2012, Smokorowski et al. 2015). To ascertain a successful transplant, monitoring efforts typically focus on plant survivorship and growth using metrics of primary (plant) production, such as mean shoot density and area of coverage (see **Table IR7-29-1** for examples, and also Durance 2007). These metrics are also generally considered appropriate surrogates of fish productivity (DFO 2012, Smokorowski et al. 2015).

Also consistent with DFO guidance, metrics that assess changes in secondary/tertiary (animal) productivity from eelgrass transplants (e.g., fish abundance and density, fish growth and condition, fish feeding rates and diet) may also be used in effectiveness monitoring (DFO 2012, Smokorowski et al. 2015). However, direct monitoring of fish productivity to evaluate efficacy of eelgrass transplants can be demanding in that extensive sampling and long-term data collection are required to capture inherent diversity in fish communities and natural variability in fish abundance (DFO 2012, Smokorowski et al. 2015). As such, fish productivity metrics are rarely monitored and no examples were located in the literature.

A review of eelgrass transplantation activities within and outside LAA boundaries (examples provided in **Table IR7-29-1**) revealed that metrics of fish productivity within constructed eelgrass beds were not used as part of effectiveness monitoring, irrespective of the projects' varying size and complexity. Regardless, established eelgrass transplants were deemed effective mitigation targeting marine fish (including juvenile Chinook salmon), based on long-term (up to five years) monitoring results. This conclusion is based on the premise (which is supported by the literature; see below) that successful eelgrass transplants that persist over time provide the same functional attributes as natural eelgrass beds, including fish refuge and rearing opportunities, as well as increased food supply (Durance 2007). This hypothesis was tested during an independent study (which included Projects #3, #6, #8, and #9 in **Table IR7-29-1**) conducted by Precision Identification (2002a) on behalf of DFO to evaluate

the long-term viability of transplanting eelgrass. During this study, a casual faunal inventory was developed of fish, shellfish, and invertebrates observed in constructed eelgrass habitats. A comparison of this inventory with faunal observations in natural eelgrass beds used as reference sites revealed no faunal differences between transplant and reference sites (Precision Identification 2002a).

Natural (and by inference constructed; DFO 2012, Smokorowski et al. 2015) eelgrass beds provide productive foraging and rearing opportunities for marine fish (including juvenile salmon); this is well understood and established in the literature (for a review, see Section 2.1 in TDR MF-7 in Appendix AIR10-C of CEAR Document #388[4], and EIS Section 11.5.1). The importance of eelgrass beds to marine fish including juvenile salmon is summarised below.

Eelgrass beds provide ecological services that assist in maintaining healthy estuarine and nearshore marine habitats (Costanza et al. 1997, Guerry et al. 2011, Fourqurean et al. 2012, Lamb et al. 2017); they are also important for many marine fish species (including juvenile salmon) that use eelgrass during or part of their life cycle. Specifically, eelgrass provides habitat structure and complexity that attracts diverse fish assemblages (e.g., Orth and Heck 1980, Lubbers et al. 1990, Sogard and Able 1991, Johnson et al. 2003, McCloskey and Unsworth 2015). Roberts Bank has a diverse fish community with more species (>55 fish species recorded; Greer et al. 1980, Conlin et al. 1982, Gordon and Levings 1984) than Sturgeon Bank, likely due to increased habitat complexity, including presence of eelgrass beds (Gordon and Levings 1984). Eelgrass blades also provide spawning substrate for marine forage fish, such as Pacific herring (Penttila 2007; also see response to IR4-18 of CEAR Document #1051[5]).

Eelgrass beds in estuaries provide a valuable link between freshwater and marine habitats for out-migrating juvenile salmon by offering refuge from predators, and cover at low tide (Simenstad et al. 1982, Semmens 2008, Levings 2016), as well as enhanced feeding opportunities during juvenile salmon rearing (e.g., MacDonald 1984, Thom et al. 1989, Webb 1991, Bottom et al. 2005, Semmens 2008, Knight et al. 2015, Kennedy 2016, Kennedy et al. 2018). Semmens (2008) posits that, based on rates of movement and patterns of survival, juvenile Chinook salmon may slow down in native eelgrass beds because the habitat affords better foraging opportunities, better cover from predators, or both. Also, the largest proportion of prey consumed by juvenile salmon in eelgrass beds has been shown to come from epifaunal species that attach to eelgrass blades (MacDonald 1984, Kennedy 2016, Kennedy et al. 2018).

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[4] CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review – Responses to Additional Information Requirements Follow-Up (See Reference Document # 345) including 22 Technical Data Reports.
[5] CEAR Document #1051 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 4 (See Reference Document #946).

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IR7-30 Marine Biophysical Components – Offsetting as Mitigation Measure

Information Source(s)

EIS Volume 3: Appendix 10-D, Appendix D; Section 17.3.1; Section 17.3.2.1; Table 17-4; Table 17-5; Appendix 17-C, Table 17-C2

CEAR Doc#577

Context

The Proponent, in Section 17.3.1 of the EIS, reported that the approach to determining offsetting measures considered the following:

- spatial trade-offs;
- species trade-offs to address effects on different life history stages and trophic levels;
- temporal losses; and
- other available offsetting alternatives.

Together these multiple lines of evidence predicted both gains and losses in productive potential.

According to the Proponent in Section 17.3.2.1 of the EIS, the consideration of offsetting as a mitigation measure for marine fish, marine vegetation, marine invertebrates and coastal birds, was carried forward only for those valued components with losses in productive potential. Biological components with negligible or positive changes to productive potential were not considered for offsetting.

Using the Roberts Bank ecosystem model, the Proponent predicted the overall biomass that each habitat type would support, and outlined valued component sub-components and representative species that the offset is intended to address. Details about the methodology used from the Roberts Bank Ecosystem Model were set out in Appendix D of Appendix 10-D of the EIS. The results of the gains associated with the proposed onsite habitat concepts (intertidal marsh, sandy gravel beach, mudflat, subtidal rock reef and eelgrass transplant) were summarized in Table 17-4 of the EIS.

As reported in Table 17-5 of the EIS, despite the application of proposed onsite Offsetting Concepts, the proposed Project is expected to have detectable residual effects on Dungeness Crab, bivalve shellfish, Orange Sea Pens, Pacific Sand Lance and other forage fish.

According to Fisheries and Oceans Canada in CEAR Doc#577, the approach used by the Proponent does not demonstrate how or if Project-related effects to valued components and valued component sub-components will be counterbalanced with the proposed offsetting concepts. For example, Table 17-C2 of Appendix 17-C showed that with the Project and onsite offsetting, there would be a 61.1% increase in productive potential of intertidal marsh in the local assessment area; however, with the Project and onsite offsetting there will be an 8.2%

loss in productive potential for bivalves. It is not clear how these trade-offs may have been considered in the development of the offsetting plan.

Information Request

Provide a description of how the benefits from offsetting measures balance adverse effects to marine vegetation, marine fish, and marine invertebrates from the proposed Project. This description should include identification of whether offsets are replacing similar habitat to that being harmfully altered or destroyed (such as eelgrass transplant to offset destruction of eelgrass), or whether offsets are targeting other factors limiting productivity at Roberts Bank.

VFPA Response

Detailed information pertaining to using productivity as a metric for RBT2 offsetting is presented in the VFPA's responses to IR7-26 and IR11-14, as well as in the Preamble to Offsetting-related Information Requests. This background information provides important clarification in support of this response.

Part 1 – Provide a description of how the benefits from offsetting measures balance adverse effects to marine vegetation, marine fish, and marine invertebrates from the proposed Project.

A productivity approach was employed to help design offset requirements to mitigate adverse effects anticipated from the Project. The productivity approach to determining offsetting requirements and selection of Offsetting Measures was consistent with the recommendations from the Productive Capacity Technical Advisory Group (TAG) (EIS Section 7.4 and Information Request Package 3 Preamble in Support of Responses to IR3-01 to IR3-24 of CEAR Document #984[1]). This approach is also consistent with current federal science advice and policy (DFO 2013a, 2013b, 2013c, 2013d, 2018; Environment Canada 2012).

The environmental assessment of the Project as described in the EIS predicted non-significant residual adverse effects to marine vegetation, marine fish, and marine invertebrates, after taking into account the implementation of mitigation measures, including offsetting. The Roberts Bank ecosystem based food-web numerical and spatial model (Roberts Bank ecosystem model) provided a quantitative estimate of changes, but the effects assessment considered multiple lines of evidence, including existing information, empirical data, including Project-specific field studies, other models, and Indigenous traditional knowledge (IR5-29 of CEAR Document #1185[2]). While changes to individual valued components (VCs) have been a focus of the EIS and are detailed in Table IR7-26-A1 in Appendix IR7-26-A, it is of interest that there is a net gain in biomass of 1,142 tonnes (t) across key functional groups, with offsetting. This net gain is dominated by seven functional groups with over 10% increases in biomass (dunlin, raptors, western sandpiper, shiner perch, macrofauna, biofilm, and tidal

[1] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).
[2] CEAR Document #1185 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-28 and IR5-29 (See Reference Document #975).

marsh species) and three functional groups with decreases in biomass over 10% (biomat, brown algae, and orange sea pens) (Table IR7-26-A1).

Given productivity benefits of the Project, it is anticipated that predicted shortfalls in some functional groups / focal species will be balanced through the surplus productivity and indirect productivity benefits in others (see **Effects on Marine Vegetation** below). Results of the Roberts Bank ecosystem model indicate that there will be both gains and losses in productivity among the different functional groups associated with the marine biophysical VCs. Overall, the Roberts Bank ecosystem model estimates a positive change (~386 t or 1.5% increase compared to existing conditions) in overall productive potential for all marine biophysical VCs combined *prior to* implementation of Offsetting Measures. The onsite Offsetting Measures, combined with the Project, result in a total biomass increase of 1,142 t (4.4%) to the key focal species (i.e., functional groups) (Table IR7-26-A1 in Appendix IR7-26-A). Gains will be partly associated with increases in new substrates for colonising species (e.g., rocky substrate for macroalgae, biofilm on mudflats), whereas there will be direct losses of habitat (e.g., sandy gravel) within the Project footprint. Out of the 37 key functional groups, 24 are expected to either benefit with increases to their productive potential or experience negligible change (<5% change), while 13 are expected to show more than a 5% decrease with the proposed onsite habitat offsetting concepts (EIS Appendix 17-C, Table 17-C2; EIS Appendix 17-A, Tables 17-A1 to 17-A5; Table IR7-26-A1). As previously mentioned, despite any forecasted decreases in productivity in certain functional groups, the Offsetting Framework for RBT2 was developed to ensure there is no net loss of productivity at Roberts Bank, to sustain the immediate Project area as a productive marine ecosystem.

Effects on Marine Vegetation

Potential effects of the Project on the marine vegetation VC (EIS Section 11.6.1) were identified through discussions with regulators, Indigenous groups, stakeholders, and the public, the TAG process, review of the *EIS Guidelines*, published scientific literature, professional experience and information from other similar environmental assessments and projects, and professional judgement of the Project team. In the EIS (Sections 11.6.1 to 11.6.2), significant residual effects on marine vegetation were defined as a) direct mortality, b) changes in water quality (e.g., salinity, total suspended solids (TSS), sedimentation affecting primary productivity), c) coastal processes (i.e., sediment deposition), and d) biotic interactions (e.g., excessive grazers from an imbalance of predator-prey relationships). For the marine vegetation VC, after mitigation (including offsetting), the assessment predicted non-significant residual effects, with a moderate level of confidence (Tables 11-10 to 11-17 and Table 11-26 of the EIS). Offsetting was proposed to mitigate productivity losses to macroalgae, through the creation of subtidal rocky reef habitat proposed Offsetting Measure.

The Roberts Bank ecosystem model estimated a minor decrease in productivity for the representative species rockweed (*Fucus*), within the macroalgae sub-component (EIS Table 17-3). However, when examined collectively as 'brown algae' (including kelps), there is a net increase in biomass of 5.2 t (Table IR7-26-A1 in Appendix IR7-26-A). The largest gains are associated with the proposed onsite sandy gravel beaches offsetting habitats and onsite subtidal rock reef offsetting habitats because this seaweed requires a stable substrate (e.g., rocks, boulders) for attachment. The increase in biomass of *Fucus* in the sandy gravel

beaches is associated with the proposed construction of 4.5 hectares (ha) of soft sediment beaches (to cover hard rip-rap structures) as an Offsetting Measure along the causeway and adjacent to the new terminal. These new onsite offsetting habitats will provide additional sites for rockweed (*Fucus*) and habitat for forage fish spawning. The proposed addition of 2.0 ha of onsite subtidal rock reef offsetting habitats will provide ideal substrate for settlement of various kelp species (e.g., *Saccharina, Nereocystis*). Based on past experience, artificial subtidal rock reef habitat successfully promotes high productivity (see Preamble to Offsetting-related Information Requests and IR11-18).

Marine vegetation focused Offsetting Measures (e.g., eelgrass and intertidal marsh) provide habitat for other estuarine or marine species. These onsite offsetting habitats provide a benefit to the sub-component representative species or groups that were forecasted to experience a decrease in productivity (e.g., bivalves and Dungeness crab). After offsetting, the Roberts Bank ecosystem model forecasts a net increase in biomass of 1,103.9 t (8.1%) for marine vegetation. Each of the five proposed onsite habitat Offsetting Concepts result in estimated increased biomass of marine vegetation, with intertidal marsh and mudflat Offsetting Measures estimated to result in the greatest biomass increases of 483.9 t and 140.8 t, respectively. Tidal marsh species and biofilm are estimated to show the greatest increases (61.6% and 34.4%, respectively) in productivity after offsetting. Given the benefits (direct and indirect) of these marine vegetation habitat-forming species on many key functional groups at Roberts Bank, increasing onsite habitat offsets associated with high productivity (yet having appropriate site suitability) was a priority during the development of the Offsetting Framework (EIS Section 17.3.2.2). For example, intertidal marsh habitat is used by invertebrates (e.g., bivalves, macro- and meiofauna) along with some of their predators (e.g., juvenile Chinook salmon, great blue heron, and American widgeon) that feed on some of these groups and will use the habitat as refuge. However, as explained in the EIS Section 10.3.3, the Roberts Bank ecosystem model does not account for the benefits of some habitat functions (e.g., refuge habitat); consequently, the Roberts Bank ecosystem model likely underestimates the importance of functional intertidal marsh habitat offsets, for certain functional groups such as juvenile salmonids (further described below in **Effects on Marine Fishes**).

Similarly, eelgrass beds serve numerous critical functions typical of estuarine communities such as providing food (primary productivity) along with spatially complex shelter and rearing habitat for numerous species (fish and invertebrates). In addition, it has key influences on sediment biogeochemical cycles, water quality, and water flow regimes. Many VC sub-components (e.g., juvenile Chinook salmon, juvenile Chum salmon, Dungeness crabs, great blue heron, geese, etc.) will benefit from increases in eelgrass beds at Roberts Bank. As the Roberts Bank ecosystem model does not account for the structure of eelgrass, (e.g., refuge habitat, sediment stabilizer), the model provides a conservative estimate of changes in productivity (EIS Section 10.3.3, see IR7-26). As evidence to support this proposed Offsetting Measure, regional case studies have demonstrated that eelgrass transplants can meet or exceed the density of the donor bed within 2 to 3 years of transplanting, especially when utilising specific techniques developed in B.C. (Precision Identification Biological Consultants 2002).

Within the Roberts Bank ecosystem, biofilm on mudflats are also highly productive habitats that are key to nutrient recycling, biogeochemical cycles and they provide a trophic link between benthic and neritic habitats. Suspended biofilm provides nutrients to neritic trophic levels, thus becomes part of larger scale trophic relay from estuaries. Biofilm serves as a source of food for meiofauna (0.45-1.0 mm), infauna (polychaetes, crustaceans), and epifauna (gastropods, crustaceans). More recently, it has been recognised that biofilm is a key food for migratory bird species (e.g., western sandpiper, dunlin). Migratory western sandpiper at Roberts Bank consume an estimated 45-59% of biofilm in their diet, accounting for estimated 38-68% of total daily energy (Kuwae et al. 2008).

Given the importance of these three marine vegetation habitats (i.e., sub-components), the onsite Offsetting Framework proposed increases of 15.0 ha, 3.0 ha, and 4.5 ha (corresponding to estimated biomass increases of 493.9 t, 8.7 t, and 169.2 t) for intertidal (salt) marsh, eelgrass, and mudflats, respectively (Table IR7-26-A1 in Appendix IR7-26-A). The addition of these three onsite habitat offsets combined with increases of 4.5 ha and 2.0 ha (corresponding to estimated biomass increases of 50.9 t and 33.2 t) for sandy gravel beaches and subtidal rock reef, respectively, is forecasted to result in overall net gains in productivity to the Roberts Bank ecosystem.

Effects on Marine Fishes

EIS Section 13.9 defines a significant adverse residual effect to marine fish as one that alters a species' population, causing a decline in abundance or change in distribution to a level at which the population cannot maintain itself and long-term population integrity is compromised, such that a) re-establishment of the population through natural recruitment (e.g., reproduction or immigration from unaffected areas) is not expected to occur, or b) re-establishment of the population to a level where population integrity is no longer compromised is expected to take longer than one generation. For the marine fish VC, after mitigation (including offsetting), the assessment predicted *non-significant* residual adverse effects, with a moderate level of confidence (EIS Table 13-16). After mitigation, including offsetting, the Roberts Bank ecosystem model forecasts a net minor decrease in biomass of 32.0 t (2.6%) for marine fish. Note that any net productivity differences less than 5% are within the margin of error (uncertainty) for the Roberts Bank ecosystem model (Section 10.3.3 of the EIS).

Among marine fishes, the Roberts Bank ecosystem model forecasts that juvenile Chinook, juvenile chum, sand lance, shiner perch, and starry flounder will all have a positive increase (i.e., benefit) in productive potential (i.e., biomass) with offsetting (Table IR7-26-A1 in Appendix IR7-26-A). Each of the five proposed Offsetting Measures result in estimated increases in biomass of marine fishes with the subtidal rock reef and sandy gravel beach Offsetting Measures, with estimated biomass increases of 3.42 t and 0.67 t, respectively.

As an example, the Roberts Bank ecosystem model forecasts biomass increases of juvenile Chinook salmon of 0.06 t (8.5%) associated with the Project *prior to* offsetting (Table IR7-26-A1 in Appendix IR7-26-A). With the proposed five onsite habitat Offsetting Concepts, juvenile Chinook salmon are forecasted to increase biomass (productive potential) by an additional 0.0008 t, 0.002 t, and 0.002 t, associated with proposed onsite eelgrass, intertidal marsh, and mudflat habitat offsets, respectively (Table IR7-26-A1). Overall, juvenile

Chinook salmon are estimated to have a net increase of 0.0548 t (8.3%) in biomass with the Project and proposed onsite Offsetting Measures. As explained in the response to IR7-26, the Roberts Bank ecosystem model does not account for the benefits of some habitat functions (e.g., refuge habitat); consequently, the Roberts Bank ecosystem model likely underestimates the importance of functional intertidal marsh and eelgrass habitats for certain functional groups such as juvenile Chinook salmon. The estimated net change in biomass of juvenile Chinook (with the Project and offsetting) may be conservative compared to the realised biomass increase.

Surf smelt and Pacific sand lance account for much of the forage fish biomass at Roberts Bank, making the development of Offsetting Measures, including sandy gravel beach, an integral component to maintaining the ongoing productivity in the Project area. Consequently, the Offsetting Framework presents construction of 4.5 ha (estimated biomass increase of 50.9 t, Table IR7-26-A1 in Appendix IR7-26-A) of sandy gravel beaches (soft sediment to cover hard rip-rap structures) along the causeway and adjacent to the new terminal (IR11-17). This Offsetting Measure will provide habitat for forage fish spawning and is consistent with the predominance of soft substrates in the Roberts Bank estuary. Conversely, the 'soft substrate' approach to onsite offsetting (soft substrates replacing hard rip-rap shoreline) has the potential to negatively affect species typically associated with hard or rock substrate, including commercial, recreational, or Aboriginal (CRA) fisheries such as rockfish and lingcod. Therefore, an additional 2.0 ha (with estimated biomass increase of 33.2 t) of subtidal rock reef habitat is proposed as onsite offsetting for rockfish. Rockfish are valued sub-components comprising several species (e.g., copper and quillback) that have been observed among artificial reefs and rip-rap structures at Roberts Bank (EIS Section 13.5.2). The new subtidal rock reef habitat will provide an additional source of recruitment for local rockfish populations (see also response to IR11-18). However, the model forecasts very low amounts in rockfish productivity among the remaining offsetting habitats (as expected because these are not optimal habitats for rockfish). Considered on an ecosystem scale, after the Project and onsite offsetting, the model estimates a small net decrease (0.4%) in rockfish productivity, but categorised as negligible in the effects assessment reflecting other lines of evidence (Table IR7-26-A1 in Appendix IR7-26-A; see also EIS Section 13.8.1). Related to the proposed Offsetting Measure for the subtidal rock reef, as previously noted, the VFPA has a successful history of creating successful subtidal rock reef structures at Roberts Bank. Additional follow-up surveys in 2012 and 2013 indicated that the constructed reefs as part of the Deltaport Third Berth Project are physically stable and that the faunal community on the expansion reefs had reached a stable community composition, with fish species abundance and diversity on all artificial reefs comparable to typical rocky reefs in the Strait of Georgia (TDR MF-5 in Appendix AIR10-C of CEAR Document #388[3], IR11-18).

Despite the net gain in overall productivity within the local assessment area (LAA) at Roberts Bank, as noted earlier, the VFPA recognises that, among the marine fishes, most marine fish functional groups will see increases but some will see decreases in productivity. Adult Chinook

[3] CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document # 345) including 22 Technical Data Reports.

salmon (5.08%) and small demersal fish (6.58%) will see decreases in productivity (after mitigation and offsetting) (Table IR7-26-A1 in Appendix IR7-26-A). Adult Chinook have low abundance and will rapidly migrate through the LAA during the spawning migration and will only occasionally occupy the LAA during the marine rearing phase. The Roberts Bank ecosystem model forecasts a productivity loss for adult Chinook (associated with the Project footprint) but it does not fully capture their 'temporal' occupancy at Roberts Bank, resulting in an overestimation of estimated loss. The estimated loss is restricted to the area of the terminal footprint, where adult Chinook are known to transit during their migration. Because most of their diet comes from outside the model system (90% import) and they are primarily transiting through this area, the model overestimates the potential loss in productivity. Moreover, the estimated decreases in productivity of adult Chinook is near the 5% margin of error associated with the model. Overall, the assessment, through multiple lines of evidence, predicted the net changes in Pacific salmon productive potential from the Project to be negligible. Small demersal fish also have estimated losses in productive potential directly associated with the Project footprint (i.e., loss of habitat). However, the addition of the proposed mitigation and Offsetting Measures (particularly the eelgrass and subtidal rock reef) reduce this estimated decrease to a net loss of 6.58%. In addition, the estimated decreases in productivity of small demersal fish is also near the 5% margin of error associated with the model and, after effects determination through multiple lines of evidence, the residual adverse effect was predicted to be negligible.

Effects on Marine Invertebrates

From EIS Section 12.9, significant adverse effects on marine invertebrates were characterised to occur when residual effects alter population and community characteristics (i.e., abundance, biomass, diversity, distribution) such that a) the long-term integrity of the population and community is compromised, and b) the population and community function in the wider marine ecosystem is not maintained. After mitigation (including offsetting), residual effects on marine invertebrates were predicted to be *non-significant* and the level of confidence was high for bivalve shellfish and Dungeness crabs and moderate for orange sea pens (Table 12-15 of the EIS). With offsetting, the Roberts Bank ecosystem model estimates a net increase in biomass of 68.5 t (0.61%) for marine invertebrates. Four of the five proposed onsite habitat Offsetting Concepts result in estimated increased biomass of marine invertebrates with mudflat and sandy gravel beach Offsetting Measures estimated to result in the greatest biomass increases of 28.3 t and 10.5 t, respectively. Macrofauna (500 µm-1 mm) and meiofauna (organisms 63-500 µm) are estimated to show the greatest increases in productivity (19.4% and 9.1%, respectively) with offsetting. EIS Section 12.5.1 further defines meio- and macrofauna as a diverse collection of oligochaeta, ostracoda, foraminifera, bivalvia, nematoda, harpacticoida, polychaeta, and cumacea that live within (infauna) or on (epifauna) the substrate. Infaunal and epifaunal meio- and macrofauna communities perform several ecosystem-level functions, including sediment bioturbation and re-suspension; production and transfer of food, oxygen, and nutrients; and recycling of waste material and sequestration of harmful substances (EIS Section 12.5.1.2). They are also key intermediate consumers, linking higher trophic levels to basal food resources, so estimated increases in their biomass will have benefits affecting many key species and functional groups at Roberts Bank.

The VFPA recognises that the Project will cause some decreases in biomass (prior to offsets) among some of the marine invertebrates at a sub-component level. Offsetting Measures were therefore directed to benefit certain species (i.e., to mitigate certain adverse effects). Dungeness crabs and bivalves are found in intertidal marsh (and other habitats at Roberts Bank) and were estimated to show minor overall decreases in productivity with offsetting with all habitat types combined (e.g., 6.9% and 9.6%, respectively) (EIS Table 17-3; Table IR7-26-A1 in Appendix IR7-26-A). The biomass changes in bivalves differ by habitat type. In the proposed onsite eelgrass, intertidal marsh, and sandy gravel beaches offsets, the biomass of bivalves will increase (Table IR7-26-A1). In contrast, the biomass will decrease in the proposed onsite mudflat and subtidal rock reef habitat offsets, primarily because these are not the preferred habitats for bivalve infaunal clams (EIS Section 12.6.3.1). Whereas the onsite subtidal rock reef habitat offset may provide additional substrate for attachment of bivalve mussels, it is not an ideal habitat for burrowing intertidal clams. Similarly, the biomass of Dungeness crabs increases in the proposed onsite eelgrass and subtidal rock reef habitat offsets, but decreases in the proposed onsite intertidal marsh, mudflat, and sandy gravel beaches habitat offsets (Table IR7-26-A1). Overall, the proposed Offsetting Measures are expected to reduce the overall forecasted biomass decreases with the Project by 1.20 t.

The Roberts Bank ecosystem model forecasted a 55% decrease in productive potential for orange sea pens (Table IR7-26-A1 in Appendix IR7-26-A). The Offsetting Framework does not propose the creation of subtidal sand habitat as an onsite offsetting measure because it was deemed to be neither economically or technically feasible (based on several lines of evidence outlined in Section 17.3.2.2 of the EIS). After Project completion, subtidal sand habitat will continue to be widespread in the local and regional areas and is not expected to be a limiting habitat for the associated VCs. Hence, no specific offsetting measures were presented in EIS Section 17.0 for those representative species that would benefit from subtidal sand habitat (e.g., orange sea pens). To address concerns about residual impacts to orange sea pens, a pilot sea pen transplant project was undertaken to test its feasibility as a directed mitigation measure (EIS Section 12.7.2.2). Results from ongoing monitoring (IR5-05 of CEAR Document #1145[4]) indicate stable densities and evidence of recruitment at two of the three transplant sites, demonstrating that environmental conditions can be successfully used to predict habitat suitability for orange sea pens across a larger study area such as Roberts Bank. The pilot study also verifies the ecological viability of transplantation as a mitigation method for orange sea pens at Roberts Bank.

Summary

Results of the EIS, via the Roberts Bank ecosystem model, forecast that there will be no net loss of productivity (after the Project and offsetting) at Roberts Bank. However, the VFPA recognises that at a species and sub-component level, there will be some increases and decreases in productive potential because of direct and indirect effects on productivity within the ecosystem. The Project will induce changes in biotic interactions; there will be changes in

[4] CEAR Document #1145 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR2-19a, IR5-05, IR5-06, IR5-07, IR5-10, IR5-45, and IR5-47 (See Reference Documents #991 & #975).

abundances of predators relative to their prey, which influences the productivity of not only marine invertebrate populations, but of trophic levels both above (e.g., marine fish, coastal birds) and below (e.g., marine vegetation), thus further emphasising the importance of addressing mitigation, including offsetting measures, at an ecosystem scale. As previously noted, the RBT2 Offsetting Framework was developed with the principle of maximising ecological productivity through the selection of optimal Offsetting Measures to ensure there is no net loss of productivity for key marine biophysical VCs at Roberts Bank, including marine vegetation, invertebrates, fish, mammals, and coastal birds, or for wetlands. Precedent shows that there is flexibility in selecting offsetting measures at an ecosystem level to achieve 'no-net-loss of productivity'. For example, the Site C project used productivity rather than areal metrics to assess offsetting requirements (CEA Agency 2016). Although there was a net gain in productivity, the Site C project acknowledged that it was not *like-for-like*; there were species estimated to have losses or gains in productivity but these were described in terms of their contribution to a net gain in the overall productivity of CRA fisheries (see Preamble to Offsetting-related Information Requests).

As described in the Preamble to Offsetting-related Information Requests, the VFPA is committed to further developing the Offsetting Framework into a successful final Offsetting Plan following engagement with Indigenous groups, regulatory agencies, and key stakeholders. The final Offsetting Plan will maximise benefits for local communities, address priority issues and concerns, meet permitting requirements (e.g., *Fisheries Act* Authorization), non-permit requirements such as the intent of the federal wetland policy on federal lands (Government of Canada 1991), and will also respond to the dynamic ecology of the Roberts Bank ecosystem. The final Offsetting Plan will provide a comprehensive and broadly supported approach to offsetting that will ensure the productivity of the Roberts Bank ecosystem, and marine biophysical VCs, is maintained or enhanced in the long-term. Moreover, the VFPA has committed to monitoring the success and effectiveness of the proposed Offsetting Measures, as part of the Project's Follow-up Program (IR13-30 of CEAR Document #1331[5]) and future permitting requirements. The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach.

Part 2 – This description should include identification of whether offsets are replacing similar habitat to that being harmfully altered or destroyed (such as eelgrass transplant to offset destruction of eelgrass), or whether offsets are targeting other factors limiting productivity at Roberts Bank.

This question employs specific terminology ("harmfully altered or destroyed") that relate to Fisheries and Oceans Canada's (DFO's) *Fisheries Act*. The use of such terminology implies a request for the specific RBT2 Offsetting Plan details. The guidance for submission of requests for Authorizations (DFO 2013a) and preparing offsetting plans (DFO 2013b) have specific information requirements, both of which will be met during the permitting phase of the Project (i.e., post-environmental assessment phase) in the development of the final Offsetting Plan, which, as noted above, will be informed by active engagement with Indigenous groups,

[5] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).

regulatory agencies, and key stakeholders. This response will focus on the initial Offsetting Framework developed to meet the environmental assessment phase of project approval.

