Final Report

SENSITIVITY ANALYSIS OF PVMRM AND OLM IN AERMOD

Alaska DEC Contract No. 18-8018-04

Submitted to:

Alaska Department of Environmental Conservation
Division of Air Quality
410 Willoughby Avenue, Suite 303
Juneau, Alaska 99801-1795

September 2004

MACTEC

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Prepared for

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1.0 INTRODUCTION

The purpose of this report is to document the results of a sensitivity analysis performed for the Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) options in the AERMOD dispersion model. The PVMRM and OLM options for modeling the conversion of NO_x emissions to NO_2 have been incorporated into the AERMOD dispersion model. The PVMRM approach was originally developed as a post-processor for the ISCST3 model (Hanrahan, 1999a). A technical description of the implementation of PVMRM in AERMOD is provided in the Addendum to the AERMOD Model Formulation Document (Cimorelli, *et al*., 2002), and user instructions on the application of the PVMRM and OLM options in AERMOD are provided in the Addendum to the AERMOD User's Guide (EPA, 2002).

The sensitivity analysis includes a comparison of NO_2 concentrations estimated by the PVMRM option to NO_2 concentrations based on the OLM option, Tier 1 screening assumption (full conversion of NO_x to NO_2), and Tier 2 screening (75 percent Ambient Ratio Method, ARM) across a range of meteorology and a range of source characteristics typical of NO_x sources. A description of the sensitivity tests is provided in Section 2. Results of the sensitivity analysis are presented in Section 3, and Section 4 provides a summary and conclusions.

2.0 DESCRIPTION OF SENSITIVITY TESTS

This section includes a description of the sensitivity tests performed on the PVMRM and OLM options in the AERMOD dispersion model. The source parameters, modeling options, meteorological data and receptor data used in the sensitivity analysis are described in detail. The sensitivity analysis includes several tests involving individual sources, and a multiple-source scenario.

2.1 SOURCE DESCRIPTIONS

A total of six different individual sources were modeled, including a non-buoyant 10m point source, a standard 35m buoyant point source (used in EPA consequence analyses), a typical diesel generator source, a typical gas turbine source, a 10m volume source, and a 10m circular area source. The source parameters used for these single source scenarios are summarized in Table 2.1. A range of buoyancy and momentum fluxes are represented by the point sources, with the diesel generator representing a relatively low buoyancy/low momentum release, the 35m stack representing medium buoyancy and momentum, and the gas turbine representing relatively high buoyancy and momentum. The emission rates for the diesel generator and gas turbine sources are considered typical for those source types. The 35m stack was modeled with two different emission rates to test the sensitivity of the PVMRM and OLM algorithms to the NO_x emission rate.

In addition to the single source scenarios, a hypothetical multiple-source scenario based in part on an actual permit application was included in the sensitivity analysis to test the plume merging algorithm contained within PVMRM. The multiple-source scenario included a total of 65 point sources and 13 area sources, with 1,598 receptors.

Table 2.1. Source Characteristics for AERMOD PVMRM Sensitivity Analysis

<table>
<tr><th colspan="8">Point Sources:</th></tr>
<tr><th>Source Description</th><th>Emission Rate (g/s)</th><th>Stack Height (m)</th><th>Exit Velocity (m/s)</th><th>Exit Temp. (K)</th><th>Stack Diameter (m)</th><th>Buoyancy Flux[a] (m^4/s^3)</th><th>Momentum Flux[a] (m^4/s^2)</th></tr>
<tr><td>10m Non-buoyant Point</td><td>10</td><td>10</td><td>0.0</td><td>Ambient</td><td>0.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>35m Buoyant Stack</td><td>1</td><td>35</td><td>11.7</td><td>432</td><td>2.4</td><td>60.71</td><td>124.64</td></tr>
<tr><td>35m Buoyant Stack</td><td>50</td><td>35</td><td>11.7</td><td>432</td><td>2.4</td><td>60.71</td><td>124.64</td></tr>
<tr><td>Diesel Engine</td><td>5</td><td>26</td><td>50.0</td><td>727</td><td>0.3</td><td>6.88</td><td>21.14</td></tr>
<tr><td>Gas Turbine</td><td>30</td><td>31</td><td>63.0</td><td>750</td><td>2.4</td><td>565.25</td><td>2081.61</td></tr>
<tr><th colspan="8">Volume Sources:</th></tr>
<tr><th>Source Description</th><th>Emission Rate (g/s)</th><th>Release Height (m)</th><th>Initial Sigma-y (m)</th><th>Initial Sigma-z (m)</th><th></th><th></th><th></th></tr>
<tr><td>10m Volume</td><td>10</td><td>10</td><td>0.1 to 9.3</td><td>0.1 to 9.3</td><td></td><td></td><td></td></tr>
<tr><th colspan="8">Area Source:</th></tr>
<tr><th>Source Description</th><th>Emission Rate (g/s)</th><th>Release Height (m)</th><th>Radius of Area (m)</th><th>Initial Sigma-z (m)</th><th></th><th></th><th></th></tr>
<tr><td>10m Circular Area</td><td>10</td><td>10</td><td>10</td><td>4.65</td><td></td><td></td><td></td></tr>
</table>

[a] Buoyancy and momentum fluxes are based on an ambient temperature of 273.16 K.

The 10m non-buoyant point source and 10m volume source were included in the analysis to test the sensitivity on the algorithms to varying the initial size of the volume source and to verify that the results for the volume source converged to the results for the point source as the initial dispersion parameters were decreased. A 10m circular area source was also included with an initial sigma-z of 4.65 for comparison with the 10m volume source of similar dimensions. The 20m width of the area source is comparable to a volume source with an initial sigma-y of 4.65m.

2.2 MODELING OPTIONS

The single sources were tested with various modeling options, including building downwash vs. no downwash, rural vs. urban dispersion, and flat vs. complex terrain. Not all sources were modeled for each modeling option. Table 2.2 summarizes the modeling options examined for each of the individual source types. A population of 250,000, which is the approximate population for Anchorage, Alaska, was used for the urban option. The complex terrain options were based on terrain in the Anchorage, Alaska area. The flat vs. complex terrain sources were located about 10km southeast of Anchorage, with relatively flat terrain (including terrain below stack base) to the north and west of the source, and terrain rising fairly steeply within about 1.5 to 2km east of the source. The terrain for the Anchorage area is shown in Figure 2.1.

Table 2.2. Modeling Options Analyzed by Source Type

Source Description	Modeling Options	Meteorological Data
10m Non-buoyant Point	Rural, Flat Terrain, No Downwash	Anchorage 1999
10m Volume Source, Varying Initial Sigmas	Rural, Flat Terrain	Anchorage 1999
10m Circular Area Source	Rural, Flat Terrain	Anchorage 1999
35m Buoyant Stack, Varying Emission Rate	Rural, Flat Terrain, No Downwash	PadA 1991-95
Diesel Generator	No Downwash vs. Downwash (Rural/Flat Terrain) Rural vs. Urban Dispersion (Flat Terrain/No Downwash) Flat Terrain vs. Complex Terrain (Rural/No Downwash)	PadA 1991-95 PadA 1991-95 Anchorage 1999
Gas Turbine	No Downwash vs. Downwash (Rural/Flat Terrain) Rural vs. Urban Dispersion (Flat Terrain/No Downwash) Flat Terrain vs. Complex Terrain (Rural/No Downwash)	PadA 1991-95 PadA 1991-95 Anchorage 1999

2.3 METEOROLOGICAL AND OZONE DATA

Three different sets of meteorological data were used, depending on the scenario. The basic single source scenarios were run using five years of site-specific meteorological data from the PadA installation on the North Slope of Alaska near Prudhoe Bay for the period 1991 through 1995. The five years of site-specific meteorological data included 10m wind speed, wind direction and temperature data, and were processed through AERMET together with National Weather Service (NWS) surface and upper air data for Barrow, Alaska. The multi-source scenario was run using one year of site-specific data from the same site in Prudhoe Bay for 1991, but differed from 1991 of the five-year dataset in that 10m sigma-theta and solar radiation data were also included. The third meteorological data set used for comparisons between flat and complex terrain consisted of one year (1999) of NWS surface and upper air meteorological data for Anchorage, Alaska. The 1999 Anchorage meteorological data were also used for the comparisons between the 10m non-buoyant point source and the volume and area sources. The meteorological data used for the single source scenarios are summarized in Table 2.2.

The site-specific meteorological data from PadA were processed using the most recent version of AERMET available from the SCRAM website, dated 03273. The following annual surface characteristics were used in processing the PadA meteorological data, and were assumed to be constant across all sectors: albedo = 0.30; Bowen ratio = 1.5; surface roughness = 0.01m. The following annual surface characteristics were used in processing the Anchorage meteorological data, and were also assumed to be constant across all sectors: albedo = 0.25; Bowen ratio = 1.5; surface roughness = 0.10m.

The hourly ozone data used with the PadA meteorological data were collected at the same location as the meteorological data. The hourly ozone data used with the 1999 Anchorage meteorological data were obtained from the U.S. EPA CASTNET website for the Denali National Park site located about 250 km north of Anchorage. A value of 40 ppb was used to substitute for missing ozone data for both databases.

2.4 RECEPTOR DATA

The individual source scenarios were modeled with a polar grid of receptors centered on the source, with distances (in meters) of 50, 100, 150, 200, 300, 500, 750, 1000, 1500, 2000, 3000, 5000, 10000, 20000, and 30000, and 36 radials, for a total of 540 receptors. The use of a polar grid allowed for the results to be summarized as a function of distance downwind from the source. The receptor elevations and hill height scales for the complex terrain scenarios were calculated using the most recent version of AERMAP (dated 03107) and 1-degree Digital Elevation Model (DEM) data for the Anchorage, Alaska area. Figure 2.1 shows the source and receptor locations and topography of the Anchorage area used for the complex terrain scenarios, out to a distance of about 10,000 meters from the source. The receptor network used for the multiple-source scenario included discrete receptors located at 25m intervals along the property boundary and gridded receptors at 100m intervals across a 4km-by-4km domain. A total of 1,598 receptors were included in the multiple-source scenario. Figure 2.2 shows the receptor and near-field source locations used in the multiple-source scenario. Additional background sources located beyond the 4km-by-4km receptor domain are not shown in Figure 2.2.

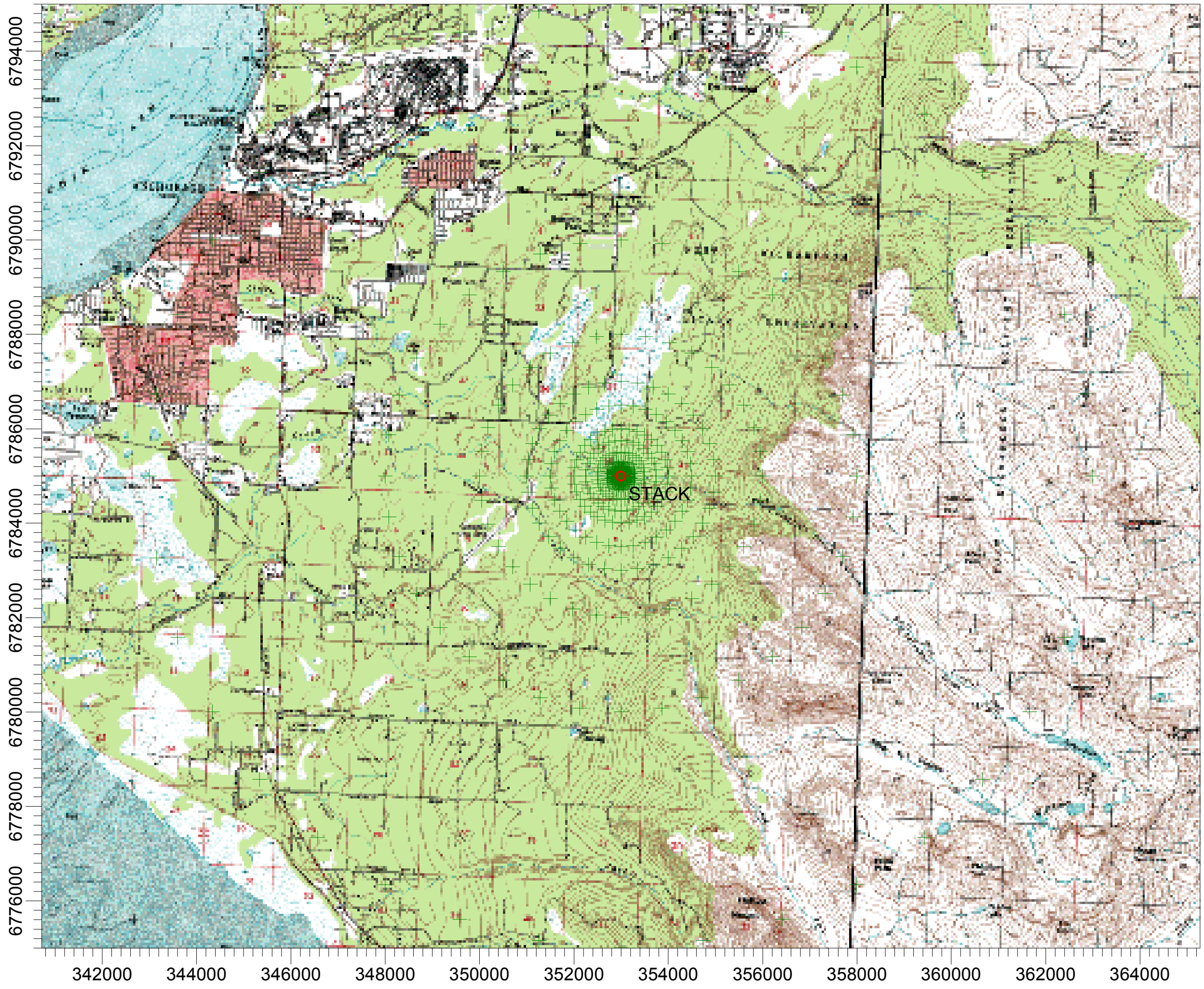


Figure 2.1. Anchorage Area Terrain, Source and Receptors for Complex Terrain Scenarios

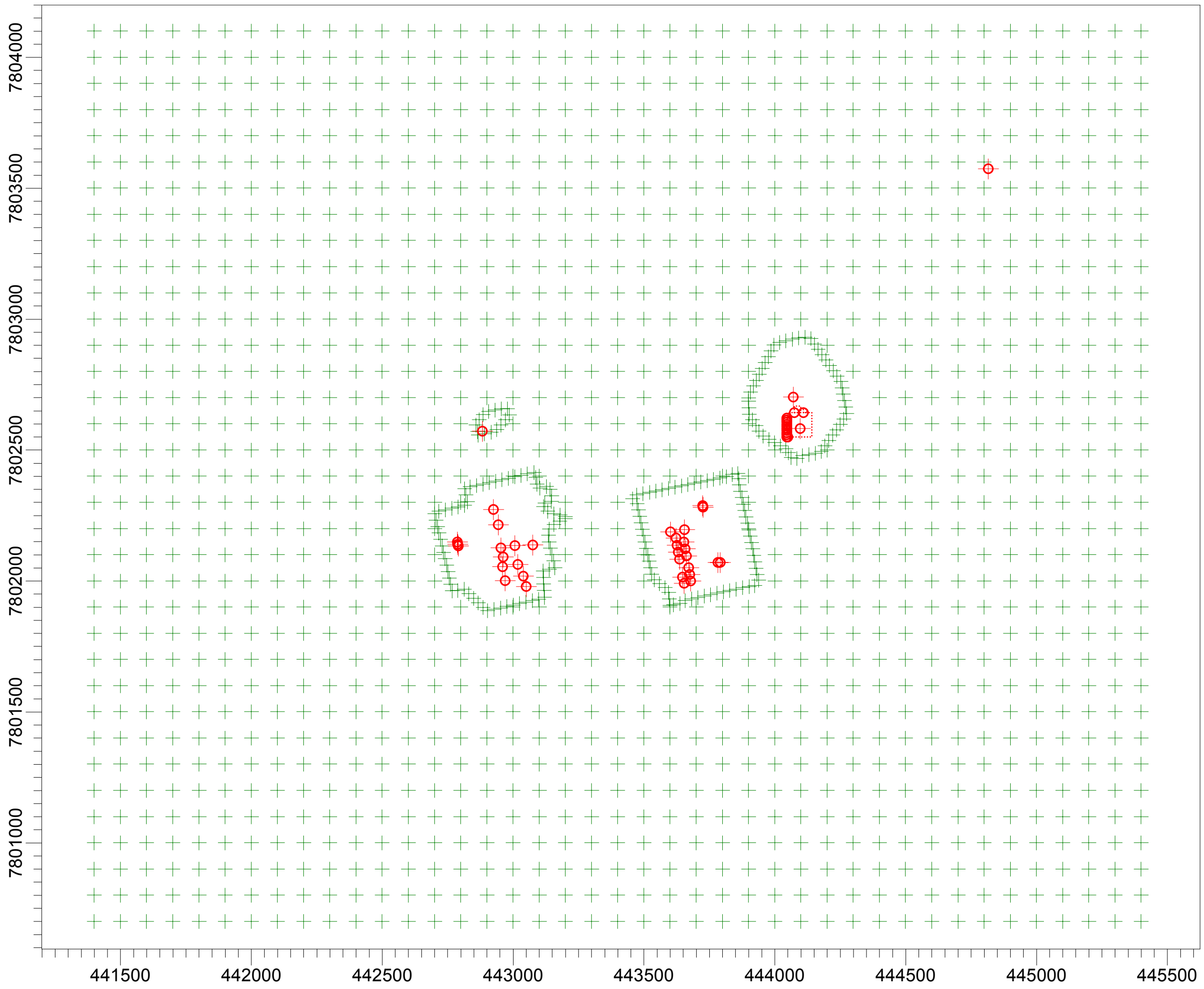


Figure 2.2. Receptor and Near-field Source Locations for Multiple Source Scenario

3.0 SENSITIVITY ANALYSIS RESULTS

The results of the PVMRM sensitivity analysis are presented in this section. The results for the single source scenarios are presented first, and include comparisons of design values based on the highest annual and 1-hour average NO_2 concentrations, and comparisons of maximum concentrations as a function of distance downwind from the source.

3.1 SINGLE SOURCE SCENARIOS

Table 3.1 includes a comparison of maximum annual average NO_2 concentrations for each of the single source scenarios involving the 35m stack, diesel generator and gas turbine sources. Results are presented for full conversion, ARM (0.75), OLM and PVMRM. The average OLM/FULL ratio for the single source annual averages is 0.88, and the average PVMRM/FULL ratio for annual averages is 0.55. In many cases, the distance to maximum annual average is further downwind from the source for PVMRM than for full conversion. This is due to the lower NO_2/NO_x ratios close to the source for PVMRM.

Table 3.2 shows comparisons of maximum 1-hour average NO_2 concentrations for each of the single source scenarios presented in Table 3.1. The average OLM/FULL ratio for the single source 1-hour averages is 0.68, and the average PVMRM/FULL ratio for 1-hour averages is 0.56. The conversion ratios for OLM and PVMRM are also summarized in the form of bar charts in Figures 3.1 and 3.2 for annual averages and 1-hour averages, respectively.

A comparison of the 35m stack with 1g/s emission rate vs. 50g/s emission rate clearly shows the sensitivity of both OLM and PVMRM to the level of NO_x emissions. For the 1g/s source, the OLM option exhibited no ozone limiting effect, giving a ratio to full conversion of 1.0. The PVMRM option showed some effects of ozone limiting, but the ratio of 0.892 is very close to the equilibrium ratio of 0.90 for PVMRM. Both options showed significantly more ozone limiting with the 50g/s source, as expected, with the OLM option providing about the same result as ARM, and the PVMRM option showing a more significant reduction.

Comparing the results for no downwash vs. downwash for the diesel generator and gas turbine sources, the maximum concentrations are much higher with downwash, as expected, and the conversion ratios are lower. The lower conversion ratios for OLM are most likely due to the higher ground-level NO_x concentrations with downwash. The lower conversion ratios for PVMRM are probably due to the fact that the maximum NO_x concentrations occur much closer to the source for the downwash cases, and the plume volume corresponding to the maximum concentrations will therefore be smaller. The urban results (no downwash) tend to be slightly lower for the diesel generator annual averages than the rural results, except for the PVMRM option, whereas the urban results tend to be higher than rural results for the gas turbine. This is probably due to the difference in plume buoyancy between the two sources. The plume rise for the diesel generator is expected to be much lower than for the gas turbine, and therefore the diesel generator is less likely than the gas turbine to experience limited mixing under stable conditions due to the urban mixing height.

The maximum annual average concentrations tend to be somewhat lower for the complex terrain scenario compared to flat terrain, with conversion rates being similar between flat and complex terrain. The lower annual averages for complex terrain are due to the fact that the maximum ground-level NO_2 concentrations occur relatively close to the source (300 meters for the FULL and OLM options), where the terrain is at or below stack base. The terrain elevations associated with the maximum ground-level concentrations as a function of downwind receptor distance are shown in Figure 3.3. For all three options (FULL, OLM and PVMRM), the terrain is below stack base at the 300 and 500 meters receptor distances for the diesel generator. The effect of terrain below stack base is to increase the effective height of the plume above local ground, and thereby reduce the ground-level concentrations. The PVMRM option for the gas turbine source is the only exception to this pattern. In this case, the maximum annual average is slightly higher for complex terrain than for flat terrain, and occurs as a downwind distance of 5,000 meters compared to 1,000 meters for the flat terrain maximum. Figure 3.3 shows that receptors are below stack base at the 1,000 meter distance for the FULL and OLM options, and well above stack base at the 5,000 meter distance for the PVMRM option.

The effect of complex terrain is more clearly evident in the maximum 1-hour averages (Table 3.2), with the complex terrain results being much higher than the flat terrain results. The PVMRM conversion ratios for 1-hour averages tend to be lower than for annual averages, which may be explained by the fact that the maximum 1-hour averages are controlled by stable conditions, during which the plume volume tends to be smaller. The OLM conversion ratios for 1-hour averages are also lower due to the much higher ground-level concentrations.

The distance to maximum concentration for the PVMRM option tends to be at or beyond the distance to maximum for full conversion. This is consistent with the fact that conversion ratios are lowest close to the source and increase with downwind distance for PVMRM. The distance to maximum concentration for the OLM option is more likely to match the distance to maximum for full conversion, and is closer to the source in a few cases.

Figures 3.4 and 3.5 show the annual average NO_2 concentrations (top pane) and conversion ratios (bottom pane) as a function of distance downwind from the source for the 35m 1g/s and 50g/s sources, respectively. These figures clearly show the dependence of the OLM conversion ratio on the emission rate and ground-level NO_x concentration, with no ozone limiting occurring for the 1g/s source, and with the dip in conversion ratio between 750-1000m roughly mirroring the increase in concentrations with distance for the 50g/s source. The dependence of the PVMRM conversion ratio on emission rate is also shown, with much lower ratios (more ozone limiting) for the 50g/s source. However, the dependence of the PVMRM conversion ratio on distance from the source is clearly shown in Figure 3.5 for the 50g/s source, with much smaller ratios close to the source where the plume volume is relatively small, and increasing with distance to the equilibrium ratio of 0.90 beyond about 10 km.

Table 3.1. Comparison of Maximum Annual NO_2 Averages and Distance to Maximum for Full Conversion, ARM, OLM, and PVMRM for Single Source Scenarios

Source Scenario	Conversion Option	Maximum NO_2 Concentration ($\mu g/m^3$)	Distance to Maximum (m)	Ratio to Full Conversion
35m Stack, 1g/s Rural, No Downwash	FULL	0.112	750.	1.000
	ARM	0.084	750.	0.750
	OLM	0.112	750.	1.000
	PVMRM	0.100	750.	0.892
35m Stack, 50g/s Rural, No Downwash	FULL	5.601	750.	1.000
	ARM	4.201	750.	0.750
	OLM	4.178	1000.	0.746
	PVMRM	1.537	3000.	0.274
Diesel Generator Rural, No Downwash	FULL	2.927	500.	1.000
	ARM	2.195	500.	0.750
	OLM	2.807	500.	0.959
	PVMRM	1.236	1500.	0.422
Diesel Generator Rural, Downwash	FULL	54.375	50.	1.000
	ARM	40.781	50.	0.750
	OLM	21.498	50.	0.395
	PVMRM	11.164	50.	0.205
Diesel Generator Urban, No Downwash	FULL	2.338	500.	1.000
	ARM	1.754	500.	0.750
	OLM	2.226	500.	0.952
	PVMRM	1.317	2000.	0.563
Diesel Generator Flat Terrain	FULL	3.682	300.	1.000
	ARM	2.761	300.	0.750
	OLM	3.604	300.	0.979
	PVMRM	1.606	1500.	0.436
Diesel Generator Complex Terrain	FULL	3.228	300.	1.000
	ARM	2.421	300.	0.750
	OLM	3.179	300.	0.985
	PVMRM	1.511	1500.	0.468
Gas Turbine Rural, No Downwash	FULL	0.441	1000.	1.000
	ARM	0.331	1000.	0.750
	OLM	0.440	1000.	0.997
	PVMRM	0.303	1500.	0.688
Gas Turbine Rural, Downwash	FULL	13.984	50.	1.000
	ARM	10.488	50.	0.750
	OLM	8.482	50.	0.607
	PVMRM	2.849	750.	0.204
Gas Turbine Urban, No Downwash	FULL	0.704	1500.	1.000
	ARM	0.528	1500.	0.750
	OLM	0.700	2000.	0.994
	PVMRM	0.591	3000.	0.839
Gas Turbine Flat Terrain	FULL	0.636	750.	1.000
	ARM	0.477	750.	0.750
	OLM	0.636	750.	1.000
	PVMRM	0.465	1000.	0.732
Gas Turbine Complex Terrain	FULL	0.571	750.	1.000
	ARM	0.428	750.	0.750
	OLM	0.571	750.	1.000
	PVMRM	0.479	5000.	0.838

Table 3.2. Comparison of Maximum 1-Hour NO_2 Averages and Distance to Maximum for Full Conversion, ARM, OLM, and PVMRM for Single Source Scenarios

Source Scenario	Conversion Option	Maximum NO_2 Concentration ($\mu g/m^3$)	Distance to Maximum (m)	Ratio to Full Conversion
35m Stack, 1g/s Rural, No Downwash	FULL	5.398	1000.	1.000
	ARM	4.048	1000.	0.750
	OLM	5.398	1000.	1.000
	PVMRM	4.858	1000.	0.900
35m Stack, 50g/s Rural, No Downwash	FULL	269.899	1000.	1.000
	ARM	202.424	1000.	0.750
	OLM	151.088	3000.	0.560
	PVMRM	131.033	3000.	0.485
Diesel Generator Rural, No Downwash	FULL	98.418	750.	1.000
	ARM	73.813	750.	0.750
	OLM	68.636	200.	0.697
	PVMRM	73.259	1000.	0.744
Diesel Generator Rural, Downwash	FULL	427.190	50.	1.000
	ARM	320.393	50.	0.750
	OLM	185.885	50.	0.435
	PVMRM	147.120	50.	0.344
Diesel Generator Urban, No Downwash	FULL	98.418	750.	1.000
	ARM	73.813	750.	0.750
	OLM	68.636	200.	0.697
	PVMRM	73.259	1000.	0.744
Diesel Generator Flat Terrain	FULL	73.535	200.	1.000
	ARM	55.151	200.	0.750
	OLM	73.093	200.	0.994
	PVMRM	34.056	1000.	0.463
Diesel Generator Complex Terrain	FULL	357.518	1500.	1.000
	ARM	268.138	1500.	0.750
	OLM	110.885	1500.	0.310
	PVMRM	94.448	5000.	0.264
Gas Turbine Rural, No Downwash	FULL	51.910	3000.	1.000
	ARM	38.933	3000.	0.750
	OLM	35.904	2000.	0.692
	PVMRM	38.187	5000.	0.736
Gas Turbine Rural, Downwash	FULL	443.448	100.	1.000
	ARM	332.586	100.	0.750
	OLM	177.423	50.	0.400
	PVMRM	138.667	750.	0.313
Gas Turbine Urban, No Downwash	FULL	61.648	1500.	1.000
	ARM	46.236	1500.	0.750
	OLM	61.395	1500.	0.996
	PVMRM	55.025	1500.	0.893
Gas Turbine Flat Terrain	FULL	38.605	750.	1.000
	ARM	28.954	750.	0.750
	OLM	38.605	750.	1.000
	PVMRM	18.481	750.	0.479
Gas Turbine Complex Terrain	FULL	378.023	2000.	1.000
	ARM	283.518	2000.	0.750
	OLM	120.449	2000.	0.319
	PVMRM	150.036	2000.	0.397

Figures 3.6 through 3.11 show the annual concentrations and conversion ratios vs. distance for the diesel generator scenarios, and Figures 3.12 through 3.17 show the results for the gas turbine scenarios. These figures show similar overall patterns for the dependence of conversion ratio on distance, with the OLM ratio being most dependent on the ground-level NO_x concentration, and the PVMRM ratio showing dependence on plume volume.

The effect of complex terrain is more noticeable for the gas turbine source (Figure 3.15) than for the diesel generator source (Figure 3.9). The gas turbine source shows a secondary maximum in the concentration plot for full conversion at a distance of 2,000 meters associated with plume impaction on the terrain to the east of the source (see Figure 3.3). All options show another maximum at a distance of 5,000 meters, also associated with complex terrain impacts.

