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APPENDIX 5.7-A

Emissions Estimation Methodology

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REPORT

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1.0 INTRODUCTION

BURNCO Rock Products Ltd. (BURNCO) has proposed to construct and operate an aggregate mine using wet extraction techniques in Howe Sound, British Columbia (the Project).

This Appendix supplements Volume 2, Part B - Section 5.7 of the Environmental Assessment Certificate Application/Environmental Impact Statement. The general approach used to evaluate the potential air quality effects of the Project included the following steps:

- **Estimate the air emissions from the Project for the phase of activity (i.e., construction, operations, and reclamation and closure) determined to have the highest (i.e., bounding) quantity of air emissions.**
- Develop a meteorological dataset for use in the dispersion modelling.
- Predict the concentrations and deposition rates of indicator compounds released from the bounding phase of the Project dispersion modelling.
- Use dispersion modelling to predict the concentrations and deposition rates of the non-indicator compounds required as inputs to other disciplines affected by changes in air quality (e.g., human health).
- Compare the predicted indicator compound concentrations to available criteria and standards, and assess the relevant significance of these effects.

This appendix outlines the first (**bolded**) step, namely the estimation of air emissions estimations from the Project.

1.1 Project Description

During the operational period of the aggregate facility five major activities will occur each year. These activities are land clearing (expected to occur over a 30 day period), aggregate extraction and initial processing (dredging, primary crushing and screening), conveying from pit to processing plant, processing (crushing and screening) and storage of material in the processing plant area and transfer to barge. A tugboat will be used to barge the aggregate from the Project to BURNCOs' facilities in Langley and Burnaby.

During each operational year the excavation pit will be expanded, land will therefore need to be cleared to accommodate the expansion. The overburden soil will be hauled and stored in berms (eventually vegetated) to the north and east of the pit area. Land clearing will be conducted using a dozer and excavator. The emissions from land clearing are expected to be a significant portion of the Project's particulate emissions; however, land clearing is expected to occur, at most, over 30 days throughout the year.

Due to the availability of power on site, through a BC Hydro transmission line coupled with a neighbouring sub-station, the need for diesel combustion equipment (both mobile and stationary) will be limited. The main aggregate extraction and processing equipment such as the dredger, screens and crushers will be powered electrically. Quarried and processed material will be transferred around the Project site using a network of conveyors, thereby eliminating the use of haul vehicles for aggregate movement.

Due to the wet mining process most of the conveyed material will have moisture content of 5% or greater; for material conveyed from the stockpiles to the barge, covered conveyors will be used.

The wet extraction process will consist of a flooded aggregate pit area below existing groundwater levels. Sand and gravel will be extracted from the pit using an electrically powered floating clamshell dredge, equipped with a primary crusher and a floating conveyor system. No pit dewatering will be required, and no explosives will be used. The wet extraction technique will act as a fugitive dust and particulate control technique thus eliminating the potential for fugitive particulate emissions. A berm will also be built on the south and north sides of the pit area.

Once conveyed to the processing plant, using over water conveyors and an underground conveyor from the pit lake to the processing plant area, the aggregate material will be stored in surge pile. At the plant the aggregate material will undergo the following processing:

- Transfer of aggregate material from surge pile to dry screening using a partially underground conveyor;
- Dry screening to extract fines and 20 mm crushed gravel;
- Crushing the remaining aggregate material;
- Dry screening of the crushed material to separate the aggregate into three sizes fractions;
- The fines and the 20 mm crushed gravel will then be wet-screened to extract four more aggregate size fractions; and
- All seven aggregate sized fractions will be sourced to stockpiles in the plant area.

Within the plant area fugitive particulate emission control practices will include enclosure of crushers and screens, enclosure of transfer points, water sprays and covered conveyors from stockpiles to the barge. A tugboat will be used to ship the aggregate once the aggregate is loaded onto the barge. It should be noted that the emissions of barge tugboat would be small compared to other activities occurring at the Project.

Emissions of NO_2, SO_2, $PM_{2.5}$ and PM_{10} from tug movements will be assessed only at the human health receptors (that will include the McNab Strata community) in the vicinity of the Project. The modelling will include emissions of the tug while maneuvering in the vicinity of the Project dock area.

1.2 Indicator Compounds

The assessment of air quality focused on predicting changes in the concentrations of selected indicator compounds. These indicator compounds represent compounds that are expected to be emitted from the Project, and are generally accepted as indicative in changing air quality, and for which relevant air quality criteria exist. These indicator compounds fall into the following 2 general categories:

- **Particulate Matter**, including total suspended particulates or particulate nominally smaller than 30 µm in diameter (TSP or TSP_{30}), particles nominally smaller than 10 µm in diameter (PM_{10}), and particles nominally smaller than 2.5 µm in diameter ($PM_{2.5}$);
- **Combustion Gases**: nitrogen dioxide (NO_2), and sulphur dioxide (SO_2).

Although not specific air quality indicators, additional compounds were assessed for use by other disciplines. For these indicators, refer to Chapter 9.1 and associated appendices of the Environmental Assessment Certificate Application/Environmental Impact Statement.

1.3 Emission Source Activities

Based on the Project description, as described in Section 1.1, activities that would result in particulate emissions are listed in Table 1. Particulate matter emissions associated with diesel vehicle exhaust will be included in the inventory and subsequent modelling.

