Technical Report
No. 13-346

AN ANALYSIS OF ASPHALT PLANT POLLUTION IMPACTS ON PUBLIC HEALTH AND AGRICULTURE IN UMATILLA COUNTY, OREGON

December 12, 2013

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AN ANALYSIS OF ASPHALT PLANT POLLUTION IMPACTS ON PUBLIC HEALTH AND AGRICULTURE IN UMATILLA COUNTY, OREGON

December 12, 2013

RE: General Air Contaminant Discharge Permit AQGP-007
Issued in Accordance with OAR 340-216-0060
Application No. 27430, Approved 08/16/2013
Issued to Humbert Asphalt, Inc.
SIC Code is 2951/NAICS Code 324121

Background Information

The Oregon Department of Environmental Quality (ñODEQò) has issued to Humbert Asphalt, Inc. a general air permit to build and operate an asphaltic concrete paving plant in Umatilla County.

The proposed plant is a counter-flow drum mix type, manufactured by Gencor in 1998. The plant design capacity is 150 tons per hour. The owner-operatorôs projected operating time is 10 hours per day, five days per week and forty weeks per year for a total of 2000 hours per year. *See* Form AQGP-107 Plant Information 2.j, 2.k, 2.l and 2.m. Also according to the permit application, projected annual asphalt production is 40,000 tons per year. *Ibid.* 2.g. The company states that it will use recycled asphalt paving, or RAP, up to a limit of 20% of product. *See* Plant Information 2.o, 2.n and Permit Condition 2.7. To support the drum mix operation at the site and included in the air permit are two electric power generators rated at 650 KWH and 100 KWH, each powered primarily by diesel fuel and operating for 10 hours per day, 5 days per week and 40 weeks per year. *See* AQGP-107, 3-Power Generator Information. Projected electric generator fuel use is given at 200 gallons per hour and 50,000 gallons per year. *Ibid*, 4-Generator Fuel Usage Information. According to Permit Conditions 7.4 and 5.1.b.i, the plant is not new and there have been no compliance source tests performed within the last five years.[1]

The Humbert Asphalt ODEQ Air Contaminant Discharge Permit Application Forms[2] (ñApplicationò) list the company address as 84899 Hwy. 11 Milton-Freewater, OR 97862, but the site address line in the application is blank. *See* Form AQGP-100, page 1. The plant is designated ñportableò but information provided by local residents indicates that the proposed plant location is 57445ï 57491 Birch Creek Road, Milton-Freewater, Oregon. The area is zoned for farm use and is primarily planted in dry land type crops wheat, peas and pasture.

Analysis

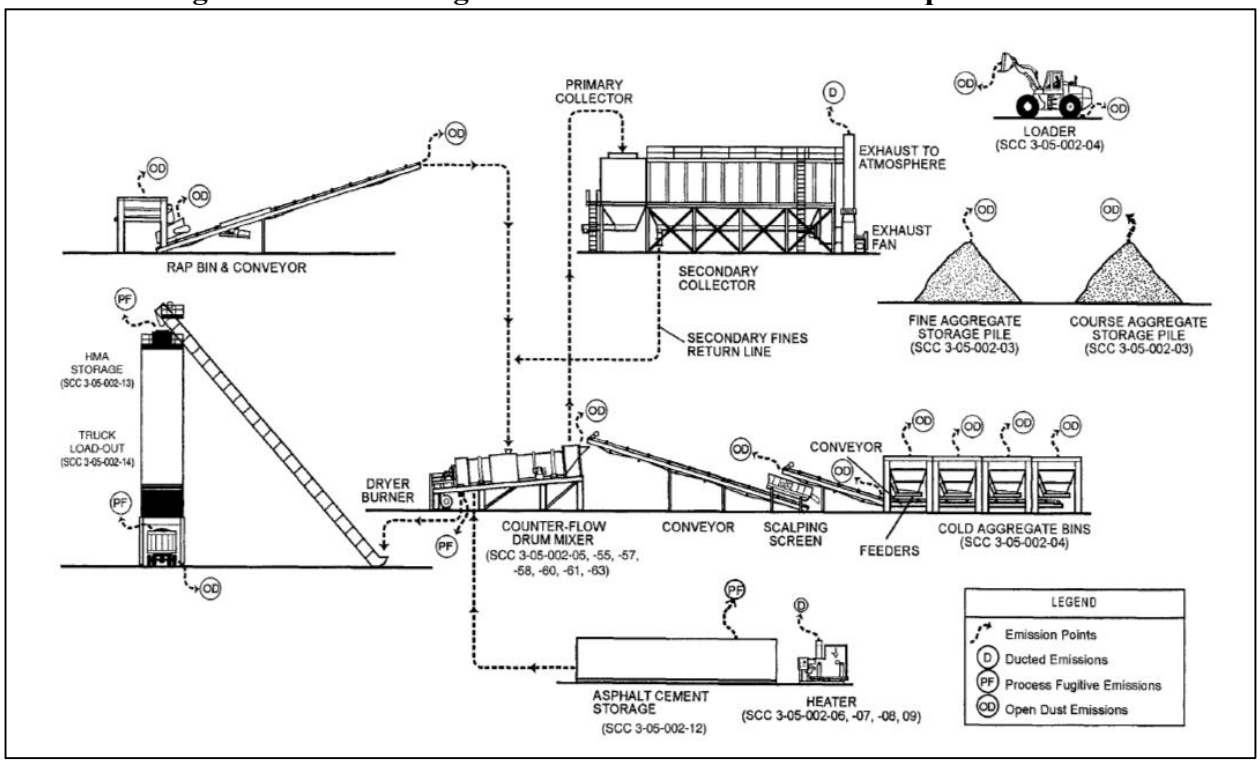
In addition to state law, asphalt plants are subject to the federal Clean Air Act. Large plants that have the potential to emit (PTE) 250 tons per year or more are required to limit emissions for the prevention of significant deterioration, or PSD. PTE is based on an air pollution emitted by a

[1] Technical specifications in this paragraph are those provided by the company in their Oregon Department of Environmental Quality Form AQGP-100, Application for General Air Contaminant Discharge Permit submitted August 8, 2013, Application No. 27430.
[2] ODEQ Forms AQGP-100, AQGP-107, AQ202, AQ304 and AQ402

plant operating for 8760 hours per year. Also, New Source Performance Standard (NSPS) require that fugitive emissions be counted when determining major source status for hot-mix asphalt plants. Further, plants that have the potential to emit 10 tons per year or more of a hazardous air pollutant (HAP) or 25 tons per year of all HAPs combined, including fugitive emissions, are also subject to the Actôs maximum achievable control technology program.

A major source of the pollution from the counter-flow drum-mix plant proposed by Humbert Asphalt is the rotary drum dryer. Emissions from the drum consist of steam evaporated from the aggregate, particulate matter (PM), products of combustion, products of incomplete combustion, and toxic compounds of various types including volatile organic compounds (VOC), methane (CH4), hazardous air pollutants (HAP) and polycyclic aromatic hydrocarbons (PAH). The carbon monoxide and organic compounds are also be released by the heated asphalt fumes, the telltale ñblue smokeò observed at many asphalt plant sites. Figure 1 illustrates the many sources of air pollution.

