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July 19, 2010

Ms. Karen E. Feahr
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Subject: **Final Preliminary Assessment of Potential Public Health Impacts Associated with $PM_{2.5}$ Emissions from Operating a Biomass-fired Combined Heat and Power Plant in Traverse City, Michigan and Associated Concerns from the Medical Community**
MACTEC Project Number: 3310100010

Dear Ms. Feahr:

MACTEC Engineering and Consulting, Inc. (MACTEC) is submitting electronically to Traverse City Light & Power (TCLP) the results of the preliminary assessment of the potential public health impacts associated with operating a biomass-fired combined heat and power plant in Traverse City, Michigan. The scope of work outlined in the draft was prepared in accordance with MACTEC's Proposal Number: PROP10CADI.0010 dated June 7, 2010.

If you have any questions, please feel free to contact any of the undersigned.

Respectfully submitted,

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PRELIMINARY ASSESSMENT OF POTENTIAL PUBLIC HEALTH IMPACTS ASSOCIATED WITH $PM_{2.5}$ EMISSIONS FROM OPERATING A BIOMASS-FIRED COMBINED HEAT AND POWER PLANT IN TRAVERSE CITY, MICHIGAN AND ASSOCIATED CONCERNS FROM THE MEDICAL COMMUNITY

Traverse City, Michigan

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EXECUTIVE SUMMARY

Traverse City Light & Power (TCLP) is considering the possibility of constructing and operating a 10 megawatt (MW) biomass-fired combined heat and power (CHP) plant in the Traverse City area as a step towards achieving its stated goal of delivering 30 percent of the utility's power from renewable sources by 2020. TCLP retained MACTEC Engineering and Consulting, Inc. (MACTEC) to evaluate the expected ambient impact of the combustion emissions associated with the proposed biomass-fired CHP plant.

Estimated short-term and annual average ambient $PM_{2.5}$ (also known as fine particulate matter in the ambient air 2.5 microns or less in size), oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) impacts of the proposed plant were modeled using the SCREEN3 model approved by the United State Environmental Protection Agency (USEPA) as an acceptable screening technique for the purpose of this assessment. The assessment was performed based on a conceptual design of the plant (equipment) and specific design parameters such as electric generating capacity, expected hours of operation, stack design, etc. and estimated emission rate factors for $PM_{2.5}$, NO_x, hydrogen chloride (HCl), SO_2 and volatile organic compounds (VOCs). Since an actual plant location has not been identified, SCREEN3 modeling was performed using two terrain scenarios: 1) flat terrain and 2) simple elevated/complex terrain.

The following summarizes the estimated emission rates for the proposed biomass-fired CHP plant and the results of the SCREEN3 modeling:

- The estimated emission rates indicate that the plant will be classified as a minor source with respect to Criteria Air Pollutants ($PM_{2.5}$, NO_x and SO_2) (e.g., less than 250 tons per year on any individual Criteria Pollutant) and Hazardous Air Pollutants (HCl) (e.g., less than 10 tons per year of any individual Hazardous Air Pollutant.
- The maximum modeled results for $PM_{2.5,}$ NO_x and SO_2 for the flat terrain scenario are all well below their respective National Ambient Air Quality Standards (NAAQS).
- The maximum modeled results for $PM_{2.5,}$ NO_x and SO_2 for the simple elevated/complex terrain scenario are all well below their respective NAAQS.

For comparative purposes, the estimated $PM_{2.5}$ emission rate (0.0171 pounds per million British Thermal Units [pounds/MMBTU]) for the biomass-fired CHP plant compared favorably with various combustion units including outdoor wood boilers, residential wood stoves, the decommissioned coal-fired Bayside Plant, recently permitted coal-fired plants and natural gas-fired power plants.

The potential impacts to human health and the environment were evaluated based on the calculated emissions and human exposure to those emissions which is dependent upon operating conditions, type of fuel, time elapsed from the addition of fuel to boiler, local weather and activity patterns and locations of those living or working nearby. These parameters and topography determine the quantity of emissions inhaled. Because particulate matter (PM) is the major component of wood smoke exposure, it is a surrogate of exposure for assessment of potential impacts of the biomass-fired CHP plant. Of particular interest is the exposure concentration to $PM_{2.5}$ resulting from the operation of the biomass-fired CHP plant since $PM_{2.5}$ exposure has been observed to lead to aggravating conditions in those with pre-existing diseases such as asthma, chronic obstructive pulmonary disease and cardiac effects.

The contribution of emissions from the proposed biomass-fired CHP plant to local cancer risk and to estimate the threshold levels on acute non-cancer adverse health effects, most notably cardiac and respiratory outcomes were determined using the modeled $PM_{2.5}$ concentrations. Using standard USEPA and published assessment methodology, the exposures were found to be within the acceptable cancer risk range, below acute non-cancer adverse affect levels and less than potential health impacts associated with local ambient background $PM_{2.5}$ concentrations.

Therefore, the $PM_{2.5}$ emissions associated with the operating conditions of the proposed biomass-fired CHP plant will not have a measurable impact on the local population, either from short-term or long-term exposures.

1.0 INTRODUCTION

Traverse City Light & Power (TCLP) is considering the possibility of constructing and operating a 10 megawatt (MW) biomass-fired combined heat and power (CHP) plant in the Traverse City area as a step towards achieving its stated goal of delivering 30 percent of the utility's power from renewable sources by 2020. The project is in the conceptual planning stages and TCLP has not selected a site or finalized the design of the plant. Local physicians and other members of the community have raised concerns regarding potential public health impacts associated with expected emissions of $PM_{2.5}$ (also referred to as fine particulate matter) from the plant. At this early stage in project development, the expected impact of the biomass-fired CHP plant on ambient concentrations of $PM_{2.5}$ had not been previously estimated. TCLP retained MACTEC Engineering and Consulting, Inc. (MACTEC) to evaluate the expected ambient impact of the combustion emissions associated with the biomass-fired CHP plant relative to $PM_{2.5}$ concentrations as well as assessing these changes in ambient $PM_{2.5}$ concentrations with respect to potential public health effects. MACTEC also modeled estimated short-term ambient oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) impacts of the proposed biomass-fired CHP plant.