Table 1: Emission Activity Types

Major Activities	Indicator Compound Producing Activity
Land Clearing	Bulldozing
	Fugitive road dust
	Material handling
	Vehicle exhaust
Aggregate Extraction and Initial Processing	Dredging
	Screening
	Crushing
Conveying from Pit to Processing Plant	Material handling
	Conveyor transfers
	Stockpile wind erosion
Processing	Material handling
	Stockpile wind erosion
	Screening
	Crushing
	Propane combustion
	Vehicle exhaust
Transfer to Barge	Material handling
Shipping	Tugboat emission

2.0 EMISSIONS ESTIMATION

Activities that generate indicator emissions were identified in section 1.3. Emission rates for the various emission activities will be calculated based on a relevant emission factors (such as US EPA AP-42 1995) and activity data supplied by BURNCO. For emission activities that would have emission controls, as specified by BURNCO, an appropriate emission reduction factor will be applied to the emission rate calculation.

2.1 Bulldozing Emission

Bulldozing activities will be undertaken during the land clearing (pit expansion) phase, this activity is expected to result in fugitive particulate emissions. Fugitive particulate emissions from bulldozing were quantified using the method detailed in AP-42 Chapter 11.9 Western Surface Coal Mining (US EPA 1998b). The emission factors for TSP_{30} and particulate nominally smaller than 15 µm in diameter (TSP_{15}) were calculated as follows:

$$EF = \frac{a \times s^b}{M^c}$$

Where:

- EF = the emission factor for particulates (kg/hour/equipment)
- s = the silt content of the material handled (% weight)
- M = the material handled moisture content (% weight)
- a = empirical constant (unitless)
- b = empirical constant (unitless)
- c = empirical constant (unitless)

The empirical constants (a,b,c) used for TSP_{30} and TSP_{15} are presented in Table 2.

Table 2: TSP_{30} and TSP_{15} Empirical Constants

Constant	TSP_{30}	TSP_{15}
A	2.6	0.45
B	1.2	1.5
C	1.3	1.4

Scaling factors in Table 3 are used to convert TSP_{30} emission to PM_{10}, and TSP_{15} emission to $PM_{2.5}$.

Table 3: Scaling Factors for PM_{10} and $PM_{2.5}$

	PM_{10} from TSP_{30}	$PM_{2.5}$ from TSP_{15}
Scaling Factor	0.75	0.105

The equation used to calculate the particulate emission rates is as follows:

$$ER = EF \times p \times h \times UC$$

Where:

- ER = the emission rate (tonne/day)
- p = the number of pieces of equipment (equipment)
- h = the daily operating hours (hours/day)
- UC = the unit conversion factor to equate the mass unit – $\frac{1\ tonne}{1000\ kg}$

The mean silt and moisture content of overburden, provided in AP-42 Chapter 13.2.4, Table 13.2.4-1 (US EPA 2006b), was assumed to be the silt and moisture content of the overburden handled at the Project.

During the land clearing phase the bulldozers' engines are assumed over the entire operating day; however, the equipment is not expected to be bulldozing the entire time. Therefore, a utilization factor of 80% was assumed, and applied bulldozing fugitive particulate to emissions.

2.2 Fugitive Road Dust

Hauling activities will be undertaken during the land clearing (pit expansion) phase. Vehicles will be used to haul the overburden soil out from the pit expansion area to berms located to the north and east of the pit. This activity is expected to result in fugitive particulate emissions. Road fugitive particulate emissions were quantified using the method detailed in AP-42 Chapter 13.2.2 Unpaved Roads (US EPA 2006a). The emission rate and factor calculations are as follows:

$$EF = k \times \left(\frac{s}{12}\right)^{a} \times \left(\frac{W}{3}\right)^{0.45} \times UC$$

Where:

- EF = the emission factor (g/VKT)
- k = empirical constant (lb/VMT)
- s = surface material silt content (%)
- a = empirical constant (unitless)
- W = mean vehicle weight (imperial tons)
- UC = unit conversion factor to equate units of mass and distance travelled by vehicle – 281.9 $\frac{g/VKT}{lb/VMT}$

Constants k and a vary depending on the particle size, Table 4 shows the constants (US EPA 2006a) used for this calculation.

Table 4: Particulate Matter Size Dependant Constants

Constants	Units	PM_{30} (TSP)	PM_{10}	$PM_{2.5}$
k	lb/VMT	4.9	1.5	0.15
a	unit less	0.7	0.9	0.9

Average silt content value found in AP-42, Chapter 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006b) was referenced to provide the silt content of the surface material. Mean vehicle weight was taken from the vehicle manufacture's specification sheet, with the assumption of vehicles travelling fully loaded on one way and empty on the return trip.

Using the emission factor calculated, the emission rate is then calculated as follows:

$$ER = EF \times VKT \times UC_1 \times \left(1 - \frac{C}{100}\right)$$

Where:

- ER = the emission rate (tonne/day)
- VKT = the daily vehicles distance travelled (km/day)
- UC_1 = unit conversion factor to equate units of mass – $\frac{1\,tonne}{10^6\,g}$
- C = the emission rate control reduction (%)

The travelled distance by vehicles were estimated by the distance between the centre point of the land clearing area to the berms east and north of the pit area. The number of trips made by vehicles was estimated using the total overburden removed each year and haul truck's maximum load capacity.

Precipitation will act as a natural dust suppressant. A precipitation control factor may be applied to the calculated emission rate to correct for precipitation suppression:

$$ER_{Precip.} = ER \times \left(\frac{365 - p}{365}\right)$$

Where:

- $ER_{Precip.}$ = the precipitation corrected emission rate (tonne/day)
- p = the number of days in a year with at least 0.254 mm of precipitation.