As clarification, from the DFO (2013c) guidelines, an *in-kind* approach to offsetting attempts to replace the habitat that is destroyed or permanently altered by the same quantity and quality of the same type of habitat (i.e., *like for like*), whereas an *out-of-kind* approach to offsetting targets the factors limiting productivity in a given area by means other than directly replacing what has been lost (i.e., indirect approach). DFO (2013c) acknowledged that although it can be more complicated to measure and compare losses caused by a project with offsetting gains when an *out-of-kind* approach is adopted, in some situations (e.g., complex ecosystems with migration of fish among habitats) greater productivity gains may be achieved through this approach.

As previously mentioned, the ecosystem-level management approach is consistent with recommendations from independent scientific advisors (i.e., the Productive Capacity TAG) and current science advice and policy (DFO 2013a, 2013b, 2013c, 2013d, 2018; Environment Canada 2012). The Offsetting Framework incorporates both *in-kind* and *out-of-kind* measures, using productivity (biomass) as a metric (see IR11-14). Given the productivity approach applied to RBT2 offsetting, it is impractical to calculate net productivity differences on an individual habitat basis because the overall net productivity is a combination of replacing similar habitats (e.g., mudflat with mudflat) and different habitats (e.g., sandy gravel with eelgrass). Moreover, changes in one habitat will have a trophic cascade effect (e.g., top-down and bottom-up effects) among predators and prey that occupy various habitats at Roberts Bank. Nonetheless, the VFPA has committed to monitoring the success and effectiveness of the proposed Offsetting Measures, as part of the Project's Follow-up Program (IR13-30 of CEAR Document #1331) and future permitting requirements by applying measurable metrics. The VFPA will respond to, then rectify, any deficiencies (if they occur) via an adaptive management approach.

Environment and Climate Change Canada has indicated that the Roberts Bank intertidal marsh at Brunswick Point and Sturgeon Bank has decreased in spatial extent over the decades; hence, the choice to create additional intertidal marsh as one of Project's Offsetting Measures, even though the Project will be increasing marsh value over time, is targeting a factor that is limiting productivity at Roberts Bank (and thus falls into the *out-of-kind* approach). Intertidal marsh provides high productivity per area, thus when considering the future physical and biological environments at Roberts Bank, the proposed 15 ha of intertidal marsh is estimated to correspond to a 493.9 t biomass increase. As previously noted, while the Project will benefit marine vegetation overall, before offsetting, additional marine vegetation is proposed for onsite habitat offsetting because of the increases in biological productivity that impacts all associated VCs.

The Offsetting Measures proposed by the VFPA are consistent with current legislation and policy and are based on well-established techniques that have been successfully implemented at Roberts Bank, and elsewhere in B.C. and the Pacific Northwest. As outlined in the Preamble to Offsetting-related Information Requests, the Offsetting Measures presented in the EIS are design concepts. These design concepts will be refined and developed as part of the final Offsetting Plan, to meet the permitting phase requirements of the Project. The final Offsetting

Plan will also comprehensively address and account for uncertainty in offsetting success and the associated time lag for the offset to become effective.

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IR7-31 Marine Biophysical Components – Mitigation Measures/Offsetting

Information Source(s)

EIS Volume 1: Appendix 7.2-A; Appendix 7.2-B, Tables 14, 15, 16 and 18

EIS Volume 3 Section 17.3.2.2

EIS Volume 5: Section 33 33.3

Context

The Proponent, in Tables 14, 15, 16, 18 of Appendix 7.2-B of the EIS, reported Indigenous groups' concerns regarding biophysical components of the environment such as marine vegetation, marine invertebrates, marine fish and coastal birds.

In Section 17.3.2.2 of the EIS, the Proponent reported that the proposed onsite habitat offsetting concepts were presented to Indigenous groups, stakeholders, and the public at open houses and small group meetings, starting in fall 2014.

Additional information about views of Indigenous groups relating to mitigation measures for potential effects on biophysical components of the environment, including the proposed offsetting concepts, is required.

Information Request

Provide information about the views of Indigenous groups in relation to proposed mitigation measures, including offsetting, for biophysical components of the environment such as marine vegetation, marine invertebrates, marine fish and coastal birds, that were used in the preparation of the EIS and any further views related to offsetting that have been expressed since the completion of the EIS.

VFPA Response

The VFPA has engaged with the Indigenous groups listed in the *Updated EIS Guidelines* to obtain their views with respect to the Project, potential effects associated with the Project, and measures to avoid, reduce, or offset potential effects associated with the Project. Consultation and engagement activities specifically related to the EIS are described in Section 7.0 of the EIS and Section 2.0 of the Additional Information to the EIS - *WSÁNEĆ*

Nation (AIEIS; see CEAR Document #930[1]). The VFPA has continued to engage with Indigenous groups since the submission of the EIS.

Table IR7-31-1 provides a summary of the views of Indigenous groups in relation to the proposed mitigation measures for each biophysical valued component, including views about offsetting as recorded by the VFPA to December 31, 2017. This table divides mitigation measures by avoidance measures, reduction measures, and offsetting measures, as described below:

- Avoidance measures: Measures that have been incorporated into Project design and construction scheduling to avoid potential effects on valued components. As an example, the terminal has been located in subtidal waters to avoid overlap with sensitive intertidal habitat;
- Reduction measures: Measures that reduce potential Project-related effects. These approaches include implementation of standard mitigation practices that have been demonstrated to be effective to address similar effects, such as erosion control measures (e.g., silt fences) and construction management plans; and
- Offsetting measures: Offsetting provides a third approach to mitigate adverse effects on marine valued components and is proposed after steps have been taken to avoid and reduce effects. As an example, the construction of tidal marsh habitat is proposed to promote productivity increases for juvenile salmon.

This table also presents where and/or how the view was considered in the EIS or through subsequent responses to information requests.

The views of Indigenous groups concerning all topics relating to the Project and marine shipping associated with the Project, including the views captured in **Table IR7-31-1**, are provided in the VFPA's response to IR10-01 (see CEAR Document #1322[2]).

The VFPA continues to consult with and consider Indigenous groups' views on mitigation, including offsetting and follow-up programs, and is committed to further engaging with Indigenous groups as described in the responses to IR10-11 and IR10-12 (see CEAR Document #1275[3]). A recent example is the Indigenous Advisory Forum (IAF) hosted by the VFPA in September 2018.

[1] CEAR Document #930 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Additional Information on the WSÁNEC Nation requested by the Canadian Environmental Assessment Agency on January 13, 2016 (See Reference Document #383).
[2] CEAR Document #1322 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR9-01 to IR9-04, IR10-01, IR10-27, IR10-28, IR11-06, IR11-24, IR12-08, and IR12-12 (See Reference Documents #1122, 1130, 1179, and 1206).
[3] CEAR Document #1275 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR5-01a, IR7-28, IR7-29, IR10-02, IR10-06 to IR10-09, IR10-11 to IR10-26, IR11-07, IR11-22, IR11-23, IR12-03, IR12-06, IR13-01, and IR13-19 (See Reference Documents #1000, 1130, 1179, 1206 and 1228).

The response to IR13-30 (CEAR Document #1331[4]) provides a compilation of proposed mitigation measures and follow-up program elements for the RBT2 Project that reflects consideration of input from regulators, Indigenous groups, and stakeholders, and is current to the date of its submission to the registry on October 19, 2018. As noted in the response to IR13-30 (CEAR Document #1331), the VFPA will provide the Panel with updated tables for mitigation and Follow-up Program elements prior to the Panel Hearing to reflect any further changes as a result of ongoing consultation, evaluation, and planning appropriate for the Project phase.

[4] CEAR Document #1331 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Requests IR13-29 and IR13-30 (See Reference Document #1228).

Table IR7-31-1 Summary of the Views of Indigenous Groups in Relation to the Proposed Mitigation Measures that have been Expressed and Considered by the VFPA

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Avoidance Measures			
Footprint design, location, and orientation	• A request was made for more information on the work that the VFPA has done on footprint designs to see why this particular option has been selected over others that may have had less impact.	Tsawwassen First Nation, 03-Dec-2012 Meeting	**Addressed in EIS Section 5.0:** The consideration of alternative design configurations and construction approaches resulted in the preferred Project design presented and assessed in EIS Section 5.0. A number of location, orientation, layout, and configuration alternatives were considered and assessed for the marine terminal (including berth pocket and marine approach areas), causeway, rail and road corridors, and the tug basin. The effects of feasible alternatives were considered based on their potential to directly or indirectly affect natural and human environment components. The anticipated effects were considered key factors when comparing and determining preferred means. **Additional information provided by the VFPA:** The results of a trade-off study undertaken by the VFPA in 2012 is also available as CEAR Document #539[5]. **Addressed in responses to IR1-06 to IR1-11:** Further discussion of project alternatives, the alternative means analysis, as well as construction alternative means is available in the responses to IR1-06 to IR1-11 (CEAR Document #897[6]).
Footprint design, location, and orientation	• Concerned that the Project will affect migrating salmon that return from the South to the Fraser River through Canoe Passage.	Halalt First Nation, Penelakut Tribe, 03-Jul-2014 Aboriginal Groups Valued Components Workshop #2	**Addressed in EIS Appendix 7.2-B (#78):** Field studies, air photo review, and modelling were undertaken during the coastal geomorphology assessment at Roberts Bank, including Canoe Passage. Changes are anticipated around the terminal and within the intertidal zone shoreward of the terminal. The potential effects of these changes on marine fish are considered in the EIS.

[5] CEAR Document #539 From the Review Panel Secretariat to the Review Panel re: Summary Report - Roberts Bank Terminal 2 Project Trade-Off Process and Output Document

[6] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559)

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	• Concerned about mitigation for natural migration patterns that are in the Project area and the impacts to salmon being made that we do not understand yet along with other animal's natural migration.	22-Oct-2014 Cowichan Nation Alliance EIS Workshop #1	An assessment was undertaken to determine the effects of the Project on the productivity of marine fish, including Pacific salmon. The assessment of marine fish, as well as marine vegetation and invertebrates upon which fish depend, consider seasonal influences, and potential Project-related changes on these influences. Terminal footprint-related changes to coastal process such as currents and freshwater-marine water mixing near and shoreward of the terminal are anticipated. Project-related changes in salinity and turbidity are discussed with respect to marine water quality. A discussion of the potential effects of these changes on marine fish, including different fish life stages, is presented in the marine fish assessment. **Addressed in EIS Section 13.6.3.1:** The potential effect on the migration behaviour of juvenile salmon from terminal placement and causeway widening was assessed qualitatively. Two effects mechanisms—changes in the light environment and changes in habitat availability—were considered to have the potential to influence migration behaviour of juvenile salmon and result in a minor decrease of juvenile salmon productivity pre-mitigation. With implementation of mitigation measures, including adherence to juvenile salmon fisheries-sensitive window, implementation of a light management plan, as well as offsetting in the form of onsite native eelgrass transplants and reconstructed tidal marsh habitats north of the widened causeway, migration-related changes in juvenile salmon productivity were assessed as negligible. **Addressed in responses to IR5-18, IR5-22 and IR5-25:** Further discussions about terminal placement's potential effects on the migratory behaviour of juvenile salmon is available in the responses to IR5-18, IR5-22, and IR5-25 (CEAR Document #1153[7]).

[7] CEAR Document #1153 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-02, IR5-11, IR5-13, IR5-17, IR5-18, IR5-22, IR5-25, IR5-26, IR5-27, IR5-43, and IR5-44 (See Reference Document # 975).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Engineering design mitigation	• A question was asked about whether venting the causeway or enabling water to flow under the causeway had been considered to limit the effect of the causeway on the inter-causeway water flow.	Cowichan Nation Alliance, Cowichan Tribes, Penelakut Tribe, Halalt First Nation, 01-Nov-2013 Tsawwassen First Nation, 07-Oct-2014 Preliminary EIS Workshop #1 Tsawwassen First Nation, 26-Nov-2014 Health & Aboriginal Rights Workshop	**Additional information provided by the VFPA:** An independent technical study, "Potential Effects of Opening the Causeway," was undertaken for the Vancouver Port Authority in 2005 to clarify issues related to physical processes and hydraulic behaviour in the inter-causeway area of Roberts Bank. This report determined that there is a substantial risk that a new opening in the causeway could initiate a new sequence of morphological changes on the tidal flats, which could adversely affect the existing habitat conditions. Furthermore, the assessed opening would be expected to have only a minimal contribution to flushing flows in the inter-causeway area. The report is available on the Project website: http://www.robertsbankterminal2.com/wp-content/uploads/RBT2-Potential-Effects-of-Opening-the-Causeway-June-2005-NHC-Memo-January-2014.pdf. Based on the findings of this report, and the evaluation of adding a flow passage channel, the VFPA does not propose to open the Roberts Bank causeway. **Addressed in response to IR1-13:** Further information concerning this study and causeway design is available in the response to IR1-13 (CEAR Document #897).
Engineering design mitigation	• An inquiry was posed about whether it was possible to narrow the entire causeway.	Lyackson First Nation, 07-Oct-2014 Preliminary EIS Results Workshop #1	**Addressed in EIS Section 5.0:** The consideration of alternative design configurations and construction approaches resulted in the preferred Project design presented and assessed in EIS Section 5.0. As noted in EIS Section 5.7, the widened causeway without the lagoon was determined to be the preferred option as it will minimise intertidal habitat loss amongst the alternatives considered, and will have the least amount of indirect habitat change from altered coastal geomorphic processes. The widened causeway was further optimised by varying widths to minimise effects to the known biofilm intertidal habitat at the east end of the causeway. **Addressed in responses to IR1-06 and IR1-07:** Further discussion of the alternative means, including consideration of the causeway alternative means, is available in the responses to IR1-06 and IR1-07 (CEAR Document #897).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Engineering design mitigation	• A question was raised about why the northwest terminal corner design is rounded.	Métis Nation British Columbia, 23-May-2014 Meeting Lyackson First Nation, 07-Oct-2014 Preliminary EIS Results Workshop #1	**Addressed in EIS Section 5.4.1.3:** The results of coastal geomorphic studies indicated that rounding the northwest corner of the terminal would have the greatest positive effect in terms of decreasing the areal extent of footprint-related effects (i.e., scour induced by flow acceleration around the west side of the terminal). Rounding the corner on a 120-m radius would reduce the scour area as compared to the square corner. The optimised configuration incorporated into the preliminary Project design is a 120-m radius rounded corner, as previously described in EIS Section 4.0 and as shown on EIS Figure 5-4.
Timing of construction activities to avoid fisheries sensitive windows	• Question about whether in-water construction activities would be planned/timed to avoid highs in cycles, including a suggestion that construction not begin on a four-year high in the context of sockeye runs.	Tsawwassen First Nation, 26-Nov-2014 Health & Indigenous Rights Workshop Tsawwassen First Nation, 19-Jul-2016 Issues Workshop	**Addressed in EIS Section 13.7:** Project construction phase avoidance measures include fisheries-sensitive windows established by DFO, which have been incorporated into the preliminary construction schedule, as described in EIS Section 4.3.1[8]. For example, aligning construction activities to avoid fisheries-sensitive windows for juvenile Pacific salmon from March 1 to August 15, above -5.0 m CD. **Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Engineering design mitigation	• A question was asked about whether venting the causeway or enabling water to flow under the causeway had been considered to limit the effect of the	Halalt First Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #253[9]) Tsawwassen First Nation, 05-May-2015 Meeting	**Additional information provided by the VFPA:** An independent technical study, "Potential Effects of Opening the Causeway," was undertaken for the Vancouver Port Authority in 2005 to clarify issues related to physical processes and hydraulic behaviour in the inter-causeway area of Roberts Bank. This report determined that there is a substantial risk that a new opening in the causeway could initiate a new sequence of morphological changes on the tidal flats, which could adversely affect the existing

[8] The Project's construction schedule is updated and presented in the Project Construction Update (CEAR Document #1210).
[9] CEAR Document #253 From Halalt First Nation to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	causeway on the inter-causeway water flow.		habitat conditions. Furthermore, the assessed opening would be expected to have only a minimal contribution to flushing flows in the inter-causeway area. The report is available on the Project website: http://www.robertsbankterminal2.com/wp-content/uploads/RBT2-Potential-Effects-of-Opening-the-Causeway-June-2005-NHC-Memo-January-2014.pdf. Based on the findings of this report, and the evaluation of adding a flow passage channel, the VFPA does not propose to open the Roberts Bank causeway. **Addressed in response to IR1-13:** Further information concerning this study and causeway design is available in the response to IR1-13 (CEAR document #897).
Mitigation for marine fish	• A request for more information on Pacific salmon, specifically regarding assumptions used in developing estimates of the effectiveness of mitigation measures, as well as the VFPA's confidence in those estimates.	Musqueam First Nation, 03-Nov-2016 Letter to Panel (CEAR Document #776[10])	**Addressed in EIS Section 13.7:** EIS Section 13.7 discusses mitigation proposed for marine fish, including Pacific salmon. **Addressed in responses to IR-7.31.15-12 and IR13-30:** The effectiveness of mitigation proposed by the VFPA for marine fish, including Pacific salmon, is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314[11]) and IR13-30 (CEAR Document #1331). In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass and intertidal marsh transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness (specifically related to juvenile salmon).
Mitigation for marine fish	• Concern relating to avoidance and mitigation strategies specific to key stages of the salmon life	Tsartlip First Nation, 20-Jul-2017 Site Tour	**Addressed in EIS Section 13.6.3.1:** The potential effect on the migration behaviour of juvenile salmon from terminal placement and causeway widening was assessed qualitatively in the EIS. Two effects mechanisms—changes in the

[10] CEAR Document #776 From the Musqueam Indian Band to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[11] 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.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	cycle, including the following: • Interest in mitigation for fry stock returning/trying to follow the same path to access freshwater sources.		light environment and changes in habitat availability—were considered to have the potential to influence migration behaviour of juvenile salmon and result in a minor decrease of juvenile salmon productivity pre-mitigation. With implementation of mitigation measures, including adherence to juvenile salmon fisheries-sensitive window, implementation of a light management plan, as well as offsetting in the form of onsite native eelgrass transplants and reconstructed tidal marsh habitats north of the widened causeway, migration-related changes in juvenile salmon productivity were assessed as negligible. **Addressed in responses to IR5-18, IR5-22, and IR5-25:** Further discussions about terminal placement's potential effects on the migratory behaviour of juvenile salmon is available in the responses to IR5-18, IR5-22, and IR5-25 (CEAR Document #1153). **Addressed in responses to IR-7.31.15-12 and IR13-30:** The effectiveness of mitigation proposed by the VFPA for Pacific salmon is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314) and IR13-30 (CEAR Document #1331). In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass and intertidal marsh transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness (specifically related to juvenile salmon).
Timing of construction activities to avoid fisheries sensitive windows	○ Comments regarding proposed DFO timing windows, and that the timing windows do not account for other species, such as eulachon migration periods (March through to the end of June is the time when eulachon and	Musqueam First Nation, 12-Jun-2017 Meeting with Administrative Staff	The VFPA will consider this input as mitigation measures are developed in more detail. **Addressed in response to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	sturgeon may still be the area). • Suggestion to review construction schedules and mitigation plans specific to eulachon, especially as they relate to spawning timing, nature/timing of work occurring in water, etc.		
Mitigation for coastal birds	• Suggestion that artificial branching or post/structures are provided by the VFPA to encourage heron nesting in proximity to the Project.	Tseycum First Nation, 01-Nov-2016 Elders Workshop	The VFPA will consider this input as mitigation measures are developed in more detail. **Addressed in response to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Mitigation for coastal birds	• Suggestion that a light pole be built for eagles to use to see fish while hunting.	Tseycum First Nation, 04-Mar-2016 Elders Workshop	The VFPA will consider this input as mitigation measures are developed in more detail. **Addressed in response to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Reduction Measures			
Mitigation for orange sea pens (including proposed salvage plans)	• An inquiry was made about whether the orange sea pen test transplant area has been determined yet to be either successful or unsuccessful.	Penelakut Tribe, 12-Nov-2014 Cowichan Nation Alliance EIS Workshop #2	**Addressed in response to IR5-05:** The response to IR5-05 (CEAR Document #1145[12]) provides the Orange Sea Pen Transplant Pilot and Monitoring Program report (Appendix IR5-05-A). In summary, the pilot sea pen transplant was successful. Stable densities, and evidence of recruitment, at two of the three transplant sites demonstrate that not only can environmental conditions successfully be used to predict habitat suitability for orange sea pens across a larger study area, but also attests to the ecological viability of transplantation as a potential mitigation method. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed sea pen transplantation verification as part of the RBT2 Follow-up Program to verify mitigation effectiveness.
Mitigation for Dungeness crabs	• Question asking whether the VFPA thinks a fisheries hatchery at RBT2 would be beneficial to have in an area where crabs hatch.	Tsawwassen First Nation, 27-Nov-2013 Community Meeting	**Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Mitigation for coastal birds	• Concern with bird strikes with power lines and suggested that power lines for the Project should be buried.	Tsawwassen First Nation, 29-Oct-2014 Aboriginal Group EIS Workshop #4	**Addressed in EIS Appendix 7.2-B (#98):** No new overhead transmission lines are required for the Project. All new electrical and communications cables required for the Project will be distributed through the site via underground ducts and conduits, as described in the EIS. Consequently, effects on coastal birds related to collisions with power lines associated with the Project are not anticipated.

[12] CEAR Document #1145 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR2-19a, IR5-05, IR5-06, IR5-07, IR5-10, IR5-45, and IR5-47 (See Reference Documents #991 & #975).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation for coastal birds	• Concern regarding proposed light mitigation measures, including the following: ○ Concern about the effectiveness of proposed light mitigation measures (to hawks and owls, and harvesters of these species).	Métis Nation British Columbia, 07-Oct-2014 Preliminary EIS Workshop #1	**Addressed in EIS Sections 15.0 and 33.0:** The EIS considers the potential effects of artificial light on coastal birds, including the potential for increased hunting opportunities for owls preying on shorebirds under artificially lit conditions. A Light Management Plan will be included in the Construction Environmental Management Plan and the Operation Environmental Management Plan, to reduce potential artificial light-related effects on coastal birds. Measures that will be incorporated into the Light Management Plans include the following: • Minimising the number of light installations; • Using shielding to minimise light trespass; • Orienting lights downward and away from known bird-occupied areas where possible; and • Controlling light levels and limiting light use to areas where activities are occurring, where possible. **Addressed in response to IR9-02:** The response to IR9-02 (CEAR Document #1322) discusses additional proposed mitigation measures related to artificial light for migratory and non-migratory birds and avian species.
	○ Suggestions for mitigation measures, including ongoing monitoring, a reduction of nighttime light leakage, and perhaps specifying periods of time when lights are turned off completely.	Tsawwassen First Nation, 24-Apr-2014 Aboriginal Traditional Knowledge Meeting with Elders Métis Nation British Columbia, 07-Oct-2014 Preliminary EIS Workshop #1; 08-Oct-2014 Preliminary EIS Workshop #2	**Addressed in EIS Sections 15.0 and 33.0:** Suggested mitigation measures were considered in the effects assessment. Mitigation measures to address effects on coastal birds consist of implementation of Environmental Management Plans, including Light Management Plans, for construction and operation phases. The Light Management Plans will describe measures to reduce excess lighting and sky glow, including the following: • Orienting lights downwards and away from residential and marine areas; • Using shielding to minimise light trespass; • Controlling light levels and limiting light use to areas where activities are occurring; • Where possible, using fixtures that emit light at wavelengths shown to minimise disorienting effects to birds; • During construction, ensuring dredge lighting system shields light from spilling outside the basic working footprint of the dredge; and

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			• During operation, establishing a centralised lighting control system to select lighting where required. **Addressed in response to IR13-30:** As noted in response to IR13-30 (CEAR Document #1331), the VFPA has proposed light trespass and sky glow monitoring as part of the RBT2 Follow-up Program to verify effects predictions made in the EIS.
Mitigation for visual resources and effects on coastal birds	• Concern about the development of mitigation for effects on birds, specifically whether or not planting of trees as a mitigation measure for the visual resource assessment could actually increase the opportunity for more bird strikes by attracting more birds to the area.	Lyackson First Nation, 29-Oct-2014 Preliminary EIS Results Workshop #4	**Addressed in EIS Appendix 7.2-B (#124)** The use of a vegetation buffer along the causeway as a proposed mitigation measure for effects on daytime visual resources (and to mitigate potential bird collisions by forcing birds to fly over vehicles) was excluded from further assessment after consideration of feedback received during consultation with Indigenous groups, as well as feedback from other stakeholders. It was concluded that a vegetation buffer would have limited, if any, effectiveness as mitigation for adverse effects on visual resources, and could result in increased bird-vehicle mortalities by acting as an attractant of some coastal birds to areas close to road and railways. Past experiences with a vegetation buffer on the causeway have been unsuccessful due to soil conditions.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation for barn owl	• Concern regarding the proposed vegetation barriers along causeway, including comments that it would not mitigate the primary visual effect (the cranes), limited prospect for success if vegetation/plants failed (wrong species for sandy or poor soil), and may have an adverse impact by luring animals onto the causeway, and putting them at risk of increased vehicle strikes. It was expressed that there was not support for this mitigation, and suggestions were made that resources could be better used for another mitigation.	Lyackson First Nation, Métis Nation British Columbia, Tsleil-Waututh Nation, 08-Oct-2014 Preliminary EIS Workshop #2 Métis Nation British Columbia, 08-Oct-2014 Preliminary EIS Workshop #2	**Addressed in EIS Appendix 7.2-B (#124)** The use of a vegetation buffer along the causeway as a proposed mitigation measure for effects on daytime visual resources was excluded from further assessment after consideration of feedback received during consultation with Indigenous groups, as well as inter-disciplinary input on technical feasibility. It was concluded that a vegetation buffer would have limited, if any, effectiveness as mitigation for adverse effects on visual resources, and could result in increased bird-vehicle collisions for some species. Past experiences with a vegetation buffer on the causeway have been unsuccessful due to soil conditions. **Addressed in responses to IR9-01 and IR13-30:** As described in the responses to IR9-01 (CEAR Document #1322) and IR13-30 (CEAR Document #1331), the VFPA will undertake the following initiatives to mitigate the predicted minor decrease in barn owl productivity, which will also benefit the larger bird community, including barn swallows and short-eared owls: • Connect and collaborate with local authorities to explore speed management within the local assessment area, as feasible, to decrease the potential for bird-vehicle collisions for multiple avian species, including barn owl; • Manage vegetation within verges associated with the Project's footprint adjacent to terrestrial upland and marsh habitat potentially used by foraging barn owls to decrease its habitat suitability to foraging owls; • Implement measures to increase education and awareness of owl-vehicle collisions along roads to influence driving habits; and • Work with an appropriate third party organisation (e.g., Delta Farmland Wildlife Trust) to increase barn owl productivity through installing and maintaining artificial nest structures as feasible.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	• Concern with bird strikes, particularly with respect to bird-vehicle collisions. Requested information on mitigation measures, as well as a request for studies on potential impacts to bird habitat and migrating bird populations.	Tsleil-Waututh Nation, 29-Oct-2014 Preliminary EIS Workshop #1 Hwlitsum, 15-Apr-2014 Technical Working Group Meeting #2	**Addressed in EIS Sections 15.0 and 35.0:** Vehicle collision-related mortalities are expected to be very low compared to population size and are not expected to affect the short- and long-term population viability of coastal birds, with the exception of barn owls. With mitigation, effects to barn owls are negligible. **Addressed in response to IR9-01:** As described in the response to IR9-01 (CEAR Document #1322),the VFPA will undertake the following initiatives to mitigate the predicted minor decrease in barn owl productivity, which will also benefit the larger bird community, including barn swallows and short-eared owls: • Connect and collaborate with local authorities to explore speed management within the local assessment area, as feasible, to decrease the potential for bird-vehicle collisions for multiple avian species, including barn owl; • Manage vegetation within verges associated with the Project's footprint adjacent to terrestrial upland and marsh habitat potentially used by foraging barn owls to decrease its habitat suitability to foraging owls; • Implement measures to increase education and awareness of owl-vehicle collisions along roads to influence driving habits; and • Work with an appropriate third party organisation (e.g., Delta Farmland Wildlife Trust) to increase barn owl productivity through installing and maintaining artificial nest structures as feasible. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed owl nest box monitoring and barn owl mortality monitoring as part of the RBT2 Follow-Up Program to verify mitigation effectiveness and effect predictions.
Mitigation for southern resident killer whale (SRKW)	• Suggestions to consider increasing the use of tug escorts to mitigate impact on SRKW.	Tsawwassen First Nation, 26-Nov-2014 Health & Indigenous Rights Workshop	The use of tug escorts for container ships was not considered an effective mitigation option to mitigate potential effects to SRKW.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			Addressed in response to IR5-50: The response to IR5-50 (CEAR Document #1172[13]) discusses measures that are within the VFPA's control and could be used to mitigate the potential effects of underwater noise on marine mammals during the proposed Project operation.
Mitigation for traditional foods	• Concerned that mitigation measures described for traditional food harvesting and gathering are unsatisfactory to Musqueam interests, as well as for commercial crab fishers.	Musqueam First Nation, 19-Nov-2014 Health & Aboriginal Rights Workshop – Musqueam First Nation	**Addressed in EIS Appendix 7.2-B (#144):** Measures to avoid, reduce, or offset include the following: • Awareness and education measures regarding contamination levels in food sources. Mitigation related to productivity of marine invertebrates includes the following: • Placing marine terminal in subtidal waters to eliminate direct effects to intertidal habitats; • Minimising causeway widening and optimising the footprint within the upper intertidal zone; • Rounding of the northwest terminal corner to reduce the potential area of scour; • Incorporating rocky shoreline in portions of the terminal perimeter and causeway perimeters; • Creating onsite habitat, including eelgrass, intertidal marsh, mudflat, and sandy gravel beach; and • Implementing various Construction Environmental Management Plans and Operation Environmental Management Plans. Information on proposed mitigation measures for potential effects on the current use of lands and resources for traditional purposes (Current Use), including food harvesting or gathering, are described in the EIS (Section 32.2.7). **Addressed in response to IR10-09:** The response to IR10-09 (CEAR Document #1275) presents the VFPA's view of the relevance and adequacy of the proposed mitigation measures to reduce the potential effects of the proposed Project on each Indigenous group's access for Current Use, the