2.0 PLANT DESIGN BASIS

TCLP provided information to MACTEC regarding the design basis of the potential biomass-fired CHP plant. The conceptual design of the plant includes the following equipment:

- Fixed bed updraft gasifier to convert biomass to syngas
- Oxidizer to combust the syngas and generate heat
- Heat recovery steam generator to produce electricity and provide steam for heating and/or process steam use by others
- Electrostatic precipitator to control $PM_{2.5}$
- Selective Non-Catalytic Reduction technology to reduce emissions of NO_x
- Scrubber or sorbent injection to reduce emissions of SO_2 and hydrochloric acid (HCl)

Design parameters established by TCLP for the biomass-fired CHP plant include:

- Heat input of gasifier: 180 millions British Thermal Units per hour (MMBTU/hr)
- Electric generating capacity: 10 MW gross/9 MW net
- Expected hours of operation: 8,400 hours/year
- Stack Height: 60 to 100 feet above grade
- Inside stack diameter: 5.5 feet
- Stack gas exit temperature: 320°F
- Stack gas exit velocity: 4,000 feet per minute
- Stack gas volumetric flow rate: 94,000 actual cubic feet per minute (acfm)

Table 1 presents the estimated emission rates for the proposed biomass-fired CHP plant provided by TCLP.

TABLE 1
Estimated Emission Rates for Proposed Biomass-fired CHP Plant

Pollutant	Emission Rate (pounds/MMBTU)	Emission Rate (pounds/hour)	Emission Rate (tons/year)	Emission Rate (grams/second [g/s])
$PM_{2.5}$	0.0171	3.08	12.9	0.39
NO_x	0.093	16.7	70.3	2.11
HCl	0.0023	0.41	1.7	---
SO_2	0.025	4.5	18.9	0.57
Volatile Organic Compounds (VOCs)	0.001	0.18	0.8	---

The emission rates presented in Table 1 indicate that the plant will be classified as a minor emissions source with respect to Criteria Air Pollutants ($PM_{2.5}$, NO_x , and SO_2) (less than 250 tons per year on any individual Criteria Pollutant) and Hazardous Air Pollutants (HCl) (less than 10 tons per year of any individual Hazardous Air Pollutant). The emission rate in Table 1 for $PM_{2.5}$ is less than the required emission limit (0.03 pounds per MMBTU) for new biomass plants in the United States Environmental Protection Agency's (USEPA's) proposed Area Source Boiler Rule (75 Federal Register 31938, June 4, 2010). The proposed Area Source Boiler Rule does not include emission limits for the other air pollutants in Table 1.

3.0 DISPERSION MODELING APPROACH/RESULTS

The elements of the screening analyses are presented below.

3.1 MODEL SELECTION

In accordance with the November 9, 2005, Federal Register (70 FR 68218), SCREEN3 (version 96043) has been utilized as an appropriate screening tool to estimate ambient impacts. SCREEN3 is referenced in Section 4.2.1 of the USEPA's Guideline on Air Quality Models (Guideline), codified in Appendix W to 40 CFR Part 51 as an acceptable screening technique. SCREEN3 is an EPA-approved, Gaussian-plume air dispersion model used to analyze single-source release scenarios in simple or complex terrain. The model enables users to prepare an initial screening analysis to establish a conservative or worst-case estimate of maximum short-term air quality impacts from a specific source. If predicted screening concentrations are under the level of concern, generally no further analysis is required.

3.2 SOURCE DATA - EMISSION ESTIMATES

The regulated air pollutants that were modeled in this study include $PM_{2.5}$, NO_x and SO_2. Table 1 presents the emission rates for each regulated pollutant modeled based on TCLP-provided data. To efficiently estimate the impact of the multiple regulated pollutants in this analysis, a unit emission rate of one gram per second (g/s) has been entered in a single SCREEN3 run for each terrain scenario (discussed below) and impacts have been scaled accordingly relative to the predicted emission rates of each individual regulated pollutant. The use of a scaling factor is appropriate due to the linear relationship between emission rate and ambient impact for a single point source.

3.3 SOURCE DATA - STACK CHARACTERISTICS

Table 2 presents the stack characteristics that are used in the modeling analyses. The table lists the stack parameters necessary for conducting dispersion modeling analysis, i.e., base elevation, stack height, stack diameter, exit velocity, exit temperature and ambient temperature.

TABLE 2
Stack Characteristics

Location	**Feet**	**Meters**
Base Elevation Above Mean Sea Level (north of the Cherry Capital Airport)	624	190.20
Stack Parameters	**Feet**	**Meters**
Stack Height	100	30.48
Stack Diameter	5.50	1.68
	Feet/Second	**Meters/Second**
Exit Velocity	66.7	20.32
	°F	**°K**
Exit Temperature	320	433
Ambient Temperature	68	293

3.4 TERRAIN/RECEPTOR DATA

The screening modeling analyses are characteristic of two terrain scenarios: 1) flat terrain, and 2) simple elevated/complex terrain. The flat terrain scenario assumes no topographical features, such that all receptors at which concentrations are calculated are equal in elevation to the base of the stack. The second terrain scenario incorporates terrain features in the Traverse City area, with an assumed plant location near the airport intended to be representative of a typical terrain setting within Traverse City. Simple elevated terrain is defined as ground level elevations above the base of the stack, but below the top of the stack, while complex terrain constitutes ground level elevations which exceed the top of the proposed stack.

For the flat terrain model run, an automated receptor array was defined out to 12 miles from the source. For the simple elevated / complex terrain scenario, the shortest distance from the modeled stack location to a given elevation above stack base was input out to a distance of approximately 2.8 miles. The elevations are entered into SCREEN3 at five meter increments.

