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Chignecto-Central Regional School Board
60 Lorne Street
Truro, NS B2N 3K3

Attention: Ms. Jackie Fahey, Coordinator, Health & Safety
Email: faheyj@ccrsb.ca

Dear Ms. Fahey:

Reference: Boiler Exhaust Gas Dispersion Analysis – Highland Consolidated Middle School, Westville, Nova Scotia

Stantec Consulting Ltd. (Stantec) conducted a limited analysis of the exhaust gas dispersion of the boiler stack at the Highland Consolidated Middle School (HCMS) located at 2157 South Main Street in Westville, Nova Scotia. The purpose of the investigation is to provide the Chignecto-Central Regional School Board (CCRSB) with information on the mechanisms involved in the dispersion of boiler stack emissions and to quantify the range of concentrations of contaminants that may be present both indoors and outdoors. The intention of the investigation is to determine whether boiler stack emissions are a contributing factor in the ongoing odour investigation at the HCMS.

BACKGROUND

The HCMS is heated through a boiler system that is supplied by furnace oil. The boiler system is located partially below ground at the rear of the school next to the gymnasium in a large mechanical room. The exhaust stack comprises brick and mortar with an interior concrete/stone finish. The stack extends approximately 8 m (27 feet) above the mechanical room roof, approximately 1.2 m (4 feet) away from the gymnasium roof, approximately 1.35 m (4.5 feet) above gymnasium roof line and approximately 15 m (50 feet) from the roof of the main section of school.

An investigation was done by C.J. MacLellan & Associates Inc. (CJ Mac) to determine whether the boiler stack meets code requirements in the report titled *Chignecto-Central Regional School Board – Highland Consolidated Middle School – Indoor Air Quality Issues, Mechanical Systems*, dated November 2012. The results from this investigation determined that the stack measurements meet the current code requirements defined in B139 Installation Code for Oil-Burning Equipment released in 2009.

MONITORING PLAN

Stantec performed the following scope of work related to the monitoring plan:

- Used orange coloured smoke signal canisters (Comet) that emit smoke for approximately 3 minutes when triggered. Smoke emitters were placed on ledge of flu opening where it mixed with combustion gasses before being dispersed by winds.
- Visually monitored and recorded the dispersion pattern of boiler stack emission through strategically placed video cameras around the subject building property.

- Measured possible concentrations of carbon monoxide (CO), nitrogen oxide (NO) and nitrogen dioxide (NO_2) gases resulting from the combustion of furnace oil through direct reading instruments capable of data-logging, and placed at strategic locations.
- Monitored weather patterns throughout investigation to determine what effect wind is having on the boiler exhaust dispersion pattern.
- Prepared this written report documenting the findings of the investigation.

LIMITATIONS

The information and observations contained within this report are based on information collected on the day of the investigation only.

CONCEPT DEVELOPMENT

An assessment of the concentrations of combustion gases dispersing from the boiler system at the HCMS was conducted. Direct reading instruments used during the assessment were provided by Pine Environmental, located in Mississauga, Ontario. Five (5) V-RAE combustible gas monitors (Model PGM-7800) and one (1) MultiRAE Plus monitor (Model PGM50-5P) manufactured by RAE Syetems with built-in sampling pump and data-logging capabilities were equipped with CO, NO and NO_2 toxic sensors.

The purpose was to visualize the exhaust plume from the boiler stack and determine the potential of those gases migrating into the school based on the knowledge that classrooms are under negative pressure when windows and doors are closed.

Weather patterns were observed prior to the day of the investigation to determine a worst-case scenario. It was determined that a south or southeast wind would be preferable to perform the investigation based on the location of the boiler stack at the school. In this scenario, the majority of the HCMS building structures would be downwind of the of the exhaust plume, which would provide the best conditions to test the theory. Monitoring equipment would be placed in both indoor and outdoor locations once it was determined on site which direction the prevailing wind was originating from.