[13] CEAR Document #1172 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-50, IR7-07, IR7-33, IR7-34, IR7-35, and IR7-43 (See Reference Documents #975 and #1000).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			availability and quality of their preferred Current Use resources, and the quality of their Current Use experience, such that the residual effects on each group's Current Use would become negligible.
Mitigation in general	• Stated that Tsawwassen First Nation believes mitigation is necessary even where no effect is predicted.	Tsawwassen First Nation, 26-Nov-2014 Health & Aboriginal Rights Workshop – Tsawwassen First Nation	**Addressed in EIS Appendix 7.2-B (#29):** As described in the EIS, the assessment process considered the effectiveness of mitigation measures to be used to avoid, reduce, offset, or otherwise mitigate each potential adverse Project-related effect. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures for the RBT2 Project that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation in general	• Concerned with the VFPA's ability to regulate its tenants and/or operators. • Concerned that this will affect the VFPA's ability to implement and/or enforce Project mitigation.	Semiahmoo First Nation, 04-Dec-2014 Health & Aboriginal Rights Workshop – Semiahmoo First Nation	**Addressed in EIS Appendix 7.2-B (#192):** Describes the proposed environmental management framework, including compliance monitoring and reporting requirements to federal and provincial environmental regulators for both the construction and operation phases. The VFPA is committed to implementing all mitigation recommended by the Minister of Environment if the Project is approved. The VFPA takes a precautionary approach and upholds a high level of environmental protection within VFPA jurisdiction that meets or exceeds legislative requirements. **Addressed in EIS Section 4.0:** Describes the construction components of the marine terminal that will be the Infrastructure Developer's responsibility, while the Terminal Operator will be responsible for constructing and installing terminal infrastructure from the pavement up. Breaches of contractual terms are governed by the agreements' terms as well as by the common law. **Addressed in response to IR1-01:** The response to IR1-01 (CEAR Document #897) discusses how the VFPA asserts its authority in the context of RBT2's construction and operation via berth corridor agreements and land leases.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Construction and operation environmental management	• Concern that animals such as gulls, crows, and other wildlife may spread non-edible waste materials across the Project site, and into surrounding waters. Stated that waste management plans should also include non-hazardous waste material, including trash and refuse generated through the construction and operation phases. Lidded bins and frequent waste removal, as well as clean-up protocols, will help offset this issue.	Métis Nation British Columbia, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #252[14])	**Addressed in responses to IR10-01 and IR13-30:** As noted in the responses to IR10-01 (CEAR Document #1322) and IR13-30 (CEAR Document #1331), the VFPA will include non-hazardous waste management practices (that avoid human-wildlife conflicts) in the construction and operation Hazardous Materials and Waste Management Plans (see EIS Sections 33.3.7 and 33.4.5).
Mitigation for Dungeness crabs (including proposed salvage plans)	• Concerns about crab mortality rates during salvage efforts, specifically surrounding the vulnerability of Dungeness crabs during moulting season when shells are soft.	Halalt First Nation, 28-Jul-2016 Issues Workshop – Island Nations Tsartlip First Nation, 20-Jul-2017 Site Tour	**Addressed in response to IR5-04:** The response to IR5-04 (CEAR Document #1209[15]) discusses the planned approach for crab salvage during the construction of RBT2. Salvages are planned for all Project activities that have the potential to cause direct mortality to legal-sized male and gravid female Dungeness crabs. A list and schedule of proposed Project activities is provided in Table IR5-04-1 (CEAR Document #1209); the activities for which Dungeness crab mortality or injury may occur are indicated, and for those activities that may cause mortality or injury, plans for salvages are also indicated. **Addressed in response to IR13-30:** In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA is committed to minimising handling of crab and

[14] CEAR Document #252 From Métis Nation BC to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.
[15] CEAR Document #1209 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Request IR5-04 (See Reference Document #975).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			to working with Indigenous groups in implementation of crab salvage mitigation.
Mitigation for Dungeness crabs (including proposed salvage plans)	• Questions about the number of crabs to be relocated and the effectiveness of crab relocation, including the following: • Concern whether crab are likely to remain in their new location or return to the Project footprint.	Musqueam First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2 Tsartlip First Nation, 06-Jun-2016 Meeting Tseycum First Nation, 02-Mar-2017 Elders Meeting	**Addressed in response to IR5-04:** The response to IR5-04 (CEAR Document #1209) discusses the planned approach for crab salvage during the construction of RBT2. Salvages are planned for all Project activities that have the potential to cause direct mortality to legal-sized male and gravid female Dungeness crabs. A list and schedule of proposed Project activities is provided in Table IR5-04-1 (CEAR Document #1209); the activities for which Dungeness crab mortality or injury may occur are indicated, and for those activities that may cause mortality or injury, plans for salvages are also indicated. **Addressed in response to IR13-30:** In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA is committed to minimising handling of crab and to working with Indigenous groups in implementation of crab salvage mitigation.
Mitigation for Dungeness crabs (including proposed salvage plans)	• Concerns about how relocation could put stress on already established crab populations and infringe on other activities taking place there.	Musqueam First Nation, 23-Feb-2017 Community Member Meeting Re: Crabbing Musqueam First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2	**Addressed in response to IR13-30:** In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA is committed to minimising handling of crab and to working with Indigenous groups in implementation of crab salvage mitigation.
Mitigation for Dungeness crabs (including proposed salvage plans)	• Request for studies to tag and track crabs in order to determine where crabs would be likely to travel after relocation.	Musqueam First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2	The VFPA will consider this input as mitigation measures and the RBT2 Follow-up Program are developed in more detail. **Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation for Dungeness crabs (including proposed salvage plans)	• Suggestion to use bait to draw crabs away from the Project area instead of relocation efforts.	Musqueam First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2	**Additional information provided by the VFPA:** As noted in IR5-04 (CEAR Document #1209), the VFPA is currently exploring this option and will determine an appropriate approach to this mitigation method through engagement with relevant regulatory agencies, stakeholders, and Indigenous groups. **Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Mitigation for Dungeness crabs (including proposed salvage plans)	• Noted that crab do not migrate and baited traps may lead them to other areas, such as Area J and H, then the mitigation suggestions and could infringe on food, social, and ceremonial activities.	Musqueam First Nation 22-Aug-2016, Community Member / Commercial Crabber and Musqueam First Nation Staff Meeting Re: Crabbing Musqueam First Nation 23-Feb-2017, Community Member / Commercial Crabber and Musqueam First Nation Staff Meeting Re: Crabbing	**Additional information provided by the VFPA:** As noted in IR5-04 (CEAR Document #1209), the VFPA is currently exploring the baiting option and will determine an appropriate approach to this mitigation method through engagement with relevant regulatory agencies, stakeholders, and Indigenous groups. **Addressed in response to IR13-30:** In addition, as noted in the response to IR13-30 (CEAR Document #1331), the VFPA is committed to minimising handling of crab and to working with Indigenous groups in implementation of crab salvage mitigation. **Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation related to the marine shipping area	• Concerned that the federal Crown has no intention of establishing enforceable conditions to require mitigation and follow up measures (e.g., monitoring of adverse effects by marine shipping beyond the VFPA boundary) necessary for the protection of our Aboriginal fishing rights.	Musqueam First Nation, 07-Oct-2015 Letter to the CEA Agency	**Additional information provided by the CEA Agency:** The CEA Agency responded in its letter of May 11, 2016 to Musqueam First Nation.

Consultation related to mitigation	• Stated that the CEA Agency must direct the Proponent to consult with Musqueam on potential adverse effects of marine shipping on Musqueam marine harvesting, and in addition, on the suitability of potential forms of mitigation, the likely degree of effectiveness of mitigation and the reasons for determining if the measures reduce the significance of the effect, the likelihood of residual effects after mitigation, and other mitigation measures that were considered but	Musqueam First Nation, 07-Oct-2015 Letter to the CEA Agency	**Addressed in responses to IR-7.31.15-12 and IR13-30:**
			The effectiveness of mitigation proposed by the VFPA for the Project is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314), IR10-09 (CEAR Document #1275) and IR13-30 (CEAR Document #1331).
			Addressed in AIMSA[16] Section 7.4:
			Discusses suggested mitigation measures related to Current Use and rights in the marine shipping area. The measures are:
			• Consultation on the development of a potential marine shipping activities communication plan that would provide affected Indigenous groups with real-time information regarding the movement of Project-associated shipping traffic through the marine shipping area, including:
			  ○ The estimated time of arrival of Project-associated container ships and their expected duration of use of the shipping lanes for inbound and outbound movements;
			  ○ Circumstances outside normal operations that might affect the expected frequency or concentration of Project-associated vessel traffic along the shipping routes (e.g., clearing backlogs in shipping traffic due to storms requiring ships to temporarily anchor before proceeding); and

[16] Additional Information to the Marine Shipping Addendum – Musqueam First Nation and Tsleil-Waututh Nation (AIMSA; CEAR Document #572).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	rejected and the reasons for their rejection.		• Consultation with the affected Indigenous groups to identify measures that would reduce the impact of the international shipping lanes to fishing by Indigenous groups. Musqueam First Nation has indicated that the above-noted mitigation measures, in Musqueam's view, "do not in themselves provide a measurable form of mitigation". Musqueam First Nation has made no specific suggestions to the VFPA regarding mitigation measures for potential effects associated with marine shipping associated with the Project. **Addressed in responses to IR10-11 and -12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Mitigation follow-up monitoring and adaptive management	• Stated that the follow-up program requires more detail related to the implementation of mitigation measures resulting from Indigenous engagement	Malahat Nation, 16-Dec-2015 Letter to the CEA Agency (CEAR Document #378[17])	**Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.

[17] CEAR Document #378 From the Malahat Nation to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Marine Shipping Addendum.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation follow-up monitoring and adaptive management	○ Stated that the proposed mitigation measures outlined throughout the EIS are all proponent-led, and are therefore insufficient. • Stated that the mitigation measures as outlined throughout various sections of the EIS do not include Indigenous group-led measures, nor do they consider seasonality for traditional use activities.	Malahat Nation, 27-Oct-2016 Letter to Panel (CEAR Document #621[18])	**Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation follow-up monitoring and adaptive management	• Request for an alternative plan for mitigation to be in place if relocation was not effective.	Tsawwassen First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2	**Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. The response also describes how the RBT2 Follow-up Program document will be developed, including adaptive management strategies as appropriate.
Mitigation for commercial, recreational, and Aboriginal (CRA) fisheries	• Stated that other than a communications plan, no specific mitigation measures specific to addressing CRA fisheries are provided in EIS Sections 17.0 or 21.0.	Tsawwassen First Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #231[19])	**Addressed in EIS Section 21.0:** As noted in EIS Table 21-7, proposed mitigation measures related to marine commercial use include: • Implementation of the marine species salvage plan and communications plan; and

[18] CEAR Document #621 From Malahat First Nation to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[19] CEAR Document #231 From Tsawwassen First Nation to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			• Work with DFO to consult with commercial crab harvesters and Indigenous groups to identify and implement feasible mitigation. **Addressed in response to IR7-34:** The response to IR7-34 (CEAR Document #1172) discusses mitigation measures currently undergoing consultation and evaluation.
Mitigation for marine fish and marine mammals	• Request for information relating specifically to types of mitigation for underwater noise, including the following: • Concern was expressed with the bubble curtain that has been proposed to be installed at the Project site to mitigate noise impact for mooring piles, noting that the vibration technique being proposed will still have an impact, as marine life feel vibrations differently than humans.	Tsartlip First Nation, 20-Jul-2017 Site Tour	**Addressed in EIS Sections 13.0, 14.0, and 15.0:** As outlined in EIS Sections 13.0, 14.0, and 15.0, underwater noise reduction and dampening methods and technologies will be implemented during Project construction to avoid or reduce potential adverse effects of pile driving and other construction activities on marine fish and marine mammals. Details pertaining to the management and monitoring of underwater noise will be addressed during the development of the Underwater Noise Management Plan (see EIS Section 33.3.7) and Construction Compliance Monitoring Plan (see EIS Section 33.3.1), respectively, prior to the start of construction activities (should the Project be approved). The VFPA committed to the development of these plans to mitigate and monitor potential Project-related effects on marine species. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation for marine fish and marine mammals	• Concerns regarding the effectiveness of underwater noise mitigation plans and request for effectiveness monitoring.	Malahat Nation, 29-Aug-2017 Follow Up Program Workshop with Cowichan Nation Alliance, Lyackson First Nation, Malahat Nation	**Addressed in responses to IR-7.31.15-12 and IR13-30:** The effectiveness of mitigation proposed by the VFPA for the Project is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314) and IR13-30 (CEAR Document #1331). **Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275), as requested by the Review Panel, describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation for marine mammals	• Question about the rationale for not providing mitigation measures for effects to marine mammals due to underwater noise during construction activities.	Malahat Nation, 27-Oct-2016 Letter to Panel (CEAR Document #621)	**Addressed in EIS Section 14.7.1.1:** As noted in EIS Section 14.7.1.1, mitigation measures that will be implemented during construction are outlined in sub-plans described in EIS Section 33.3, including EIS Sections 33.3.2, 33.3.7, and 33.3.8. These sub-plans will be implemented during Project construction to reduce or eliminate potential adverse underwater noise-related effects to marine mammals resulting from the Project. **Additional information provided by the VFPA:** The response to IR5-49 (CEAR Document #1167[20]) discusses mitigation options related to potential effects to marine mammals due to underwater noise during construction activities. The response also notes that the VFPA will require that both vibratory and/or impact pile driving during installation of the temporary barge ramps only be conducted during daylight hours. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation for marine mammals	• Suggestion to consider PLOS One whale monitoring technology for mitigation for underwater noise effects.	Lake Cowichan First Nation, 29-Oct-2014 Preliminary EIS Results Workshop #3 Lake Cowichan First Nation, 05-Jun-2017 Meeting with Chief & Administrative Staff	**Additional Information provided by the VFPA:** Technologies, such as thermal imaging described, are being explored by the VFPA as a potential mitigation measure during periods of darkness and low visibility; however, the ability of these technologies to detect killer whales is not yet well understood. The VFPA is committed to continue to explore new technologies to mitigate potential underwater noise disturbance during the construction period. The response to IR5-49 (CEAR Document #1167) discusses mitigation options related to potential effects to marine mammals due to underwater noise during construction activities.

[20] CEAR Document #1167 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Requests IR5-37, IR5-42, IR5-48, IR5-49, IR5-51, IR5-52, IR6-30 and IR8-10 (See Reference Documents #975, #991 and #1071).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			Addressed in response to IR13-30: The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation for marine mammals	• Asked whether proposed mitigation measures (such as for underwater noise) would have an element of monitoring to them.	Tsleil-Waututh Nation, Métis Nation of British Columbia, Semiahmoo First Nation, 03-Aug-2016 Issues Workshop - Tsleil-Waututh Nation, Métis Nation of British Columbia, and Semiahmoo First Nation	**Addressed in EIS Section 33.3.1:** The Construction Compliance Monitoring Plan will describe the environmental compliance monitoring and reporting framework for the Project's construction phase, including measurements for underwater noise as applicable. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Mitigation for marine fish Construction and operation environmental management	• Request for more information regarding the environmental management plan for lighting effects, and concern regarding impacts to juvenile salmon.	Lyackson First Nation, 04-Oct-2017 Meeting	**Addressed in EIS Section 33.0:** The Light Management Plans for construction and operation phases will be developed prior to the respective phases. The Light Management Plans will describe measures to reduce excess lighting and sky glow. Feedback on applicable environmental management plan sub-plans will be solicited from Indigenous groups potentially affected by the Project. **Addressed in response to IR5-25:** The response to IR5-25 (CEAR Document #1153) further discusses the potential effects of lighting and shading on juvenile salmon, including associated proposed mitigation. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Mitigation for marine mammals Construction and operation environmental management	• Concern that the Construction and Operation Environmental Management Plans described in the EIS will be insufficient to mitigate against the effects of noise, and the possibility of vessel strikes to SRKWs. Request for further description on how the Project might be modified in the event that the environmental management plans are found to be insufficiently protecting SRKW from harm.	Tsawwassen First Nation, 28-Oct-2016 Letter to Panel (CEAR Document #651)	**Addressed in responses to IR-7.31.15-12 and IR13-30:** The effectiveness of mitigation proposed by the VFPA for marine mammals, including SRKW, is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314) and IR13-30 (CEAR Document #1331). **Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. The response also describes how the RBT2 Follow-up Program document will be developed, including adaptive management strategies as appropriate.
Construction and operation environmental management	• Comments that were expressed regarding light included the following: • A request that the Light Management Program ensure minimal impact of lighting, as lighting can play a role in predator-prey interactions.	Halalt First Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #253)	**Addressed in EIS Section 33.0:** The Light Management Plans for construction and operation phases will be developed prior to the respective phases. The Light Management Plans will describe measures to reduce excess lighting and sky glow. Feedback on applicable environmental management plan sub-plans will be solicited from Indigenous groups potentially affected by the Project. **Addressed in response to IR9-02:** The response to IR9-02 (CEAR Document #1322) discusses additional proposed mitigation measures related to artificial light for migratory and non-migratory birds and avian species. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	• How Indigenous communities could be involved with these management programs, and if Indigenous groups would receive copies of the Light Management Program.	Halalt First Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #253)	**Addressed in EIS Section 33.0:** The Light Management Plans for construction and operation phases will be developed prior to the respective phases. The Light Management Plans will describe measures to reduce excess lighting and sky glow. Feedback on applicable environmental management plan sub-plans will be solicited from Indigenous groups potentially affected by the Project. **Addressed in responses to IR10-11 and -12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting.
Construction and operation environmental management	• Request for more information regarding the Ecosystem Modelling Projections Related to Overall Productivity of Fish Species, including further explanation of the model - the assumptions built into projections for determining extent, degree, and direction of productivity effects, and detail how the level of certainty was reached for conclusions regarding overall productivity at the population level (e.g., for Pacific salmon) in order to demonstrate how the proposed	Musqueam First Nation, 03-Nov-2016 Letter to Panel (CEAR Document #776)	**Addressed in Information Request Package 3 Responses to IR3-01 to IR3-24 (Part 1):** Information Request Package 3 (CEAR document #984[21]) further explains the Roberts Bank ecosystem model, including the assumptions built into its projections for determining the extent, degree, and direction of productivity effects, and detail how the level of certainty was reached for conclusions regarding overall productivity. **Addressed in responses to IR-7.31.15-12 and IR13-30:** The effectiveness of mitigation proposed by the VFPA for marine fish is further discussed in the responses to IR-7.31.15-12 (CEAR Document #314) and IR13-30 (CEAR Document #1331).

[21] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	mitigation measures will be successful.		
Construction and operation environmental management	• Request for the Construction Environmental Management Plan to include provisions that require the dredging contractors check weather conditions regularly to reduce risk to dredging operations, including correct siting and safety.	Métis Nation British Columbia, Lake Cowichan First Nation, Tsleil-Waututh Nation, Hwlitsum, 30-Aug-2017 RBT2 Follow Up Program Workshop: Métis Nation British Columbia, Lake Cowichan First Nation, Tsleil-Waututh Nation, Hwlitsum	**Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Programs and offsetting. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Offsetting Measures			
Development of onsite habitat offsetting location	• Request that offsetting be undertaken as close to the Project as possible.	Tsawwassen First Nation, 26-Nov-2014 Health & Aboriginal Rights Workshop – Tsawwassen First Nation	**Addressed in EIS Section 17.0:** Onsite habitat is intended to soften the perimeter of the Project's shoreline to be more ecologically representative of the existing estuary, to create similar habitat to those that will be affected by the Project, and to create habitat that generally enhances the productivity of the Roberts Bank ecosystem.
Development of onsite habitat offsetting location	• Concern about the development and/or effectiveness of previous onsite habitat mitigation options (i.e., Deltaport Third Berth Project (DP3)) and if/how they have been considered within the EIS.	Multiple Indigenous groups, at multiple consultation events and workshops.	**Addressed in EIS Sections 17.0 and 33.5:** Onsite habitat selection considered lessons learned from previous habitat creation programs (e.g., DP3). The effectiveness monitoring reports for DP3 increased the understanding of the successes and challenges of previous habitat projects. The VFPA publishes annual reports on the Adaptive Management Strategy for DP3, which are available on the VFPA website (https://www.portvancouver.com/development-and-permits/status-of-applications/deltaport-third-berth-project/). The VFPA will implement a Follow-up Program (as noted in EIS Section 33.5), which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in responses to IR7-28 and IR7-29:** Further discussion on the effectiveness of previous onsite habitat compensation (i.e., onsite intertidal marsh creation and eelgrass transplant for DP3) is available in the responses to IR7-28 and IR7-29 (CEAR Document #1275).
	• Concern with the potential for species using habitat mitigation along the causeway to be contaminated from Project-related truck emissions.	Cowichan Nation Alliance, 22-Oct-2014 Cowichan Nation Alliance EIS Workshop #1	**Addressed in EIS Appendix 7.2-B (#202):** There is not anticipated to be a Project interaction between air emissions from truck traffic on the causeway, and uptake of contaminants in soils, plants, or species relying on soils and plants. Rationale for this conclusion is included in EIS Appendix 27-A.
	• Questions and concerns regarding proposed eelgrass transplants included the following: ○ Concern around the potential for proposed eelgrass transplants to displace other productive species of vegetation, or provide opportunity for less productive species to propagate.	Lyackson First Nation, 28-Oct-2014 Preliminary EIS Results Workshop #3	**Addressed in EIS Section 17.0 :** Following terminal construction, there is an opportunity to transplant up to three hectares of native eelgrass within the Roberts Bank study area as a mitigation measure. The potential donor areas are located north of the existing terminal and in the inter-causeway area. The existing presence of eelgrass at this location is an indication of suitable conditions for establishment and growth of eelgrass. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.
	○ Request for more information on where current eelgrass beds are located, and where the proposed beds would go.	Lyackson First Nation, 07-Oct-2014 Preliminary EIS Results Workshop #1 Lyackson First Nation, 28-Oct-2014	**Addressed in EIS Sections 11.0 and 17.0:** Eelgrass bed location is provided in EIS Figure 11-2. As noted in EIS Section 17.0, eelgrass beds are highly productive habitats in the Roberts Bank ecosystem, serving numerous critical functions, such as food, shelter, and rearing habitat for numerous species. Approximately three hectares of native eelgrass will be

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
		Preliminary EIS Results Workshop #3	established through transplants in north of the existing terminal and in the inter-causeway area.
	○ Concern with limited ability of planted eelgrass to take root.	Tsawwassen First Nation, Semiahmoo First Nation, Hwlitsum, Lyackson First Nation, Tsleil-Waututh Nation, 07-Oct-2014 Preliminary EIS Workshop #1 and 28-Oct-2014 Preliminary EIS Workshop #3	**Addressed in EIS Sections 17.0 and 33.5:** Following terminal construction, there is an opportunity to transplant up to three hectares of native eelgrass within the Roberts Bank study area as a mitigation measure. The potential donor areas are located north of the existing terminal and in the inter-causeway area. The existing presence of eelgrass at this location is an indication of suitable conditions for establishment and growth of eelgrass. The VFPA will implement a Follow-up Program, which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.
Mitigation follow-up monitoring and adaptive management	○ Request for a contingency plan to be in place if eelgrass transplants prove to be unsuccessful as a mitigation measure. ○ Stated that much of the basis of mitigation measures proposed for marine vegetation, marine fish, marine invertebrates, coastal birds, and SRKWs depends entirely on the	Tsleil-Waututh Nation, 07-Oct-2014 Preliminary EIS Workshop #1 Tsleil-Waututh Nation, 28-Oct-2014 Preliminary EIS Workshop #3 Tsleil-Waututh Nation, 20-Nov-2014 Health and Aboriginal Rights Workshop	**Addressed in EIS Section 33.5:** The VFPA will implement a Follow-up Program, which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	success of eelgrass transplanting.		
Development of onsite habitat offsetting types	• Inquiries about whether onsite habitat enhancement targets juvenile salmon.	Multiple Indigenous groups, at multiple consultation events and workshops.	**Addressed in EIS Sections 13.0 and 17.0:** Proposed offsetting habitat discussed in EIS Section 17.0 is intended to support multiple fish species, including juvenile salmon. Habitat proposed that supports marine fish includes the following: • Eelgrass – to promote productivity increases for juvenile salmon, juvenile rockfish, forage fish, and small demersal fish; • Tidal marsh – to promote productivity increases for juvenile salmon; • Mudflat – to promote productivity increase in benthic invertebrates, which are food sources for fish; • Sandy gravel beach – to promote prey production for juvenile salmon and flatfish, and promote forage fish spawning; and • Subtidal rock reef – to promote increase in reef fish productivity.
Development of onsite habitat offsetting types	• Requested prioritisation of traditional plants as part of mitigation measures.	Lake Cowichan First Nation, 12-Aug-2014 Meeting with Chief & Administrative Staff	The VFPA will continue to consider this comment in the development of the offsetting plan.
Offsetting, Mitigation follow-up monitoring and adaptive management	• General interest in offsetting strategies and thresholds for measuring habitat and mitigation success, as well as opportunities to participate in monitoring for mitigation effectiveness.	Malahat Nation, 30-May-2017 Meeting with Administrative Staff Malahat Nation, 26-Nov-2015 EIS Results Workshop #1 - Saanich Nations Malahat Nation, 29-Aug-2017 Follow Up Program Workshop with Cowichan Nation Alliance, Lyackson	**Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. The response also describes how the RBT2 Follow-up Program document will be developed, including adaptive management strategies as appropriate. The VFPA will continue to engage with Indigenous groups in developing the RBT2 offsetting plan.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
		First Nation, Malahat Nation	
Development of onsite habitat offsetting types	• Question about why a subtidal rock reef is only proposed for one area, and whether this is related to vessel traffic.	Malahat Nation, 27-Nov-2015 EIS Results Workshop #2 - Saanich Nations	**Addressed in AIEIS Appendix 2-B, Table 22 (#95):** Onsite habitat is intended to soften the perimeter of the Project's shoreline to be more ecologically representative of the existing estuary, to create similar habitat to those that will be affected by the Project, and to create habitat that generally enhances the productivity of the Roberts Bank ecosystem. The creation of reef habitat will benefit macroalgae vegetation, and provide refuge, feeding, and spawning habitat for invertebrates, fish, and birds. Subtidal rock reef has been proposed in the location identified in the EIS because it is feasible as an extension of existing rock reefs, avoiding the destruction of natural habitat.
Development of onsite habitat offsetting types	• Questions and concerns regarding proposed eelgrass transplants included the following: • Support expressed for eelgrass restoration and enhancement, including a request for a net gain of eelgrass habitat from the Project.	Musqueam First Nation, 12-Sep-2016 Issues Workshop – Musqueam First Nation / Tsawwassen First Nation #2 Musqueam First Nation, 10-Jul-2017 Roberts Bank Boat Tour #2 Tsleil-Waututh Nation, 03-Aug-2016 Issues Workshop - Métis Nation British Columbia, Semiahmoo First Nation, Tsleil-Waututh Nation	**Addressed in EIS Sections 11.0 and 17.0:** As noted in EIS Section 11.0, the ecosystem model predicts a net gain in the productive potential of native eelgrass (+11 tonnes (t); +4%) and a net loss in the productive potential of non-native eelgrass (-0.05 t, -1%). **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness. The VFPA will continue to engage with Indigenous groups in developing the RBT2 offsetting plan.
	• Concerns regarding the effectiveness of eelgrass transplants, including a perceived lack of	Malahat Nation, 30-May-2017 Meeting with Administrative Staff	**Addressed in EIS Appendix 7.2-B (#201) and EIS Section 17.0:** Onsite eelgrass habitat creation is proposed through transplanting in an area approximating three hectares. Based on the review of

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	evidence in the EIS supporting the success of eelgrass transplants, a request for more information regarding success rates, questions around the past experience of the VFPA specific to eelgrass transplants, and a request for a contingency plan to be in place if eelgrass transplants proved to be unsuccessful as a mitigation measure.	Tsawout First Nation, 30-Jan-2017 *W*SÁNEĆ All-Chiefs Meeting (Pauquachin, Tsartlip, Tsawout, Tseycum) Tsawout First Nation, 19-Jun-2017 Meeting with Chief, Councillor, Administrative, and Consulting Staff Tsleil-Waututh Nation, 07-Oct-2014 Preliminary EIS Workshop #1 Tsleil-Waututh Nation, 28-Oct-2014 Preliminary EIS Workshop #3 Tsleil-Waututh Nation, 20-Nov-2014 Health and Aboriginal Rights Workshop Tsleil-Waututh Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #249) Tsleil-Waututh Nation, 08-Jun-2016 Meeting Tsleil-Waututh Nation, 03-Aug-2016 Issues Workshop - Métis Nation British Columbia, Semiahmoo First	previous habitat creation programs (e.g., DP3), eelgrass transplants are considered to be an effective means of increasing productivity of marine vegetation. The VFPA will implement a Follow-up Program, which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
		Nation, Tsleil-Waututh Nation	
	• Comments regarding the use of eelgrass donor sites—in particular, that eelgrass used for transplants should not originate from locations within the Burrard Inlet, as this could threaten the viability of the species in this area.	Tsleil-Waututh Nation, 08-Jun-2016 Meeting	The VFPA will continue to consider this comment through detailed design of eelgrass transplants.
Development of onsite habitat offsetting construction approach	• Concern regarding the use of potentially contaminated Fraser River sand as fill for eelgrass transplants.	Tsleil-Waututh Nation, 03-Aug-2016 Issues Workshop - Métis Nation British Columbia, Semiahmoo First Nation, Tsleil-Waututh Nation	**Additional information provided by the VFPA:** The placement of fill for the construction of subtidal eelgrass habitat, if required, will meet applicable sediment quality guidelines (e.g., Canadian Council of Ministers of the Environment (CCME) marine Interim Sediment Quality Guidelines (ISQG). The source of fill material for this work has not been selected at this time but measures will be implemented to ensure that the fill material meets these regulatory guidelines.
Development of onsite habitat offsetting types	• Concern that much of the basis of mitigation measures proposed for marine vegetation, marine fish, marine invertebrates, coastal birds, and SRKW depend on the success of eelgrass transplanting.	Tsleil-Waututh Nation, 03-Aug-2016 Issues Workshop - Métis Nation British Columbia, Semiahmoo First Nation, Tsleil-Waututh Nation	**Addressed in EIS Section 33.5:** The VFPA will implement a Follow-up Program, which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.
Development of onsite habitat offsetting types	• Questions and concerns whether proposed habitat, particularly eelgrass, is appropriate for smolts or fingerlings	Hwlitsum, 10-Dec-2015 Meeting	**Addressed in EIS Section 17.0:** As described in EIS Section 17.0, eelgrass beds are highly productive habitats in the Roberts Bank ecosystem, serving numerous critical functions, such as food, shelter and rearing habitat for numerous species. Approximately three hectares of