3.5 METEOROLOGICAL DATA

The full meteorology option is selected in SCREEN3. This option utilizes a full range of stability class and wind speed combinations to identify the conditions that result in the maximum ground-level concentrations. The stability class and wind speed combinations are described in Table 2 of the "SCREEN3 Model User's Guide." Regulatory default mixing heights are used, which are a function of wind speed and based on stability class. The regulatory default anemometer height of 10 meters is used. An ambient air temperature of 293 degrees Kelvin (°K**)** (68 degrees Fahrenheit [°F]) is entered in SCREEN3 as a default value.

3.6 MODEL RESULTS

As discussed above, SCREEN3 was executed twice (i.e., once for flat terrain, once for simple elevated/complex terrain at a unit emission rate of one g/s).

3.6.1 Flat Terrain

Output from the SCREEN3 flat terrain scenario is in the form of a 1-hour average concentration. An averaging period scaling factor of 0.4 was used to convert the flat terrain 1-hour average concentration to a 24-hour average, based on "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources" (USEPA, October 1992).

The maximum modeled unit emission rate 1-hour average concentration is 4.5 micrograms per cubic meter (µg/m^3) at a distance of 0.5 miles from the biomass-fired CHP plant. For the regulated pollutants of interest, the emission rate of each pollutant is multiplied by the maximum modeled 1-hour unit concentration (in µg/m^3 per one g/s) to arrive at the pollutant-specific concentration. The time averaging conversion factor discussed above was applied to determine maximum concentrations for the 24-hour averaging period. Refer to Table 3 for a tabular form of the flat terrain modeling results. As shown in Table 3, the maximum modeled results for $PM_{2.5}$, NO_x and SO_2 are all well below their respective National Ambient Air Quality Standards (NAAQS).

The complete flat terrain SCREEN3 model output is provided in Appendix A.

TABLE 3
SCREEN3 Ambient Impact Results – Flat Terrain

		Averaging Time - 1 Hour		**Averaging Time - 24 Hour**	
Pollutant	**Emission Rate (g/s)**	**Maximum Modeled Concentration Ambient (µg/m^3)**	**National Ambient Air Quality Standard (µg/m^3)**	**Maximum Modeled Concentration Ambient (µg/m^3)**	**National Ambient Air Quality Standard (µg/m^3)**
UNIT MODEL RUN	1	4.5	Not applicable (N/A)		
$PM_{2.5}$	0.39	1.7	N/A	0.7	35
NO_x	2.11	9.5	189	3.8	N/A
SO_2	0.57	2.6	200	1.0	365

3.6.2 Simple Elevated/Complex Terrain

Output from the SCREEN3 simple elevated/complex terrain scenario is in the form of a 1-hour average concentration for simple terrain results and a 24-hour average concentration for complex terrain results. A factor of 2.5 is appropriate to convert the complex terrain 24-hour average concentration to a 1-hour average, based on “Screening Procedures for Estimating the Air Quality Impact of Stationary Sources” (USEPA, October 1992).

The resulting maximum unit emission rate 1-hour concentration between the two terrain types is 5.9 µg/m^3 at a distance of 2.6 miles from the biomass-fired CHP plant. The conversion factor discussed above was applied to determine maximum concentrations for the 24-hour averaging period. Refer to Table 4 for a tabular form of the simple elevated/complex terrain modeling results. As shown in Table 4, the maximum modeled results for $PM_{2.5}$, NO_x and SO_2 are all well below their respective NAAQS.

The complete elevated/complex terrain SCREEN3 model output is provided in Appendix B.

TABLE 4
SCREEN3 Ambient Impact Results – Simple Elevated/Complex Terrain

Pollutant	**Emission Rate (g/s)**	**Averaging Time - 1 Hour**		**Averaging Time - 24 Hour**	
		Maximum Modeled Concentration Ambient (μg/m³)	**National Ambient Air Quality Standard (μg/m³)**	**Maximum Modeled Concentration Ambient (μg/m³)**	**National Ambient Air Quality Standard (μg/m³)**
UNIT MODEL RUN	1	5.9	N/A		
PM 2.5	0.05	2.3	N/A	0.9	35
NOx	2.11	12.4	189	5.0	N/A
SO2	0.57	3.3	200	1.3	36

4.0 DISCUSSION OF $PM_{2.5}$ EMISSION RATES AND PREDICTED AMBIENT IMPACTS

4.1 $PM_{2.5}$ EMISSION RATES

Table 5 compares $PM_{2.5}$ emission rates for various combustion units to the expected $PM_{2.5}$ emission rate for the biomass-fired CHP plant. Presented in units of pounds of $PM_{2.5}$ emitted per MMBTU of heat input, the emissions from the proposed biomass-fired CHP plant are much lower than other wood burning devices commonly operated in the Traverse City region. Table 5 also compares $PM_{2.5}$ emission rates for coal-fired and natural gas-fired power plants to the expected $PM_{2.5}$ emission rate for the biomass-fired CHP plant. In units of pounds per MMBTU, the expected emissions from the proposed biomass-fired CHP plant are approximately equal to recently permitted coal-fired and approximately two times as high as natural gas-fired power plants. However, on an hourly basis, $PM_{2.5}$ emissions are much greater for these fossil fuel-fired power plants because recently permitted coal-fired and natural gas-fired power plants are generally much larger in electric generating capacity than the proposed biomass-fired CHP plant under consideration by TCLP.

Another point of comparison for PM2.5 emissions is the former coal-fired TCLP Bayside Plant. From a review of plant records, the Bayside Plant emissions are estimated to be more than ten times the hourly emissions expected for the biomass-fired CHP plant. A final point for consideration with respect to emissions comparisons is the combined heat and power features of the proposed plant. The biomass-fired CHP plant will employ the waste heat from the electric generation process to produce steam or hot water that can be used for other purposes. In other words, the steam or hot water produced by the waste heat from the biomass-fired CHP plant can replace the need for an existing boiler or boilers. Therefore, the emissions from the biomass-fired CHP plant (3.08 pounds/hour) can be reduced by the emissions from the boiler or boilers that are shut down which will result in a net emissions increase of less than 3.08 pounds/hour to the Traverse City air shed.