Smoke emitters were used to provide visual information on the dispersion pattern of the exhaust plume. Measures were taken to ensure safety of individuals triggering the smoke emitters through reviewing product Material Safety Data Sheets (MSDSs) and wearing personal protective equipment (PPE).

CHEMICAL EXPOSURE LIMITS

Most Canadian jurisdictions, including Nova Scotia, have adopted as industrial standards the Threshold Limit Values (TLVs) published by the American Conference of Governmental Industrial Hygienists (ACGIH) in an annually updated booklet titled *Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices*. The 2012 version was in effect at the time of this study.

ACGIH defines the maximum average concentration of airborne chemicals to which *nearly all* workers may be exposed for specific work intervals, usually the typical 8-hour workday over a 40-hour week, without adverse effect. The Threshold Limit Value-Time-Weighted Average concentration is referred to as the TLV-TWA. ACGIH also defines a Threshold Limit Value-Short-Term Exposure Limit for 15 minute exposures, which is referred to as a TLV-STEL. Ceiling values are also defined for some chemicals where the concentration should not be exceeded during any part of the workday.

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The National Ambient Air Quality Objectives (NAAQOs) identify benchmark levels of protection for outdoor air quality that protects public health and the environment. The NAAQO established a desirable and acceptable levels for certain pollutants based on exposure time where adverse human health effects and/or environmental effects may be demonstrated. The NAAQOs are established by Environment Canada under the *Canadian Environmental Protection Act* (CEPA), 1999.

Concentration units are typically expressed in parts per million (ppm) if the chemical is a gas or vapour.

For this investigation, the contaminants of concern in the exhaust are nitrogen dioxide (NO_2), nitrogen oxide (NO) and carbon monoxide (CO). The two species of nitrogen oxides (often referred to as NOX) in exhausts are NO and NO_2. The latter is potentially harmful and is regulated, the former is not. CO is a colourless, odourless, toxic gas that is a product of incomplete combustion and is regulated. This study does not include all contaminants involved with combustion gases, however uses specific substances that would appear in higher concentrations as indicators of contamination.

Table 1 summarizes the standards that apply to the test results collected in this investigation:

Table 1 Chemical Standards

Chemical	ACGIH TLV-TWA	ACGIG TLV-STEL	NAAQO-DESIREABLE	NAAQO-ACCEPTABLE	NAAQO-TOLERABLE
Carbon monoxide (CO)	25 ppm	-	8 hour: 5 ppm 1 hour: 13 ppm	8 hour: 13 ppm 1 hour: 31 ppm	8 hour: 17 ppm 1 hour: --
Nitrogen dioxide (NO_2)	0.2 ppm	-	24 hour: -- 1 hour: --	24 hour: 0.106 ppm 1 hour: 0.213 ppm	24 hour: 0.160 ppm 1 hour: 0.532 ppm
Nitrogen oxide (NO)	25 ppm	-	-	-	-

EXECUTION OF MONITORING PLAN

The monitoring investigation was carried out on Tuesday November 13, 2012. Weather conditions fluctuated leading up to the investigation, however a limited window was available on this day where the winds were favorable to conduct the work. Site work was carried out by Don Hartt, Karen Cameron, and Mike McLean of Stantec.

The direction of the wind on the day of the investigation varied from south to southwest. Portable direct reading instruments were set up at strategic locations to capture possible contaminants emitting from the boiler stack. Five (5) locations were identified to set up the instruments, which included; on the north side of the stack on the roof (Loc 3), north side of stack outside at rear entrance (Loc 2), in room 201 (Loc 5), in room 203 and 206 (Loc 4), and a reference sample outdoors upwind (south) of the stack in the soccer field. A site plan showing the monitor locations is provided in Attachment 1.

Direct reading instruments measuring CO, NO_2 and NO were programmed to provide sample logging at one (1) minute intervals.