The deviation of the OLM value from the full conversion value at the 2,000 meter receptor distance for the gas turbine (Figure 3.15) bears explanation. As shown in the conversion ratio plot in Figure 3.15, the conversion ratio for OLM drops to about 0.73 at that distance. The maximum NO_2 concentration for the OLM option occurs for terrain below stack base north-northwest (NNW) of the source, while the maximum NO_2 concentrations for full conversion and PVMRM occur for complex terrain about 126 meters above stack base east-southeast (ESE) of the source (see Figure 3.3). The average concentration for the receptor to the NNW is based on a larger number of values associated with one of the peaks in the annual wind rose. The average concentration for the receptor to the ESE is based on a smaller number of values with higher concentrations due to the complex terrain impact. Since the OLM conversion ratio is strongly dependent on the ground-level NO_x concentration, the hourly conversion ratios are lower for the complex terrain impacts to the ESE than for the impacts to the NNW. The NO_2 concentrations for the OLM option are nearly equal for the NNW and ESE receptors, but the conversion ratio is 0.71 for the complex terrain receptor to the ESE and 1.0 for the receptor below stack base to the NNW.

There is also a noticeable dip in the conversion ratio for PVMRM at the 2,000 meter distance shown in Figure 3.15. This can be explained by the fact that the maximum impacts occurring on complex terrain for receptors at and beyond 2,000 meters are associated with stable atmospheric conditions, whereas the maximum impacts for receptors located at or below stack base out to about 1,500 meters are associated with convective atmospheric conditions. The plume volume will tend to be much smaller for stable plumes than for convective plumes, resulting in lower conversion ratios for the complex terrain impacts.

Figures 3.18 through 3.31 show the 1-hour average concentrations and conversion ratios for the 35m stack, diesel generator and gas turbine single source scenarios. These figures show some similar trends as the annual averages, but the curves tend to be less smooth as the results are more sensitive to variations in the controlling meteorological conditions and hourly ozone data at each distance. The effects of complex terrain are more noticeable than for annual averages for both the diesel engine and gas turbine sources, with sharp peaks occurring at the distance where the plume impacts the terrain to the east. The peak appears to be slightly further downwind for the gas turbine than for the diesel generator. This is consistent with the higher plume rise for the gas turbine, resulting in the plume impacting the terrain further away.

3.2 MULTIPLE-SOURCE SCENARIO

Table 3.3 provides the results of the multiple-source scenario, showing the maximum annual average NO_2 concentrations and conversion ratios, and maximum 1-hour NO_2 averages and ratios for each of the conversion options. Table 3.3 includes results for OLM based on individual plumes, and results for OLM based on combining plumes for six groups of sources based on proximity of the sources and the likelihood that plumes from those sources would quickly merge. The PVMRM option shows the lowest conversion ratio for the annual averages, 0.62, which is slightly lower than the conversion ratio for the OLM-Group option of 0.65. The OLM-Group ratio is somewhat lower than the OLM-Individual ratio, as expected. The result for the OLM option for individual plumes is similar to the result based on ARM.

It should be noted that while the annual average NO_2 concentrations presented in Table 3.3 exceed the 100 $\mu g/m^3$ National Ambient Air Quality Standard (NAAQS) for NO_2, these values do not reflect predicted impacts from an actual facility. While the multiple-source scenario was based in part on actual sources, several changes and assumptions were made to simplify the sensitivity analysis. Therefore, the results do not reflect the impacts that would likely occur based on a more rigorous assessment.

Table 3.3. Comparison of Maximum Annual and 1-Hour NO_2 Averages for Full Conversion, ARM, OLM, and PVMRM for Multiple-Source Scenario

Averaging Period	Conversion Option	Maximum NO_2 Concentration ($\mu g/m^3$)	Ratio to Full Conversion
Annual	Full Conversion	166.6	1.00
	ARM	125.0	0.75
	OLM-Individual	126.3	0.76
	OLM-Group	108.0	0.65
	PVMRM	103.8	0.62
1-Hour	Full Conversion	5,290.3	1.00
	ARM	3,967.7	0.75
	OLM-Individual	2,079.9	0.39
	OLM-Group	1,822.2	0.34
	PVMRM	3,196.9	0.60

The results in Table 3.3 for 1-hour averages from the multiple-source scenario show much lower conversion ratios for the OLM options (0.39 for individual plumes and 0.34 with combined plumes) than for the PVMRM option (0.60). This is not unexpected given the fact that the ozone limiting potential under the OLM options is strongly related to the maximum ground-level concentration of NO_x, whereas the PVMRM ratio is related to the volume of the plume. As an example, for an elevated source the maximum 1-hour average concentration is typically associated with light wind, convective conditions. The OLM ratio will tend to be low for this case because of the high ground-level concentration, whereas the PVMRM ratio will tend to be high due to the relatively large volume of the plume under convective conditions. It is worth noting that the 1-hour conversion ratio for PVMRM is similar to the ratio for annual averages, whereas the OLM ratios are quite dissimilar between annual and 1-hour averages.

3.3 POINT VS. VOLUME AND AREA SOURCE COMPARISONS

Additional comparisons were made between a 10m non-buoyant point source, a 10m volume source with varying initial dispersion coefficients (sigmas), and a 10m circular area source with an initial vertical dispersion coefficient (sigma-z). These comparisons provide additional sensitivity results for relatively low-level sources. They also provide a test of whether the volume source results converge to the point source result as the initial dispersion coefficients are decreased, and provide a comparison of a circular area source to a volume source of similar dimensions.

The results for the point vs. volume and area source comparisons are provided in Table 3.4 for annual NO_2 averages and in Table 3.5 for 1-hour NO_2 averages. The initial sigma values for the volume sources apply to both lateral (sigma-y) and vertical (sigma-z) dispersion coefficients. For both averaging periods the results for the volume source with initial sigmas of 0.1m are nearly identical to the point source results. As the initial sigmas are increased, up to 9.3m, the maximum concentrations for the volume sources also increase. This result is reasonable as the larger initial sigmas will bring the plume to the ground quicker. For the two largest values of initial sigma, the distance to maximum concentration also drops from 100m to 50m.

The OLM annual average conversion ratios for the volume sources get smaller as the ground-level concentration increases, as expected. The PVMRM ratios are nearly the same for the point source and the first three volume sources (0.1, 1.0, and 2.3m initial sigmas). The PVMRM ratio drops slightly between the 2.3m and 4.65m initial sigmas, due to the closer distance to maximum concentration for the 4.65m case, resulting in a smaller plume volume. The largest change in PVMRM conversion ratio occurs between the initial sigmas of 4.65m and 9.3m. The ratio increases for the larger initial sigma due to the corresponding increase in the plume volume resulting in more ozone available for conversion. The plume volume for volume sources incorporates the initial volume of the source defined by the initial sigmas in addition to the plume volume resulting from relative dispersion.

Table 3.4. Comparison of Maximum Annual NO_2 Averages and Distance to Maximum for Full Conversion, ARM, OLM, and PVMRM for 10m Point, Volume and Area Sources

Source Scenario	Conversion Option	Maximum NO_2 Concentration ($\mu g/m^3$)	Distance to Maximum (m)	Ratio to Full Conversion
10m Point	FULL	376.871	100.	1.000
	ARM	282.654	100.	0.750
	OLM	66.148	100.	0.176
	PVMRM	47.685	100.	0.127
10m Volume Initial sigma = 0.1m	FULL	376.974	100.	1.000
	ARM	282.731	100.	0.750
	OLM	66.162	100.	0.176
	PVMRM	47.698	100.	0.127
10m Volume Initial sigma = 1.0m	FULL	383.590	100.	1.000
	ARM	287.693	100.	0.750
	OLM	67.036	100.	0.175
	PVMRM	48.504	100.	0.126
10m Volume Initial sigma = 2.3m	FULL	409.933	100.	1.000
	ARM	307.450	100.	0.750
	OLM	71.006	100.	0.173
	PVMRM	51.694	100.	0.126
10m Volume Initial sigma = 4.65m	FULL	742.539	50.	1.000
	ARM	556.904	50.	0.750
	OLM	114.185	50.	0.154
	PVMRM	91.998	50.	0.124
10m Volume Initial sigma = 9.3m	FULL	1,085.476	50.	1.000
	ARM	814.107	50.	0.750
	OLM	156.531	50.	0.144
	PVMRM	182.709	50.	0.168
10m Area Initial sigmaz = 4.65m 20m wide circular area	FULL	751.711	50.	1.000
	ARM	563.782	50.	0.750
	OLM	97.653	50.	0.130
	PVMRM	104.517	50.	0.139

Table 3.5. Comparison of Maximum 1-Hour NO_2 Averages and Distance to Maximum for Full Conversion, ARM, OLM, and PVMRM for 10m Point, Volume and Area Sources

Source Scenario	Conversion Option	Maximum NO_2 Concentration ($\mu g/m^3$)	Distance to Maximum (m)	Ratio to Full Conversion
10m Point	FULL	11,106.540	50.	1.000
	ARM	8,329.905	50.	0.750
	OLM	1,178.703	50.	0.106
	PVMRM	1,258.679	50.	0.113
10m Volume Initial sigma = 0.1m	FULL	11,119.789	50.	1.000
	ARM	8,339.842	50.	0.750
	OLM	1,180.025	50.	0.106
	PVMRM	1,260.190	50.	0.113
10m Volume Initial sigma = 1.0m	FULL	11,138.263	50.	1.000
	ARM	8,353.697	50.	0.750
	OLM	1,182.047	50.	0.106
	PVMRM	1,262.501	50.	0.113
10m Volume Initial sigma = 2.3m	FULL	11,408.523	50.	1.000
	ARM	8,556.393	50.	0.750
	OLM	1,219.742	50.	0.107
	PVMRM	1,295.209	50.	0.114
10m Volume Initial sigma = 4.65m	FULL	11,804.340	50.	1.000
	ARM	8,853.255	50.	0.750
	OLM	1,247.224	50.	0.106
	PVMRM	1,326.409	50.	0.112
10m Volume Initial sigma = 9.3m	FULL	11,804.340	50.	1.000
	ARM	8,853.255	50.	0.750
	OLM	1,247.224	50.	0.106
	PVMRM	1,326.409	50.	0.112
10m Area Initial sigmaz = 4.65m 20m wide circular area	FULL	12,106.910	50.	1.000
	ARM	9,080.184	50.	0.750
	OLM	1,286.426	50.	0.106
	PVMRM	1,474.794	50.	0.122

The results for the area source with an initial sigma-z of 4.65m are similar to the results for the volume source with initial sigmas of 4.65m. The full conversion results for the area source are about 1 percent higher than for the comparable volume source for the annual averages. This difference is reasonable since the area source simulates a uniform emission rate over the 20m wide circular area, whereas the volume source is treated as a virtual point source with a peak emission density at the center of the source. This creates a higher emission density for the area source for the downwind portion of the source closest to the receptors. The slightly higher ground-level NO_x concentrations may contribute to the slightly lower NO_2 concentrations for the OLM option for the area source, with a lower conversion ratio reflecting more ozone limiting conditions.

The PVMRM option gives higher average NO_2 concentrations for the area source than for the corresponding volume source for both annual and 1-hour averages, by about 10 percent. This is related to the differences in the definition of the plume volume for area sources vs. volume sources. Since the area source simulates a uniform emission density across the source, the lateral dimension of the plume is defined as the projected width of the area source (which equals 20m for the circular area) plus 2 times the relative dispersion coefficient to account for lateral plume spread beyond the edges of the source. The lateral dimension of the volume source plume is based on combining the initial sigma-y with the relative dispersion coefficient. This difference will result in slightly larger plume volumes for area sources than for volume sources with similar dimensions, which will result in higher NO_2/NO_x conversion ratios for PVMRM.

Figures 3.32, 3.33, and 3.34 compare the annual NO_2 concentration and conversion ratio plots vs. distance for the 10m point source, the 10m volume source with initial sigmas of 4.65m, and the 10m circular area source, respectively. Since these are low-level sources with peak impacts close to the source, the conversion ratios for OLM and PVMRM show a more similar pattern than for the other sources with elevated plumes, with low conversion ratios close to the source and ratios increasing relatively smoothly with increasing distance. However, the PVMRM conversion ratio increases more gradually with distance than OLM out to a distance of about 500m, with a steeper increase in the ratio beyond that distance. As noted in previous discussions, the change in conversion ratio with distance for PVMRM is primarily controlled by the volume of the plume, whereas the conversion ratio for OLM is primarily controlled by the ground-level NO_x concentration.

Figure 3.1. Ratios of Maximum Annual NO_2 Concentrations to Full Conversion

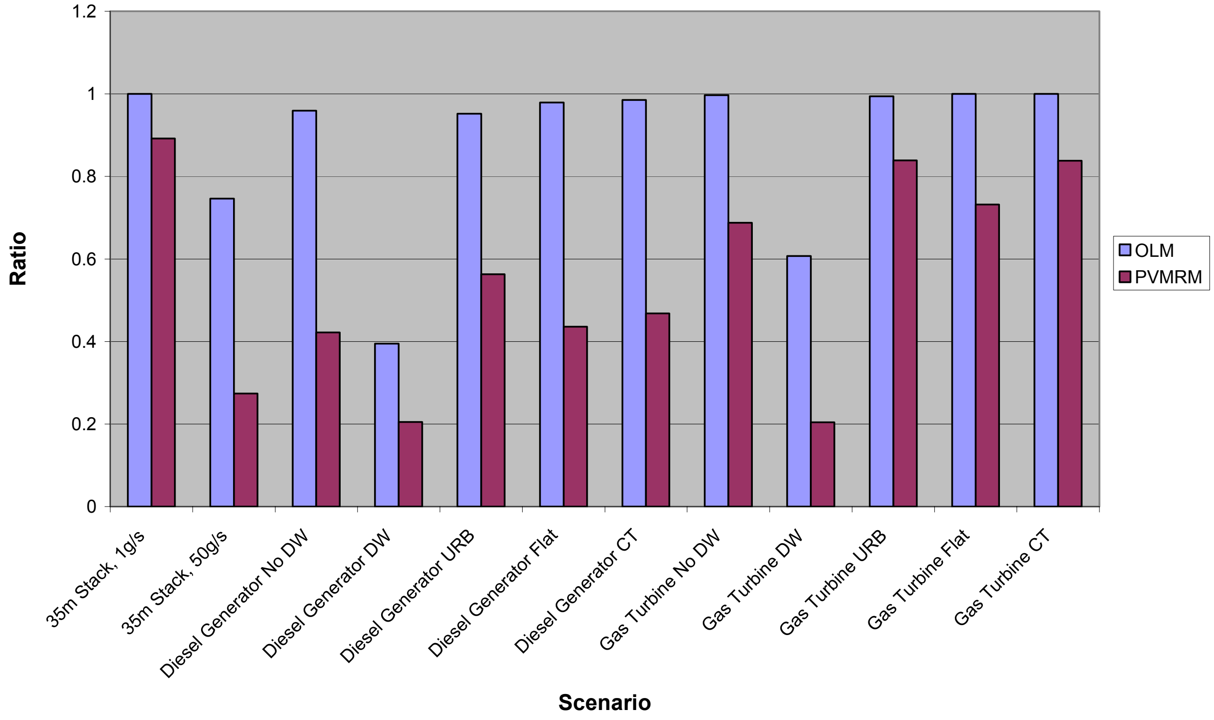
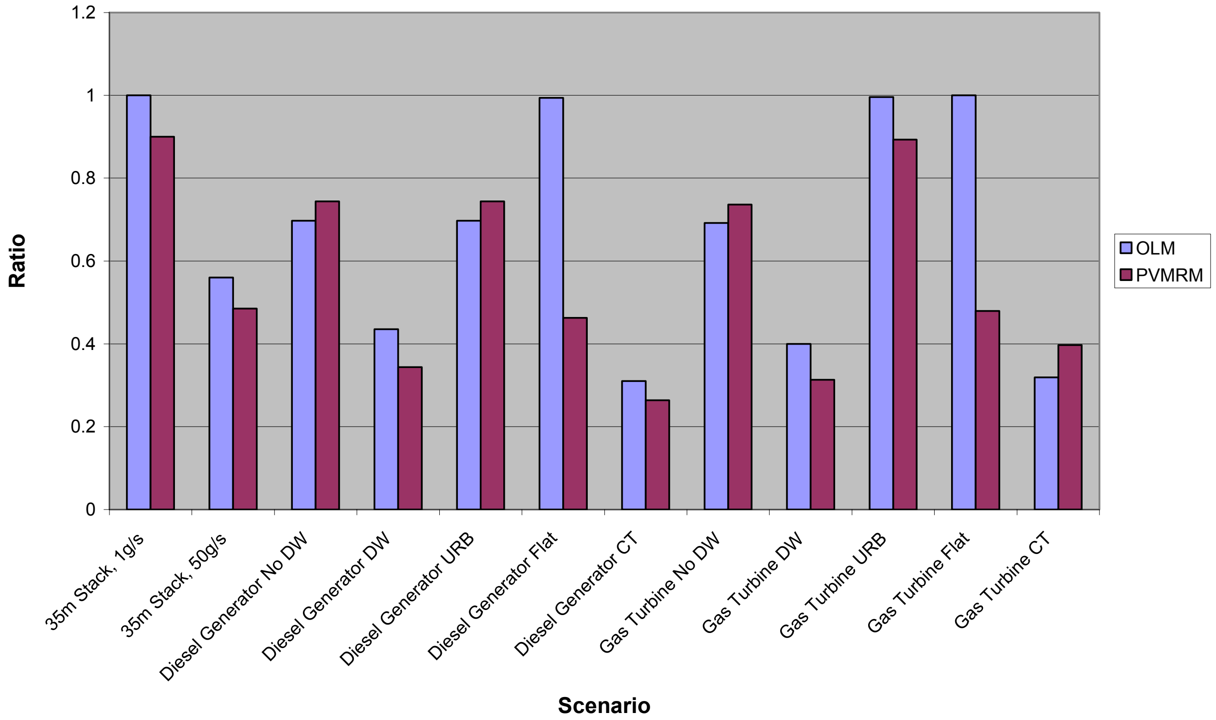
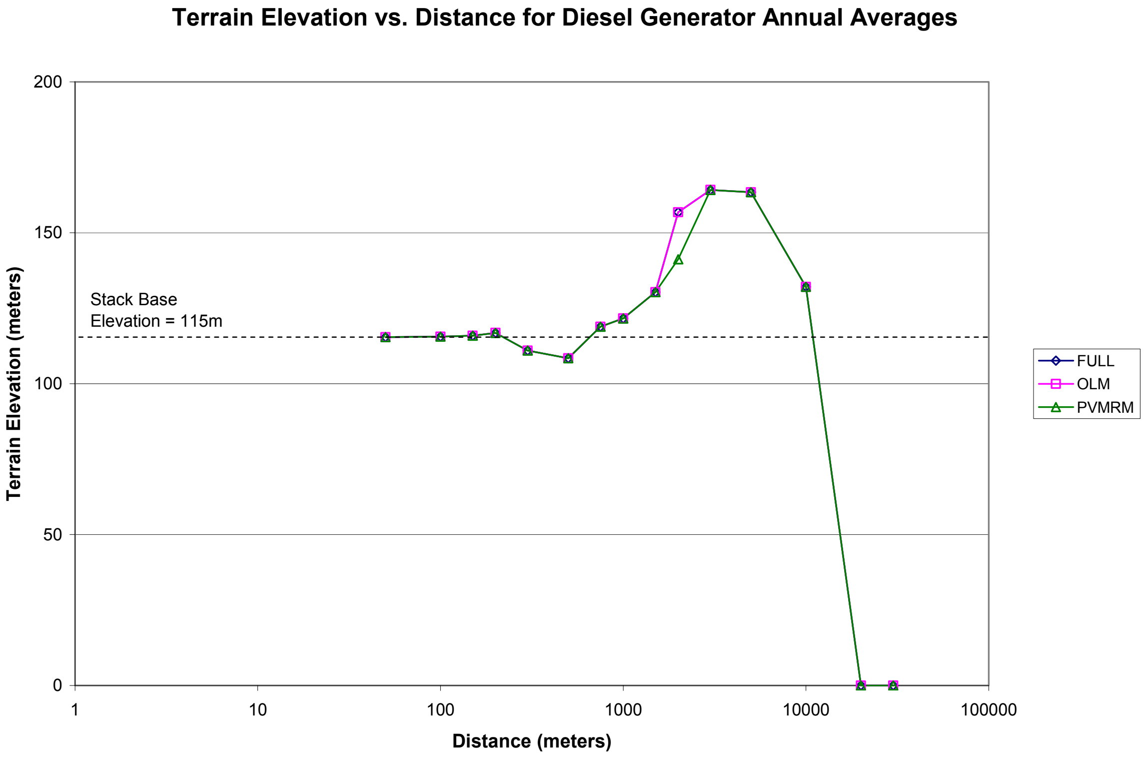


Figure 3.2. Ratios of Maximum 1-Hour NO_2 Concentrations to Full Conversion





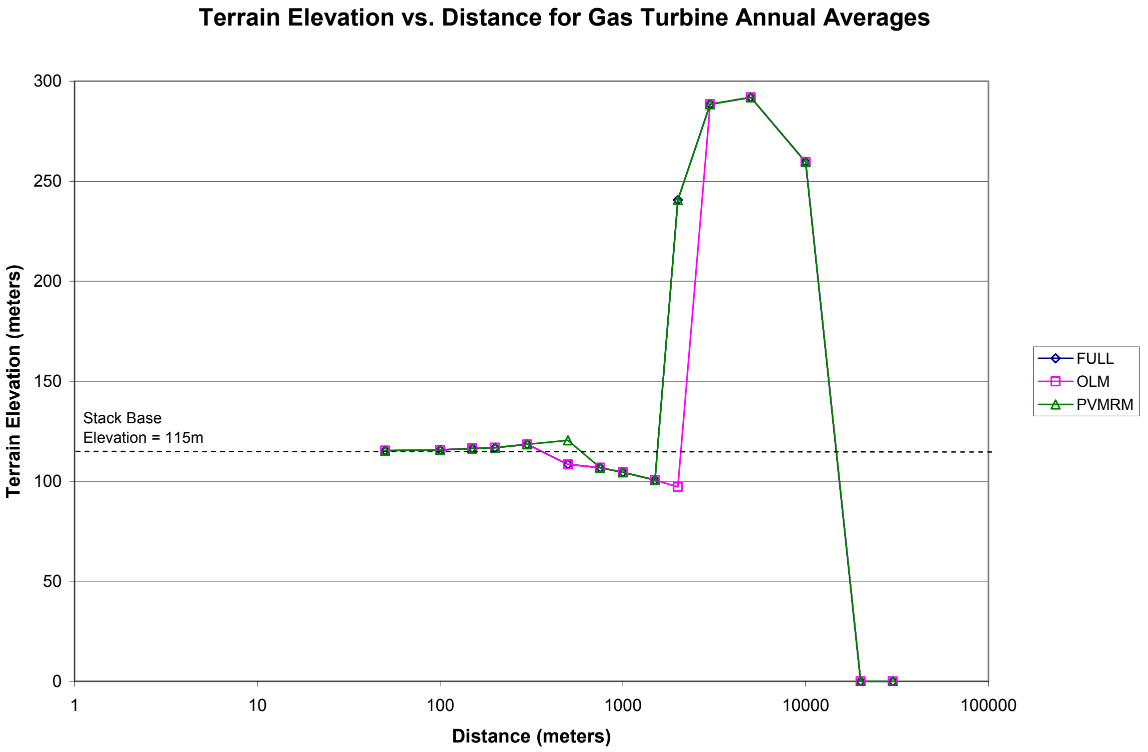
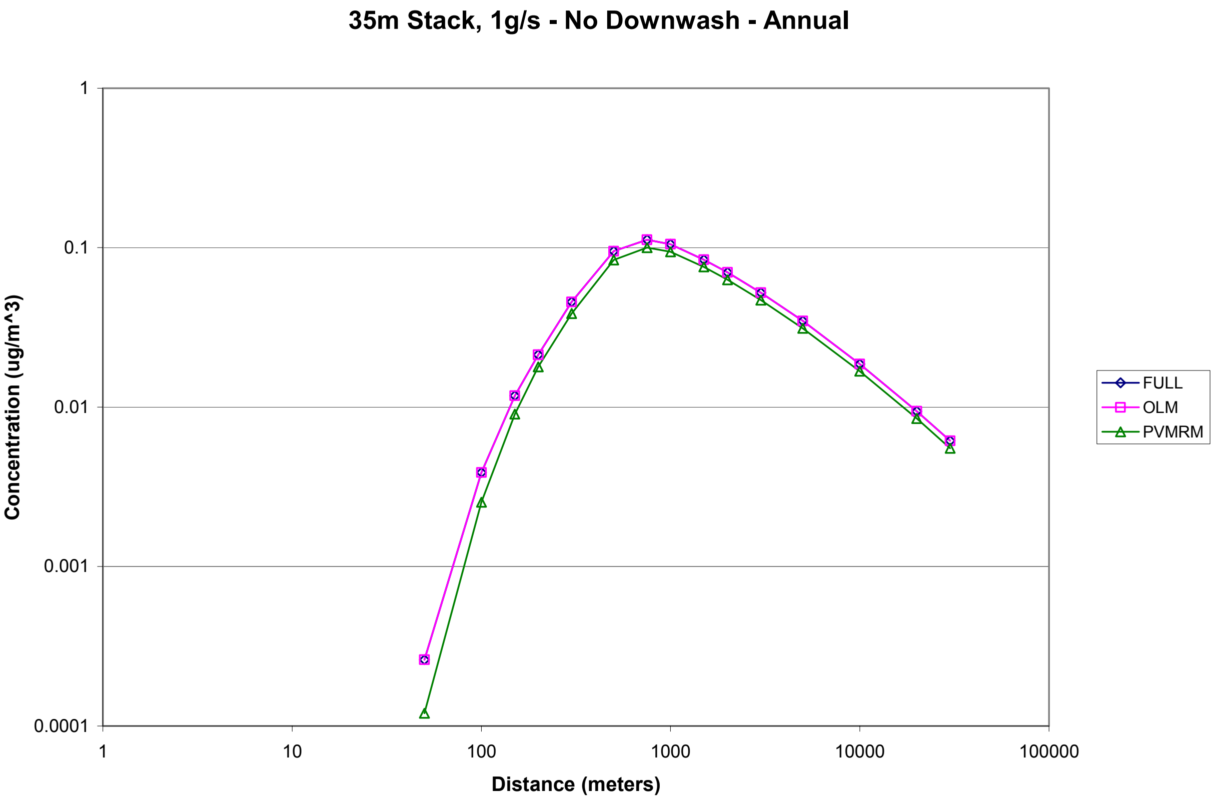


Figure 3.3. Terrain Elevation vs. Downwind Distance for Maximum Annual NO_2 Averages for Diesel Generator (top) and Gas Turbine (bottom) Sources



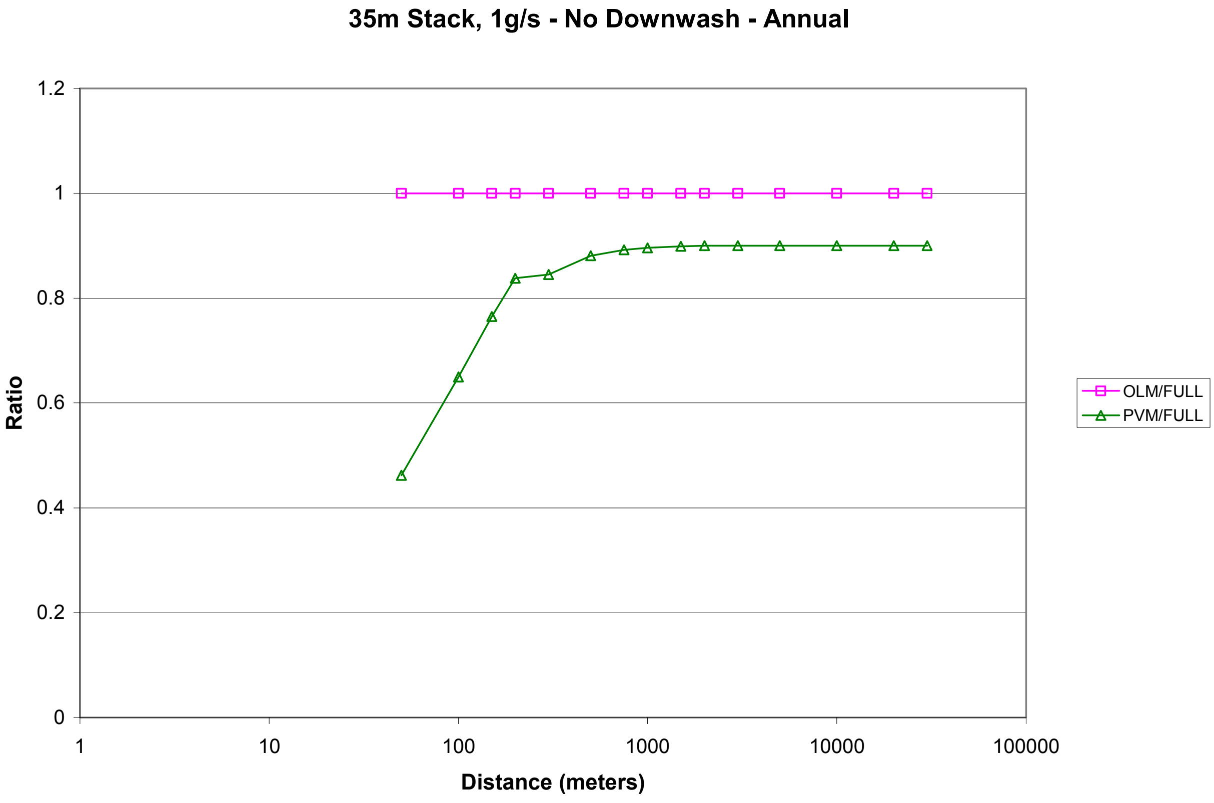
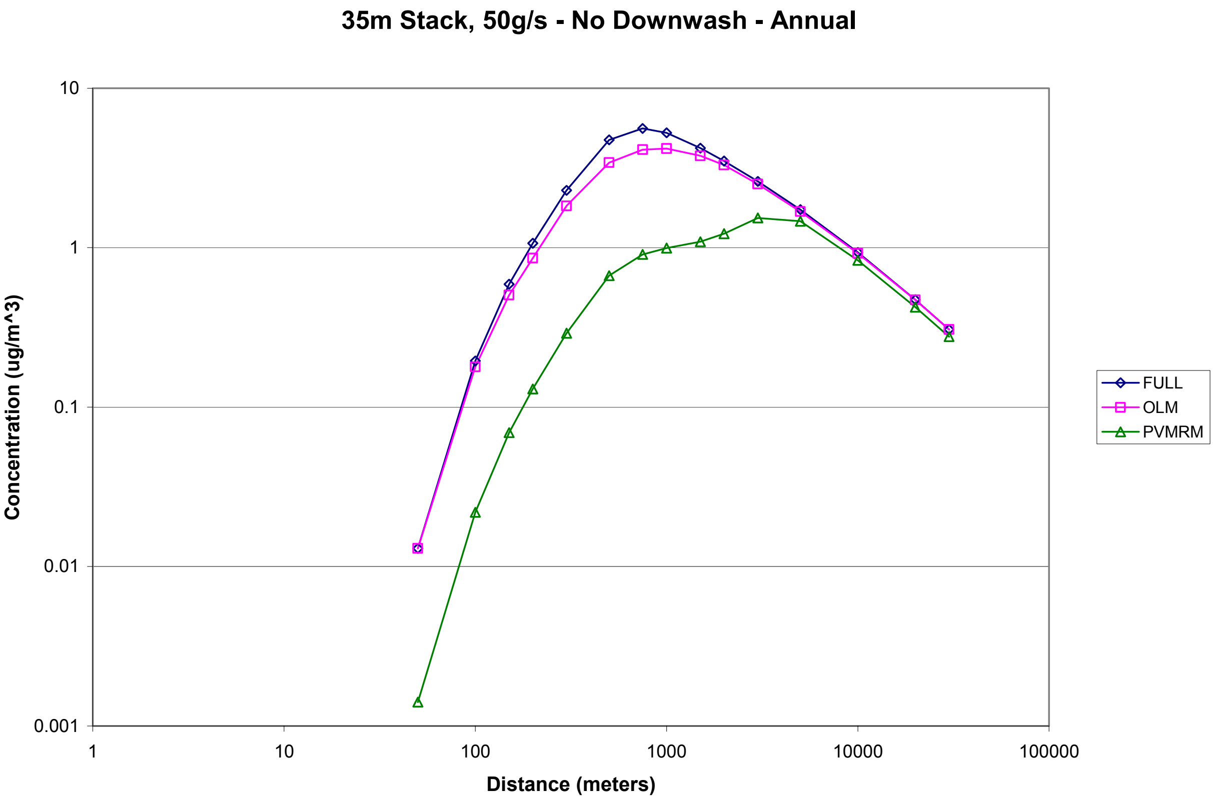


