Air Quality Report

For

EIA of The Cayman Islands Berthing Facility

Prepared June 1, 2015
for

TECHNOLOGICAL & ENVIRONMENTAL MANAGEMENT NETWORK LIMITED

Prepared By

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1. BASELINE ENVIRONMENT

1.1 BASELINE ENVIRONMENT METHOD STATEMENT

1.1.1 Baseline Meteorological Environment

Meteorological data was collected from the National Climatic Data Center (NCDC) Integrated Surface Database (ISD) for Owen Roberts International Airport. Data was collected for the five year time period leading up to the start of the air quality assessment (June 20, 2009 to June 19, 2014). Analysis of the five year data set indicated that the predominant winds in the Cayman Islands are easterlies, with components ranging from southeasterly to northeasterly (see wind rose in Figure 1). Calm winds are considered winds below 0.5 m/s, which is the lowest measureable threshold at Owen Roberts International Airport, and represent periods of stagnant air flow; these occurred 0.18% of the time over the five year period considered.

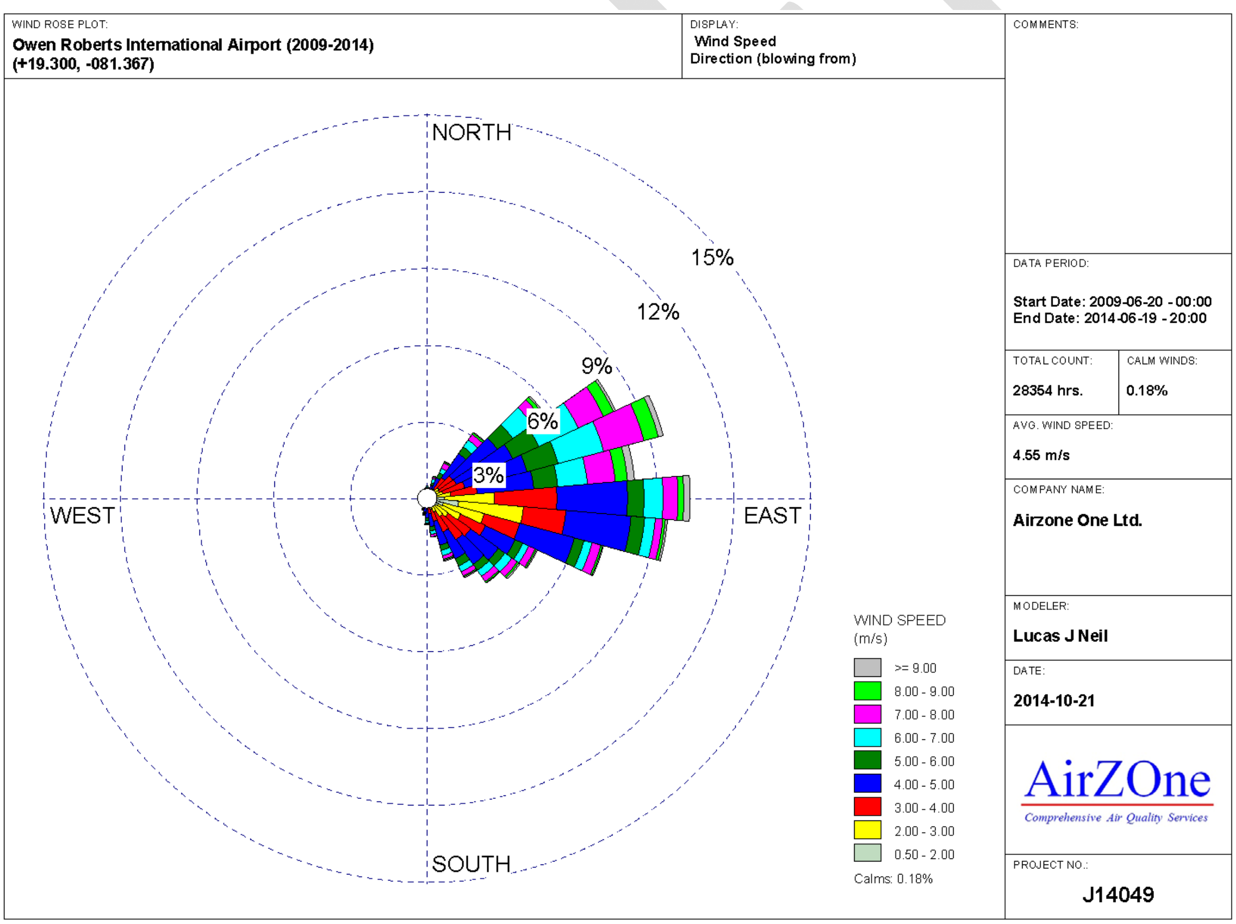

Figure 1: Cayman Island Wind Rose (Owen Roberts International Airport, 2009 – 2014).

1.1.2 Baseline Air Quality Environment

The Terms of Reference (ToR) calls for focus on certain pollutants: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and the finer size fraction of airborne particles (PM_{10}). The ToR also calls for quantification of Greenhouse Gas emissions (GHGs) focusing on carbon dioxide (CO_2). Together, in this assessment, these four substances are termed compounds of potential concern (COPC).

Air quality monitoring is not routinely undertaken on the Cayman Islands, and no data is publicly available on existing levels of air pollutants. Due to the lack of existing ambient air quality monitoring data available within the study area, a three month survey for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) was carried out using passive sampling devices (PSDs) as called for in the ToR. Use of the small, portable and passive monitors provided readily deployable methods without requirements for local power, and thus allowed for flexibility in sampling site selection. The objective of the air monitoring program was to determine an initial indication of background (baseline) levels of target contaminants.

1.1.2.1 Sampling Methods

NO_2 and SO_2 samples were collected using commercially-available Ogawa PSDs with pre-coated filters. An NO_2 filter element is housed within one end of the small, cylindrical PSD body and an SO_2 filter element is housed within the other end. Samples were collected at a height of approximately 2 m above ground to represent typical human inhalation exposures. The samplers were mounted under a custom-built shelter to protect samples from sunlight and rainfall (see Figure 2).

Figure 2: PSD custom-build rain shelter.

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The $NO_2$and SO_2PSDs were loaded with filters in a clean, NO_x- and SO_2-free, area at the laboratories of Airzone One Ltd (Airzone). Assembled PSDs were placed in a manufacturer-supplied, re-sealable pouch, which was stored and transported in a manufacturer-supplied air-tight storage vial. After exposure, the PSD was replaced into the re-sealable pouch and air-tight storage vial and transported to the Airzone laboratory. It was disassembled and the filter pads were removed using dedicated forceps for each filter element. Each $NO_2$and SO_2filter element was placed into separate, labelled, 8 mL polyethylene vials and sealed with a cap. 8 mL of deionized water was added to each NO_2 vial for long term storage of the filters in a clean refrigerator. The PSD was cleaned with distilled water and Kimwipes, allowed to dry, and reassembled with new, unexposed filter elements for subsequent sampling. NO_2 and SO_2 filter element field blanks were also processed in this manner. All exposed SO_2 filter elements were transported in the capped 8 mL polyethylene vials for analysis at RTI International.

One field blank of each media type was exposed and immediately sealed during each sampling period. Field blanks are used to account for interferences and contributions from sample handling and transport. In the laboratory, the blank is treated as a sample in all respects including, storage, preservation and analysis. At the end of the sample collection period, the samples were sealed, transported to the laboratory, and analysed.

The sampling period encompassed a two week period and therefore included weekends. Therefore, the sampling period would account for all periods of activity for a typical week and resultant emission variability.

