September 28, 2006

Mr. Dennis Doll
Work Assignment Manager
U.S. Environmental Protection Agency
USEPA Mailroom, Mail Code: C304-01
Research Triangle Park, NC 27711

STI-905213.05-3040-TM

Re: EPA AIRNow Operations and AQI Support Contract # EP-D-05-004 Work Assignment 2-13, Accountability—Tracking and Evaluating Air Quality Programs, Task 3–Detroit, Michigan

Dear Dennis,

Attached is a technical memorandum detailing Sonoma Technology, Inc.'s (STI) study of the Detroit area to identify changes in ambient air quality that are a result of the implementation of known regulations. This study fulfills a requirement of Task 3 of Work Assignment (WA) 2-13. Detroit was selected for application of the technical approach described in Task 2 of the WA.

Please let me know if you have any questions.

Sincerely,

Steven G. Brown
Manager, Environmental Data Analysis Group

Attachment

cc: Ellen Baldridge, EPA
Hilary Hafner, STI
Katie Wade, STI

ACCOUNTABILITY CASE STUDY: DETROIT

INTRODUCTION

The goal of this project was to identify and quantify changes in ambient air quality that are a result of the implementation of known regulations. The Detroit area was chosen for a case study that focuses on acid rain program regulations (1995 and 2000) and the 2003/2004 nitrogen oxides (NO_x) State Implementation Plan (SIP) Call. Two approaches were used:
(1) identification of when control measures were implemented and which pollutants were targeted and examination of ambient data during the two periods of regulation; and
(2) examination of ambient data for trends to determine whether any changes in concentrations occurred at the same time that known and documented regulations were in place. Both these approaches require long data records and significant changes in ambient concentration to identify trends above the "noise" of the data, that is, year-to-year variability due to meteorology, fluctuations in emissions, etc. Long data records are particularly important for regional pollutants, such as NO_x, sulfate, and particulate matter (PM) mass, which typically are spatially homogeneous. Urban-rural site pairs are also useful to segregate local and regional impacts. A rural site is expected to have few local sources nearby and be representative of regional impact. An urban site is expected to have many local sources and be representative of local impact.

In this case study, acid rain program regulations were expected to impact sulfur dioxide (SO_2) concentrations, with the potential for impact on particulate sulfate, acid deposition, and visibility degradation due to sulfate aerosol. A long SO_2 data record was available for Detroit and the nearby area, and emissions were well-quantified. NO_x SIP call regulations were expected to impact NO_x and ozone concentrations in the summer months. However, NO_x data are only available beginning in 2002; this data set is likely not sufficiently long to see any impact in ambient NO_x concentrations resulting from the NO_x SIP Call in 2003-2004.

SULFUR – ACID RAIN PROGRAM REGULATIONS

SO_2 is both a local and regional pollutant, so intra-urban differences are expected. If local sources are close to monitors, they may obscure long-term regional trends. Continuous SO_2 data for 1993-2005 are available from the U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS) for five sites in the Detroit area. National SO_2 emissions trends estimates are available for 1993-2002,[1] and electric generating facility emissions are available from 1995-2005[2]. In addition to SO_2, sulfate aerosol, visibility extinction from sulfate aerosol, and acid deposition should be impacted by the acid rain program. To understand the multipollutant effect of SO_2 regulations, ambient sulfate aerosol concentration, sulfur deposition, and light extinction due to sulfate aerosol data for 1993-2005 were obtained from the Ann Arbor, Michigan, Clean Air Status and Trends Network (CASTNET) site.

[1] National Emission Inventory; <http://www.epa.gov/ttn/chief/trends/>.
[2] Clean Air Markets; <http://www.epa.gov/airmarkets/emissions/prelimarp/index.html>.

Between 1993 and 2002, national SO_2 emissions reductions were gradual, with a large decrease in 1995 according to the NEI.[1] Emissions from electrical generating facilities in Michigan and regionally showed a large decrease in concentrations from 1998-2001.[2] Specific dates and locations of local SO_2 controls in the Detroit area are not known; regional controls may also impact concentrations in the Detroit area.

Overall, all sites showed a decrease in ambient SO_2 concentrations from 1993 to 2005; **Figures 1 and 2** illustrate the results. Three-year averages were used for most of this analysis to limit year-to-year variability. A large decrease (about 30%) in year-to-year concentrations of SO_2 is evident between 1994 and 1995, corresponding to the largest decrease in year-to-year emissions nationally (28%). Changes noted include a

14% decrease in Michigan SO_2 emissions from electric power generation (1995-1997 to 2003-2005);

26% region-wide decrease in SO_2 emissions from electric power generation (1995-1997 to 2003-2005);

26% decrease in Detroit average SO_2 (1993-1995 to 2003-2005);

24% decrease in sulfate concentrations in Ann Arbor (1991-1993 to 2003-2005);

7% decrease in sulfate concentrations in Allen Park (2001-2003 to 2003-2005);

26% decrease in total sulfur deposition in Ann Arbor (1991-1993 to 2003-2005); and

17% decrease in light extinction due to sulfate (1991-1993 to 2003-2005).