Figure 1. Process Diagram: Counter-flow Drum Mix Asphalt Plant[3]



The above process diagram breaks the emissions into three types: 1) ducted emissions which exit the plant through the stack via a pollution control device such as a fireproof fabric filter, 2) process fugitive emissions which are hot gases emitted from various points without passing through any filters and 3) open dust emissions from the many piles, bins and conveyors of aggregate rock and sand.

[3] US EPA AP-42 Emission Factors, Figure 11.1-3

Omissions and Errors in the Permit

The company omits certain projected pollution emissions for the asphalt plant. Projected emissions of eight air contaminants are listed for natural gas operation of the plant, but oil-fired emissions are listed as ñ0.ò[4] However, elsewhere in the Application the company states that the primary fuel will be Diesel. Natural gas (propane) is only listed as a back-up fuel.[5]

Although the ODEQ permit application projects a maximum annual production of 40,000 tons of asphalt, the plant capacity and operating schedule of 2000 hours per year indicate maximum asphalt production of 300,000 tons per year, or 7 ½ times more than projected by the Application. The permit as issued does not limit annual production. There is no enforcement, no penalties and no fines to be levied by ODEQ for exceeding the 40,000 ton level or even the 300,000 ton level of projected annual asphalt production.

Further, although the Application states proposed asphalt plant hours of operation at 10 hours per day, testimony offered at public hearing indicated that ñduring project production the operating hours are typically 6 AM ï 6 PM.[6] Therefore, plant operations of 12 hours per day, 5 days per week and 40 weeks per year would result in annual totals of 2,400 hours of operation and 360,000 tons of asphalt. This would be a more logical basis for ODEQ to calculate maximum air contaminant impacts than the 40,000 tons of asphalt per year projected by the company.

The Application underestimates power generator fuel use.[7] If the electric generators use 200 gallons of fuel per hour, annual fuel usage would be 400,000 gallons per year, not 50,000 gallons per year as listed in the Application (200 gallons/hour × 2000 hours/year = 400,000 gallons/year).

The Applicationôs Power Generator Information lists the primary fuel as Diesel with propane as back-up fuel (AQGP-107 Section 3, page 2). However, elsewhere in the Application the asphalt plant information lists primary fuel as liquid propane with Diesel as back-up fuel (ODEQ Asphalt Plant Information Answer Sheet, Form AQ202, page 2).

Pollution Impacts

Asphalt plants are largely regulated as point sources of air pollution from the main smoke stack which carries emissions from the aggregate dryer through the bag-house filter. Based on information provided by the permit applicant to ODEQ and US EPA emission factors, the annual air pollution emissions from the main stack are listed in Table A.

[4] ODEQ Form AQGP-107 page 4, Section 4.b. Maximum Projected Pollution Emissions, Drum Plants
[5] ODEQ Form AQGP-107 page 2, Section 3. Power Generator Information
[6] Testimony of Troy Humbert, ñFinal Findings and Conclusions, Umatilla County Planning Commission, Humbert Asphalt, Conditional Use Requestï Asphalt Plant #C-1226-13,ò October 24, 2013, page 6.
[7] ODEQ Form AQGP-107 page 2, Section 4. Fuel Information

Table A. Yearly Asphalt Plant Pollution–Main Stack

Pollutant	**Annual Emissions** (pounds) Natural Gas (propane)	**Annual Emissions** (pounds) Fuel Oil #2
CO	39000	39000
NO_x	7800	16500
PM	9900	9900
PM-10	6900	6900
SO_2	1020	3300
HAP	1590	2610
Formaldehyde	930	930
PAH	57	264
Naphthalene	27	195
Benzene	117	117

The ODEQ permit allows Humbert Asphalt to burn either natural gas or diesel fuel to operate the plant. Natural gas and diesel fuel have different pollution impacts, with fuel oil in some cases many times dirtier. Relative emissions of polynuclear aromatic hydrocarbons (PAH) and hazardous air pollutants (HAP) using natural gas and fuel oil are compared in Table B.

Table B. Air Pollution from Fuel Oil versus Natural Gas [8]

	Natural gas	**Fuel oil**	**Difference: Fuel Oil emissions are**
Total non-PAH HAP	0.0051	0.0078	53% higher
Total PAH HAP	0.00019	0.00088	4.6 times higher

The dual fuel permit means that it is up to the operator to decide which fuel to use; the availability and the cost of fuel are the determining factors: either fuel may be used on any given day of operation.

In addition to the main stack, asphalt plants have many sources of emissions including the asphalt cement heater and storage tank, fuel tanks, conveyor belts, hoppers and other equipment close to ground level. Because these emissions occur close to ground level and are not ejected upwards through the main stack, wind velocity is reduced and air pollution is not subject to the dispersion which occurs at higher levels. Stagnant air conditions and inversions increase the level of exposure to the local community.

Fugitive emissions from asphalt are greatly underestimated. Asphalt cement typically comprises 5% of hot mix asphalt. Fugitive air emissions equal 1.07% of the consumed asphalt cement. Two thousand hours of operation at 150 tons per hour (which the ODEQ permit posits) would yield the production of 300,000 tons of hot mix asphalt per year. If we factor these percentages with the proposed plant output, we find the following:

300,000 tons asphalt × 0.05 = 15,000 tons per year of asphalt cement

15,000 x 0.0107 = 160 tons per year of asphalt vapor fugitive emissions

[8] US Environmental Protection Agency, Air Pollution Emission Factors, AP-42, Chapter 11.1 Hot Mix Asphalt Plants, Table 11.1-10

The bulk of the fugitive emissions are condensed particulates. Volatile organic compounds (VOCôs) comprise about 29% of the total.[9] Therefore, in addition to the emissions from the drum-mix heater vented through the bag house filter, about 114 tons of particulates and 46 tons of VOC may be emitted by the Humbert Asphalt plant as fugitive emissions unfiltered and uncontrolled. There are almost 2000 dangerous chemicals in asphalt fume, and the decision to build an asphalt plant must include fugitive emissions as well as smokestack emissions.

Drum mix asphalt plants also release fugitive emissions of particulate matter and volatile organic compounds from transport and handling of the asphalt from the drum mixer to the storage silos and from the load-out operations to the delivery trucks (illustrated in Figure 1).

In addition to plant process emissions and fugitive emissions, the Humbert Application states that the plant will utilize onsite electric generators to provide motive power. Two generators would use internal combustion engines, emitting a variety of air pollutants similar to those of the main stack but which are uncontrolled by fabric filtering devices. The Humbert Application projects annual fuel usage of 50,000 gallons for these power generators. These pollutant totals are compiled in column two of Table C.[10] However, the stated 200 gallon per hour rate running for the full 2000 operating hours per year would result in 400,000 gallons of fuel use annually. Therefore, column three includes pollution totals which would be emitted at the higher level of operation projected by the companyôs Application.

