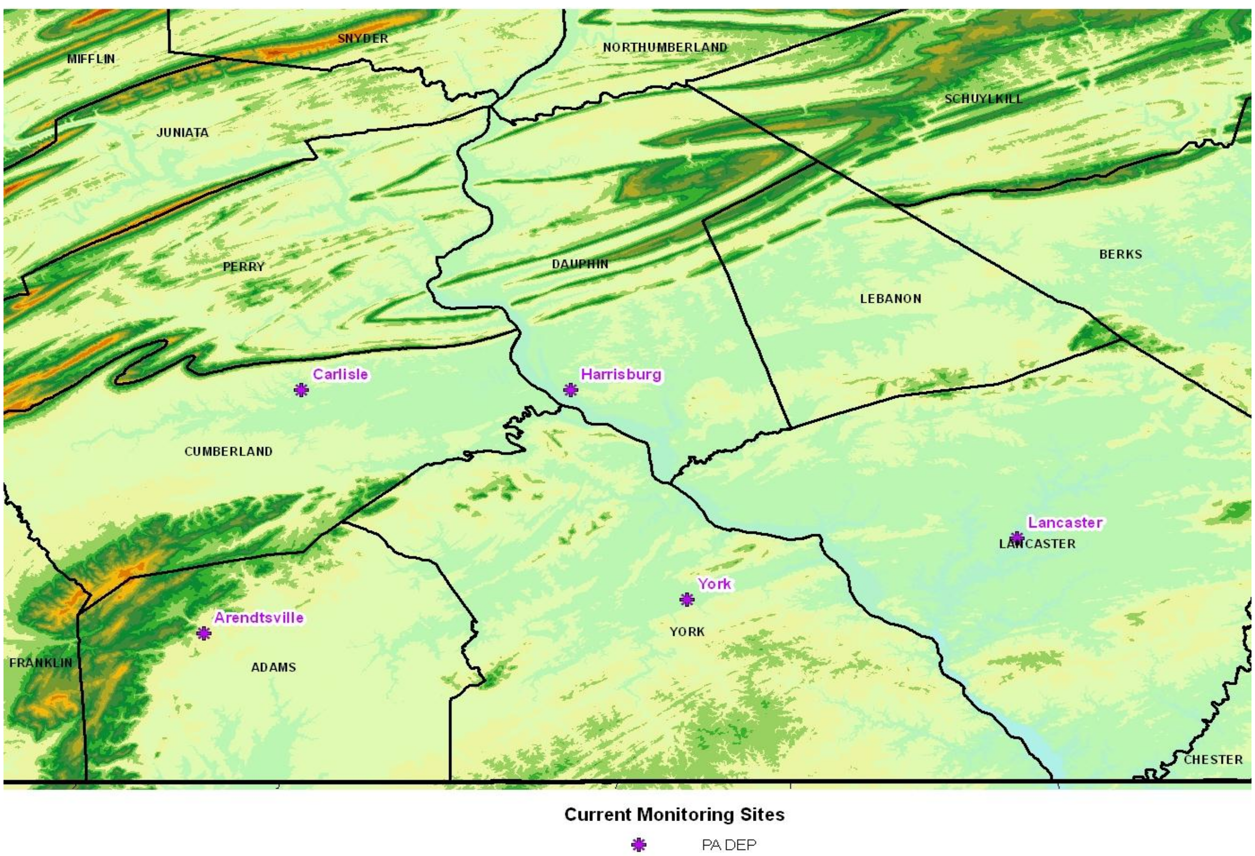
Appendix C-3
LANCASTER COUNTY AREA

The Department is recommending a Lancaster County annual $PM_{2.5}$ NAAQS nonattainment area consisting of Lancaster County. The Department completed an analysis of the $PM_{2.5}$ ambient air quality data, which outlines the reason for recommending an area consisting of only Lancaster County. This analysis is provided below.

Analysis of the Ambient $PM_{2.5}$ Data – A Design Value Contribution Analysis

Based on EPA-certified 2012 $PM_{2.5}$ design values, one monitor in the Lancaster metropolitan statistical area (MSA) is violating the 2012 $PM_{2.5}$ annual standard of 12 µg/m^3. The monitor and its design value are: Lancaster (AIRS # 42-071-0007) at 12.1 µg/m^3 (in Lancaster County). Figure C-3.1 is a map outlining the location of this monitor, along with monitors in attainment in the vicinity of the Lancaster County area.

Figure C-3.1: Lancaster Area $PM_{2.5}$ Monitoring Map



The Department has completed a design value contribution analysis for all of the $PM_{2.5}$ monitors in the proximity of the Lancaster monitor. The analysis attempts to determine the daily contribution of $PM_{2.5}$ concentrations to the annual $PM_{2.5}$ design value. Daily $PM_{2.5}$ measurements were grouped into different $PM_{2.5}$ concentration ranges. An analysis of each range's contribution was then conducted to determine which measurements are contributing to the monitor's design value. Dates of these measurements were then further analyzed to determine if there are specific meteorological conditions or sources that are adversely impacting the monitor's design value.