Within the inventory the precipitation reduction correction was not applied to fugitive road particulate emissions. The reason for this is the period which land clearing occurs is unknown, and land clearing will lasts for 30 days or less each year. It is possible to have no precipitation during this period, and implementing the precipitation control factor may conservatively estimate the unpaved road dust emissions.

Fugitive road dust particulate emissions are expected to comprise a significant portion of the total Project emission. Therefore, a watering truck will be used to reduce the unpaved road dust emissions. Watering the roads is expected to reduce the emissions by 55% according to Table 6-7 of *WRAP Fugitive Dust Handbook* (Countess Environmental 2004).

2.3 Material Handling Emission

Aggregate material will be handled and transferred at various stages and locations throughout the Project site; this handling will result in the release of particulate emissions. Material handling occurs during land clearing, conveying from pit to processing plant, processing and transferring to barge activities. All material handling emissions are calculated using the method outlined in AP-42 Chapter 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006b). The emission factor calculation is listed below:

$$EF = k \times (0.0016) \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

- EF = the emission factor (kg/tonne)
- k = the particle size multiplier (dimensionless)
- U = the mean wind speed (m/s)
- M = the material moisture content (%)

And the emission rate equation is:

$$ER = EF \times M_h \times \left(1 - \frac{CE}{100}\right) \times UC$$

Where:

- ER = the emission rate (tonne/day)
- M_h = the material handled (tonne/day)
- CE = the control efficiency of the dust control technique (unitless)
- UC = the unit conversion factor to equate the mass unit - $\frac{1\ tonne}{1000\ kg}$

To obtain representative local wind speed data, Port Mellon meteorological station's hourly wind record over five years period (2008-2012) was downloaded from the BC Ministry of Environment (MoE) website (BC MoE 2014), and used to calculate the maximum daily average wind speed. The Port Mellon meteorological station is operated by Environment Canada.

The particle size multipliers are provided in AP-42 Chapter 13.2.4 – Aggregate Handling and Storage Piles (US EPA 2006b), the particle size multipliers are presented in Table 5.

Table 5: Particle Size Multipliers for Material Handling

Description	Value
TSP ≤ 30 μm, unitless	0.74
PM_{10}, unitless	0.35
$PM_{2.5}$, unitless	0.053

The moisture content of the material handled varies depending on where the material transfer occurs within the processing stage. The moisture content values were provided by BURNCO.

For some of aggregate the transfer points control measures such as partial enclosure or partial enclosure and water spray are implemented to reduce particulate emissions. These controls were assumed to have similar reduction efficiencies as the controls for screening operations. An emission control efficiency of 50% was applied to partially enclosed drops, while an emission control efficiency of 75% was applied to partially enclosed drops with mist spray. Control efficiency values were provided in Pits and Quarries Guidance Chapter 8 (Environment Canada 2009)

2.4 Vehicle Exhaust

Various diesel powered surface equipment will be used within the Project site and expected emissions include particulates, SO_2 and NO_2. During the Project's operational phase surface equipment that will be used will include a bull dozer, haul trucks, a forklift, an excavator, and a loader. These vehicle emissions are expected to occur as a result of land clearing and processing activities. Emission rates for all vehicular exhaust were calculated using the same method as US EPA NON-ROAD model. NON-ROAD uses the emission factors provided in documents published by US EPA (2004b, 2004c, 2010). TSP emission was assumed to be the same as that of PM_{10}. The general equation used for finding particulate, SO_2 and NO_2 emissions is as follows:

$$ER = EF \times Horsepower\ Rating \times LF \times time \times UC_3$$

Where:

- ER = emission rate (tonne/day)
- EF = emission factor (g/hp-hr)
- $Horsepower\ Rating$ = the output power of engine used (hp)
- LF = load factor (unitless)
- $time$ = Time that the engine is in operation (hours)
- UC_3 = Unit conversion factor to equate the unit of time and mass

As previously mentioned in 2.1, bulldozing emission applied a utilization rate of 80% to the activity. However, this machinery is assumed to be operating even during the time they are not bulldozing. Therefore the exhaust emissions are calculated based on 14 hour per day emission rate.

The calculation method follows that of US EPA NON-ROAD model for selecting the appropriate emission factor and load factors. Emission factors vary depending on the substance of interest, the sulphur content of the fuel, the emission type, the equipment type, and the equipment model year. The emission factors are found using the methods in Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression Ignition – Report No. NR-009c (US EPA 2004b). Load factor is determined by the type of equipment defined in Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling – Report No. NR-005c (US EPA 2004c).

2.5 Dredging

Aggregate material will be dredged during the active phase of the Project. This is a wet process, as the aggregate will be dredged from below the waterline within an artificial lake. Therefore, this process is not expected to produce any particulate emissions.

2.6 Screening

There are five screens present on the Project site; screening activities are expected to generate particulate emissions. The screens are part of the aggregate extraction and initial processing and the processing activities. Screening particulate emissions where based on the method provided in AP-42 Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (US EPA 2004a). The equation for determining the emission rate for screening activities is as follows:

$$ER = EF \times M_h \times \left(1 - \frac{CE}{100}\right)$$

Where:

- ER = the emission rate (tonne/day)
- EF = the emission factor (kg/tonne)
- M_h = the material handled (tonne/day)
- CE = the emission reduction efficiency (%)

Different emission factors are used for TSP, PM_{10}, and $PM_{2.5}$ emissions. Table 6 shows the emission factors for controlled and uncontrolled screens.