1.1.2.2 Sampling Locations

Seven sites were established within a 2 km radius of the Royal Watler Cruise Terminal, with an eighth site at the Terminal, to capture representative background, typical, and worst-case concentrations based on current land-use and taking into consideration features of the local terrain and prevailing winds. Sites were chosen based on accessibility, security reasons (e.g. 24-hr security to prevent vandalism of sample collectors), and proximity to sensitive receptors (e.g. Site ID 2 and 4). The location of the sites also ensured an almost complete coverage of all dominant wind directions. In general, samplers were placed within 50’ of a driveway/road in order to capture one of the main sources of pollution (automotive traffic) in the project area.

Descriptions of the air quality sites are provided in Table 1, while the locations of each site are shown in Figure 3. Note that one site (Bolas Engineering offices) was sampled in duplicate for quality assurance.

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Table 1: Descriptions for Monitoring Sites.

Site ID	Site Name	GPS Location		Elevation	Description
		N (°)	W (°)	(MASL)	
1	Whitehall	19.314668	81.383471	8	Residential area 2 km N of Royal Watler
2	NBSC – Elgin Road	19.293824	81.381271	7	400m NW of George Town Hospital; 300m SE of Public Library
3	Royal Watler	19.296016	81.383294	7	200mWof Public Library
4	Cayman Prep	19.288952	81.377300	5	School Zone – in Airport flight path
6i	Bolas Eng 1	19.291907	81.368684	4	Commercial area near Airport
6ii	Bolas Eng 2	19.291907	81.368684	4	Commercial area near Airport
7	Glen Eden Road	19.283178	81.390021	3	Residential area 1.5 km SSW of Royal Watler
8	John Greer Blvd	19.285298	81.374361	7	Residentialarea1.5 km SEof Royal Watler

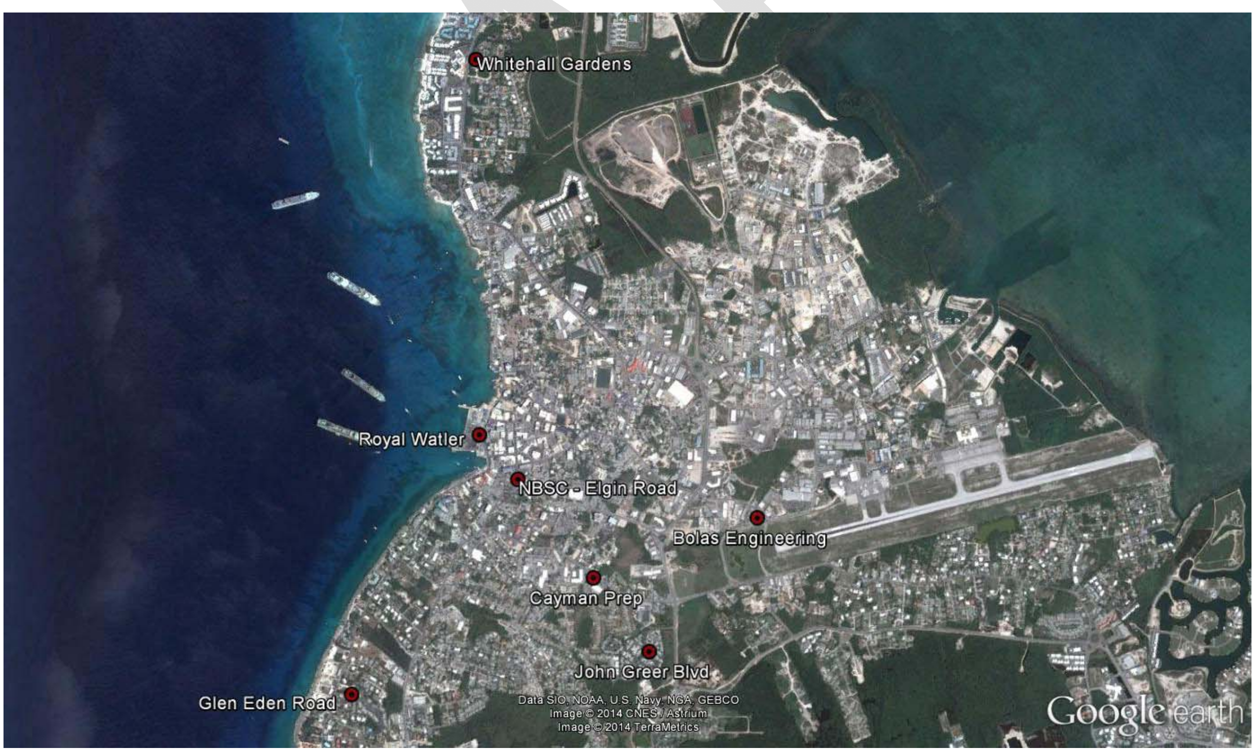

Figure 3: Sampling locations surrounding Royal Watler Cruise Terminal.

1.1.2.3 Analytical Methods

NO_2samples were analyzed at the Airzone laboratory, which is accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) using the ISO 17025:2005 protocol. This program defines a comprehensive QA/QC program including continuous auditing of methods through participation in CALA-mandated round-robin programs and requires the use of qualified, certified suppliers for external laboratory services. Airzone uses standard methods of analysis validated by appropriate agencies including Environment Canada, United States Environmental Protection Agency (US EPA), the National Institute of Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA) and the Ontario Ministry of Labour. SO_2 samples were analyzed by RTI International, whose systems incorporate all EPA-required quality assurance and reporting requirements.

For analysis, NO_2 filters were extracted with 8 mL of ultrapure water. After extraction, a colour-producing reagent was added to facilitate analysis by a colorimetric method for absorbance using a spectrophotometer at a wavelength of 545 nm. Standard solutions were also prepared. The spectrophotometer sample cell was washed twice with distilled water and once with an aliquot of the sample prior to sample introduction. The cell was wiped clean with a lens tissue prior to insertion in the cell holder. The same cell was used for all samples, standard and blank analyses.

For analysis, the SO_2filters were extracted with 8 mL of ultrapure water and the filter extract was analyzed by ion chromatography (IC). Sulphate ion concentration was determined and the amount of SO_2 collected was calculated in direct proportion to the sulphate concentration in the extract. Airborne SO_2 concentrations were based on the amounts collected in each sample, blank results, and the accurate air volumes collected during the sampling period.

1.1.3 Ambient Air Quality Standards

As listed in the ToR, "The Cayman Islands has not adopted numerical standards for ambient air quality. There are a range of standards applied in countries such as the United Kingdom and the United States. Those that apply to the UK (for England) for NO_2 and SO_2, are presented" in Table 2.

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Table 2: UK Ambient Air Quality Standards (AAQS).

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)
Nitrogen Dioxide (NO_2)	1-hour	200
	Annual	40
Sulfur Dioxide (SO_2)	15 minute	266
	1-hour	350
	24-hour	125

The ToR indicates that "the island has a limited number of stationary sources of pollutants, and it is expected that transportation is likely to be the biggest contributor to local ambient air quality."

1.2 BASELINE ENVIRONMENT RESULTS

1.2.1 Baseline Meteorological Environment

Meteorological data was collected from the National Climatic Data Center (NCDC) Integrated Surface Database (ISD) for Owen Roberts International Airport. Data was collected for the thirteen week period of the air quality assessment (June 20, 2014 to September 16, 2014).

Table 3 provides a summary of relevant meteorological parameters for all sampling periods. Note that parameters provided in Table 3 are measured at Owen Roberts International Airport, which is approximately 2.5 km to east of the Royal Watler Cruise Terminal and the monitoring locations.

Table 3: Meteorological Parameters for Sampling Period.