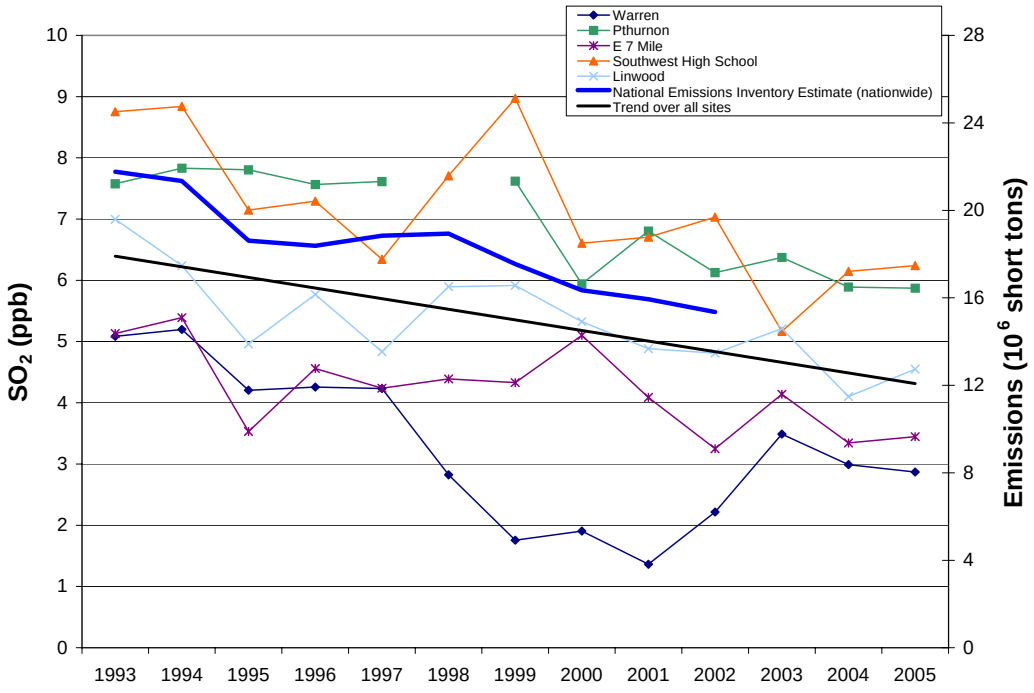
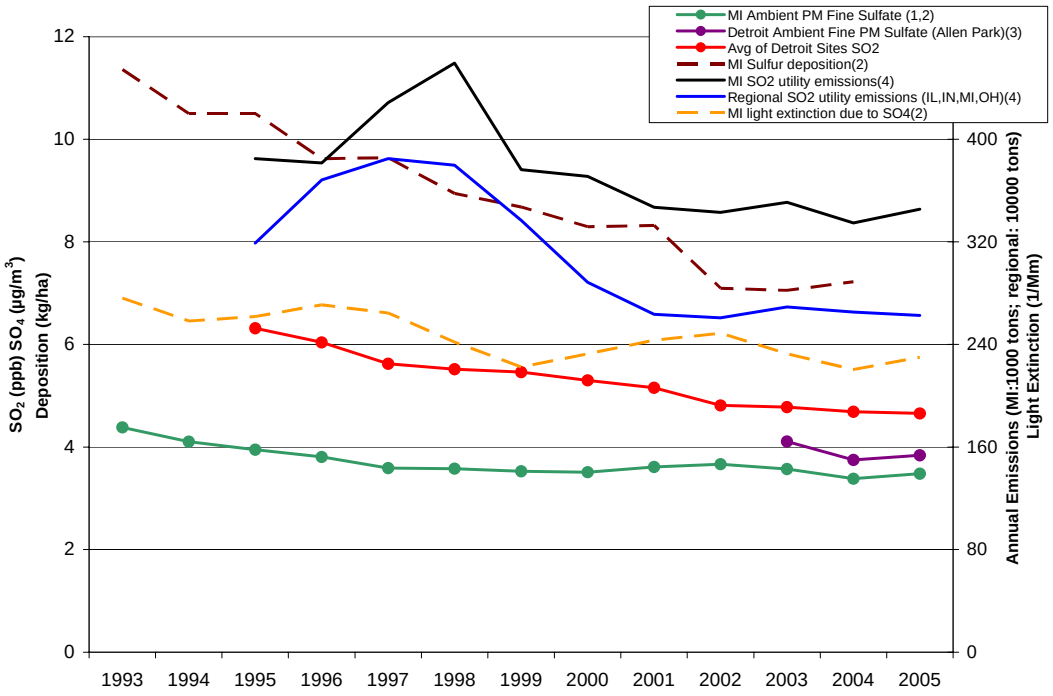


Figure 1. Annual average SO_2 concentrations at Detroit area sites, 1993-2005, and national SO_2 emissions trends, 1993-2002. Average SO_2 trend across sites is shown as a black line.



Legend notes: (1) Excluding 1996-1997 (incomplete data); (2) Ann Arbor CASTNET data (representative of other Michigan sites); (3) Speciation Trends Network (STN) network data; (4) utility emissions from http://www.epa.gov/airmarkets/emissions/prelimarp/index.html.

Axis note: Light extinction calculated from b=(3)ft(RH)[SO_4^{2-}], where RH is relative humidity

Figure 2. Annual total SO_2 emissions in Michigan and regional area; three-year averaged concentrations of sulfur species in Michigan (end year shown on graph).

$PM_{2.5}$ mass concentrations may have been impacted by a decrease in the sulfate aerosol component; however, $PM_{2.5}$ data were available only from 1999-2005, and sulfate data from 2002-2005 in the Detroit area. Because decreases in sulfate aerosol after 2001 were small, meteorology and transport confound any trends that may be due to changes in SO_2 emissions. **Figure 3** shows that no $PM_{2.5}$ mass trends were evident from 1999 to 2005 (years for which data were available).

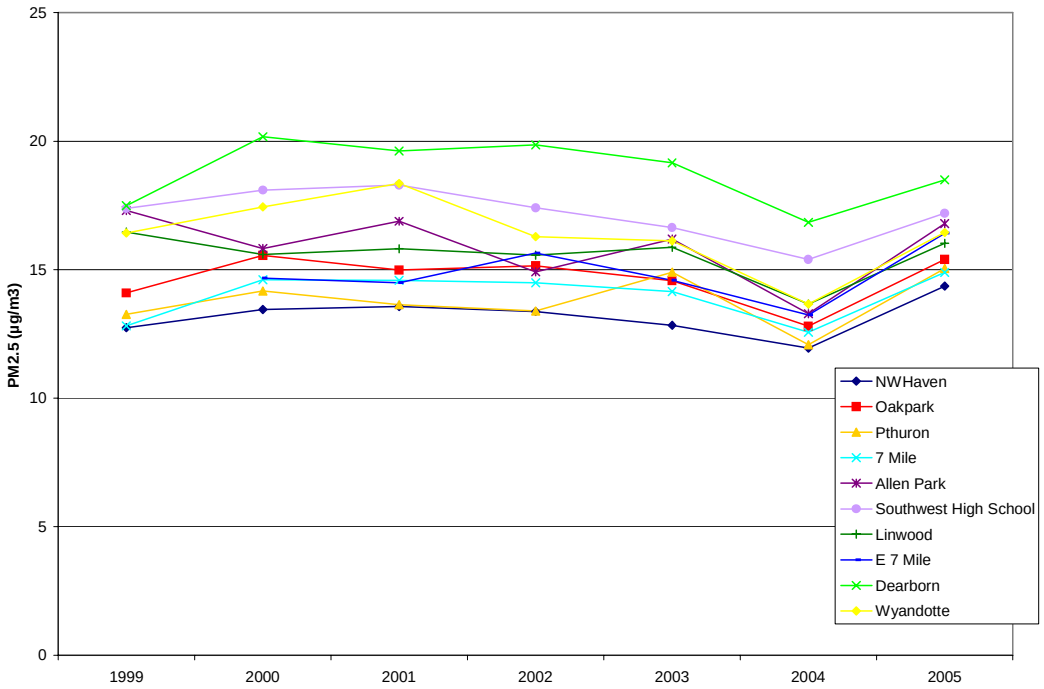


Figure 3. Annual average $PM_{2.5}$ concentrations for the Detroit area, 1999-2005.