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	when they go to sea. Statement that if smaller fish are unhealthy when they go to sea that they will not come back or survive.		native eelgrass would be established through transplants in the inter-causeway area. **Addressed in response to IR13-30:** As noted in the response to IR13-30 (CEAR Document #1331), the VFPA has proposed eelgrass transplantation monitoring as part of the RBT2 Follow-up Program to verify mitigation effectiveness.
Development of onsite habitat offsetting construction approach	• Request for more information about the proposed intertidal marsh and the plants, including a specific question about how habitat would be built. Note the recent deterioration of the intertidal marsh (south of the causeway) and asked if marsh deterioration will also be addressed in the EIS.	Hwlitsum, 21-May-2015 Meeting Tseycum First Nation, 04-Mar-2016 Elders Workshop	**Addressed in EIS Appendix 7.2-B (#66):** The technical data report for *RBT2 Intertidal Marsh, Foreshore Habitat and Invertebrate, Eelgrass, Ulva and Biomat Survey Results* discusses the existing conditions of intertidal marsh both north and south of the Roberts Bank Causeway. As noted in the Preamble to Information Request Package 2 (CEAR Document #984), changes to the inter-causeway area and area south of the BC Ferries Terminal related to the Project components situated to the north of the causeway are not anticipated. Intertidal marsh south of the causeway would be unaffected by RBT2, and therefore not directly addressed in the EIS. **Additional information provided by the VFPA:** Information on the intertidal marsh onsite habitat concept is provided in EIS Section 17.3.2. Details concerning construction approach will be developed in detailed design.
Development of onsite habitat offsetting construction approach	• Concern regarding the presence of English cordgrass (*Spartina anglica*) at Roberts Bank. Potential interest expressed in means of offsetting that involve the eradication of *Spartina anglica*.	Musqueam First Nation, 10-Jul-2017 Roberts Bank Boat Tour #2	**Additional information provided by the VFPA:** As noted in the response to IR-7.31.15-03 (CEAR Document #314), the VFPA is a part of the B.C. Spartina Working Group, which maps, tests eradication methods, and supports the removal of invasive English cordgrass from the Fraser River estuary. Beyond the offsetting measures suggested in the EIS, the VFPA encourages Indigenous groups participating in the environmental assessment to suggest specific offsetting measures for consideration.
Development of onsite habitat offsetting types	• Comment that the EIS should have made a determination as to whether a wetland compensation plan is required, through a	Musqueam First Nation, 15-Jun-2015 Letter to the CEA	**Addressed in EIS Section 17.4:** As part of the development of the Offsetting Plan, the VFPA has initiated discussions and will continue to work with the Canadian Wildlife Service to complete a wetland ecological functions assessment to confirm that the requirements for wetland

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	wetland ecological functions assessment. Should a wetland compensation plan be required, a request was made to be consulted regarding potential offsetting locations to ensure accommodation of impacts on territory and rights.	Agency (CEAR Document #241[22])	compensation have been met, based on the habitat assessments completed as part of the EIS. **Addressed in response to IR-7.31.15-22:** The response to IR-7.31.15-22 (CEAR Document #314), provides a consolidated description of the location, size, type, species composition, and ecological functions of wetlands potentially affected by the Project. **Additional information in response to IR11-21:** The VFPA will be submitting a wetland function assessment as requested by the Panel.
Development of onsite habitat offsetting types	• Comment about the presence of ghost shrimp in the mudflat habitat, along with a suggestion about the possibility of incorporating ghost shrimp into onsite mudflat habitat work.	Musqueam First Nation, 16-Jun-2017 Meeting with Administrative Staff	Beyond the offsetting measures suggested in the EIS, the VFPA encourages Indigenous groups participating in the environmental assessment to suggest specific offsetting measures for consideration. The VFPA will continue to consider this comment in the development of the offsetting plan.
Mitigation follow-up monitoring and adaptive management	• Request for more information on mitigation measures and follow-up program proposed for coastal birds, marine fish (herring and herring spawning habitat, impacts from light on eulachon, salmon), and marine water quality. Concerns that the VFPA will not act responsibly if things go wrong and	Malahat Nation, 30-May-2017 Meeting with Administrative Staff	**Addressed in EIS Section 33.5:** The VFPA will implement a Follow-up Program, which will include monitoring to confirm that all offsetting measures meet intended objectives and function as designed. Monitoring will include methods and success measures to confirm that offsetting measures have been effective. The *Fisheries Act* Authorization will require that functional objectives are met. **Addressed in response to IR10-11:** The response to IR10-11 (CEAR Document #1275) describes how Indigenous groups will be involved in the development, implementation, and management of the RBT2 Follow-up Program. The response also describes how the RBT2 Follow-up Program

[22] CEAR Document #241 From the Musqueam First Nation to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
	requested having plans in writing with regard to mitigation measures and offsets.		document will be developed, including adaptive management strategies as appropriate. **Addressed in response to IR13-30:** The response to IR13-30 (CEAR Document #1331) provides a compilation of proposed mitigation measures and RBT2 Follow-up Program elements that reflects consideration of input received from regulators, Indigenous groups, and stakeholders.
Development of onsite habitat offsetting construction approach	• Request that potential time-lag factors that may delay the efficacy of habitat offsetting be considered as this could lead to potential decreases in abundance of species of high cultural, social, or economic concern, and the potential closure of harvesting by federal conservation officers.	Musqueam First Nation, 03-Nov-2016 Letter to Panel (CEAR Document #776)	**Addressed in response to IR10-10:** The VFPA's forthcoming response to IR10-10, as requested by the Review Panel, discusses the potential effects of the proposed Project on availability of preferred traditional resources taking into account the time lag required for the establishment of functioning habitat offsets. **Addressed in responses to IR7-27 and IR11-15**: The VFPA's forthcoming responses to IR7-27 and IR11-15 discuss aspects of time lag as it relates to RBT2 offsetting.
Development of onsite habitat offsetting types	• Comment that in EIS Section 15.5.6.2 (Piscivorous Species), there is no clear explanation of if, where, and how compensation will be used to mitigate effects to these species.	Métis Nation British Columbia, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #252)	**Addressed in EIS Section 15.0 and 17.0:** Decreases to the productivity potential for waterfowl and diving birds are expected to be minor. Effects to waterfowl can be mitigated through the creation of eelgrass, mudflat, and intertidal marsh habitats. Effects to diving birds can be partially offset through the creation of onsite eelgrass and subtidal rock reef habitats, which would create habitat for their prey, which include mussels and other invertebrates. EIS Section 17.0 describes the mitigation framework for avoiding, reducing, or offsetting potential adverse effects to marine biophysical valued components. Proposed onsite habitat concepts, including for piscivorous bird species-supporting eelgrass and subtidal rock reef habitats, are presented in EIS Section 17.3.2.2. **Addressed in responses to IR11-17 and IR11-18**:

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
			The VFPA's forthcoming responses to IR11-17 and IR11-18 discuss the effectiveness of proposed eelgrass and subtidal rock reef offsetting.
Development of onsite habitat offsetting types	• Comment that beautifying the causeway as part of RBT2 is important to Indigenous groups. Requested that the following occur along the causeway: ○ Planting to compensate for the loss in marine habitat. • Incorporating natural plants in retaining walls, similar to a green wall, with plants facing the ocean side, and using of beach soil to encourage natural plant growth.	Lyackson First Nation, 24-Feb-2016 Phone call	Beyond the offsetting measures suggested in the EIS, the VFPA encourages Indigenous groups participating in the environmental assessment to suggest specific offsetting measures for consideration. The VFPA will continue to consider this comment in the development of the offsetting plan.
Development of onsite habitat offsetting types	• Comment about the importance of creating natural habitat areas through offsetting.	Lake Cowichan First Nation, 30-Aug-2017 RBT2 Follow Up Program Workshop	Beyond the offsetting measures suggested in the EIS, the VFPA encourages Indigenous groups participating in the environmental assessment to suggest specific offsetting measures for consideration. The VFPA will continue to consider this comment in the development of the offsetting plan.
Development of onsite habitat offsetting types	• Concern that traditional plants may not be available for use in offsetting, and requested that harvestable areas are created to supply cattails, lomatium, and other traditional plants.	Musqueam First Nation, 16-Jun-2017 Meeting with Administrative Staff	Beyond the offsetting measures suggested in the EIS, the VFPA encourages Indigenous groups participating in the environmental assessment to suggest specific offsetting measures for consideration. The VFPA will continue to consider this comment in the development of the offsetting plan.

Mitigation Topic	Views on Proposed Mitigation Measure	Source	Where and/or How the View Has Been Considered
Development of onsite habitat offsetting types	• Request for more information regarding how Indigenous traditional knowledge (ITK) was used in the development of the conceptual fish habitat compensation plan and the proposed development of onsite habitat concepts—including proposed locations for fish habitat compensation components to be implemented, and knowledge from Indigenous groups relating to effectiveness of previous fish habitat compensation plans and other fish habitat related offsets.	Musqueam First Nation, 15-Jun-2015 Letter to the CEA Agency (CEAR Document #241)	**Addressed in EIS Section 17.3.2.2:** As noted in EIS Section 17.3.2.2, the VFPA presented proposed onsite habitat offsetting concepts to Indigenous groups, stakeholders, and the public at open houses and small group meetings, starting in fall 2014. **Addressed in responses to IR-7.31.15-08 and IR10-02:** The responses to IR-7.31.15-08 (CEAR Document #314) and IR10-02 (CEAR Document #1275) provide a description of where and how ITK has been used to support the selection of valued components, baseline descriptions, the assessment of effects including the identification of mitigation measures, and in the determination of significance of adverse environmental effects. **Addressed in responses to IR10-11 and IR10-12:** The responses to IR10-11 and IR10-12 (CEAR Document #1275) discuss the VFPA's proposed approach to engagement and consultation with Indigenous peoples during and after the environmental review, including concerning such potential project mitigation measures, Follow-up Program, and offsetting. **Addressed in responses to IR7-28 and IR7-29:** Further discussion on the effectiveness of previous onsite habitat compensation (i.e., onsite intertidal marsh creation and eelgrass transplant for DP3) is available in the responses to IR7-28 and IR7-29 (CEAR Document #1275).

IR7-32 Marine Commercial Use – Crab Harvesting, Clarification

Information Source(s)

EIS Volume 4: Appendix 21-A, Table 21-A3, Table 21-A4

Context

The Proponent, in Appendix 21-A of the EIS, presented crab license, harvest and landed value data. There are discrepancies in the data provided in Appendix 21-A. For example, in Table 21-A4 the Proponent reported crab values of $585,763 and $394, 536 in Pacific Fisheries Management Area (PFMA) sub area 29-7 for 2007 and 2008 respectively. In Table 21-A3, it was reported that only one crab vessel fished in PFMA sub-area 29-7 in 2007 and that no crab vessels fished the area in 2008 indicating errors within these Tables.

Information Request

Update and reconcile any discrepancies in crab license, harvest and crab landed value data reported in Appendix Table 21-A of the EIS.

Present the data in tabular format and graphically.

VFPA Response

Revisions to EIS Appendix 21-A to correct one error and to clarify crab license harvest and crab landed value data have been made and are reflected in Tables IR7-32-A1 to IR7-32-A4. Two additional tables, titled IR7-32-A5 and IR7-32-A6, are included in addition to those in EIS Appendix 21-A to further clarify the crab data reporting. All tables are presented in **Appendix IR7-32-A**.

The revisions and clarifications to EIS Appendix 21-A do not alter the conclusions pertaining to Project effects on commercial crab harvesting, as specified in EIS Section 21.7.

Revisions reflect the following:

- There is one numerical error correction noted in Table IR7-32-A1 (revised Table 21-A1) in red font. No other numerical errors are noted in EIS Appendix 21-A tables.
- As indicated in EIS Section 21.3.3, DFO uses different methods to collect crab harvest and crab harvest value data. With the exception of crab landed value data, all catch data reported in EIS Section 21.5 (and EIS Appendix 21-A) were derived from logbooks, which are generally recognised as the most accurate data source (DFO 2009). EIS Section 21.3.3 also indicates that crab landed value data (as reflected in Table 21-A4) are drawn from fish slips, which are the primary source of information on catch value. Further clarification has been provided in the title of each of the revised Appendix 21-A tables (see **Appendix IR7-32-A**) to indicate the data source; data

from logbooks is included in Table 21-A2 and 21-A3, and data from fish slips is included in Table 21-A4.

- The crab landed value data received from DFO during preparation of the EIS from fish slips also included corresponding data on crab harvest (kg) and vessel counts associated with crab landed value data. This data is presented in **Appendix IR7-32-A**, Tables IR7-32-A5 and IR7-32-A6. The crab harvest (kg) data from logbooks (Table 21-A2 of EIS Appendix 21-A, and Table IR7-32-A2 in **Appendix IR7-32-A**) and crab vessel count data from logbooks (Table 21-A3 of EIS Appendix 21-A and Table IR7-32-A3 in **Appendix IR7-32-A**) varies from crab harvest (kg) and vessel count data as reported in the fish slip data.
- When considering crab harvest (kg), crab vessel counts, and crab value ($) data from fish slip data, Pacific Fishery Management Area (PFMA) sub-area 29-7 reported four crab vessels in 2007 and five vessels in 2008, with a crab harvest of 106,861 kg in 2007 and 67,464 kg in 2008, which is reflective of the specified $585,762 and $394,536 crab harvest values for 2007 and 2008, respectively.
- Further clarification has been provided within table cells, and as a note, where confidential data does not meet criteria for public release (identified by DFO as less than three vessels reporting for the time period and area), or where there was no actual data reported (Tables IR7-32-A2 and IR7-32-A4, or revised Tables 21-A2 and 21-A4, respectively).
- Tabular data in each revised EIS Appendix 21-A table (as reflected in Tables IR7-32-A1 to IR7-32-A4) and in the two additional tables (Tables IR7-32-A5 and IR7-32-A6) in **Appendix IR7-32-A** is also shown graphically below each table.

References

Fisheries and Oceans Canada (DFO). 2009. Revisions to the Official DFO Commercial Pacific Salmon Catch Estimates for 1996 to 2004. Available at http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2009/2009_031_e.pdf. Accessed October 2017.

Appendices

Appendix IR7-32-A Revised EIS Appendix 21-A Tables and Graphic Representation of Tabular Data

APPENDIX IR7-32-A
REVISED EIS APPENDIX 21-A TABLES AND GRAPHIC REPRESENTATION OF TABULAR DATA

APPENDIX IR7-32-A: REVISED EIS APPENDIX 21-A TABLES AND GRAPHIC REPRESENTATION OF TABULAR DATA

Appendix IR7-32-A1 **Crab Licences for Crab Management Area I and J** (Revised Table 21-A1 in EIS Appendix 21-A)

Area		2000	2001 to 2002	2003 to 2005	2006	2007 to 2008	2009	2010 to 2012	2013 to 2015
Area I	Number	36	36	36	41	41	42	51	32
	Percentage of Total BC Licences	16.2%	16.2%	16.2%	18.5%	18.5%	18.9%	23.1%	14.5%
Area J	Number	19	19	18	22	22	21	18	20
	Percentage of Total BC Licences	8.6%	8.6%	8.1%	9.9%	9.9%	9.5%	8.1%	9.0%

Source: DFO 2014b

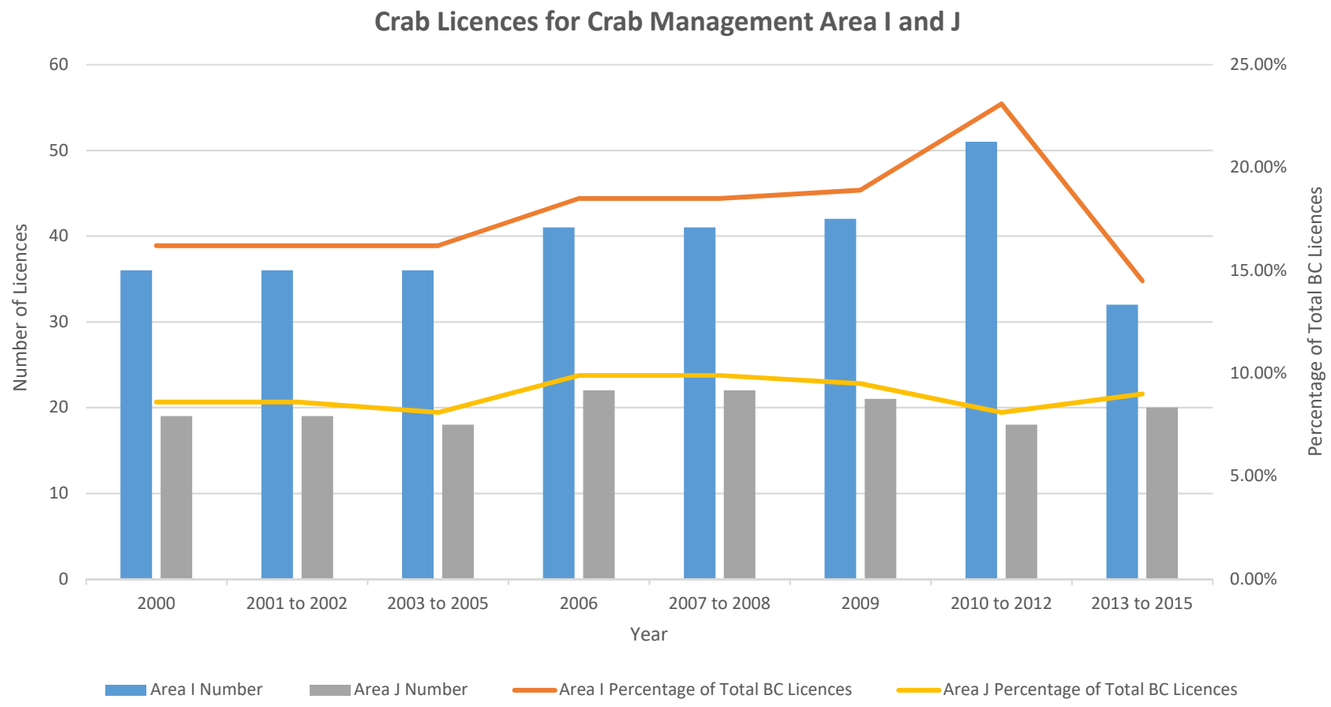


Table IR7-32-A2 Crab Harvest (kg) by Sub-area from Logbook Data (Revised Table 21-A2 in EIS Appendix 21-A)

Study Area	PFMA Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
LAA	29-6	69,874	202,080	160,621	491,547	512,623	400,355	387,471	201,243	222,019	180,432	112,035	2,940,300
	29-7	29,589	*	11,076	15,330	*	-	16,200	5,639	6,882	6,945	29,075	120,736
	29-9	38,879	19,756	48,775	78,693	104,813	65,572	69,501	25,006	*	12,705	5,638	469,338
Other RAA[a]	29-3	88,282	94,537	104,119	160,457	186,090	207029	310,426	241,075	155,955	133,397	109,780	1,791,147
	29-4	22,087	49,800	39,815	119,313	106,884	*	72,202	39,962	21,303	26,150	27,071	524587
	29-8	237,510	247,930	240,577	326,715	228,289	269,037	220,125	214,776	278,495	271,193	252,765	2,787,412
	29-10	17,564	32,077	7,980	52,825	42,283	43,061	72,444	54,131	22,195	53,095	46,746	444,401
Total		503,785	658,489	612,963	1,260,748	1,181,856	1,018,847	1,180,282	817,468	754,626	693,287	591,829	9,274,180

Source: DFO 2014c.

Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area)

- = No data reported

a. Refers to PFMA sub-areas that overlap with the regional assessment area (RAA) but do not overlap with the local assessment area (LAA).

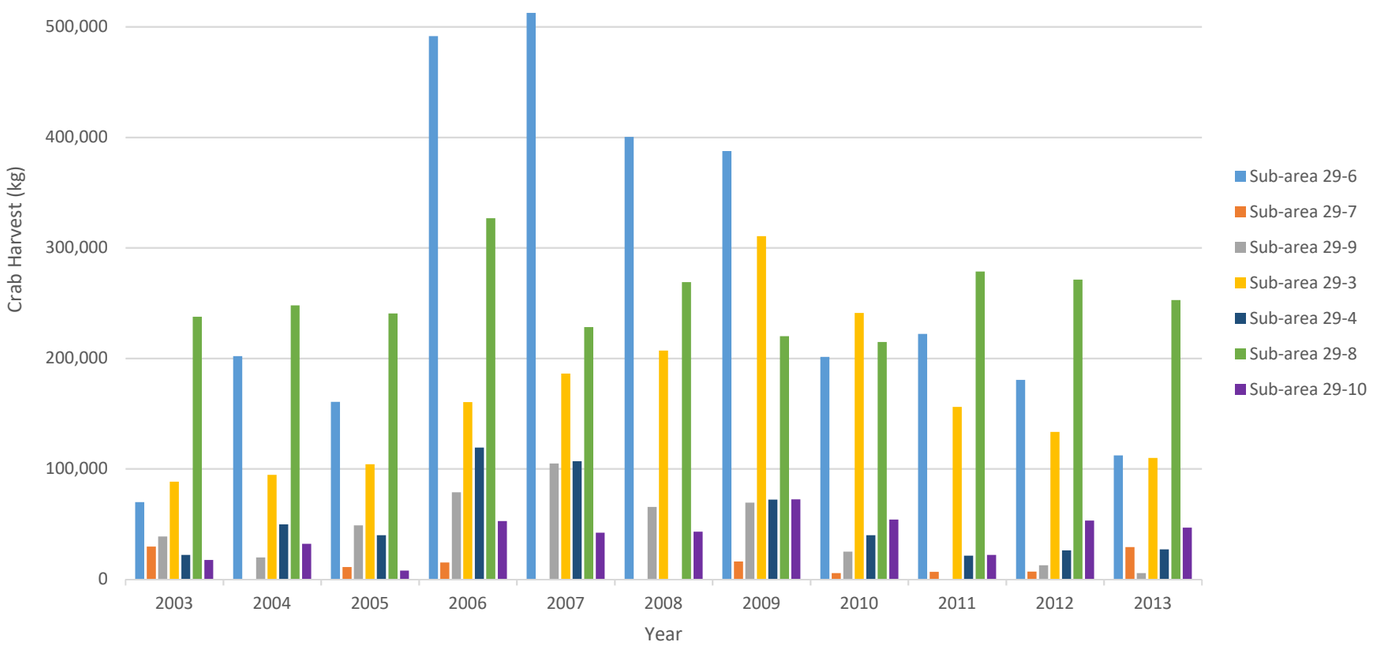


Table IR7-32-A3 Crab Vessel Count by Sub-area from Logbook Data (Revised Table 21-A3 in EIS Appendix 21-A)

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	9	15	14	19	20	20	20	28	27	21	14
LAA	29-7	4	2	4	3	1	0	3	3	3	6	5
LAA	29-9	6	4	5	6	7	7	7	13	2	10	5
Other RAA	29-3	12	11	14	10	19	20	24	29	31	31	14
Other RAA	29-4	4	9	4	7	9	2	8	8	6	7	6
Other RAA	29-8	19	18	18	21	22	22	22	18	19	18	21
Other RAA	29-10	6	7	3	5	5	6	11	14	9	18	9

Source: DFO 2014c.

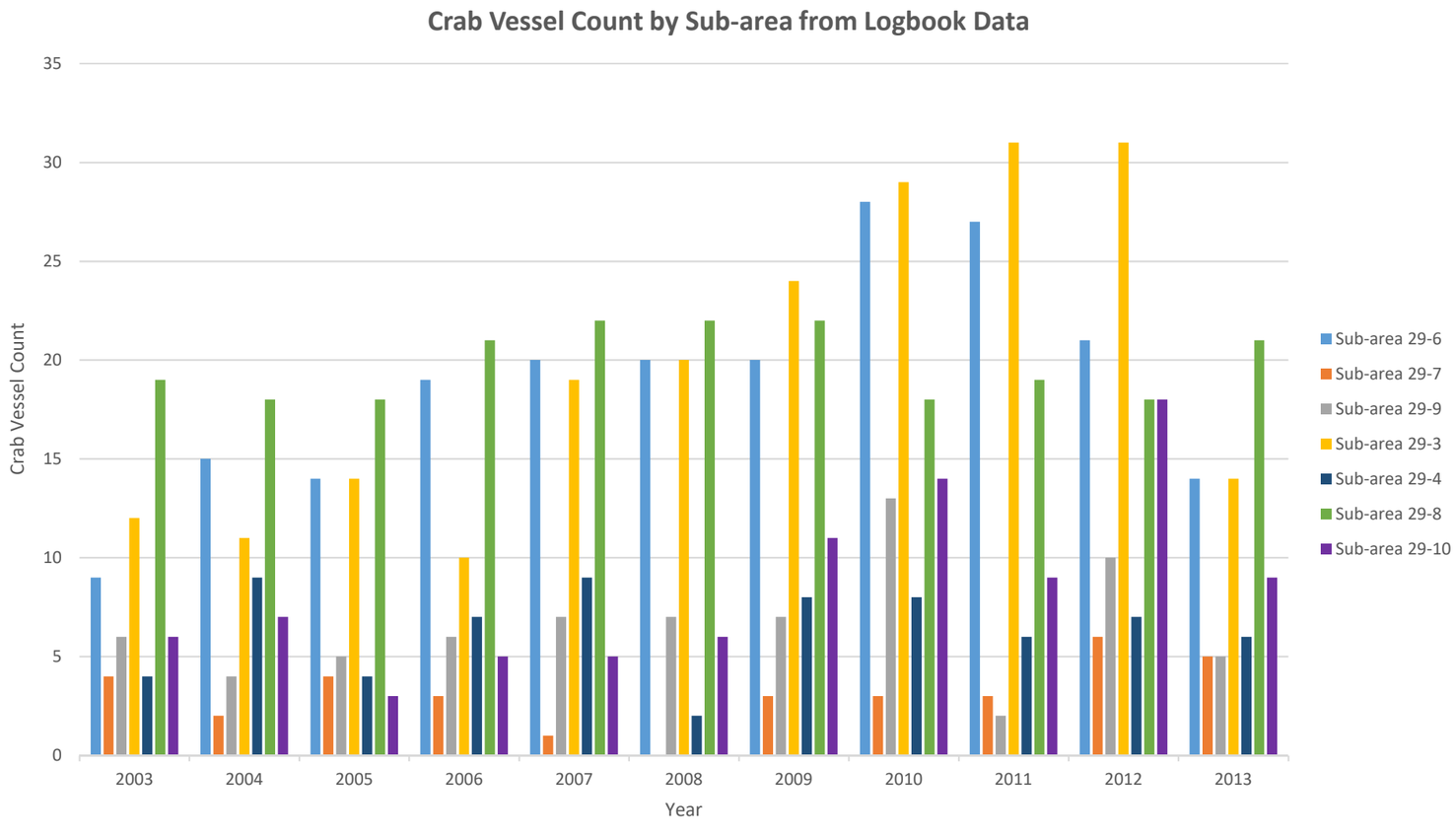
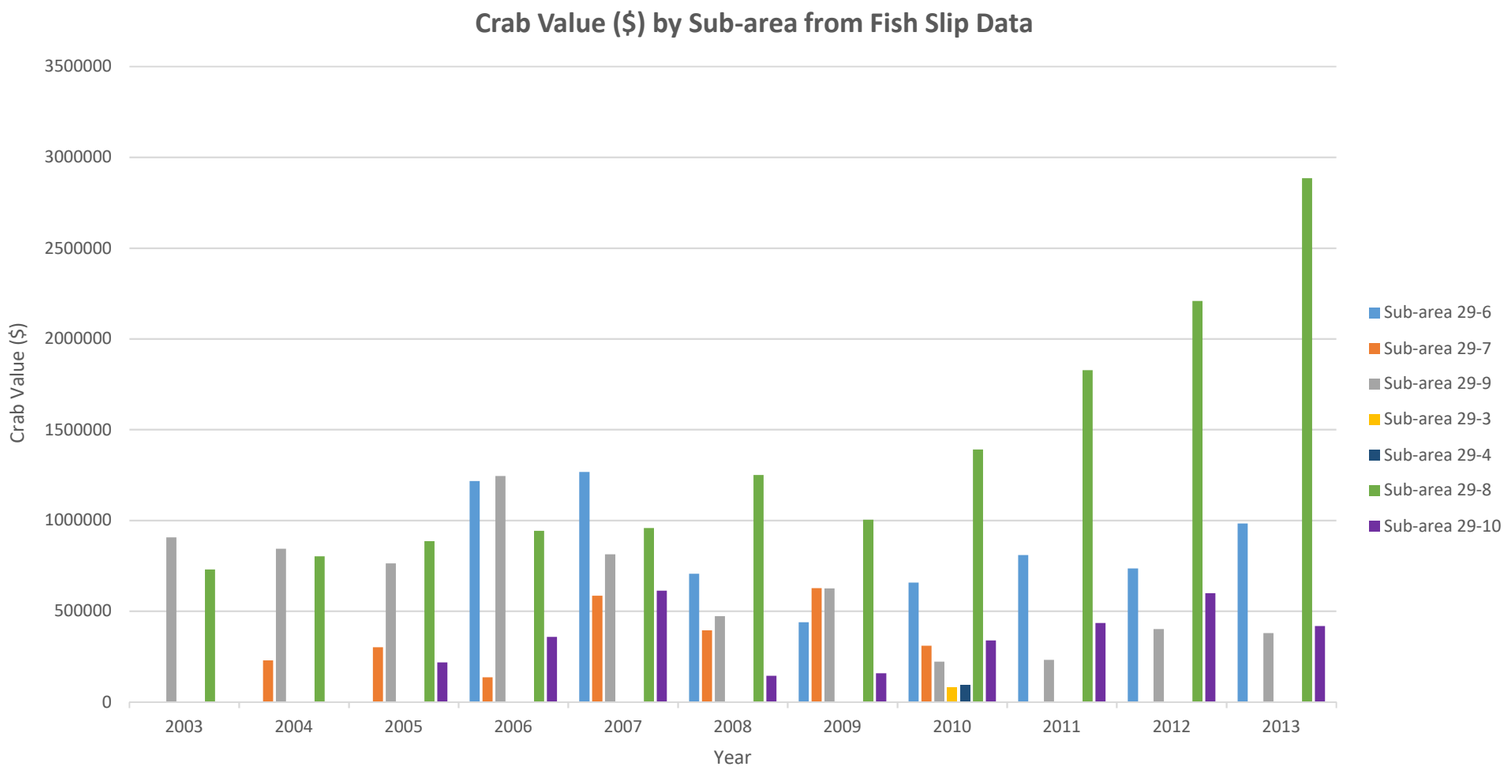


Table IR7-32-A4 Crab Value ($) by Sub-area from Fish Slip Data (Revised Table 21-A4 in EIS Appendix 21-A)

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	*	*	$1,217,157	$1,267,158	$705,650	$439,610	$657,993	$809,026	$734,928	$983,693
LAA	29-7	*	$229,379	$301,754	$136,370	$585,763	$394,536	$626,719	$310,446	*	*	
LAA	29-9	$906,528	$843,951	$763,017	$1,244,507	$813,738	$473,015	$625,893	$221,608	$231,850	$401,459	$379,065
Other RAA	29-3	-	-	*	*	*	*	*	$ 79,295	*	*	-
Other RAA	29-4	-	-	-	-	-	-	-	$94,615	-	-	-
Other RAA	29-8	$730,277	$802,959	$885,168	$943,246	$958,270	$1,250,742	$1,003,648	$1,390,596	$1,827,614	$2,208,659	$2,884,885
Other RAA	29-10	*	*	$217,968	$358,205	$612,634	$143,911	$157,884	$339,360	$434,523	$599,031	$418,522
Total		$3,128,647	$3,815,354	$3,749,936	$6,610,500	$6,539,871	$6,346,532	$7,329,578	$6,201,775	$6,739,736	$6,613,455	$6,102,069

Source: DFO 2014d.
Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area
- = No data reported



ADDITIONAL TABLES

Table IR7-32-A5 Crab Vessel Count by Sub-area from Fish Slip Data

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	1	2	6	7	7	4	6	8	9	8
	29-7	2	3	3	3	4	5	4	5	2	2	2
	29-9	11	10	9	12	13	11	11	6	5	12	8
Other - RAA	29-3	-	-	2	2	1	2	1	4	2	1	-
	29-4	-	-	-	-	-	-	-	-	-	-	-
	29-8	11	11	12	17	18	22	17	14	17	18	20
	29-10	1	1	4	4	10	5	5	9	5	16	9