Start Date	End Date	Temperature (°C)			24 hr Precipitation (mm)		Wind Speed (m/s)	
		Min	Max	Avg	Max	Avg	Max	Avg
20-Jun-14	04-Jul-14	25.0	32.2	29.4	0.00	0.00	6.71	3.34
04-Jul-14	18-Jul-14	26.1	32.2	30.0	0.51	0.08	7.15	3.58
18-Jul-14	01-Aug-14	26.1	32.8	30.4	0.25	0.02	7.15	3.22
01-Aug-14	15-Aug-14	25.0	32.8	29.6	7.11	0.90	6.26	2.60
15-Aug-14	01-Sep-14	25.0	32.8	30.1	6.10	0.78	8.05	3.81
01-Sep-14	16-Sep-14	25.0	32.2	29.2	22.1	3.44	11.2	4.37

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Analysis of the thirteen week data set indicated that the predominant winds during this period were from the east, with components ranging from southeasterly to northeasterly (see wind rose in Figure 4). This is consistent with the five year wind rose presented in Figure 1, and suggests that the meteorological conditions of the study period matched those of the five year average.

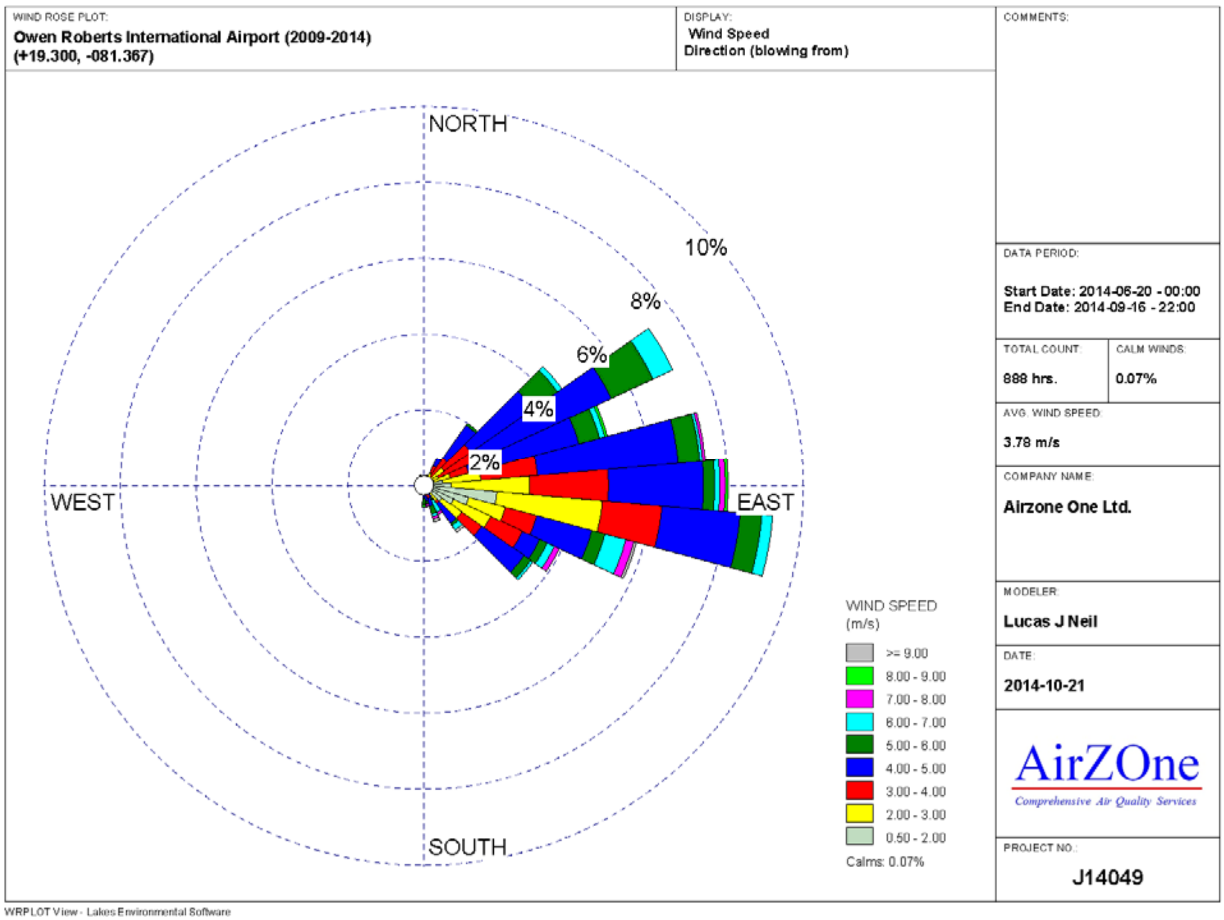

Figure 4: Cayman Island Wind Rose (Owen Roberts International Airport, June 20, 2014 – September 16, 2014).

1.2.2 Baseline Air Quality Environment

1.2.2.1 Monitored COPC Concentrations Below Detection Limit

The Ontario (Canada) Ministry of the Environment (MOE) document entitled "Operations Manual for Air Quality Monitoring in Ontario" (March 2008, PIBS 6687e) provides guidance on how to deal with the analysis of non-continuous data when values are less than the analytical method detection limits (MDLs). MDL is the smallest measurable amount, above which the risk of a false positive is 1%, or above which the confidence level is

99%. According to this MOE document, "for the purposes of performing statistical analyses(e.g., means, etc.) and in keeping with a commonly accepted practice, a value of half the MDL must be substituted for concentrations less than the MDL". This methodology was adopted for estimating background values using the measurements taken during the 2014 field campaign when samples were below the MDL.

1.2.2.2 Nitrogen Dioxide

A summary of the NO_2 results for the entire sampling campaign for each site is summarized in Table 4 based on six 2-week samples. The detection limit for two week NO_2 samples is 0.30 µg/m^3. From the table, it is clear that the Whitehall sampling location experienced lowerNO_2 values than all other sites. It is also evident from the table that the other seven sites experienced similar levels of NO_2 during the sampling campaign. These results most likely reflect the fact that Sites 2 through 8 are located within 2 kms of each other, while Site 1 is located 2 km north of the other sampling sites (see Figure 3). Based on local meteorology, Sites 2 through 8 are likely influenced by the same upwind sources. Site 1, however, is further north and would appear to be subject to different sources. Site 1 is just off the main road in a residential area and is on the grounds (front yard) of a residence adjacent to an empty lot that borders the main road. This would suggest that Site 1 may be less influenced by the direct emissions of NO_2 from the main road than the other sites, which are more closely located to traffic emission sources.

Table 4: Summary of NO_2 Results.

SITE NO.	LOCATION	NO_2 (µg/m3)		
		MIN	MAX	AVG
1	Whitehall	4.3	10	6.0
2	NBSC – Elgin Road	12	20	16
3	Royal Watler	16	24	20
4	Cayman Prep	12	19	16
6i	Bolas Eng 1	1.3	35	17
6ii	Bolas Eng 2	11	22	17
7	Glen Eden Road	6.8	26	12
8	John Greer Blvd	6.3	22	10

1.2.2.3 Sulfur Dioxide

A summary of the SO_2 results for the entire sampling campaign for each site is provided in Table 5based on six 2-week samples. The detection limit for two week SO_2 samples is 0.67 µg/m^3 ("BDL" indicates sample values were below detection limit). From

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the table, it is clear that the Whitehall sampling location experienced higher SO_2 values than all other sites. It is also evident from the table that the other seven sites experienced similar levels of SO_2 during the sampling campaign. These results reflect the findings for NO_2 and reinforce the conclusion that Site 1 is influence by different sources than Sites 2 through 8.

Table 5: Summary of SO_2 Results.