NO_X SIP CALL

Like SO_2, NO_x is both a local and regional pollutant. Intra-urban differences are likely, and mobile sources are expected to be the largest source of NO_x in an urban area. NO_x from power generation (the target of the NO_x SIP call) is about 40% of total NO_x emissions in the Detroit area, so changes in NO_x emissions from other sources (such as mobile sources) could confound the results. In addition, NO_x data are only available from two sites in the Detroit area for 2002-2005, and regulations in Michigan to reduce NO_x were not implemented until 2004. Decreases in NO_x concentrations because of these regulations are probably not large enough to be noticeable with such a short data record. Ozone concentrations are expected to decrease corresponding to a decrease in NO_x concentrations, but nitrate and $PM_{2.5}$ mass are not expected to change as a result of regulation because the regulation is only in effect during summer months. In summer months, nitrate formation is minimal; thus, nitrate contribution to $PM_{2.5}$ mass is very small.

When summer-only yearly box whisker plots were examined for the two Detroit NO_x measurement sites—East 7 Mile and Linwood, no change in concentrations after 2004 was seen. East 7 Mile measurements showed a decrease in NO_x concentrations in 2004, followed by an increase in 2005, but it is not clear that controls were in place prior to the summer of 2004. This change in ambient NO_x concentrations was not observed at the Linwood site, even though it is closer to NO_x point sources. Differences between the sites could be due to stack height and mixing as distance from point sources increases. Concentrations were segregated by hour to examine rush-hour (i.e., mobile source-dominated) versus non-rush hour trends, nighttime hours (lowest mobile source contribution), and daytime hours, but no consistent trend was evident

across sites. Since mobile source activity is lower on weekends but electricity generation activity generally is not, ambient NO_x concentrations were also segregated by day of week and hour to determine if examining periods when mobile source emissions are low could reveal trends from electrical generation sources. No consistent trend was observed at sites from which data were available (see example, **Figure 4**).

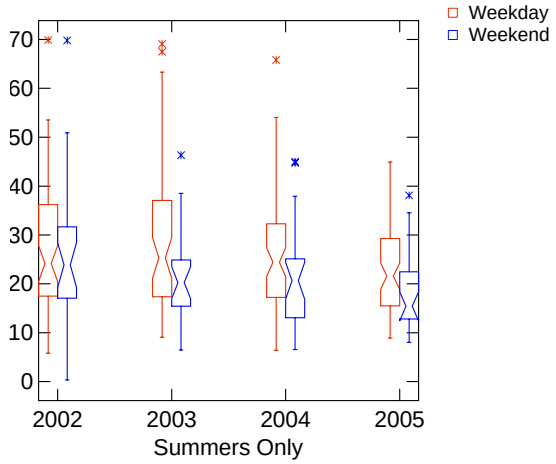


Figure 4. NO_x concentrations at the Linwood site, segregated by day of week.[3]

Because the large mobile source contribution to NO_x may confound any changes in concentration due to the NO_x SIP Call, wind direction analysis was also performed to isolate the point sources of NO_x. Point sources were expected to dominate concentrations when winds were 180-225 degrees from the monitors. The remaining data were divided into two sectors: (1) winds from the Detroit area—mobile-dominated and (2) winds from Canada—no emissions information available. Concentrations were significantly higher at East 7 Mile and Linwood when the wind was from 180-225 degrees, supporting the hypothesis that large point sources in this direction impact ambient concentrations. However, no significant year-to-year change in concentrations was evident at either site (see example, **Figure 5**). Data were divided by hours to further isolate the point source-versus-mobile source contribution, but no consistent change across years was seen with morning hour data only or nighttime hour data only.

[3] The box shows the 25th, 50th (median), and 75th percentiles. The whisker shows the highest or lowest data point with a maximum length of 1.5 times the interquartile range, IQR. Data outside this range are shown as "outliers" identified with asterisks representing the points that fall within three times the IQR and circles representing points beyond this. The boxes are notched (narrowed) at the median and return to full width at the 95% lower and upper confidence interval values.

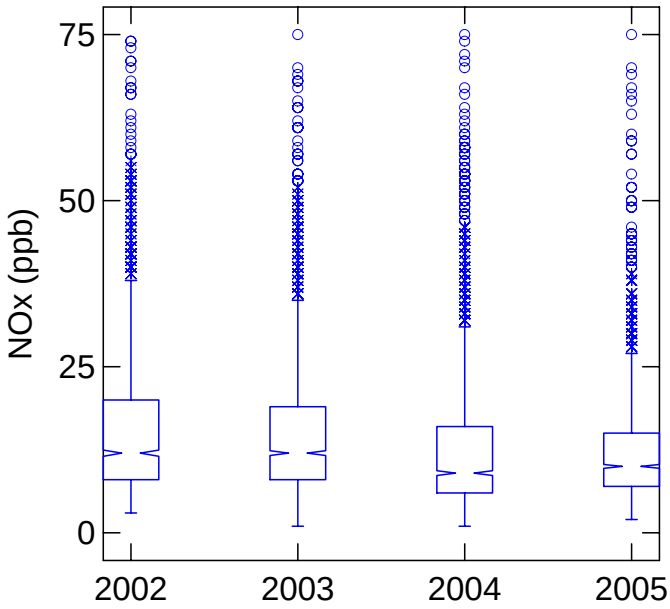


Figure 5. NO_x concentrations at East 7 Mile when wind is from the southwest (direction of major point sources).

Ratio analysis was also conducted using ratios of NO_x with mobile source-dominated pollutants. If the mobile source species (benzene and TNMOC) do not change with time, a change in their ratios to NO_x could indicate a change in the point source contribution. However, no consistent year-to-year change was seen in these ratios at the sites (see example, **Figure 1-6**).

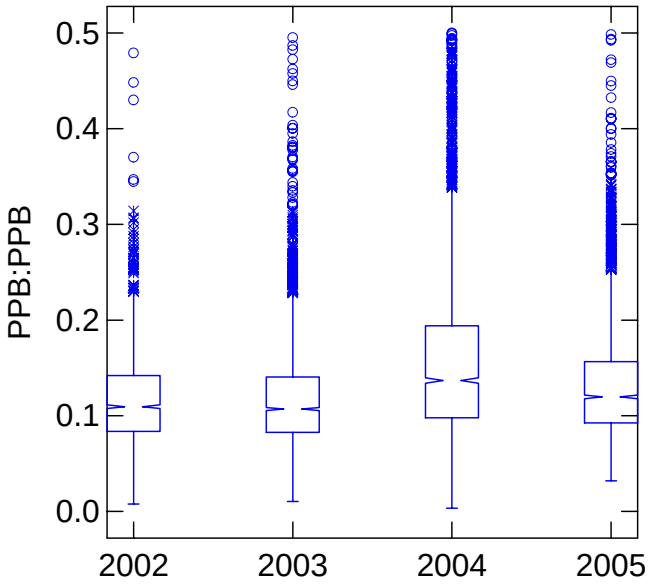


Figure 6. Benzene:NO_x ratio, East 7 Mile site, 2002-2005.

Continuous Emissions Monitoring Systems (CEMS) data for the Detroit area are only available from 2003-2005 (**Figure 7**). The available data show similar NO_x emissions from 2003-2004 followed by a large increase in emissions from 2004-2005. However, not enough information is currently available to determine a trend in emissions.

