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M E M O R A N D U M

TO: File

FROM: Tom Orth, Air Quality Modeler

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SUBJECT: Nitrogen Dioxide (NO_2) Dispersion Modeling Evaluation of Generic Wellhead Sites

I. OBJECTIVE

The Division of Air Quality (UDAQ) is proposing to develop a General Approval Order (GAO) process for qualifying oil and gas wellhead sites in Utah. Wellhead sites meeting basic site horsepower ratings and operating conditions would be issued a GAO, and would not be required to go through the normal Approval Order process. The GAO would be structured to ensure that the site and its operator would comply with all State and Federal Air Quality laws and rules.

In support of this effort the UDAQ has conducted a generic dispersion modeling analysis of NO_2 emissions from typical IC engine wellheads and associated equipment used in Utah's oil and gas industry. The purpose of the analysis was to evaluate basic exhaust stack release methods and establish exhaust stack release criteria necessary to ensure compliance with the 1-hour National Ambient Air Quality Standard (NAAQS) for NO_2.

This memorandum outlines the methodology used in the dispersion modeling analysis and the subsequent modeling results. It makes no determination with respect to compliance with National Ambient Air Quality Standards related to any specific permitting action by the Division, or to impacts from other pollutants released by these processes.

II. APPLICABLE APPLICATIONS

The analysis was limited to the review of a single wellhead sites with a maximum site HP rating of 130 HP containing the following associated equipment:

- Single IC pump jack engine sites with a 40, 65, 100, or 130 HP ratings
- One 40 HP and one 65 HP pump jack engine, 105 HP / site
- Two - 65 HP IC pump jack engines, 130 HP / site.
- Multiple oil storage tank and equipment heaters with 3, 5 and 10 MMBtu/hr in total heating capacity
- Combustion Flares 2 MMBtu/hr

III. MODELING METHODOLOGY

A. Dispersion Model

The analysis is based on dispersion estimates provided by the EPA-AERMOD modeling system (Version 13350).

B. Modeling Assumptions

1. Topography/Terrain

The analysis assumes the presence of both simple and complex terrain surrounding the subject sources. Changes in terrain elevations over land that were simulated in this analysis vary from areas that are relatively flat to areas where the terrain heights change over distance 0.125 m per 8 meters of horizontal distance.

2. Urban or Rural Area Designation

Since most of the wellheads will be located in unpopulated areas of eastern Utah, it was concluded that the general area is "rural" for air modeling purposes.

3. Ambient Air

The area surrounding wellheads in eastern Utah are generally not fenced off or restricted to public access. It was therefore assumed for the purposes of this analysis that all areas in the vicinity of the wellhead meet the State's definition of ambient air.

4. Building Downwash

Wellheads and flares are generally stand-alone units not housed within a structure. Storage tank size and number of units may vary between site, however, the grouping of tank units and the manner in which the tank heaters are vented adjacent to the tank suggest that downwash may have a significant effect on model predicted concentrations. Therefore, building downwash was included in the analysis for the storage tank units. The analysis assumes an average tank size of 20 feet in height and 12 feet in diameter, based on information provided by industry. The analysis used the EPA- Building Profile Input Program (BPIP) to generate a 360° profile of a generic tank battery for input to the AERMOD model.

5. Meteorology

The analysis is based on multiple years of meteorological monitoring at three sites in eastern Utah where the bulk of oil and gas operations occur. They include surface data collected at:

Vernal, Utah National Weather Service ASOS Station – 2005 through 2008
Price, Utah National Weather Service ASOS Station – 2006 through 2010
Canyonlands National Park, Utah 10 meters tower – 2006 through 2010

Meteorological data was processed using the AERMET processor which is included AERMINUTE in the AERMOD modeling system. Upper atmospheric data used in AERMET processing was taken from:

Salt Lake City, Utah National Weather Service Upper Air 2006-2010
Grand Junction, Colorado National Weather Service Upper Air 2005-2010

6. Background

The analysis does not rely on a single background concentration level when comparing model impact estimates with the 1-hour NAAQS for NO_2. Rather, the analysis assumes that the combined model predicted impacts for the wellhead sources themselves at each site should be low enough to accommodate the 40 to 65 $\mu g/m^3$ one-hour ambient NO_2 values that have been recorded at various monitoring sites in the Uintah Basin region.

The exhaust evaluation analysis is limited to a single wellhead site. Cumulative impacts from multiple wellheads that would be found in a typical oil field were not modeled in this analysis. Based on the review of aerial photos of Utah's oil and gas fields in the Uintah Basin, the analysis assumes the spacing between wellheads will be no less than 1000 feet. Previous modeling of Utah's oil and gas fields covering multiple sites suggests that the maximum allowable impact of single wellhead on the area of any adjacent wellheads would be less than 20% of the NO_2 1-hour NAAQS.

7. Receptor and Terrain Elevations

The model uses polar grid receptors placed at each ten degrees of arc. Receptor coverage begins at 100 meters from the sources at extends out to 1 km at intervals of 100, 150, 200, 300, 500, and 1000 meters. Terrain elevations were obtained from USGS-SRTM1 (~30m) data points processed using the AERMAP processor which is part of the AERMOD modeling system.