SITE NO.	LOCATION	SO_2 (µg/m^3)		
		MIN	MAX	AVG
1	Whitehall	2.2	4.0	3.1
2	NBSC – Elgin Road	BDL	1.5	0.73
3	Royal Watler	BDL	1.3	0.86
4	Cayman Prep	BDL	1.0	0.62
6i	Bolas Eng 1	BDL	0.90	0.51
6ii	Bolas Eng 2	BDL	1.3	0.76
7	Glen Eden Road	BDL	0.96	0.59
8	John Greer Blvd	BDL	1.4	0.92

1.2.2.4 Field Blanks

Field blanks are used to assess contributions to samples from background on the sampling media, and handling and shipping protocols. Capped and cleaned samplers are brought to the sample collection site, removed from the transport packaging and handled in the same manner as the collection samplers to serve as field blanks. Blank samplers are then immediately sealed and replaced in the transport container. One field blank was collected for each sampling period.

Table 6: Field Blank Results.

Start Date	End Date	SO_2 (µg/m^3)	NO_2 (µg/m^3)
20-Jun-14	04-Jul-14	BDL	2.8
04-Jul-14	18-Jul-14	BDL	2.0
18-Jul-14	01-Aug-14	BDL	2.2
01-Aug-14	15-Aug-14	BDL	2.2
15-Aug-14	01-Sep-14	BDL	0.54
01-Sep-14	16-Sep-14	BDL	1.0

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1.2.3 Comparison to Ambient Air Quality Standards

Ambient measurements presented in Sections 1.2.2.2. and 1.2.2.3. are two week averaged values. The Ontario Ministry of the Environment provides guidance on converting between averaging periods in their guidance document entitled "Procedure for Preparing an Emission Summary and Dispersion Modelling Report", dated March 2009 (ESDM Procedure Document). According to the ESDM Procedure Document, ambient values can be converted to other averaging periods using the following formula:

$$C_0 = C_1 \times F$$

where,
C_0 = the concentration at the averaging period t_0
C_1 = the concentration at the averaging period t_1
F = factor to convert from the averaging period t_1 to the averaging period $t_0 = (t_1/t_0)^n$

and where, the exponent *n* is 0.28, which is generally representative of average conditions across a range of atmospheric stabilities.

Using these conversion equations, the two week samples can be converted to the averaging times of the air quality standards listed in Table 2. The results of the conversions can be found in Table 7and Table 8. The results suggest that the UK Ambient Air Quality Standards were not exceeded for both NO_2 and SO_2 during the sampling period. These results, however, are not absolutely conclusive as the levels for the shorter averaging times are estimates based on the measurements.

Table 7: NO_2 Results Converted to Air Quality Standard Averaging Times.

SITE NO.	LOCATION	NO_2 (µg/m^3)			
		1-hour		Annual	
		MAX	AVG	MAX	AVG
UK AAQS		*200*		*40*	
1	Whitehall	50	30	3.9	2.4
2	NBSC – Elgin Road	104	82	8.2	6.5
3	Royal Watler	123	100	10	7.9
4	Cayman Prep	94	82	7.4	6.5
6i	Bolas Eng 1	179	86	14	6.8
6ii	Bolas Eng 2	113	86	8.9	6.7
7	Glen Eden Road	132	61	10	4.8
8	John Greer Blvd	113	53	8.9	4.2
MAX Value		*179*	*100*	*14*	*7.9*
% of UK AAQS		*89.5*	*50.0*	*35.0*	*19.8*

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Table 8: SO_2 Results Converted to Air Quality Standard Averaging Times.

SITE NO.	LOCATION	SO_2 (µg/m^3)					
		15 minute		1-hour		24-hour	
		MAX	AVG	MAX	AVG	MAX	AVG
UK AAQS		*266*		*350*		*125*	
1	Whitehall	37	29	21	16	8.5	6.6
2	NBSC – Elgin Road	13	6.7	7.4	3.7	3.1	1.5
3	Royal Watler	12	7.9	6.8	4.4	2.8	1.8
4	Cayman Prep	9.5	5.7	5.3	3.2	2.2	1.3
6i	Bolas Eng 1	8.2	4.6	4.6	2.6	1.9	1.1
6ii	Bolas Eng 2	12	6.9	6.6	3.9	2.7	1.6
7	Glen Eden Road	8.7	5.4	4.9	3.0	2.0	1.2
8	John Greer Blvd	13	8.4	7.2	4.7	3.0	1.9
MAX Value		37	29	21	16	8.5	6.6
% of UK AAQS		13.9	10.9	6.0	4.6	6.8	5.3

1.3 BASELINE ENVIRONMENT RECOMMENDATIONS

The current survey of a limited subset of the COPC defined by the ToR was only a three month campaign limited to the summer months. We would recommend that a longer measurement period would be better in order to capture the complete variability within pollutant levels. Furthermore, since the main cruise season is during the fall to spring months (October to April), we would recommend that future monitoring include this time period to ensure samples representative of the cruise period and at times when pollutant levels may be higher. We would also recommend that PM_{10}baseline monitoring be included in future measurement campaigns as it is a defined ToR COPC.

It should be noted that while the converted results presented in Table 7 and Table 8do not exceed the UK AAQS values, the 1-hour NO_2 values approach upwards of 90% of the standard value. This leaves little "space" for increased impacts from changes at the cruise terminal. Therefore, we would also recommend that measurements be made that allow for direct comparison to the averaging time of the appropriate standards to ensure a more accurate assessment of exceedances, or potential for exceedances, of the AAQS values. For example, SO_2 measurements should be made with a minimum of a 15 minute averaging time, which can then be averaged into the other, longer, averaging times.

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2. ENVIRONMENTAL IMPACT

2.1 AIR QUALITY AND GREENHOUSE GASES EMISSIONS

As per the ToR, an assessment of the operation phase for the expanded berthing terminal was conducted to determine possible effects of the development on air quality and greenhouse gas emissions. Effects are possible due to air emissions both during construction and operation of the development. For air emission assessment purposes we divide sources into three groupings of relevance to this EIA:

1. Development construction-related sources: cargo ships, dredgers, on-land construction equipment and construction-site dust emissions.
2. Marine sources – (i) ocean-going vessels [OGVs], consisting largely of cruise ships, and, (ii) harbour craft, consisting of tender craft, pilot boats, pleasure craft, etc. Cargo vessel traffic will also contribute to emissions but is not included in this assessment.
3. Land sources – On-road vehicular emissions consisting of road dust and vehicle exhaust emissions from trucks, buses, taxis, etc.

The ToR calls for focus on certain pollutants from these sources: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and the finer size fraction of airborne particles (PM_{10}). The ToR also calls for quantification of Greenhouse Gas emissions (GHGs) focusing on carbon dioxide (CO_2). Together, in this assessment, these four substances are termed compounds of potential concern (COPC).

This assessment involved a review of the expected change in nature, and location of emissions of NO_2, SO_2, PM_{10} and CO_2 from shipping activities, as well as on-road sources, as a result of the proposed changes to the berthing terminal. The emissions due to the proposed changes at the berthing terminal were compared with a baseline scenario that assumed no expansion of the berthing terminal. Following this review, recommendations will be made as to the need for dispersion modelling to assess whether or not the changes are likely to cause significant air quality effects at coastal sensitive receptors (residences, hospitals, hotels, etc.).

2.1.1 BERTHING TERMINAL EMISSIONS ASSESSMENT

Presently, cargo operations take place at night and cruise operations take place during the day; this mode of operation will remain after construction and operation of the development. Cargo operations occurring at the cargo terminal will not be affected by the cruise activities according to the ToR. Therefore, in terms of assessing changes in emissions of COPC imposed by the development, cargo operations can be ignored at this stage. In later work, emissions from cargo operations may need to be considered for dispersion modelling of impacts.

The ToR calls for an assessment of the expected change in nature and location of these COPC from operational marine activities. Accordingly emission estimates are conducted under a "no change" scenario versus the development scenario; the change in location of the emission sources was considered qualitatively as called for in the ToR. A more formal and quantitative assessment of the impact of these changes (in emission location) will require dispersion modeling, which is outside the presently approved scope of work.