Table C. Electric Power Generator Emissions

Pollutant	Annual Emissions At 50,000 gallons/year	Annual Emissions At 400,000 gallons per year
CO	6500	52000
NOx	30200	241600
PM/PM-10	2125	17000
SO2	1985	15880
VOC	2495	19720

The air pollution impact of this asphalt plant operation is complicated by the combination of the drum-mix operation, fugitive emissions and electric generator emissions.

Ambient Pollution Estimates

This report uses an EPA spreadsheet based on the SCREEN3 air dispersion model which calculates all emission modeling modes: area source and volume source as well as point source. Pollution calculations were done for asphalt production levels of 300,000 tons per year. The higher number is the more realistic estimate of maximum projected annual production based on the applicantôs projected work schedule.

Appendix B outlines the air pollution model used in this report. The maps in Appendix C and the data readouts in Appendix D indicate the extent of modeled air pollution impacts above

[9] Data on fugitive emissions from the work of Dr. R.M. Nadkarni

[10] The values in Table Bôs Column two are identical to those listed in the Application Form AQGP-107, Section c, page 5, but are rendered in pounds instead of tons.

minimal response levels, or MRLs, set by the Agency for Toxic Substances and Disease Registry. According to information on MRLs published by the National Center for Biotechnology Information:

> Minimal risk levels (MRLs) are health-based guidance values derived for individual substances by conducting a thorough review of the literature, identifying appropriate target organs of response, and identifying a dose level where a no adverse effect or the lowest adverse effect level is seen. This level is then evaluated for uncertainty in the data base and for other extenuating factors and subsequently adjusted with uncertainty or modifying factors. The resulting calculation yields the MRL that is defined as an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.

Naphthalene, benzene, formaldehyde, mercury and cadmium are hazardous air pollutants emitted by all asphalt plants. These toxic substances are not reduced by bag-house filter pollution controls because they are much too small for capture by such devices.

Benzene is a known carcinogen or cancer-causing agent. Formaldehyde is a probable human carcinogen and an eye, skin, and respiratory tract irritant. Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are created during the incomplete burning of fossil fuel and other organic substances. The Department of Health and Human Services has determined that some PAHs may reasonably be expected to cause cancer. Breathing air with low levels of cadmium over long periods of time may result kidney disease, lung damage and fragile bones. Animal studies show that inhalation of cadmium promotes lung cancer, liver damage and changes in the immune system. Exposure to naphthalene by inhalation and ingestion is associated with hemolytic anemia, damage to the liver, and neurological damage. Mercury and most of its compounds are extremely toxic, causing tremors, impaired cognitive skills, and sleep disturbance with chronic exposure even at low concentrations.

The highest risk levels as determined by the modeling show mercury exceeding acceptable levels 300 meters from the asphalt plant (about a football field), benzene and cadmium exceeding acceptable levels 600 meters from the plant (over one-third of a mile), naphthalene exceeding acceptable levels 1,800 meters from the plant (over one mile), and formaldehyde exceeding acceptable levels 2,600 meters from the plant (over a mile and a half).

Agricultural Impacts

The Umatilla County area proposed for the asphalt plant is primarily agricultural. A recent study indicates that edible wheat would serve as a portal for human exposure to polycyclic aromatic hydrocarbons (PAH).[11] Appendix A includes the full abstract of this analysis. As outlined in the study, the risk to humans is significant. A number of PAHs are mutagenic or carcinogenic, and PAH may be absorbed into the blood through inhalation, ingestion, and dermal contact, causing systemic toxic effects.

[11] ñPolycyclic aromatic hydrocarbons in edible grain: A pilot study of agricultural crops as a human exposure pathway for environmental contaminants using wheat as a model crop,ò Kobayashi R et al, Environmental Research 107 (2008) 145ï 151

According to ATSDR, naphthalene has been found in milk from dairy cows and eggs from laying hens exposed to the pollutant. Also, naphthalene and methylnaphthalenes have been found in fish and shellfish in polluted bodies of water.

Conclusion

The Oregon Department of Environmental Quality has issued a defective permit filled with internal contradictions and errors of fact. Toxic air pollution levels indicated in this report based on the permit present an unacceptable level of risk to the residents living near the plant site. The permit should provide no confidence to county officials that public health and agricultural livelihood would be protected.

Louis A. Zeller, Science Director
December 12, 2013

Appendices

Appendix A

Polycyclic aromatic hydrocarbons in edible grain: A pilot study of agricultural crops as a human exposure pathway for environmental contaminants using wheat as a model crop

Kobayashi R et al, Environmental Research 107 (2008) 145ï 151

Abstract

The concentrations of polycyclic aromatic hydrocarbons (PAHs) were investigated in a pilot study of field wheat grain as a model indicator for environmental contamination. The edible grain would serve as a portal for human exposure. Wheat grain was initially studied since it is one of the major food crops consumed internationally by many including infants and children. Wheat grain samples from five different geographical growing locations in California that span approximately 450km were collected during the same growing season. The same variety of grain was harvested and analyzed for PAHs that ranged from 2- to 6-rings. PAHs were detected in all grain samples and were mainly 2- to 4-ring PAHs with naphthalene the most abundant among them. There were geographical differences in the levels of PAHs in the grain. The sources of the PAHs were not known in this pilot study, but the principal component analysis indicates that the major source is similar in all locations except for naphthalene. Grain naphthalene concentrations may reflect local naphthalene emissions. Diesel-fueled harvesting operations did not appear to contribute to the observed PAH concentrations in the grain. An estimate of naphthalene intake from eating grain compared to inhalation intake demonstrated the potential importance of field contamination of grain as a possible portal of human exposure. The relationship between PAH concentrations in grain and air should be quantitatively investigated to better quantitate exposure and to identify effective measures to lower the risk from PAH exposure through eating grain.

Appendix B

Screen modeling tool to calculate worst case calculations

Air pollutant emission sources are commonly characterized as point, area or volume sources:

- Point source: A single, identifiable source of air pollutant emissions; for example, a combustion boiler flue gas stack. A point source has no geometric dimensions.
- Area source: A two-dimensional source of diffuse air pollutant emissions; for example, a landfill or vapors from a large spill of volatile liquid.
- Volume source: A three-dimensional source of diffuse air pollutant emissions. Essentially, it is an area source with height; for example, the fugitive gaseous emissions from piping flanges, valves and other equipment at various heights within industrial facilities such as petrochemical plants.