Source: DFO 2014d.
Note: - = No data reported

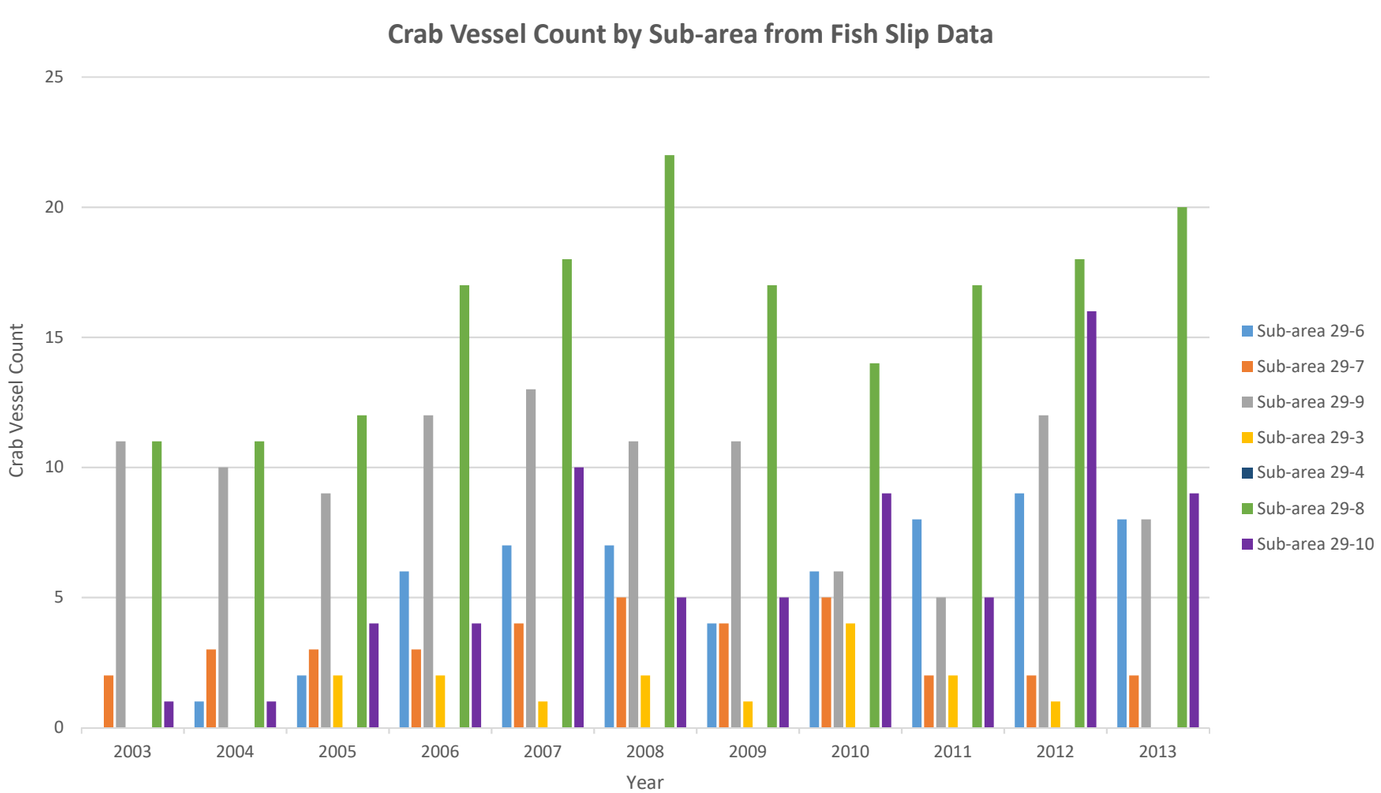


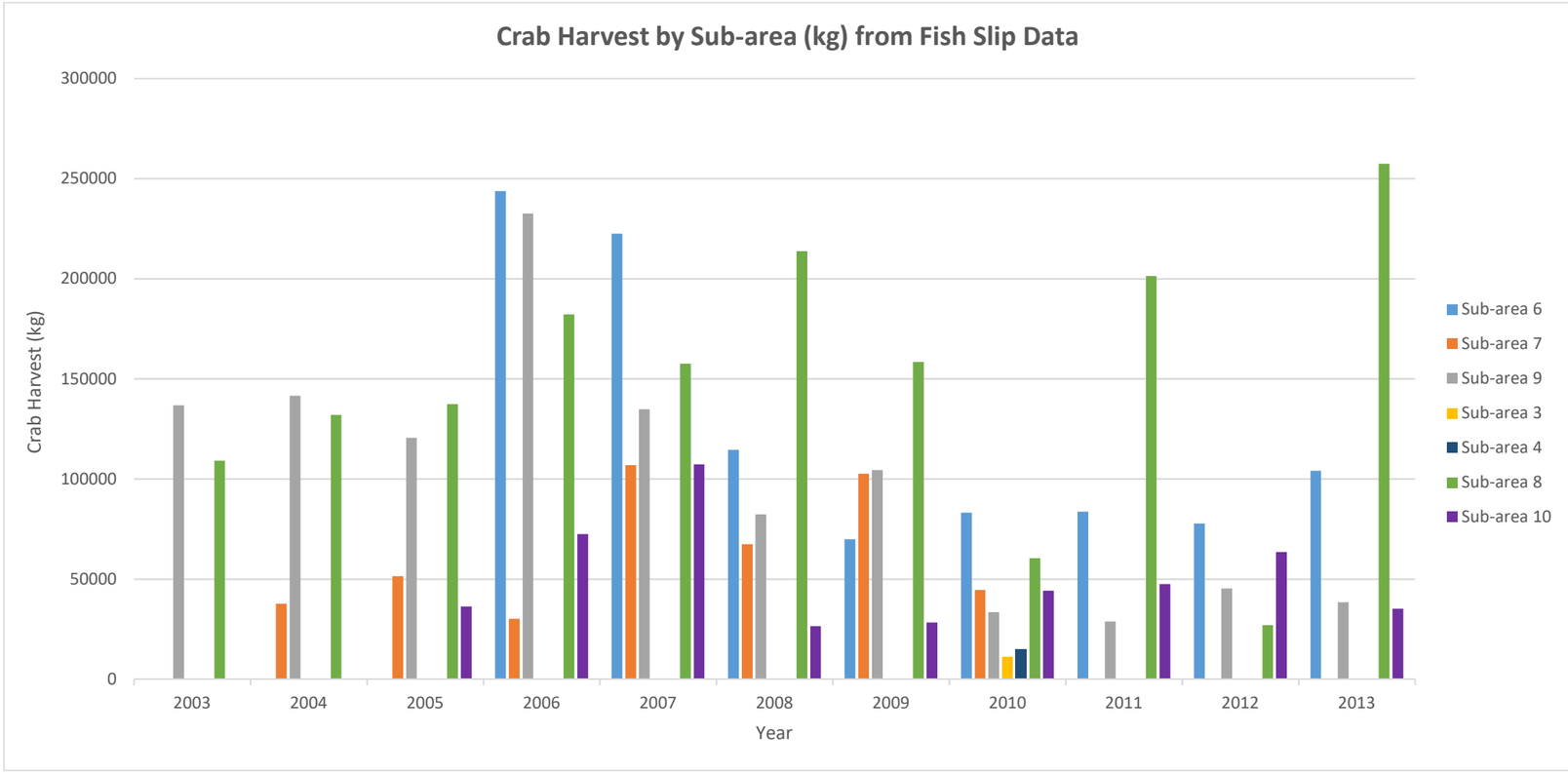
Table IR7-32-A6 Crab Harvest (kg) by Sub-area from Fish Slip Data

Study Area	Sub-area	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LAA	29-6	-	*	*	243,756	222,491	114,528	69,838	83,144	83,667	77,799	104,112
LAA	29-7	*	37,679	51,396	30,197	106,861	67,464	102,630	44,586	*	*	*
LAA	29-9	136,772	141,578	120,524	232,582	134,786	82,280	104,467	33,519	28,821	45,271	38,353
Other RAA	29-3	-	-	*	*	*	*	*	11,199	*	*	-
Other RAA	29-4	-	-	-	-	-	-	-	14,740	-	-	-
Other RAA	29-8	109,152	132,036	137,383	182,108	157,516	213,780	158,411	60,452	201,372	26,925	257,467
Other RAA	29-10	*	*	36,272	72,495	107,297	26,449	28,286	44,186	47,493	63,533	35,178

Source: DFO 2014d.

Notes: * = Confidential data does not meet criteria for public release (less than 3 vessels reporting for the time period and area)

- = No data reported



IR7-33 Marine Commercial Use – Crab, Effects Assessment

Information Source(s)

EIS Volume 4: Section 21.7

Context

The Proponent, in Section 21.7.5 of the EIS, stated that a quantifiable prediction of the effects from expansion of the navigational exclusion zone and displacement of crab harvesters cannot be made. The Proponent anticipated that displaced commercial crab harvesters including those that fish the area in the vicinity of the western boundary of the existing commercial exclusion zone would be subject to a moderate residual adverse effect both during construction and operation. According to the Proponent, this would result in a small reduction in crab harvest and reduction in associated revenues arising from the proposed Project-induced changes in harvesting areas and displacement of commercial crab harvesting activity.

Information Request

Describe and quantify the potential reductions in commercial crab harvest levels and the potential reductions in revenue from the proposed decrease in the size of the fishing areas in Fisheries and Oceans Canada Area 29-6.

VFPA Response

Clarification of Context

The effects associated with marine area displacement due to the Project terminal and proposed navigational closure expansion could not be predicted in quantifiable terms at the time of completing the EIS (as indicated in EIS Section 21.7.5). During preparation of the EIS, publicly available information from DFO on commercial crab harvest and revenues was utilised. This information is reported at the Pacific Fishery Management Area (PFMA) sub-level (e.g., PFMA 29-6 and 29-7), resulting in limitations for interpreting existing conditions and Project effects within the local assessment area (LAA), and within the proposed navigational closure expansion, specifically. During preparation of the EIS, the VFPA was aware of, and requested access and use of, Crab Management Area (CMA) I[1] electronic monitoring data on commercial crab vessel counts and crab trap hauls (inclusive of the Project terminal and proposed navigational closure expansion) collected by the Area I Crab Fisherman Association (AICFA), to support the assessment of Project effects on commercial crab harvesting. At that time, the VFPA did not receive authorisation to incorporate and present a spatial analysis of vessel and trap haul electronic monitoring data into the EIS.

[1] Crab Management Area I is the CMA where the Project is located.

In the October 26, 2016 submission to the CEA Agency registry, the AICFA requested that the VFPA use the electronic monitoring data to analyse potential Project effects, as well as effects of the 2009 navigational closure (2009 Closure) on commercial crab harvesting. The VFPA subsequently consulted with DFO and the AICFA to request access to the CMA I electronic monitoring data, and DFO logbook and fish slip harvest landing and landing value information for the proposed navigational closure expansion and existing 2009 Closure at Roberts Bank. The two new sets of data from CMA I and DFO were provided to the VFPA in spring 2017 and reviewed collectively, and summarised in the response below.

Clarification of Pacific Fishery Management Areas

Portions of the Project terminal footprint and the proposed navigational closure expansion for Project operations transect PFMA sub-areas 29-6 and 29-7, with 100% of the proposed navigational closure expansion (including the Project terminal footprint) being located in PFMA sub-areas 29-6 and 29-7 (**Table IR7-33-1**).

Table IR7-33-1 Proportion of the Proposed Navigational Closure Expansion Located in Sub-areas 29-6 and 29-7

	Portion of Proposed Navigational Closure Expansion Located in Sub-area 29-6		Portion of Proposed Navigational Closure Expansion Located in Sub-area 29-7		Total	
	ha	% of Total Proposed Navigational Closure Expansion in Sub-area 29-6	ha	% of Total Proposed Navigational Closure Expansion in Sub-area 29-7	ha	%
Proposed Navigational Closure Expansion (Operations)	275.7	79.2%	72.4	20.8%	348.1	100%

As the proposed navigational closure expansion for operations will displace commercial crab harvesting activity in both sub-areas 29-6 and 29-7, this response considers potential Project effects on commercial crab harvest landings and associated landing revenues from the proposed navigational closure expansion, and associated decrease in the size of the fishing areas in sub-areas 29-6 and 29-7, collectively.

For context, the proposed navigational closure expansion area represents 3.7% of the total area of sub-areas 29-6 and 29-7 combined, or 6.5% of sub-area 29-6 and 1.4% of sub-area 29-7.

Describe and quantify the potential reductions in commercial crab harvest levels and the potential reductions in revenue from the proposed decrease in the size of the fishing areas in Fisheries and Oceans Canada Area 29-6 and 29-7.

Historical DFO data on annual commercial crab harvest landings and landing values obtained from crab harvesting activity in the area designated as the proposed navigational closure expansion can inform the potential reduction in crab harvest landings and landing values once the proposed navigational closure expansion is in place. This data from DFO is presented

below. However, reductions in crab harvest levels and reductions in revenue from the proposed decrease in the size of the fishing areas in DFO sub-areas 29-6 and 29-7 due to the navigational closure expansion cannot be reliably predicted or quantified due external factors, both environmental and anthropogenic, that influence harvest landings and landing values year over year, as discussed further below.

As indicated in **Table IR7-33-1**, the proposed navigational closure expansion will restrict commercial crab harvesting in 348.1 hectares (ha) from sub-areas 29-6 and 29-7, collectively. Sub-areas 29-6 and 29-7 combined cover an area of 9,530.7 ha (sub-areas 29-6 and 29-7 are 4,240.1 ha and 5,290.6 ha, respectively). This area includes the 714.7 ha of the 2009 Closure at Robert Bank.

Annual commercial crab vessel counts, harvest landings (kg), and landing values ($) provided by DFO for the area identified for the proposed navigational closure expansion for the 10-year period between 2006 and 2015 are summarised in **Table IR7-33-2** and **Figure IR7-33-1** below[2,3]. Data for years 2006 to 2008 in **Table IR7-33-2** indicates the similarity (same order of magnitude) in terms of the number of vessels, and commercial crab harvest landings and landing values obtained from the 2009 Closure at Roberts Bank area (i.e., pre-closure) and the proposed navigational closure expansion area.

Table IR7-33-2 Commercial Crab Harvest Landings (kg) and Landing Values from Commercial Crab Harvesting in the Area Identified for the Proposed Navigational Closure Expansion and 2009 Closure Area

Year	Proposed Navigational Closure Expansion[a]			2009 Closure Area at Roberts Bank		
	Vessel Count[b]	Harvest Landings (kg)[b]	Landing Value ($)[b]	Vessel Count[b]	Harvest Landings (kg)[b]	Landing Value ($)[b]
2006	7	124,483	647,312	6	123,136	604,307
2007	9	202,875	1,162,474	8	151,582	868,565
2008	10	175,722	1,043,789	5	98,928	587,632
2009	10	189,117	1,189,546	-	-	-
2010	9	113,222	843,504	-	-	-
2011	5	75,228	664,263	-	-	-
2012	12	81,323	753,864	-	-	-
2013	6	41,649	428,152	-	-	-

[2] Total landing values are quantified as total crab landed multiplied by unit price or value supplied by buyer. Total landing values can provide an indication of collective gross revenues (i.e., before expenses such as fuel cost, at-sea and offload monitoring, licence fees, bait, and gear purchase and maintenance).
[3] Only males larger than the minimum size limit as regulated by DFO are permitted to be retained by harvesters.

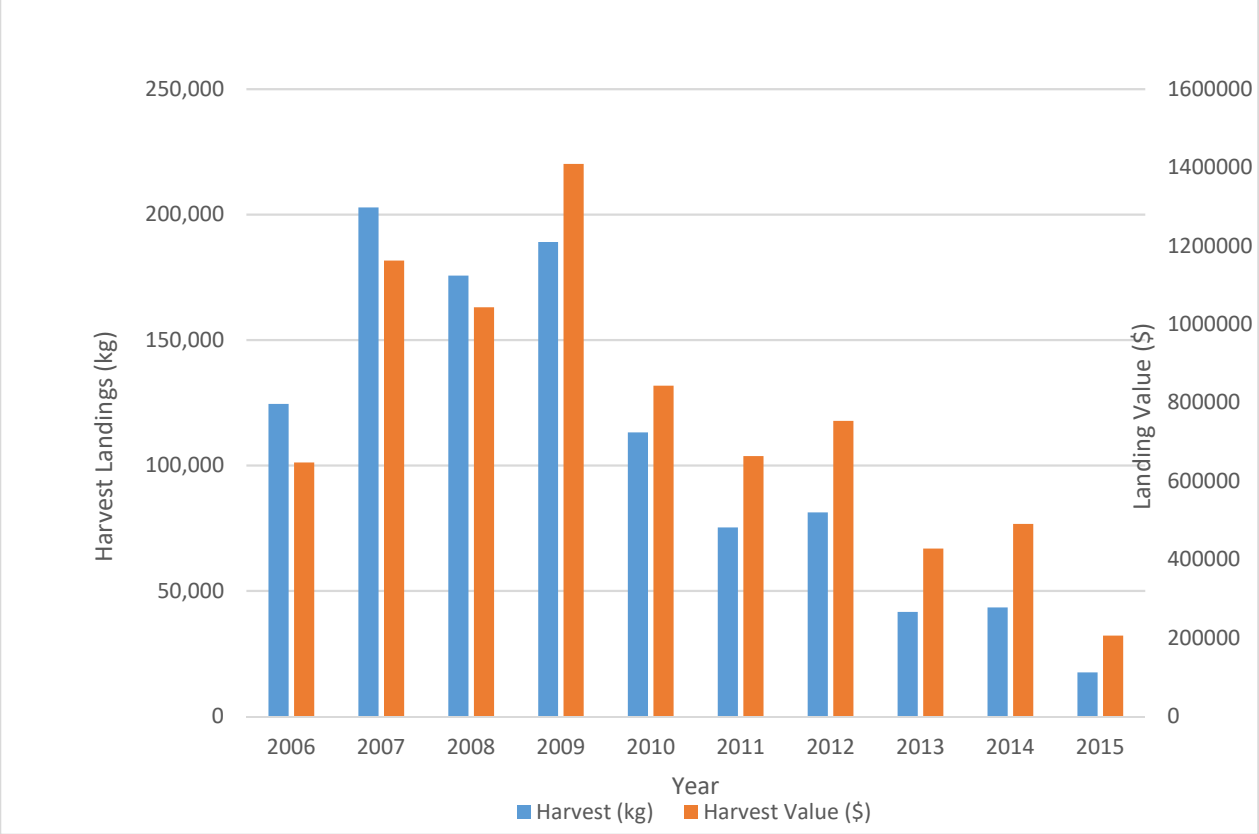
Year	Proposed Navigational Closure Expansion[a]			2009 Closure Area at Roberts Bank		
	Vessel Count[b]	Harvest Landings (kg)[b]	Landing Value ($)[b]	Vessel Count[b]	Harvest Landings (kg)[b]	Landing Value ($)[b]
2014	4	43,397	490,820	-	-	-
2015	4	17,510	206,268	-	-	-

Source: DFO 2017a.

Notes: a. Data spatially reflects the proposed navigational closure expansion for RBT2 operations (including terminal footprint) and does not spatially include or reflect harvest landings and landing values in the existing 2009 Closure at Roberts Bank.

b. Vessel count and harvest landings (kg) obtained from logbooks, and landing values obtained from fish slip data (DFO 2017a). Landing values are based on yearly $/kg nominal values for CMA. Fishery dependent catch reporting relies on individual harvesters or groups of harvesters to monitor and report their own catch. Dependability of data arising from fishery dependent catch programs is higher for those fisheries that also participate in independent verification, such as third party monitoring programs. Crab trap fisheries are not managed with comprehensive independent verification programs, and as such the dependability of the data is unknown. All data has been reviewed and consideration given to individuals' rights to privacy as described in the *Privacy Act* and *Access to Information Act*.

Figure IR7-33-1 Commercial Crab Harvest Landings (kg) and Landing Values ($) From Commercial Crab Harvesting in the Area Identified for the Proposed Navigational Closure Expansion – DFO Data



Source: DFO 2017a.

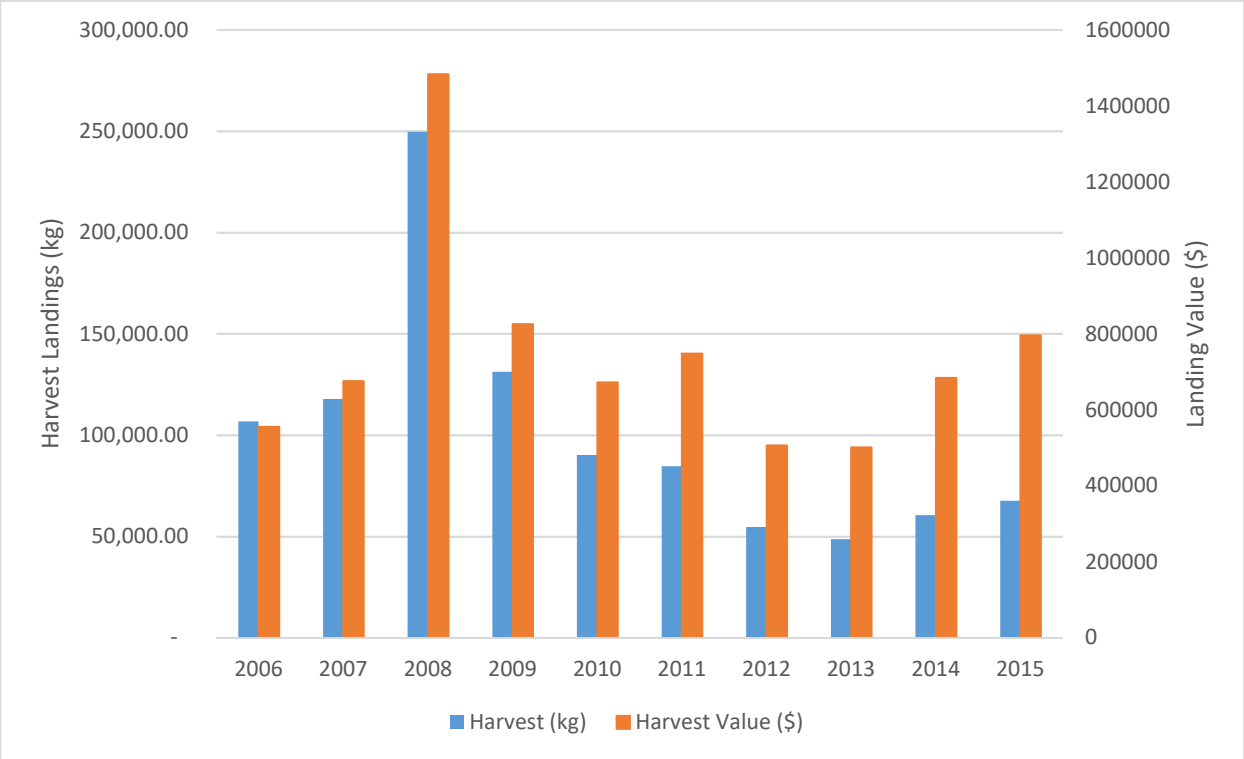
The above harvest landings and value data indicates that between 2006 and 2015, commercial crab harvest landings in the proposed navigational closure expansion ranged from a low of 17,510 kg in 2015 (with four vessels reportedly harvesting in this area in 2015) to a high of 202,875 kg in 2007 (with nine vessels reportedly harvesting in this area in 2007), with an annual average harvest of 106,453 kg. During this same 10-year period, commercial crab harvest landing values ranged from a low of $206,268 in 2015 to a high of $1,408,222 in 2009, with an annual average harvest value of $742,999.[4]

For comparison with commercial crab harvest landings regionally, between 2006 and 2015, annual commercial crab harvest landings and associated landing values obtained from the area within the proposed navigational closure expansion (as described above) ranged from a low of 3.8% (in 2015) to a high of 18.9% (in 2008) of annual commercial crab harvest landings (and landing values) from CMA I, and from a low of 13.3% (in 2015) to a high of 54.3% (in 2010) of annual commercial crab harvest landings (and landing values) in sub-areas 29-6 and 29-7 combined.

DFO harvest landing data for CMA I were analysed in conjunction with crab trap haul numbers for CMA I (obtained from CMA I electronic monitoring data) to further estimate average annual landings per trap haul for CMA I. This estimate, along with annual trap haul numbers from within the proposed navigational closure expansion area were applied to estimate historical annual commercial crab harvest landings and landing values from the proposed navigational closure expansion area (**Figure IR7-33-2**).

[4] The number of CMA I licences and the number of vessels harvesting in the navigational closure expansion area have declined in the last two licence selection periods (i.e., 2013-2015 and 2016-2018) from previous periods, which have, in part, contributed to reduced harvest levels throughout CMA I, including the proposed expansion of the navigational closure area (Section 21.5.1.1 and Appendix 21-A of the EIS).

Figure IR7-33-2 Commercial Crab Harvest Landings (kg) and Landing Values ($) From Commercial Crab Harvesting in the Area Identified for the Proposed Navigational Closure Expansion - Calculated from Electronic Monitoring and DFO Data



Source: DFO 2017a; Pacific Coast Fishery Services Inc. 2017.

The harvest landings and value data estimated based on trap haul numbers indicates that between 2006 and 2015, commercial crab harvest landings in the proposed navigational closure expansion area ranged from a low of 48,752 kg in 2013 (with 15 vessels reportedly harvesting in this area in 2013) to a high of 249,730 kg in 2008 (with 29 reportedly harvesting in this area in 2008), with an annual average harvest of 101,207 kg. During this same 10-year period, commercial crab harvest landing values ranged from a low of $501,166 in 2013 to a high of $1,483,399 in 2008, with an annual average harvest value of $744,797.

For comparison with commercial crab harvest landings regionally, between 2006 and 2015, estimates of annual commercial crab harvest landings and associated landing values obtained from the area within the proposed navigational closure expansion (as illustrated in **Figure IR7-33-2**) ranged from a low of 9.7% (in 2006) to a high of 26.9% (in 2008) of annual commercial crab harvest landings (and landing values) from CMA I, and from a low of 13.4% (in 2006) to a high of 37.5% (in 2015) of total annual commercial crab harvest landings (and values) in sub-areas 29-6 and 29-7 combined.

The analysis of DFO and electronic monitoring data, as presented above, shows a range of magnitude of annual commercial crab harvest landings and values obtained from the proposed navigational closure expansion between 2006 and 2015, with this range on average comprising a relatively large proportion of annual commercial crab harvest landings from sub-

area 29-6 specifically. Several factors have influenced commercial crab harvest landings and associated landing values within the Pacific region generally year over year, and will continue to do so with the proposed navigational closure expansion (Sections 21.7.5 and 21.10.1 of the EIS). This combination of factors, described below, will continue to influence annual harvest landings and landing values during Project construction and operations, making it difficult to quantify or reliably predict potential reductions in harvest levels and revenues[5]:

- Fluctuations in crab productivity – Landings in all crab management areas have generally fluctuated with the cyclical nature of crab stock, with higher periods of crab productivity in a spatial area linked to higher levels of landings. As indicated in Section 12.5.3.3 of the EIS and the Dungeness Crab Productivity Technical Data Report (TDR MI-4 in Appendix AIR10-C of CEAR Document #388[6]), environmental and biophysical factors such as ocean currents and temperatures, wind stress, and other aspects of habitat affecting larval advection survival and settlement have affected crab productivity and abundance year over year in the Pacific region. With respect to the Roberts Bank area, a period of low crab productivity between 1982 and 2005 was followed by exceptional crab productivity between 2006 and 2009, which in turn influenced biomass and a relatively high fishery catch between 2006 and 2009 in CMA I and sub-areas 29-6 and 29-7, as well as the proposed navigational closure expansion. The crab productivity model showed that 2006 to 2009 were the most productive crab years on record across all of CMA I (TDR MI-4 in Appendix AIR10-C of CEAR Document #388). This period was followed by a trend post-2009 to crab productivity levels similar to those pre-2006. These historical fluctuations in crab productivity have influenced, and would continue to influence, availability of crab and, in turn, crab harvest landings in the Roberts Bank area over time.
- Movement of crabs to baited traps – As discussed in the response to IR7-35 and reflecting research on movement of crabs to baited traps, it is anticipated that with the proposed navigational closure expansion in place, some portion of eligible male crabs would migrate from within the proposed navigational closure expansion to baited traps outside of the proposed navigational closure expansion.
- Ability to harvest in other areas – As per DFO crab harvesting management regulations CMA I licence holders can legally harvest anywhere in CMA I (as discussed further in IR7-35). Commercial crab harvesters harvesting in the proposed navigational closure expansion could re-establish their harvesting activities in the open area along the

[5] It should be noted that fishery management measures are not likely to have affected observed variations over time in crab landings and landing values within the proposed navigational closure expansion. Fishery management measures have been applied consistently across CMA I throughout the time period, and DFO has indicated there would be no alteration to regulatory management of commercial crab harvesting in response to the proposed navigational closure expansion for the Project (DFO, personal communication, 2014). This includes no anticipated change to regulation of number of commercial crab licences; commercial crab harvest season and seasonal closures; daily harvesting time restrictions, trap/gear limits, haul limits, size, sex, and hardness restrictions.

[6] CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document # 345) including 22 Technical Data Reports.

western boundary of the proposed navigational closure expansion and elsewhere in CMA I, or they may choose to re-select their CMA during a future re-selection period.

This assumption of re-establishment is supported by the review of commercial crab harvesters' response to the 2009 Closure completed through analysis of the CMA I electronic monitoring data and is spatially represented in Figures IR7-33-A1 to IR7-33-A11 in **Appendix IR7-33-A**. The figures show that after the 2009 Closure, commercial crab harvesters who were harvesting in the area prior to the closure (as illustrated by crab trap hauls) continued to harvest in the area immediately west of the closure, as well as the broader outer slopes of Roberts Bank and northward. The electronic monitoring data of crab trap hauls for CMA I licence holders also shows that approximately a third of the harvesters who were harvesting within the 2009 Closure at Roberts Bank prior to the closure did not show trap hauls in CMA I after 2012, indicating CMA licence re-selection, with CMA I licences declining from 51 during the 2010-2012 selection period to 32 licences during the 2013-2015 selection period.

- Fluctuation in market price for Dungeness crab – In addition to total landings, year to year variability in market prices for Dungeness crab (e.g., $/kg) affects total harvest landing values and revenues accrued to commercial crab harvesters. In the past few years, landing values have in part been buoyed by an increase in price per kilogram. In the Pacific region, prices have generally been increasing since 2012, with 2015 price per kilogram being 39% higher than 2012 as shown in **Figure IR7-33-1** (DFO 2017b).