Although the temperature outdoors was approximately 15 degrees Celsius, CCRSB staff ensured that the boiler was operating at a higher capacity than it was programmed for that particular day. It should be noted that the level of operation of the boiler was unknown during the investigation. No smoke resulting from the combustion of fuel oil was observed while the boiler was operating, however a large amount of heat and air was observed emitting from the flu as the smoke emitters were being set up. For this investigation it is assumed that the boiler was operating during the entire time on site.

Six (6) Comet orange smoke signals were used to monitor the boiler exhaust plume. The smoke emitters were placed on the mortar crown of the stack in such a manner to effectively mix with the boiler exhaust. The intention was to perform six (6) separate tests, however it was determined after the wind speed kept increasing throughout the day that it would be more effective to trigger two smoke emitters simultaneously during the final two test. This provided a more useful visual assessment of the dispersion patterns through using video.

RESULTS

The tests were conducted while the boiler at the HCMS was operating. The wind direction during the time of the investigation was from the south to southwest averaging 40 km/hr, and gusting later in the afternoon up to 80 km/hr.

The concentrations of CO, NO and NO_2 were measured and recorded at 60 second intervals. The monitoring locations were determined after evaluating the weather conditions on the day of the investigation. The locations of the instruments and are as follows:

- Location 1 – Upwind outdoor reference location, rear of school in soccer field;
- Location 2 – Outdoors at rear entrance area of school representing a possible high traffic area for staff and students entering/exiting building;
- Location 3 – Outdoors on main section (northeast corner) roof downwind of exhaust plume representing a possible worst-case scenario;
- Location 4 – Indoors in Room 206 representing an area in the north portion of the school downwind from the exhaust plume; and,
- Location 5 – indoors in Room 201 representing an area in the south portion of the school downwind from the exhaust plume.

Based on the variable wind direction and speed the instrument situated at Location 3 was moved to the lower roof section located above the boiler mechanical room downwind of exhaust plume, and the instrument situated at Location 4 was relocated to Room 203, also downwind of exhaust plume. A site plan showing the location of the monitoring locations is located in Attachment 1.

Four (4) tests were conducted with smoke emitters. Video cameras were set up at three (3) locations and one video camera was used to maneuver around to observe exhaust plume. Each smoke emitter has a pre-determined run-time of 3 minutes. Smoke deployment times were as follows:

- Test No. 1 – 12:58 (1 smoke emitter);
- Test No. 2 – 13:17 (1 smoke emitter);
- Test No. 3 – 13:32 (2 smoke emitters simultaneously); and,
- Test No. 4 – 13:50 (2 smoke emitters simultaneously).

The time history of the concentrations at monitoring locations along with smoke emitter deployment times, monitor location changes and other observations are shown in Figures 1, 2, 3, 4 and 5 below.

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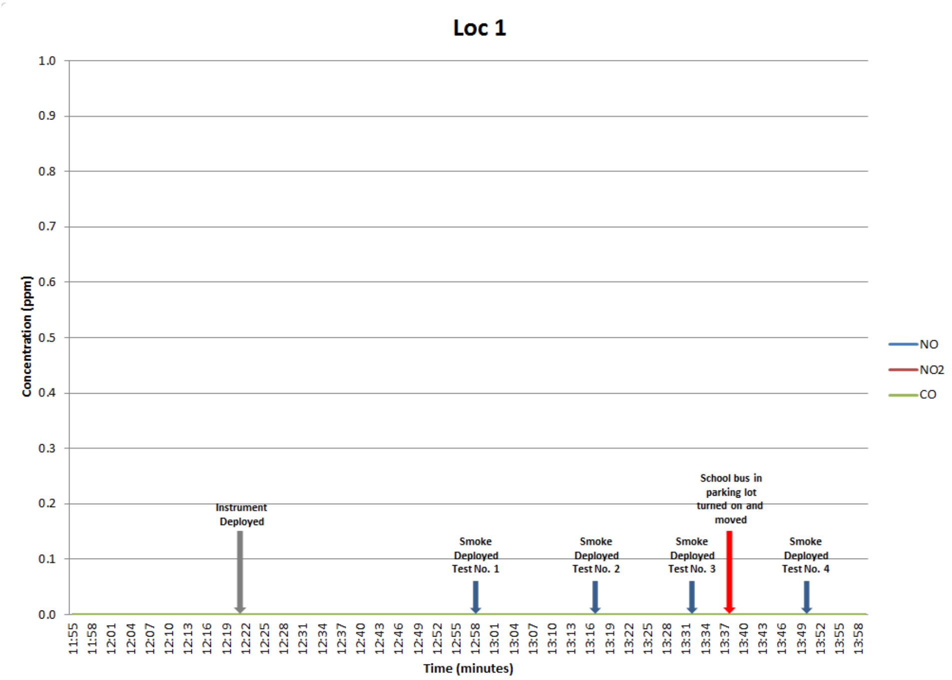