To calculate worst case calculations from point, area or volume source with spreadsheet:

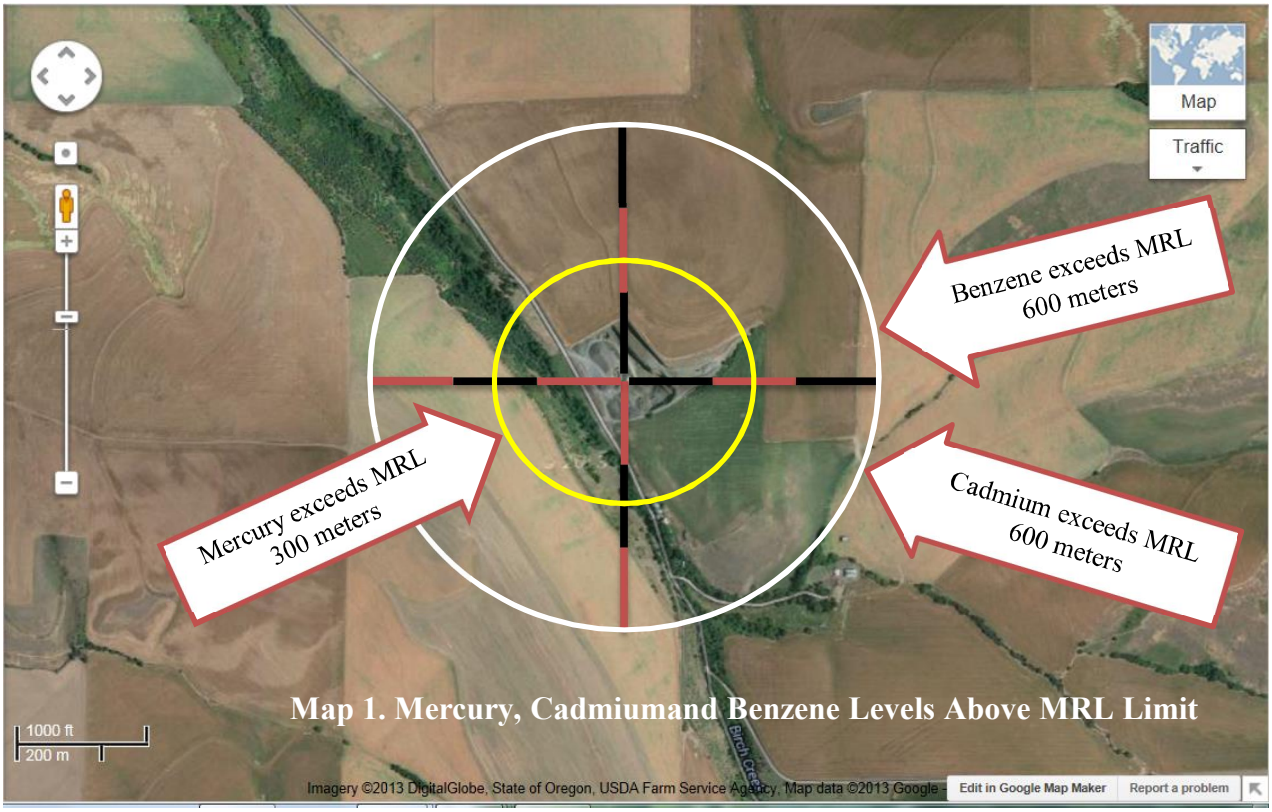
If the emission rate is entered (where the big red value is) the spreadsheet will make the downwind calculations for each of the source types.

If the concern level is entered (at the smaller red value) the spreadsheet will make a comparison of the values.

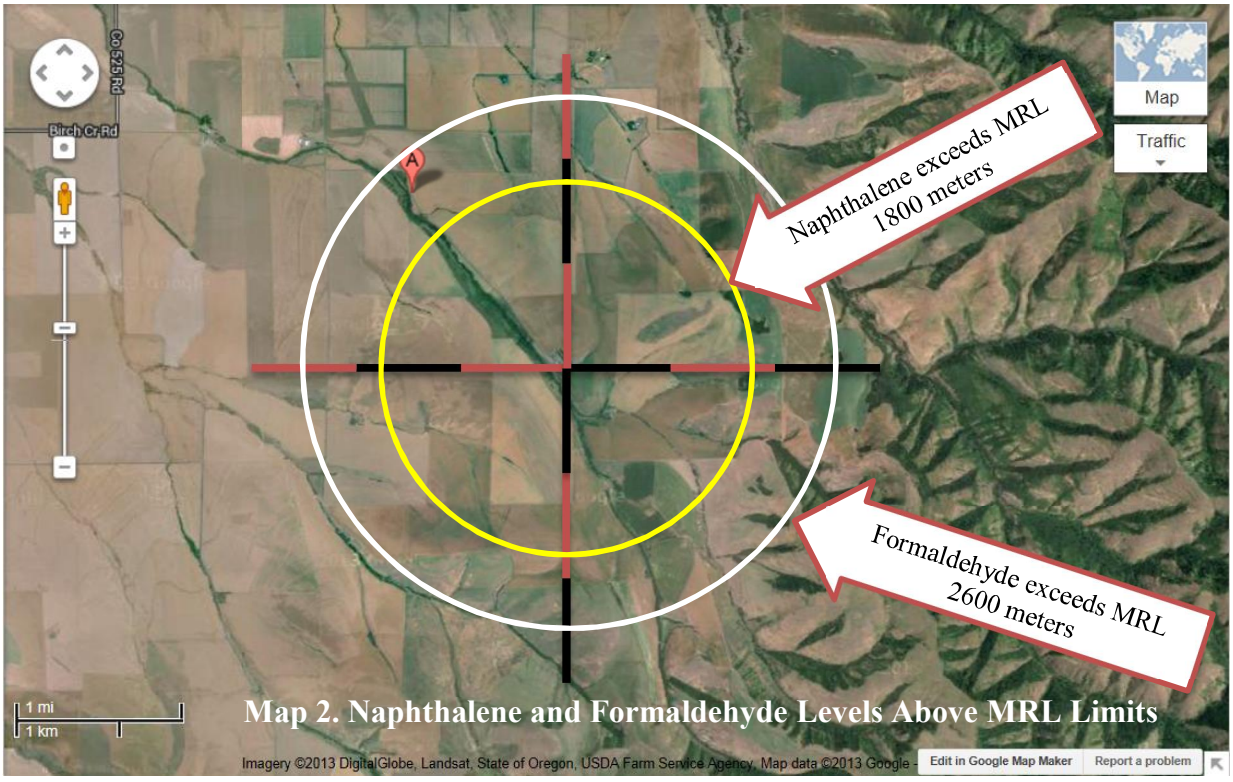
In the calculations below, the emission rate is from US Environmental Protection Agency AP-42 Emission Factors, Chapter 11, Mineral products Industry for hot-mix asphalt, Available at http://www.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf

The concern level is set at the Minimal Risk Levels (MRLs) for hazardous substances established by the Agency for Toxic Substances and Disease Registry, updated July 2013. Available at http://www.atsdr.cdc.gov/mrls/mrllist.asp

Appendix C



Map 1. Mercury, Cadmiumand Benzene Levels Above MRL Limit



Map 2. Naphthalene and Formaldehyde Levels Above MRL Limits

Appendix D

This section contains pollution impact calculations from a 150 ton per hour asphalt plant burning No. 2 fuel oil and/or natural gas (propane). US EPA Emission Factors are used to determine Peak (30 minute) Emission Rates. Concern Levels are from the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs), updated July 2013. The pollution level and radius of impact for each substance is an instantaneous result; i.e., the impacts calculated under point, area, volume and worst would occur anytime the plant operates at full capacity. The right-most column recommends emission reductions at all distances from the plant for which ambient air pollution would exceed the corresponding level of concern.