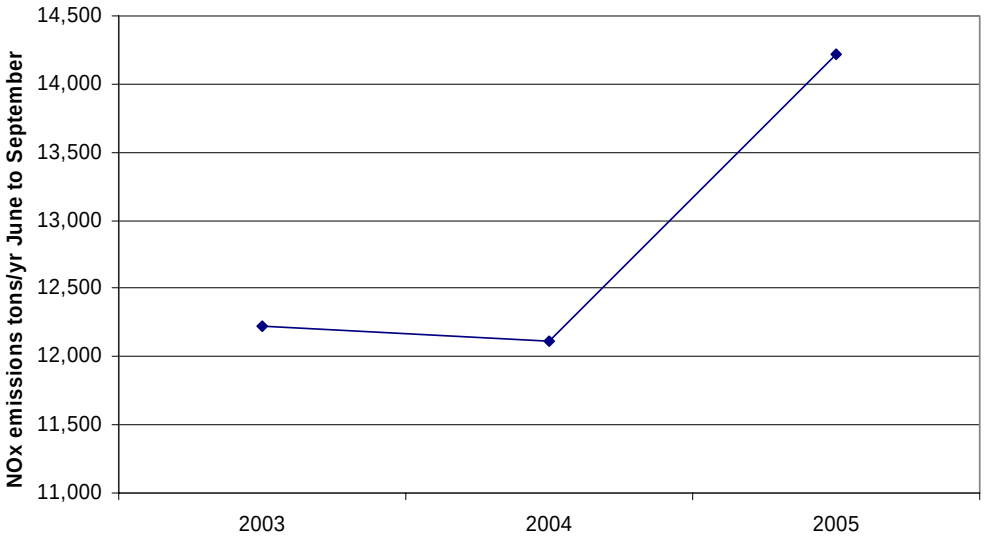


Figure 7. NO_x CEMS data for the Detroit area, 2003-2005. Only June-September data were included.

The NO_x SIP call is intended to decrease ozone concentrations. Because ozone is a photochemical pollutant, and because we want to understand the change in ozone resulting from changes in ozone precursor emissions rather than inter-annual variability in meteorology, ozone concentrations need to be adjusted for meteorology before trends can be examined. Meteorologically adjusted ozone concentrations are available for the Detroit area from 1997 through 2005 (a much longer time frame than that for available NO_x data). **Figure 8** shows that ozone concentrations decreased slightly over the 1997-2005 period.

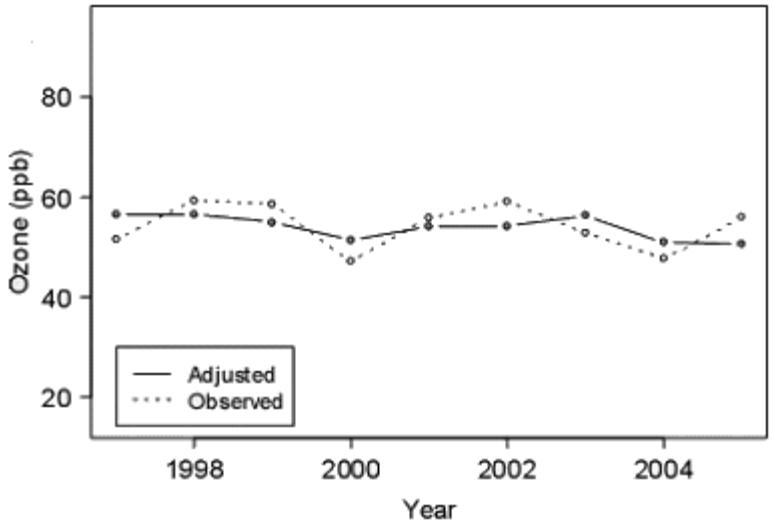


Figure 8. Meteorologically-adjusted ozone, Detroit area, 1997-2005 (source: Bill Cox, EPA).

CONCLUSIONS

In response to acid rain program regulations, a large decrease in SO_2 emissions coupled with a long ambient SO_2 data record was critical in observing a decrease in ambient concentrations of SO_2. A 28% decrease in emissions in the Michigan area was coincident with a 30% decrease in ambient SO_2 in the Detroit area. Secondary pollutants and other environmental measures were also affected by the decrease in SO_2, including sulfate aerosol, visibility extinction due to sulfate aerosol, and sulfur deposition. The data record was not long enough to determine the impact on $PM_{2.5}$ mass concentrations.

The NO_x SIP Call affected Michigan only in 2004. Because the data record prior to 2004 was short and the influence of mobile sources was confounding, no trend was established in ambient NO_x concentrations in response to the NO_x SIP Call at the Detroit urban sites. Several analyses (wind direction, time of day, weekday/weekend, and ratio) were used to isolate the point source contributions; however, in all cases, no consistent trend was evident at any site. More data are needed to establish a measurable temporal trend.

APPENDIX A

ADDITIONAL ANALYSES FOR DETROIT CASE STUDY

Additional analyses of the NO_x data were conducted for the Detroit case study:

- Seasonal trends – determine whether changes in concentrations would be confounded by seasonal variation.
- Weekday/weekend trends – look for a difference in mobile-dominated (i.e., weekday) versus nonmobile-dominated (weekend) days.
- Morning only analysis – look for a difference in mobile-dominated (i.e., rush hour) versus nonmobile dominated (non-rush hour) times.
- Ratio analyses – examine ratios of mobile source pollutants to NO_x; a change in ratios could indicate a change in nonmobile NO_x emissions, assuming the mobile source pollutant used remains constant.
- Ozone/total oxidant (O_x) analysis – as a product of NO_x, ozone concentrations should be affected by any change in NO_x concentrations; O_x is the sum of NO_x + ozone and would also reflect changes in NO_x concentrations.

No consistent trend was evident in any of these analyses to support a decrease in NO_x concentrations resulting from the NO_x SIP Call. Graphs generated in the additional analyses follow.