Results from the design value contribution analysis for the Lancaster County area are summarized in Table C-3.1. Ultimately, the type of contribution a given monitor's daily value had on the 3-year design value (by comparing this value to 12 $\mu g/m^3$) was determined. The daily value for each day a monitor measured $PM_{2.5}$ levels was placed in one of the ten categories. For example, on January 8, 2010, the Lancaster monitor's 24-hour $PM_{2.5}$ average was 24 $\mu g/m^3$. Since this value falls in the 18-24 $\mu g/m^3$ category in Table C-3.1, the calculated daily contribution to the design value was placed in this category. In the first quarter of 2010 (January 1 to March 31), the Lancaster monitor recorded 80 measurements. The Department determined that the January 8, 2010, contribution assessment to the 2012 design value was 0.0125 $\mu g/m^3$. The 0.0125 $\mu g/m^3$ was calculated by dividing the average daily value of 24 $\mu g/m^3$ by a factor of the number of measurements for the quarter (80) by 12 (there are a total of 12 quarters in a 3-year design value period). This type of analysis was completed for every day of measurements from January 1, 2010, through December 31, 2012. In Table C-3.1, the sum of the categorical breakdowns for the Lancaster monitor equals 0.11 $\mu g/m^3$, which demonstrates that the design value is 0.11 $\mu g/m^3$ above the annual standard of 12 $\mu g/m^3$.

Table C-3.1: Lancaster Area
2012 $PM_{2.5}$ Annual Design Value Contribution Analysis

Site Name	Site ID	Owner	0 - 6.0	6.0 - 12.0	12.0 - 18.0	18.0 - 24.0	24.0 - 30.0	30.0 - 36.0	36.0 - 42.0	42.0 - 48.0	48.0 - 54.0	54.0 - 60.0	Sum
Monitors Attaining 2012 PM 2.5 Standard													
Carlisle	420410101	PA DEP	-2.2671	-1.0983	0.5772	0.8099	0.4437	0.3272	0.1197	0.0620	0.0000	0.0000	-1.0257
Arendtsville	420010001	PA DEP	-1.5064	-1.2343	0.5945	0.9867	0.4176	0.3170	0.0540	0.0000	0.0000	0.0000	-0.3710
York	421330008	PA DEP	-1.4100	-1.3579	0.6939	0.9591	0.4741	0.2743	0.0234	0.0000	0.0000	0.0000	-0.3431
Harrisburg	420430401	PA DEP	-1.9733	-1.0485	0.6803	0.9606	0.6412	0.4097	0.1289	0.0301	0.0746	0.0000	-0.0963
Monitors Not Attaining 2012 PM 2.5 Standard													
Lancaster	420710007	PA DEP	-1.6300	-1.1159	0.6843	1.0150	0.5705	0.3273	0.2257	0.0284	0.0000	0.0000	0.1052
Lancaster Regional Average			-1.7574	-1.1710	0.6460	0.9463	0.5094	0.3311	0.1103	0.0241	0.0149	0.0000	

Table C-3.1 illustrates the differences between the monitors that are attaining the 2012 $PM_{2.5}$ annual standard and the monitor that is not attaining the 2012 $PM_{2.5}$ annual standard. The Lancaster monitor has slightly fewer "clean" days (0-12 $\mu g/m^3$) than the monitors that are attaining the standard. For example, the Lancaster monitor's $PM_{2.5}$ contribution to the design value in the 0-12 $\mu g/m^3$ range was 0.18 $\mu g/m^3$ lower than the regional average.

The analysis described in the remainder of this Appendix focuses on the Lancaster monitor because it is the only monitor of concern. Figure C-3.2a illustrates the trend of annual averages while Figure C-3.2b illustrates the trend of annual design values during the period in the Lancaster County area. The Lancaster monitor's $PM_{2.5}$ levels have continued to decline over the last ten years along with the regional monitors' $PM_{2.5}$ levels. The Lancaster monitor's 2012 design value is very close to the 2012 $PM_{2.5}$ annual standard.