8. Model and Options

The analysis uses the EPA-AERMOD Plume Volume Molar Ratio Method (PVMRM) to estimate the conversion of NOx into NO_2 during transport between the source and the receptor location under evaluation.

The model assumes the levels of O_3 available for NO_X to NO_2 conversion will vary by season as indicated in ambient O_3 monitoring from the Uintah basin. The UDAQ reviewed multiple monitor sites in the basin and identified the following seasonal values as representative potential O_3 levels for use in this analysis:

- Winter – 78 ppb
- Spring – 66 ppb
- Summer – 66 ppb
- Fall – 58 ppb

The in-stack thermal conversion ratio used in the model to account for conversion of NO_x to NO_2 during the combustion process was assumed to be 25%. The atmospheric equilibrium ratio for NO_2/NO_x was set to the default level of 90%.

9. NO_2 Emission Rates

The pump jack IC engines are limited to 2.84 g/hp-hr for HC and NO_X under Subpart JJJJ. Since it is unclear what percentage of the emissions would be HC and what would be NO_X, the analysis defaulted to the limit for NO_X that the engine would be required to meet during stack testing (2.84 g/hp-hr). The analysis evaluated the impact of four engine size HP ratings; 40, 65 HP, 100 HP, and 130 HP size engines.

The analysis assumes a site total storage tank and associated equipment heater rating per site of 3, 5, and 10 MMBtu/hr, with a NO_X emission rate of 0.09804 lb of NO_X per MMBTU, from AP-42 Table 1.4-1.

The analysis assumes a maximum site rating of 2 MMBtu/hr for the flare activities and a NO_X emission rate of 0.068 lb per MMBtu.

10. Horizontal vs Vertical Stack Venting

When modeling emissions from point sources (stacks) in AERMOD, the model assumes that the pollutant is released through a vent or opening, and the gas stream is assumed to vent vertically, without any restriction after the opening. The model calculates the momentum of the upwardly forced gases and calculates a final plume height based on buoyancy rise and the upward momentum. Vertically venting plumes allows the plume to stay aloft for a longer distance, enhancing dilution before the plume reaches ground levels.

IC pump jack engines and tank heaters frequently vent the gases horizontally to prevent rain from entering the stack. This type of venting does not have any upward momentum, and the only rise is due to plume buoyancy. Horizontal plume venting results in higher initial ground concentrations. The plume is vertically restricted and generally reaches ground levels within a few meters.

The Division defines the two pollutant release processes as:

"Vertically Restricted Emissions Release" means the release of an air contaminant through a stack or opening whose flow is directed in a downward or horizontal direction due to the alignment of the opening or a physical obstruction placed beyond the opening, or at a height which is less than 1.3 times the height of an adjacent building or structure, as measured from ground level.

"Vertically Unrestricted Emissions Release" means the release of an air contaminant through a stack or opening whose flow is directed upward without any physical obstruction placed beyond the opening, and at a height which is at least 1.3 times the height of an adjacent building or structure, as measured from ground level.

The IC pump jack engines and tank heaters were modeled as venting both vertically restricted and vertically unrestricted. The flare was assumed to only vent vertically unrestricted.

11. Stack Parameters

The pump jack engines and heaters were the main contributor to model estimated impacts in the analysis. Stack heights and venting configurations were evaluated for each engine size, heater capacity, and engine grouping scenario to determine if the combined 1-hour NO_2 impact from each wellhead site configuration would be less than the NAAQS.to 120 ug/m3 or less. The flare stack height was set to 12 feet, consistent with values provided by industry.

Exit gas temperature and flow rates for the IC engines were taken from stack test data submitted to the Division from various sites in the Uintah basin for the most commonly used Arrow L-795 65 HP engine. Flow rates for 40, 100, and 130 HP engines were adjusted based on the flow rate for the 65 HP engine.

The tank heater flow rate was set at 15 m/s to simulate a passive heating unit exhausting under low pressure with minimal back pressure.

Gas temperatures for the IC engine was set at 650°F, 600°F for the heater units, and 1273°F for the flare based on EPA’s default value for flaring gases.

The stack diameter for the smaller 40 and 65 HP IC engines set at 4 inches based on manufacturer specification. Diameters for the 100 and 130 HP engines were adjusted upward to conserve flow while maintaining exit gas velocity. The flare stack diameter was set to 2 feet.

As mentioned above, the analysis simulated multiple stack heights, diameters and exit velocity to determine the proper parameters needed to ensure that each wellhead site would comply with the

1-hour NAAQS for NO_2. After multiple simulations, Table 1 outlines the resulting minimum parameters needed to ensure compliance with the air quality standard.

Table 1: Stack Parameters for Wellhead Site Analysis.