SEASONAL TRENDS

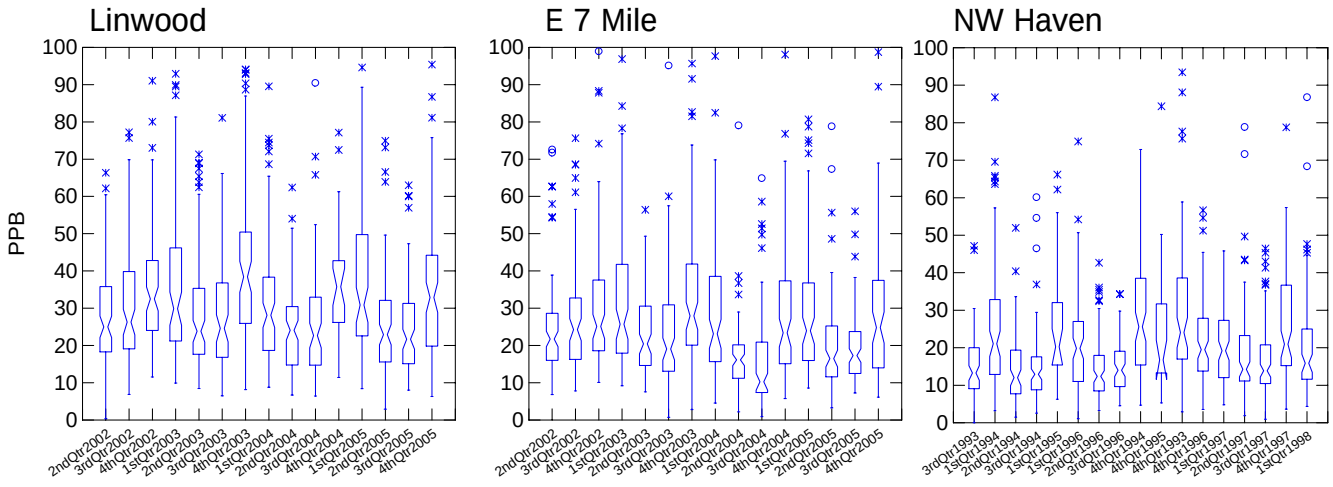


Figure A-1. Seasonal distributions of NO_x at three Detroit area sites. Seasonal trends do not appear to change over time.

WEEKDAY/WEEKEND ANALYSIS

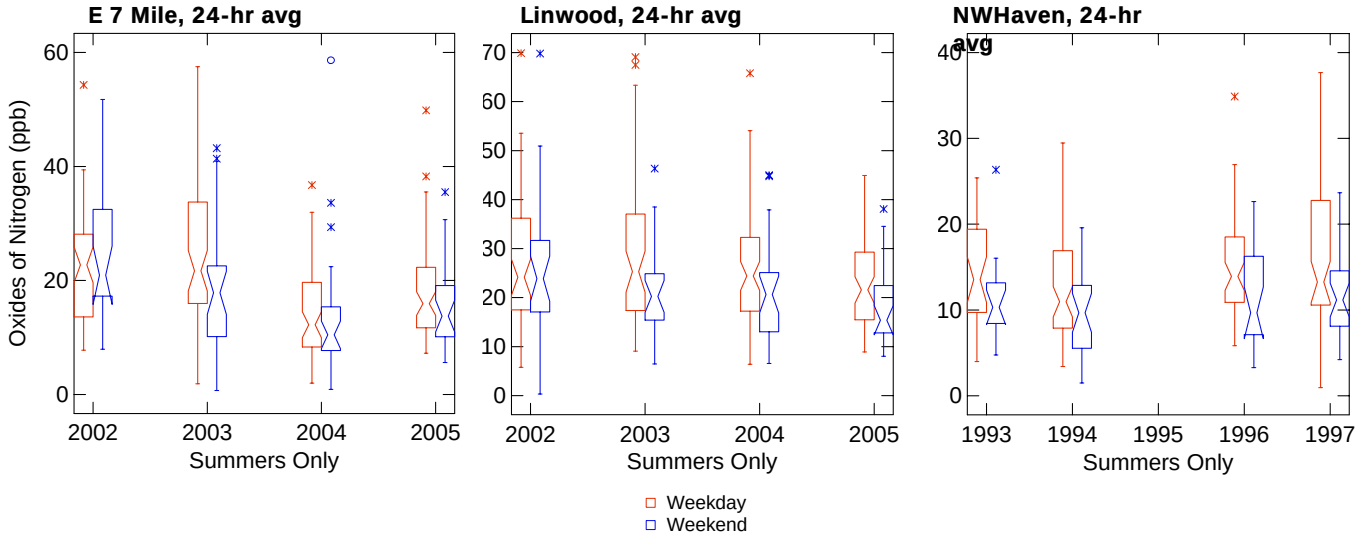


Figure A-2. Weekday versus weekend NO_x concentrations at Detroit area sites. Only summer data (June-August) were used.

MORNING ONLY ANALYSIS

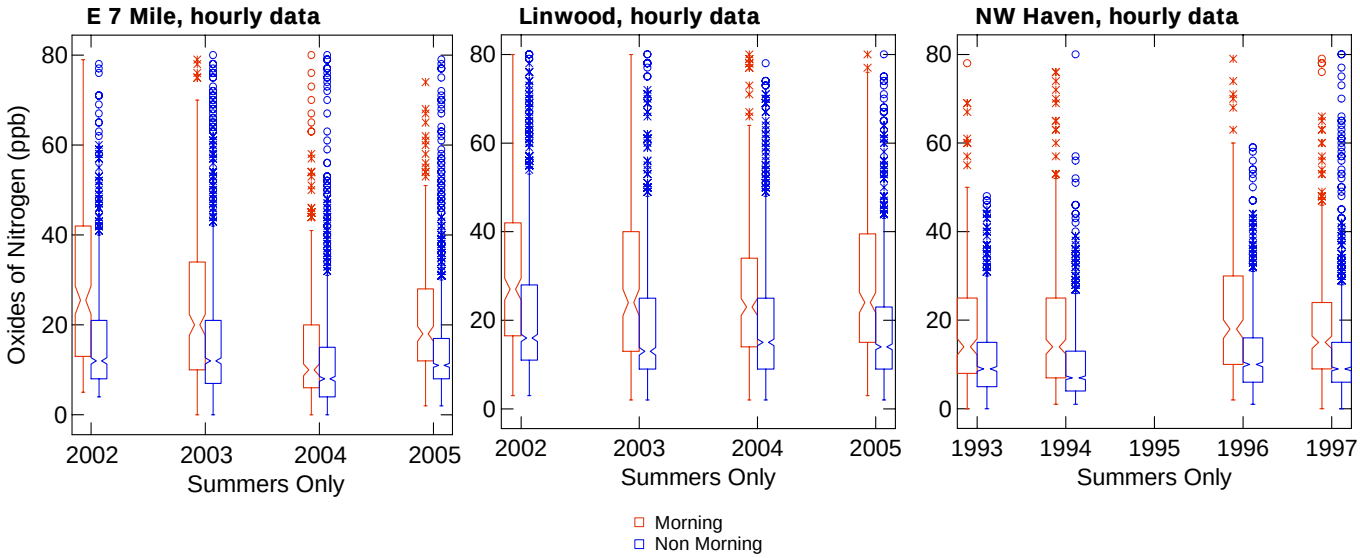


Figure A-3. NO_x concentrations at Detroit area sites comparing morning hours (5 a.m.-9 a.m.) with the rest of the day. Only summer data (June-August) were used. Concentrations above ppb are not shown.