The above factors and individual decisions by commercial crab harvesters on preferred harvesting locations will further influence the potential adjustments to commercial crab harvesting and landing values from the proposed navigational closure expansion. Based on this, it is difficult to quantifiably estimate, or predict, reductions in landing values due to the decrease in the size of the fishing areas in sub-area 29-6 and sub-area 29-7 directly attributable to the navigational closure expansion. However, the analysis of the additional DFO data on commercial crab harvest landings and landing values and CMA I electronic monitoring data supports the conclusions made in the EIS (EIS Section 21.9):

- The Project terminal and proposed navigational closure expansion would displace a large portion of commercial crab harvesting in the LAA, and result in a demonstrable change to harvest landings and revenues, particularly from sub-area 29-6; and
- The re-establishment of displaced commercial crab harvesters and effects on commercial crab harvest landings and revenues accrued to displaced harvesters and other harvesters harvesting outside of the proposed closure boundary, would be similar to that which occurred with the 2009 Closure, and be within historical norms.

References

Fisheries and Oceans Canada (DFO). 2017a. Commercial Crab Harvest Log book and Fish Slip Data Sets for the Proposed Navigational Closure Expansion. Provided by DFO to the VFPA on May 18, 2017.

Fisheries and Oceans Canada (DFO). 2017b. Pacific Region Integrated Fisheries Management Plan: Crab by Trap, January 1, 2017 to March 31, 2018. Electronic copy requested to and provided by DFO.

Fisheries and Oceans Canada (DFO). 2014. Personal Communication (Interview). Interview between DFO Representative and Golder Associates Ltd for the purposes of RBT2 Project EIS.

Pacific Coast Fishery Services Inc. 2017. Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Electronic copy requested to and provided by Pacific Coast Fishery Services Inc.

Appendices

Appendix IR7-33-A Electronic Monitoring Data Showing Commercial Crab Trap Haul Activity for the Period 2006 to 2016 (All Vessels)

APPENDIX IR7-33-A
ELECTRONIC MONITORING DATA SHOWING COMMERCIAL CRAB TRAP HAUL ACTIVITY FOR THE PERIOD 2006 TO 2016 (ALL VESSELS)

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Subarea 17-11
Subarea 29-2
Subarea 29-3
Subarea 29-10
Subarea 29-9
Subarea 29-4
Subarea 29-7
Subarea 29-6
Subarea 28-6
Subarea 28-9
Subarea 28-7
Subarea 28-8
Subarea 28-11
Subarea 28-12
Ballenas Channel
Dolphin Beach
Gibsons
Plumper Cove Marine Provincial Park
Snug Cove
Gambier Harbour
Bowen Island
Collingwood Channel
Queen Charlotte Channel
Horseshoe Bay
Cypress Provincial Park
Capilano River
Lynn Creek
Mount Seymour Provincial Park
Delbrook
Lynn Valley
Cottrell-Westmount
Edgemont Village
Indian Arm
North Vancouver
Seymour Heights
Deep Cove
Belcarra
Anmore
Pleasantside
Port Moody
University Hill
Vancouver
Burnaby
Coquitlam
New Westminster
Sea Island
North Arm
LULU ISLAND
Surrey
Richmond
North Delta
Delta
Ladner
South Surrey
White Rock
Boundary Bay
Tsawwassen
CANADA
UNITED STATES
Point Roberts
Semiahmoo Bay
Strait of Georgia
Valdes Island
Dionisio Point Provincial Park
Trincomali Channel
Bodega Ridge Provincial Park
Wallace Island Marine Provincial Park
Saltspring Island
Galiano Island
Steveston Hwy
Richmond Country Club
Moncton St
No. 1 Rd
Port Metro Vancouver-Deltaport
1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
- 2009 NAVIGATIONAL CLOSURE FOR COMMERCIAL CRAB HARVESTING
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (CONSTRUCTION)
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

2006

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2006)

DATE: 03/15/2018

FIG No. IR7-33-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

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Subarea 17-11
Subarea 29-2
Subarea 29-3
Subarea 29-10
Subarea 29-9
Subarea 29-4
Subarea 29-7
Subarea 29-6
Subarea 28-6
Subarea 28-9
Subarea 28-7
Subarea 28-8
Subarea 28-11
Subarea 28-12
Ballenas Channel
Dolphin Beach
Gibsons
Plumper Cove Marine Provincial Park
Snug Cove
Gambier Harbour
Bowen Island
Collingwood Channel
Queen Charlotte Channel
Horseshoe Bay
Cypress Provincial Park
Capilano River
Lynn Creek
Mount Seymour Provincial Park
Delbrook
Lynn Valley
Cottrell-Westmount
North Vancouver
Seymour Heights
Deep Cove
Belcarra
Indian Arm
Armore
Pleasantside
Port Moody
University Hill
Vancouver
Burnaby
Coquitlam
New Westminster
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North Arm
LULU ISLAND
Richmond
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Saltspring Island
Galiano Island
Steveston Hwy
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Moncton St
No. 1 Rd
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Port Metro Vancouver-Deltaport Terminal
1:100,000

Legend

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- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N

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PORT of vancouver

2007

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2007)

DATE:	FIG No.
03/15/2018	IR7-33-A2

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

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Subarea 17-11
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Subarea 28-8
Subarea 28-11
Subarea 28-12
Ballenas Channel
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Gibsons
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Snug Cove
Gambier Harbour
Bowen Island
Collingwood Channel
Queen Charlotte Channel
Horseshoe Bay
Cypress Provincial Park
Capilano River
Lynn Creek
Mount Seymour Provincial Park
Delbrook
Lynn Valley
Cottrell-Westmount
Lonsdale
North Vancouver
Seymour Heights
Deep Cove
Belcarra
Indian Arm
Ambore
Pleasantside
Port Moody
University Hill
Vancouver
Burnaby
Coquitlam
New Westminster
Sea Island
North Arm
LULU ISLAND
Richmond
Surrey
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Ladner
South Surrey
White Rock
Tsawwassen
CANADA
UNITED STATES
Point Roberts
Boundary Bay
Semiahmoo Bay
Strait of Georgia
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Wallace Island Marine Provincial Park
Saltspring Island
Galiano Island
Steveston Hwy
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Moncton St
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41-B St
Port Metro Vancouver-Deltaport
1:100,000

Legend

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- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N

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PORT of vancouver

2008

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2008)

DATE: 03/15/2018

FIG No. IR7-33-A3

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

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Subarea 17-11
Subarea 29-2
Subarea 29-3
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Subarea 28-9
Subarea 28-11
Subarea 28-12
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Mount Seymour Provincial Park
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North Vancouver
Seymour Heights
Deep Cove
Belcarra
Armore
Pleasantside
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LULU ISLAND
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Galiano Island
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41-B St
Port Metro Vancouver-Deltaport Terminal
1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
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- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10
Kilometers
1:250,000
NAD 1983 UTM Zone 10N

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PORT of vancouver

2009

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2009)

DATE: 03/15/2018

FIG No. IR7-33-A4

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

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Subarea 17-11
Subarea 29-2
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Snug Cove
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Bowen Island
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Cypress Provincial Park
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North Vancouver
Seymour Heights
Deep Cove
Belcarra
Armore
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Steveston Hwy
Richmond Country Club
Moncton St
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41-B St
Port Metro Vancouver-Deltaport
1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
- 2009 NAVIGATIONAL CLOSURE FOR COMMERCIAL CRAB HARVESTING
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- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N
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PORT of vancouver

2010

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2010)

DATE: 03/15/2018

FIG No. IR7-33-A5

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

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Subarea 17-11
Subarea 29-2
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Gibsons
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Cypress Provincial Park
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Queen Charlotte Channel
Ballenas Channel
Dolphin Beach
Cottrell-Westmount
Delbrook
Lynn Valley
Mount Seymour Provincial Park
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North Vancouver
Seymour Heights
Deep Cove
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Armore
Pleasantside
Port Moody
University Hill
Vancouver
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UNITED STATES
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Dionisio Point Provincial Park
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Galiano Island
Steveston Hwy
Richmond Country Club
Moncton St
No. 5 Rd
Port Metro Vancouver-Deltaport Terminal
1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
- 2009 NAVIGATIONAL CLOSURE FOR COMMERCIAL CRAB HARVESTING
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (CONSTRUCTION)
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10
Kilometers
1:250,000
NAD 1983 UTM Zone 10N

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PORT of vancouver

2011

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2011)

DATE: 03/15/2018

FIG No. IR7-33-A6

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

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Subarea 17-11
Subarea 29-2
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Subarea 28-9
Subarea 28-11
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Queen Charlotte Channel
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Deep Cove
Belcarra
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Armore
Pleasantside
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Vancouver
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CANADA
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Moncton St
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41-B St
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1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
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CRAB TRAP HAUL PER 625m²

- 1 - 4
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- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N

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PORT of vancouver

2012

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2012)

DATE: 03/15/2018

FIG No. IR7-33-A7

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

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Subarea 17-11
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Legend

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Notes:
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Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers
1:250,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

2013

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2013)

DATE: 03/15/2018

FIG No. IR7-33-A8

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

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Roberts Bank Superport
Point Roberts

1:100,000

Legend

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CRAB TRAP HAUL PER 625m²

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Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10
Kilometers
1:250,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

2014

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2014)

DATE:	FIG No.
03/15/2018	IR7-33-A9

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

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Subarea 29-7

Subarea 29-9

Subarea 29-10

Subarea 28-6

Subarea 28-7

Subarea 28-8

Subarea 28-9

Subarea 28-11

Subarea 28-12

Vancouver

Richmond

Delta

Surrey

Tsawwassen

White Rock

Gibsons

Plumper Cove Marine Provincial Park

Snug Cove

Gambier Harbour

Bowen Island

Horseshoe Bay

Cypress Provincial Park

Mount Seymour Provincial Park

Collingwood Channel

Queen Charlotte Channel

Ballenas Channel

Dolphin Beach

Delbrook

Lynn Valley

North Vancouver

Seymour Heights

Deep Cove

Belcarra

Indian Arm

Armore

Pleasantside

Port Moody

Coquitlam

Burnaby

New Westminster

University Hill

Sea Island

North Arm

LULU ISLAND

North Delta

Ladner

South Surrey

Boundary Bay

Semiahmoo Bay

Point Roberts

CANADA

UNITED STATES

Strait of Georgia

Valdes Island

Dionisio Point Provincial Park

Trincomali Channel

Bodega Ridge Provincial Park

Wallace Island Marine Provincial Park

Saltspring Island

Galiano Island

Steveston Hwy

Richmond Country Club

Moncton St

No. 5 Rd

41-B St

Port Metro Vancouver-Deltaport

1:100,000

Legend

- BOUNDARY OF RBT2 PROJECT AREA
- 2009 NAVIGATIONAL CLOSURE FOR COMMERCIAL CRAB HARVESTING
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (CONSTRUCTION)
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers

1:250,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

2015

ROBERTS BANK TERMINAL 2

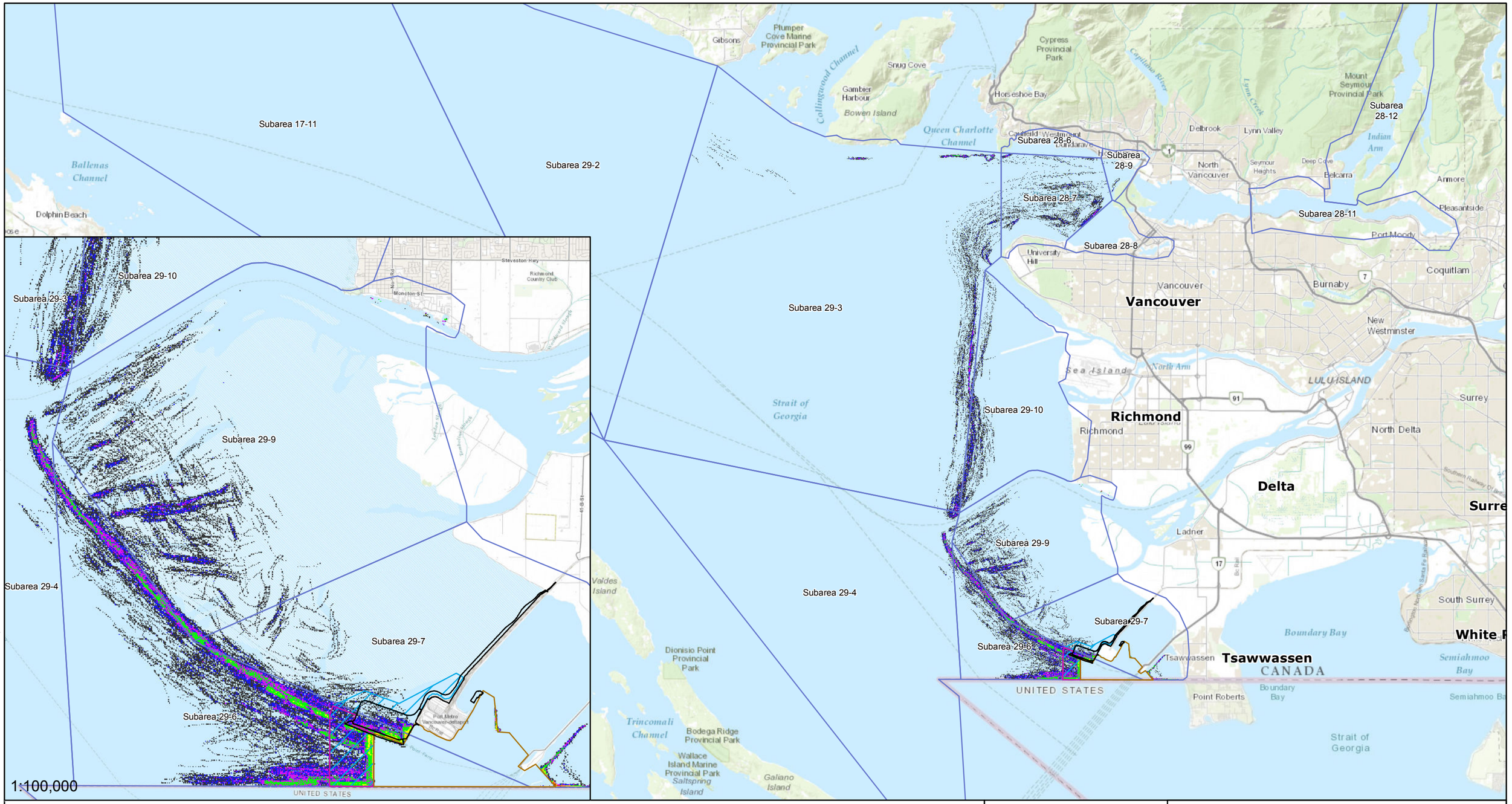
AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2015)

DATE: 03/15/2018

FIG No. IR7-33-A10

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

Path: Y:\burnaby\CAD-GIS\Client\Vancouver_Fraser_Port_Authority\Delta\09_PROJECTS\1648389\02_PRODUCTION\MXD\Report\1648389_IR7-33-A_Area_I_Crab_Hauls_All_Harvesters_25m.mxd



Legend

- BOUNDARY OF RBT2 PROJECT AREA
- 2009 NAVIGATIONAL CLOSURE FOR COMMERCIAL CRAB HARVESTING
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (CONSTRUCTION)
- RBT2 PROPOSED NAVIGATIONAL CLOSURE EXPANSION FOR COMMERCIAL CRAB HARVESTING (OPERATIONS)
- DFO PFMA SUBAREA

CRAB TRAP HAUL PER 625m²

- 1 - 4
- 5 - 11
- 12 - 19
- 20 - 29
- 30 - 42
- 43 - 62
- 63 - 101
- 102 - 228

Notes:
DFO SUBAREAS OBTAINED FROM DATA B.C.
Crab trap hauls obtained from Pacific Coast Fishery Services Inc. (2017). Electronic Monitoring Data of Vessel Trap Hauls for Crab Management Area I. Provided by PCFSI September 2017.

0 5 10 Kilometers

1:250,000

NAD 1983 UTM Zone 10N

N

PORT of vancouver

2016

ROBERTS BANK TERMINAL 2

AREA I CRAB HARVESTERS: CRAB HARVESTERS' TRAP HAULS (2016)

DATE: 03/15/2018

FIG No. IR7-33-A11

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

IR7-34 Marine Commercial Use - Crab, Mitigation Measures

Information Source(s)

EIS Volume 4: Section 21.7, Section 21.7.5, Table 21-7

Context

The proposed mitigation measures identified in Table 21-7 of the EIS included:

- implementation of the marine species salvage plan and communications plan; and
- work with Fisheries and Oceans Canada to consult with commercial crab harvesters and Indigenous groups to identify and implement feasible mitigation.

Information Request

Describe technically and economically feasible mitigation measures that could address the potential effects on commercial harvesters including a reduction in 1,183 hectares of crab fishing areas during construction of the proposed Project and 1,063 hectares during operations, other than those identified in Table 21-7 of the EIS.

Provide information about the engagement activities held to date with stakeholders and Indigenous groups that could be affected by the proposed expansion of the navigational closure and displacement from crab harvest areas.

VFPA Response

Describe technically and economically feasible mitigation measures that could address the potential effects on commercial harvesters including a reduction in 1,183 hectares of crab fishing areas during construction of the proposed Project and 1,063 hectares during operations, other than those identified in Table 21-7 of the EIS.

As discussed in EIS Section 21.8.1, other sections of the EIS describe mitigation measures that are relevant to the assessment of effects on seafood harvesting area use and displacement. These include mitigation measures to address biophysical effects on marine invertebrates through avoidance and reduction of potential effects, as outlined in the EIS, and are summarised below:

- Specific modifications to Project component locations and designs that will reduce potential effects to crabs, including the following:
    - Placement of terminal in subtidal waters (EIS Section 12.7.1.1); and
    - Reduced footprint of causeway widening (EIS Section 12.7.1.1);

- Implementation of construction and operation environmental management plans related to the following:

    - Construction work windows (EIS Section 12.7.1.2) and crab salvages around key crab life cycle windows and to relocate gravid female crabs (EIS Section 33.3.12);
    - Water quality and sediment management (EIS Section 12.21.24); and
    - Communications to include information about the timing and area of proposed construction and operational navigational closure expansion for commercial and recreational crab harvesting, and information about access restrictions and procedures for maintenance of safety commercial, recreational, and Aboriginal crab harvesting activity (EIS Section 33.3.16); and

- Offsetting effects by the creating habitat, including eelgrass, intertidal marsh, mudflat, and sandy gravel beach to mitigate adverse effects to the productivity of crab populations and associated crab fisheries (including commercial, recreational, and Aboriginal) (EIS Section 17.5).

In addition to these mitigation measures, the VFPA also committed to work with DFO to consult with commercial and Aboriginal crab harvesters to do the following (EIS Section 21.8.1):

- Communicate timing and spatial area of proposed navigational closure expansion for commercial crab harvesting;
- Communicate access restrictions and procedures for maintenance of safety for commercial crab harvesting activity;
- Provide a process for commercial crab harvesters and Aboriginal groups to ask questions and submit concerns about the proposed navigational closure expansion and associated displacement of commercial crab harvesting; and
- Where identified and agreed upon through this consultation process, the VFPA will work with DFO, commercial crab harvesters, and Aboriginal groups to implement additional mitigation measures (EIS Section 21.8.1).

Consultation is currently ongoing with commercial and Aboriginal crab harvesters and through this process, additional mitigation measures have been identified related to commercial crab harvesting (in addition to those presented in Section 21.8 and Table 21-7 of the EIS). The suggestions received since the EIS was submitted are summarised in **Table IR7-34-1** below.

The evaluation of additional mitigation measures is being informed by consultation with commercial crab harvesters (including the Area I Crab Fisherman Association), Aboriginal groups, DFO, and may include other relevant regulatory agencies regarding their specific interests and concerns. Evaluation of technical and economic feasibility of the suggested measures is currently underway to inform this consultation. Technical feasibility considers the following:

- Availability, applicability, and effectiveness of the specific technology;
- Fit with local site characteristics, Project design, construction schedule;

- Applicable regulatory frameworks; and
- Whether implementation is within the VFPA's jurisdiction.

Economic feasibility considers the following:

- Scope of the Project design (Project re-design not required);
- Construction schedule (Project construction delay not required); and
- Total cost of implementation of each measure during construction and/or operation.

Table IR7-34-1 Additional Mitigation Measure Suggestions Relevant to Commercial Crab Harvesting Under Review

Additional Mitigation Measures Under Review	Description of Additional Mitigation Measures
Request for removal of intermediate transfer pit (ITP)	As a result of work undertaken in 2017 to address Tsawwassen First Nation and regulator concerns and reduce the Project's environmental effects, including those effects related to crab, the VFPA has determined that the use of the ITP for temporary storage is no longer required to support construction of the Project. **COMPLETE: ITP removed from Project components (Post-EIS Submission).[1]**
Crab Management Area re-selection opportunity	Create an arrangement with DFO to provide Area I commercial crab harvesting licence holders with the opportunity to re-select their management area prior to the establishment of the Roberts Bank proposed navigational closure area expansion. The intent would be to create re-selection opportunities prior to commencement of construction and operation phase, which could potentially be outside of the typical three-year re-selection time period. Status: Undergoing consultation and evaluation.
Adjustment of proposed navigational closure area expansion with consideration of commercial harvesting during Project operations	Request by commercial crab harvesters to reduce the size of the proposed navigational closure area expansion to support continued use of some of the areas where higher crab harvesting activity and harvest landings occur for commercial crab harvesting. Evaluation of this suggestion includes consideration of safety, biophysical benefits, commercial, recreational, and Aboriginal crab harvesting areas, and DFO fisheries management policies. Status: Undergoing consultation and evaluation.
Adjustment of the proposed navigational closure area expansion with consideration of Aboriginal harvesting during operations	Through the independent panel review process, Tsawwassen First Nation submitted a study titled "Dungeness Crab Abundance and Movement Study in the Roberts Bank Terminal 2 Project Area (March 2018)" (CEAR Document #997). The study indicated that additional measures may be required to mitigate the loss of food, social, and ceremonial (FSC) crab fishing area due to the Project and ensure access to the resource, without competition with the commercial fishery. Further discussion with Tsawwassen First Nation and analysis is underway related to this study. Status: Undergoing consultation and evaluation.

[1] See *Preamble in Support of Responses to IR3-25 to IR3-40* of CEAR Document #984 for more information.

Additional Mitigation Measures Under Review	Description of Additional Mitigation Measures
Navigational Limited Access Fishing Area (multi-user system during operations)	Proposal to establish a Navigational Limited Access Fishing Area in area where tug assisted container vessel movements occur (proposed expansion of the navigational closure area), to allow crab fishing (including commercial) with no floats. An adjacent float zone would allow commercial harvesters to access traps within the closure. A notification mechanism (e.g., transit light or phone app notification) would be created to indicate to commercial harvesters when harvesting is not allowed within the navigational closure area due to incoming and/or outgoing container terminal vessel traffic. Status: Undergoing consultation and evaluation.
Financial compensation	Compensation measures have been raised, including the purchase of Area I crab harvesting license(s) and/or financial compensation of Project effect on crab harvest landings/revenues. Status: Undergoing consultation and evaluation.

Provide information about the engagement activities held to date with stakeholders and Indigenous groups that could be affected by the proposed expansion of the navigational closure and displacement from crab harvest areas.

Pre-EIS Engagement Activities Regarding Commercial Crab Harvesting

Interviews and workshops were conducted during development of the EIS with representatives from the commercial fish and seafood harvesting industry, including Area I Crab Fisherman Association, regulatory agencies (including DFO), and Aboriginal groups, to clarify information obtained through secondary sources and to gather further information on commercial crab harvesting activity. Information gathered through these interviews, workshops, and meetings is reflected in Sections 21.5.1.1, 21.5.2.1, and Appendices 18-A and 18-B of the EIS. The interviews specifically sought information to assist in identifying marine commercial use interests and concerns related to the Project and potential mitigation measures to address Project effects on commercial crab harvesting. Information received addressed trends in harvest activity, including harvest volume, harvest location, and concerns related to the Project and commercial crab harvesting.

Representatives from the following organisations, Aboriginal groups, and regulatory agencies were involved in pre-EIS engagement activities:

- Commercial crab harvesters: Discussions with Crab Management Area (CMA) I commercial harvesters on crab productivity, location of harvest, seasonality, the existing closure area, harvest trends, and concerns with the proposed Project;
- Representatives from individual Aboriginal groups with CMA I Commercial Crab Licences, including Tsawwassen First Nation, Musqueam First Nation, and Tsleil-Waututh Nation;
- Aboriginal groups: Engagement on valued components of the EIS, existing conditions, and preliminary results pertaining to marine commercial use and commercial crab

harvesting. Meetings were held with individual Aboriginal groups as well as in large group engagement workshops, with invitations extended to all identified Aboriginal groups[2] (EIS Guidelines, January 7, 2014);
- Regulatory agency: Meetings with DFO, as the regulatory agency responsible for management of the commercial crab fishery. Information received from DFO on the proposed navigational closure expansion, and discussion on commercial crab openings, harvesting areas and access, and harvest trends; and
- Recreational crab harvester and public consultation: See response to IR7-43.

Post-EIS and Ongoing Engagement Activities Regarding Commercial Crab Harvesting

The VFPA is committed to continue working with DFO, commercial crab harvesters, and Aboriginal groups to share information and provide opportunities for questions and discussion.

A summary of consultation and engagement activities that have been undertaken post-EIS submission and are ongoing with the following stakeholders, Aboriginal groups, and regulatory agencies is provided below:

- Commercial crab harvesters: Meetings with Area I Crab Fisherman Association directors to discuss mitigation options, access of additional electronic monitoring data, and additional data analysis (as presented in responses to IR7-33 and IR7-35);
- Individual Aboriginal groups with CMA I Commercial Crab Licences, including Tsawwassen First Nation, Musqueam First Nation, and Malahat Nation;
- Aboriginal groups:
    - Meetings and workshops with the *W̲SÁNEĆ* to discuss additional input (*Additional Information to the Environmental Impact Statement – W̲SÁNEĆ Nation*, CEAR Document #930[3]);
    - Invitations to post-EIS meetings and workshops extended to all identified Aboriginal groups[4] (Updated EIS Guidelines, April 17, 2015) to review EIS results and obtain input on potential mitigation measures to address Project effects, which included effects on commercial crab harvesting;
    - Meetings held with individual Aboriginal groups where individuals or administration has expressed an interest in further discussion regarding commercial crab harvesting; and
    - RBT2 Follow-up Program planning workshops with Aboriginal groups;

[1] Tsawwassen First Nation, Musqueam First Nation, Semiahmoo First Nation, Tsleil-Waututh Nation, Stz'uminus First Nation, Cowichan Tribes, Halalt First Nation, Lake Cowichan First Nation, Lyackson First Nation, Penelakut Tribe, Métis Nation British Columbia, Hwlitsum.
[3] CEAR Document #930 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Additional Information on the WSÁNEC Nation requested by the Canadian Environmental Assessment Agency on January 13, 2016 (See Reference Document #383).
[4] Tsawwassen First Nation, Musqueam First Nation, Semiahmoo First Nation, Tsleil-Waututh Nation, Stz'uminus First Nation, Cowichan Tribes, Halalt First Nation, Lake Cowichan First Nation, Lyackson First Nation, Penelakut Tribe, Métis Nation British Columbia, Hwlitsum, Tsawout First Nation, Pauquachin First Nation, Tsartlip First Nation, Tseycum First Nation, Malahat First Nation.

- Regulatory agency: Discussions with DFO regarding consultation activities with crab harvesters and evaluation of suggested additional mitigation measures; and
- Recreational crab harvesters and public consultation: See response to IR7-43.

IR7-35 Marine Commercial Use – Crab Harvesting

Information Source(s)

EIS Volume 4: Section 21; Section 21.9.2; Section 21.10.1

CEAR Doc#611

Context

The Proponent, in Section 21.9.2 of the EIS, reported that crabs are known to move substantial distances toward baited traps, and experience with the navigational closure established in 2009 at Roberts Bank resulted in commercial crab harvesters concentrating activities along the open area at the western boundary of the newly closed area. The Proponent further reported in the EIS that although crabs are known to move toward baited traps, bait detection and response field research was not undertaken for this assessment in relation to the situation associated with the proposed navigational closure area expansion, including effects of factors such as local currents, distance between the proposed new and current western boundaries of the closure area, and depth of waters near the proposed new western boundary.

The Proponent, in Section 21.10.1 of the EIS, predicted that adverse residual effect on changes in commercial use crab area, harvest, and revenue associated with the expanded navigational closure area was not significant based on:

- the capacity for crabs to migrate over considerable distances; and
- the potential for crab harvesters to move to other areas of the local assessment area, or to another open crab harvesting area within Crab Management Area I, or to another crab management area.

According to the Area I Crab Fisherman Association in CEAR Doc#611, the proposed Project footprint and the proposed expansion of the area closed to commercial crab harvesting will result in significant adverse residual effects to commercial crab harvesting revenues, and displaced commercial crab harvesters will be forced into other crowded areas within Area I and possibly into other adjacent commercial crab license areas.

Information Request

Provide information to support the following assertions from Section 21 of the EIS:

- Dungeness Crabs are known to move substantial distances to baited traps;
- Dungeness Crab migration behavior within the proposed navigational commercial crab fishing exclusion zone would suffice to repopulate adjacent crab fishing areas in the local assessment area during the commercial crab fishing season between June 15 - November 30; and
- displaced crab harvesting activity from the navigational closure area as a result of the proposed Project can shift to an open area in the local assessment area, or to another

open crab harvesting area within Crab Management Area I, or to another Crab Management Area.

VFPA Response

Provide information to support the assertion from Section 21 of the EIS that Dungeness crabs are known to move substantial distances to baited traps.

The following information supports the understanding of Dungeness crab movements, including movement with baited traps:

- A study completed by Holsman et al. (2006) that included telemetric observations of sub-adult Dungeness crab movements showed, in a number of cases, individual crabs repeatedly migrating more than 1.2 km round trip; and
- Studies by Stone and O'Clair (2001) show Dungeness crabs migrate several hundred metres in one tidal cycle in order to feed on preferred prey and remain within suitable habitat.

In addition to the above studies, during preparation of Section 21.0 of the EIS, DFO indicated they anticipate crabs would migrate from the area of the proposed navigational closure expansion to traps outside of the proposed expansion area (DFO 2014).

Since submission of the EIS, a study on Dungeness Crab Abundance and Movement in the Roberts Bank Terminal 2 Project Area (LGL Ltd. 2017) included an analysis of movement rates and distances for anchor tagged and acoustically tagged male Dungeness crabs. Anchor and acoustic tagged crabs were recovered throughout the study area, as well as by food, social, and ceremonial (FSC) fishers and commercial fishers, with both fisher groups generally using baited traps to harvest crab. The results of the study indicated the following:

- Movement distances of anchor tagged males were variable, ranging from 113 m to 4,896 m (with distance values not accounting for time elapsed between observations), and daily movement distances ranged from 4.9 m to 816.6 m per day;
- The spatial distribution of anchor tag recoveries showed that the majority of males were recovered outside the existing navigational closure (2009 Closure) by the commercial fishery. Of the tags recovered outside the existing navigational closure, the majority were initially tagged within the 2009 Closure; and
- Total movement distance of observed acoustically tagged males ranged from 162 m to 5,298 m over a 2-month mobile tracking period, and daily movement distances ranged from 2.7 m to 2,338.0 m per day.