Figure C-3.2a: Lancaster Area $PM_{2.5}$ Annual Averages

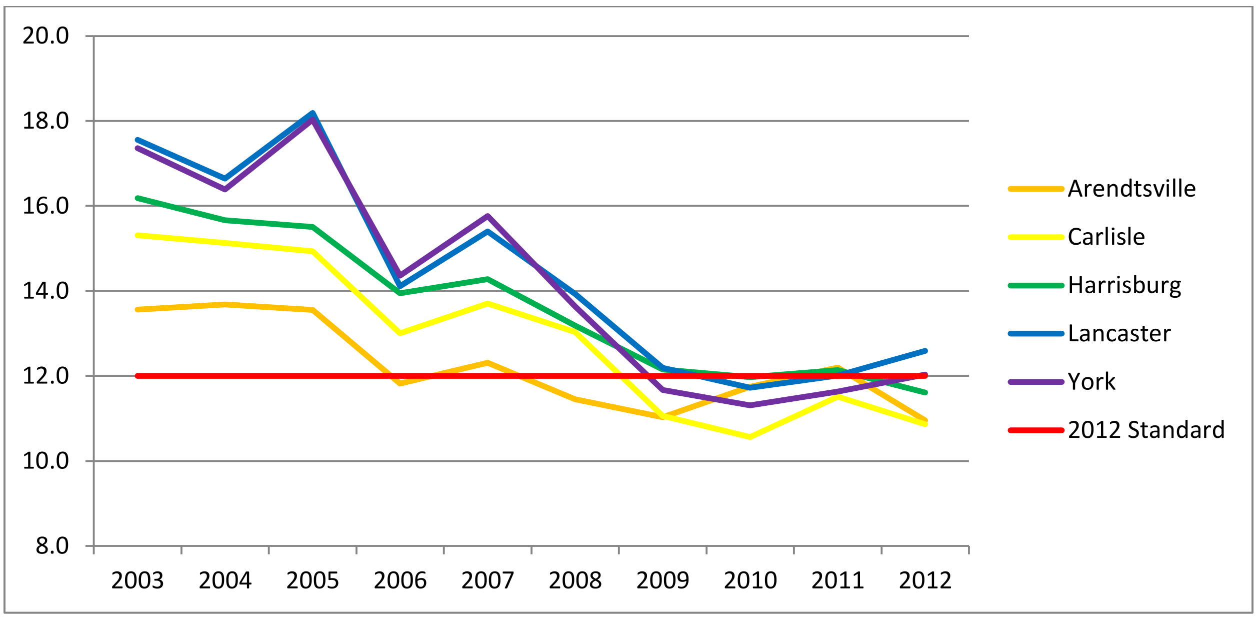
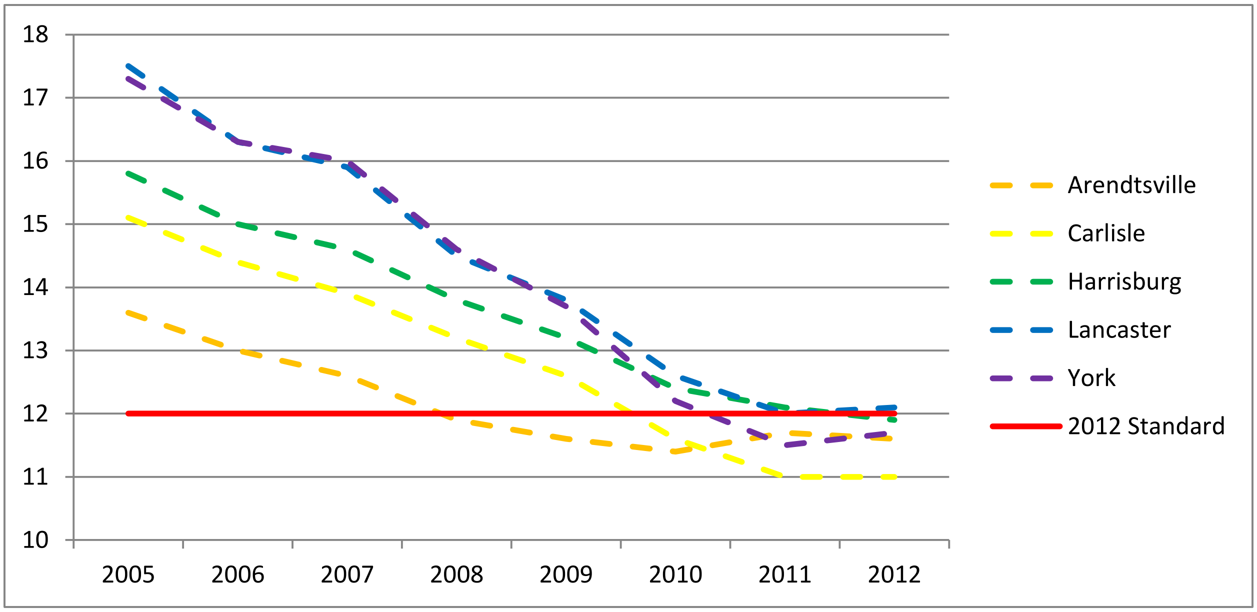


Figure C-3.2b: Lancaster Area $PM_{2.5}$ Annual Design Values



Additional analyses were completed to determine what was contributing to the fewer number of "clean" days at the Lancaster monitor. The Department identified days when the Lancaster monitor's $PM_{2.5}$ concentrations were relatively high but regional monitoring concentrations in the Lancaster area were "clean." Between 2010 and 2012, the Department identified 119 days in which the Lancaster monitor was at least one standard deviation above the regional average while the regional average was at or below 12 µg/m^3. The most extreme events (top 25%) were further analyzed to determine why the Lancaster monitor's concentrations were high when regional concentrations were low.