RATIO ANALYSES

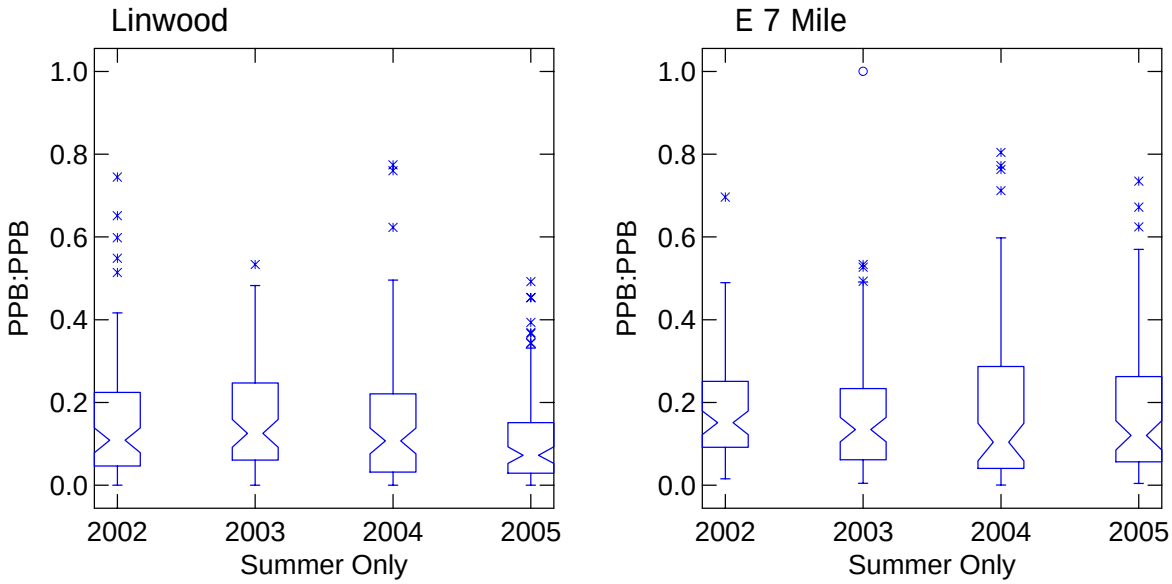


Figure A-4. SO_2:NO_x ratio for Detroit area sites. Only summer data (June-August) were used.

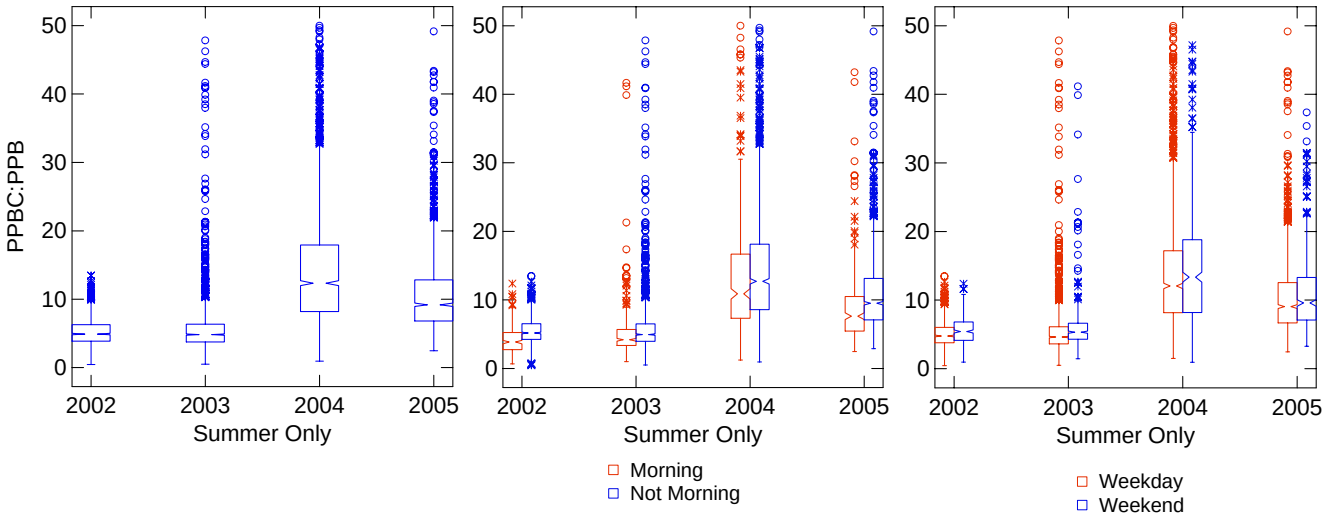


Figure A-5. TNMOC:NO_x ratio at East 7 Mile site. All hours/days, morning versus non-morning, and weekday/weekend groupings presented. Only summer data (June-Aug) were used.

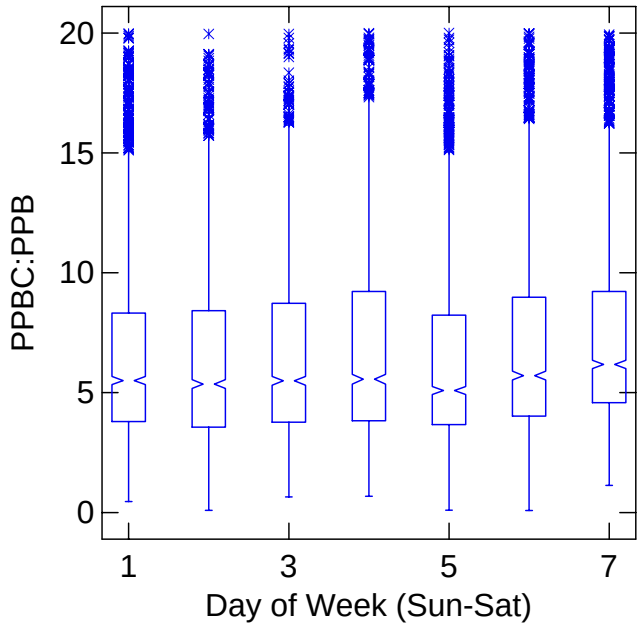


Figure A-6. TNMOC:NO_x by day of week, East 7 Mile site, 2002-2005.