EMISSIONS CALCULATIONS—ONLY FUEL OIL

Naphthalene: $C_{10}H_8$ CAS No. 91-20-3

Peak (30 min) Emission Rate =			0.012	g/s	0.4272	tons/yr	
MW=			128.17				
Concern level			0.0007	ppm	3.6695	ug/m3	
Fuel: FO							
Distance (M)	Point	Area	Volume	Worst		Recommendation	
10	1.58E+02	2.11E+03	2.10E+02	**2.11E+03**		reduce emissions	
100	9.07E+00	2.90E+02	9.47E+01	**2.90E+02**		reduce emissions	
200	4.95E+00	1.15E+02	5.25E+01	**1.15E+02**		reduce emissions	
300	3.40E+00	6.24E+01	3.38E+01	**6.24E+01**		reduce emissions	
400	2.61E+00	3.95E+01	2.38E+01	**3.95E+01**		reduce emissions	
500	2.13E+00	2.75E+01	1.78E+01	**2.75E+01**		reduce emissions	
600	1.80E+00	2.04E+01	1.43E+01	**2.04E+01**		reduce emissions	
700	1.52E+00	1.58E+01	1.16E+01	**1.58E+01**		reduce emissions	
800	1.33E+00	1.28E+01	9.64E+00	**1.28E+01**		reduce emissions	
900	1.33E+00	1.07E+01	8.26E+00	**1.07E+01**		reduce emissions	
1000	1.33E+00	9.03E+00	7.13E+00	**9.03E+00**		reduce emissions	
1100	1.31E+00	7.81E+00	6.24E+00	**7.81E+00**		reduce emissions	
1200	1.32E+00	6.84E+00	5.52E+00	**6.84E+00**		reduce emissions	
1300	1.31E+00	6.05E+00	4.92E+00	**6.05E+00**		reduce emissions	
1400	1.30E+00	5.40E+00	4.43E+00	**5.40E+00**		reduce emissions	
1500	1.29E+00	4.86E+00	4.01E+00	**4.86E+00**		reduce emissions	
1600	1.26E+00	4.40E+00	3.65E+00	**4.40E+00**		reduce emissions	
1700	1.24E+00	4.01E+00	3.35E+00	**4.01E+00**		reduce emissions	
1800	1.21E+00	3.68E+00	3.08E+00	**3.68E+00**		reduce emissions	
1900	1.18E+00	3.39E+00	2.84E+00	**3.39E+00**		its OK	
2000	1.15E+00	3.13E+00	2.67E+00	**3.13E+00**		its OK	
2100	1.12E+00	2.92E+00	2.50E+00	**2.92E+00**		its OK	
2200	1.08E+00	2.73E+00	2.34E+00	**2.73E+00**		its OK	
2300	1.05E+00	2.56E+00	2.20E+00	**2.56E+00**		its OK	
2400	1.02E+00	2.41E+00	2.07E+00	**2.41E+00**		its OK	

2500	9.93E-01	2.27E+00	1.96E+00	**2.27E+00**		its OK	
2600	9.64E-01	2.14E+00	1.85E+00	**2.14E+00**		its OK	
2700	9.37E-01	2.03E+00	1.76E+00	**2.03E+00**		its OK	
2800	9.10E-01	1.92E+00	1.67E+00	**1.92E+00**		its OK	
2900	8.84E-01	1.83E+00	1.59E+00	**1.83E+00**		its OK	
3000	8.60E-01	1.74E+00	1.52E+00	**1.74E+00**		its OK	
3500	7.51E-01	1.41E+00	1.24E+00	**1.41E+00**		its OK	
4000	6.63E-01	1.18E+00	1.04E+00	**1.18E+00**		its OK	
4500	5.92E-01	1.00E+00	8.86E-01	**1.00E+00**		its OK	
5000	5.32E-01	8.69E-01	7.69E-01	**8.69E-01**		its OK	
5500	4.82E-01	7.63E-01	6.77E-01	**7.63E-01**		its OK	
6000	4.40E-01	6.78E-01	6.02E-01	**6.78E-01**		its OK	
6500	4.04E-01	6.08E-01	5.41E-01	**6.08E-01**		its OK	
7000	3.72E-01	5.50E-01	4.90E-01	**5.50E-01**		its OK	
7500	3.45E-01	5.02E-01	4.48E-01	**5.02E-01**		its OK	
8000	3.22E-01	4.62E-01	4.12E-01	**4.62E-01**		its OK	
8500	3.01E-01	4.27E-01	3.81E-01	**4.27E-01**		its OK	
9000	2.82E-01	3.96E-01	3.54E-01	**3.96E-01**		its OK	
9500	2.66E-01	3.69E-01	3.30E-01	**3.69E-01**		its OK	
10000	2.51E-01	3.45E-01	3.08E-01	**3.45E-01**		its OK	

Mercury: Hg CAS No. 7439-97-6

Peak (30 min) Emission Rate =			**0.000049**	**g/s**	**0.0017**	**tons/yr**
MW=			**200.59**			
Concern level			**0.000024**	**ppm**	**0.1969**	**ug/m3**
Fuel: FO						
Distance (M)	**Point**	**Area**	**Volume**	**Worst**		**Recommendation**
10	6.29E-01	8.42E+00	8.38E-01	**8.42E+00**		reduce emissions
100	3.61E-02	1.16E+00	3.77E-01	**1.16E+00**		reduce emissions
200	1.97E-02	4.58E-01	2.09E-01	**4.58E-01**		reduce emissions
300	1.36E-02	2.48E-01	1.35E-01	**2.48E-01**		reduce emissions
400	1.04E-02	1.57E-01	9.50E-02	**1.57E-01**		its OK
500	8.47E-03	1.10E-01	7.09E-02	**1.10E-01**		its OK
600	7.16E-03	8.13E-02	5.69E-02	**8.13E-02**		its OK
700	6.06E-03	6.30E-02	4.62E-02	**6.30E-02**		its OK
800	5.28E-03	5.11E-02	3.84E-02	**5.11E-02**		its OK
900	5.30E-03	4.25E-02	3.29E-02	**4.25E-02**		its OK
1000	5.32E-03	3.60E-02	2.84E-02	**3.60E-02**		its OK
1100	5.24E-03	3.11E-02	2.49E-02	**3.11E-02**		its OK
1200	5.24E-03	2.72E-02	2.20E-02	**2.72E-02**		its OK
1300	5.23E-03	2.41E-02	1.96E-02	**2.41E-02**		its OK
1400	5.19E-03	2.15E-02	1.76E-02	**2.15E-02**		its OK
1500	5.12E-03	1.94E-02	1.60E-02	**1.94E-02**		its OK