Figure 1: CO, NO and NO_2 Concentrations, Location 1, Outdoor Reference

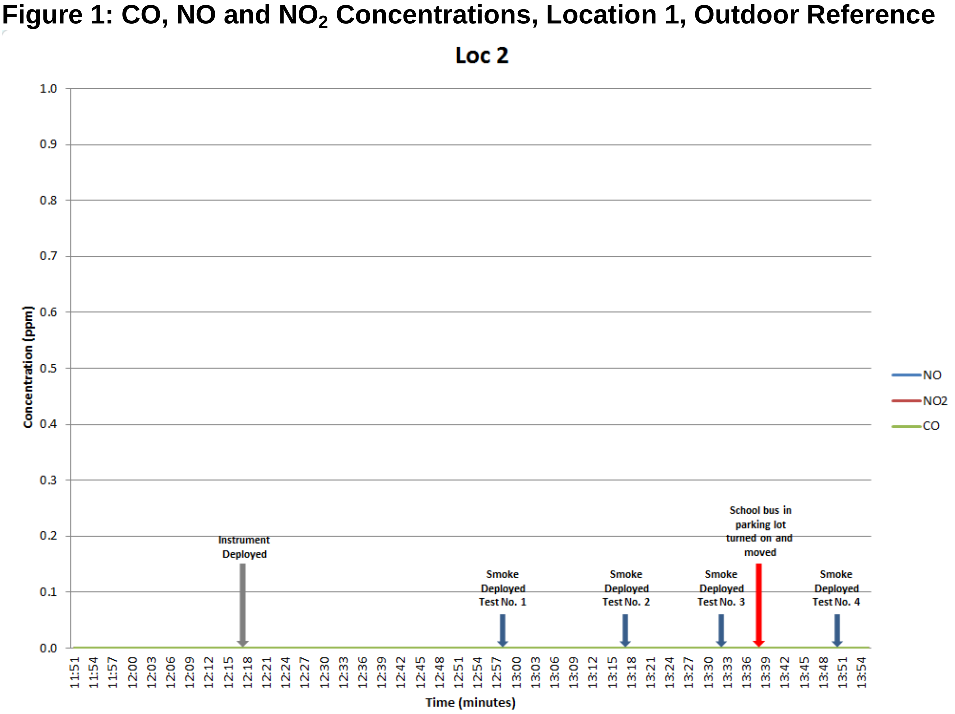

Figure 2: CO, NO and NO_2 Concentrations, Location 2, Outdoor Rear Entrance

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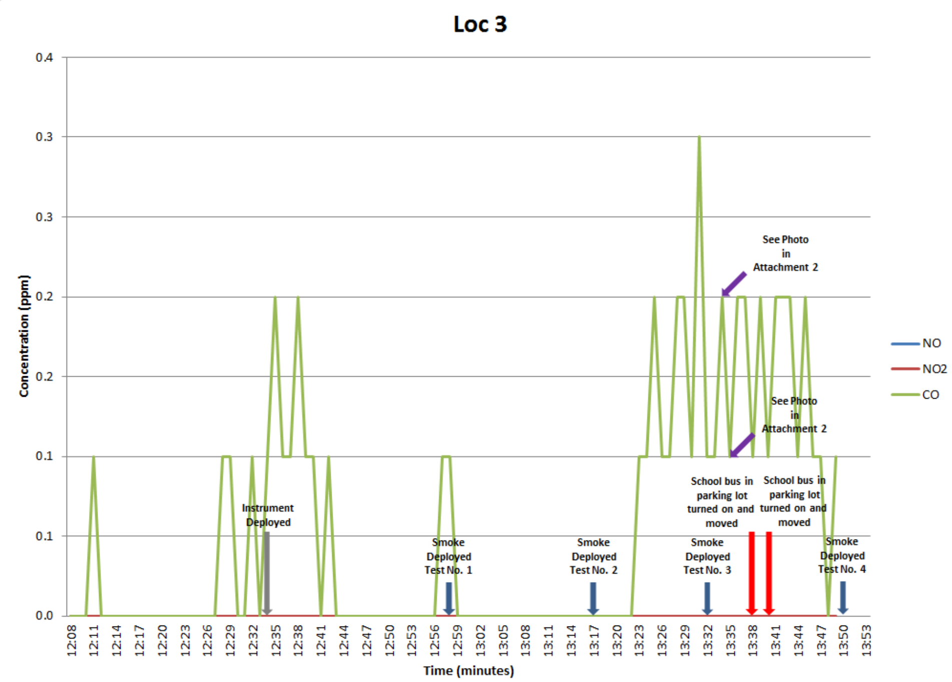

Figure 3: CO, NO and NO_2 Concentrations, Location 3, Outdoor Upper and Lower Roof