TABLE 5
$PM_{2.5}$ Emission Rates for Various Combustion Units

Combustion Unit	Emission Rate (pounds/MMBTU)
Biomass-fired CHP Plant	0.0171
Outdoor Wood Boiler of Type Typically Operated in Michigan[1]	1.44
Outdoor Wood Boiler in Compliance with USEPA Phase 1 Program[2]	0.6
Outdoor Wood Boiler in Compliance with USEPA Phase 2 Program[2]	0.32
Residential Wood Stove[1]	1.18
New Natural Gas-fired Power Plant[3]	0.008
New Coal-fired Power Plant[4]	0.016

[1] Peter Guldberg, Tech Environmental, Inc.: "Outdoor Wood Boilers – New Emissions Test Data and Future Trends" presented at USEPA's 16th Annual International Emission Inventory Conference, Raleigh, NC (May 2007)
[2] EPA Hydronic Heater Program Phase 2 Partnership Agreement (http://www.epa.gov/burnwise/pdfs/owhhphase2agreement.pdf)
[3] Data retrieved from USEPA RBLC Clearinghouse (http://cfpub.epa.gov/rblc/) – average $PM_{2.5}$ emission limit from seven natural gas-fired power plants permitted since 2007.
[4] Data retrieved from USEPA RBLC Clearinghouse (http://cfpub.epa.gov/rblc/) – average $PM_{2.5}$ emission limit from seven coal-fired power plants permitted since 2007.

4.2 $PM_{2.5}$ AMBIENT IMPACTS

Table 6 compares predicted maximum 1-hour and 24-hour $PM_{2.5}$ ambient impacts associated with the biomass-fired CHP plant to ambient $PM_{2.5}$ concentrations measured at monitoring stations operated by the Michigan Department of Natural Resources and Environment (DNRE), Air Quality Division (AQD). AQD operated a $PM_{2.5}$ monitoring station in Traverse City until 2002. Table 6 includes historical data from the station. The other monitoring stations included in Table 3 and their distances from Traverse City are:

- Manistee – 50 miles
- Houghton Lake – 50 miles
- Seney – 110 miles

Data from Manistee, Houghton Lake and Seney are provided in Table 6 as AQD's current monitoring stations that are most representative of ambient $PM_{2.5}$ concentrations in Traverse City. The Traverse City and Manistee monitoring stations only measured 24-hour concentrations of $PM_{2.5}$. The Houghton Lake and Seney monitoring stations measured hourly and 24-hour concentrations of $PM_{2.5}$. The data for the four monitoring stations presented in Table 6 was provided to MACTEC by Debbie Sherrod of the DNRE.

TABLE 6
Comparison of Modeled $PM_{2.5}$ Impact of Biomass-fired CHP Plant to Measured Ambient Concentrations

Sampling Site	$PM_{2.5}$ 24-Hour Concentration ($\mu g/m^3$)	Predicted Biomass-fired CHP Plant Impact as Percent of Measured 24-Hour Concentration (%)	$PM_{2.5}$ 1-Hour Concentration ($\mu g/m^3$)	Predicted Biomass-fired CHP Plant Impact as Percent of Measured 1-Hour Concentration (%)
Maximum Modeled Biomass-fired CHP Plant Impact	0.9	---	2.3	---
Traverse City Maximum 2000 – 2002	38.3	2.3%	---	---
Manistee Maximum 2008 – 2010	30.6	2.9%	---	---
Houghton Lake Maximum 2008 – 2010	23.4	3.8%	76.0	3.0%
Seney Maximum 2008 – 2009	30.0	3.0%	53.0	4.3%

Table 6 indicates that the predicted ambient impacts of the biomass-fired CHP plant will be minor components of the maximum ambient $PM_{2.5}$ concentrations in Traverse City.

Table 7 compares predicted maximum 1-hour and 24-hour $PM_{2.5}$ ambient impacts associated with the biomass-fired CHP plant to maximum 1-hour and 24-hour $PM_{2.5}$ ambient impacts modeled by AQD[5,6] for individual outdoor wood boilers. Table 7 indicates that the impact of the biomass-fired CHP plant to ambient $PM_{2.5}$ concentrations is much less than the impact of a single outdoor wood boiler that is typical of the type operated in Michigan and less than 16% of the impact of a single, "clean-burning", high-efficiency outdoor wood boiler that complies with USEPA's Phase 2 Hydronic Heater Partnership program.

TABLE 7
Comparison of Modeled $PM_{2.5}$ Impact of Biomass-fired CHP Plant to AQD's Modeled $PM_{2.5}$ Impact of Outdoor Wood Boilers

Emission Source	$PM_{2.5}$ 24-Hour Concentration ($\mu g/m^3$)	Predicted Biomass-fired CHP Plant Impact as Percent of AQD Modeled 24-Hour Concentration (%)	$PM_{2.5}$ 1-Hour Concentration ($\mu g/m^3$)	Predicted Biomass-fired CHP Plant Impact as Percent of AQD Modeled 1-Hour Concentration (%)
Maximum Modeled Biomass-fired CHP Plant Impact	0.9	---	2.3	---
Typical Pre-2007 Outdoor Wood Boiler	---	---	879	<0.3%
Outdoor Wood Boiler in Compliance with USEPA Phase 1 Program	14.5	6.2%	30.2	7.6%
Outdoor Wood Boiler in Compliance with USEPA Phase 2 Program	7.3	12.3%	15.1	15.2%

5 Steve Kish, DNRE – AQD: "High Efficiency Residential Wood Boiler Modeling Assumptions Based on Monitored Data", 2007 (http://www.michigan.gov/documents/deq/DEQ-AQD-AERMODforCleanOWB2007_193033_7.pdf)
6 Steve Kish, DNRE – AQD: "Residential Wood Boiler Study" (http://www.michigan.gov/documents/Residential_Wood_Boiler_Study_plots_118450_7.pdf)