Table 6: Particulate Emission Factors

	TSP	PM_{10}	$PM_{2.5}$
Uncontrolled Screen	0.0125	0.0043	0.000291
Controlled Screen	0.0011	0.00037	0.000025

Of the five screens used on the Project site, three are expected to have control measures. As seen in Table 6, AP-42 Chapter 11.19.2 (2004a) provides emission factors for controlled and uncontrolled screens, however, the description of control measures were not clearly defined. Therefore, uncontrolled emission factors were conservatively used in the emission rate calculation and the control efficiency term was used to account for emission reductions based on a control measure. Control efficiency values were provided in Pits and Quarries Guidance, Chapter 8 (Environment Canada 2009), where applicable. The screens in the processing area are partially enclosed and are expected to reduce emission rates by 50%. The wash plant screen (processing activity) is described to be a totally wet process; therefore no particulate emissions are expected from this activity.

2.7 Crushing

Mined aggregate will be crushed into smaller aggregate sizes during the aggregate extraction and initial processing and the processing activities. Crushing is expected to generate particulate emissions. The emission rate of crushing activities are calculated using emission factors provided in AP-42 Chapter 11.19.2, Crushed Stone Processing and Pulverized Mineral Processing (US EPA 2004a). Crushing particulate emissions will be quantified as follows:

$$ER = EF \times M_h \times \left(1 - \frac{CE}{100}\right)$$

Where:

- ER = the emission rate (tonne/day)
- EF = the emission factor (kg/tonne)
- M_h = the material handled (tonne/day)
- CE = the emission reduction efficiency (%)

AP-42, Chapter 11.19.2 (US EPA 2004a) provides emission factors used in crushing operations. Table 7 shows the emission factors of particulate emissions from different types of crushers.

Table 7: Crusher Particulate Emission Factors

	TSP (kg/tonne)	PM_{10} (kg/tonne)	$PM_{2.5}$ (kg/tonne)
Primary Crushing	0.0027	0.0012	0.0006
Tertiary Crushing	0.0027	0.0012	0.00005

There are two crushers at the Project, a jaw crusher and a fines crusher. The jaw crusher will be used for primary crushing, when the aggregate material is dredged. The fines crusher will be used to further reduce the aggregates in size. Therefore, the jaw crusher will use the emission factors for primary crushing, and the fines crusher will use the emission factors for tertiary crushing.

The crushers used at the Project site are partially enclosed to minimize the particulate emissions. The emission control efficiency used was assumed to be 85% and was provided in Pits and Quarries Guidance, Chapter 8 (Environment Canada 2009).

2.8 Conveyor Transfers

Mined aggregate is transferred to the processing area by a conveyor. The drop of aggregate at conveyor transfer point (conveyor to conveyor) is expected to generate particulate emissions. The emission rate of a conveyor to conveyor transfer is calculated using the method outlined in AP-42 chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (US EPA 2004a). The equation is as follows:

$$ER = EF \times Transfers \times M_h \times \left(1 - \frac{CE}{100}\right) \times UC$$

Where:

- ER = the emission rate (tonne/day)
- EF = the emission factor (kg/tonne)
- $Transfers$ = the number of transfer points (number)
- M_h = the material handled (tonne/day)
- CE = the emission reduction efficiency (%)
- UC = unit conversion factor to equate units of mass - $\frac{1\ tonne}{1000\ kg}$

The emission factors provided in AP-42 chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing US EPA (2004a) are as follows:

Table 8: Conveyor Transfer Point Emission Factors

Description	Units	TSP	PM_{10}	$PM_{2.5}$
Conveyor Transfer Point (uncontrolled)	kg/tonne	0.0015	0.00055	0.000139
Conveyor Transfer Point (controlled)	kg/tonne	0.00007	0.000023	0.0000065

Emission factor for $PM_{2.5}$ for uncontrolled conveyor transfer point was not provided in AP-42 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing US EPA (2004a). Therefore, the emission factor was estimated using the ratio of TSP and $PM_{2.5}$ for controlled conveyor transfer point emission factor.

The conveyor transfer point is in the material processing area, where the aggregate is expected to be still wet from dredging. Therefore, the emission factor for controlled conveyor transfer point was used in estimating the emissions from this activity.

2.9 Stockpile Wind Erosion

Stockpiles will be used to store mined aggregated and processed aggregate material. These stockpiles are expected to generate particulate emissions as they are exposed to wind. Stockpile wind erosion occurs as a result of conveying from pit to processing plant, and, processing activities. The emission rate from stockpile wind erosion is calculated using the method provided in Control of Open Fugitive Dust Source (US EPA 1988). The emission rate equation is as follows:

$$ER = 1.9 \times \left(\frac{s}{1.5}\right) \times \left(\frac{(365 - p)}{235}\right) \times \left(\frac{f}{15}\right)$$

Where:

- ER = the TSP emission rate (kg/day/ha)
- s = the silt content (% weight)
- p = the number of days with precipitation > 0.2 mm (days)
- f = the percentage of time that unobstructed wind speed is greater than 19.3 km/h (%)

Emission rates for PM_{10} and $PM_{2.5}$ were found by using scaling factors provided in AP-42 Chapter 13.2.5 – Industrial Wind Erosion (US EPA 2006c); these factors are shown in Table 9.

Table 9: Scaling Factors for Stockpile Wind Erosion

Description	Value
PM_{10}	0.5
$PM_{2.5}$	0.075

Wind speed data from Port Mellon meteorological station were used to estimate the occurrence of wind speed being greater than 19.3 km/h. The silt content of the stockpiles were provided by BURNCO. For the overburden stockpile, where the silt content was unknown, the mean silt content value of overburden, provided in AP-42 Chapter 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006b) was used.