Meteorological Conditions Impacting High $PM_{2.5}$ Days at the Lancaster Monitor

The top 25% days were examined to determine the reason the Lancaster monitor's concentrations were high. The Lancaster monitor has a collocated meteorological tower that monitors wind direction and wind speed. Figure C-3.3 illustrates the number of hours the wind is coming from a particular direction, while Figure C-3.4 illustrates the total $PM_{2.5}$ concentration coming from a particular direction.

Figure C-3.3: Lancaster Wind Direction Frequency
Top 25% of Regionally "Clean" Days

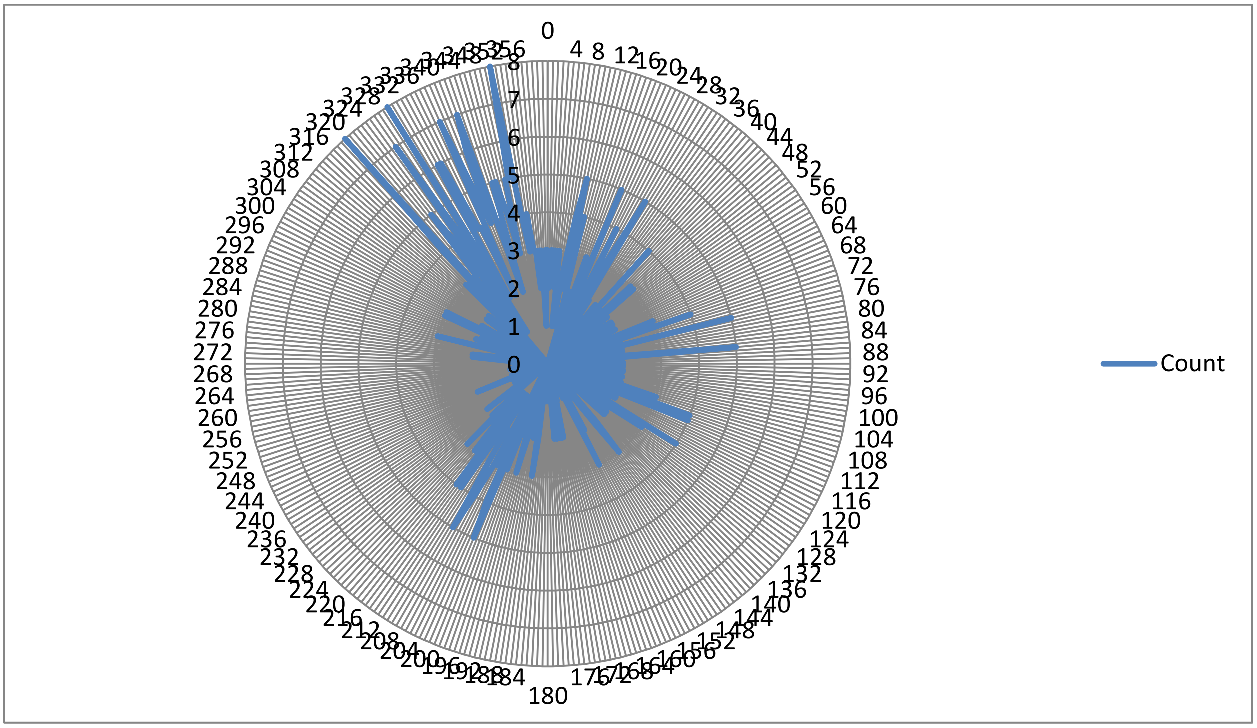


Figure C-3.4: Lancaster $PM_{2.5}$ Concentration Distribution by Wind Direction
Top 25% of Regionally "Clean" Days