4.3 BIOMASS EMISSION: POTENTIAL IMPACTS ON HEALTH

Critical to the operation of the proposed 10 MW biomass-fired CHP plant is protection of human health and the environment. To that end, understanding of and compliance with regulatory requirements including meeting current health-based standards is essential. As discussed and evaluated in the previous sections, combustion of biomass is associated with emissions and human exposure to those emissions is dependent upon operating conditions, type of fuel, time elapsed from the addition of fuel to boiler, local weather and activity patterns, and locations of those living or working nearby. These parameters and topography determine the amounts of emissions inhaled. Because PM is the major component of wood smoke exposure, it is a surrogate of exposure for assessment of potential impacts of the biomass-fired CHP plant. While there are some variability in entities comprising NO_x and SO_2, the dose-response associated with exposure to NO_x and SO_2 are relatively well-defined and threshold levels have been demonstrated and serve as the basis for protective regulatory standards for short-term exposures. Unlike SO_2 and NO_x, PM is not a single entity but a mixture of compounds that varies with the source(s). This heterogeneity of PM has lead to difficulty in understanding the dose-response curve and establishing a bright line or regulatory limit protective of public health including sensitive sub-populations. Therefore, of particular interest is the exposure concentration to $PM_{2.5}$ resulting from the operation of the biomass-fired CHP plant since $PM_{2.5}$ exposure has been observed to lead to aggravating conditions in those with pre-existing diseases such as asthma, chronic obstructive pulmonary disease (COPD) and cardiac effects. Therefore for purposes of this assessment, $PM_{2.5}$ was used as a surrogate for the potential for health impacts associated with the operation of the biomass-fired CHP plant.

The current annual $PM_{2.5}$ NAAQS of 15 $\mu g/m^3$ (arithmetic mean) is based on protecting for the epidemiologic evidence of mortality. The range of human health effects associated with ambient PM levels or demonstrated in laboratory studies has expanded from earlier concerns for total mortality and respiratory morbidity to include cardiac mortality and morbidity, blood vessel constriction, stroke, premature birth, low birth weight, retarded lung growth, enhancement of allergic responses, reduced resistance to infection, degenerative lesions in the brain and lung cancer. The 24-hour NAAQS was revised downward to 35 $\mu g/m^3$ from 65 $\mu g/m^3$ based upon scientific evidence of acute effects including asthma associated with short-term exposures (24-hours). However, while local regulations or ambient air pollution statutes attempt to address the public health impact, of particular interest is the potential for emissions to produce health effects in time frames shorter than those addressed by the air standards.

The USEPA's Air Quality Index (AQI) for particulate PM_{10} and $PM_{2.5}$ is an index of probable health risk from particulate matter based on 12-hour averaging that could be applied to short-term health concerns. Five levels of risk are designated based on the review of extensive epidemiologic, case studies and animal research (EPA 2003). While the AQI is a regional guidance tool, it can be applied to local settings to put exposures to biomass-fired CHP plant emissions in perspective.

4.4 $PM_{2.5}$ RISK ASSESSMENT

The objective of this risk assessment is to determine the contribution of emissions from the proposed biomass-fired CHP plant to local cancer risk and to estimate the threshold levels of acute non-cancer adverse health effects, most notably cardiac and respiratory outcomes. The modeled $PM_{2.5}$ concentrations provided in the previous section serves as the basis for this risk assessment. Polycyclic aromatic hydrocarbons (PAHs) are present in $PM_{2.5}$ and seven PAHs are considered carcinogens by the EPA; therefore, a cancer risk assessment was performed for PAHs associated with $PM_{2.5}$. Cancer risks were derived using standard procedures and assumptions including PAH concentrations in $PM_{2.5}$ published in the literature.

The acute risk assessment used a dose-based analysis approach from the perspective of thresholds for acute actions based on potential exposures to $PM_{2.5}$. The "unhealthy air day" (UAD) approach incorporating the EPA's AQI is designed to measure the potential increase in adverse health effects by assessing the risks as put forth by Brown et al, 2005. It has been found that current ambient exposure episodes to $PM_{2.5}$ in the United States increase hospitalization rates and emergency room visits for both cardiovascular and respiratory disease after a few hours of elevated $PM_{2.5}$ exposure (Dominici et al, 2006). The threshold dose for inducing an acute cardiopulmonary event for each day was used to assess the risk. Based on the literature, increases of $PM_{2.5}$ greater than 11 $\mu g/m^3$ are associated with increased incidence of morbidity (Brown et al, 2005; Slaughter et al, 2003; Mar et al, 2004; Dominici et al, 2006; Metzger et al, 2004; Peel et al, 2005).

4.5 $PM_{2.5}$ EXPOSURE - CHRONIC RISK ASSESSMENT

Studies have demonstrated differences in mortality and morbidity between populations with different long-term PM exposures (Dockery et al. 1993; Pope et al. 1992, 2002, 2004). Current $PM_{2.5}$ NAAQS assume that all $PM_{2.5}$ mass is of equal toxicity, but it is unlikely that the mechanisms of action and relative toxicities do not differ across constituents. Different $PM_{2.5}$ components (e.g., metals, organics) drive different types of toxicity (some components are more toxic than others for certain effects), and the same PM composition administered in different particle sizes has different potencies. In part, size is incorporated into the NAAQS as a rough surrogate for composition (because most fine PM stems from combustion processes, whereas coarse particles tend to arise from fugitive dust, pollens and spores, and sea salt).