Figure 3.4. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 35m Buoyant Stack with 1g/s Emission Rate



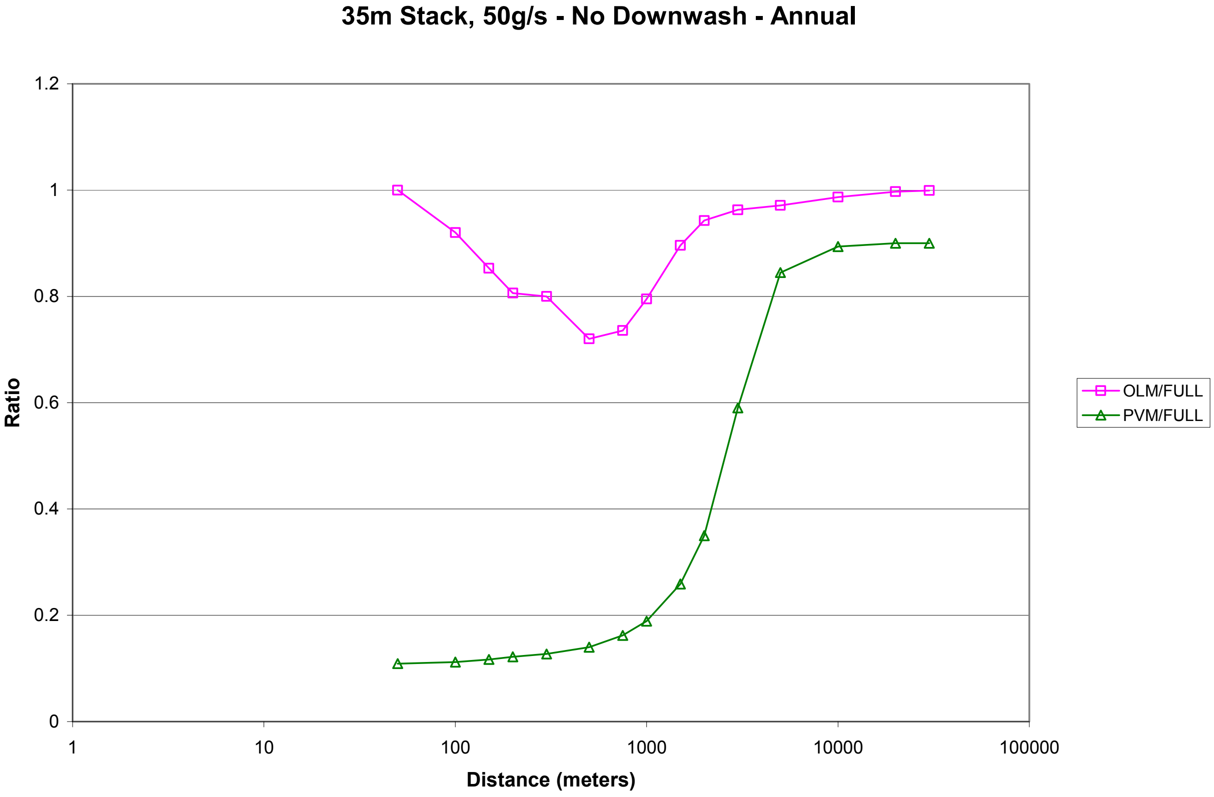
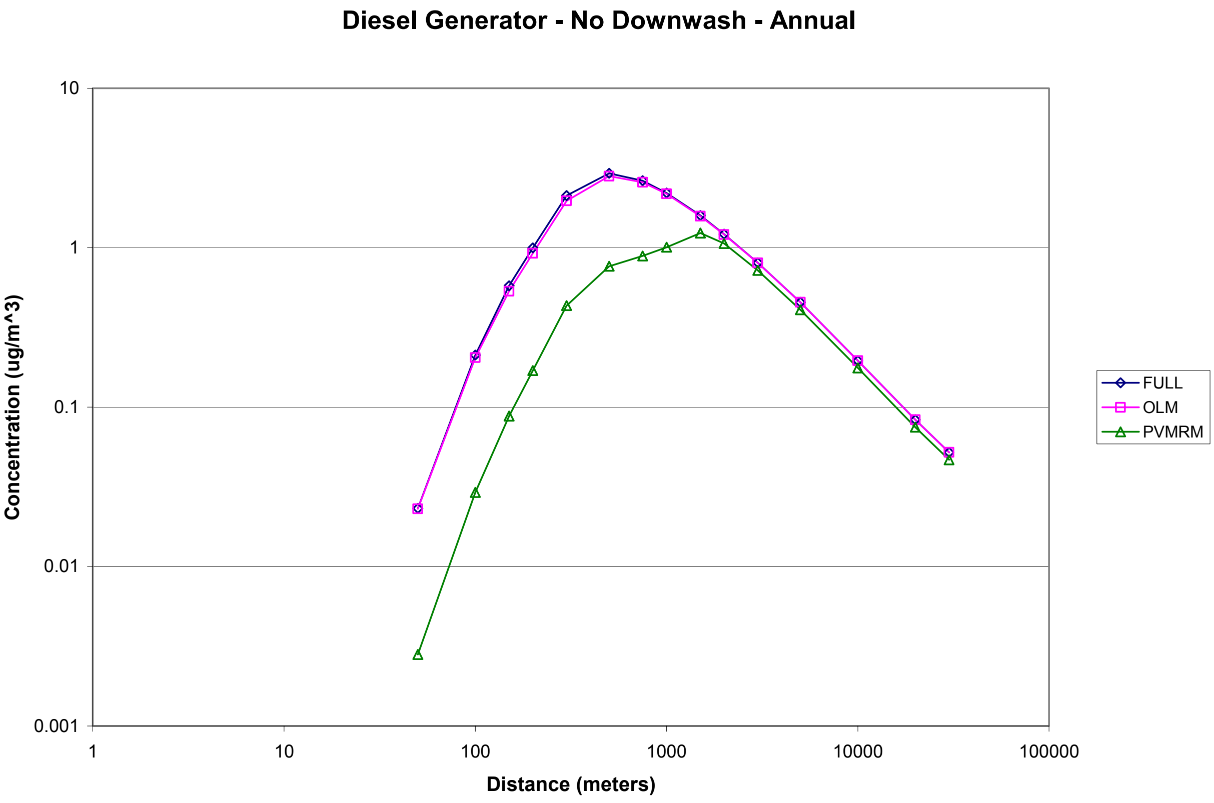


Figure 3.5. Annual Average NO_2 Concentration (µg/m^3) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 35m Buoyant Stack with 50g/s Emission Rate



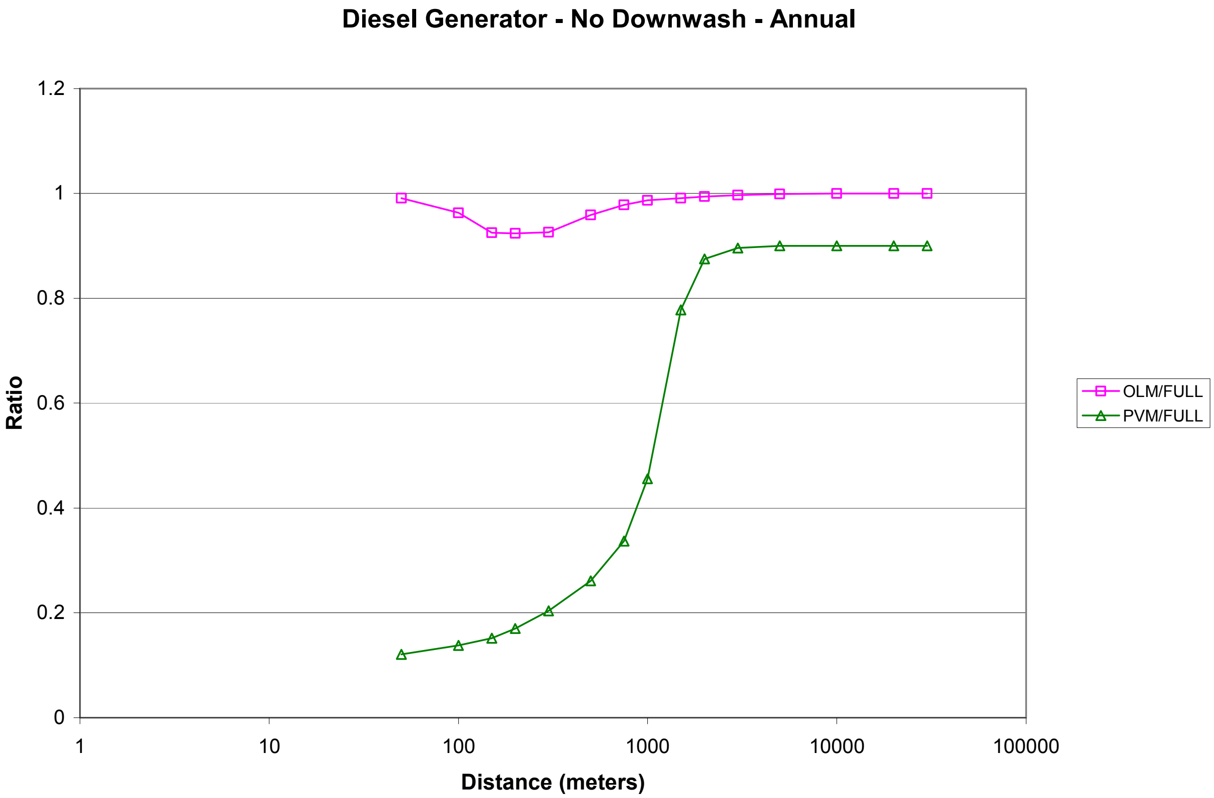
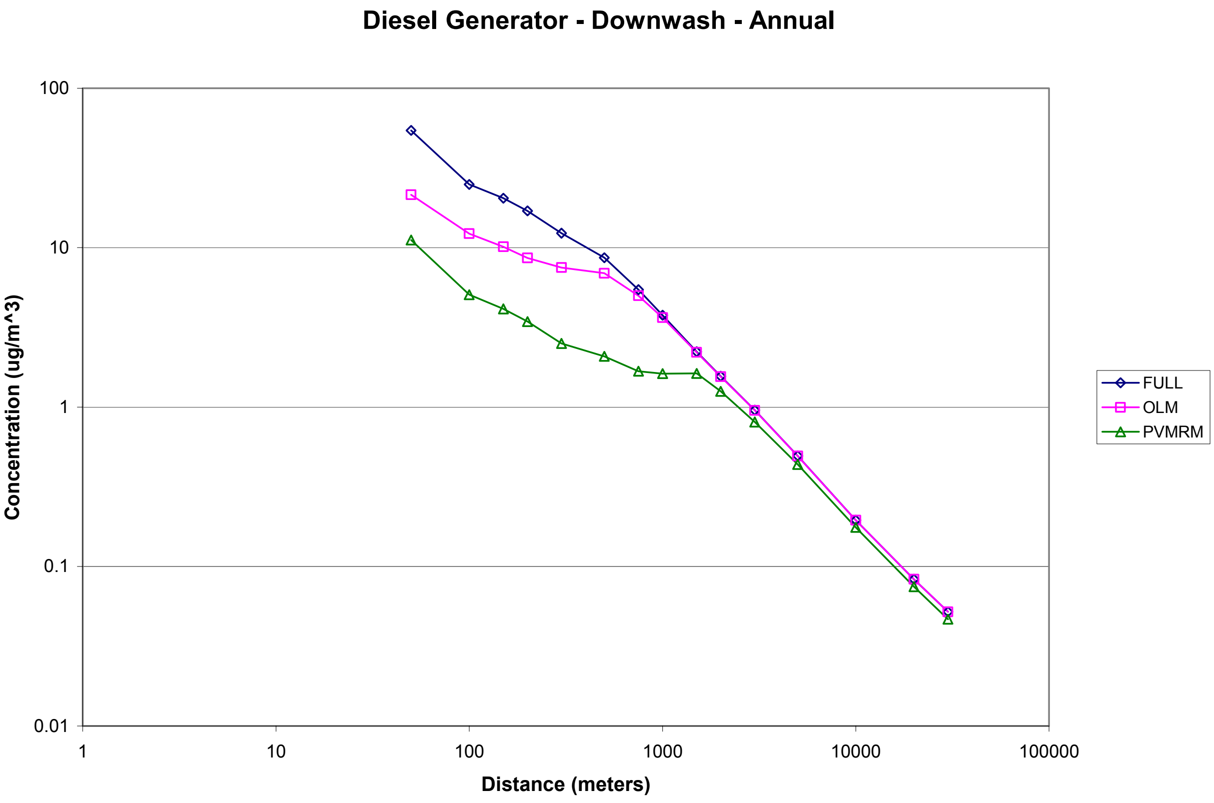


Figure 3.6. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with No Downwash



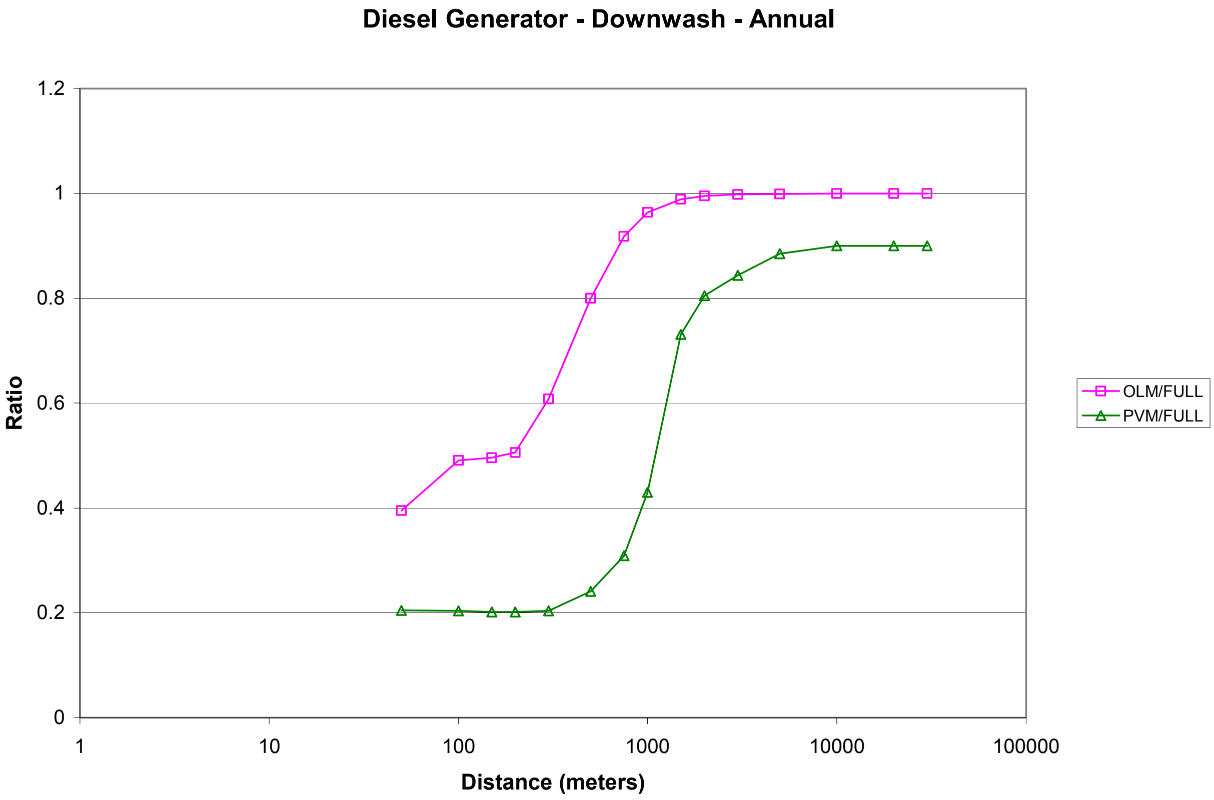
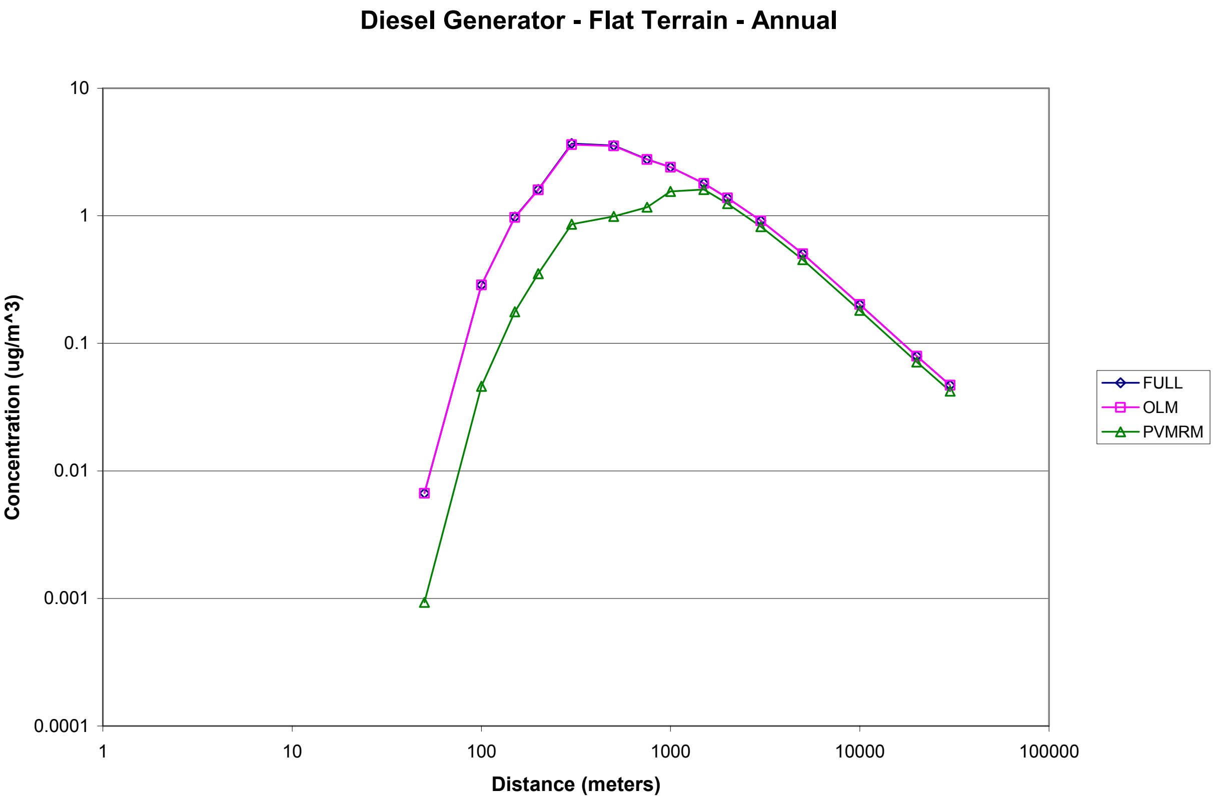


Figure 3.7. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Downwash



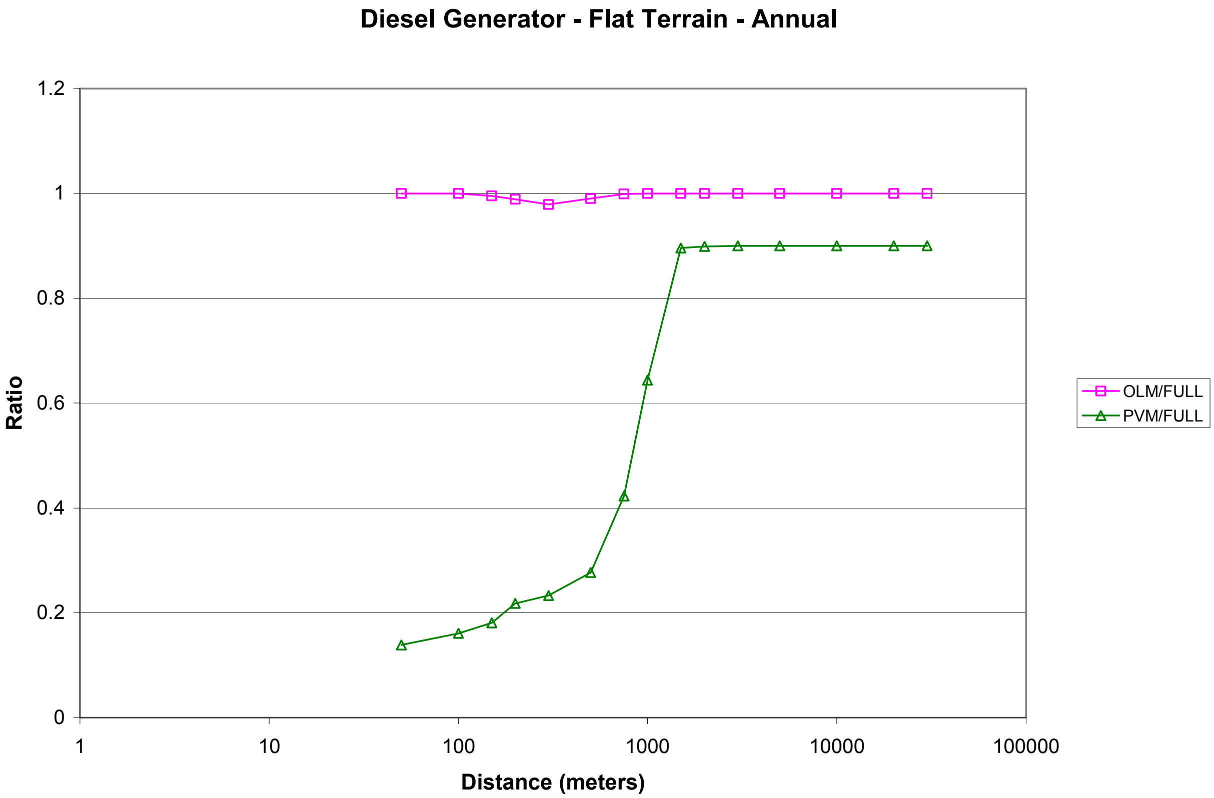


Figure 3.8. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Flat Terrain

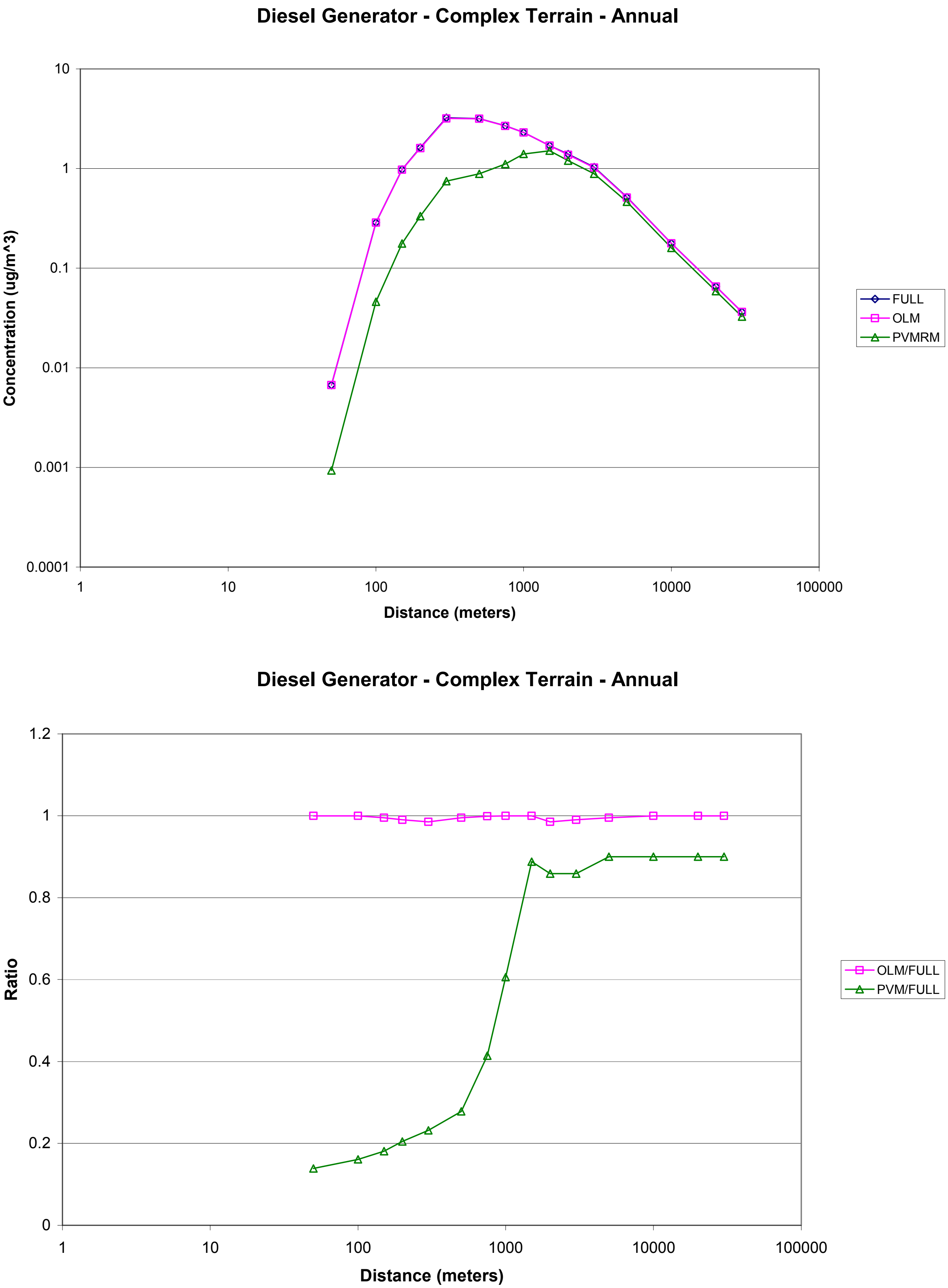
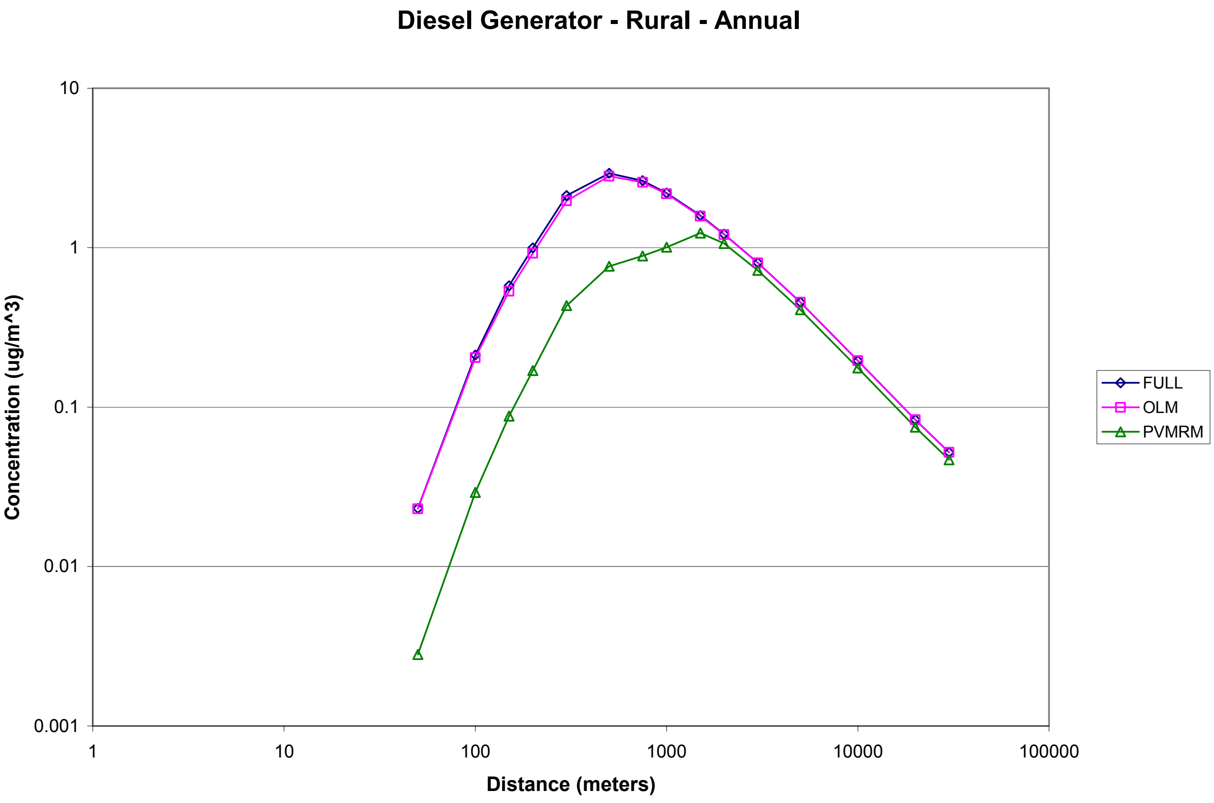