Two of the stockpiles in the processing area have mist spray as an emission control measure. The emission reduction efficiency was assumed to be 50% and provided in Pits and Quarries Guidance Chapter 8 (Environment Canada 2009).

As the wind erosion equation suggests, precipitation acts as a natural dust suppressant which reduces the emissions generated from stockpiles. However, to conservatively estimate the stockpile wind erosion, the number of days with precipitation greater than 0.2 mm was assumed to be 0.

2.10 Propane Combustion Emission

Project equipment (screens, crushers, vehicles, tools, etc.) will require maintenance from time to time. A propane powered welder will be used to repair equipment. The combustion from propane is expected to generate particulates, SO_2, and NO_2. Propane combustion emission is calculated using the method outlined in US EPA AP-42 Section 1.5 Liquefied Petroleum Gas Combustion (US EPA 2008). The emission rate calculation is as follows:

$$ER = EF \times P \times UC$$

Where:

- ER = the emission rate (tonne/day)
- EF = the emission factor (lb/10^3gal)
- P = the propane used (litre/day)
- UC = the unit conversion factor to equate the volume and mass - $\frac{1\,Gallon}{3.79\,L} \times \frac{1\,tonne}{2205\,lb}$

Particulate emissions from propane combustion is assumed to be similar to the emission for natural gas and is expected to be less than 10 µm, as stated in Chapter 1.4 of AP-42 (US EPA 1998a). The emission factors for propane combustions is provided in US EPA AP-42 Section 1.5 Liquefied Petroleum Gas Combustion (2008), and shown in Table 10.

Table 10: Emission Factors for Propane Combustion

Substance	Units	Value
TSP	lb/10^3 gal	0.7
PM_{10}	lb/10^3 gal	0.7
$PM_{2.5}$	lb/10^3 gal	0.7
SO_2	lb/10^3 gal	1.5
NO_2	lb/10^3 gal	13

2.11 Tugboat Emission

Mined aggregate materials are transported by a barge pulled by a tugboat. The tugboat emissions include particulate emissions, sulphur oxides (SO_x), and nitrogen oxides (NO_x). The exhaust emission from Project related tugboats from the Project site to its destination were calculated using the method outlined in *2005 – 2006 BC Ocean-Going Vessel Emissions Inventory* (The Chamber of Shipping 2007). Within The Chamber of Shipping (2007) marine vessels are categorized as travelling in two modes underway mode and maneuvering mode; emission factors are based on the operation mode of the vessel.

The addition of one tug boat a day to the ocean-going vessel traffic in the Howe Sound are predicted to be negligible. Based on conversations with Health Canada, emissions of NO_2, SO_2, $PM_{2.5}$ and PM_{10} from tug movements will be assessed only at the human health receptors (that will include the McNab Strata community) in the regional study area (RSA). The modelling will include emissions of the tug while maneuvering in the vicinity of the Project dock area.

It was assumed that the tugboat would be in maneuvering mode approximately 90 minutes each day, and the tugboat would be in underway mode when travelling. The emission rates of particulates, SO_x, and NO_x are calculated using the equation below:

$$ER = P \times EF \times LF \times T \times UC$$

Where:

- ER = the emission rate (g/duration of travel)
- P = the engine power at maximum continuous rating (kW)
- EF = the emission factor (g/kWh)
- LF = the load factor (%)
- T = the duration of travel per day (hour/day)
- UC = the unit conversion factor to equate the volume and mass - $\frac{tonne}{10^6 g}$

The emissions factors for NO_x, in both underway mode and maneuvering mode are provided in The Chamber of Shipping (2007). Similarly, the emission factor for PM_{10} and $PM_{2.5}$ in maneuvering mode was provided The Chamber of Shipping (2007). The emissions factors for particulate matter (TSP, PM_{10} and $PM_{2.5}$) for underway mode are a function of brake specific fuel consumption (BSFC) and the sulphur content within the fuel. The emission factor for SO_x, in both underway mode and maneuvering mode are a function of the sulphur content within the fuel. Table 11 and Table 12 summarize the emission factors used to calculate the emission rates. It was assumed that the calculated SO_x emissions represented SO_2, and the calculated NO_x emissions represented NO_2.

Table 11: Emission Factors for Tugboat Emission- Underway Mode

	TSP	PM_{10}	$PM_{2.5}$	SO_x	NO_x
Slow Vessel – Underway Mode	0.20	0.20	0.18	0.006	17.00
Comment	Assumed to be same as PM_{10}	Calculated from sulphur content and BSFC	90% of PM_{10}	Calculated from sulphur content	2005-2006 BC Ocean-Going Vessel Emissions Inventory

Table 12: Emission Factors for Tugboat Emission - Maneuvering Mode

	TSP	PM_{10}	$PM_{2.5}$	SO_x	NO_x
Slow Vessel – Maneuvering Mode	1.12	1.12	1.01	0.02	49.64
Comment	Assumed to be same as PM_{10}	2005-2006 BC Ocean-Going Vessel Emissions Inventory	2005-2006 BC Ocean-Going Vessel Emissions Inventory	Calculated from sulphur content	2005-2006 BC Ocean-Going Vessel Emissions Inventory

The sulphur content of the fuel was provided by the tugboat operator Seaspan Marine (L. Pyper, 2014, pers. comm.). The brake specific fuel consumption is provided in The Chamber of Shipping (2007).

2.12 Summary of Emission Rates

Table 13 presents a summary of emission rate for different activities occurring within the Project.