$PM_{2.5}$ concentrations can be used to extrapolate to those carcinogens that would be distributed on this fraction, the most prevalent and toxic being the PAHs. Using benzo(a)pyrene as a surrogate for carcinogenic PAHs and other compounds, a risk assessment was performed for the contribution of the biomass-fired CHP plant. Based on ambient $PM_{2.5}$ concentrations obtained from dispersion modeling, the projected average annual ambient concentration of $PM_{2.5}$ due to the biomass-fired CHP plant is calculated to be 0.23 $\mu g/m^3$ for 8,400 hours of operation. Approximately one percent of urban $PM_{2.5}$ is benzo(a)pyrene (Johannsson et al, 2009) and adjusting the $PM_{2.5}$ for the assumed ambient benzo(a)pyrene yields a concentration of 0.0023 $\mu g/m^3$. The EPA risk-based ambient air concentration for benzo(a)pyrene is 0.00087 $\mu g/m^3$ based on the probability of producing one excess cancer case in one million similar exposed individuals (EPA, 1999). The estimated benzo(a)pryrene concentration associated with the operation of the biomass-fired CHP plant results an acceptable risk of 3 x 10^{-6} assuming 30 years of residential exposure consistent with Michigan and the EPA's exposure assumptions (Dockery, et al 1993).

By way of comparison, the cancer risk approach was used to evaluate the impact of the biomass-fired CHP plant emissions on background $PM_{2.5}$ conditions in Traverse City. The range of available elevated 24-hour $PM_{2.5}$ concentrations in the Traverse City area ranged from 23.4 to 38.3 $\mu g/m^3$ (See Table 6). Using the same assumptions as above (one percent benzo(a)pyrene) for the $PM_{2.5}$, the resultant benzo(a)pyrene equivalent is 0.23 to 0.38 $\mu g/m^3$. Adjusting these daily concentrations to assume exposure during the winter months (three months), the average annual benzo(a)pyrene equivalent would be 0.058 to 0.096 $\mu g/m^3$ (Noullet, et al, 2006). Based on the EPA risk-based ambient air concentration for benzo(a)pyrene of 0.00087 $\mu g/m^3$ for 1 x 10^{-6} risk, the estimated cancer risk for this exposure range is 7 x 10^{-5} to 1 x 10^{-4}, risks within the acceptable risk range of 10^{-4} to 10^{-6}. The biomass-fired CHP plant operations would add *de minimis* increased risk to the existing background air quality.

4.6 NON-CANCER ACUTE AND CHRONIC RISK

The non-cancer risk assessment was designed to measure the threshold at which daily health effects may be predicted to occur. The inhaled dose derived from the $PM_{2.5}$ concentration in air is used to evaluated acute risk. The UAD approach using the EPA's AQI is proposed as a unit to measure trends in the acute risks.

The 6-hour total inhaled dose in µg of PM is a reproducible metric for dose-response. The AQI was designed by the EPA to provide warnings of the sub-daily (less than 24 hours) elevations in exposure to $PM_{2.5}$ (EPA, 2003). The inhaled dose exposures were derived from the AQI data and the epidemiologic cardiopulmonary dose-response findings. The range of doses at which health effects are expected is provided in Table 8.

TABLE 8

Air Quality Index Classification and Corresponding Ambient and Inhaled Dose of $PM_{2.5}$

Air Quality	**$PM_{2.5}$ Concentration (µg/m3)**	**6-Hour Inhaled Dose (µg)**
Good	0-20	Less than 96
Moderate	21-40	96-192
Unhealthy for Sensitive Groups	41-60	193-288
Unhealthy for All	61-80	289-384
Very Unhealthy	81-120	385-586

Based on the AQI approach, the ambient $PM_{2.5}$ concentrations resulting from the biomass-fired CHP plant emissions are predicted to produce a "good" AQI. Using the modeled 1-hour maximum $PM_{2.5}$ concentration of 2.3 µg/m^3 for the nearest residential receptor (Table 4) the inhaled dose was calculated to be 11.0 µg during the 6-hour period based on an adult inhalation rate of 0.8 m^3 per hour as calculated below. The inhaled dose of 11.0 µg is well within the "good" AQI.

$$\textit{Inhaled } PM_{2.5} \textit{ dose (6-hour)} = PM_{2.5} \textit{ concentration} \times 0.8\ m^3/\textit{hour} \times 6\textit{-hours}$$

$$\textit{Inhaled } PM_{2.5} \textit{ Dose} = 11.0\ \mu g$$

The AQI scale does not predict specific health outcomes and is not a specific scale of respiratory or cardiovascular risk. However, the dose-response evaluation demonstrates that no adverse health effects from biomass-fired CHP plant operations would be expected.

By way of comparison, the AQI approach was used to evaluate the impact of the biomass-fired CHP plant emissions on background $PM_{2.5}$ conditions in Traverse City. The range of available maximum 1-hour $PM_{2.5}$ in the area ranged from 53 to 76 µg/m^3 (Table 6). Using the above equation, the resulting inhaled dose range would be 254 to 365 µg corresponding to an "unhealthy for sensitive groups to unhealthy for all" AQIs suggesting that UADs may occur in the area currently. Given that adverse impacts on human health are associated with increases of 10 µg/m^3 of $PM_{2.5}$ above background (Dominici et al, 2006), it is unlikely that the operation of the biomass-fired CHP plant would have any observable impact on the community health even considering the existing UADs/AQIs for ambient air.

4.7 SUMMARY AND CONCLUSIONS

Both the short-term and long-term exposure potentials for $PM_{2.5}$ from the proposed biomass-fired CHP plant were evaluated and are presented in Table 9. For short-term $PM_{2.5}$ exposures, the $PM_{2.5}$ concentrations modeled from the biomass-fired CHP plant emissions were compared to documented exposure responses including sensitive reversible endpoints such as asthma attacks and cardio-respiratory effects. No discernible impact of the short-term exposures resulting from the proposed biomass-fired CHP plant emissions would be detectable in the local population based on the UAD/AQI approach. Chronic irreversible effects were evaluated by estimating the long-term exposure to carcinogenic compounds associated with $PM_{2.5}$ using benzo(a)pyrene as the surrogate. The estimated annual $PM_{2.5}$ ambient air concentration modeled from the biomass-fired CHP plant emissions was extrapolated to a benzo(a)pyrene equivalency. The estimated risk was acceptable, i.e. within the range of 10^{-4} to 10^{-6}. Therefore, the $PM_{2.5}$ emissions associated with the proposed operating conditions of the proposed biomass-fired CHP plant will not have a measurable impact on the local population, either from short-term or long-term exposures.