Figure 3.9. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Complex Terrain



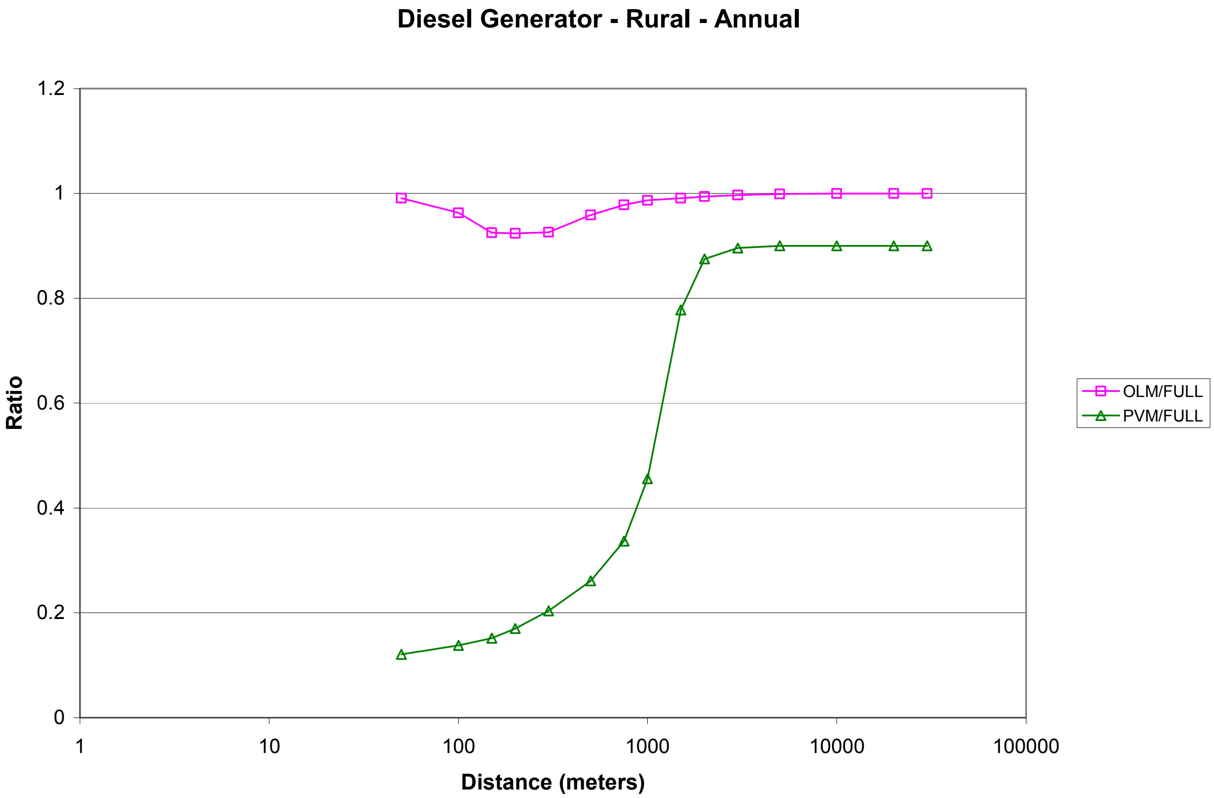
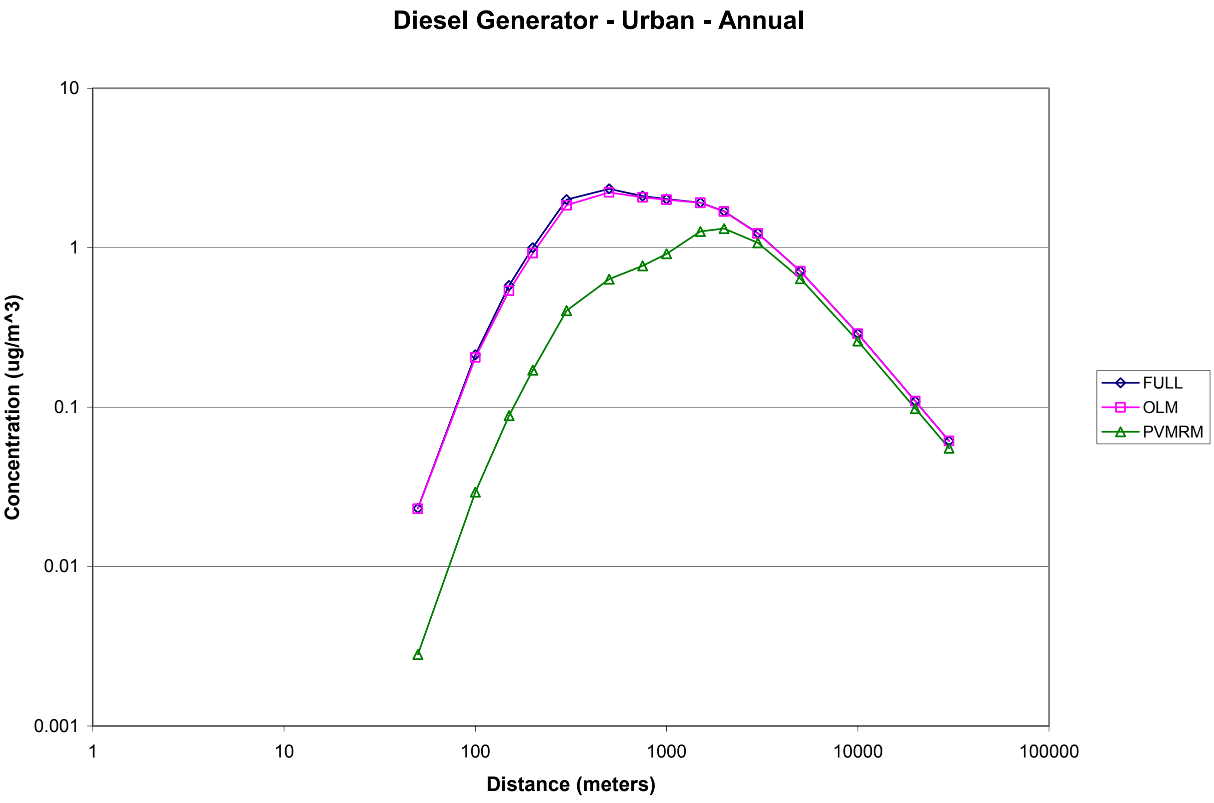


Figure 3.10. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Rural Dispersion



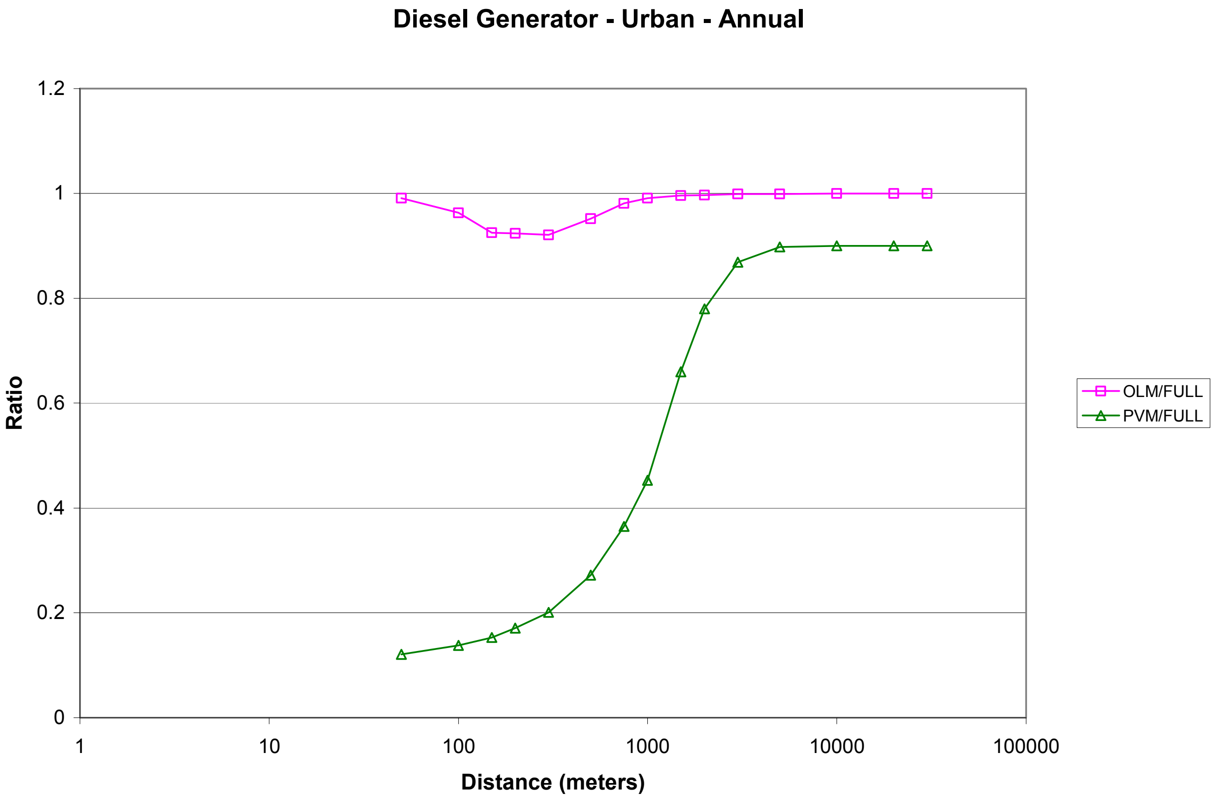
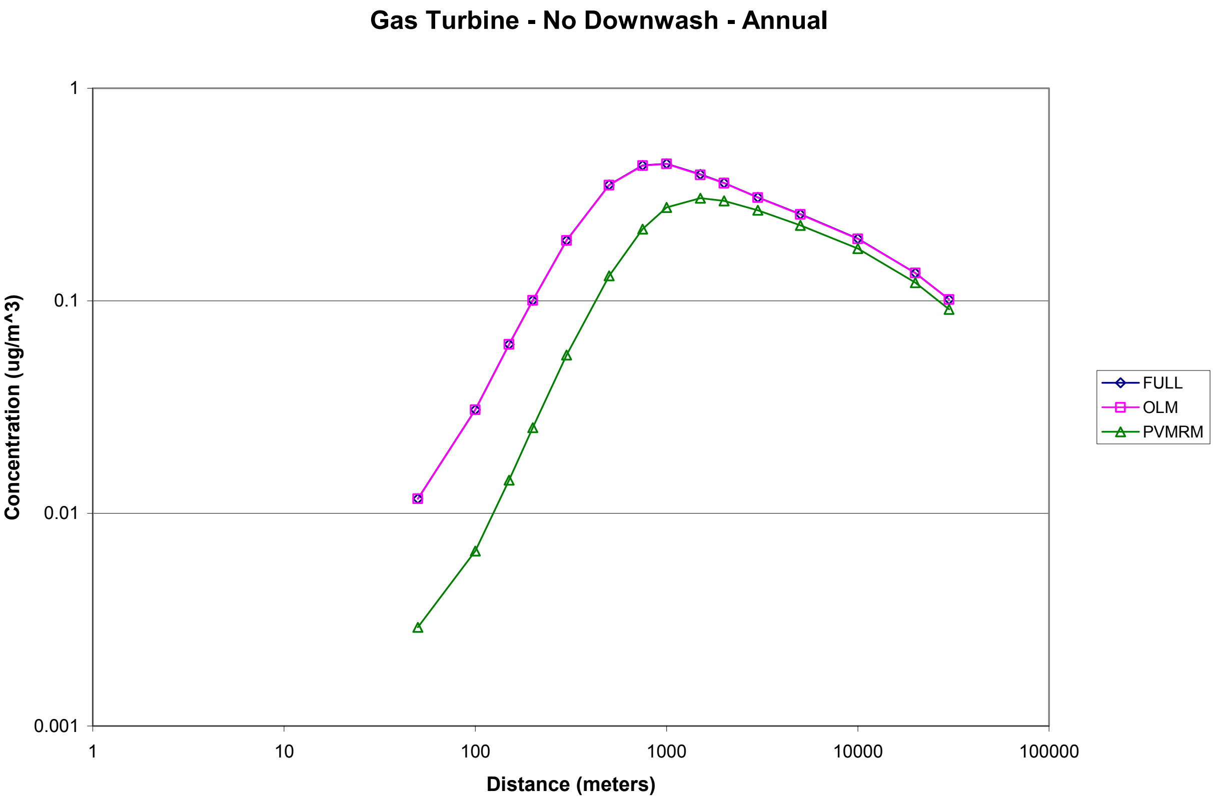


Figure 3.11. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Urban Dispersion



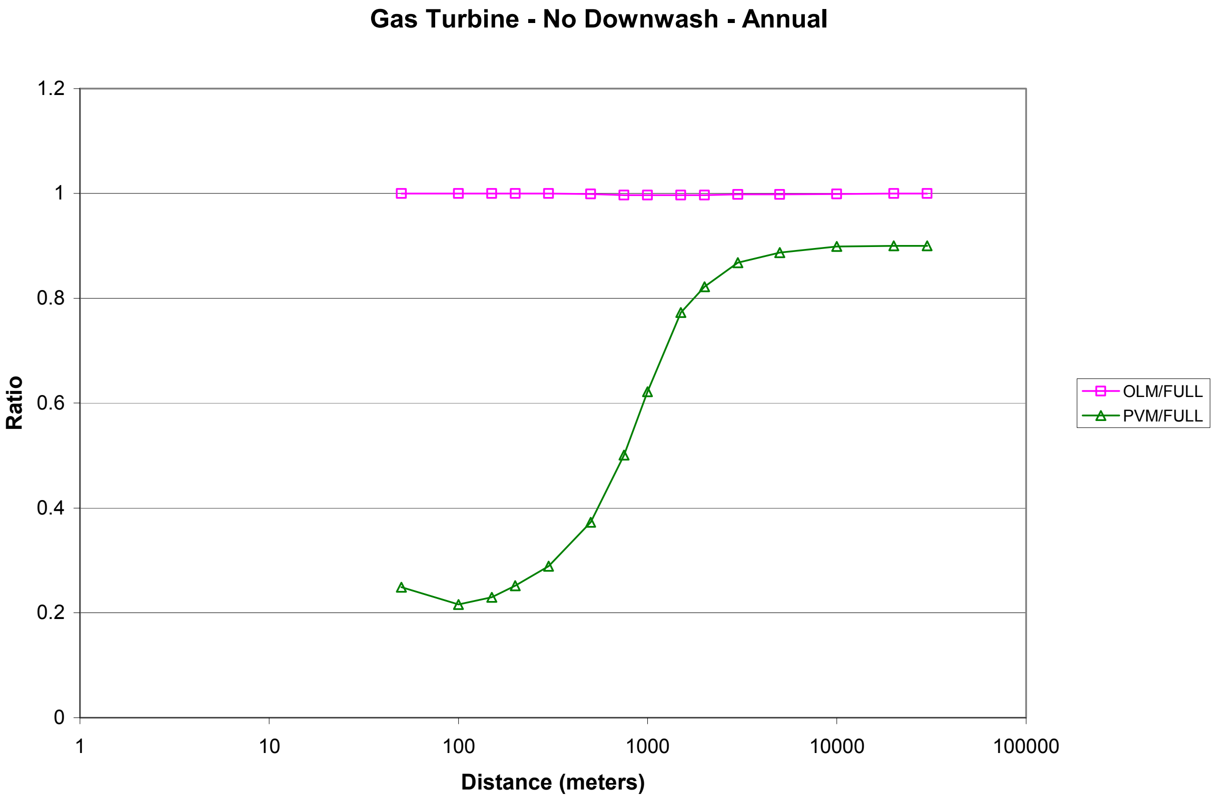
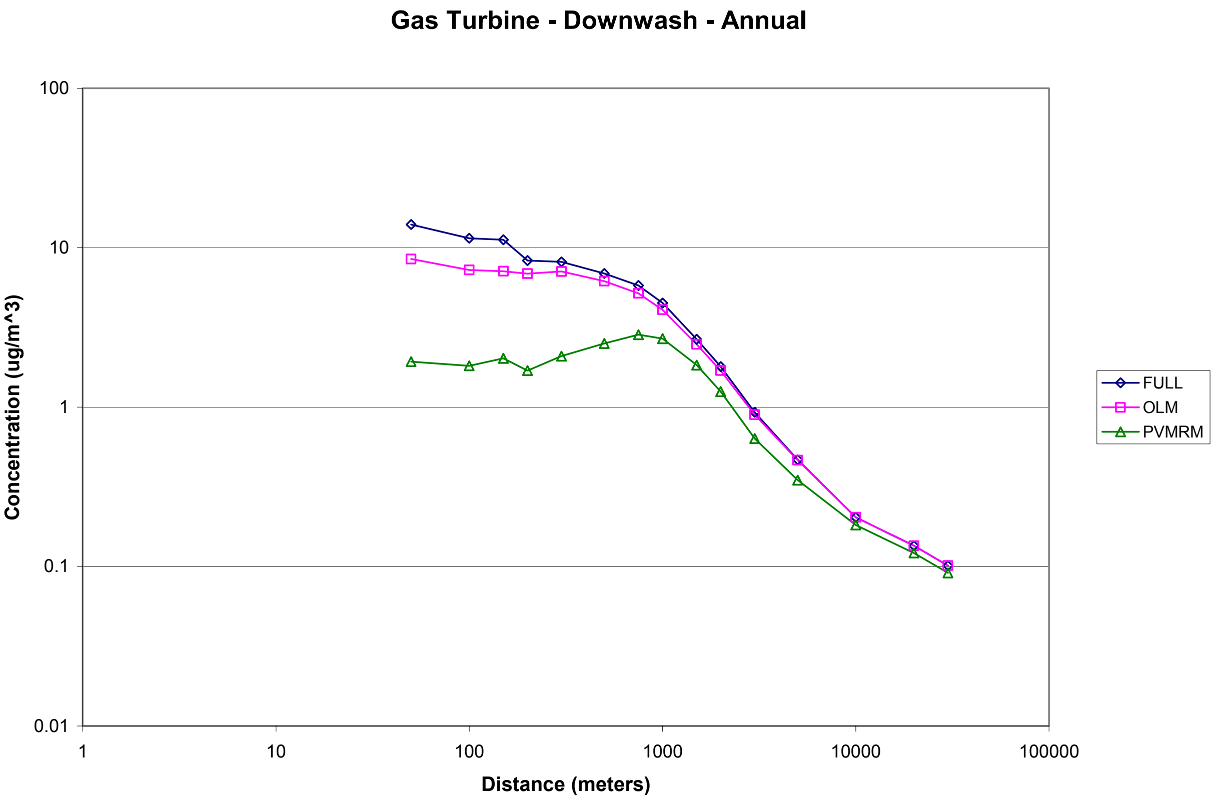


Figure 3.12. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with No Downwash



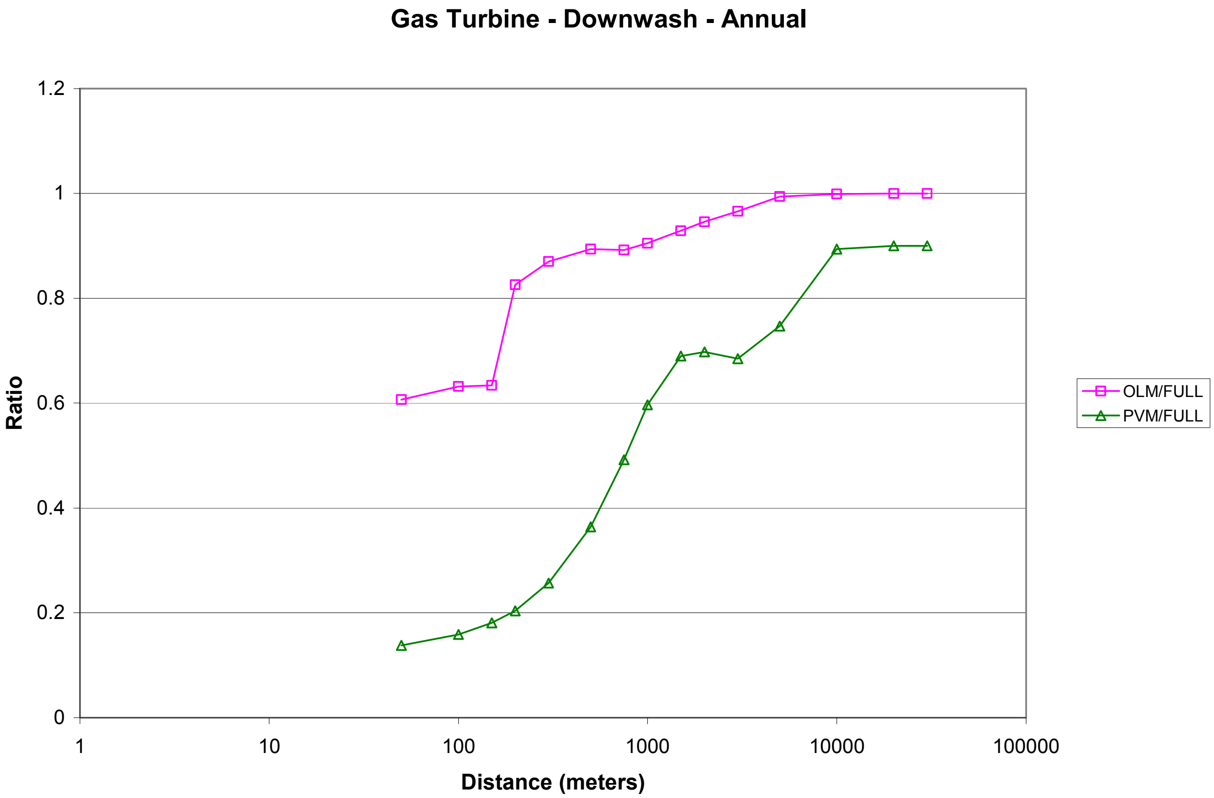
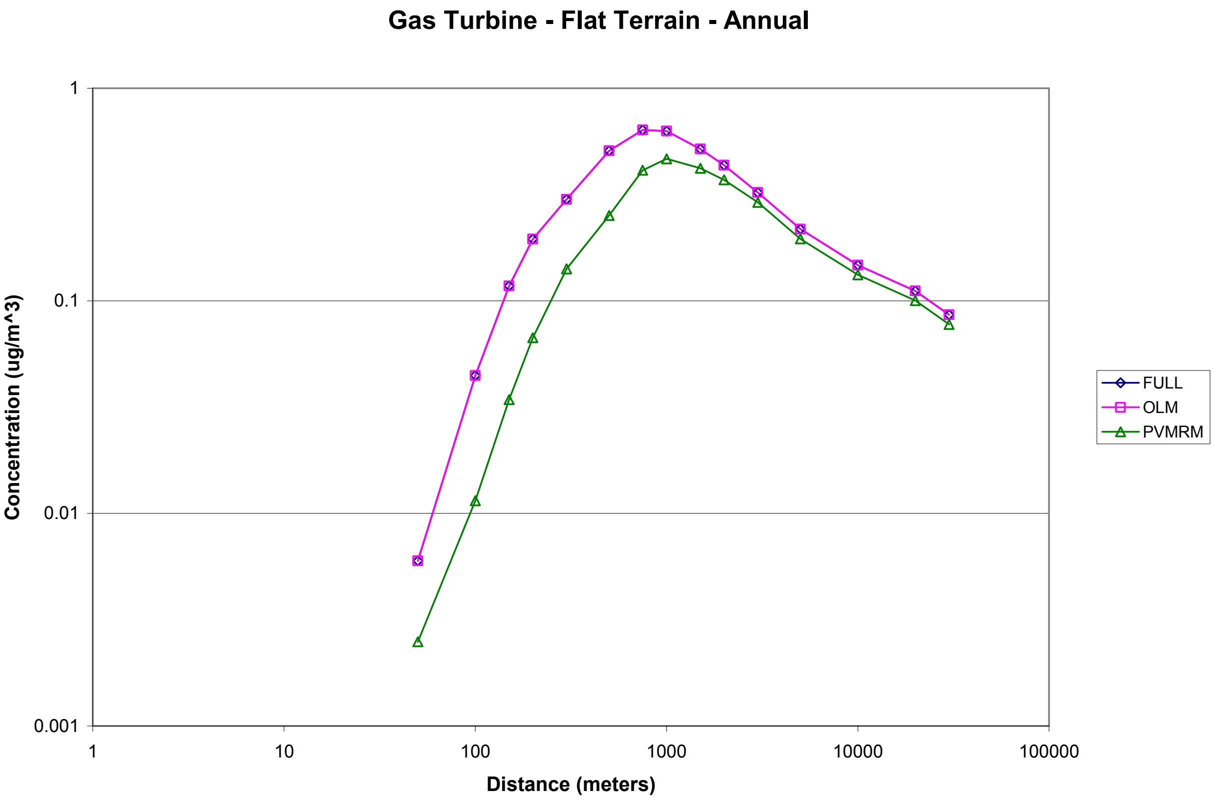