Stack Parameters for Vertically Venting Sources						
Emitting Unit	Emission Rate (lb/hr)	Stack Height (ft)	Stack Temp. (F)	Flow Rate (acfm)	Exit Velocity (ft/s)	Stack Diameter (ft)
40 HP IC Engine	0.31	4	650	250	47.6	0.33
65 HP IC Engine	0.40	4	650	400	77.3	0.33
100 HP IC Engine	0.62	4	650	618	77.3	0.41
130 HP IC Engine	0.80	4	650	800	77.3	0.47
3 MMbtu Heater[2]	0.147	21	600	860	49.2	0.33
5 MMbtu Heater[2]	0.245	21	600	1440	49.2	0.50
10MMbtu Heater[2]	0.49	22	600	2875	49.2	0.50
2 MMbtu Flare	0.14	12	1273	6200	32.8	2.0
Stack Parameters for Horizontally Venting Sources						
Emitting Unit	Emission Rate (g/s)	Stack Height (ft)	Stack Temp. (K)	Flow Rate (acfm)	Exit Velocity[1] (m/s)	Stack Diameter (ft)
40 HP IC Engine	0.31	4	650	250	0.01	12.7
65 HP IC Engine	0.40	4	650	400	0.01	16.1
100 HP IC Engine	0.62	4	650	618	0.01	20.0
130 HP IC Engine	0.80	4	650	800	0.01	22.8
3 MMbtu Heater[2]	0.147	21	600	860	0.01	13.7
5 MMbtu Heater[2]	0.245	21	600	1440	0.01	17.4
10MMbtu Heater[2]	0.49	22	600	2875	0.01	19.3
2 MMbtu Flare	0.14	12	1273	6200	10	0.61

1 – EPA's horizontal venting method to eliminate upward momentum while conserving flow rates
2 - Simulated using multiple stacks

IV. MODEL RESULTS

The 1-hour NAAQS for NO_2 is 188 ug/m3 while the annual NAAQS is 100 ug/m3. Results of the analysis indicate that a wellhead site with a 130 HP or less engine(s) configuration and 10 MMbtu or less of heating capacity would comply with the NAAQS. Model predicted annual impacts on the NO2 standard were estimated to be less than 20% of the NAAQS, including background. Model predicted impacts on the 1-hour NAAQS varied significantly, and for larger engine size, approached the standard but did not exceed it. Table 2 shows the maximum model predicted 1-hour NO_2 impacts for the various engine size and heating capacity configurations simulated in the analysis.

Table 2: Model Predicted 1-Hour NO_2 Impacts

Vertically Venting Sources (Vertically Unrestricted)			
IC Engine(s) / Site	Range of Maximum Potential Impact (ug/m3)*		
	3 MMbtu Heater Capacity/Site	5 MMbtu Heater Capacity/Site	10 MMbtu Heater Capacity/Site
1-Hour NO_2 NAAQS – 188 µg/m3			
Single 40 HP Engine	82 - 108	91 - 117	na
Single 65 HP Engine	84 - 114	91 - 122	108 – 140
Single 100 HP Engine	91 - 122	97 - 130	112 – 145
Single 130 HP Engine	97 - 128	102 - 136	116 – 150
Two 40 HP Engines	104 - 134	111 - 143	125 – 162
Two 65 HP Engines	113 - 142	119 - 150	133 – 167
40 HP &65 HP Engine	106 - 136	113 - 144	128 – 162
Horizontally Venting Sources (Vertically Restricted)			
IC Engine(s) / Site	Range of Maximum Potential Impact (ug/m3)*		
	3 MMbtu Heater Capacity/Site	5 MMbtu Heater Capacity/Site	10 MMbtu Heater Capacity/Site
1-Hour NO_2 NAAQS – 188 µg/m3			
Single 40 HP Engine	84 – 123	89 – 127	na
Single 65 HP Engine	88 – 124	93 – 126	113 – 141
Single 100 HP Engine	94 – 125	100 – 128	118 – 146
Single 130 HP Engine	101 – 133	107 – 136	122 – 148
Two 40 HP Engines	112 – 164	115 – 169	133 – 180
Two 65 HP Engines	126 – 169	129 – 174	148 – 186
40 HP &65 HP Engine	117 – 165	121 – 168	139 – 182

* Included Background concentration Ranging from 40 – 65 $\mu g/m^3$.

V. CONCLUSIONS

Results of the analysis indicate that wellhead sites with an engine sizing of 130 HP or less and up to 10 MMbtu of heating capacity will comply with the NAAQS for NO_2, and may be covered under a GAO process.

The modeling results indicated that beyond 100 meters, plume that were vented either vertically or horizontally, have reached ground level. Differences in their rates of dispersion beyond that distance are minimal, resulting in similar concentration predictions.

The modeling did identify two stack exhaust characteristics that are important to ensuring compliance with the NO_2 NAAQS:

1. Engine exhaust should be vented at a level no less than 4 feeat above ground level.

2. Tank heater exhaust should be vented at a minimum height of one foot above the height of the storage tank.

   It is the reviewing modelers recommendation that these two enforceable conditions be included in any GAO issued for a wellhead site.

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