1600	5.03E-03	1.75E-02	1.46E-02	**1.75E-02**		its OK
1700	4.93E-03	1.60E-02	1.33E-02	**1.60E-02**		its OK
1800	4.82E-03	1.47E-02	1.23E-02	**1.47E-02**		its OK
1900	4.70E-03	1.35E-02	1.13E-02	**1.35E-02**		its OK
2000	4.58E-03	1.25E-02	1.06E-02	**1.25E-02**		its OK
2100	4.45E-03	1.16E-02	9.95E-03	**1.16E-02**		its OK
2200	4.32E-03	1.09E-02	9.32E-03	**1.09E-02**		its OK
2300	4.19E-03	1.02E-02	8.77E-03	**1.02E-02**		its OK
2400	4.07E-03	9.58E-03	8.26E-03	**9.58E-03**		its OK
2500	3.95E-03	9.04E-03	7.80E-03	**9.04E-03**		its OK
2600	3.84E-03	8.54E-03	7.38E-03	**8.54E-03**		its OK
2700	3.73E-03	8.09E-03	7.00E-03	**8.09E-03**		its OK
2800	3.63E-03	7.67E-03	6.65E-03	**7.67E-03**		its OK
2900	3.52E-03	7.29E-03	6.33E-03	**7.29E-03**		its OK
3000	3.43E-03	6.94E-03	6.07E-03	**6.94E-03**		its OK
3500	2.99E-03	5.63E-03	4.94E-03	**5.63E-03**		its OK
4000	2.64E-03	4.69E-03	4.13E-03	**4.69E-03**		its OK
4500	2.36E-03	3.99E-03	3.53E-03	**3.99E-03**		its OK
5000	2.12E-03	3.46E-03	3.06E-03	**3.46E-03**		its OK
5500	1.92E-03	3.04E-03	2.70E-03	**3.04E-03**		its OK
6000	1.75E-03	2.70E-03	2.40E-03	**2.70E-03**		its OK
6500	1.61E-03	2.42E-03	2.15E-03	**2.42E-03**		its OK
7000	1.48E-03	2.19E-03	1.95E-03	**2.19E-03**		its OK
7500	1.38E-03	2.00E-03	1.78E-03	**2.00E-03**		its OK
8000	1.28E-03	1.84E-03	1.64E-03	**1.84E-03**		its OK
8500	1.20E-03	1.70E-03	1.52E-03	**1.70E-03**		its OK
9000	1.13E-03	1.58E-03	1.41E-03	**1.58E-03**		its OK
9500	1.06E-03	1.47E-03	1.31E-03	**1.47E-03**		its OK
10000	1.00E-03	1.37E-03	1.23E-03	**1.37E-03**		its OK

EMISSIONS CALCULATIONS—EITHER FUEL OIL OR NATURAL GAS

Benzene: C_6H_6 CAS No. 71-43-2

Peak (30 min) Emission Rate =			**0.007**	**g/s**	**0.256**	**tons/yr**	
MW=			**78.11**				
Concern level			**0.003**	**ppm**	**9.584**	**ug/m3**	
Fuel: FO/NG							
Distance (M)	**Point**	**Area**	**Volume**	**Worst**		**Recommendation**	
10	9.46E+01	1.27E+03	1.26E+02	**1.27E+03**		reduce emissions	
100	5.43E+00	1.74E+02	5.67E+01	**1.74E+02**		reduce emissions	

200	2.96E+00	6.89E+01	3.15E+01	**6.89E+01**		reduce emissions	
300	2.04E+00	3.74E+01	2.03E+01	**3.74E+01**		reduce emissions	
400	1.57E+00	2.37E+01	1.43E+01	**2.37E+01**		reduce emissions	
500	1.27E+00	1.65E+01	1.07E+01	**1.65E+01**		reduce emissions	
600	1.08E+00	1.22E+01	8.56E+00	**1.22E+01**		reduce emissions	
700	9.12E-01	9.48E+00	6.95E+00	**9.48E+00**		its OK	
800	7.94E-01	7.69E+00	5.77E+00	**7.69E+00**		its OK	
900	7.97E-01	6.39E+00	4.95E+00	**6.39E+00**		its OK	
1000	8.00E-01	5.41E+00	4.27E+00	**5.41E+00**		its OK	
1100	7.88E-01	4.68E+00	3.74E+00	**4.68E+00**		its OK	
1200	7.89E-01	4.10E+00	3.31E+00	**4.10E+00**		its OK	
1300	7.87E-01	3.63E+00	2.95E+00	**3.63E+00**		its OK	
1400	7.80E-01	3.24E+00	2.65E+00	**3.24E+00**		its OK	
1500	7.70E-01	2.91E+00	2.40E+00	**2.91E+00**		its OK	
1600	7.57E-01	2.64E+00	2.19E+00	**2.64E+00**		its OK	
1700	7.41E-01	2.41E+00	2.00E+00	**2.41E+00**		its OK	
1800	7.25E-01	2.20E+00	1.84E+00	**2.20E+00**		its OK	
1900	7.07E-01	2.03E+00	1.70E+00	**2.03E+00**		its OK	
2000	6.89E-01	1.88E+00	1.60E+00	**1.88E+00**		its OK	
2100	6.69E-01	1.75E+00	1.50E+00	**1.75E+00**		its OK	
2200	6.50E-01	1.63E+00	1.40E+00	**1.63E+00**		its OK	
2300	6.31E-01	1.53E+00	1.32E+00	**1.53E+00**		its OK	
2400	6.12E-01	1.44E+00	1.24E+00	**1.44E+00**		its OK	
2500	5.95E-01	1.36E+00	1.17E+00	**1.36E+00**		its OK	
2600	5.78E-01	1.28E+00	1.11E+00	**1.28E+00**		its OK	
2700	5.61E-01	1.22E+00	1.05E+00	**1.22E+00**		its OK	
2800	5.45E-01	1.15E+00	1.00E+00	**1.15E+00**		its OK	
2900	5.30E-01	1.10E+00	9.52E-01	**1.10E+00**		its OK	
3000	5.15E-01	1.04E+00	9.13E-01	**1.04E+00**		its OK	
3500	4.50E-01	8.46E-01	7.43E-01	**8.46E-01**		its OK	
4000	3.98E-01	7.05E-01	6.22E-01	**7.05E-01**		its OK	
4500	3.55E-01	6.01E-01	5.31E-01	**6.01E-01**		its OK	
5000	3.19E-01	5.20E-01	4.61E-01	**5.20E-01**		its OK	
5500	2.89E-01	4.57E-01	4.05E-01	**4.57E-01**		its OK	
6000	2.64E-01	4.06E-01	3.61E-01	**4.06E-01**		its OK	
6500	2.42E-01	3.64E-01	3.24E-01	**3.64E-01**		its OK	
7000	2.23E-01	3.29E-01	2.93E-01	**3.29E-01**		its OK	
7500	2.07E-01	3.01E-01	2.68E-01	**3.01E-01**		its OK	
8000	1.93E-01	2.77E-01	2.47E-01	**2.77E-01**		its OK	
8500	1.80E-01	2.56E-01	2.28E-01	**2.56E-01**		its OK	
9000	1.69E-01	2.37E-01	2.12E-01	**2.37E-01**		its OK	
9500	1.59E-01	2.21E-01	1.98E-01	**2.21E-01**		its OK	
10000	1.50E-01	2.07E-01	1.85E-01	**2.07E-01**		its OK	