Figure 3.13. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Downwash



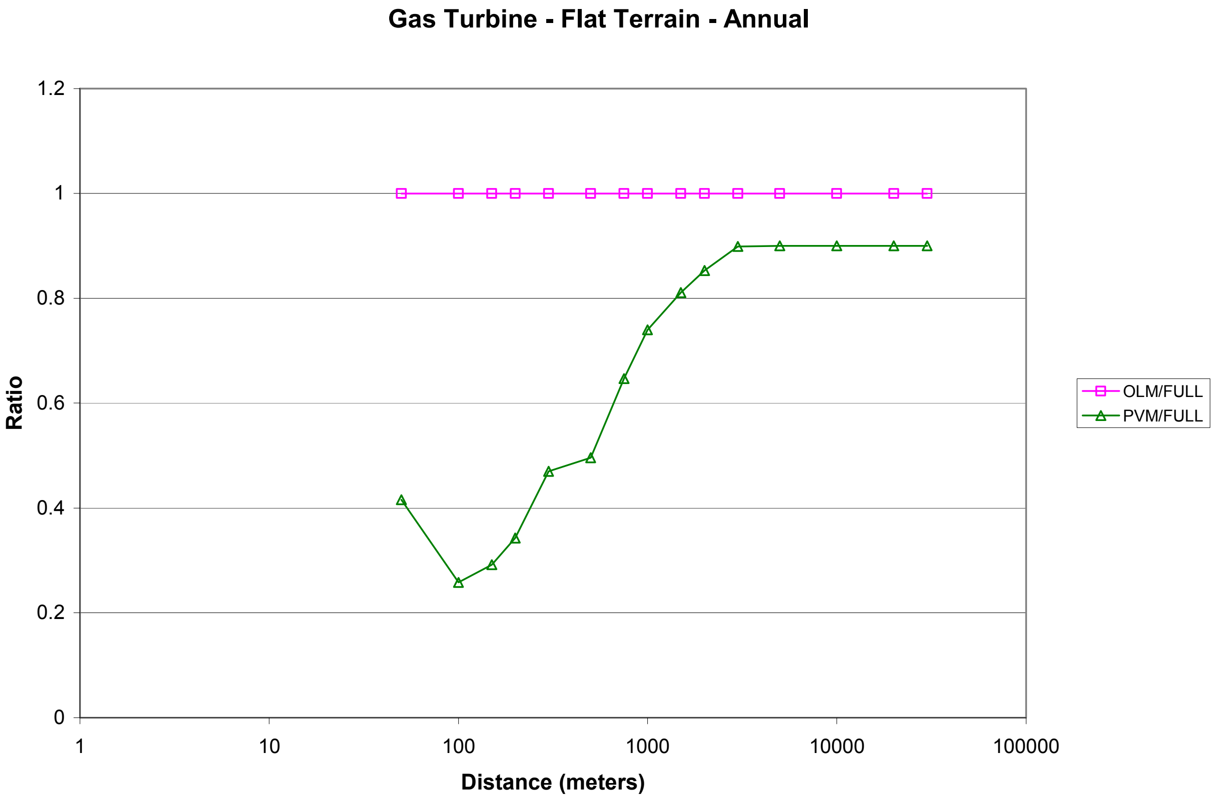


Figure 3.14. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Flat Terrain

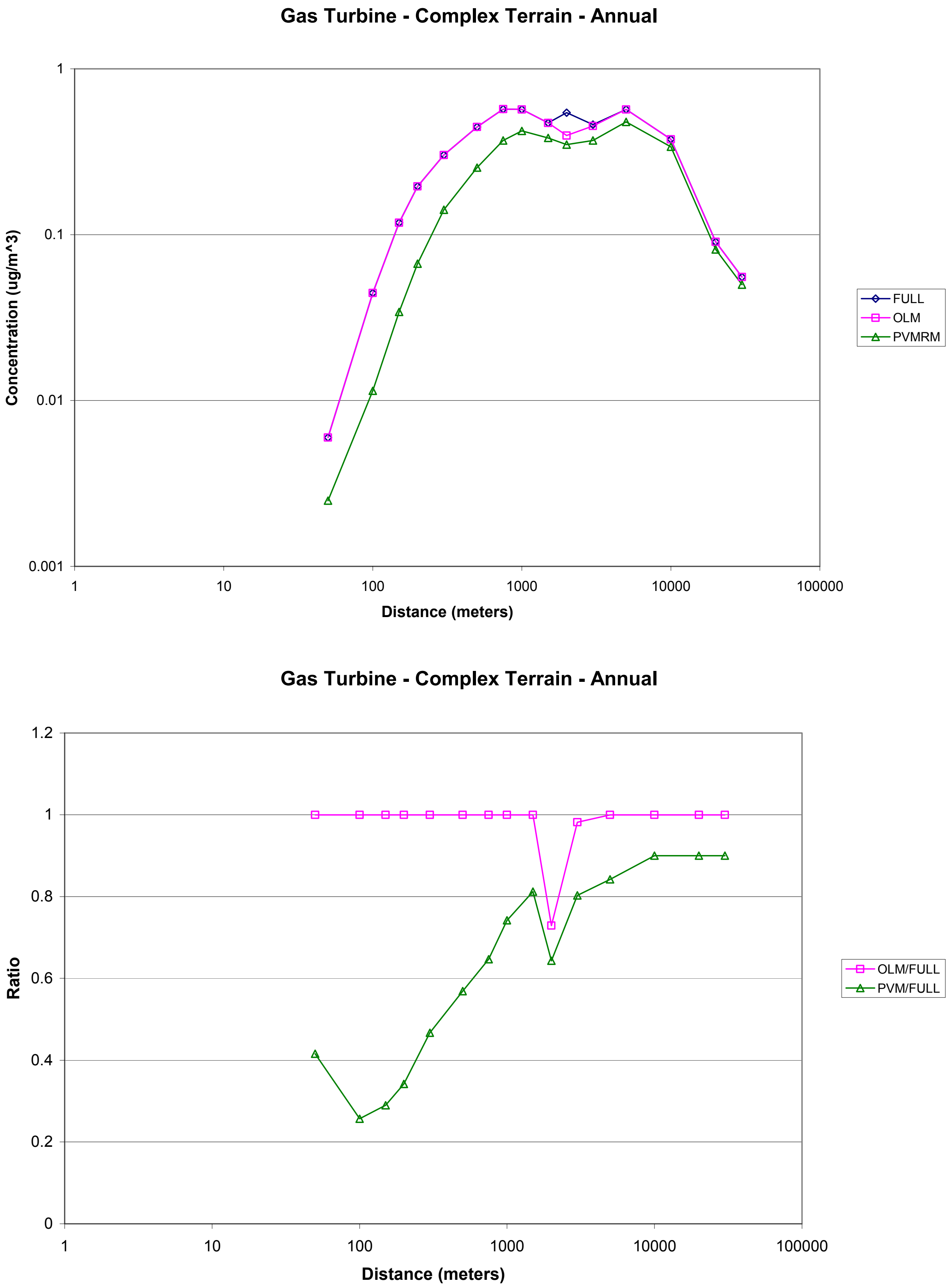
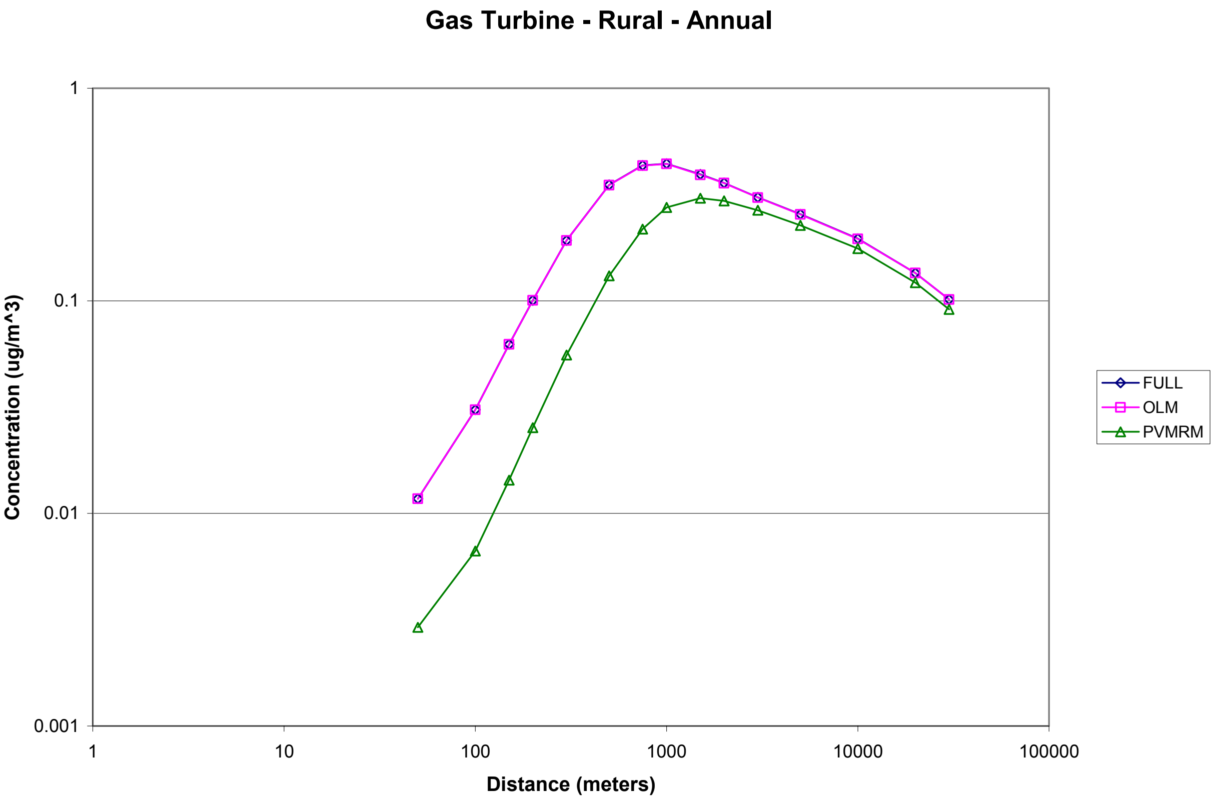


Figure 3.15. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Complex Terrain



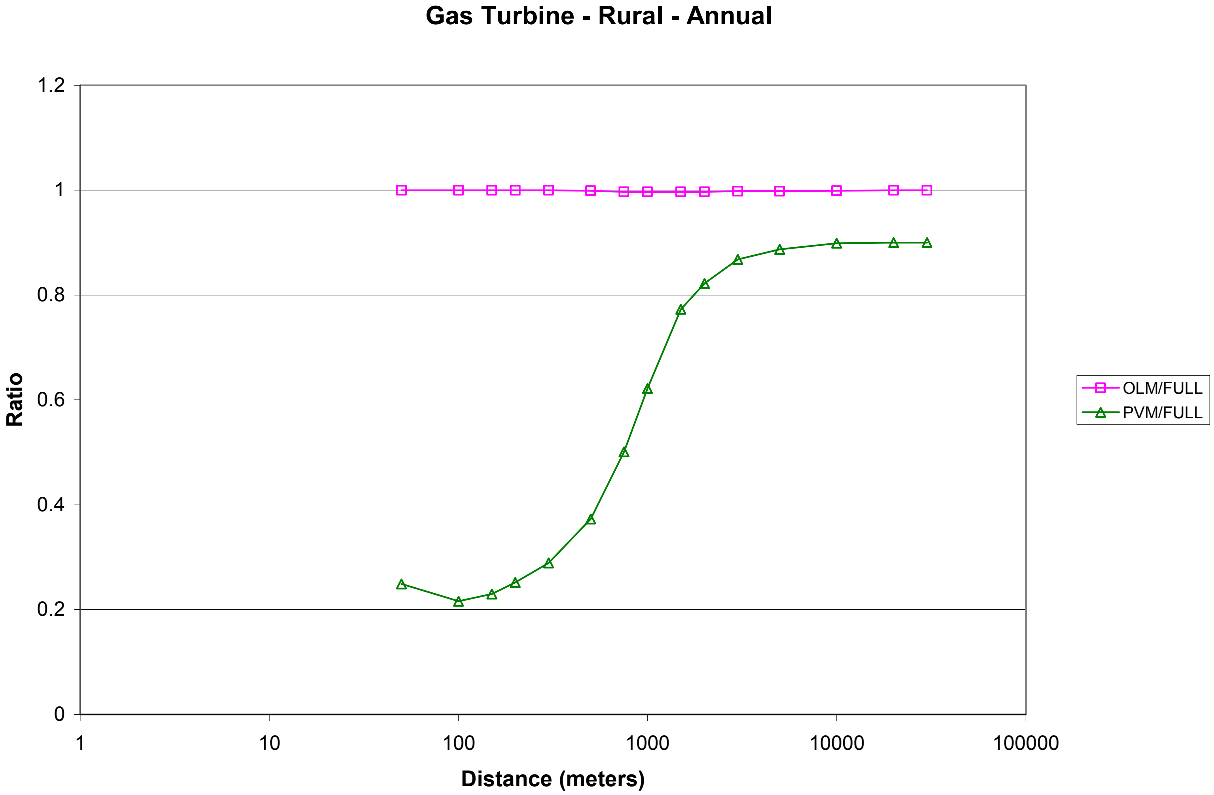
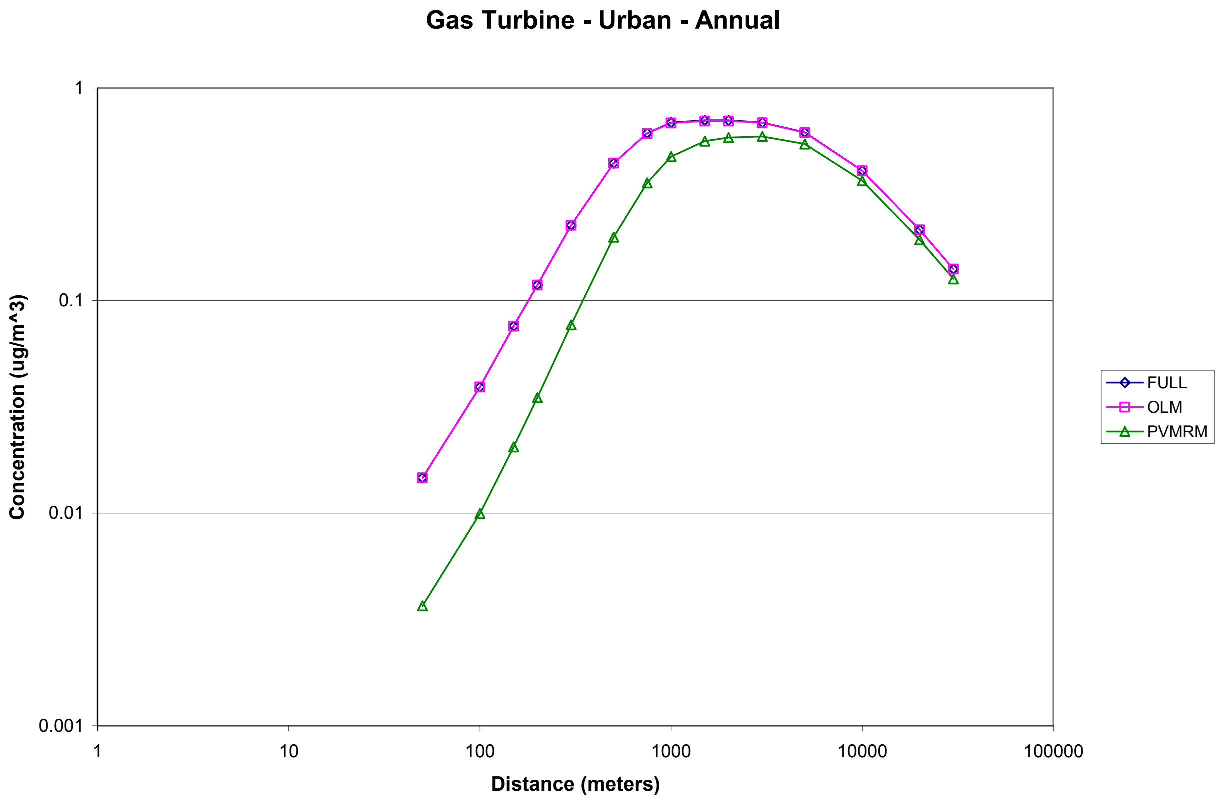


Figure 3.16. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Rural Dispersion



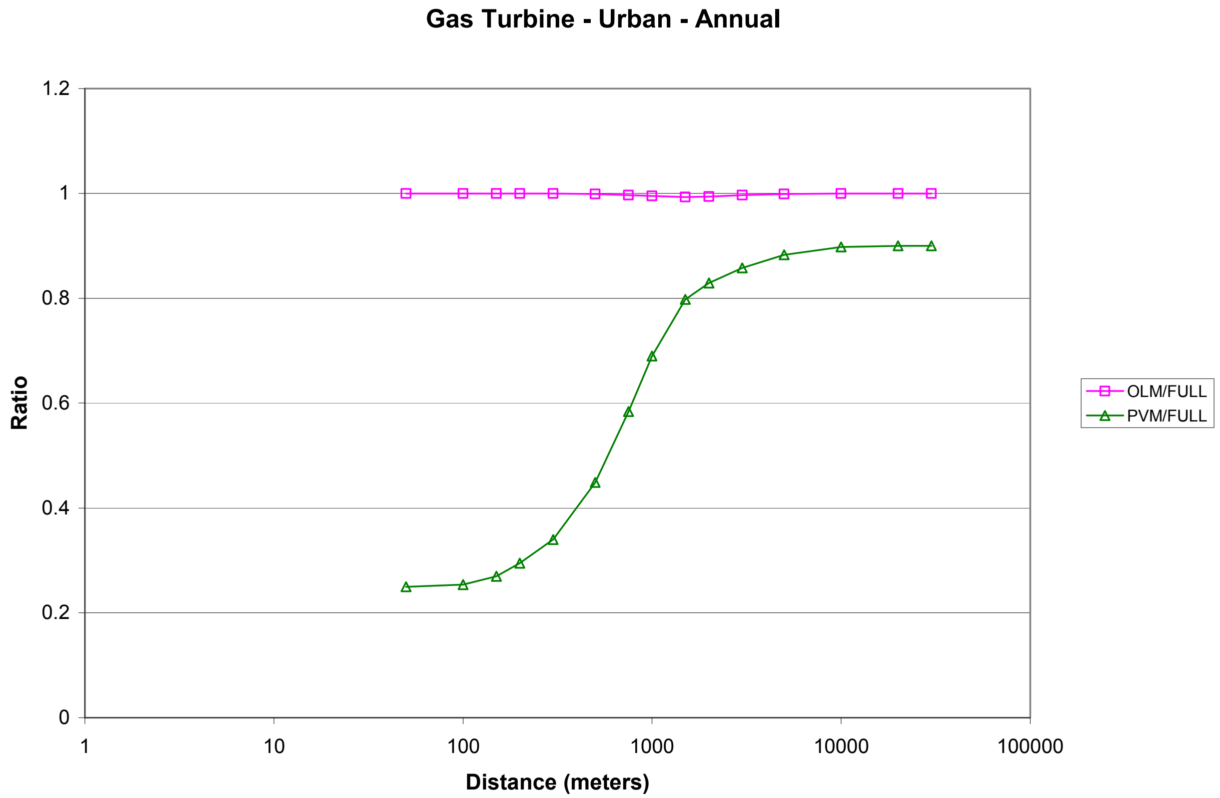
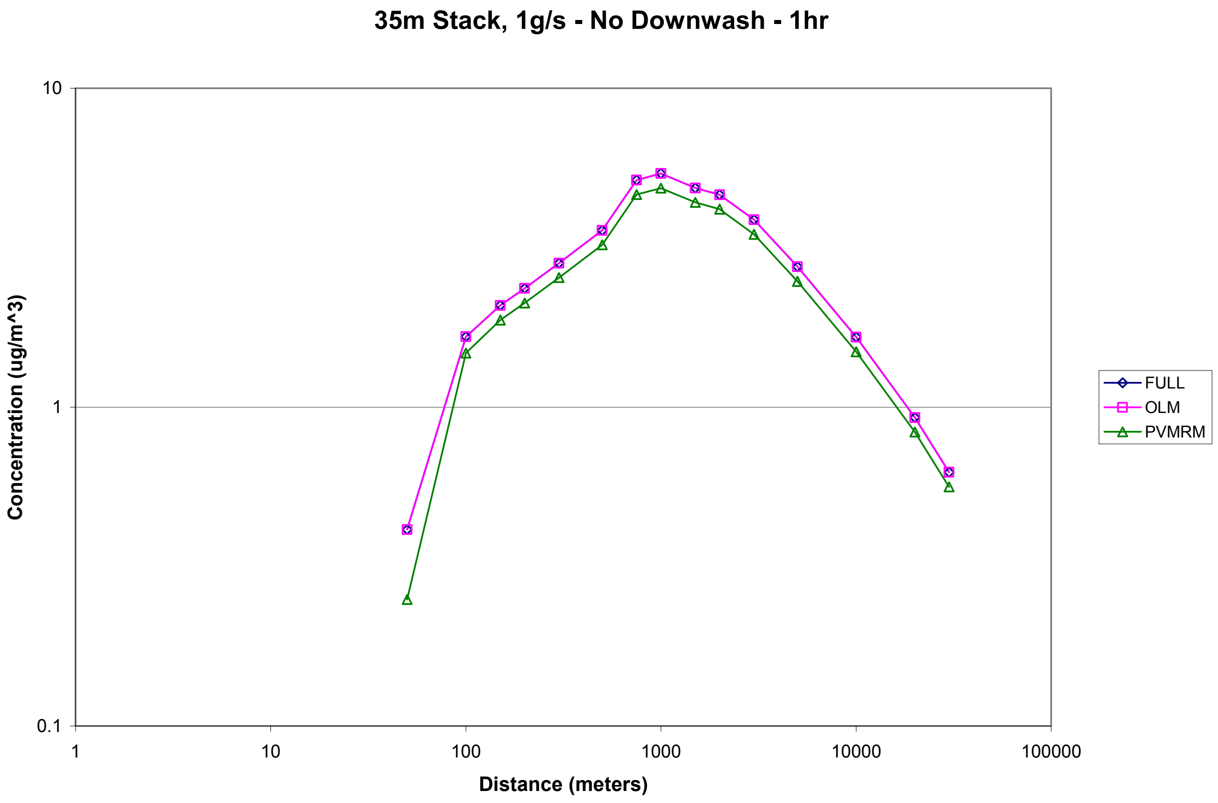


Figure 3.17. Annual Average NO_2 Concentration (µg/m^3) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Urban Dispersion



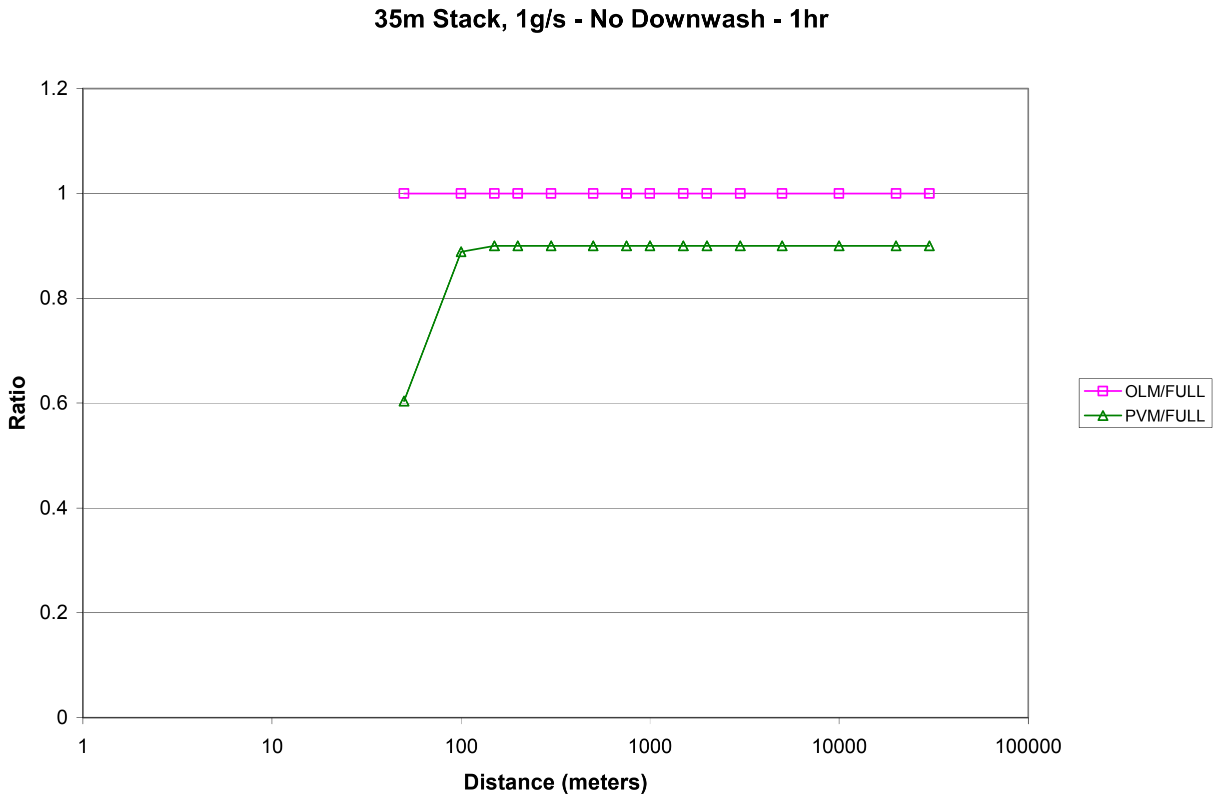
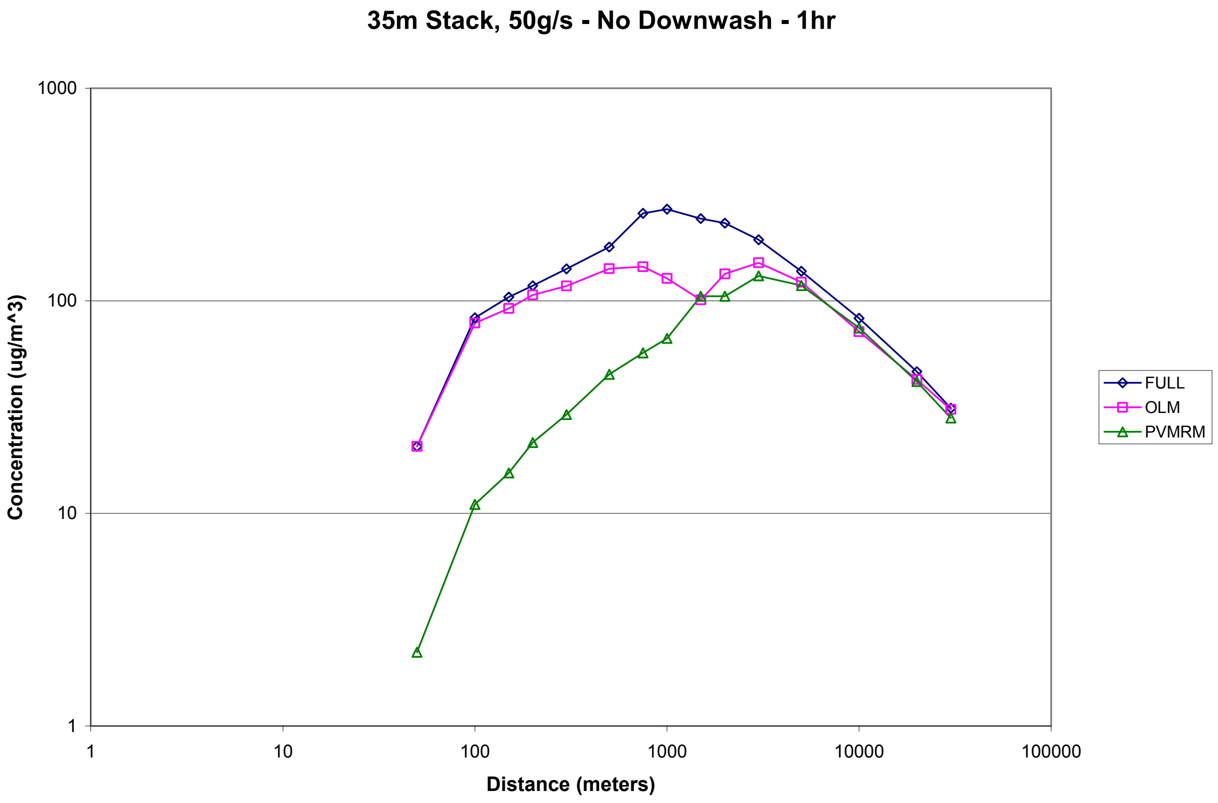


Figure 3.18. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 35m Buoyant Stack with 1g/s Emission Rate



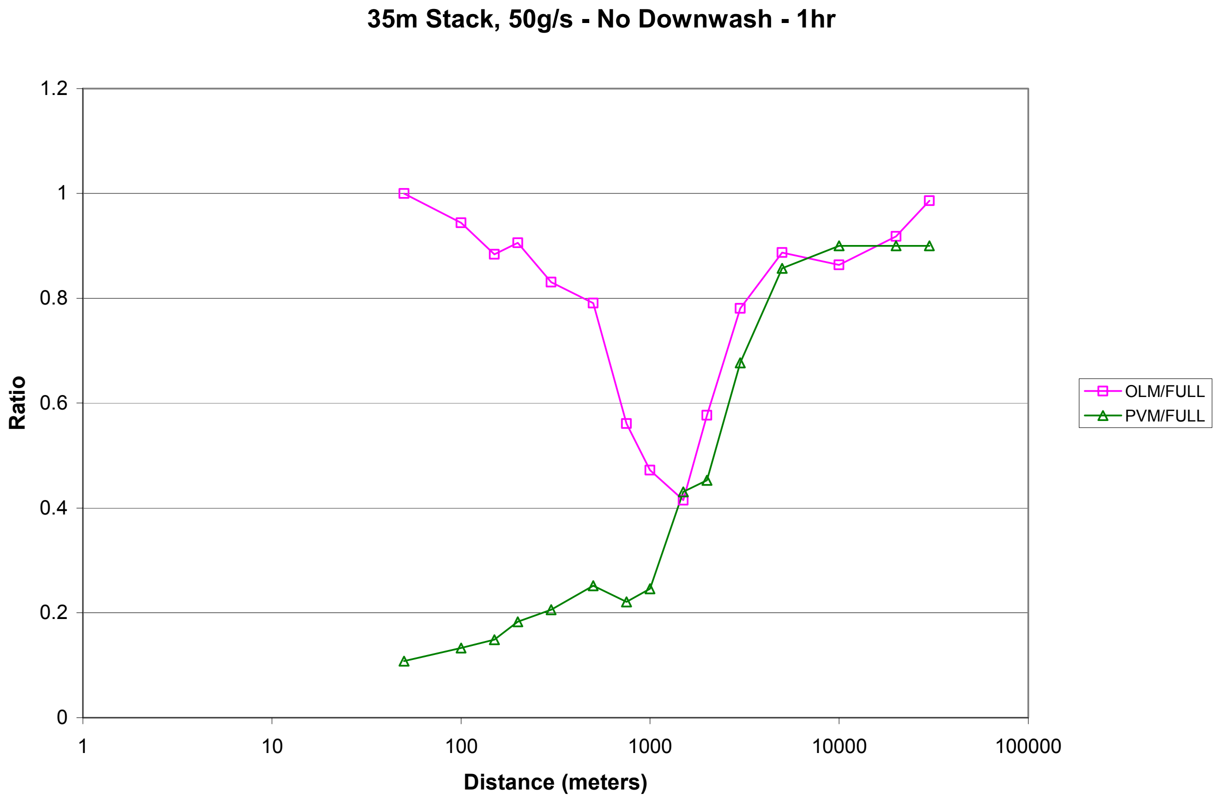
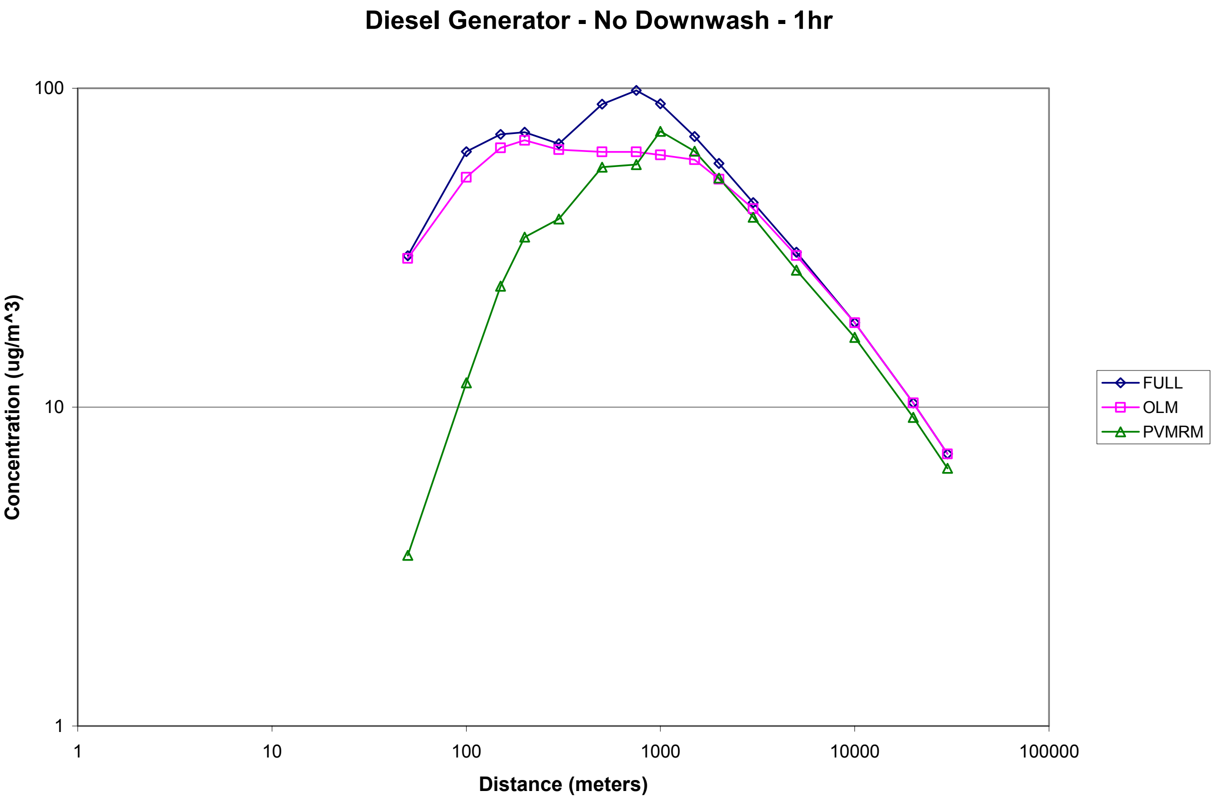