Air emissions from marine vessels, counted as part of a port emission inventory, are generally assessed within 25 nautical miles (nm) from where the pilot boards the ship (US EPA 2009)[1]; this radius, from the Royal Watler Cruise Terminal in Georgetown, will serve to enumerate and characterize relevant vessels for emissions calculation purposes. The Port Authority of Cayman Islands (PACI) has indicated that the pilot station is located 1 mile due west of the cargo pier. Thus the total ocean-side domain boundary extends a radius of appropriately 48.2 km from Georgetown and serves as the ocean-side "domain" of interest.

For the purposes of this comparative study emissions will be estimated based on an operating scenario provided by W.F. Baird & Associates Ltd., in consultation with the Government of the Cayman Islands. A common 24-hour basis is chosen for all COPC as this is a common time period for cruise liners calls at Georgetown.

It should be noted that EIAs typically require impact assessments to be conducted on a worst-case basis. However, an assessment of a typical busy day was requested in order to reflect defined operating conditions.

The two classes of marine vessels that will be most affected by the development are cruise ships and harbour craft.

2.1.1.1 Cruise Ships

The proposed development may allow more cruise ships to call, simultaneously, and will allow some of those ships to locate closer to shore where sensitive receptors are located.

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[1] US EPA, 2009, "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories", prepared by ICF International.

2.1.1.1.1 Change in Location and Number of Cruise Ships

Under the No Development scenario (as at present),that we were asked to analyze, four cruise ships anchor at designated anchors points (numbered 1 – 4) which are aligned N-S approximately 650 m NW of the current docks. Occasionally, up to three additional cruise ships have remained "on-engine offshore", located approximately 1500 m NW of the current docks, over a day (based on historical data supplied by PACI). However, these vessels were not included in this analysis. Figure 5 provides a current example of cruise ship locations at the Terminal.

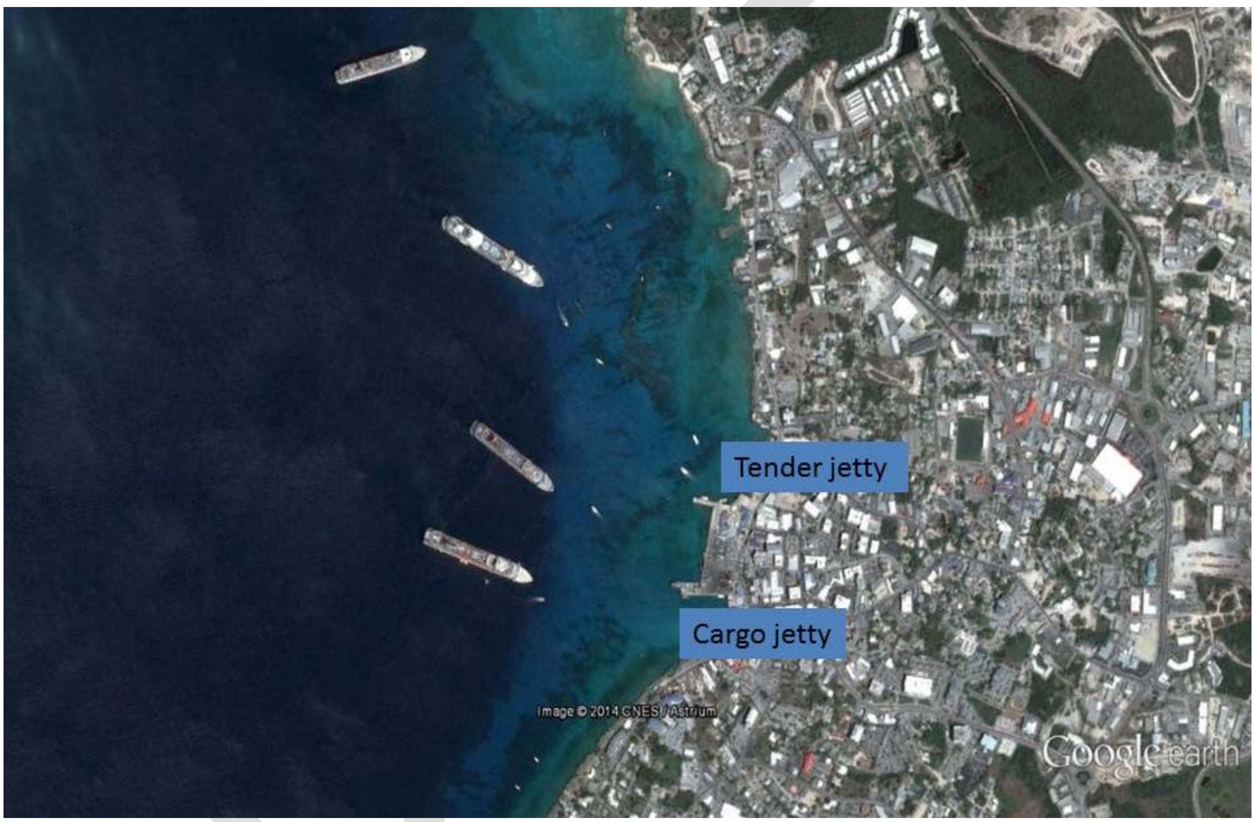

Figure 5: Satellite photo (latest GoogleEarth image for 10 March 2014) of cruise ships called at George Town. Current terminal shows tender jetty on north side and cargo terminal on south side. Ships at anchorages 1-3 are seen; the northernmost liner is on-engine offshore.

Under the Development scenario provided to us, all four ships will move dockside, and therefore operate closer to on-shore sensitive receptors. Two offshore anchor points will be eliminated; therefore, two additional ships will be accommodated at those anchor points. Therefore the total number of cruise ships present will increase to six under the provided development scenario.

2.1.1.1.2 Nature of Emissions

Generally, cruise ships possess a number of different combustion sources that will cause air emissions of the COPC. Propulsion engines exhausts are a significant source of air emissions from cruise liners. Engines are sometimes divided into two sets; main engines used for propulsion and auxiliary engines used to provide on-board power. In general these engines are fuelled by diesel, commonly residual oil (RO), marine diesel oil (MDO) or marine gas oil (MGO). In addition, cruise ships may possess separate boilers for water heating and also garbage incinerators.

Emissions from the engines vary according to engine number, size, fuel type and mode of operation. The modes of operation, which dictate the load on the engine, include cruise speed mode where main engines are subject to highest loads. Cruise speed is generally attained in open water. As ships approach a port they will often enter a reduced speed zone (RSZ) imposing lower loads on main engines; this is termed the RSZ mode. Maneuvering mode, close to dock or final anchor point, can still require the use of main engines but at low load (causing lower emissions). Conversely, auxiliary engines tend to operate in inverse fashion, and may operate at low loads (or not at all) during cruise mode but at progressively higher loads as main engines are slowed on approaching port. Auxiliary engines can operate at normal maximum while at berth as they are designed to provide power throughout the ship so the main engines can be shut down as the ship remains in "hoteling" mode.

Using this information, emissions per ship call, and for each mode, can be determined using the equation below:

$$E = P \times LF \times A \times EF$$

Where E = Emissions (grams [g])
P = Maximum Continuous Rating Power (kilowatts [kW])
LF = Load Factor (percent of engine's total power)
A = Activity (hours [h])
EF = Emission Factor (grams per kilowatt-hour [g/kWh])

2.1.1.1.3 No Development

To estimate the existing baseline emissions from cruise ships, we were provided with an operating scenario (over a 24 hour period) as described above. The scenario involved four Dream Class liners, with the Carnival Dream providing a representative vessel. It was indicated that days with this many large ships occur less than 10% of the time.