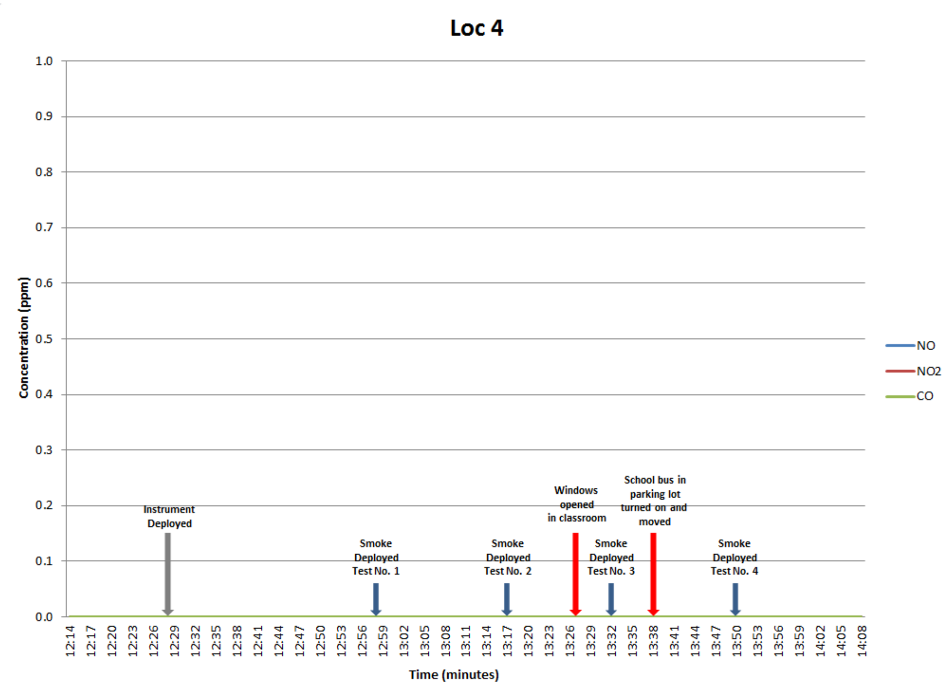

Figure 4: CO, NO and NO_2 Concentrations, Location 4, Indoor Rooms 203 and 206

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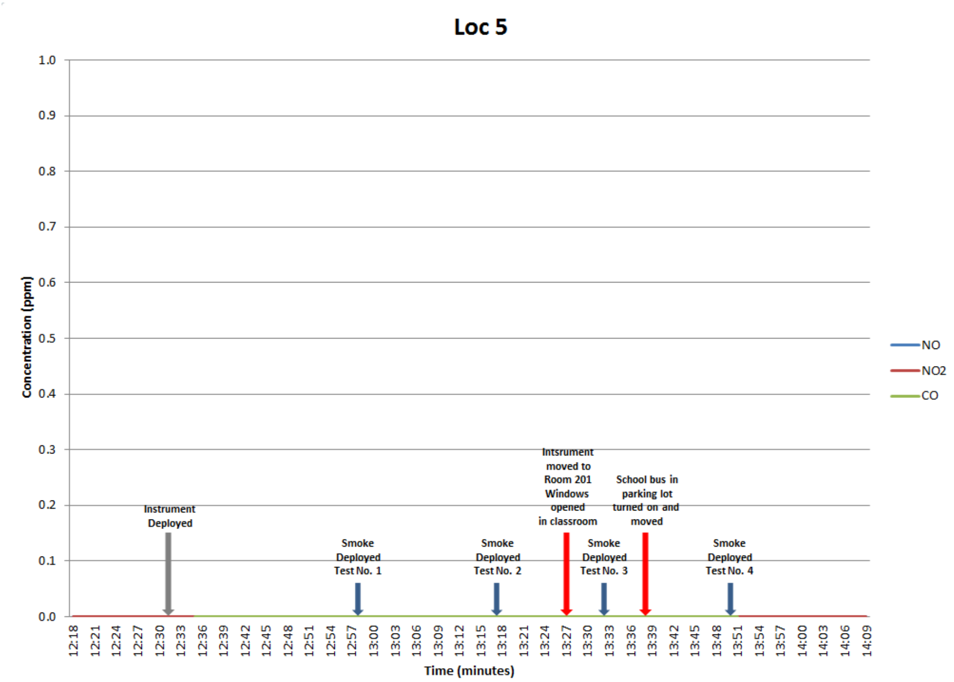

Figure 5: CO, NO and NO_2 Concentrations, Location 5, Indoor Room 201

The results of the concentrations showed no sustained levels of CO, NO and NO_2 resulting from combustion of fuel oil in the boiler in Locations 1, 2, 4 and 5. Location 3 recorded CO levels ranging from 0.0 ppm to 0.3 ppm during the 1 hour and 17 minutes that the monitor was data-logging.

Video cameras were used to monitor the exhaust plume from the boiler stack. Cameras clearly show that as the wind was traveling across the mortar cap of the boiler stack, emissions were being swept directly downwards towards the rear parking lot in a recirculation zone where a tremendous amount of turbulence was observed. Still frame photos were captured at 13:34 and 13:35 during Test Number 3 illustrating this phenomenon located respectively in Photos 1 and 2 below.

Photo 1: Showing smoke emitter deployed in Test No. 3 at 13:34 minute mark. Direct reading instrument at Location 3 on lower mechanical room roof measured CO concentration of 0.2 ppm during the same time this still frame was captured.

Photo 2: Showing smoke emitter deployed in Test No. 3 at 13:35 minute mark. Direct reading instrument at Location 3 on lower mechanical room roof measured CO concentration of 0.1 ppm during the same time this still frame was captured.

Locations 4 and 5 were indoor locations located downwind from the exhaust plume. Those classrooms are under negative pressure when the windows and doors are closed and smoke emitter test number 1 and 2 attempted to record possible contaminant concentrations based on those simulated conditions. Visual observation of the boiler exhaust showed that the plume was washing directly on the southeast facing (downwind) section of the school. To simulate an alternative scenario, windows were opened in Rooms 201 and 203 during smoke emitter test 3 and 4 in an attempt to observe if the exhaust plume was migrating into the school. A faint smell that the smoke emitters produced was observed in the classrooms during Tests 3 and 4 signaling a potential for contaminants to enter into the school.