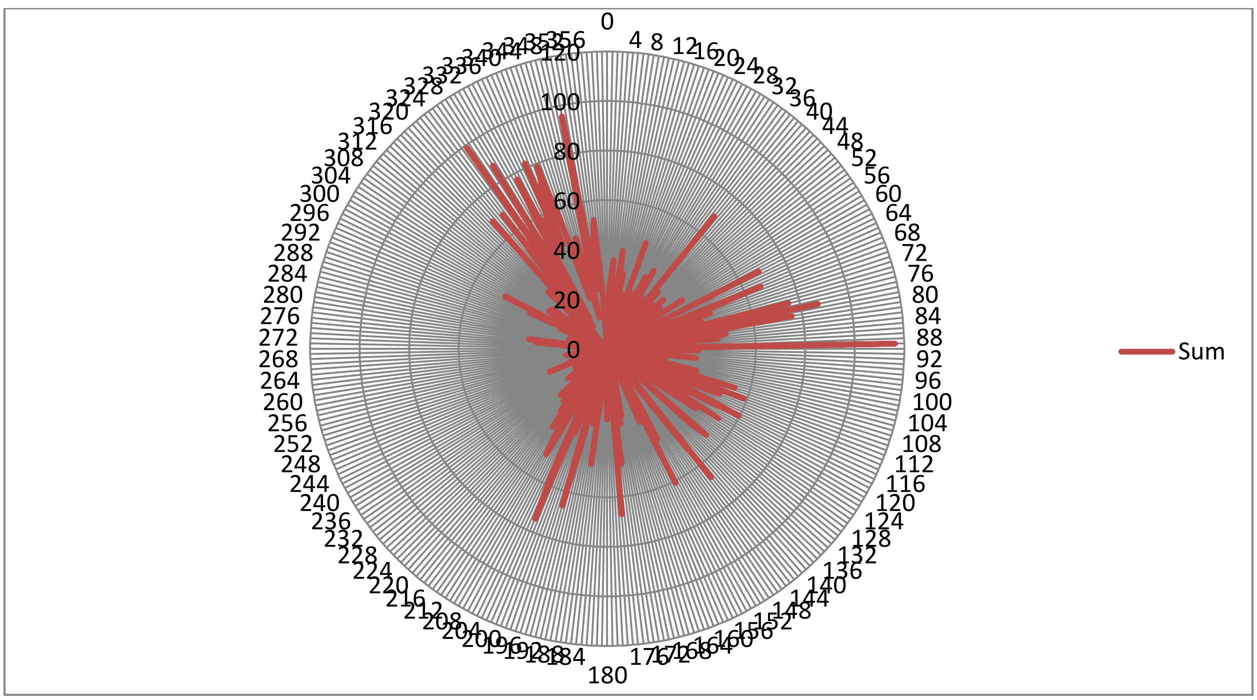
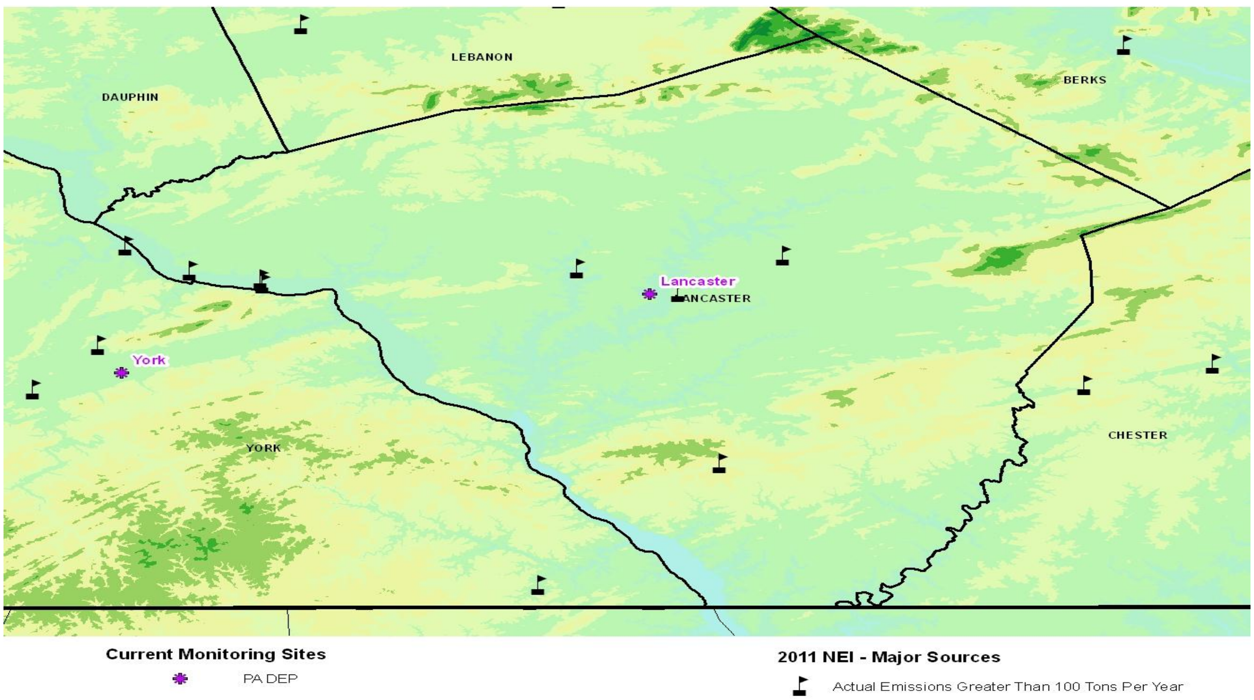


Figure C-3.3 illustrates that the highest frequency of wind distribution on the top 25% days is coming from the east, southwest and northwest. Figure C-3.4 illustrates that the highest $PM_{2.5}$ concentrations are coming from east and northwest as well. Figure C-3.5 displays the major sources of sulfur dioxide in the Lancaster area.