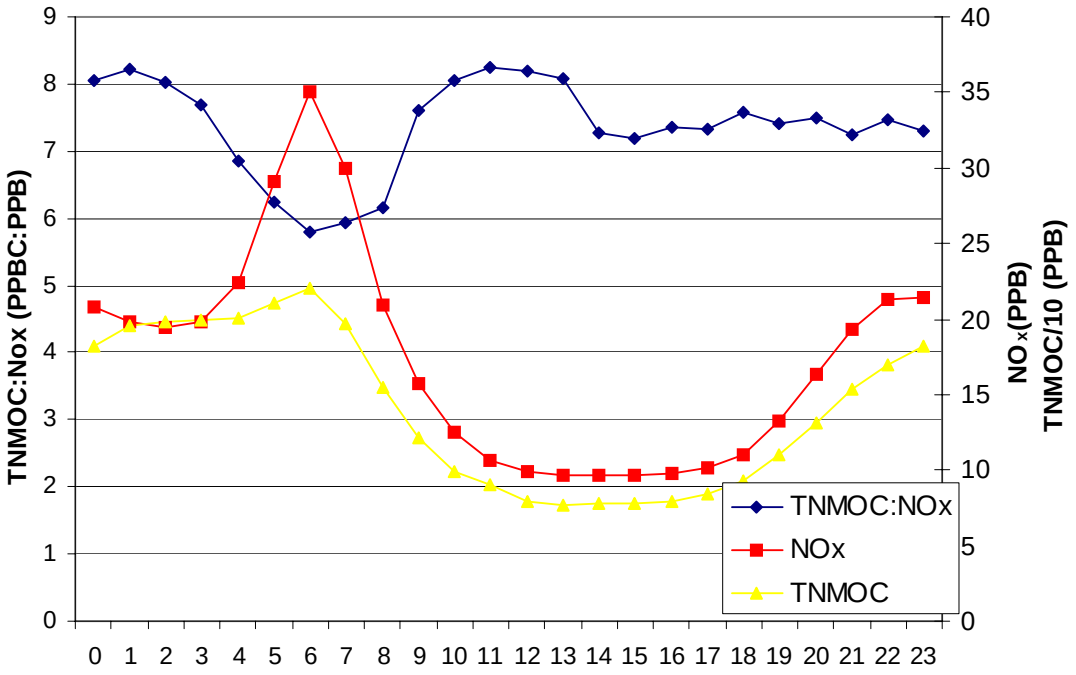


Figure A-7. NO_x, TNMOC, and TNMOC:NO_x diurnal profiles at East 7 Mile site; 2002-2005 average.

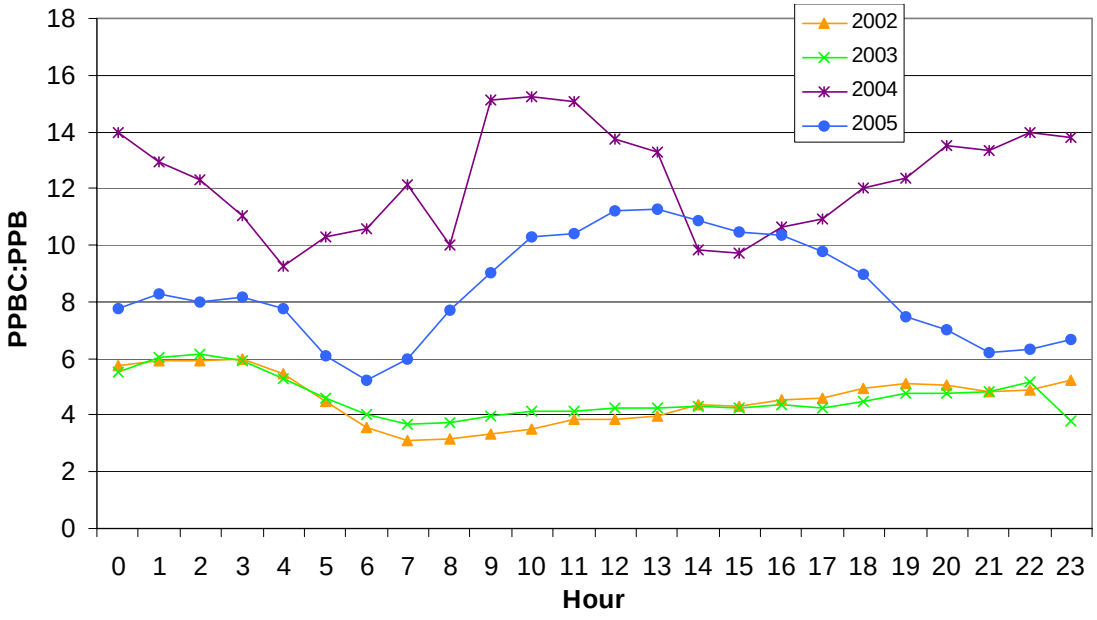


Figure A-8. TNMOC:NO_x diurnal profile by year for East 7 Mile site, 2002-2005. Median concentrations for each hour are shown.

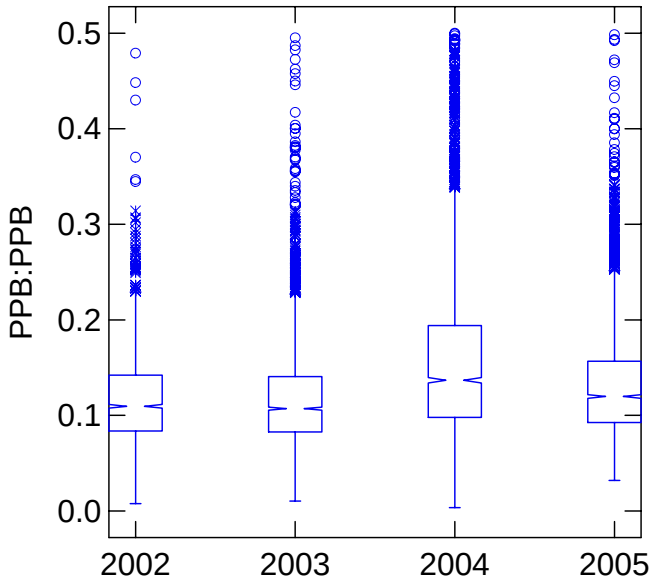


Figure A-9. Benzene:NO_x, East 7 Mile site, 2002-2005.