To calculate emissions from each Dream Class vessel, information is required on engine configuration and ship activities while in the domain of interest. The Carnival Dream possesses engines totaling approximately 75,600 kW maximum power; no information was available on whether these engines were main or auxiliary engines and so they were assumed all main. Emission factors for COPC were referenced from US EPA (2009) "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" based on the assumed use of RO fuel and the assumption that engines were medium speed (130 – 1,400 RPM). It is assumed that any onboard garbage incinerators do not operate within the domain.

Ship activities while in the domain were based upon assumed time-in-mode estimates. Each ship was assumed to spend 1.5 hours at full cruise speed, 1.5 hours in RSZ mode, 1 hour maneuvering and 8 hours hoteling for a total of 12 hours inside the 25nm domain during a 24 hours period. As shore power is currently not provided, and not envisaged as part of the development, no "cold ironing" (ship powered from shore) is assumed. No over-nighting of cruise ships was assumed.

The engine load factors at cruise speed were assumed to be 83% (US EPA 2009). Load factors at lower speeds were based on the Propeller Law (US EPA 2009) where cruise speed of Dream Class vessels is 21 knots (approximately 93% of maximum speed of 22.5knots). Speeds at RSZ were assumed to be 12 knots, and maneuvering at 8 knots maximally. Corresponding engine load factors are 19 and 6%, respectively. While at berth, ship power was assumed to be provided by 6% load of the main engines also.

The above factors are combined with the Entec OGV engine emission factors (US EPA 2009) for medium speed engines burning RO fuel (2.7% sulphur). The baseline emission factors for the COPC are 14 (NO_x, conservatively assumed to be 100% NO_2), 11.24 (SO_x, conservatively assumed to be 100% SO_2), 1.43 (PM_{10}) and 677.91 (CO_2), all in units of g/kWh.

US EPA (2009) indicates "The International Maritime Organization (IMO) adopted NO_x limits in Annex VI to the International Convention for Prevention of Pollution from Ships in 1997. These NO_x limits apply for all marine engines over 130 kilowatts (kW) for engines built on or after January 1, 2000, including those that underwent a major rebuild after January 1, 2000. The required number of countries ratified Annex VI in May 2004 and it went into force for those countries in May 2005. Most ship engine manufacturers have been building engines compliant with Annex VI since 2000."

The Annex has been ratified by the Cayman Islands and passed into law as the "Merchant Shipping (Marine Pollution) (Prevention of Air Pollution from Ships) Regulations, 2012". These regulations set provisions for the types of vessels that may use national waters, and specifically sets emission standards for vessels. The regulations consider emissions of NO_x, SO_x and ozone (O_3) depleting substances. Since Dream Class vessels were built after the year 2000, and by analogy with vessel composition at US ports,

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a NO_x reduction factor of 0.802 is applied (US EPA 2009, Table 2-12) providing a resultant NO_x emission factor of 11.228 g/kWh. This also accounts for vessel compliance with new IMO Emission Control Areas (ECAs) even though Cayman Island territorial waters are not within an ECA. The 0.802 factor is relevant to the 2015 analysis year, an estimation of the first full year of development operation in 2018.

Below about 20% engine load, emission factors begin to increase due to inefficient engine operations (US EPA 2009). Based on Table 2-15 of US EPA (2009) emissions for COPC at 6% load (maneuvering and hoteling) were adjusted by 1.6 (NO_x), 1.61 (SO_x), 2.04 (PM_{10}) and 1.59 (CO_2).

Based on the assumption of four Dream Class cruise ships within the domain, emissions are estimated as follows: 7,881kg NO_x, 7,906 kg SO_x, 1,098 kg PM_{10} and 474,784 kg CO_2 for the defined 24 hour period.

Note that the (generic) Entec emission factors have been applied to specific Dream Class ships. More ship-specific emissions data may indicate that these newer ships may have lower emissions than other (older) ships (despite having larger engine sizes). As this is a comparative emission inventory estimate, however, a more in-depth investigation of ship-specific emissions can be delayed until dispersion modelling is authorized.

2.1.1.1.4 Development

Under the development scenario, as described above, we have been provided that the cruise ships would be two Oasis Class and four Dream Class. Therefore, based on the provision of two Oasis Class and four Dream class ships in the domain over 24 hours, emissions would increase to: 12,937 kg NO_x, 12,979 kg SO_x, 1,803kg PM_{10} and 779,437 kg CO_2. These emissions reflect an increase by a factor of 64% over the no development scenario.

Table 9: Summary of Cruise Ship Emissions under Existing and Possible Future Scenarios

Parameter	No Development (4 Cruise Ships)	Development (6 Cruise Ships)	Relative Change
NO_2 (kg)	7,881	12,937	64%
PM_{10} (kg)	1,098	1,803	64%
SO_2 (kg)	7,906	12,979	64%
CO_2 (kg)	474,784	779,473	64%

2.1.1.2 Harbour Craft

There are a variety of different harbour craft that currently frequent George Town Harbour including tenders, dive boats, and private recreational boats. Of specific interest are the CMS tender fleet which consist of 16 vessels and are expected to be impacted significantly by the proposed berthing facility. The US EPA (2009) Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories were used to prepare an estimate of the emissions associated with the tender operation under both existing and possible future scenarios.

The CMS tender fleet consists of 12 large tenders and 4 smaller tenders. We have assumed a large tender has engines totaling 800HP while small tenders are 400HP and they operate 8 hours a day with emission factors obtained from EPA (2009). During operations it was assumed they spend 30% of their time in-transit (under 90% power), and 70% of their time loading/unloading (under 20% power) to give a weighted average load factor of 41%.

2.1.1.2.1 No Development

Under the no development scenario 4 Dream Class vessels are anchored offshore and all require tender services. All 16 tenders are assumed to be in operation on this day with estimated emissions summarized in Table 9.

2.1.1.2.2 Development

Under the future development scenario any days with 4 or fewer cruise ships in port (this currently occurs over 90% of the time) there will be no emission associated with tendering as the ships are expected to use the berthing facility. This represents a 100% decrease in tender emissions over 90% of the year.

We have also considered a scenario with 6 ships calling in Cayman where 2 Dream Class vessels are anchored offshore and require tender services, while 2 Dream and 2 Oasis class vessels are berthed at the piers. Under this scenario 10 large tenders were assumed to be in operation with estimated emission summarized in Table 9. The assumption of 10 tenders for 2 ships was based upon CMS records indicating that when Carnival Magic (Dream Class vessel) and Freedom of the Seas (comparable to Dream Class) were in port there were 5 tenders deployed for each ship. This estimate is conservative as it is unlikely there will be 10 large tenders available if the proposed berthing facility is constructed.

Table 10: Summary of Tender Emissions under Existing and Possible Future Scenarios

Parameter	No Development (4 Cruise Ships)	Development (6 Cruise Ships)	Relative Change
NO_2 (kg)	276	197	-29%
PM_{10} (kg)	8	6	-29%
SO_2 (kg)	36	26	-29%
CO_2 (kg)	19,011	13,579	-29%

There is a significant reduction expected in overall tender emissions but it should be noted that relative to the cruise ship emissions the tender emission quantities are relatively small. However, the tender emissions tend to occur closer to sensitive receptors so dispersion modeling is recommended to evaluate the potential impacts of the proposed facility in more detail.

2.1.2 PUBLIC ROADS EMISSIONS ASSESSMENT

The development is expected to cause increased cruise ship passenger loads onshore, and therefore increased road traffic and congestion (refer to Traffic Impact Assessment). Roads that serve to bring passengers to and from the cruise terminal may become busier; increase traffic causes increased traffic-related air emissions and this would mean there may be some affected sensitive (e.g., residential) receptors along any key routes that serve the terminal. On-road vehicles (mobile sources) on public roads emit COPC via re-suspension of road dust (PM_{10}) and tail-pipe emissions (NO_2, SO_2, CO_2, and PM_{10}).