Figure 3.19. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 35m Buoyant Stack with 50g/s Emission Rate



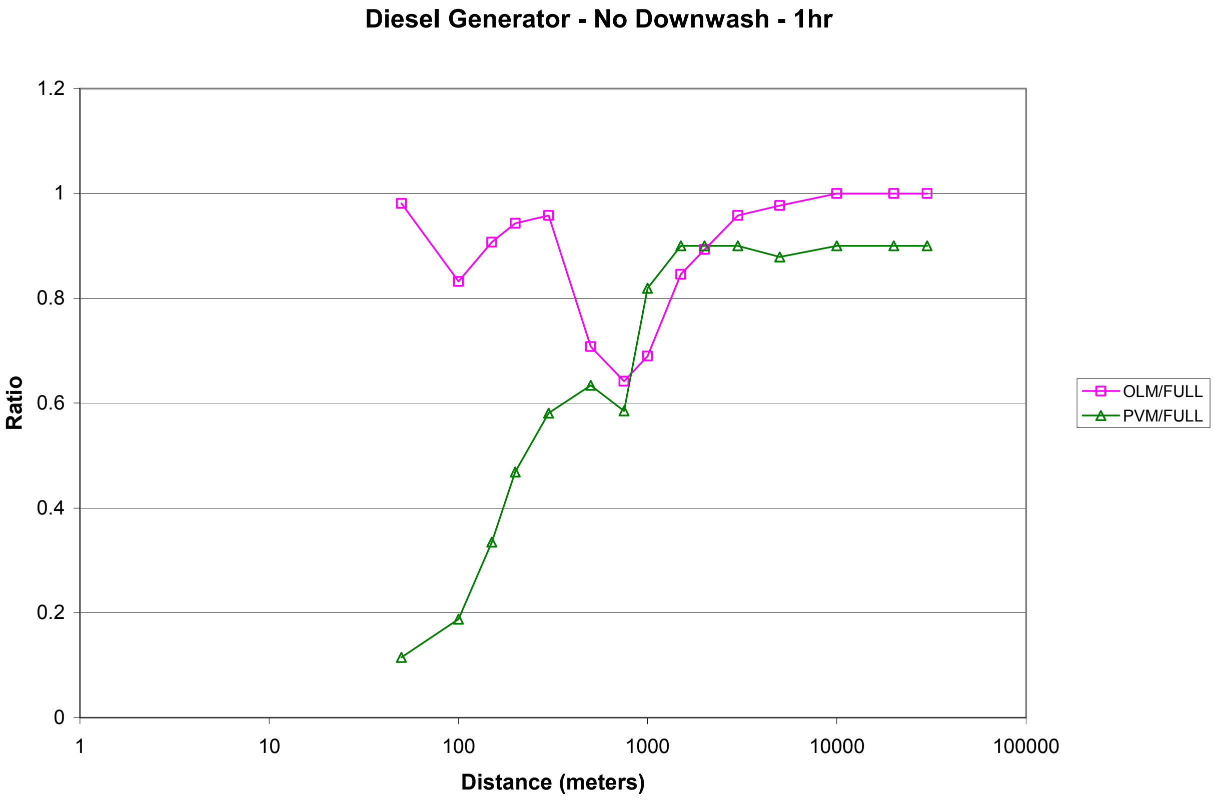
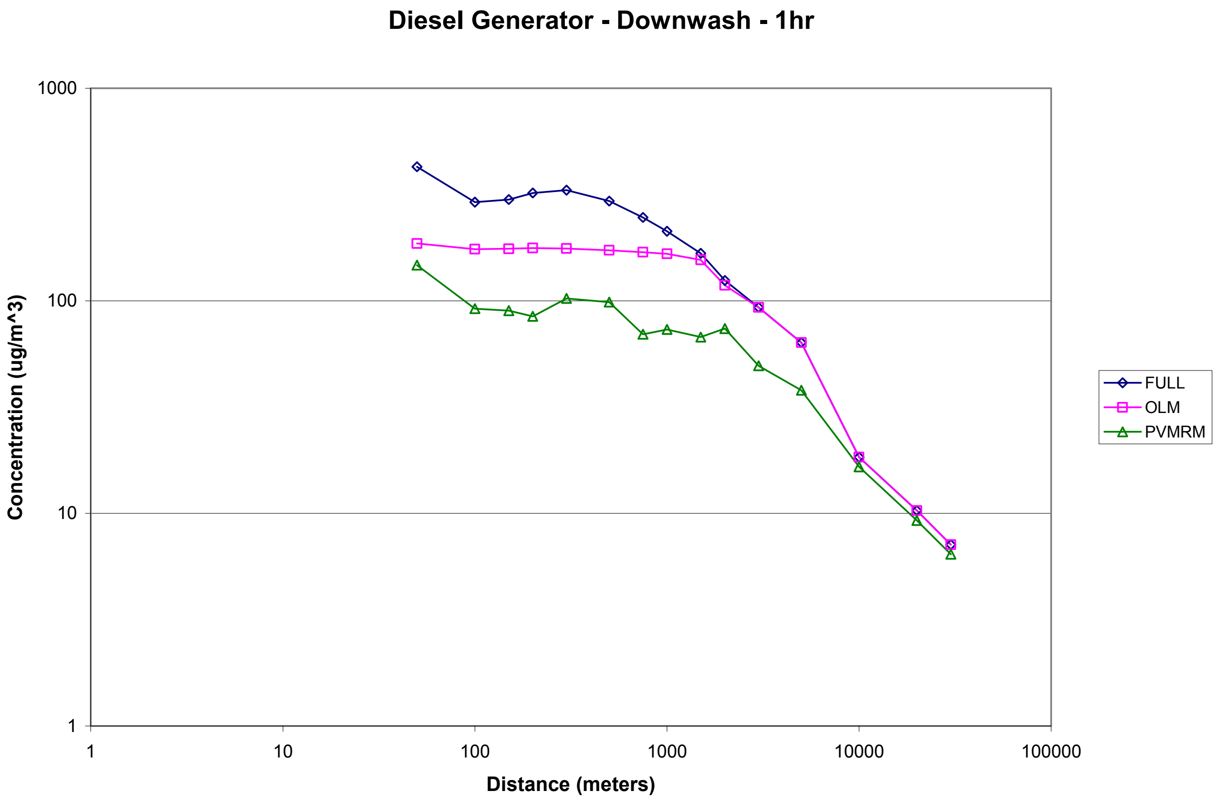


Figure 3.20. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with No Downwash



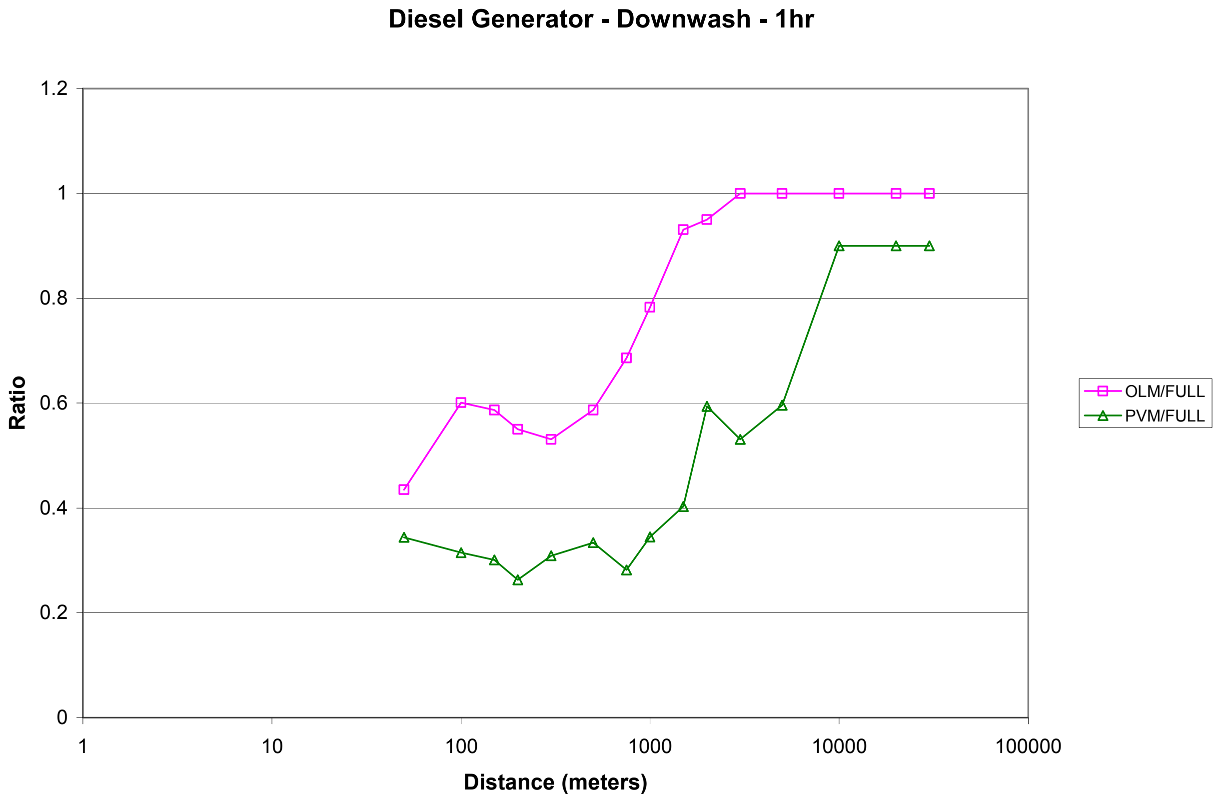
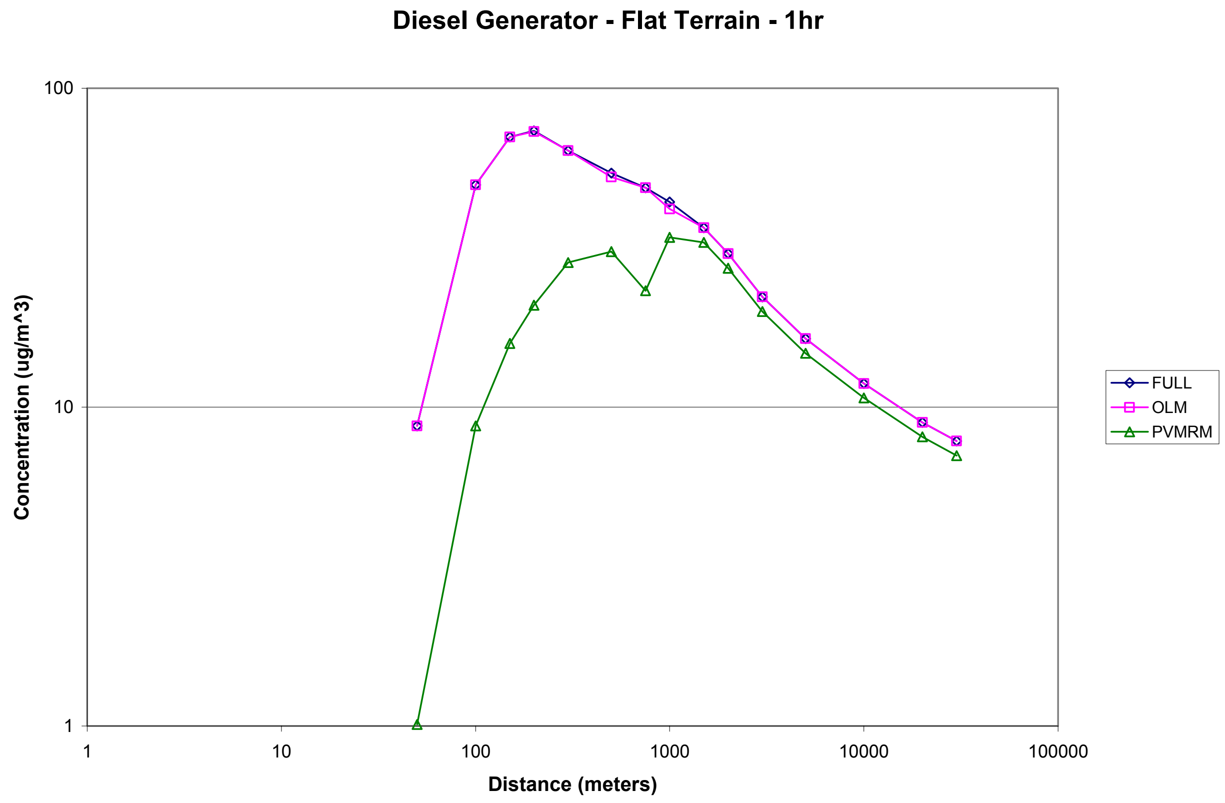


Figure 3.21. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Downwash



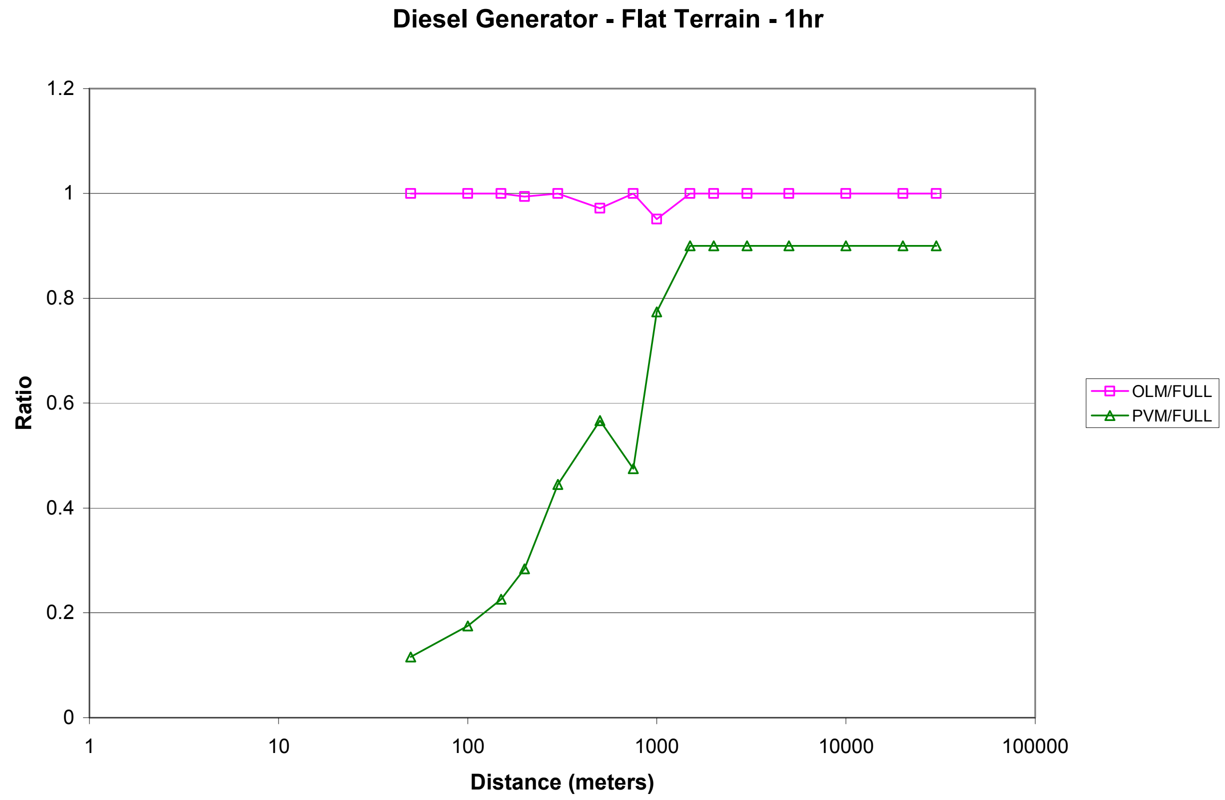
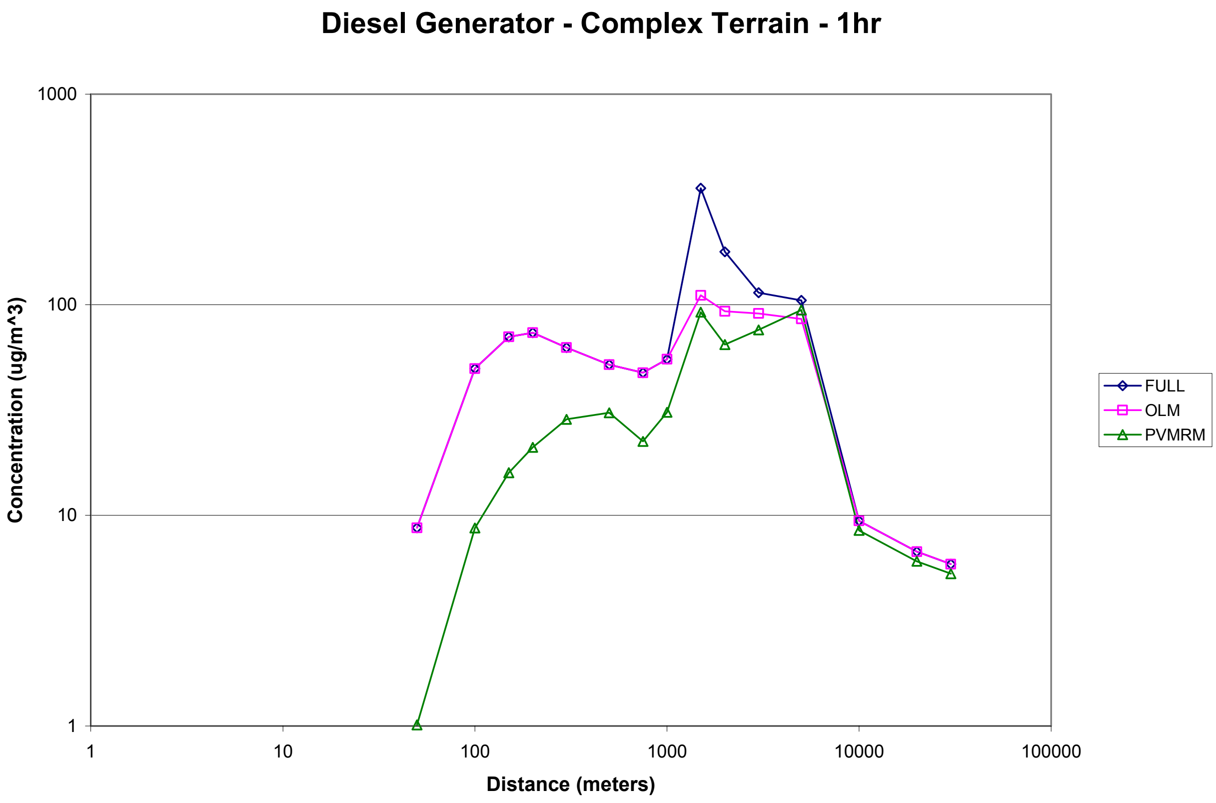


Figure 3.22. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Flat Terrain



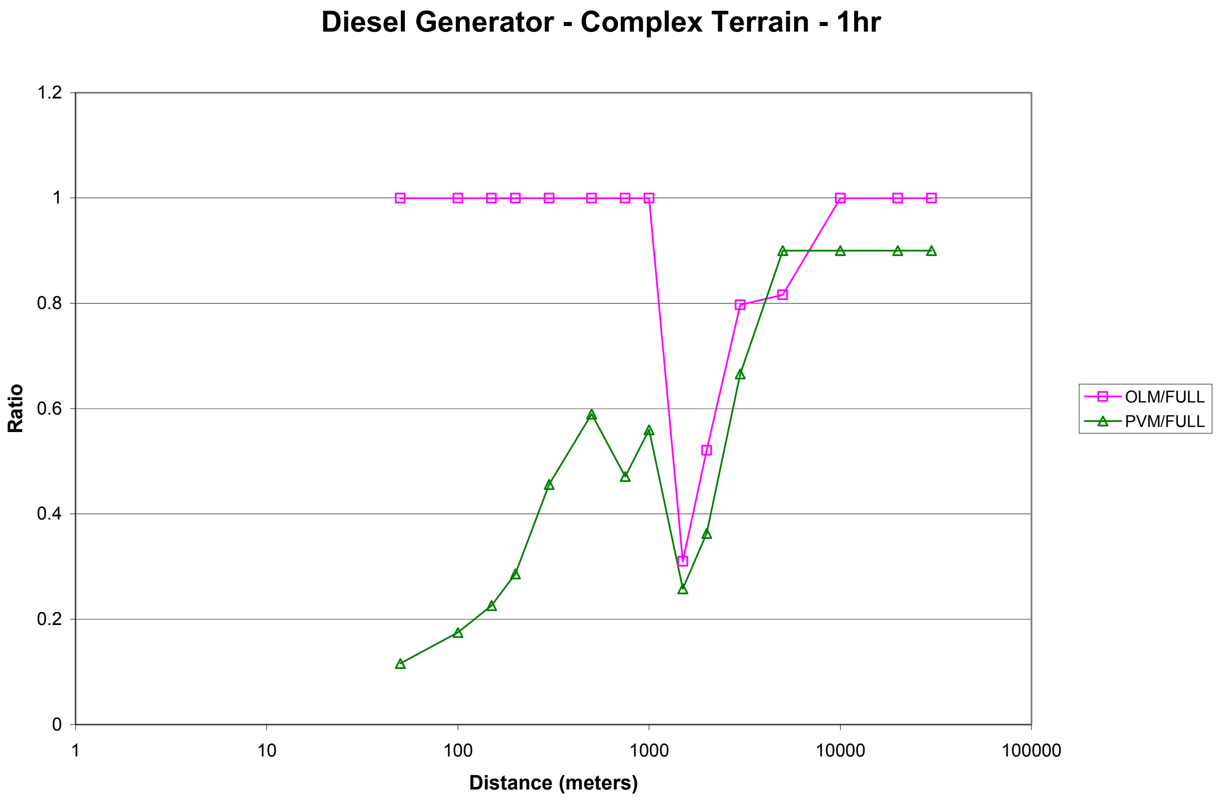
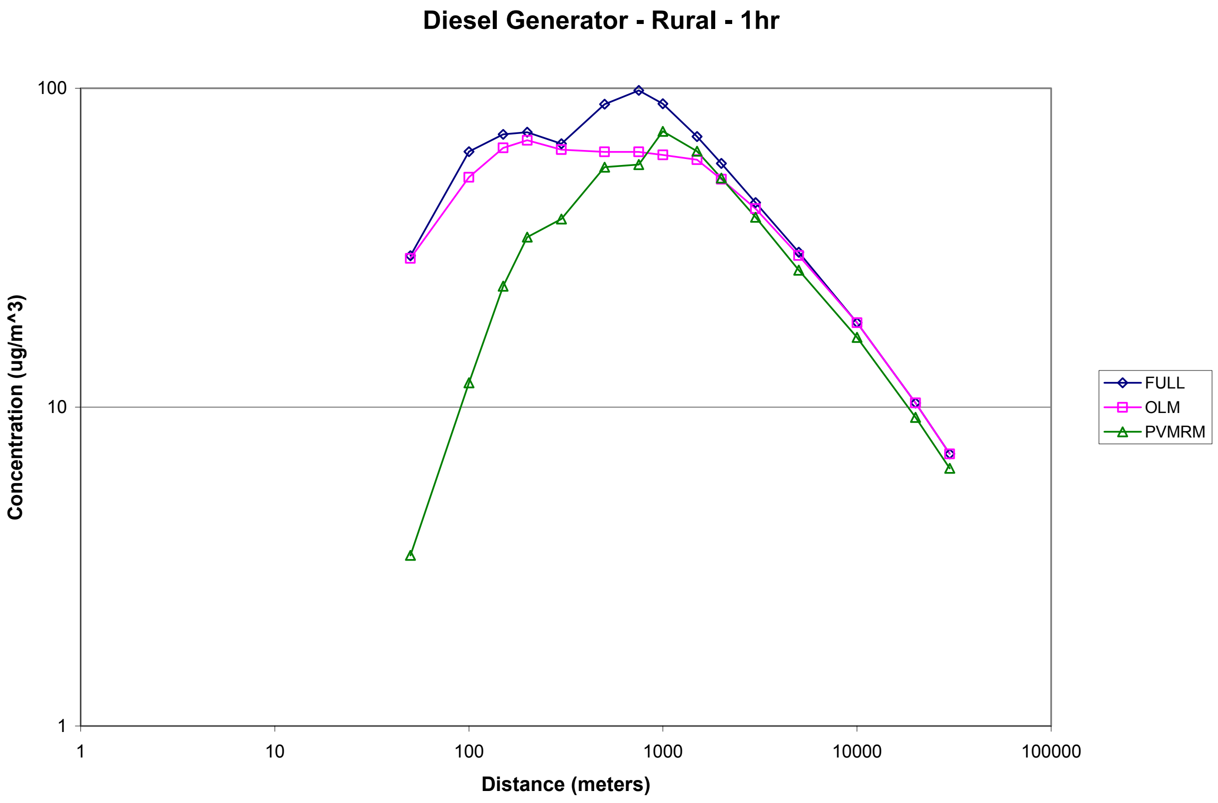


Figure 3.23. 1-Hour Average NO_2 Concentration (μg/m^3) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Complex Terrain



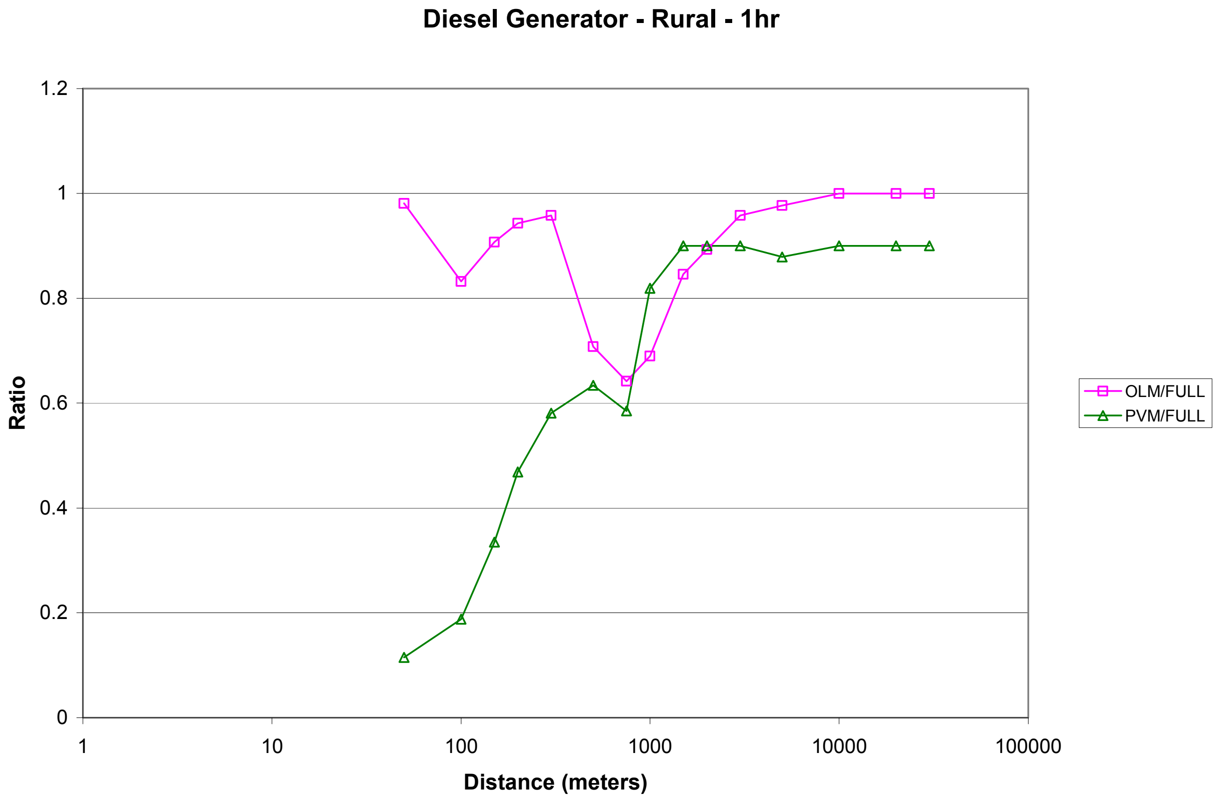


Figure 3.24. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Rural Dispersion