The above results indicate that in the Roberts Bank area, Dungeness crabs move variable distances, with daily and longer term range distances being substantial in some cases.

Provide information to support the assertion from Section 21 of the EIS that Dungeness crab migration behaviour within the proposed navigational closure expansion would suffice to repopulate adjacent crab fishing areas in the local assessment area during the commercial crab fishing season between June 15 to November 30.

Based on information discussed above, some migration of harvestable crabs will occur from inside the proposed navigational closure expansion to the adjacent harvesting areas, as well as to other areas within the local assessment area (LAA). These crab movement patterns will occur throughout the year, including during the commercial crab harvesting season. Also, as indicated in Section 12.6.3.3 of the EIS, the local Dungeness crab population is sustained by larvae originating over large geographical distances (metapopulation), and it is expected that this will continue to replenish the population in the LAA under Project conditions, including harvesting areas adjacent to the proposed navigational closure expansion.

With respect to the Project, the following proposed mitigation measures (as described in Section 12.7 of the EIS) to address Project effects on crab mortality and productivity loss (as described in Section 12.6.2 and 16.6.1 of the EIS) would further support productivity of the Dungeness crab population in the LAA, including in harvesting areas adjacent to the proposed navigational closure expansion:

- Fisheries sensitive timing window for the protection of gravid female Dungeness crabs, preventing works from occurring below −5 m chart datum (CD) between October 15 to March 30;
- Crab salvages to capture and relocate individual crab to nearby suitable areas;
- Attracting juvenile crab to intertidal areas adjacent to, but not affected by, the Project; and
- Onsite habitat offsetting through creation of eelgrass beds.

As described in Section 12.8 of the EIS, with proposed mitigation, residual Project effects on Dungeness crab productivity loss within the LAA (which includes the harvesting areas adjacent to the proposed navigational closure expansion) are considered to be within the range of natural variability and will not affect Dungeness crab population integrity or function in the LAA, and therefore will not be significant.

Based on the above, and as indicated in Section 21.7.1 of the EIS, the Project would not affect the availability of eligible male crabs for commercial harvest in the LAA.

Provide information to support the assertion from Section 21 of the EIS that displaced crab harvesting activity from the proposed navigational closure expansion can shift to an open area in the local assessment area, or to another open crab harvesting area within Crab Management Area I, or to another Crab Management Area.

DFO directs the total number of commercial crab licences for the Pacific region, and since 2000 the total number of crab fishing licences has been set at 222 licences. The commercial crab fishery in the Pacific region is divided into seven crab management areas (CMAs). Each licence holder can operate in only one CMA but is allowed to harvest anywhere within their

designated CMA during designated commercial crab harvesting seasons (with the exception of temporary and fixed closures as managed and updated by DFO). As per DFO crab harvesting management regulations, CMA I (the CMA where the Project is located) licence holders can legally harvest anywhere in CMA I, including anywhere in the LAA.

DFO regulates and manages licence re-selections, which occur every three years, and DFO confirms the assignment of the crab licences to the selected areas. Licence holders choose their CMA for a three-year period. DFO has indicated that the next CMA selection process (whereby licensed commercial crab vessels choose one CMA to fish in) will likely commence in the summer of 2018 for implementation on April 1, 2019, and will likely be for a period not less than three years (DFO 2017).

A review of electronic monitoring data from 2006 to 2015, as discussed in detail in IR7-33, indicated that after the 2009 Closure was implemented, commercial crab harvesters who were harvesting at Roberts Bank prior to the closure continued to harvest in the area immediately to the west of the closure, as well as the broader outer slopes of Roberts Bank and northward (see IR7-33 for further details and figures).

As indicated in Sections 21.7.5 and 21.10.2 of the EIS, and supported through the review of the commercial crab harvester response to the 2009 Closure (through analysis of the CMA I electronic monitoring data in IR7-33), it is reasonable to assume that commercial crab harvesters who have been harvesting in the proposed navigational closure expansion would re-establish some portion of their harvesting activities in the open area along the western boundary of the proposed navigational closure expansion and elsewhere in CMA I, or they may choose to re-select their CMA during a future re-selection period.

References

Holsman, K. K., P. S. McDonald, and D. A. Armstrong. 2006. Intertidal Migration and Habitat Use by Subadult Dungeness Crab *Cancer magister* in a NE Pacific Estuary. Available at www.int-res.com/articles/meps2006/308/m308p183.pdf. Accessed December 2017.

Fisheries and Oceans Canada (DFO). 2014. Personal Communication (Interview). Interview between DFO and Golder Associates Ltd on July 14, 2014.

Fisheries and Oceans Canada (DFO). 2017. Pacific Region Integrated Fisheries Management Plan Crab by Trap, January 1st, 2017 to March 31st, 2018. Available from Fisheries and Oceans Canada.

LGL Ltd. 2017. Dungeness Crab Abundance and Movement Study in the Roberts Bank Terminal 2 Project Area. Prepared by LGL Ltd. for Tsawwassen First Nation.

Stone, R. P. and C. E. O'Clair. 2001. Seasonal Movements and Distribution of Dungeness Crabs Cancer magister in a Glacial Southeastern Alaska Estuary. Available at www.int-res.com/articles/meps/214/m214p167.pdf. Accessed December 2017.

IR7-36 Outdoor Recreation – Baseline and Effects Assessment

Information Source(s)

EIS Guidelines: Section 9.1.8

EIS Volume 4: Section 24.2; Appendix 18-A; Appendix 18-B

Context

The Updated Guidelines for the Preparation of the Environmental Impact Statement stated that, with respect to Indigenous groups potentially affected by the proposed Project, the EIS will include recreational uses of the Project area.

The Proponent, in Section 24.2 of the EIS, reported that Indigenous groups were consulted in the preparation of the outdoor recreation effects assessment. Only Tsawwassen First Nation and Musqueam First Nation provided comments to the Proponent on outdoor recreation for its preparation of the EIS. This information is found in Appendices 18-A and 18-B. There was no specific information reported in the EIS about potential Project effects on outdoor recreational activities undertaken by other Indigenous groups.

Information Request

Provide information about the outdoor recreational activities of Indigenous groups - other than Tsawwassen First Nation and Musqueam First Nation - in the outdoor recreation local assessment area and the regional assessment area. For each relevant recreational activity, include information about the level of use, frequency of activity and number of users.

Evaluate any potential effects from the proposed Project on those outdoor recreational activities.

VFPA Response

Provide information about the outdoor recreational activities of Indigenous groups - other than Tsawwassen First Nation and Musqueam First Nation - in the outdoor recreation local assessment area and the regional assessment area. For each relevant recreational activity, include information about the level of use, frequency of activity and number of users.

Other than information on outdoor recreational activities carried out by Tsawwassen First Nation, no other outdoor recreation activities carried out specifically by other Aboriginal groups in the local and regional assessment areas (LAA and RAA) were identified through the preparation of the EIS or the Additional Information to the EIS – *WSÁNEĆ* Nation (AIEIS), which incorporates *WSÁNEĆ* Nation Aboriginal groups. In accordance with section 9.1.8 of the Updated EIS Guidelines, various processes were applied to obtain information on outdoor recreational activities from Aboriginal groups for the EIS and the AIEIS, as described below.

Review of Secondary Information Sources

Identification and review of available secondary sources on outdoor recreational activities within the LAA/RAA for the general Aboriginal population, as well as specific Aboriginal groups was undertaken. No specific publicly-available information on outdoor recreational activities for the Aboriginal population or specific Aboriginal groups was identified.

Interviews

Interviews were held with representatives of Tsleil-Waututh Nation to gather information on outdoor recreational activities in the LAA/RAA. No outdoor recreational activities in the LAA/RAA were identified by Tsleil-Waututh Nation representatives through these interviews.

Interviews were requested by the VFPA with all *WSÁNEĆ* groups involved in the AIEIS to gather information on marine commercial use and outdoor recreation activities as part of the AIEIS data collection program for existing conditions. Tseycum First Nation and Malahat Nation accepted the invitation for this interview. The interviews included questions regarding outdoor recreational use in the LAA/RAA. No outdoor recreational activities within the LAA/RAA were identified by Tseycum First Nation or Malahat Nation during this interview.

Written Requests for Information

Written requests for information on outdoor recreational use in the LAA were sent to Métis Nation B.C., Semiahmoo First Nation, and Lyackson First Nation. No information was received back from these Aboriginal groups on outdoor recreational activities in the LAA/RAA.

Meetings and Workshops

Meetings and workshops were held with the following Aboriginal groups to present and obtain input on initial EIS findings for the existing conditions (including outdoor recreation existing conditions), preliminary Project effects assessment results, and proposed mitigation measures (including those pertaining to outdoor recreation). **Table IR7-36-1** below summarises these engagement activities.

Table IR7-36-1 Additional Engagement Activities with Aboriginal Groups on Outdoor Recreation Activities in the LAA/RAA

Aboriginal Group	Engagement Method and Date	Engagement Summary
Tsawwassen First Nation Tsleil-Waututh Nation Musqueam First Nation Hwlitsum Stz'uminus First Nation Lyackson First Nation Cowichan Tribes Penelakut Tribes Métis Nation B.C.	EIS Working Group Meetings[1]: • May 27, 2014 • June 17, 2014	No information or input received from Aboriginal groups on outdoor recreational activities in the LAA/RAA, Project effects, or mitigation measures.
Tsawwassen First Nation Tsleil-Waututh Nation Semiahmoo First Nation Musqueam First Nation Lake Cowichan First Nation Lyackson First Nation Métis Nation B.C. Hwlitsum	EIS Technical Workshops – Valued Component Identification: • June 2014 • July 2014	
Tsawwassen First Nation Tsleil-Waututh Nation Semiahmoo First Nation Musqueam First Nation Lake Cowichan First Nation Lyackson First Nation Métis Nation B.C. Hwlitsum	EIS Technical Workshops – EIS Preliminary Results: • October 2014 (four meetings)	
Tsawwassen First Nation Musqueam First Nation	Review and comment on First Nations Community Assessments: • January 2015	
Cowichan Tribes Halalt First Nation Penelakut Tribes Stz'uminus First Nation	Technical Workshops – Review of Draft EIS: • October 2014 • November 2014	

[1] Working group meetings were also held on February 25, 2014 and April 15, 2014; however, content did not pertain directly to the outdoor recreation valued component.

Aboriginal Group	Engagement Method and Date	Engagement Summary
Tseycum First Nation Tsartlip First Nation Malahat Nation Pauquachin First Nation Tsawout First Nation	Technical Workshop – Review of Draft EIS: • November 2015	No information or input received from Aboriginal groups on outdoor recreational activities in the LAA/RAA, Project effects, or mitigation measures.
Tseycum First Nation	Elders Workshop – AIEIS: • March 2016	
Tsawout First Nation Tsartlip First Nation Tseycum First Nation Malahat Nation Pauquachin	AIEIS Issues Workshop: • July 2016	
Pauquachin First Nation Tsawout First Nation Tsartlip First Nation	Emails requesting additional input – AIEIS: • April 2016	
Pauquachin First Nation Tsartlip First Nation Tseycum First Nation	Meetings to discuss additional input – AIEIS: • February 2016 • April 2016 • June 2016	
Tsawout First Nation Malahat Nation	Email with comments on the draft AIEIS • January 2017	

As indicated in EIS Section 24.2.1 and in the response to Information Request #27 (IR-7.31.15-27 of CEAR Document #314[2]), while certain Aboriginal traditional cultural activities such as canoeing, hunting, fishing, and gathering may be viewed as having recreational benefit or attributes, these activities are pursued for traditional purposes. Descriptions of these and other traditional cultural activities by Aboriginal groups and potential Project effects on these and other cultural activities are described in EIS Section 32.2 and AIEIS Section 7.0 (and not EIS Section 24.0 (Outdoor Recreation Effects Assessment) and AIEIS Section 4.0 (Outdoor Recreation Effects Assessment)).

No outdoor recreational activities occurring in the LAA/RAA (that were not identified as pursued for traditional purposes) were identified by Aboriginal groups through implementation of secondary and primary data collection and engagement processes for EIS and AIEIS as described above (with the exception of outdoor recreation activities carried out by

[2] 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.

Tsawwassen First Nation Members as described in in EIS Sections 24.5.4.3 and 24.5.5 as well as EIS Appendix 18-A).

Evaluate any potential effects from the proposed Project on those outdoor recreational activities.

As described in the response to IR-7.31.15-27 (CEAR Document #314), based on the information received on outdoor recreational activities by Aboriginal groups, the outdoor recreation existing conditions identified in EIS Section 24.5 and AIEIS Section 4.0 are presented for, and assumed to be reflective of, the general population, which includes members of Aboriginal groups who may engage in these outdoor recreational activities in the LAA.

A minor potential effect of the Project was identified for changes in recreational crab harvesting area use, access, and displacement from the area of the Project terminal footprint and proposed expanded navigational closure areas, prohibiting recreational crab harvesting in these areas during construction and operations, as indicated in EIS Section 24.6.5.2. The identified Project effect on recreational crab harvesting would affect members of the general population who may engage in these outdoor recreational activities in the LAA. No recreational seafood harvesting activities connected with specific Aboriginal groups were identified through the above data collection and consultation and engagement process.

IR7-37 Outdoor Recreation – Baseline

Information Source(s)

EIS Guidelines: Section 9.1.7

EIS Volume 4: Section 24.5.4.1; Figure 24.1; Section 24.5.4.2

Context

The Proponent, in Section 24.5 of the EIS, reported the following types of activities on recreational trails in the local assessment area:

- Walking and running;
- Cycling; and,
- Horseback riding.

Indication was given that Brunswick Point is a popular birding location in the local assessment area and the existence of the Delta Nature Casual Birding Club, a local naturalist club, and its activities was also mentioned. There was no information provided on the use of the trail by its members or the general public. According to the Proponent, data on the levels of trail use was not available at the time of the assessment.

Information about land-based outdoor recreational activities within the local assessment area - with respect to frequency of use by activity type and the number of trail users for each activity type - is required.

Information Request

Provide information on the levels of trail use within the local assessment area, especially the Brunswick Point/Dyke-Great Blue Heron trail, including bird watching. Include data on number of users, and the frequency of each type of activity (for example, bird watching and horseback riding).

VFPA Response

The main trails identified in the local assessment area (LAA) include the Brunswick Point Trail and the Tsawwassen Outer Dyke (also referred to as Great Blue Heron Trail), as indicated in Section 24.5.4.1 of the EIS. In addition to these two trails, the Brunswick Point Trail connects to inland farm roads, and the Tsawwassen Outer Dyke connects to inland road networks, enabling users to undertake circular routings. As indicated in EIS Section 24.5.4.1, the beach area adjacent to the Tsawwassen waterfront is also used by dog walkers and for bonfires.

At the time of writing the EIS, the VFPA undertook a secondary data search of publicly available information sources on use levels at the Brunswick Point Trail and Tsawwassen Outer Dyke, as well as the Tsawwassen Beach. Information sources included local planning

documents, local user group websites and reports, City of Delta (formally the Corporation of Delta) website and municipal documents, and Tsawwassen First Nation key planning documents and reports (see EIS Section 24.11 for a full list of references). A review of public sources indicated secondary information on use levels for these trails was not available.

The City of Delta (Delta) is the owner/administrator of the Brunswick Point Trail, while Tsawwassen First Nation is the diking authority responsible for the maintenance of the Tsawwassen Sea Dike where the Tsawwassen Outer Dyke trail is located. During preparation of the EIS, the VFPA contacted Delta, and held in-person interviews with Tsawwassen First Nation representatives to inquire whether trail use information had been gathered for the Brunswick Point Trail and Tsawwassen Outer Dyke. Follow-up consultations were also held with Delta and Tsawwassen First Nation to review and obtain input on draft EIS findings, including outdoor recreation trail use. Through these engagement processes, Delta and Tsawwassen First Nation confirmed that trail use counts had not been gathered for these trails.

In August 2017, the VFPA renewed their requests to Delta and Tsawwassen First Nation inquiring if any trail use information had been gathered subsequent to the previous request in 2014. On September 6, 2017, Delta provided to the VFPA a letter written by Urban Systems on January 31, 2014 describing the potential options of improving safety related to pedestrian and bicycle crossing conditions at Deltaport Way and the sea dyke (on Tsawwassen First Nation Lands). The letter references a pedestrian count at the sea dyke at Deltaport Way that identified 400 people walking and cycling. The letter does not indicate what time of year this count was completed or over how many days the study was undertaken. Follow-up requests were made to Urban Systems to better understand the estimate; however, no response has been received to date.

Also, on August 30, 2017, Tsawwassen First Nation provided the VFPA with a copy of their Internal Roads Analysis Report which provides details around their future plans for a multi-use trail, Great Blue Heron Way, but does not include trail use or count information.

To further understand trail use in the LAA, the VFPA commissioned trail use surveys of the Brunswick Point Trail and the Tsawwassen Outer Dyke Trail in summer and fall of 2017.

Provide information on the levels of trail use within the local assessment area, especially the Brunswick Point/Dyke - Tsawwassen Outer Dyke, including bird watching. Include data on number of users, and the frequency of each type of activity (for example, bird watching and horseback riding).

Survey Results

A summer use survey (August 31 to September 2, 2017) and a winter use survey (November 18, 2017) were conducted for the Brunswick Point Trail, at the entrance to the trail. A winter use survey was conducted at the Tsawwassen Outer Dyke on November 18, 2017 at the three entrances to the trail. Both surveys were conducted during daylight hours; in summer, the duration was from 7:30 am to 7:30 pm and during the winter, survey duration was from 7:30 am to 4:30 pm. The results of the surveys are provided in **Table IR7-37-1**.

The summer survey was held on a Thursday and a Saturday to capture summer use on both a weekday and weekend. The weather on both days was sunny and warm. As summertime is the low season for bird watching on the Brunswick Point Trail, a winter survey was completed in November to capture the use associated with peak bird watching season, when raptors and waterfowl have arrived on their wintering range. The weather on the winter survey day was clear and cool, with no rain.

Table IR7-37-1 Number of Trail Users

	Summer Weekday Survey August 31, 2017 Brunswick Point Trail	Summer Weekend Survey September 2, 2017 Brunswick Point Trail	Winter Weekend Survey November 18, 2017 Brunswick Point Trail	Winter Weekend Survey November 18, 2017 Tsawwassen Outer Dyke
Total Counted (no. of people)	78	91	101	56
Number of Parties Surveyed	41	49	45	33
Average Size of Party (no. of people)[a]	1.7	1.5	1.8	1.5
Main Activity (no. of parties):				
Biking	8	9	2	4
Walking/Running	24	16	14	4
Dog Walking	7	11	14	25
Hunting	0	2	9	0
Bird Watching or Photography	0	6	5	0
Horseback Riding	0	2	0	0
Other	2	3	1	0

Note: a. Average size of party was calculated from the Number of Parties Surveyed data set (and not Total People Counted data set).

Brunswick Point Trail Survey Result Summary

The results of the summer survey at Brunswick Point indicated the most common trail uses were walking or running (44.4%) and dog walking (20.0%), followed by biking (18.9%). During the winter, walking (31.1%), dog walking (31.1%), hunting (20.0%), and bird watching or photography (11.1%) were the most popular activities. The majority of trail users interviewed during the Brunswick Point Trail summer survey indicated they use the Brunswick Point Trail at least once a week. Close to 50% of the parties interviewed for the summer survey indicated they use the trail at least once a week, and 15% indicated they use the trail every day (**Table IR7-37-2**). By comparison, 38% of parties interviewed in the winter survey on the Brunswick Point Trail indicated they use the trail at least once a week, with a

substantially higher percentage of winter trail users indicating they only use the trail a few times a year. Winter weather, combined with short timing windows for migratory bird viewing and regulated bird hunting season open dates (which are approximately early September through March), influence less frequent and more seasonally dependent trail use during the winter. In addition, some regular trail users interviewed over the summer indicated they tend to use the trail less in the winter, as they are not comfortable using the trail when hunting is occurring (**Table IR7-37-2**).

Table IR7-37-2 Frequency of Trail Use

	Summer Weekday Survey August 31, 2017 Brunswick Point Trail	**Summer Weekend Survey September 2, 2017 Brunswick Point Trail**	**Winter Weekend Survey November 18, 2017 Brunswick Point Trail**	**Winter Weekend Survey November 18, 2017 Tsawwassen Outer Dyke**
How Often User Uses Trail (no. of parties):	n = 40	n = 48	n = 45	n = 33
Daily	8	5	4	10
A few times a week	12	13	7	15
Once a week	3	2	6	1
A few times a month	4	10	4	4
Once a month	4	4	9	1
A few times a year	3	7	11	1
Today is my first visit	6	7	4	1

Bird watching is known to be a common activity on the Brunswick Point Trail, particularly during peak bird viewing season, which takes place later into the fall / early winter when snow geese and other migratory birds are migrating through the area. Five individuals interviewed during the Brunswick Point winter survey indicated bird watching was their primary activity; however, several users also noted that while their primary activity was dog walking, they were also bird watching.

Tsawwassen Outer Dyke Survey Result Summary

At the Tsawwassen Outer Dyke, dog walking was the most prevalent activity (75.8%), followed by walking or running (12.1%) and biking (12.1%). No other trail uses were observed. Based on survey responses, trail use on the Tsawwassen Outer Dyke appears to be less seasonal, with many of the trail users responding that they use the trail multiple times a week, all year round, for routine activities such as walking and dog walking. Over 75% of parties interviewed on the Tsawwassen Outer Dyke indicated they are regular trail users, accessing the trail more than once a week (**Table IR7-37-2**). Only two parties indicated they use the trail less than once a month, and the party who indicated this was their first visit

indicated they intend on accessing the trail more in the future. Nearly 80% of parties interviewed indicated they use the trail with the same frequency year-round, while the six of the remaining seven parties indicated higher trail use in the spring and summer. This is consistent with the observation of the high percentage of regular dog walkers, as dogs need to be walked year-round, regardless of the weather.

The trail survey results support land-based outdoor recreation existing conditions information as presented in Section 24.5.4 of the EIS, and do not alter the Project effects assessment results as presented in EIS Section 24.6.4.

IR7-38 Outdoor Recreation – Tsawwassen First Nation Recreational Boating, Effects and Mitigation

Information Source(s)

EIS, Volume 4: Section 24.5.5; Section 24.6.1, Table 24-5; Appendix 18-A, Section 8.1

Context

The Proponent estimated that by 2030 there would be an increase of 172 large vessels movements per year at the Roberts Bank terminals compared to 2012, in addition to the 520 movements from the proposed Project. According to the Proponent in Section 24.6.1 of the EIS, recreational boaters accessing the local assessment area via Canoe Passage may have to travel around the Project footprint, which would require more travel time and fuel, but the Project would not prevent access or use. The Proponent also reported that recreational vessels would have to change speed or direction to avoid collision when traversing the local assessment area and predicted that the Project-induced change to access and navigation for recreational use is expected to be negligible for construction and operation.

The Proponent, in Appendix 18-A of the EIS, reported that Tsawwassen First Nation have an ocean-going canoe used for ocean and river journeys. According to the Proponent, the canoe is launched from the beach on the south side of the Ferry causeway, and the team paddles to Canoe Pass for river based journeys. As reported by the Proponent, the canoe skipper must follow a path that avoids the shallow waters of Tsawwassen First Nation community as well as the busy vessel traffic. Presently, the route traverses through the footprint of the Project.

Concerns were expressed by Tsawwassen First Nation about the safety of the canoe team with the increase in vessel traffic due to the Project.

More information about the potential effects of increased vessel traffic on Tsawwassen First Nation recreational boaters (canoeing) and the proposed mitigation measures is required.

Information Request

Describe the measures, other than the proposed communication advisories, that would be applied to mitigate the effects of the proposed Project on recreational boating and provide the anticipated effectiveness of the proposed mitigation measures.

Provide an assessment of the residual effects of increased marine vessel traffic from the Project on Tsawwassen First Nation recreational boating (canoeing) after the implementation of the above mitigation measures. Include information about the safety of the users and the necessary changes to the route presently used.

If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect on Tsawwassen First Nation recreational boating (canoeing) and the likelihood that the effect would occur.

VFPA Response

Clarification

The Tsawwassen First Nation canoeing described in EIS Appendix 18-A was assessed in EIS Section 32.0 (Potential or Established Aboriginal and Treaty Rights and Related Interests, including Current Use of Lands and Resources for Traditional Purposes).

Describe the measures, other than the proposed communication advisories, that would be applied to mitigate the effects of the proposed Project on Tsawwassen First Nation canoeing and provide the anticipated effectiveness of the proposed mitigation measures.

As described in EIS Section 32.2.7, mitigation measures to address potential effects on access to Tsawwassen First Nation's preferred Current Use locations, including Tsawwassen First Nation's canoe journeys through the Project area to and from Canoe Passage, and on the canoers' safety during these journeys as a result of increased marine vessel traffic, are as follows:

- The VFPA and Tsawwassen First Nation have a Memorandum of Agreement to accommodate Tsawwassen First Nation for effects from the Project;
- The VFPA will implement the mitigation measures set out in EIS Section 26.0 that are intended to reduce potential disturbance to marine access to Tsawwassen First Nation community lease lands (i.e., Tsawwassen Water Lots identified in Appendix F-2 of the *Tsawwassen First Nation Final Agreement*) associated with Project-related vessel traffic during construction;
- The VFPA will develop a communications protocol to inform appropriate Aboriginal groups of events related to Project construction or operation that may affect Tsawwassen First Nation's ability to canoe in the project area; and
- The VFPA will develop and implement a communications mechanism that will support dialogue between the VFPA and appropriate Aboriginal groups on topics of concern that arise during the construction phase and initial operation phase, including Project status, safety issues, effectiveness of mitigation programs, and sharing of information from environmental monitoring and follow-up programs.

The combination of the existing accommodation agreement with Tsawwassen First Nation, the measures set out in EIS Section 26.0, and the communications protocol and mechanism identified above are expected to be effective at addressing planned and unforeseen events that may interfere with access to and quality of experience (e.g., safety) at marine locations for Current Use purposes (other than crab harvesting), including canoe journeys. With the implementation of these measures, residual Project-related effects on Current Use access and quality of experience were therefore predicted in EIS Section 32.2.7 to be negligible (i.e., not measurable or detectable) and were not assessed further.

Provide an assessment of the residual effects of increased marine vessel traffic from the Project on Tsawwassen First Nation canoeing after the implementation of the above mitigation measures. Include information about the safety of the users and the necessary changes to the route presently used. If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect on Tsawwassen First Nation canoeing and the likelihood that the effect would occur.

As described above (following EIS Section 32.2.7), with the application of mitigation, residual effects of the Project on Current Use access to and quality of experience at marine locations for Tsawwassen First Nation's canoe journeys were predicted to be negligible, and therefore were not assessed further.

IR7-39 Outdoor Recreation – Beach Access, Clarification

Information Source(s)

EIS Volume 4: Section 24.5.4.3; Figure 24.4

CEAR Doc #654

Context

In Section 24.5.4.3 of the EIS, the Proponent indicated that the south side of the Roberts Bank causeway (east facing, inter-causeway side), is a popular place for dog walking and bonfires. The area is used both by Tsawwassen First Nation members and the broader community.

According to Metro Vancouver in CEAR Doc #654, the public presently has access to a beach along the existing Roberts Bank causeway.

Information Request

Indicate if the public will be restricted from accessing the beach and shoreline along the causeway (east facing, inter-causeway side) during construction or operation of the proposed Project.

VFPA Response

Public access to the beach and shoreline along the causeway is not expected to be restricted during Project construction or operations.

IR7-40 Outdoor Recreation – Recreational Trail, Mitigation

Information Source(s)

EIS Volume 1: Section 4.1.2

EIS Volume 4: Section 24.5.4.1; Section 25.5.5; Appendix 18-A, Section 8.2

CEAR Doc#996: Section 7.2.3

Context

The Proponent, in Section 24.5.4.1 of the EIS, noted that the trail used for walking, running, cycling and horseback riding runs from Brunswick Point to the base of the Roberts Bank causeway, at which point the trail becomes the Great Blue Heron Way trail on Tsawwassen First Nation lands. According to the Proponent, on its western end, the Brunswick Point trail connects to River Road West allowing riders to continue onto Westham Island, Ladner or other parts of Delta.

The Tsawwassen First Nation Neighbourhood Plan (CEAR Doc#996) indicated its intention to have the Great Blue Heron Way as a multi-purpose trail on the eastern end of the trail. Tsawwassen First Nation's vision is for a safe pedestrian and bicycle route strengthening Tsawwassen First Nation's connection with other First Nations and neighbouring communities, such as Delta, the USA border, Boundary Bay and the islands accessible through the Tsawwassen Ferry Terminal. Further, it will identify cultural and heritage sites.

The Deltaport Causeway transects this trail mid-way. In order to access the second half of the trail, recreational users must cross both the Deltaport Causeway and the railroad tracks. The crossings have the required safety precautions for highway and rail rights of way. However, there is no marked crossing for recreational users. Tsawwassen First Nation expressed concerns regarding the safety of users crossing tracks at unmarked crossings and the limited visibility of incoming trains in the vicinity of the dyke trail.

In Section 4.1.2 of the EIS, the Proponent stated that the causeway widening would require a new land area of approximately 42.4 hectares, including slope and toe of slope at the seabed, for additional rail, road and utility requirements. At the east end of the causeway, rail infrastructure would extend eastward 450 m in a narrow strip of approximately one hectare on the existing British Columbia Railway right-of-way for tie-in purposes to the exiting mainline rail network via the Roberts Bank Rail Corridor.

Information is needed about the potential loss to this trail as a result of the proposed Project and the mitigation measures needed to ensure safe access between the two sections of the trail and to respect the purpose envisioned for the planned Great Blue Heron Way.

Information Request

Provide the total area (in hectares) and the length (in kilometres) of the recreational trail that will be lost due to the proposed widening of the causeway.

Provide a description of the mitigation measures that could improve the connection between the two segments of the trail; ensure the safety of present and future trail users that will be crossing the expanded causeway; and which respects the purpose of the planned Great Blue Heron Way by Tsawwassen First Nation.

VFPA Response

Clarification

The Brunswick Point Trail and the Tsawwassen Sea Dyke Trail (also referred to as Great Blue Heron Way) are not connected as the Roberts Bank causeway and British Columbia Railway (BCR) lines are situated between the two trails. Public access to the Roberts Bank causeway and the Tsawwassen Sea Dyke via Brunswick Point Trail is currently prohibited to maintain public safety and access restrictions are enforced by BCR as per the *Railway Safety Act* (1985). Individuals who choose to access the Roberts Bank causeway from the Brunswick Point trail are doing so illegally. This restriction will remain in place with the Project.

Provide the total area (in hectares) and the length (in kilometres) of the recreational trail that will be lost due to the proposed widening of the causeway.