TABLE 9
Summary of Health Effects Assessment

Health Effect	**Modeled $PM_{2.5}$ Concentrations (1-hour) (µg/m^3)**	**No Effect/Acceptable $PM_{2.5}$ Level (µg/m^3)**
Decreased lung function[a]	2.3	71 (Slaughter et al 2003)
Induction of asthma attack[a]	2.3	10 (Slaughter et al 2003)
Respiratory infection or Emergency Room Visit[a]	2.3	10 (Metzger et al 2004)
Cancer[b]	0.0023[c]	0.087 – 0.00087 (EPA 2010)

[a] Based on short-term exposures (24 hours)
[b] Based on long-term exposures (30 years) and the exceptable risk range of 10^{-4} to 10^{-6}.
[c] Based on benzo(a)pyrene concentrations extrapolated from $PM_{2.5}$

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APPENDIX A

FLAT TERRAIN SCREEN3 MODEL OUTPUT

07/09/10
09:21:37

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

TCLP - PARSONS RD LOCALE, TERRAIN CONSIDERATIONS, RURAL, 100 FT. STACK

COMPLEX TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.00000
STACK HT (M)	=	30.4800
STACK DIAMETER (M)	=	1.6800
STACK VELOCITY (M/S)	=	20.3200
STACK GAS TEMP (K)	=	433.0000
AMBIENT AIR TEMP (K)	=	293.0000
RECEPTOR HEIGHT (M)	=	.0000
URBAN/RURAL OPTION	=	RURAL

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

BUOY. FLUX = 45.459 M**4/S**3; MOM. FLUX = 197.145 M**4/S**2.

FINAL STABLE PLUME HEIGHT (M) = 95.3
DISTANCE TO FINAL RISE (M) = 151.3

			VALLEY 24-HR CALCS		**SIMPLE TERRAIN 24-HR CALCS**				
TERR HT (M)	DIST (M)	MAX 24-HR CONC (UG/M**3)	CONC (UG/M**3)	PLUME HT ABOVE STK BASE (M)	CONC (UG/M**3)	PLUME HT ABOVE STK HGT (M)	SC	U10M (M/S)	USTK (M/S)
35.	4190.	2.356	.3397	95.3	2.356	71.8	6	1.0	1.8
40.	4206.	2.356	.4209	95.3	2.356	71.8	6	1.0	1.8
45.	4222.	2.356	.5113	95.3	2.356	71.8	6	1.0	1.8
50.	4285.	2.355	.6036	95.3	2.355	71.8	6	1.0	1.8
55.	4381.	2.353	.6923	95.3	2.353	71.8	6	1.0	1.8
60.	4444.	2.352	.7826	95.3	2.352	71.8	6	1.0	1.8
65.	4508.	2.350	.8665	95.3	2.350	71.8	6	1.0	1.8

07/09/10
09:21:37

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

07/06/10

13:58:32

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

TRAVERSE CITY LIGHT & POWER - FLAT TERRAIN, 100 FT. STACK, RURAL

SIMPLE TERRAIN INPUTS:

```
   SOURCE TYPE            =        POINT
   EMISSION RATE (G/S)    =      1.00000
   STACK HEIGHT (M)       =      30.4800
   STK INSIDE DIAM (M)    =       1.6800
   STK EXIT VELOCITY (M/S)=      20.3200
   STK GAS EXIT TEMP (K)  =     433.0000
   AMBIENT AIR TEMP (K)   =     293.0000
   RECEPTOR HEIGHT (M)    =        .0000
   URBAN/RURAL OPTION     =        RURAL
   BUILDING HEIGHT (M)    =        .0000
   MIN HORIZ BLDG DIM (M) =        .0000
   MAX HORIZ BLDG DIM (M) =        .0000
```

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

BUOY. FLUX = 45.459 M**4/S**3; MOM. FLUX = 197.145 M**4/S**2.

*** FULL METEOROLOGY ***

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**********************************
*** SCREEN AUTOMATED DISTANCES ***
**********************************
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*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
1.	.0000	1	1.0	1.1	378.4	377.42	4.31	4.29	NO
100.	.6727E-03	5	1.0	1.5	10000.0	123.62	24.57	24.06	NO
200.	.9817E-02	5	1.0	1.5	10000.0	123.62	29.04	27.33	NO
300.	.5181	1	3.0	3.2	960.0	146.13	75.22	52.52	NO
400.	2.121	1	3.0	3.2	960.0	146.13	96.65	76.22	NO
500.	3.130	1	3.0	3.2	960.0	146.13	117.40	109.34	NO
600.	3.031	1	2.5	2.7	800.0	169.26	138.67	158.96	NO
700.	3.777	1	1.0	1.1	378.4	377.42	181.72	235.23	NO
800.	4.481	1	1.0	1.1	378.4	377.42	198.00	299.86	NO
900.	4.478	1	1.0	1.1	378.4	377.42	214.47	376.42	NO
1000.	4.215	1	1.0	1.1	378.4	377.42	231.05	464.55	NO
1100.	3.937	1	1.0	1.1	378.4	377.42	247.69	564.07	NO
1200.	3.689	1	1.0	1.1	378.4	377.42	264.35	674.91	NO
1300.	3.470	1	1.0	1.1	378.4	377.42	281.00	797.02	NO
1400.	3.276	1	1.0	1.1	378.4	377.42	297.62	930.43	NO
1500.	3.103	1	1.0	1.1	378.4	377.42	314.20	1075.18	NO
1600.	2.948	1	1.0	1.1	378.4	377.42	330.73	1231.30	NO
1700.	2.809	1	1.0	1.1	378.4	377.42	347.19	1398.86	NO