Figure C-3.5: Lancaster Area
Major Sources (Over 100 Tons Per Year) Based on 2011 NEI



The closest major source of sulfur dioxide (which would create sulfates, a major constituent of $PM_{2.5}$ in the eastern US) is located approximately 20 kilometers to the west-northwest of the Lancaster monitor. Figure C-3.3 and Figure C-3.4 illustrate that the wind does not come from that direction on the top 25% days. This analysis also illustrates that there is a potential local influence to the high $PM_{2.5}$ concentrations at the Lancaster monitor.

The Change in the Composition of the $PM_{2.5}$

The composition of $PM_{2.5}$ has changed at the Lancaster monitor since the height of $PM_{2.5}$ concentrations in the 2005 to 2007 time period. Table C-3.2 outlines the main speciated components of $PM_{2.5}$ during the cold season (1^{st} quarter). Table C-3.3 outlines the main speciated components of $PM_{2.5}$ during the warm season (3^{rd} quarter). Overall, Table C-3.2 and Table C-3.3 illustrate the decline in the main speciated components of $PM_{2.5}$ from the 2005 to 2007 period to the 2010 to 2012 period.

*Table C-3.2: Lancaster Speciated $PM_{2.5}$ Data**
Cold Season (1st Quarter) Comparison – 2005-07 Versus 2010-12

Year	Ammonium	Nitrate	Sulfate	OC	EC	Crustal
2005 – 07	4.03363248	6.80728034	4.68105853	5.01901610	0.85225712	0.45108978
2010 – 12	1.78220900	3.40209955	2.44059214	2.50229362	0.33200174	0.25016904
Difference (2005 – 07 minus 2010 – 12)	2.25142349	3.40518079	2.24046639	2.51672248	0.52025538	0.20092075

*All concentrations are averages and have units of µg/m³

*Table C-3.3: Lancaster Speciated $PM_{2.5}$ Data**
Warm Season (3rd Quarter) Comparison – 2005-07 Versus 2010-12

Year	Ammonium	Nitrate	Sulfate	OC	EC	Crustal
2005 – 07	3.16090351	1.95417791	7.10641873	4.62527334	0.65753995	0.48242955
2010 – 12	1.26162865	1.31270310	2.99130570	2.77750490	0.30896226	0.32314873
Difference (2005 – 07 minus 2010 – 12)	1.89927487	0.64147481	4.11511303	1.84776844	0.34857770	0.15928082

*All concentrations are averages and have units of µg/m³

During the cold season, there has been an equal amount of reduction in ammonium, nitrate, sulfate, and organic carbon concentrations. During the warm season, the largest reductions have occurred in ammonium, sulfate and organic carbon concentrations.

To analyze this further, we chose to compare these seasonal values with what has occurred in Arendtsville (AIRS # 42-001-0001), located in Adams County. Arendtsville is in a rural location of Pennsylvania and does not have a major nitrogen oxide or sulfur dioxide source within 50 kilometers of the monitor. For that reason, the Arendtsville monitor reflects the transport that is coming into eastern Pennsylvania from areas to the west (prevailing wind flow is from west to east across Pennsylvania).

*Table C-3.4: Arendtsville Speciated $PM_{2.5}$ Data**
Cold Season (1st Quarter) Comparison – 2005-07 Versus 2010-12

Year	Ammonium	Nitrate	Sulfate	OC	EC	Crustal
2005 – 07	2.22066410	3.57683769	3.39904757	3.17044419	0.45550711	0.22843761
2010 – 12	1.23919565	2.07028981	2.18818154	1.68097944	0.16095925	0.18801487
Difference (2005 – 07 minus 2010 – 12)	0.98146846	1.50654787	1.21086602	1.48946475	0.29454786	0.04042275

*All concentrations are averages and have units of µg/m³

Table C-3.5: Arendtsville Speciated $PM_{2.5}$ Data*
Warm Season (3rd Quarter) Comparison – 2005-07 Versus 2010-12

Year	Ammonium	Nitrate	Sulfate	OC	EC	Crustal
2005 – 07	2.43772827	0.68269750	7.29288441	3.85331667	0.37004536	0.34223237
2010 – 12	0.98470271	0.50452874	3.13218233	2.13687247	0.15489114	0.32755852
Difference (2005 – 07 minus 2010 – 12)	1.45302555	0.17816876	4.16070208	1.71644420	0.21515422	0.01467385

*All concentrations are averages and have units of $\mu g/m^3$

The reductions at Arendtsville reflected in the "difference" row of Table C-3.5 are more representative of the reductions observed in eastern Pennsylvania due to emission control strategies of various sources (for example, the installation of flue gas desulfurization units on electric generation units across western Pennsylvania into the Ohio Valley). The data indicates that the greatest level of reduction at the Lancaster and Arendtsville monitors occurs during the summer months (when sulfate is the primary constituent of $PM_{2.5}$). During the 2005 – 07 time frame, Arendtsville had a 3rd quarter total mass average of 19.08 $\mu g/m^3$, and during the 2010 – 12 time frame it had a 3rd quarter total mass average of 12.06 $\mu g/m^3$; a 7 $\mu g/m^3$ reduction.