Cadmium: Cd CAS No. 7440-43-9

Peak (30 min) Emission Rate =			0.000007749	g/s	0.0003	tons/yr	
MW=			112.4				
Concern level			0.00000218	ppm	0.01	ug/m3	
Fuel: FO/NG							
Distance (M)	Point	Area	Volume	Worst		Recommendation	
10	9.94E-02	1.33E+00	1.33E-01	1.33E+00		reduce emissions	
100	5.71E-03	1.83E-01	5.97E-02	1.83E-01		reduce emissions	
200	3.12E-03	7.24E-02	3.31E-02	7.24E-02		reduce emissions	
300	2.14E-03	3.93E-02	2.13E-02	3.93E-02		reduce emissions	
400	1.65E-03	2.49E-02	1.50E-02	2.49E-02		reduce emissions	
500	1.34E-03	1.74E-02	1.12E-02	1.74E-02		reduce emissions	
600	1.13E-03	1.29E-02	9.00E-03	1.29E-02		reduce emissions	
700	9.59E-04	9.97E-03	7.30E-03	9.97E-03		its OK	
800	8.35E-04	8.08E-03	6.07E-03	8.08E-03		its OK	
900	8.38E-04	6.72E-03	5.20E-03	6.72E-03		its OK	
1000	8.41E-04	5.69E-03	4.49E-03	5.69E-03		its OK	
1100	8.28E-04	4.92E-03	3.93E-03	4.92E-03		its OK	
1200	8.29E-04	4.31E-03	3.48E-03	4.31E-03		its OK	
1300	8.28E-04	3.81E-03	3.10E-03	3.81E-03		its OK	
1400	8.21E-04	3.40E-03	2.79E-03	3.40E-03		its OK	
1500	8.10E-04	3.06E-03	2.53E-03	3.06E-03		its OK	
1600	7.96E-04	2.77E-03	2.30E-03	2.77E-03		its OK	
1700	7.80E-04	2.53E-03	2.11E-03	2.53E-03		its OK	
1800	7.62E-04	2.32E-03	1.94E-03	2.32E-03		its OK	
1900	7.43E-04	2.13E-03	1.79E-03	2.13E-03		its OK	
2000	7.24E-04	1.97E-03	1.68E-03	1.97E-03		its OK	
2100	7.03E-04	1.84E-03	1.57E-03	1.84E-03		its OK	
2200	6.83E-04	1.72E-03	1.47E-03	1.72E-03		its OK	
2300	6.63E-04	1.61E-03	1.39E-03	1.61E-03		its OK	
2400	6.44E-04	1.52E-03	1.31E-03	1.52E-03		its OK	
2500	6.25E-04	1.43E-03	1.23E-03	1.43E-03		its OK	
2600	6.07E-04	1.35E-03	1.17E-03	1.35E-03		its OK	
2700	5.90E-04	1.28E-03	1.11E-03	1.28E-03		its OK	
2800	5.73E-04	1.21E-03	1.05E-03	1.21E-03		its OK	
2900	5.57E-04	1.15E-03	1.00E-03	1.15E-03		its OK	
3000	5.42E-04	1.10E-03	9.60E-04	1.10E-03		its OK	
3500	4.73E-04	8.90E-04	7.81E-04	8.90E-04		its OK	
4000	4.18E-04	7.42E-04	6.53E-04	7.42E-04		its OK	
4500	3.73E-04	6.32E-04	5.58E-04	6.32E-04		its OK	
5000	3.35E-04	5.47E-04	4.84E-04	5.47E-04		its OK	
5500	3.04E-04	4.81E-04	4.26E-04	4.81E-04		its OK	
6000	2.77E-04	4.27E-04	3.79E-04	4.27E-04		its OK	
6500	2.54E-04	3.83E-04	3.41E-04	3.83E-04		its OK	

7000	2.35E-04	3.46E-04	3.08E-04	**3.46E-04**		its OK	
7500	2.18E-04	3.16E-04	2.82E-04	**3.16E-04**		its OK	
8000	2.03E-04	2.91E-04	2.59E-04	**2.91E-04**		its OK	
8500	1.90E-04	2.69E-04	2.40E-04	**2.69E-04**		its OK	
9000	1.78E-04	2.49E-04	2.23E-04	**2.49E-04**		its OK	
9500	1.67E-04	2.32E-04	2.08E-04	**2.32E-04**		its OK	
10000	1.58E-04	2.17E-04	1.94E-04	**2.17E-04**		its OK	

Formaldehyde: CH_2O CAS No. 50-00-0

Peak (30 min) Emission Rate =			**0.059**	**g/s**	**2.0349**	**tons/yr**	
MW=			**30.03**				
Concern level			**0.008**	**ppm**	**9.8258**	**ug/m3**	
Fuel: FO/NG							
Distance (M)	**Point**	**Area**	**Volume**	**Worst**		**Recommendation**	
10	7.52E+02	1.01E+04	1.00E+03	**1.01E+04**		reduce emissions	
100	4.32E+01	1.38E+03	4.51E+02	**1.38E+03**		reduce emissions	
200	2.36E+01	5.48E+02	2.50E+02	**5.48E+02**		reduce emissions	
300	1.62E+01	2.97E+02	1.61E+02	**2.97E+02**		reduce emissions	
400	1.25E+01	1.88E+02	1.14E+02	**1.88E+02**		reduce emissions	
500	1.01E+01	1.31E+02	8.48E+01	**1.31E+02**		reduce emissions	
600	8.57E+00	9.73E+01	6.80E+01	**9.73E+01**		reduce emissions	
700	7.25E+00	7.53E+01	5.52E+01	**7.53E+01**		reduce emissions	
800	6.32E+00	6.11E+01	4.59E+01	**6.11E+01**		reduce emissions	
900	6.34E+00	5.08E+01	3.93E+01	**5.08E+01**		reduce emissions	
1000	6.36E+00	4.30E+01	3.40E+01	**4.30E+01**		reduce emissions	
1100	6.26E+00	3.72E+01	2.97E+01	**3.72E+01**		reduce emissions	
1200	6.27E+00	3.26E+01	2.63E+01	**3.26E+01**		reduce emissions	
1300	6.26E+00	2.88E+01	2.35E+01	**2.88E+01**		reduce emissions	
1400	6.20E+00	2.57E+01	2.11E+01	**2.57E+01**		reduce emissions	
1500	6.12E+00	2.32E+01	1.91E+01	**2.32E+01**		reduce emissions	
1600	6.02E+00	2.10E+01	1.74E+01	**2.10E+01**		reduce emissions	
1700	5.89E+00	1.91E+01	1.59E+01	**1.91E+01**		reduce emissions	
1800	5.76E+00	1.75E+01	1.47E+01	**1.75E+01**		reduce emissions	
1900	5.62E+00	1.61E+01	1.36E+01	**1.61E+01**		reduce emissions	
2000	5.48E+00	1.49E+01	1.27E+01	**1.49E+01**		reduce emissions	
2100	5.32E+00	1.39E+01	1.19E+01	**1.39E+01**		reduce emissions	
2200	5.16E+00	1.30E+01	1.11E+01	**1.30E+01**		reduce emissions	
2300	5.01E+00	1.22E+01	1.05E+01	**1.22E+01**		reduce emissions	
2400	4.87E+00	1.15E+01	9.87E+00	**1.15E+01**		reduce emissions	
2500	4.73E+00	1.08E+01	9.33E+00	**1.08E+01**		reduce emissions	
2600	4.59E+00	1.02E+01	8.82E+00	**1.02E+01**		reduce emissions	
2700	4.46E+00	9.67E+00	8.37E+00	**9.67E+00**		its OK	
2800	4.33E+00	9.17E+00	7.96E+00	**9.17E+00**		its OK	