There will be no loss in total area or in length of the Brunswick Point or Tsawwassen Sea Dyke trails due to the proposed widening of the Roberts Bank causeway.

As indicated in EIS Section 4.1.2 and illustrated in Figure 4-6 of the EIS, at the east end of the causeway, Project-related rail infrastructure would extend eastward of the shoreline for 450 m in a narrow strip of approximately one hectare on the existing BCR right-of-way. The purpose of this rail infrastructure is to tie-in the rail lines on the widened causeway to the existing mainline rail network on the Roberts Bank Rail Corridor. As described in EIS Section 4.2.2 and illustrated in Figure 4-6 of the EIS, the width of the widened causeway will vary from no change at the east end to 140 m at the S-bend of the causeway. As indicated in Figure IR7-40-A1 in **Appendix IR7-40-A**, near the area where Brunswick Point Trail ends, the proposed causeway widening would parallel the existing BCR right of way and be approximately 30 m wide. At this point, the boundary of the expanded causeway would be approximately 60 m from the gate marking the end of Brunswick Point Trail.

There will be no alteration to the causeway footprint on the south side of the causeway where the Tsawwassen Sea Dyke Trail is located. As indicated in Section 24.6.4 of the EIS, potential Project construction and operation will not displace use or prevent access to land-based outdoor recreation amenities and areas within the local assessment area, including Brunswick Point Trail and Tsawwassen Sea Dyke Trail.

Provide a description of the mitigation measures that could improve the connection between the two segments of the trail; ensure the safety of present and future trail users that will be crossing the expanded causeway; and which respects the purpose of the planned Great Blue Heron Way by Tsawwassen First Nation.

As explained above, the Project will not change the current access to, use of, or spatial footprint of the Brunswick Point Trail and Tsawwassen Sea Dyke Trail. As per the environmental assessment methodology outlined in Section 8.0 of the EIS, no project interaction and in turn, no effects to other land-based outdoor recreation sub-component of the outdoor recreation valued component (which includes land-based walking, hiking, running, and cycling activities in the local assessment area) were identified or carried forward for assessment. As mitigation measures are only required when effects are identified, mitigation is not required.

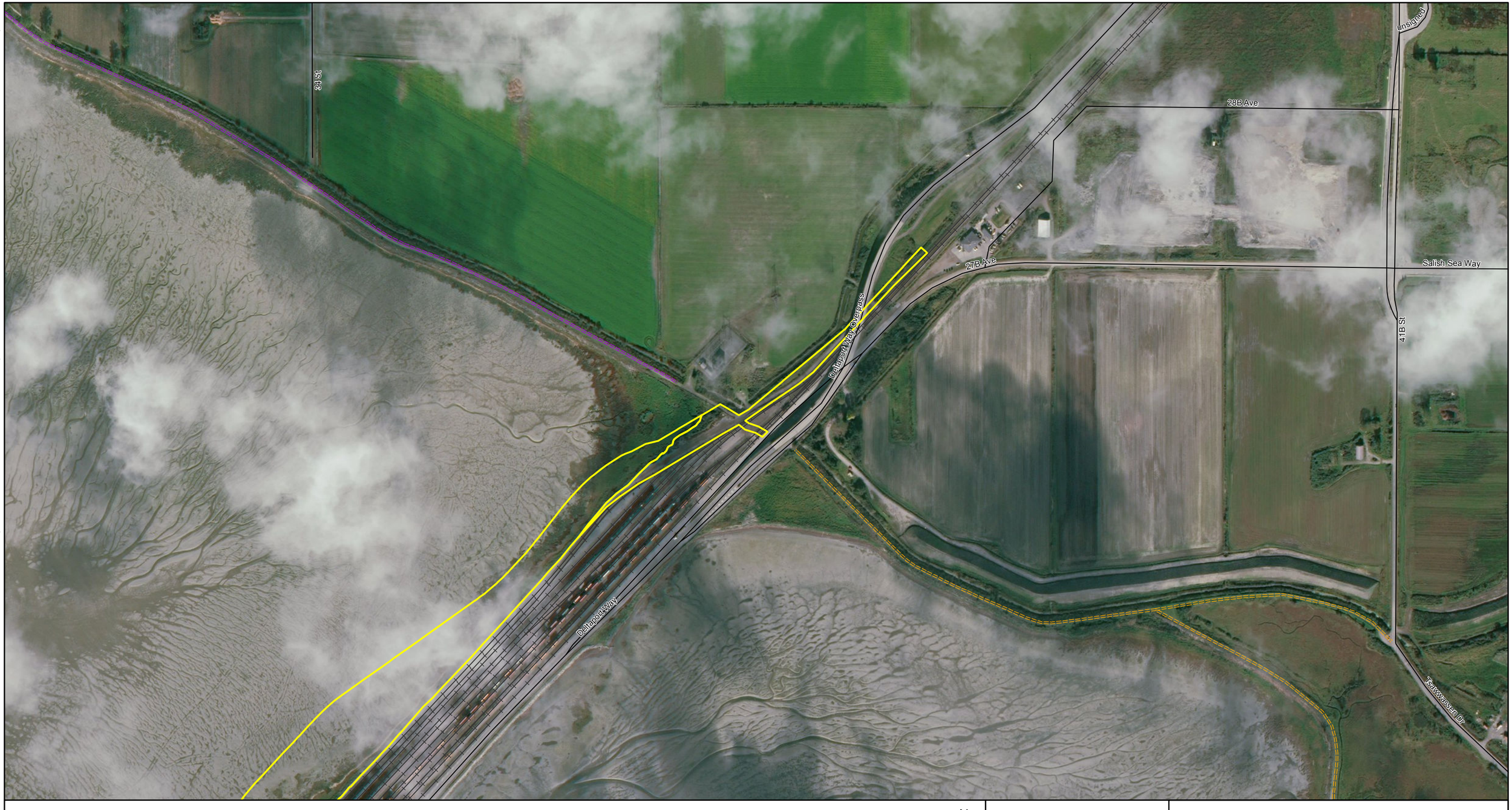
As part of the community benefit program, the VFPA welcomes further discussion on the development of a pedestrian and cyclist overpass at Deltaport Way with Tsawwassen First Nation and the City of Delta. The VFPA has indicated in a letter dated July 11, 2017 to Tsawwassen First Nation and City of Delta that it is open to further discussion on the possibility of the pedestrian and cyclist overpass, as well as other potential community benefits.

Appendices

Appendix IR7-40-A Supporting Figure

APPENDIX IR7-40-A
SUPPORTING FIGURE

Path: Y:\burnaby\CAD-GIS\Client\Vancouver_Fraser_Port_Authority\Delta\99_PROJECTS\1648389\02_PRODUCTION\MXD\Report\1648389_IR7-40-A1_Causeway.mxd



Legend

- BOUNDARY OF PROJECT AREA
- BRUNSWICK POINT TRAIL
- GREAT BLUE HERON TRAIL
- ROAD
- RAILWAY

0 80 160
Metres
1:5,000
NAD 1983 UTM Zone 10N

N

Notes:
RAILWAYS AND ROADS OBTAINED FROM DATA B.C.

PORT of vancouver

ROBERTS BANK TERMINAL 2

PROPOSED CAUSEWAY WIDENING

DATE: 12/07/2017

FIG No. IR7-40-A1

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

IR7-41 Outdoor Recreation – Tourism and Bird Watching, Effects Assessment

Information Source(s)

EIS Volume 4: Section 24.5.4.2; Section 24.6.4

CEAR Doc #558; CEAR Doc #574; CEAR Doc #581

Context

The Proponent mentioned that, due to Delta's location on the Pacific Flyway, there are a number of bird-watching opportunities in the local assessment area and the regional assessment area. The annual frequency of visitors is reported for the George C. Reifel Migratory Bird Sanctuary and for the participation in Delta Nature Casual Birding Club, a local naturalist club.

In Section 24.6.4 of the EIS, the Proponent reported that there would need to be an adverse population-level effect on birds, due to an adverse effect on productivity in order to have a measurable change in availability of birds for bird watching, which would affect the number of sightings. According to the Proponent, the proposed Project is not anticipated to affect coastal bird productivity at the population level; as a result, no effect on availability and number of sightings is anticipated. Therefore, the assessment of effects of the Project on tourism and birding activities was not conducted.

According to Environment and Climate Change Canada in CEAR Doc #581, there is a risk of significant adverse environmental effects to biofilm and consequently to migratory shorebirds - the Western Sandpiper in particular - and, in this instance, the Department would consider species-level impacts to migratory birds to be significant.

Participants in the environmental assessment have underlined the value of the regional assessment area for birds and for bird-related recreational activities. Comments have included:

- the area is an important stop-over for migratory birds;
- part of the area is a Ramsar site designated as a Wetland of international importance;
- the Western Hemisphere Shorebird Reserve Network considers the Fraser River Estuary as a site of hemispheric importance;
- the estuarine, marine and terrestrial environments around Delta are recognized nationally and internationally for their ecological significance for a wide variety of shore birds; and
- the area is a significant tourist draw because of the unique environment.

Information Request

Provide an assessment of the potential effects of the proposed Project on tourism and bird watching activities (for example, educational school visits, birding-club visits) in terms of a

reduction in the quality of the environmental setting and the potential loss of opportunities for the tourism industry of the area. In the analyses, include the consideration of the Alaksen National Wildlife Area and its international designation as a Ramsar site.

VFPA Response

Clarification

In CEAR Document #581[1], Environment and Climate Change Canada (ECCC) stated there is a risk of significant adverse environmental effects to biofilm and consequently, to migratory shorebirds, in particular Western Sandpiper, based on rationale presented in CEAR Document #574[2]. While the VFPA stands by the approach taken and science presented within the EIS that forms the basis of conclusions of the assessment of effects of the Project, the VFPA considered ECCC's comments and conducted studies during the 2016 Western Sandpiper northward migration to address the concerns raised by ECCC. Results from these studies support conclusions concerning Western Sandpipers and biofilm described in the EIS—specifically that the Project is unlikely to affect the availability of Western Sandpiper prey (including biofilm) during the Western Sandpiper's northward migration. For further detail, see IR8-04 of CEAR Document #1110[3].

As stated in EIS Section 15.10.1, a significant adverse residual effect to coastal birds would be characterised as one that negatively affects food resources or associated habitats to the extent that it compromises the long-term productive potential of the local assessment area (LAA) to support coastal bird productivity. Specific to Western Sandpiper and other shorebirds, studies conducted to support the assessment of effects of the Project indicate that food resources (i.e., biofilm, meiofaunal, and macrofaunal invertebrates) within the LAA available to support shorebirds are very large and, even under worst-case scenarios of change resulting from RBT2, will not become limiting (see EIS Section 15.7.2.2). This conclusion is supported by research conducted by the VFPA in 2016 to investigate factors affecting biofilm-associated essential fatty acids (see IR8-04 of CEAR Document #1110). Therefore, conclusions in the EIS regarding the ability of biofilm in the LAA to support Western Sandpiper populations with the Project remain unchanged after consideration of the results of additional studies in 2016.

Also, as stated in EIS Section 15.10.2, all habitats affected by the Project are anticipated to be mitigated except for subtidal soft-bottom habitat lost to the Project terminal footprint that is currently used for foraging by diving birds. The magnitude of this residual Project effect to diving birds was assessed to be low as the affected area represents 7% and 1% of the existing soft-bottom, shallow subtidal habitat within the LAA and regional assessment area (RAA),

[1] CEAR Document #581 From Environment and Climate Change Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[2] CEAR Document #574 From Environment and Climate Change Canada to the Review Panel re: Comments on the information relating to the environmental assessment of the Roberts Bank Terminal 2 Project.
[3] CEAR Document #1110 From the Vancouver Fraser Port Authority to the Review Panel re: Response to Information Request IR8-04 (See Reference Document #1071).

respectively, and therefore, the loss of this foraging habitat would not limit diving bird productivity or the ability of the areas to support diving birds. The geographic extent was determined to be local (including Roberts Bank from the north side of the BC Ferries causeway to Canoe Passage, and from the high-water mark to -100 m chart datum (CD)), permanent, irreversible, and infrequent. Overall, the potential residual effect to productivity loss for diving birds was rated not significant indicating the ability of the LAA and RAA to support existing coastal bird populations will remain unchanged with the Project.

Provide an assessment of the potential effects of the proposed Project on tourism and bird watching activities (for example, educational school visits, birding-club visits) in terms of a reduction in the quality of the environmental setting and the potential loss of opportunities for the tourism industry of the area. In the analyses, include the consideration of the Alaksen National Wildlife Area and its international designation as a Ramsar site.

Results for the above mentioned studies used to inform potential effects to birds and biofilm and other coastal habitats support the conclusions stated in EIS Section 24.6.4 of the outdoor recreation assessment—that the Project is not anticipated to have an effect on availability of birds, number of bird sightings, or bird watching activities within the outdoor recreation LAA. The LAA was established to encompass the area within which Project effects on outdoor recreation could potentially occur, and effects are not anticipated to occur outside of the LAA. The Alaksen National Wildlife Area (ANWA) is located outside the coastal birds and outdoor recreation LAAs. As LAA boundaries are established to capture the extent of Project effect, no effects on bird watching outdoor recreation at the ANWA are anticipated.

Section 24.5.4.2 of the EIS identifies the following:

- Roberts Bank, the BC Ferries Tsawwassen Terminal, and Brunswick Point were identified as popular birding locations in the outdoor recreation LAA;
- Other identified popular locations in the outdoor recreation RAA include the George C. Reifel Migratory Bird Sanctuary (overlaps with the ANWA, which is an internationally recognised Ramsar site), Deas Island Regional Park, Boundary Bay Regional Park, Burns Bog, Serpentine Wildlife Management Area, and Point Roberts; and
- The outdoor recreation LAA overlaps the Pacific Flyway, which is a major north-south migration route for migratory birds in North and South America and an important stop-over for migratory birds.

Iona Beach Regional Park (located outside of the outdoor recreation RAA and LAA) is also a popular area for bird watchers.

EIS Section 15.5.3 further identifies the Fraser River estuary has been designated a site of hemispheric importance and that the marine and terrestrial environments around Delta are recognised for their ecological significance for a variety of shorebirds.

The VFPA acknowledges the unique environment and bird population supports bird tourism in the area. Given the assessment results as presented above, the Project is not anticipated to adversely affect availability of birds nor bird watching opportunity for bird tourism in the area.

The information request asks for an assessment of the potential effects of the proposed Project on tourism and bird watching activities in terms of a reduction in the *quality of the environmental setting* (italics added) and the potential loss of opportunities for the tourism industry of the area. As defined in EIS Section 24.6, the outdoor recreation valued component 'quality of environmental setting' pathway considered changes in noise and visual resources conditions, and effects on character of the environmental setting for bird watching (for clarification, this is a different pathway from the 'resource availability and presence' pathway, which, as indicated in EIS Section 24.6, considered Project effects on availability of birds and effects on bird watching activities, as addressed in the above section of this response). Potential effects of the proposed Project on reduction in the quality of the environmental setting and effects on outdoor recreation—including bird watching—is described in EIS Section 24.6.4. Based on this effects analysis, the Project is not anticipated to affect the bird tourism industry in the LAA, including bird tourism associated with the ANWA (which as indicated above is not located in the Project LAA, but in the RAA).

IR7-42 Outdoor Recreation – Astronomy, Effects Assessment

Information Source(s)

EIS Volume 4: Section 24.5.4

CEAR Doc #222

Context

According to a participant (CEAR Doc #222), members of the Royal Astronomical Society of Canada use Boundary Bay as an observation site.

The effect of increased nighttime light from the proposed Project on this activity is not discussed in the outdoor recreation section of the EIS.

Information Request

Provide an assessment of the potential effects of the increased nighttime light from the proposed Project on recreational astronomy in the local assessment area and regional assessment area in terms of changes to areas used and quality of environmental setting.

VFPA Response

Clarification

Section 24.0 of the EIS describes the assessment of potential Project effects on outdoor recreation. The local assessment area (LAA) encompasses the area in which the Project is expected to interact with and potentially have an effect on outdoor recreation (EIS Section 24.3.1). The regional assessment area (RAA) provides regional context for the assessment of Project-related effects. As per this methodology (see EIS Section 8.0), potential Project effects are identified and assessed within the LAA only.

The Boundary Bay astronomical viewing site identified in CEAR Document #222[1] is located within the land-based outdoor recreation RAA, but not within the LAA and is therefore outside of the area where the Project is expected to interact with and potentially affect astronomical nighttime viewing activity. The VFPA did not receive any concerns from the Royal Astronomical Society of Canada (RASC) or the public pertaining to Project effects on astronomical recreation activity (nighttime viewing) either within the LAA or at Boundary Bay during the scoping phase of the EIS, or through presentation of draft EIS results to stakeholders and Aboriginal groups.

[1] CEAR Document #222 From Harvey Dueck to the Canadian Environmental Assessment Agency re: Comment on the Completeness of the Environmental Impact Statement.

Consequently, the VFPA did not include astronomical recreational activity in its assessment of the effects of the Project on outdoor recreation at the time.

While the VFPA views the assessment of outdoor recreation in Section 24.0 of the EIS to be complete, in response to the concern raised in this information request, an assessment of the potential effects of the increased nighttime light from the proposed Project on astronomical recreational activity (with a focus on Boundary Bay viewing location) has being carried out. The results of this additional work are presented below.

Provide an assessment of the potential effects of the increased nighttime light from the proposed Project on recreational astronomy in the local assessment area and regional assessment area in terms of changes to areas used and quality of environmental setting.

In order to collect information on the recreational astronomy activities identified in this request, an interview was held with the President of the Vancouver Centre of the RASC (Suzanna Nagy, personal communication, 13 September 2017). The interview was held to confirm astronomy viewing locations in the outdoor recreation LAA and RAA, including Boundary Bay, and to discuss the Boundary Bay viewing location's use characteristics (including seasonal variations, number of users, and use trends) by the RASC. The RASC representative confirmed that some recreational astronomy currently takes place at Boundary Bay, on the Boundary Bay dyke near the parking area at the end of 72 Street in Delta, as indicated on the RASC website (http://rasc-vancouver.com/observing/observing-sites/boundary-bay/). The RASC indicated that September to November and March to May are the times with the highest number of viewers at this location. When conditions are favourable, daily viewing numbers can range from 5-6 to 40-50 people, with larger number of viewers being present during a celestial event, such as a comet.

According to the RASC representative, recreational astronomy activity at the Boundary Bay site has generally declined over the past five years. The RASC indicated that organised RASC viewing events are no longer held at Boundary Bay due to light pollution from greenhouses built approximately five years ago. Prior to the greenhouses, Boundary Bay was the preferred location for events as it was easy to access. First choice locations for organised viewing events are now the Porteau Cove area or in Maple Ridge.

With the exception of the viewing location at Boundary Bay, no other areas in the outdoor recreation LAA or RAA were identified by the RASC as areas used for recreational astronomy by the RASC. During the September 13, 2017 communication with RASC, light pollution was identified as a general concern, and the RASC is working with local municipalities to develop 'Urban Dark Sky Preserves' in local parks to maintain darkness and viewing opportunities within urban areas.

To address this information request, additional light measurements were collected at the Boundary Bay astronomical viewing site and light modelling was conducted. The results of the modelling were assessed based on the change in nighttime viewing conditions criteria identified in Section 25.0 of the EIS, then assessed for potential effects to recreational astronomy.

Existing light measurements were conducted at the Boundary Bay astronomical viewing site (BB) (situated at 498228 m Easting, 5434105 m Northing) on the night of September 14, 2017. Measurements were collected under clear skies and taken after astronomical twilight (i.e., after 9:15 p.m.) and while the moon was set. Light trespass measurements were carried out using a Solar Light PMA2100 photometer and a PMA2131 scotopic detector. Sky quality measurements were carried out using a Unihedron Sky Quality Meter (SQM), which provides sky quality measurements in mag/arcsec^2.

The measurement results are presented in **Table IR7-42-1**.

Table IR7-42-1 Existing Light Measurement Results at Boundary Bay Astronomical Viewing Site

Site	**Existing Light Trespass** (lux)	**CIE Environmental Classification for Light Trespass**	**Existing Sky Quality** (mag/ arcsec^2)	**Existing Sky Glow** (% Brightness above Natural Dark Sky)	**CIE Zone Classification for Sky Glow**
Boundary Bay Astronomical Viewing Site (BB)	0.011	E2	19.45	566	G4

Light trespass and sky quality measured at BB were similar to other nearby points of reception (PORs) described in the EIS with similar conditions (i.e., EIS POR8, Crescent Beach).

Modelling was undertaken to predict the effect of the Project on the existing light trespass and sky glow at BB. Light trespass was modelled using the AGi32 lighting software and sky glow was modelled using a computer program based on Garstang's model (Garstang 1986, 1989); more details on the modelling methodology are presented in Section 2.4 of Appendix 9.4-A of the EIS.

Table IR7-42-2 summarises the modelling results and the CIE (Commission Internationale de L'Éclairage) classifications for light trespass and sky glow when considering the predicted changes due to the Project. The Project is not predicted to result in a change to the CIE classifications.

Table IR7-42-2 Predicted Changes in Light Trespass and Sky Glow with the Project at Boundary Bay Astronomical Viewing Site

Site	Predicted Project Light Trespass (lux)	Existing + Project Light Trespass (lux)	CIE Environmental Classification for Light Trespass	Existing + Predicted Sky Quality (mag/ arcsec^2)	Existing + Predicted Sky Glow (% Brightness above Natural Dark Sky)	CIE Zone Classification for Sky Glow
Boundary Bay Astronomical Viewing Site (BB)	0.002	0.013	E2	19.35	623	G4

No changes are predicted at BB in CIE Environmental Classification for Light Trespass and in CIE Zone Classification for Sky Glow.

Based on the above modelling results, no visible alteration to nighttime viewing conditions at BB with the Project are anticipated. Based on the predicted change in light trespass and sky glow associated with the Project at BB, and no anticipated change in nighttime viewing conditions at BB, Project effects on quality of the nighttime visual environmental setting and on outdoor recreational experience at the Boundary Bay recreational astronomy viewing site are anticipated to be negligible. Based on current understanding that the Boundary Bay viewing site is the only recreational astronomy viewing area within the LAA or RAA, Project effects on recreational astronomy viewing in other parts of the LAA or RAA are not identified. There is no change to the land-based outdoor recreation assessment results as described in EIS Section 24.6.4.

References

Garstang, R. H. 1989. Night-sky Brightness at Observatories and Sites. Publications of the Astronomical Society of the Pacific 101:306-329.

Garstang, R. H. 1986. Publications of the Astronomical Society of the Pacific 98:364-375.

Nagy, Suzanna. Royal Astronomical Society of Canada (RASC), September 13, 2017.

IR7-43 Outdoor Recreation – Crab Harvesters, Mitigation and Effects Assessment

Information Source(s)

EIS Volume 4: Sections 24.5.2, Section 24.6, Table 24-5, Table 24-7, Figure 24-4

Context

The existing navigational closure for recreational crab harvesting is 502.9 hectares. The proposed expansion of the closure with the proposed terminal footprint would be 399 hectares during Project construction which would be reduced to 279 hectares during Project operations.

On a peak-use day, the Proponent estimated that approximately 50 boats harvest crabs between Point Roberts and west of the Roberts Bank terminals with 40 boats to the east of the B.C. Ferries Terminal and 10 boats to the west.

According to the Proponent, displacement of recreational crab harvesters to other crab harvesting areas is expected as a result of the proposed Project construction and operation. Further, crabs are expected to move to baited traps that will be placed outside of the navigational closure for recreational crab harvesting.

Recreational crab harvesters that currently use the inter-causeway area will have to travel further to undertake the activity which would require more time and fuel. The effects from the Project, however, are predicted by the Proponent to be negligible since crab harvesters will still be able to use the inter-causeway area and waters near the BC. Ferries Terminal, as well as areas to the west of the navigational closure. During Project operations, the area behind the terminal would also be available.

However, despite the above claims, the Proponent is proposing to recommend to DFO that the currently open area for recreational crab harvesting (in the inter-causeway area and waters near the B.C. Ferries Terminal) be closed to recreational crab harvesting due to navigational safety concerns.

The Proponent's proposed measures to mitigate the reduction in harvesting areas and required displacement of harvesters include a communication plan. In addition, the Proponent proposes to work with Fisheries and Oceans Canada and recreational crab harvesters to implement measures to address the effects from displacement due to the navigational closure but does not provide any details regarding what these measures may be.

More information is needed as to the proposed mitigation measures and the predicted effectiveness of the mitigation in reducing the effects of the Project on recreational crab harvesters.

Information Request

Provide information about the engagement activities held to date with recreational crab harvesters potentially affected by the proposed expansion of the navigational closure and

displacement from recreational crab harvest areas. Indicate any elements discussed regarding future changes in the areas used and the quality of experience.

Present specific measures, other than the already-mentioned communication plan, that could mitigate the predicted effects of the proposed Project on recreational crab harvesters and an assessment of the expected efficacy of the mitigation.

Describe whether there would be an adverse residual effect to recreational crab harvesters after the implementation of the above mitigation measures.

If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect to recreational crab harvesters and the likelihood that the effect would occur.

VFPA Response

Clarification

The VFPA would like to provide clarification of the following statement included in the context to this information request: *"the Proponent is proposing to recommend to DFO that the currently open area for recreational crab harvesting (in the inter-causeway area and waters near the B.C. Ferries Terminal) be closed to recreational crab harvesting due to navigational safety concerns."*

As indicated in EIS Section 24.6.5.2, recreational crab harvesters reported that recreational crab harvesting occurs east of the BC Ferries Terminal causeway, west of Roberts Bank terminals, and in the inter-causeway area, with the majority of recreational crab harvesters tending to harvest east of the BC Ferries Terminal causeway. The proposed navigational closure expansion areas for construction and operation for recreational crab harvesting would be located west and north of the existing Deltaport Terminal and the proposed Project terminal footprint, and would include a small area between the two terminals (i.e., along the south-west boundary of Deltaport Terminal and east side of the RBT2 terminal) as detailed in EIS Figure 24-4 (EIS Section 24.6.5.2). The inter-causeway area and waters near the BC Ferries Terminal currently open to recreational crab harvesting would not be affected by the proposed navigational closure expansions for the Project.

Recreational crab harvesters accessing the inter-causeway area from Canoe Passage will be required to travel around the proposed navigational closure expansion at Roberts Bank to access harvesting locations east of the BC Ferries causeway. Travel routing and travel time for recreational crab harvesters accessing the inter-causeway area from the east of the BC Ferries Terminal causeway will not be affected by the proposed navigational closure expansion.

Provide information about the engagement activities held to date with recreational crab harvesters potentially affected by the proposed expansion of the navigational closure and displacement from recreational crab harvest areas. Indicate any elements discussed regarding future changes in the areas used and the quality of experience.

The recreational crab harvesting community is a diverse group of individuals that are not formally organised. During preparation of the outdoor recreation assessment, members of local hunting and fishing associations who participated in recreational crabbing were interviewed to gather information on recreational crab harvesting in the local assessment area, as discussed in the section above. Given the individual nature of recreational crab harvesters, there are no organisations or associations to consult with directly. Therefore, the VFPA sought to provide consultation opportunities to individual recreational crab harvesters through the broader RBT2 public consultation program. The VFPA-led consultation regarding RBT2 prior to EIS submission included four rounds of consultation over four years and included extensive notifications, open houses in local schools and community centres, multi-stakeholder meetings, and online forums to provide a variety of opportunities to share and receive information on the Project, including information pertaining to recreational crab harvesting as part of the outdoor recreation assessment. Summaries of the consultation, which included information on recreational crab harvesting are provided in the four following consultation summary reports:

- Pre-Consultation (June 2011)[1];
- Project Definition Consultation (October-November 2012)[2];
- Pre-Design Consultation (October-November 2013)[3]; and
- Preliminary Environmental Mitigation Concepts (September-October 2014)[4].

In addition, the VFPA has several ongoing communication mechanisms available for public comments and questions, including the following:

- In person at the Port of Vancouver community office in Delta, which provides an opportunity for community members to meet VFPA staff and learn about port operations, initiatives, and projects, including the RBT2 Project;
- By phone through the 24-hour Community Feedback phone line; and
- By email or online forum at either the dedicated RBT2 Project email address (container.improvement@portvancouver.com) or via PortTalk, the online discussion forum to ask questions or participate in active consultations.

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[1] http://www.robertsbankterminal2.com/wp-content/uploads/Roberts-Bank-Terminal-2-Project-Pre-Consultation-Summary-Report-July-2011.pdf

[2] http://www.robertsbankterminal2.com/wp-content/uploads/RBT2-Project-Definition-Consultation-Summary-Report-January-2013.pdf

[3] http://www.robertsbankterminal2.com/wp-content/uploads/RBT2-Pre-Design-Consultation-Summary-Report-January-2014.pdf

[4] http://www.robertsbankterminal2.com/wp-content/uploads/RBT2-Preliminary-Environmental-Mitigation-Concepts-Consultation-Summary-Report-FINAL-October-2014.pdf

Since submission of the EIS, the VFPA has initiated discussions on crab harvester engagement (including Aboriginal, commercial, and recreational crab) with DFO to support information sharing and consultation. The VFPA will work to provide information to recreational crab harvesters of the RBT2 Project and the proposed navigational closure expansion, the predicted displacement effects on recreational crab harvesting, as well as to communicate the existing opportunities for recreational crab harvesters to raise questions and identify suggestions for mitigation, as outlined in EIS Section 24.7.1.

The VFPA will make efforts to engage recreational crab harvesters directly by working with DFO on existing outreach activities with recreational crab harvesters, and by posting information both publicly and sending information to recreation groups, such as the local rod and gun clubs, that may have individual members who undertake recreational crab harvesting at Roberts Bank. The timing of and approach to engagement activities will be determined based on discussions with DFO and interest from recreational crab harvesters.

Present specific measures, other than the already-mentioned communication plan, that could mitigate the predicted effects of the proposed Project on recreational crab harvesters and an assessment of the expected efficacy of the mitigation.

Subsequent to submission of the EIS, the VFPA has continued to consider and evaluate mitigation measures, as discussed in EIS Section 24.7.1. The VFPA will continue to review additional mitigation measure suggestions identified through consultation, Panel registry documents, and follow-up engagement. Commercial crab harvester mitigation measure suggestions received to date are summarised in response to IR7-34.

Describe whether there would be an adverse residual effect to recreational crab harvesters after the implementation of the above mitigation measures. If there is a residual effect predicted, provide a characterization of the effect and determine the significance of the effect to recreational crab harvesters and the likelihood that the effect would occur.

With the implementation of mitigation as specified in EIS Section 24.7.1 and EIS Table 24-7, residual effects on recreational crab harvesting area use and access are anticipated to be negligible (EIS Section 24.8). During Project construction and operation, recreational crab harvesters would continue to be able to harvest in the inter-causeway area and waters near the BC Ferries Terminal where recreational crab harvesting is concentrated in the local assessment area, as well as areas west of the proposed navigational closure expansion for recreational crab harvesting. The VFPA will continue to evaluate potential additional mitigation measure suggestions, identified through engagement with DFO and recreational harvesters as described above.