An onshore 1 km study area was chosen based on data provided by Technological & Environmental Management Network Ltd. (TEMN) as being representative of the area of influence and falling within the boundary of the traffic assessment.

2.1.2.1 Road Dust Emissions

The US EPA AP-42 Chapter 13.2.1 for Paved Roads[2] was used to determine dust emissions in the PM_{10} size fraction. The required input information for road surface silt loading and the average weight of vehicles travelling the road were assumed for this assessment. The assumption for silt was the maximum ubiquitous baseline default value from AP-42, which is 0.6g/m^2. In order to determine an average weight of vehicles

[2]US EPA. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, January 2011. http://www.epa.gov/ttnchie1/ap42/

travelling the road, the vehicle km travelled in the onshore domain was used to determine an approximate weighted average, based on the assumed vehicle fleet. The vehicle fleet is estimated to consist of 2-wheeled and 3-wheeled vehicles, passenger vehicles, taxis, buses and trucks.

2.1.2.2 Tail-Pipe Emissions

In order to determine traffic vehicular exhaust emissions of NO_2, SO_2, CO_2, and PM_{10}, the International Vehicle Emissions model (IVE model) was used.[3] The IVE model was designed to provide flexibility in emission modelling for countries outside of the USA and Europe, who have their own emission projection models. The vehicular technologies outside of the USA and Europe may differ significantly from those jurisdictions and the IVE model helps to account for those differences.

2.1.2.3 Public Roads Emission Estimates Assumptions

Since site specific data regarding IVE model inputs (e.g. fleet age, fuel types, vehicle kilometers travelled, etc.) for Cayman Islands were not available at the time when this assessment was completed, assumptions for the inputs into the IVE Model were made for the No Development scenario and for the Development scenario, both for the year 2018, which is the predicted first full year of operation of the development. The IVE team had previously performed studies in various cities around the world and provided input data specific to those cities. Therefore, from available datasets, it was decided that the vehicular dataset for Lima, Peru was the most similar to Cayman Islands in terms of vehicular regulations and location (Lents et al, 2004)[4]. Lima is a major urban center, however, and Cayman Islands is not as densely populated, and so estimations were required to scale Lima's input data to appropriate levels for the Cayman Islands.

In order to determine emission estimates, IVE requires input information on driving behavior (e.g. amount of driving, driving patterns, and air conditioning use) and environmental conditions (e.g. altitude, temperature and relative humidity) for a specific area. Additionally, information on maintenance programs in force, the number of vehicle starts in an area (vehicle "start-ups") and the distribution of engine resting times is required. Information on fuel quality, type, contaminants and additives added to the fuel are also required as inputs to the IVE model. Estimates for these data inputs were made based on information provided by TEMN, information from the IVE Lima study and default data available within the IVE model. However, no data was available to highlight certain

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[3]IVE Team. (published 2008, May). IVE Model Users Manual Version 2.0.International Vehicle Emissions Model.Retrieved September 10, 2013, from http://www.issrc.org/ive/.
[4]Lents, J. et al. (published 2004, June 28). Lima Vehicle Activity Study Report. International Vehicle Emissions Model.Retrieved September 10, 2013, from http://www.issrc.org/ive/.

differences in vehicle fleets between the Cayman Islands and Lima (e.g. the age distribution of the vehicles). In further work, more accurate estimates of on-road vehicle exhaust emissions may be derived with more site specific details about the on-road fleet in and around Georgetown.

As indicated, the number of vehicle start-ups and vehicle kilometers travelled (VKT) for the vehicle fleet is required as an input to the IVE model. The Lima data set included data on VKT travelled in the metropolis of Lima and the number of vehicle start-ups for each section of the vehicle fleet and were used as surrogate data here. Lima data were scaled to Georgetown on the basis of comparative population and the size of the area modelled within the 1 km study area, both of which are much less than for Lima. The Georgetown estimated VKT values were used for both tail-pipe emissions and the paved roads assessment.

For the emission estimates with the development in place, it was assumed that only the taxi fleet and bus fleet would be affected as these two vehicle types would increase if passenger numbers arriving to the terminal station increases. The affect was an assumed increase by 10% in vehicle activity for these two classes of vehicles. This assumed increase was based on information from other Caribbean jurisdictions that experienced port facility upgrades and witnessed an approximate 10% increase in cruise ship passenger arrivals following those facility upgrades.[5]Cruise ship passenger arrivals in the Bahamas and St. Maarten increased 9.2 and 9.5%, respectively. It is noted that although the passenger numbers may increase by 10%, the number of taxis and buses active in the domain over 24 hours may not necessarily increase by the same 10% value since passenger activity at the Terminal may be altered. Also, it is assumed that the 2-wheeled vehicle (motorcycles) and passenger vehicle numbers will not increase, although it is possible that with more cruise ship passengers arriving, there may be more 2-wheeled and passenger cars on the roads if rented by cruise passengers. Increased congestion, due to the presence of more tourists, was not explicitly accounted for here. Lastly, a potential increase in the native population (which may occur if more people move into the region due to increased prosperity) was not accounted for here in either the population scaling or the number of vehicles and vehicle types on the roads. While not available at the time of writing, details from the finalized traffic assessment would be incorporated into future work to fine-tune the emission assessments.

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[5]http://www.onecaribbean.org/statistics/latest-tourism-statistics-tables/, http://www.onecaribbean.org/wp-content/uploads/Lattab2011UpdatedApril2013.pdf