Table 13: Emission rate of activities in BURNCO Project (tonne/day)

Major Activities	Indicator Compound Producing Activity	TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_2
Land Clearing	Bulldozing	4.38E-02	8.45E-03	4.60E-03	0.00E+00	0.00E+00
	Fugitive road dust	4.88E-02	1.36E-02	1.36E-03	0.00E+00	0.00E+00
	Material handling	1.00E-03	4.75E-04	7.19E-05	0.00E+00	0.00E+00
	Vehicle exhaust	4.63E-03	4.63E-03	4.49E-03	1.44E-04	4.45E-02
Aggregate Extraction and Initial Processing	Dredging	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Screening	1.10E-02	3.70E-03	2.50E-04	0.00E+00	0.00E+00
	Crushing	5.06E-04	2.25E-04	1.13E-04	0.00E+00	0.00E+00
Conveying from Pit to Processing Plant	Material handling	1.39E-03	6.56E-04	9.94E-05	0.00E+00	0.00E+00
	Conveyor transfers	3.50E-04	1.15E-04	3.25E-05	0.00E+00	0.00E+00
	Stockpile wind erosion	1.25E-04	6.27E-05	9.41E-06	0.00E+00	0.00E+00
Processing	Material handling	8.20E-03	3.88E-03	5.88E-04	0.00E+00	0.00E+00
	Stockpile wind erosion	1.14E-04	5.70E-05	8.55E-06	0.00E+00	0.00E+00
	Screening	5.33E-02	1.83E-02	1.24E-03	0.00E+00	0.00E+00
	Crushing	1.43E-03	6.35E-04	2.65E-05	0.00E+00	0.00E+00
	Propane combustion	2.09E-06	2.09E-06	2.09E-06	4.49E-06	3.89E-05
	Vehicle exhaust	1.40E-03	1.40E-03	1.36E-03	4.59E-05	1.21E-02
Transfer to Barge	Material handling	1.80E-02	8.51E-03	1.29E-03	0.00E+00	0.00E+00
Shipping	Tugboat emission	3.21E-03	3.21E-03	2.89E-03	1.00E-04	2.70E-01

3.0 CONCLUSIONS

The air quality assessment involved emission rate quantification of activities that occur within the Project. The emission estimation methods were adopted from the emission formulas and emission factors published by US EPA. Some of the activities are expected to implement emission controls, where appropriate, accepted emission reduction efficiencies were applied to the calculated emission rates.

4.0 REFERENCES

British Columbia Ministry of Environment (BC MoE). 2014. BC Air Data Archive Website. Available at: http://envistaweb.env.gov.bc.ca/. Accessed June 2014.

The Chamber of Shipping. 2007. 2005 – 2006 BC Ocean-Going Vessel Emissions Inventory.

Countess Environmental. 2004. WRAP Fugitive Dust Handbook.

Environment Canada. 2009. Pits and Quarries Guidance. Available at: http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=A9C1EE34-1 Accessed June 6, 2014.

Golder (Golder Associates Ltd.). 2013. BURNCO McNab Creek Aggregate Project Conceptual Air Dispersion Model Plan. Technical Memorandum submitted to Ministry of Environment.

Pyper, Luke. 2014. Port Engineer. Seaspan ULC. Telephone Conversation with Taishi Baba (Golder) on July 3, 2014.

US EPA (United States Environmental Protection Agency). 2010. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, NR-009d.

US EPA. 2008. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 1.5 Liquefied Petroleum Gas Combustion.

US EPA. 2006a. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 13.2.2 Unpaved Roads.

US EPA. 2006b. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 13.2.4 Aggregate Handling and Storage Piles.

US EPA. 2006c. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 13.2.5 Industrial Wind Erosion.

US EPA. 2004a. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing.

US EPA. 2004b. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition. NR-009c.

US EPA . 2004c. Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, NR-005c.

US EPA. 1998a. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors: Chapter 1.4. Natural Gas Combustion.

US EPA. 1998b. AP-42, Fifth Edition Compilation of air Pollutant Emission Factors: Chapter 11.9 Western Surface Coal Mining.

US EPA. 1988. Control of Open Fugitive Dust Source.

US EPA. 1995. AP 42, Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources.