An analysis of the 2010-12 differences between the Lancaster and Arendtsville monitors indicates the nature of the problem at the Lancaster monitor.

Figure C-3.6: Urban Excess
Lancaster vs. Arendtsville
2010-12 – 1st Quarter

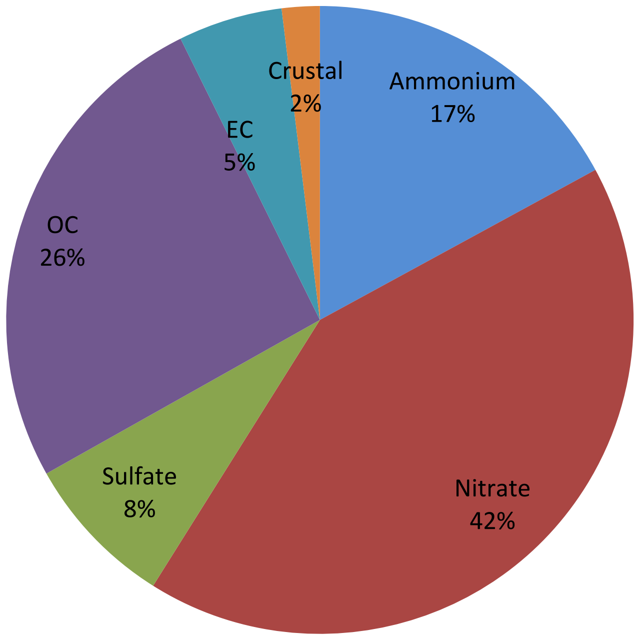


Figure C-3.7: Urban Excess
Lancaster vs. Arendtsville
2010-12 – 3rd Quarter

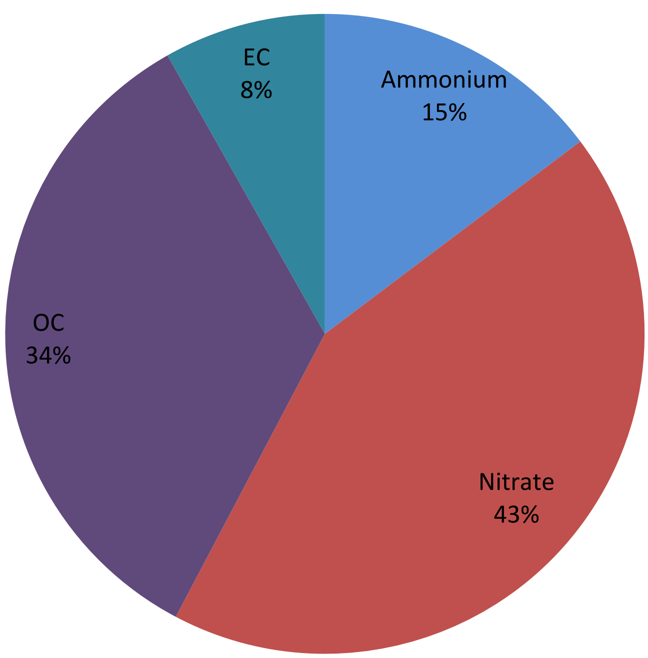
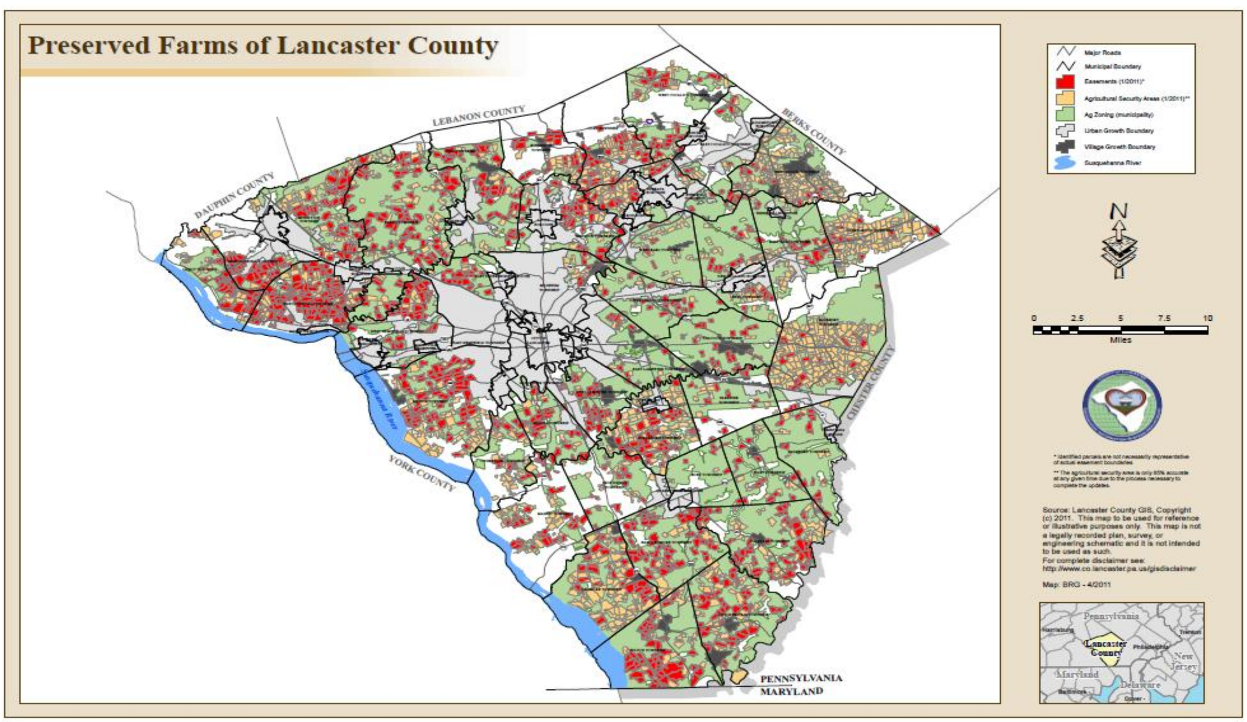