APPENDIX B

SIMPLE ELEVATED/COMPLEX TERRAIN SCREEN3 MODEL OUTPUT

1800.	2.682	1	1.0	1.1	378.4	377.42	363.60	1577.91	NO
1900.	2.566	1	1.0	1.1	378.4	377.42	379.94	1768.50	NO
2000.	2.526	2	1.0	1.1	378.4	377.42	302.50	253.96	NO
2100.	2.558	2	1.0	1.1	378.4	377.42	314.47	265.85	NO
2200.	2.570	2	1.0	1.1	378.4	377.42	326.42	277.87	NO
2300.	2.564	2	1.0	1.1	378.4	377.42	338.35	290.03	NO
2400.	2.545	2	1.0	1.1	378.4	377.42	350.25	302.31	NO
2500.	2.515	2	1.0	1.1	378.4	377.42	362.13	314.70	NO
2600.	2.477	2	1.0	1.1	378.4	377.42	373.97	327.19	NO
2700.	2.433	2	1.0	1.1	378.4	377.42	385.79	339.77	NO
2800.	2.385	2	1.0	1.1	378.4	377.42	397.58	352.45	NO
2900.	2.334	2	1.0	1.1	378.4	377.42	409.33	365.20	NO
3000.	2.282	2	1.0	1.1	378.4	377.42	421.05	378.04	NO
3500.	2.030	2	1.0	1.1	378.4	377.42	479.19	443.26	NO
4000.	1.943	3	1.0	1.1	367.0	366.01	373.96	237.48	NO
4500.	2.042	5	1.0	1.5	10000.0	123.62	200.85	59.15	NO
5000.	2.132	5	1.0	1.5	10000.0	123.62	220.47	61.74	NO
5500.	2.194	5	1.0	1.5	10000.0	123.62	239.90	64.23	NO
6000.	2.232	5	1.0	1.5	10000.0	123.62	259.14	66.63	NO
6500.	2.251	5	1.0	1.5	10000.0	123.62	278.21	68.95	NO
7000.	2.256	5	1.0	1.5	10000.0	123.62	297.13	71.19	NO
7500.	2.249	5	1.0	1.5	10000.0	123.62	315.90	73.37	NO
8000.	2.232	5	1.0	1.5	10000.0	123.62	334.53	75.49	NO
8500.	2.209	5	1.0	1.5	10000.0	123.62	353.02	77.55	NO
9000.	2.181	5	1.0	1.5	10000.0	123.62	371.40	79.56	NO
9500.	2.148	5	1.0	1.5	10000.0	123.62	389.65	81.52	NO
10000.	2.113	5	1.0	1.5	10000.0	123.62	407.79	83.43	NO
15000.	1.711	5	1.0	1.5	10000.0	123.62	583.99	99.19	NO
20000.	1.489	6	1.0	1.8	10000.0	102.24	501.37	63.68	NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 1. M:

845.	4.539	1	1.0	1.1	378.4	377.42	205.55	333.62	NO

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	4.539	845.	0.

TCLP - PARSONS RD LOCALE, TERRAIN CONSIDERATIONS, RURAL, 100 FT. STACK

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.00000
STACK HEIGHT (M)	=	30.4800
STK INSIDE DIAM (M)	=	1.6800
STK EXIT VELOCITY (M/S)	=	20.3200
STK GAS EXIT TEMP (K)	=	433.0000
AMBIENT AIR TEMP (K)	=	293.0000
RECEPTOR HEIGHT (M)	=	.0000
URBAN/RURAL OPTION	=	RURAL
BUILDING HEIGHT (M)	=	.0000
MIN HORIZ BLDG DIM (M)	=	.0000
MAX HORIZ BLDG DIM (M)	=	.0000

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

BUOY. FLUX = 45.459 M**4/S**3; MOM. FLUX = 197.145 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 1. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
413.	2.396	1	3.0	3.2	960.0	145.13	99.38	80.22	NO

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 3. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
1079.	4.025	1	1.0	1.1	375.4	374.42	244.19	542.23	NO

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 5. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
2159.	2.633	2	1.0	1.1	373.4	372.42	321.53	272.93	NO

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********************************
*** SCREEN DISCRETE DISTANCES ***
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*** TERRAIN HEIGHT OF 10. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
3175.	2.406	5	1.0	1.5	10000.0	113.62	147.81	51.09	NO

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********************************
*** SCREEN DISCRETE DISTANCES ***
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*** TERRAIN HEIGHT OF 15. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
3206.	2.994	5	1.0	1.5	10000.0	108.62	149.07	51.30	NO

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********************************
*** SCREEN DISCRETE DISTANCES ***
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*** TERRAIN HEIGHT OF 20. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
3270.	3.693	5	1.0	1.5	10000.0	103.62	151.66	51.72	NO

```
********************************
*** SCREEN DISCRETE DISTANCES ***
********************************
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*** TERRAIN HEIGHT OF 25. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
3302.	4.471	5	1.0	1.5	10000.0	98.62	152.96	51.94	NO

```
********************************
*** SCREEN DISCRETE DISTANCES ***
********************************
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*** TERRAIN HEIGHT OF 30. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
3746.	5.726	6	1.0	1.8	10000.0	72.24	114.18	36.26	NO

DWASH= MEANS NO CALC MADE (CONC = 0.0)

DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
********************************************
*   SUMMARY OF TERRAIN HEIGHTS ENTERED FOR  *
*     SIMPLE ELEVATED TERRAIN PROCEDURE     *
********************************************
```

TERRAIN HT (M)	DISTANCE RANGE (M) MINIMUM	MAXIMUM
1.	413.	--
3.	1079.	--
5.	2159.	--
10.	3175.	--
15.	3206.	--
20.	3270.	--
25.	3302.	--
30.	3746.	--

```
***************************************
*** SUMMARY OF SCREEN MODEL RESULTS ***
***************************************
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CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)	
SIMPLE TERRAIN	5.726	3746.	30.	
COMPLEX TERRAIN	2.356	4190.	35.	(24-HR CONC)