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APPENDIX A

Detailed Breakdown of Emission Rates

Table A-1: Detailed Breakdown of Emission Rates

Major Activity	Detailed Activity	Emission Rate (tonne/day)				
		TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_2
I.1 Land Clearing	A1 - Fugitive PM Emissions - Bulldozing	2.19E-02	4.22E-03	2.30E-03		
I.1 Land Clearing	A2 - Fugitive PM Emissions - Excavating	2.19E-02	4.22E-03	2.30E-03		
I.1 Land Clearing	A3 - Fugitive PM Emissions - Material Drop into Rock Trucks - Material Drops	5.02E-04	2.37E-04	3.59E-05		
I.1 Land Clearing	A4 - Fugitive PM Emissions - Material from Rock Trucks to Berm - Material Drops	5.02E-04	2.37E-04	3.59E-05		
I.1 Land Clearing	A5 - Fugitive PM Emissions - Rock Trucks - Fugitive Road Dust	4.88E-02	1.36E-02	1.36E-03		
I.1 Land Clearing	B1 - Exhaust Emissions - Excavator	8.76E-04	8.76E-04	8.49E-04	2.73E-05	8.43E-03
I.1 Land Clearing	B2 - Exhaust Emissions - Rock Trucks (3)	3.24E-03	3.24E-03	3.15E-03	1.01E-04	3.12E-02
I.1 Land Clearing	B3 - Exhaust Emissions - Bulldozer	5.09E-04	5.09E-04	4.93E-04	1.59E-05	4.89E-03
I.2 Overburden	A - Fugitive PM Emissions - Stockpile Wind Erosion	4.38E-05	2.19E-05	3.28E-06	0.00E+00	0.00E+00
I.3 Dredging	A - Fugitive PM Emissions - Dredging	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I.4 Grizzly Screen (6" material)	A1 - Fugitive PM Emissions - Screening	5.50E-03	1.85E-03	1.25E-04		
I.4 Grizzly Screen (6" material)	A2 - Fugitive PM Emissions - Dewatering Screen	5.50E-03	1.85E-03	1.25E-04		
I.4 Grizzly Screen (6" material)	A3 - Fugitive PM Emissions - Grizzly Screen to Surge Material conveyor - Material Drops	5.20E-04	2.46E-04	3.73E-05		
I.5 Jaw Crushing	A1 - Fugitive PM Emissions - Crushing	5.06E-04	2.25E-04	1.13E-04		
I.5 Jaw Crushing	A2 - Fugitive PM Emissions - Jaw Crusher to Surge Material conveyor - Material Drops	1.73E-04	8.21E-05	1.24E-05		
I.6 Surge Material	A1 - Fugitive PM Emissions - Conveyor transfer point - Mine area to Surge Material - Conveyor Transfer Point	3.50E-04	1.15E-04	3.25E-05		
I.6 Surge Material	A2 - Fugitive PM Emissions - Conveyor to Surge Material - Material Drops	6.94E-04	3.28E-04	4.97E-05		
II.1 Surge Material	A1 - Fugitive PM Emissions - Stockpile Wind Erosion	8.16E-05	4.08E-05	6.12E-06		
II.1 Surge Material	A2 - Fugitive PM Emissions - Front End Loader to Dry Screen conveyor - Material Drops	0.00E+00	0.00E+00	0.00E+00		

Major Activity	Detailed Activity	Emission Rate (tonne/day)				
		TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_2
II.1 Surge Material	B - Exhaust Emissions - Loader	1.02E-03	1.02E-03	9.85E-04	3.83E-05	9.77E-03
II.2 Dry Screen 1	A1 - Fugitive PM Emissions - Screening	3.13E-02	1.08E-02	7.26E-04		
II.2 Dry Screen 1	A2 - Fugitive PM Emissions - Dry Screen 1 to Crusher conveyor - Material Drops	9.69E-04	4.58E-04	6.94E-05		
II.2 Dry Screen 1	A3 - Fugitive PM Emissions - Dry Screen 1 to 20 mm Crushed Gravel Stockpile conveyor - Material Drops	1.39E-04	6.56E-05	9.94E-06		
II.3 Crushing	A - Fugitive PM Emissions - Crushing	1.43E-03	6.35E-04	2.65E-05		
II.4 Dry Screen 2	A1 - Fugitive PM Emissions - Screening	2.21E-02	7.59E-03	5.13E-04		
II.4 Dry Screen 2	A2 - Fugitive PM Emissions - Dry Screen 2 to Crusher conveyor - Material Drops	3.08E-04	1.46E-04	2.21E-05		
II.5 25 mm Crushed Rock	A1 - Fugitive PM Emissions - Dry Screen 2 to 25 mm Crushed Rock Stockpile conveyor - Material Drops	4.29E-04	2.03E-04	3.07E-05		
II.5 25 mm Crushed Rock	A2 - Fugitive PM Emissions - Conveyor to 25 mm Crushed Rock Stockpile - Material Drops	8.58E-04	4.06E-04	6.15E-05		
II.5 25 mm Crushed Rock	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	8.88E-06	4.44E-06	6.66E-07		
II.6 10 mm Crushed Gravel	A1 - Fugitive PM Emissions - Dry Screen 2 to 10 mm Crushed Gravel Stockpile Conveyor - Material Drops	3.78E-04	1.79E-04	2.71E-05		
II.6 10 mm Crushed Gravel	A2 - Fugitive PM Emissions - Conveyor to 10 mm Crushed Gravel Stockpile - Material Drops	1.51E-03	7.16E-04	1.08E-04		
II.6 10 mm Crushed Gravel	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	3.55E-05	1.78E-05	2.66E-06		
II.7 20 mm Crushed Gravel	A1 - Fugitive PM Emissions - Dry Screen 2 to 20 mm Crushed Gravel Stockpile Conveyor - Material Drops	2.13E-04	1.01E-04	1.52E-05		
II.7 20 mm Crushed Gravel	A2 - Fugitive PM Emissions - Conveyor to 20 mm Crushed Gravel Stockpile - Material Drops	8.51E-04	4.03E-04	6.10E-05		
II.7 20 mm Crushed Gravel	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	5.04E-05	2.52E-05	3.78E-06		
II.7 20 mm Crushed Gravel	A4 - Fugitive PM Emissions - Screen 1 conveyor to 20 mm Crushed Gravel Stockpile - Material Drops	2.78E-04	1.31E-04	1.99E-05		