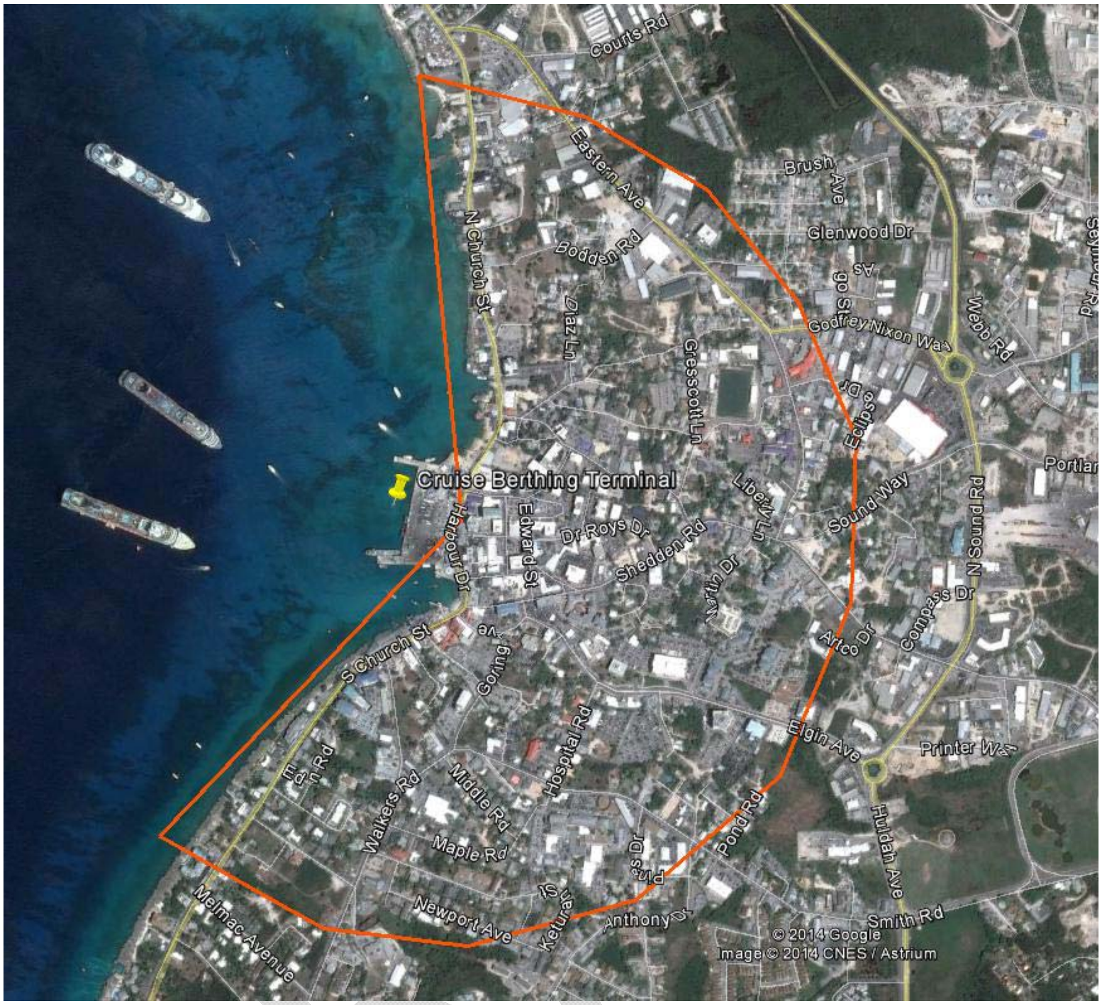

Figure 6: Area (orange) Source used to simulate public road traffic emission sources.

A 1 km area surrounding the Royal Watler Cruise Terminal includes a network of roadways in Georgetown; this domain was modelled as an area source, as shown in Figure 6.

2.1.2.4 Public Roads Emissions Assessment Results

Table 11 shows the combined results from the IVE model and paved roads assessment for each of the criteria air contaminants (NO_2, SO_2, and PM_{10}) and CO_2 for a standard 24 hour period.

Table 11: Results from IVE model and paved road assessment for the No Development scenario and for the Development scenario, both assessed in the year 2018. These numbers are totals for the area shown in Figure 6, in units of kilograms per day.

(kilograms/24 hours)	No Development	Development	% Change
NO_2	23.3	24.6	5.58%
SO_2	4.03	4.22	4.71%
CO_2	23,873	25,069	5.01%
PM_{10}	366	384	4.92%

2.1.3 AIR QUALITY EMISSIONS

Emissions under the different scenarios are summarized in Table 11. Under the existing and future development scenarios considered, air emissions from cruise ships may increase by approximately 64% and tender services may decrease by approximately 29%, while emissions from on-road vehicles may increase by an estimated 5%. In addition, and more importantly, offshore sources will change their general location to come closer to sensitive receptors onshore. The increased traffic along roadways may also increase exposure at sensitive receptors, as pollutant levels may be enhanced in street canyons.

Table 12: Summary of Possible Emission Impacts

Parameter (kg/24 hr)	Source	No Development (4 Cruise Ships)	Development (6 Cruise Ships)	Relative Change
NO_2	Cruise Ships	7,881	12,937	64%
	Tenders	276	197	-29%
	Vehicles	23.3	24.6	5.6%
PM_{10}	Cruise Ships	1,098	1,803	64%
	Tenders	8	6	-29%
	Vehicles	366	384	4.9%
SO_2	Cruise Ships	7,906	12,979	64%
	Tenders	36	26	-29%
	Vehicles	4.03	4.22	4.7%
CO_2	Cruise Ships	474,784	779,437	64%
	Tenders	19,011	13,579	-29%
	Vehicles	23,873	25,069	5.0%

Cruise ship emissions are 1-3 orders of magnitude greater than tender or vehicle traffic emissions so it should be noted that the potential decrease in tender emissions may not act as a significant offset to the increase in emissions from cruise vessels.

There are a number of uncertainties in the emission estimates that can be reduced by the collection of site-specific vessel and on-road data from Georgetown. In particular,

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while it was not available at the time of writing, the on-road assessment should include a more accurate assessment of road emissions based on the results of the Traffic Impact Assessment.

The emission estimates provided describe emissions released at source into the entire domain; the effect on air quality at particular sensitive receptors can only be determined by dispersion modelling, as an additional analysis step. Therefore, dispersion modelling is recommended (as indicated in the ToR, p. 39) along with expanded emissions estimations, as described in more detail below.

Furthermore, the assessment conducted here cannot be considered a worst-case scenario, as it does not account for the maximum number of vessels, and potentially the largest vessels, that can be accommodated by the port. EIAs typically require impact assessments to be conducted on a worst-case basis. Therefore, we recommend that a worst-case scenario assessment be conducted for comparison with the "typical busy day" assessment conducted in this report.

2.1.3.1 Additional Recommendations

Based on the significant increase in the emissions of COPCs predicted by this review, dispersion modelling is recommended in keeping with the Terms of Reference to predict levels at specific sensitive receptors. Information from the modelling will serve as a basis for the formulation 0f policy and strategies for effective management of ambient air quality ambient quality.

The wind-rose plots in Figure 1 and Figure 4indicates that most emissions from the Royal Watler Cruise Terminal location would be carried out to sea and may have minimal impact on the surrounding area. However, this does not mean that there may not be significant impacts on local air quality caused by the Development. It can be noted from the two figures that there is a north-south element to the wind, which, when combined with the shape of the coastline at the harbor location and increased emissions from both harbor and on-road activity, may cause local impacts in air quality on the timescales of the AAQS. The only way to accurately assess the impact of the altered emissions is through dispersion modelling.

To support the recommended dispersion modelling the emission inventory should be extended to all sources with common contaminants to allow an accurate estimate of changes in air quality levels due to the proposed development. This may include additional marine sources, such as cargo ships, but also additional land-based sources such as cargo handling equipment, on-road shipping trucks, etc. The emissions inventory will need to account for varying time basis according to varying averaging period of each air quality guideline (ref. Table 3.4 in ToR).

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COPC should include additional contaminants including very fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), and hazardous air pollutants such as volatile organic compound (VOC) species and diesel particulate matter. These substances are common port emissions and have known health concerns (US EPA 2009) separate from the COPC assessed in this report.

For estimating marine vessel emissions survey/data collection systems or time-limited surveys should be conducted to track and record vessel activity and characteristic data. This will allow emissions to be estimated on a more accurate, Georgetown-specific basis, especially for harbour craft. In tandem with this effort, more detailed ship-specific emission data should be collected (if available) from ship owners/operators to determine if the generic Entec emission factors are accurate for representative ships.

Ultimately, a health/ecological risk assessment may also be required if dispersion modelling indicates that air quality guideline values are approached or breached.

2.1.4 GREENHOUSE GAS EMISSIONS

The latest data on GHG emissions from the Cayman Islands was published in 2013 and covers emissions from 1990 to 2011 as part of the UK's reporting under the Kyoto Protocol. In 2011, the emissions accounted towards domestic transport were 0.18 $MtCO_2$. The results in Section 2.1.2 (on-road traffic emissions) can be converted to annual values of 0.0087 $MtCO_2$ for the No Development scenario and a value of 0.0092 $MtCO_2$ for the Development scenario. This results in an increase of 0.28%over all transportation emissions.

The assessment of marine fleet activities suggests an increase of 64% in CO_2 emissions from cruise ships and a decrease of 29% in CO_2 emissions from harbour craft. As a result, this could significantly change the attributable CO_2 emissions for international travel, which already account for 13% of GHG emissions in the Cayman Islands.

However, as outlined in Section 2.1.3, there are a number of uncertainties in the emission estimates. Therefore, we recommend the collection of site-specific vessel and on-road data from Georgetown to provide a more accurate estimate of the impact on GHG emissions.

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