During the time that the instruments were data-logging, a school bus parked near the rear entrance was turned on at 13:38 and left parking lot. Results observed at all locations showed that the diesel combustion from the school bus had no effect on the concentrations recorded.

DISCUSSION/CONCLUSIONS

The investigation was intended to determine whether or not combustion gases resulting from the burning of furnace oil in the boiler was having any exposure effect on individuals that may occupy the HCMS. The monitoring portion of the study showed that no concentrations of CO, NO or NO2 were recorded over a sustained period throughout the investigation.

CO concentrations were measured in the outdoor roof location (Loc 3) which was nearest to the boiler stack and represented a worst case scenario. These concentrations were well below the ACGIH TLV-TWA of 25 ppm and would pose little concern to occupants of the school on the day of the investigation. CO concentrations were also well below the NAAQOs maximum desirable level of 13 ppm over an hour period and would pose little concern to human health on the day of the investigation.

The visualization portion of the investigation showed that the boiler exhaust plume was not streamlining over top of the HCMS in an efficient manner. Videos and still images show that the plume was washing downwards in a recirculation zone at ground level where a large amount of turbulence was observed. The exhaust plume could be seen circulating at the rear entrance of the HCMS and also washing against the southeast facing classrooms before sweeping around the northern end of the school away from the property.

The wind speed and direction played a large role in this investigation. Winds averaged 45 km/hr and gusts of 80 km/hr were recorded before the study was finished. Having said that, the smoke being emitted from the canisters was being dispersed extremely quickly, which made it difficult to properly observe the plume over a large distance. Given the conditions, a substantial amount of fresh air was likely mixing with the exhaust fumes which did not make for favorable conditions to perform the direct reading for contaminants. It is likely that on a calmer day with a similar wind direction, exhaust would downwash in the same manner. This may result in measurable concentrations of contaminants in outdoor and indoor locations.

The south to southwest wind direction helps prove this down-washing phenomenon and it can be assumed that any wind direction originating from a southerly direction may impact the way that boiler exhaust gases are dispersed and recirculated around the HCMS. It is not likely that the boiler stack emissions contributed to the odour problems experienced at the HCMS given the concentrations of contaminants recorded during this investigation, however there may be occasions when the presence of exhaust gases makes the indoor air quality unpleasant.

RECOMMENDATIONS

Although no significant concentrations of boiler combustion contaminants were measured on the day of the investigation, visually it was determined that the dispersion patterns of the boiler exhaust was interacting with the building structure and down-washing to ground level to an area frequented by building occupants. As a due diligence measure, the boiler stack should be fitted with an extension piece to raise the height of the stack allowing the exhaust emission to enter a streamline zone over the school preventing recirculation.

CLOSURE

This report is prepared for the sole benefit of the Chignecto-Central Regional School Board. The report may not be relied upon by any other person or entity without the express written consent of Stantec Consulting Ltd. and the Chignecto-Central Regional School Board.

Any uses which a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices at the time the work was performed. The conclusions presented herein represent the best technical judgment of Stantec Consulting Ltd. based on the information obtained from the specific sampling locations.

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The conclusions presented represent the best judgment of the assessor based on the data obtained from the work. The conclusions are based on the site conditions encountered by Stantec at the time the work was performed at the specific testing and/or sampling locations, and can only be extrapolated to an undefined limited area around these locations. Due to the nature of the investigation and the limited data available, Stantec cannot warrant against any undiscovered liabilities.

If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that this information be brought to our attention so that we may re-assess the conclusions presented herein.

Sincerely,

STANTEC CONSULTING LTD.

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Attachments– Site Plan – Boiler Stack Emissions Investigation, HCMS