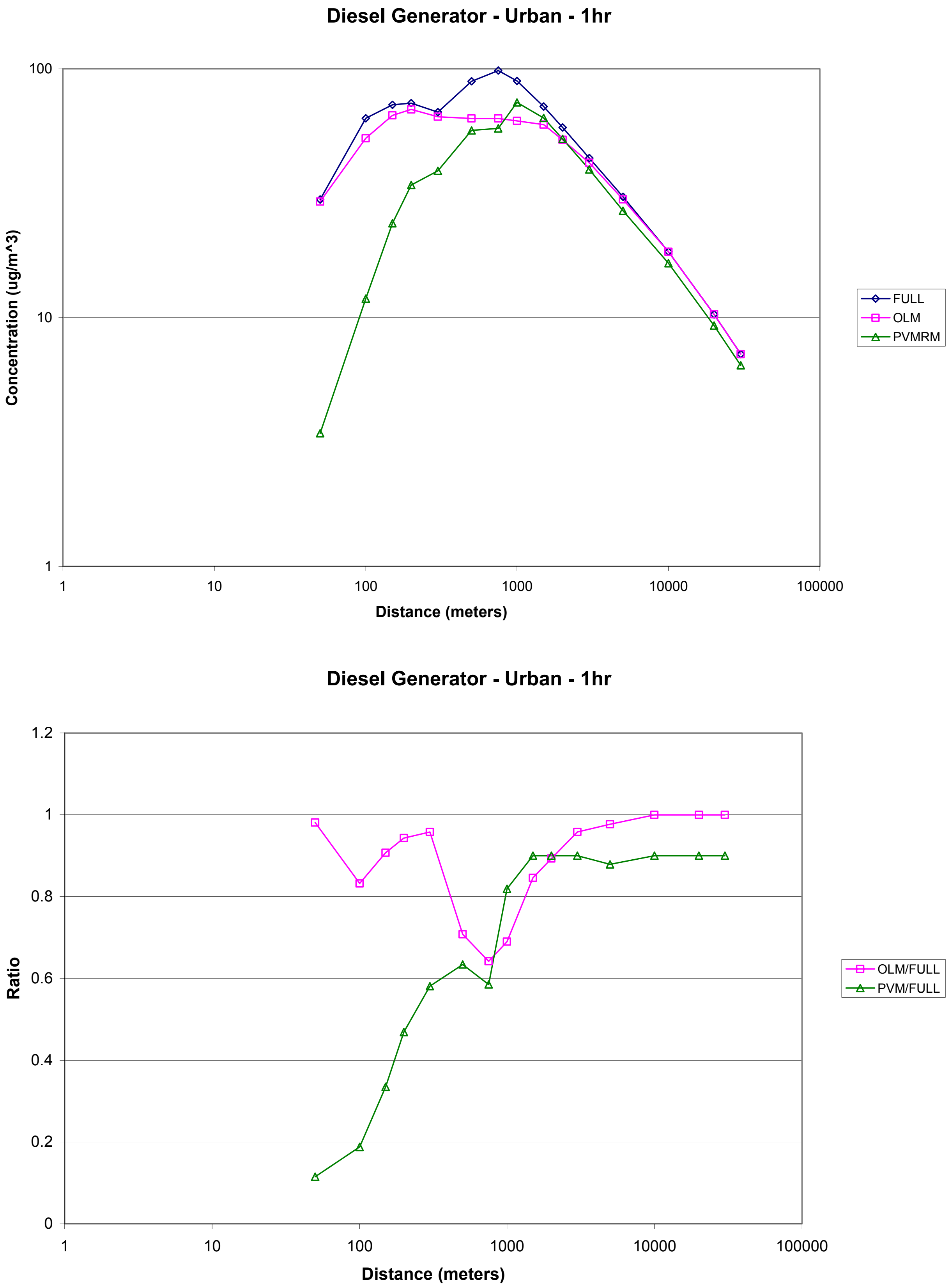
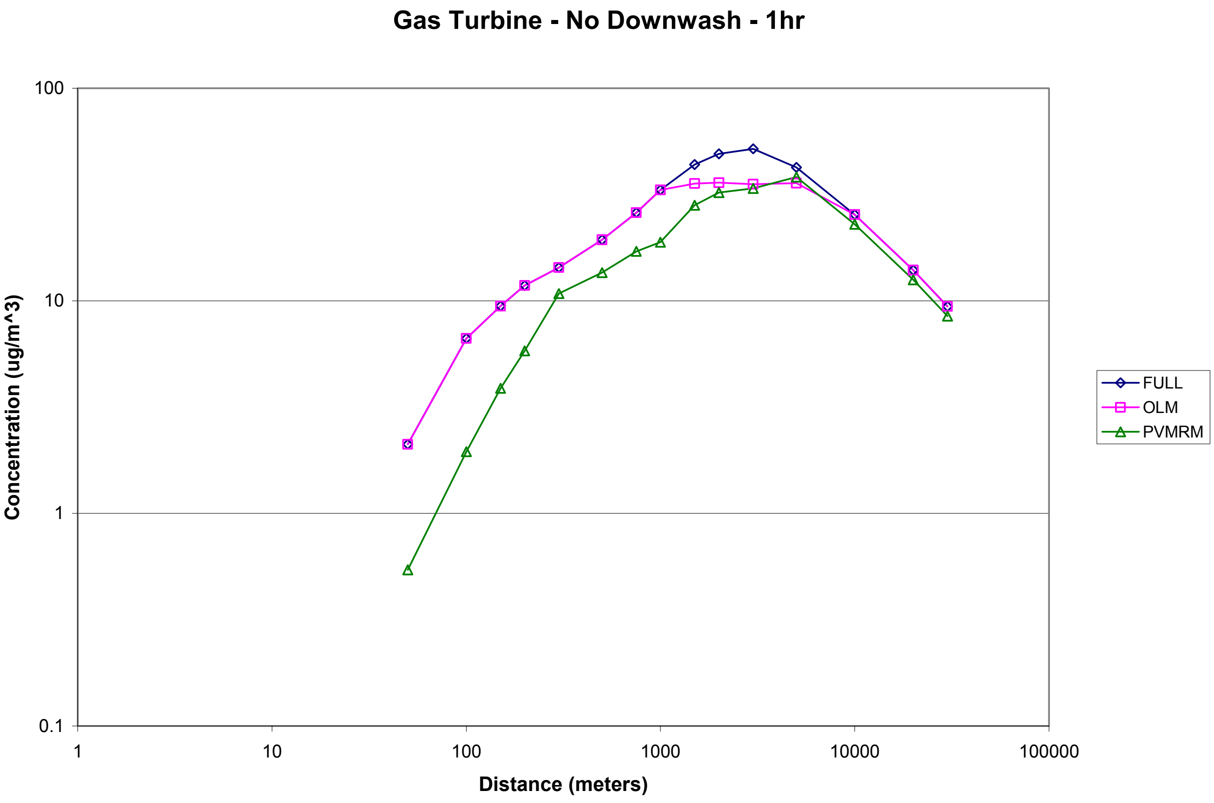


Figure 3.25. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Diesel Generator Source with Urban Dispersion



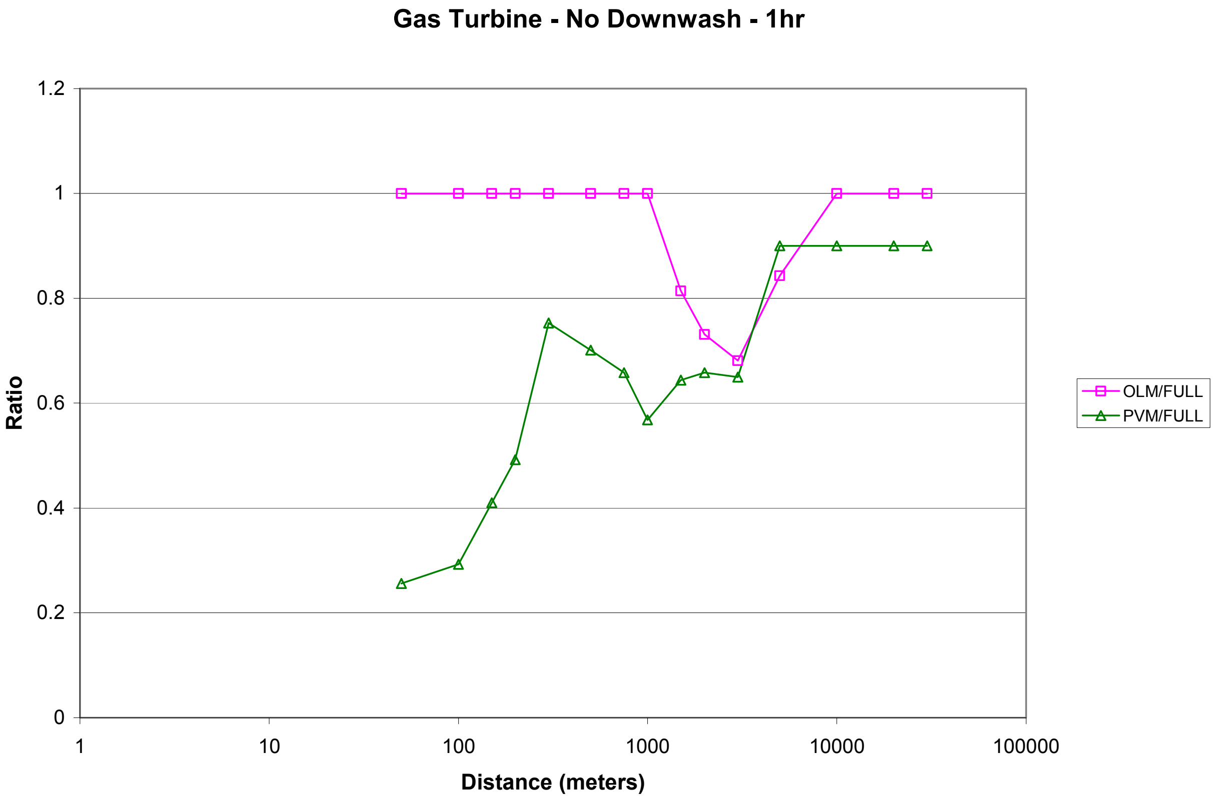
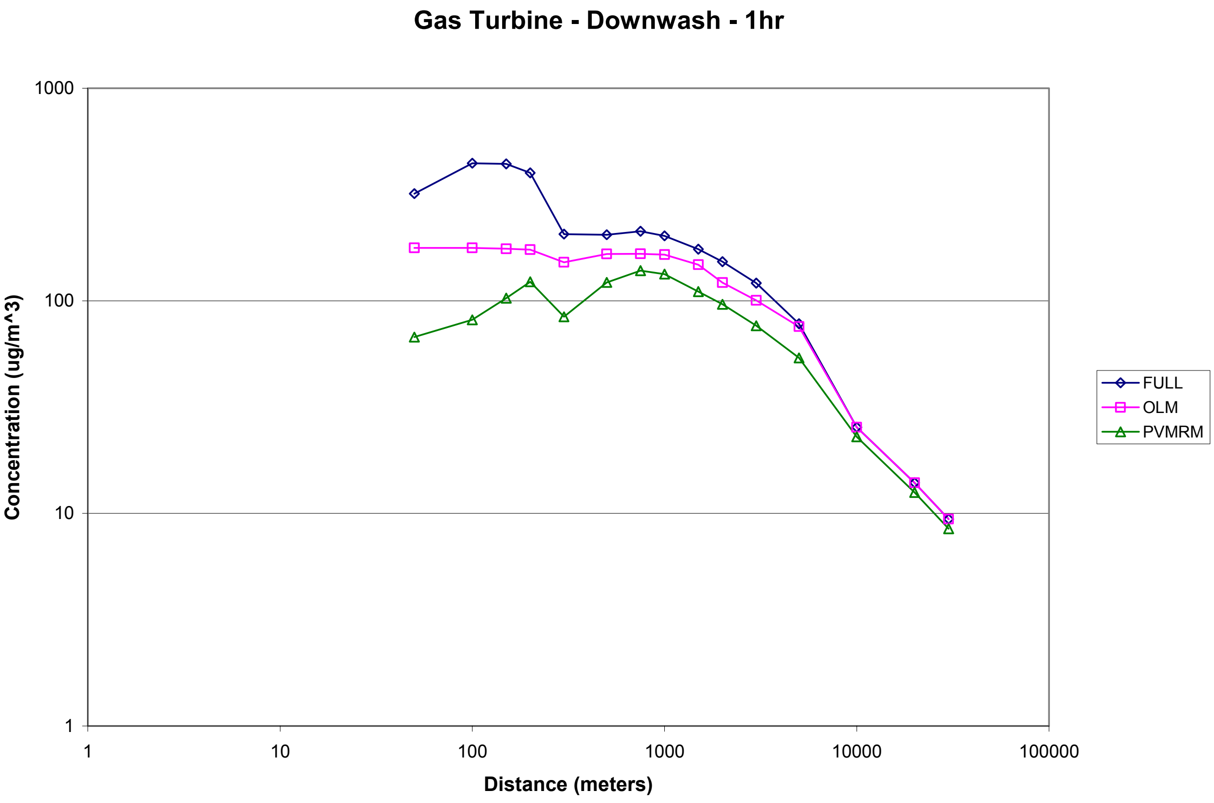


Figure 3.26. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with No Downwash



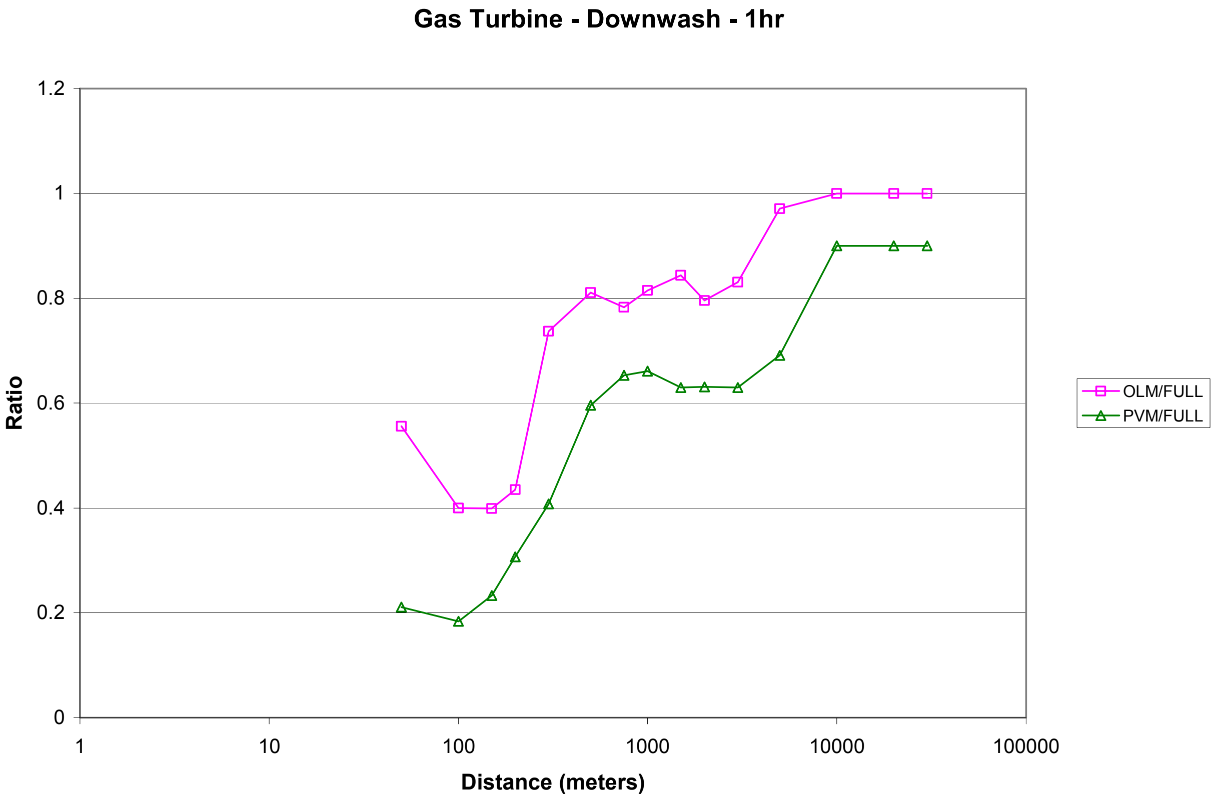
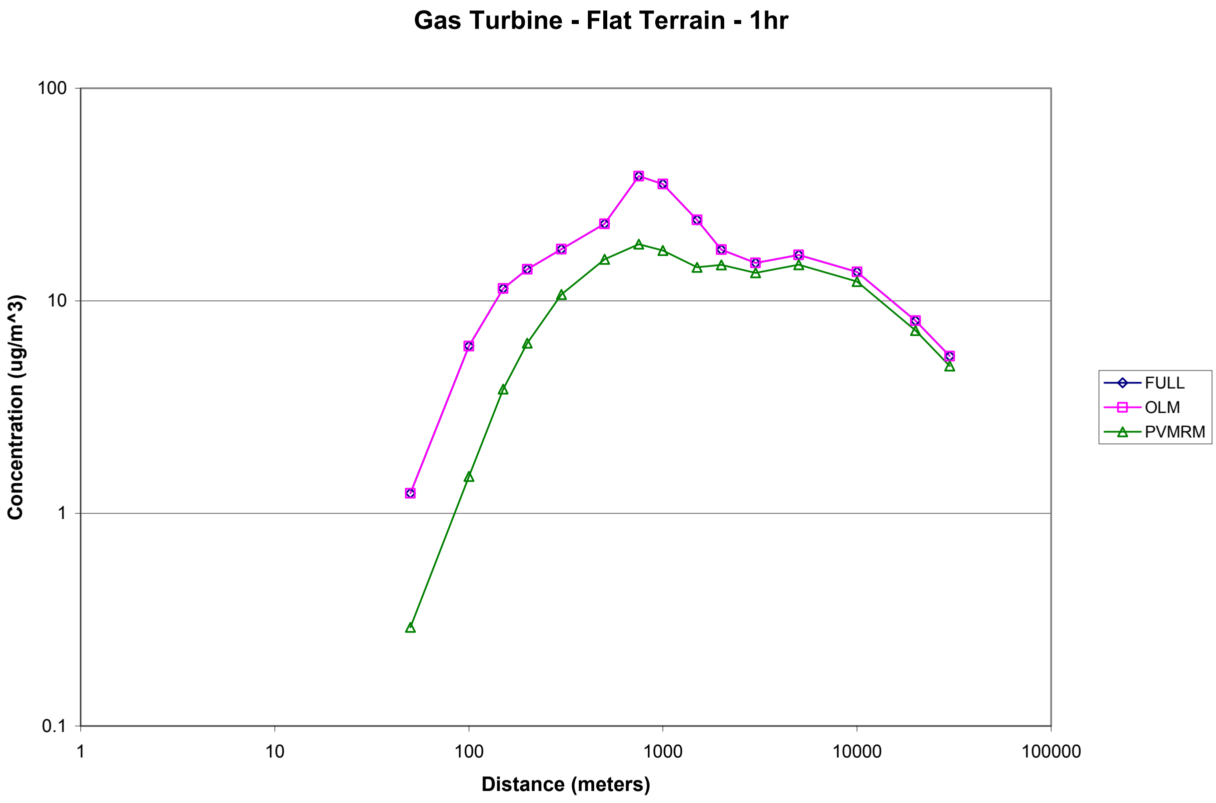


Figure 3.27. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Downwash



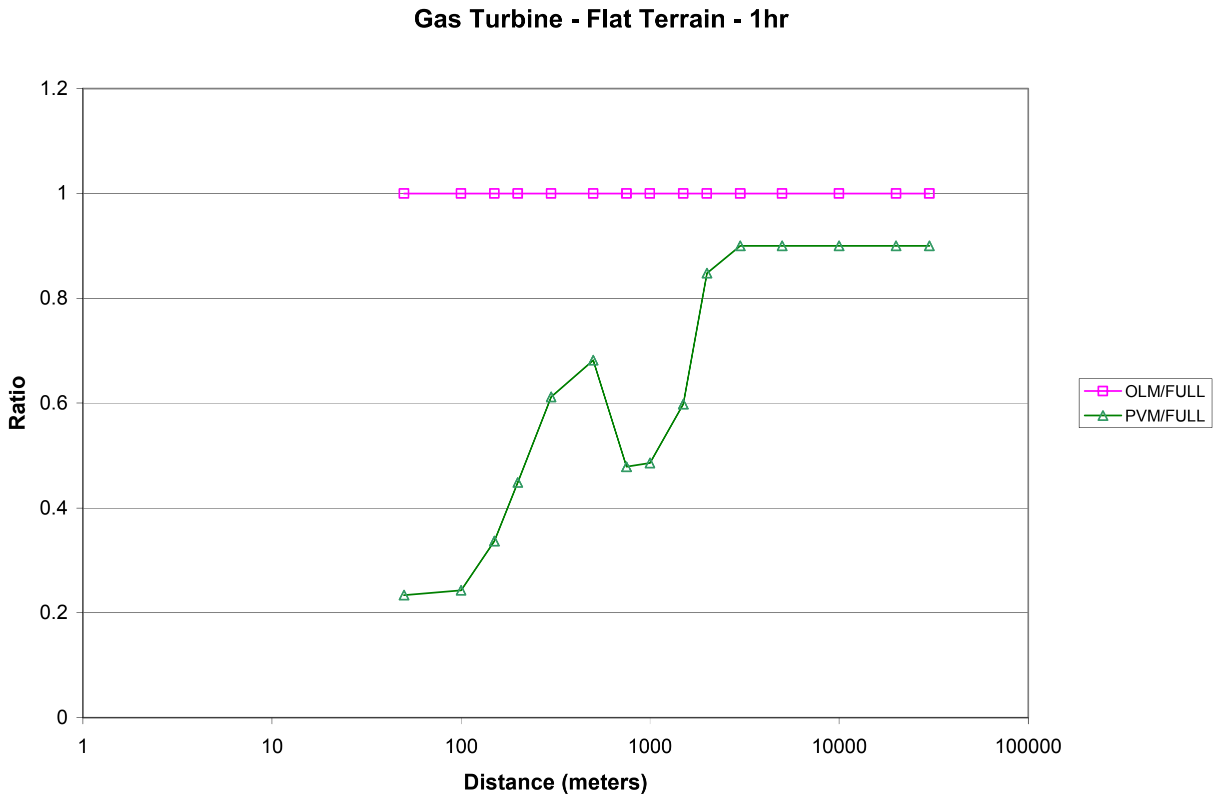
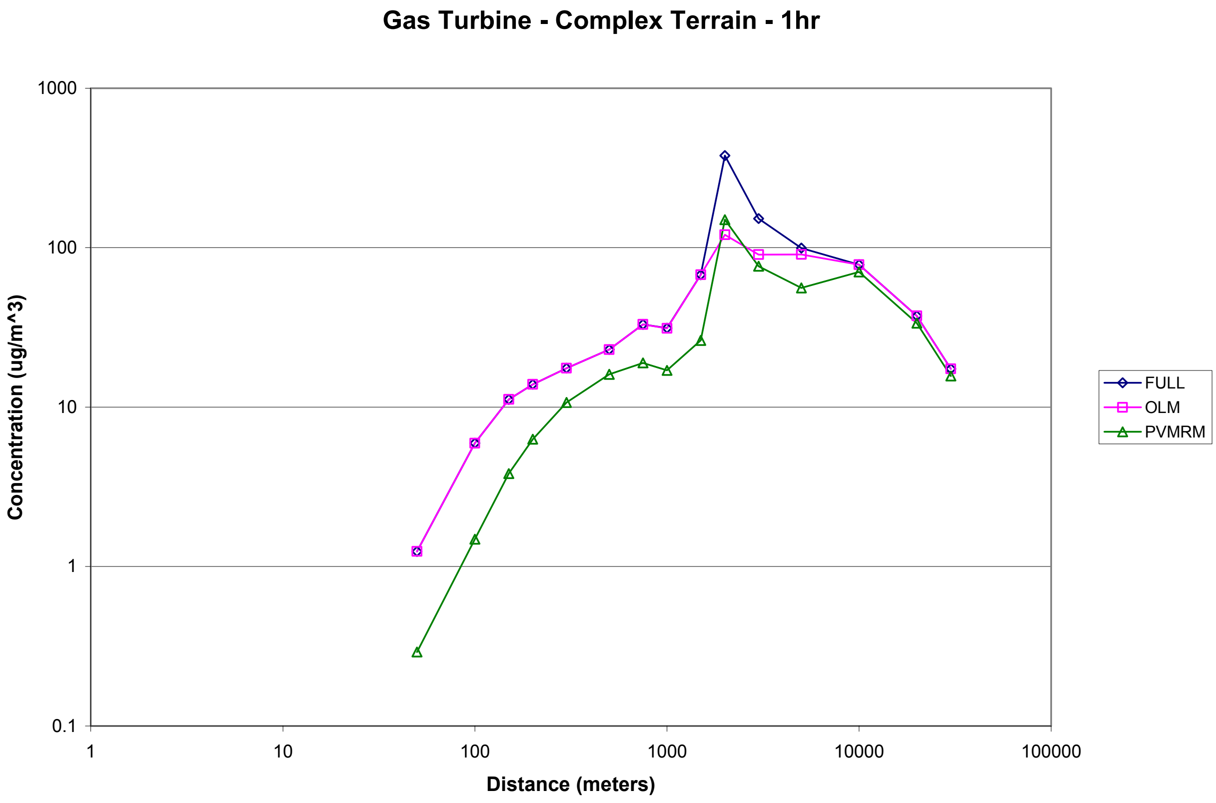


Figure 3.28. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Flat Terrain



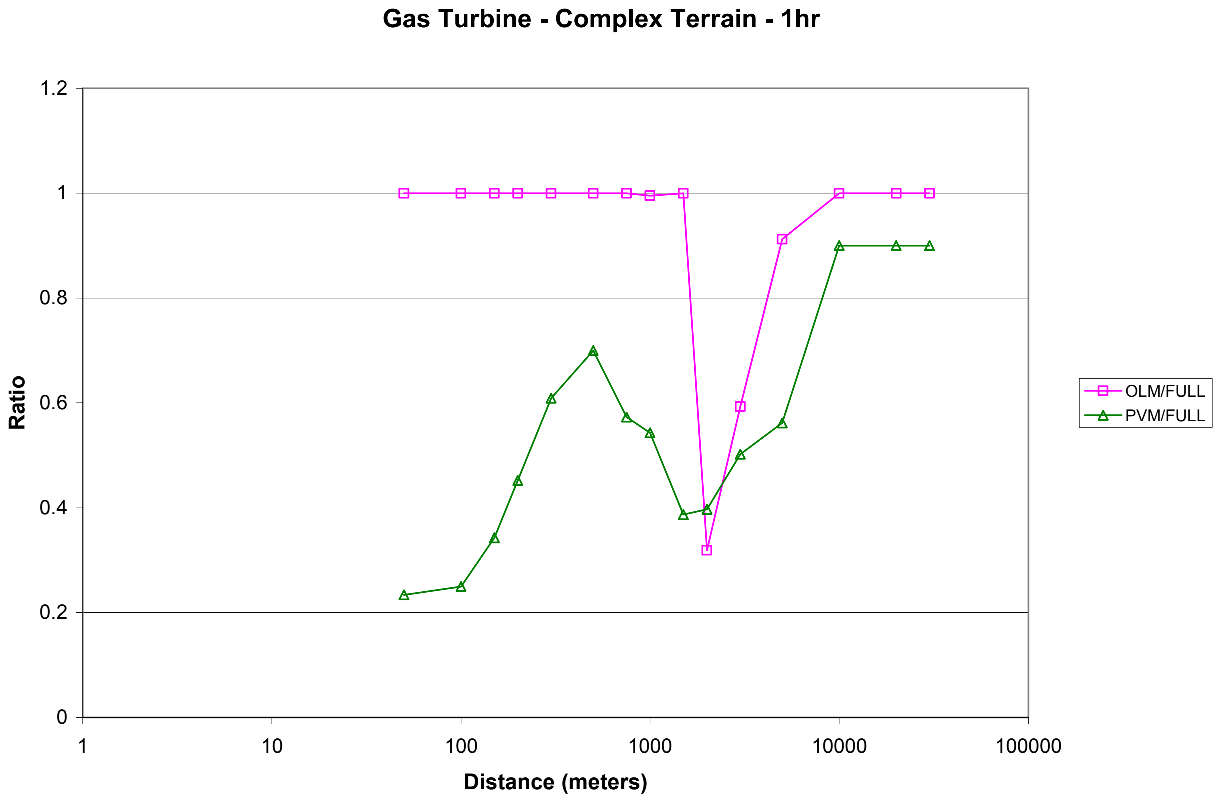
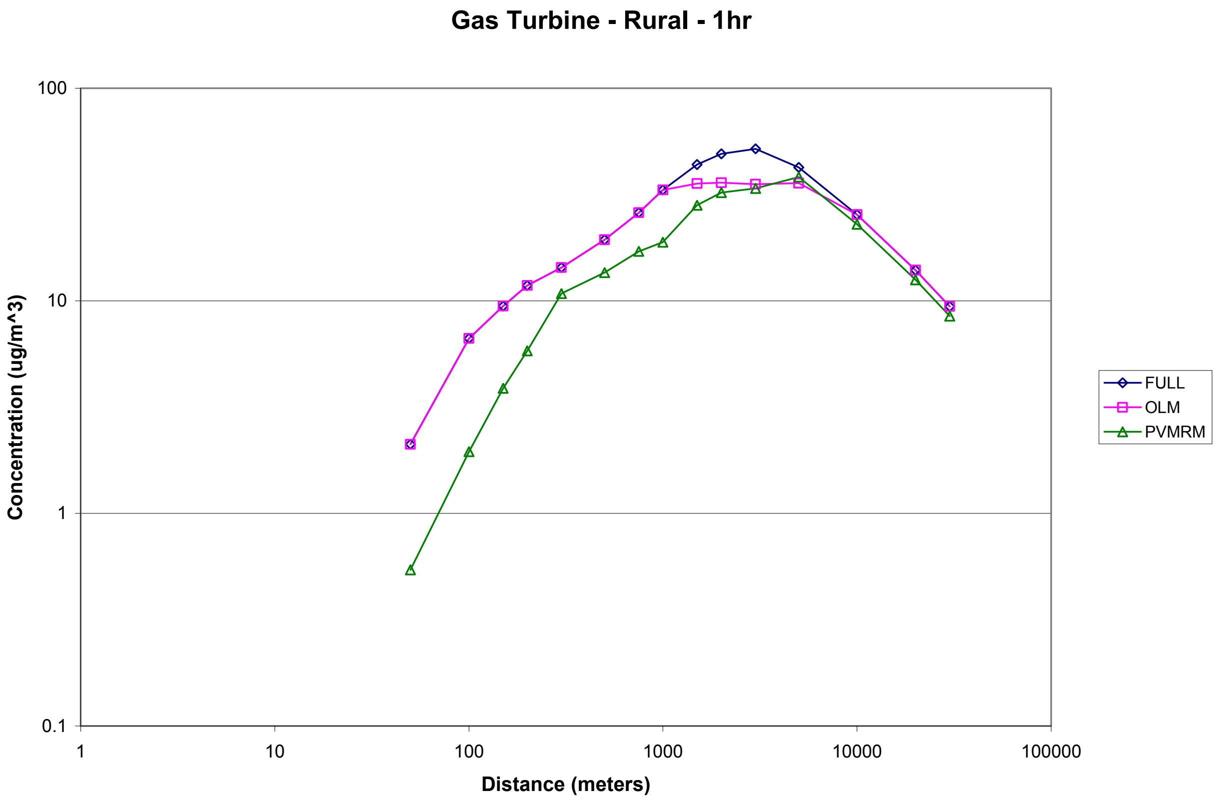