Major Activity	Detailed Activity	Emission Rate (tonne/day)				
		TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_2
II.8 Wash Plant Screen	A - Fugitive PM Emissions - Screening	0.00E+00	0.00E+00	0.00E+00		
II.8 Processing Plant Area	B - Exhaust Emissions - Forklift	3.83E-04	3.83E-04	3.72E-04	7.67E-06	2.37E-03
II.9 14 mm Concrete Stone	A1 - Fugitive PM Emissions - WP to 14 mm Concrete Stone Stockpile conveyor - Material Drops	2.08E-04	9.85E-05	1.49E-05		
II.9 14 mm Concrete Stone	A2 - Fugitive PM Emissions - Conveyor to 14 mm Concrete Stone Stockpile - Material Drops	4.16E-04	1.97E-04	2.98E-05		
II.9 14 mm Concrete Stone	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	0.00E+00	0.00E+00	0.00E+00		
II.10 10 mm Concrete Stone	A1 - Fugitive PM Emissions - WP to 10 mm Concrete Stone Stockpile conveyor - Material Drops	2.08E-04	9.85E-05	1.49E-05		
II.10 10 mm Concrete Stone	A2 - Fugitive PM Emissions - Conveyor to 10 mm Concrete Stone Stockpile - Material Drops	4.16E-04	1.97E-04	2.98E-05		
II.10 10 mm Concrete Stone	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	0.00E+00	0.00E+00	0.00E+00		
II.11 Washed Sand (5mm)	A1 - Fugitive PM Emissions - WP to 5 mm Washed Sand Stockpile conveyor - Material Drops	1.31E-04	6.18E-05	9.35E-06		
II.11 Washed Sand (5 mm)	A2 - Fugitive PM Emissions - Conveyor to 5 mm Washed Sand Stockpile - Material Drops	2.61E-04	1.24E-04	1.87E-05		
II.11 Washed Sand (5 mm)	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	1.92E-05	9.58E-06	1.44E-06		
II.12 20 mm Concrete Stone	A1 - Fugitive PM Emissions - WP to 20 mm Concrete Stone Stockpile conveyor - Material Drops	2.08E-04	9.85E-05	1.49E-05		
II.12 20 mm Concrete Stone	A2 - Fugitive PM Emissions - Conveyor to 20 mm Concrete Stone Stockpile Material Drops	4.16E-04	1.97E-04	2.98E-05		
II.12 20 mm Concrete Stone	A3 - Fugitive PM Emissions - Stockpile Wind Erosion	0.00E+00	0.00E+00	0.00E+00		
III.1 Hopper	A1 - Fugitive PM Emissions: Drop of 25 mm Crushed Rock to Hopper - Material Drops	4.29E-04	2.03E-04	3.07E-05		
III.1 Hopper	A2 - Fugitive PM Emissions: Drop of 10 mm Crushed Gravel to Hopper - Material Drops	7.57E-04	3.58E-04	5.42E-05		

Major Activity	Detailed Activity	Emission Rate (tonne/day)				
		TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_2
III.1 Hopper	A3 - Fugitive PM Emissions: Drop of 20 mm Crushed Gravel to Hopper - Material Drops	1.75E-04	8.29E-05	1.26E-05		
III.1 Hopper	A4 - Fugitive PM Emissions: Drop of 14 mm Concrete Stone to Hopper - Material Drops	2.08E-04	9.85E-05	1.49E-05		
III.1 Hopper	A5 - Fugitive PM Emissions: Drop of 10 mm Concrete Stone to Hopper - Material Drops	2.08E-04	9.85E-05	1.49E-05		
III.1 Hopper	A6 - Fugitive PM Emissions: Drop of 5 mm Washed Sand to Hopper - Material Drops	1.31E-04	6.18E-05	9.35E-06		
III.1 Hopper	A7 - Fugitive PM Emissions: Drop of 20 mm Concrete Stone to Hopper - Material Drops	2.08E-04	9.85E-05	1.49E-05		
III.2 Barge	A1 - Fugitive PM Emissions: Hopper to Barge conveyor - Material Drops	1.17E-02	5.51E-03	8.35E-04		
III.2 Barge	A2 - Fugitive PM Emissions: Conveyor to Barge - 25 mm Crushed Rock - Material Drops	8.58E-04	4.06E-04	6.15E-05		
III.2 Barge	A3 - Fugitive PM Emissions: Conveyor to Barge - 10 mm Crushed Gravel - Material Drops	1.51E-03	7.16E-04	1.08E-04		
III.2 Barge	A4 - Fugitive PM Emissions: Conveyor to Barge - 20 mm Crushed Gravel - Material Drops	3.51E-04	1.66E-04	2.51E-05		
III.2 Barge	A5 - Fugitive PM Emissions: Conveyor to Barge - 14 mm Concrete Stone - Material Drops	4.16E-04	1.97E-04	2.98E-05		
III.2 Barge	A6 - Fugitive PM Emissions: Conveyor to Barge - 10 mm Concrete Stone - Material Drops	4.16E-04	1.97E-04	2.98E-05		
III.2 Barge	A7 - Fugitive PM Emissions: Conveyor to Barge - 5 mm Washed Sand - Material Drops	2.61E-04	1.24E-04	1.87E-05		
III.2 Barge	A8 - Fugitive PM Emissions: Conveyor to Barge - 20 mm Concrete Stone - Material Drops	4.16E-04	1.97E-04	2.98E-05		
III.3 Tugboat	B - Exhaust Emissions - Seaspan Commander (Underway Mode)	3.15E-03	3.15E-03	2.83E-03	9.89E-05	2.67E-01
III.3 Tugboat	B - Exhaust Emissions - Seaspan Commander (Maneuvering Mode)	6.59E-05	6.59E-05	5.95E-05	1.08E-06	2.92E-03
IV.1 Welding	C - Combustion	2.09E-06	2.09E-06	2.09E-06	4.49E-06	3.89E-05

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