2900	4.21E+00	8.72E+00	7.57E+00	**8.72E+00**		its OK	
3000	4.10E+00	8.30E+00	7.26E+00	**8.30E+00**		its OK	
3500	3.58E+00	6.73E+00	5.91E+00	**6.73E+00**		its OK	
4000	3.16E+00	5.61E+00	4.94E+00	**5.61E+00**		its OK	
4500	2.82E+00	4.78E+00	4.22E+00	**4.78E+00**		its OK	
5000	2.54E+00	4.14E+00	3.66E+00	**4.14E+00**		its OK	
5500	2.30E+00	3.63E+00	3.22E+00	**3.63E+00**		its OK	
6000	2.10E+00	3.23E+00	2.87E+00	**3.23E+00**		its OK	
6500	1.92E+00	2.90E+00	2.58E+00	**2.90E+00**		its OK	
7000	1.77E+00	2.62E+00	2.33E+00	**2.62E+00**		its OK	
7500	1.65E+00	2.39E+00	2.13E+00	**2.39E+00**		its OK	
8000	1.53E+00	2.20E+00	1.96E+00	**2.20E+00**		its OK	
8500	1.43E+00	2.03E+00	1.81E+00	**2.03E+00**		its OK	
9000	1.35E+00	1.89E+00	1.68E+00	**1.89E+00**		its OK	
9500	1.27E+00	1.76E+00	1.57E+00	**1.76E+00**		its OK	
10000	1.20E+00	1.64E+00	1.47E+00	**1.64E+00**		its OK	

EMISSIONS CALCULATIONS—ONLY NATURAL GAS

Naphthalene: $C_{10}H_8$ CAS No. 91-20-3

Peak (30 min) Emission Rate =			**0.002**	**g/s**	**0.059**	**tons/yr**	
MW=			**128.17**				
Concern level			**0.0007**	**ppm**	**3.6695**	**ug/m3**	
Fuel: NG							
Distance (M)	**Point**	**Area**	**Volume**	**Worst**		**Recommendation**	
10	2.18E+01	2.92E+02	2.91E+01	**2.92E+02**		reduce emissions	
100	1.25E+00	4.01E+01	1.31E+01	**4.01E+01**		reduce emissions	
200	6.84E-01	1.59E+01	7.26E+00	**1.59E+01**		reduce emissions	
300	4.71E-01	8.62E+00	4.68E+00	**8.62E+00**		reduce emissions	
400	3.61E-01	5.46E+00	3.29E+00	**5.46E+00**		reduce emissions	
500	2.94E-01	3.81E+00	2.46E+00	**3.81E+00**		reduce emissions	
600	2.49E-01	2.82E+00	1.97E+00	**2.82E+00**		its OK	
700	2.10E-01	2.19E+00	1.60E+00	**2.19E+00**		its OK	
800	1.83E-01	1.77E+00	1.33E+00	**1.77E+00**		its OK	
900	1.84E-01	1.47E+00	1.14E+00	**1.47E+00**		its OK	
1000	1.84E-01	1.25E+00	9.86E-01	**1.25E+00**		its OK	
1100	1.82E-01	1.08E+00	8.62E-01	**1.08E+00**		its OK	
1200	1.82E-01	9.45E-01	7.63E-01	**9.45E-01**		its OK	
1300	1.82E-01	8.36E-01	6.81E-01	**8.36E-01**		its OK	
1400	1.80E-01	7.47E-01	6.12E-01	**7.47E-01**		its OK	
1500	1.78E-01	6.72E-01	5.54E-01	**6.72E-01**		its OK	

1600	1.75E-01	6.09E-01	5.05E-01	**6.09E-01**		its OK	
1700	1.71E-01	5.55E-01	4.62E-01	**5.55E-01**		its OK	
1800	1.67E-01	5.08E-01	4.26E-01	**5.08E-01**		its OK	
1900	1.63E-01	4.68E-01	3.93E-01	**4.68E-01**		its OK	
2000	1.59E-01	4.33E-01	3.69E-01	**4.33E-01**		its OK	
2100	1.54E-01	4.03E-01	3.45E-01	**4.03E-01**		its OK	
2200	1.50E-01	3.77E-01	3.24E-01	**3.77E-01**		its OK	
2300	1.46E-01	3.54E-01	3.04E-01	**3.54E-01**		its OK	
2400	1.41E-01	3.33E-01	2.86E-01	**3.33E-01**		its OK	
2500	1.37E-01	3.13E-01	2.71E-01	**3.13E-01**		its OK	
2600	1.33E-01	2.96E-01	2.56E-01	**2.96E-01**		its OK	
2700	1.29E-01	2.81E-01	2.43E-01	**2.81E-01**		its OK	
2800	1.26E-01	2.66E-01	2.31E-01	**2.66E-01**		its OK	
2900	1.22E-01	2.53E-01	2.20E-01	**2.53E-01**		its OK	
3000	1.19E-01	2.41E-01	2.11E-01	**2.41E-01**		its OK	
3500	1.04E-01	1.95E-01	1.71E-01	**1.95E-01**		its OK	
4000	9.17E-02	1.63E-01	1.43E-01	**1.63E-01**		its OK	
4500	8.18E-02	1.39E-01	1.22E-01	**1.39E-01**		its OK	
5000	7.36E-02	1.20E-01	1.06E-01	**1.20E-01**		its OK	
5500	6.67E-02	1.05E-01	9.35E-02	**1.05E-01**		its OK	
6000	6.08E-02	9.37E-02	8.32E-02	**9.37E-02**		its OK	
6500	5.58E-02	8.40E-02	7.47E-02	**8.40E-02**		its OK	
7000	5.15E-02	7.60E-02	6.77E-02	**7.60E-02**		its OK	
7500	4.77E-02	6.94E-02	6.19E-02	**6.94E-02**		its OK	
8000	4.45E-02	6.38E-02	5.69E-02	**6.38E-02**		its OK	
8500	4.16E-02	5.90E-02	5.26E-02	**5.90E-02**		its OK	
9000	3.90E-02	5.47E-02	4.89E-02	**5.47E-02**		its OK	
9500	3.67E-02	5.10E-02	4.56E-02	**5.10E-02**		its OK	
10000	3.47E-02	4.77E-02	4.26E-02	**4.77E-02**		its OK	