Figure 3.29. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Complex Terrain



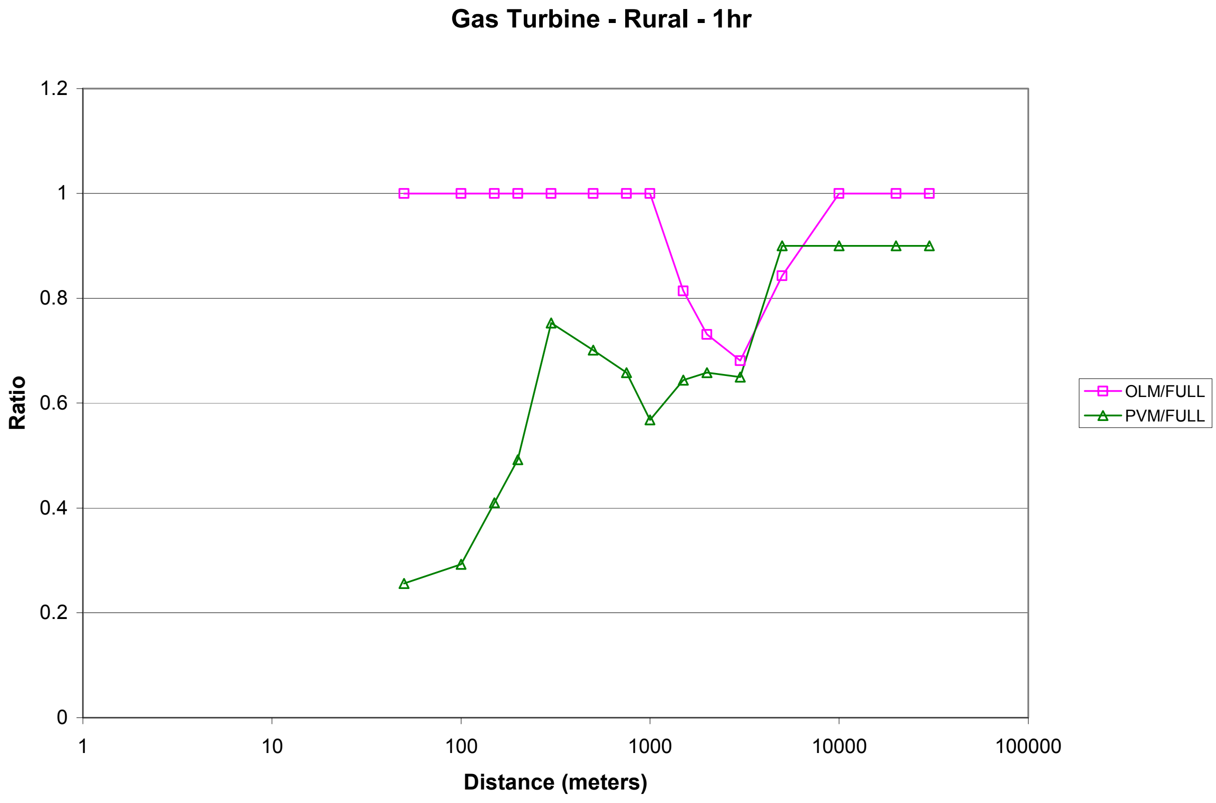
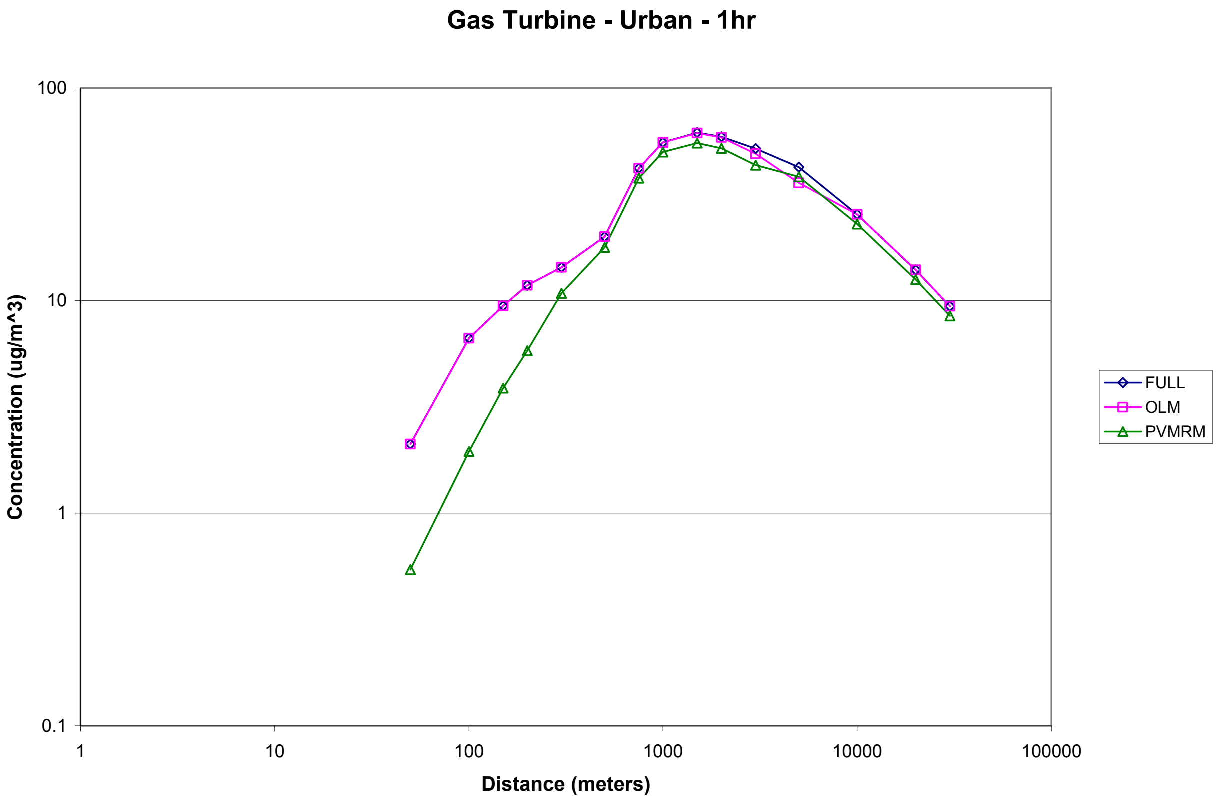


Figure 3.30. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Rural Dispersion



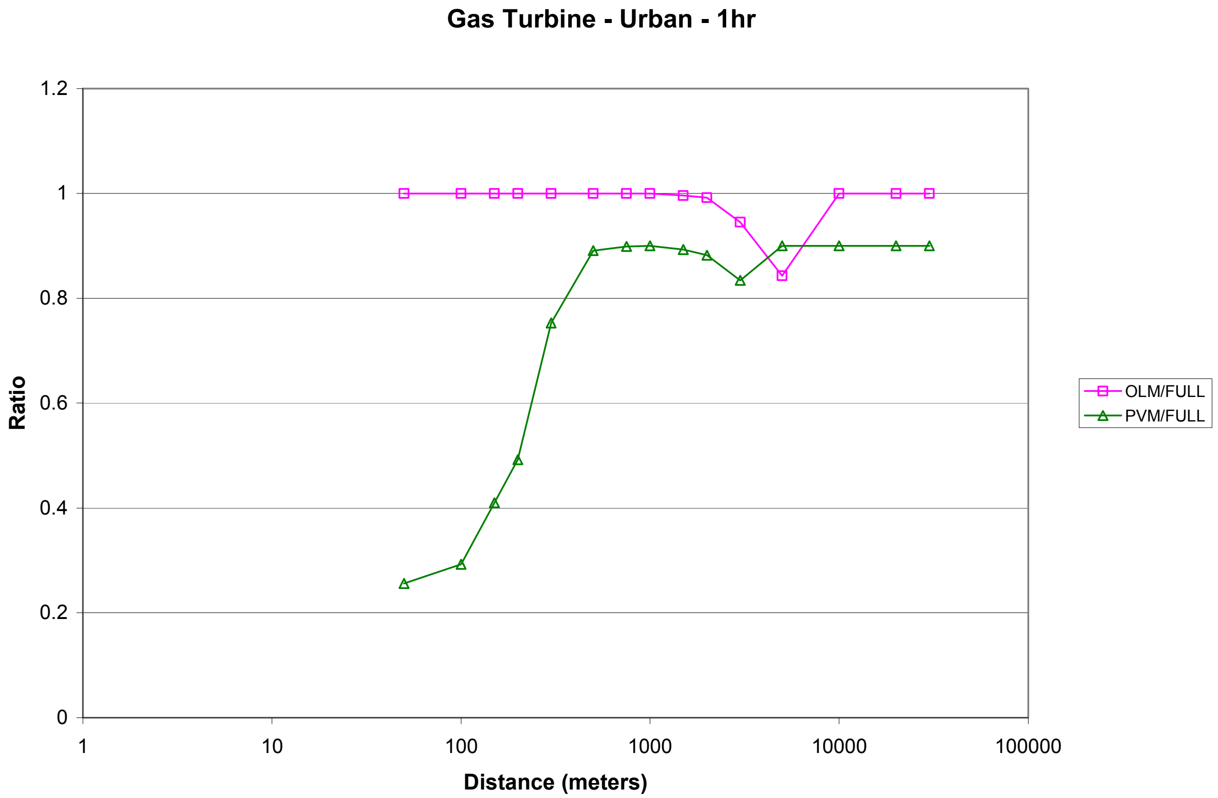
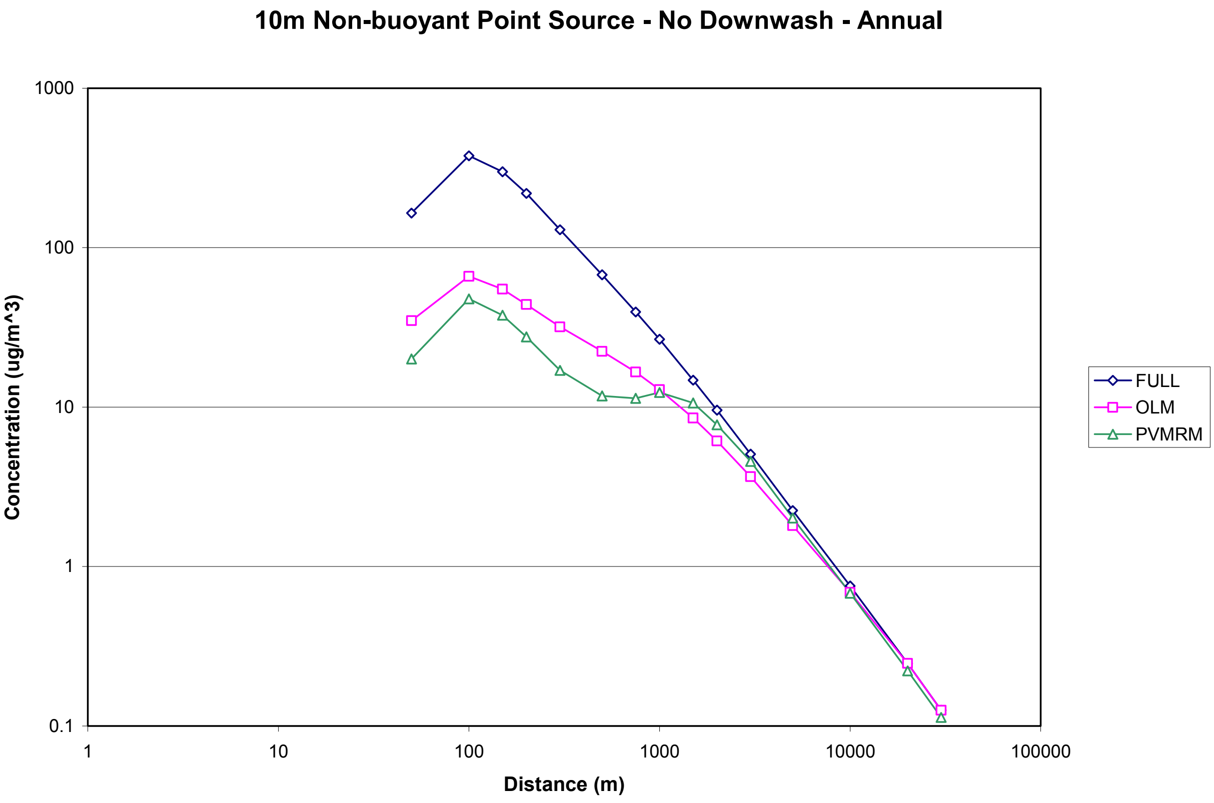


Figure 3.31. 1-Hour Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for Gas Turbine Source with Urban Dispersion



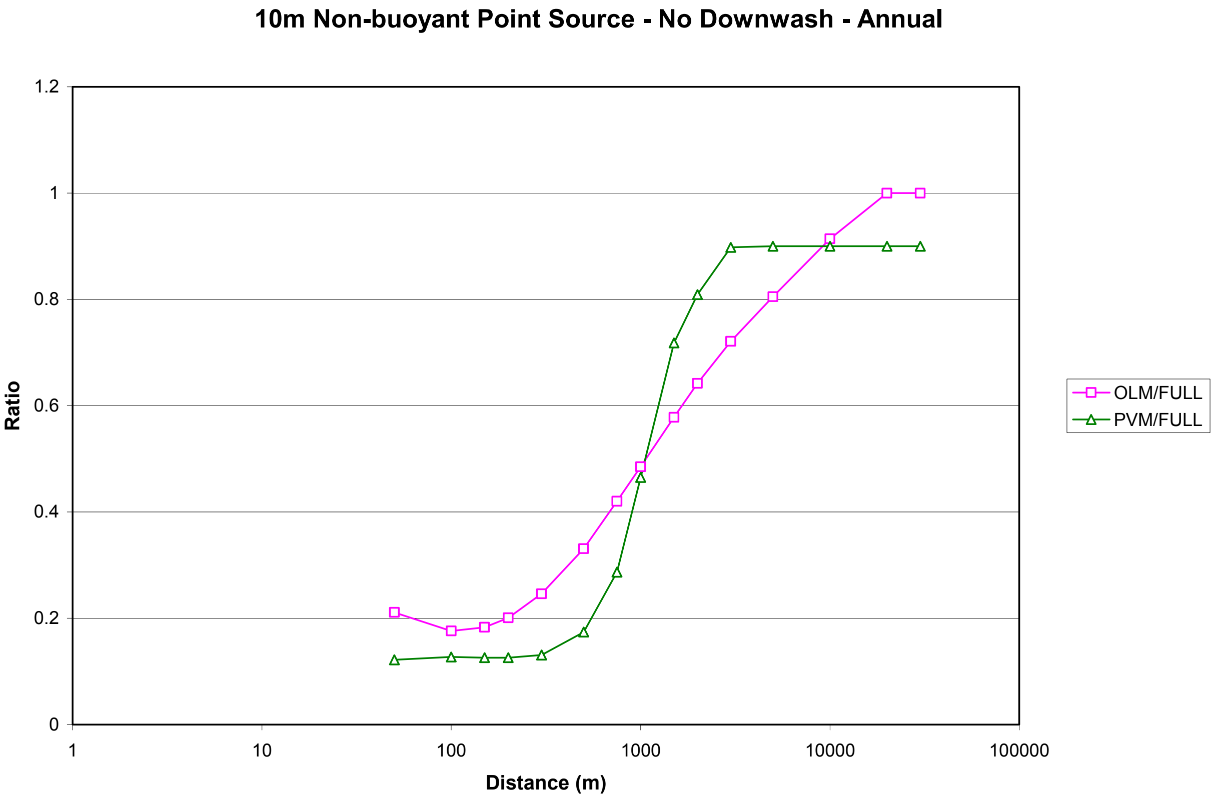


Figure 3.32. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 10m Non-buoyant Point Source

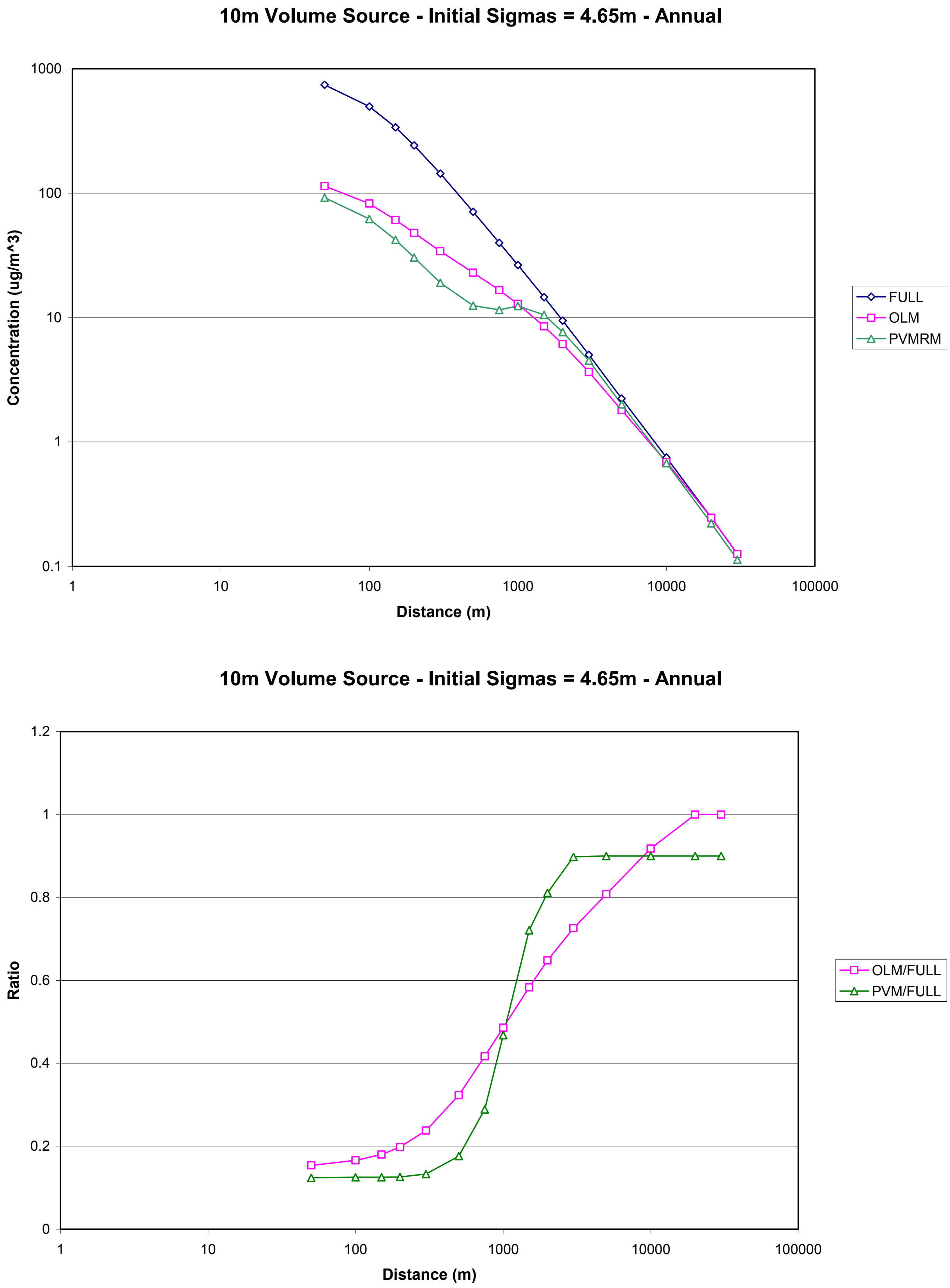
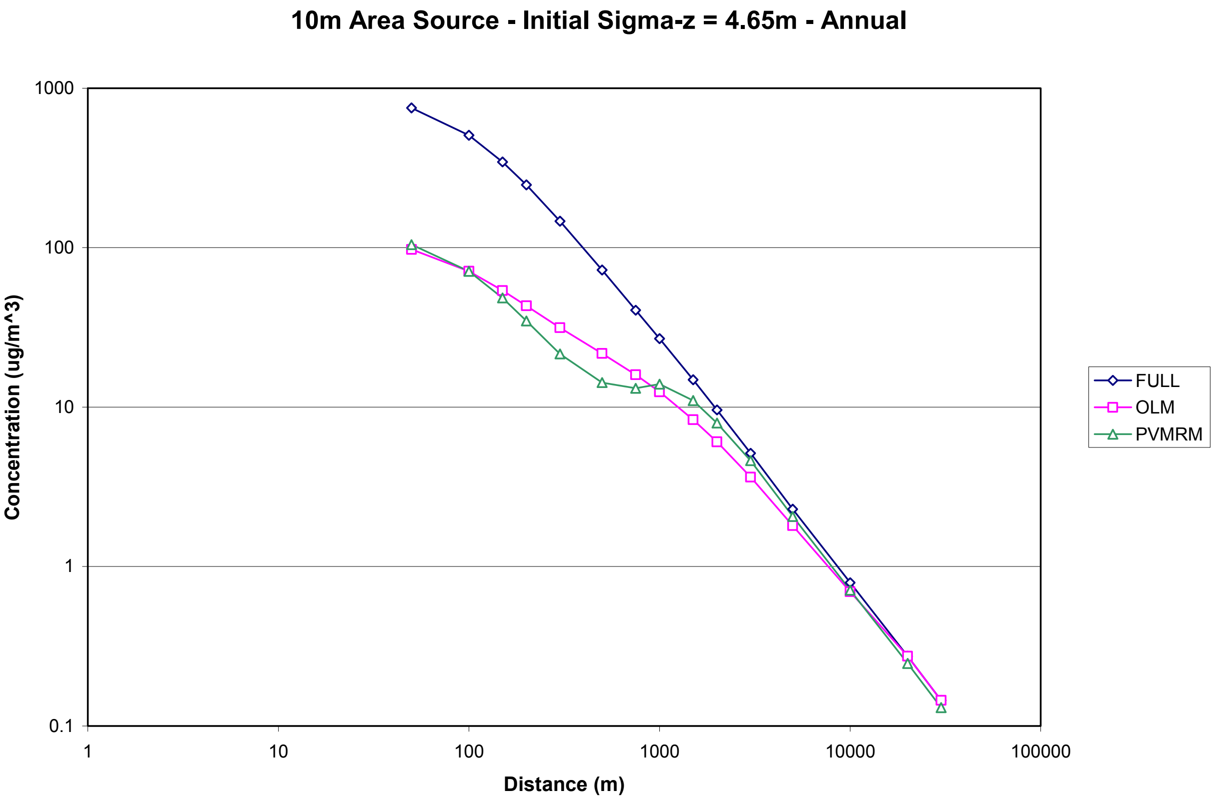


Figure 3.33. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 10m Volume Source with Initial Sigmas=4.65m



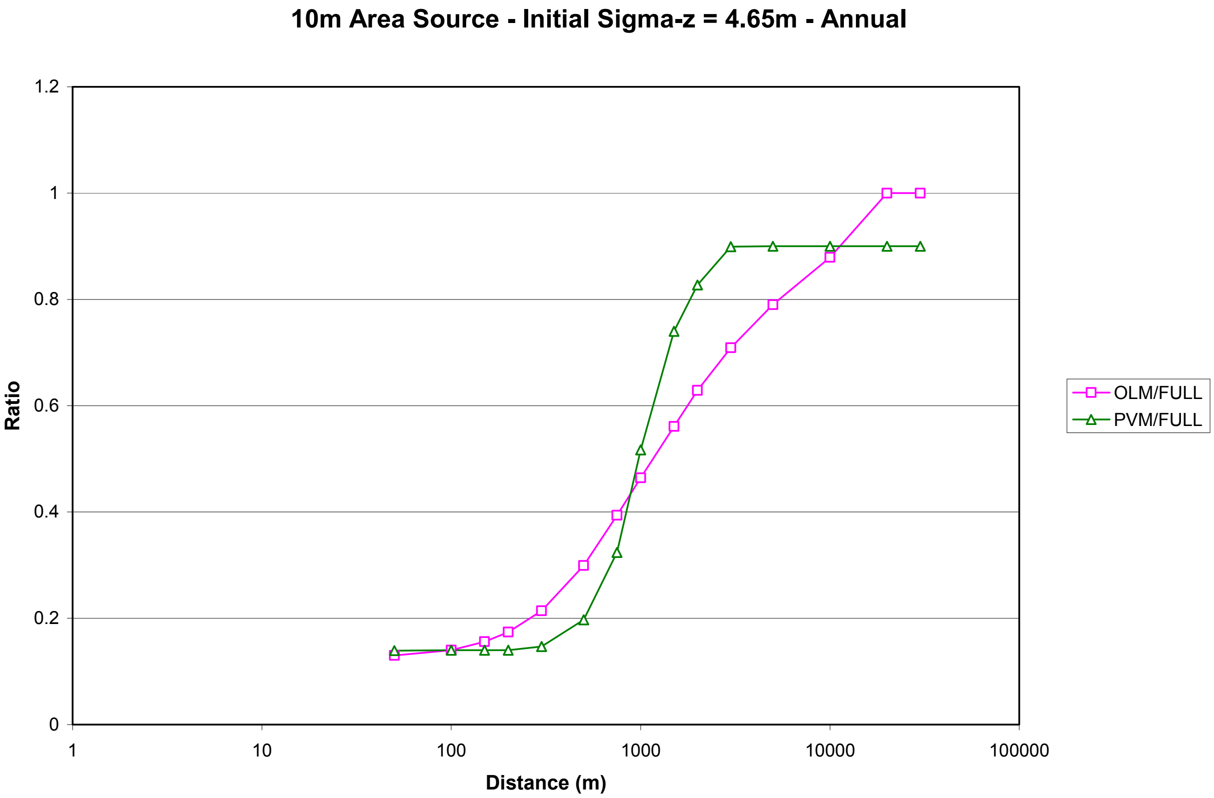


Figure 3.34. Annual Average NO_2 Concentration ($\mu g/m^3$) vs. Downwind Distance (top) and Conversion Ratio (bottom) for 10m Area Source with Initial Sigma-z=4.65m

4.0 SUMMARY AND CONCLUSIONS

This report presents results of a sensitivity analysis of the PVMRM and OLM options for NO_x to NO_2 conversion in the AERMOD dispersion model. Several single source scenarios were examined as well as a multiple-source scenario. The average conversion ratios of NO_2/NO_x for the PVMRM option tend to be lower than for the OLM option and for the Tier 2 option of 0.75 ARM. The sensitivity of the PVMRM and OLM options to emission rate, source parameters and modeling options appear to be reasonable and are as expected based on the formulations of the two methods. For a given NO_x emission rate and ambient ozone concentration, the NO_2/NO_x conversion ratio for PVMRM is primarily controlled by the volume of the plume, whereas the conversion ratio for OLM is primarily controlled by the ground-level NO_x concentration.

Overall the PVMRM option appears to provide a more realistic treatment of the conversion of NO_x to NO_2 as a function of distance downwind from the source than OLM or the other NO_2 screening options (Hanrahan, 1999a; Hanrahan, 1999b). No anomalous behavior of the PVMRM or OLM options was identified as a result of these sensitivity tests.

5.0 REFERENCES

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Hanrahan, P.L., 1999a. "The plume volume molar ratio method for determining NO_2/NO_x ratios in modeling. Part I: Methodology," *J. Air & Waste Manage. Assoc.*, **49**, 1324-1331.

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