Figure C-3.6 and Figure C-3.7 display the same problem; Lancaster has excess nitrate, ammonium, and organic carbon emissions compared to Arendtsville. Sulfate levels, which are indicative of regional emissions from sources such as coal fired electric generation units, were fairly uniform at the Lancaster and Arendtsville monitors. The largest difference in overall emission concentrations is in the 1st quarter (cold season). The total mass emissions concentration at the Lancaster monitor is 4.40 $\mu g/m^3$ higher than that at the Arendtsville monitor. During the 3rd quarter (warm season), the Lancaster monitor is only 0.23 $\mu g/m^3$ higher than the Arendtsville monitor. Lancaster County has a strong tie to the agricultural sector. Lancaster County has the most farms and acres of farmland in the Commonwealth. Lancaster County consists of mostly farmlands surrounding downtown Lancaster and the location of the Lancaster monitor. Figure C-3.8 displays a map of Lancaster County and the proximity of preserved farms, which are farms and acres of land preserved for agricultural production, to the Lancaster monitor. Figure C-3.3 and Figure C-3.4 illustrate the distribution of wind and $PM_{2.5}$ concentrations surrounding the Lancaster monitor. From 2010 to 2012, the highest $PM_{2.5}$ concentrations were coming from the eastern and northwestern wind directions. In addition, Figure C-3.6 displays ammonium as comprising 17% of the $PM_{2.5}$ during the cold season. Ammonia emissions are prevalent in the agricultural sector due to the abundance of manure from livestock and a higher concentration of animals, for instance. The abundance of ammonium during the cold season allows for additional nitrate (from vehicles) to form ammonium nitrate, a constituent of $PM_{2.5}$.

Figure C-3.8: Preserved Farms in Lancaster County Map



Source:
http://www.co.lancaster.pa.us/lanco/lib/lanco/agpreserve/lancastercountyeasements2011.pdf

Summary

The Department's analysis illustrates the need for a small nonattainment area constituting Lancaster County. An analysis of the $PM_{2.5}$ data monitored at the Lancaster monitor in Lancaster County illustrates that the Lancaster monitor sees concentrations in the 12-30 $\mu g/m^3$ range while the regional concentrations are in the 0-12 $\mu g/m^3$ range. A further examination into the monitoring data demonstrates that the high concentrations are coming out of two primary directions: easterly and northwesterly. These wind profiles travel over local farms, further illustrating the local issue at the Lancaster monitor. An analysis of the speciated data at the Lancaster and Arendtsville monitors illustrates the excess nitrate, ammonium, and organic and elemental carbon at the Lancaster monitor, primarily during the 1st quarter (cold season). The excess ammonium is likely a function of the high number of farms in the immediate vicinity of the Lancaster monitor. The excess ammonium, when in contact with excess nitrate, forms ammonium nitrate, a large constituent of $PM_{2.5}$ during the cold season. Therefore, the Department is recommending the Lancaster County nonattainment area encompassing Lancaster County in Pennsylvania be designated nonattainment for the 2012 annual $PM_{2.5}$ NAAQS. A map of the proposed nonattainment area is provided below as Figure C-3.9.

Figure C-3.9: Recommended Lancaster County $PM_{2.5}$ Nonattainment Area