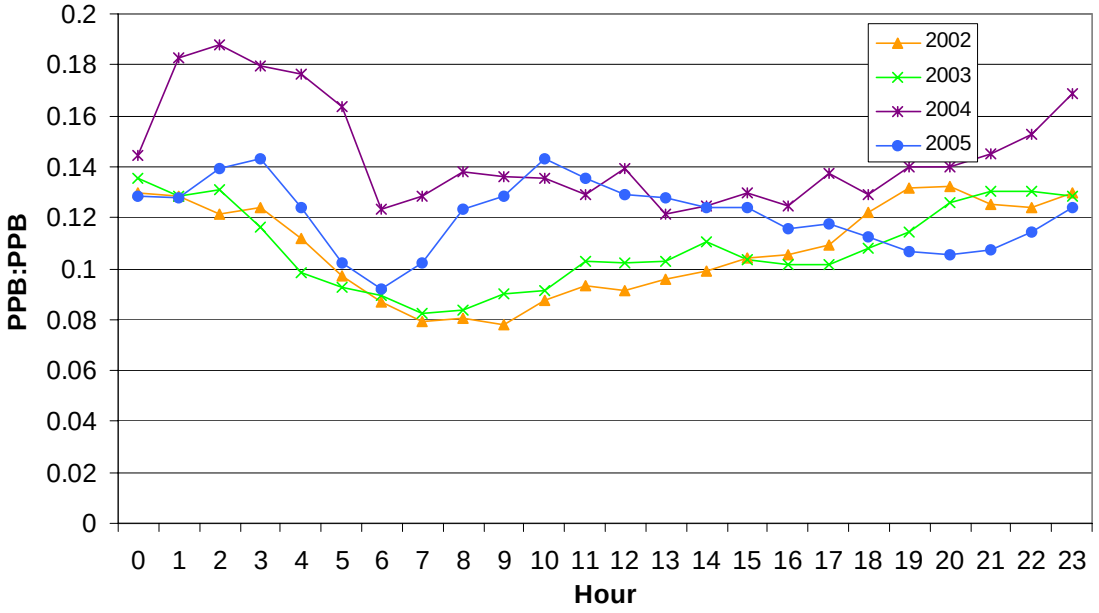


Figure A-10. Diurnal profile of benzene:NO_x by year, East 7 Mile, 2002-2005. Median concentrations by hour are shown; only summer data (June-August) were used.

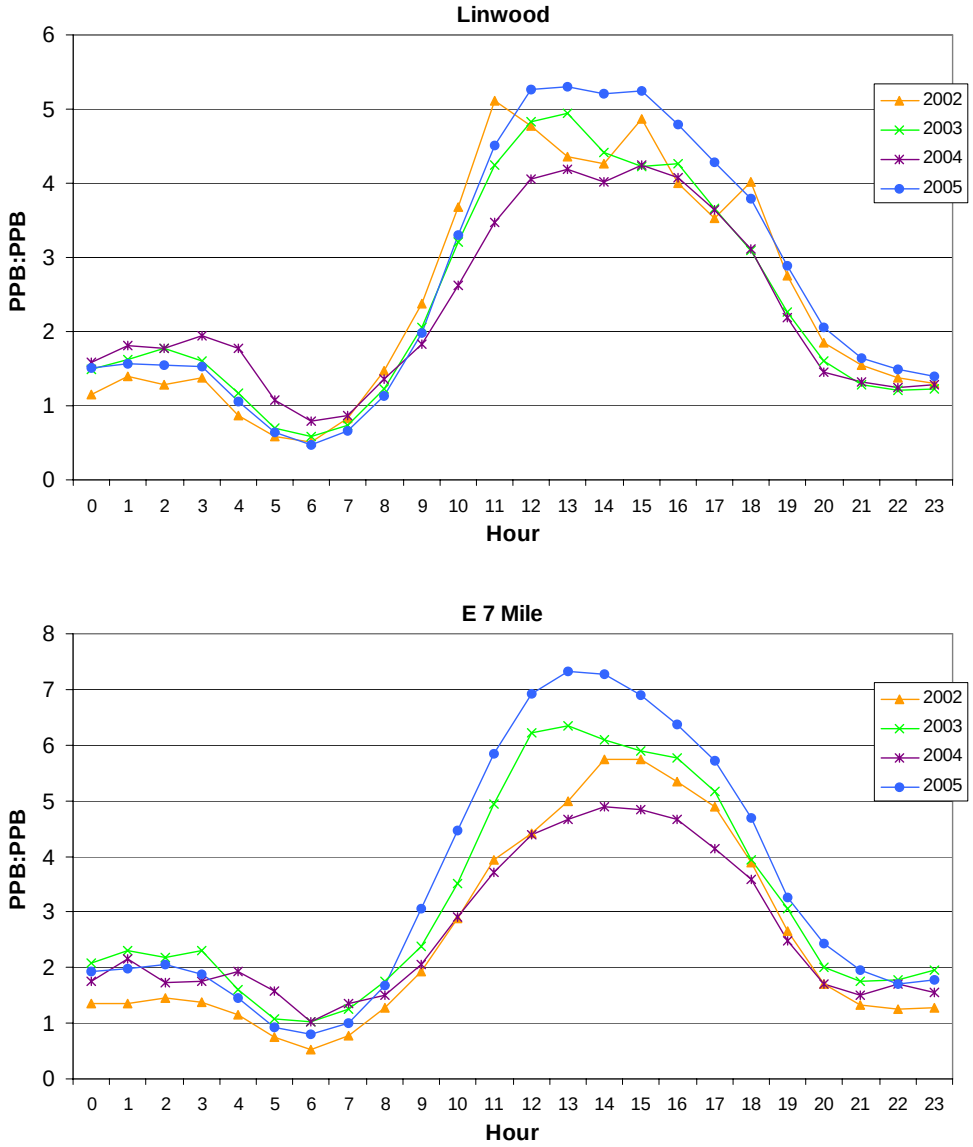


Figure A-11. Ozone:NO_x diurnal profile by year for Detroit area sites. Only summer data (June-August) are shown. Ratios above 1000 were excluded from analysis.

OZONE/O_X ANALYSIS

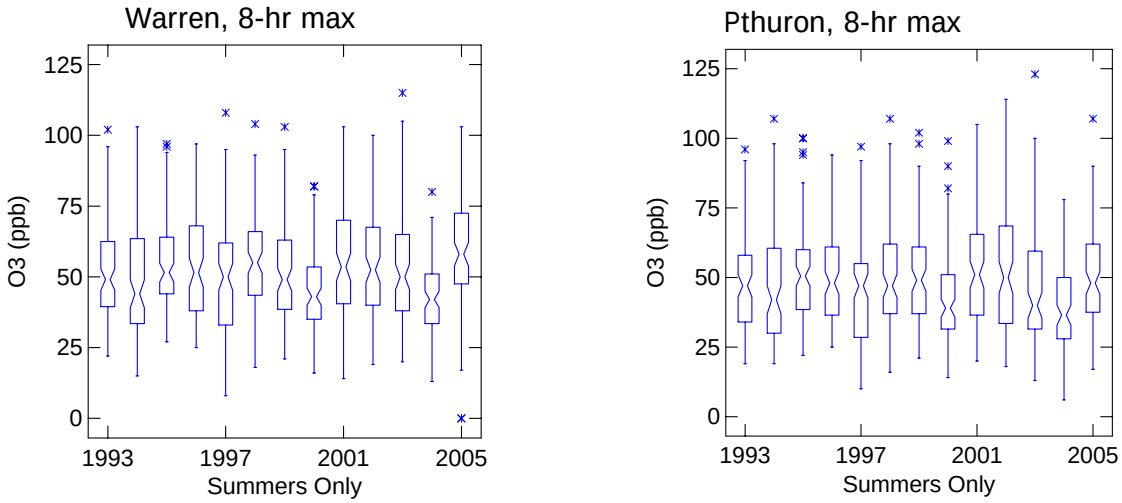


Figure A-12. Seasonal ozone concentrations at Detroit area sites, 1993-2005. Only summer data (June-Aug) are shown.

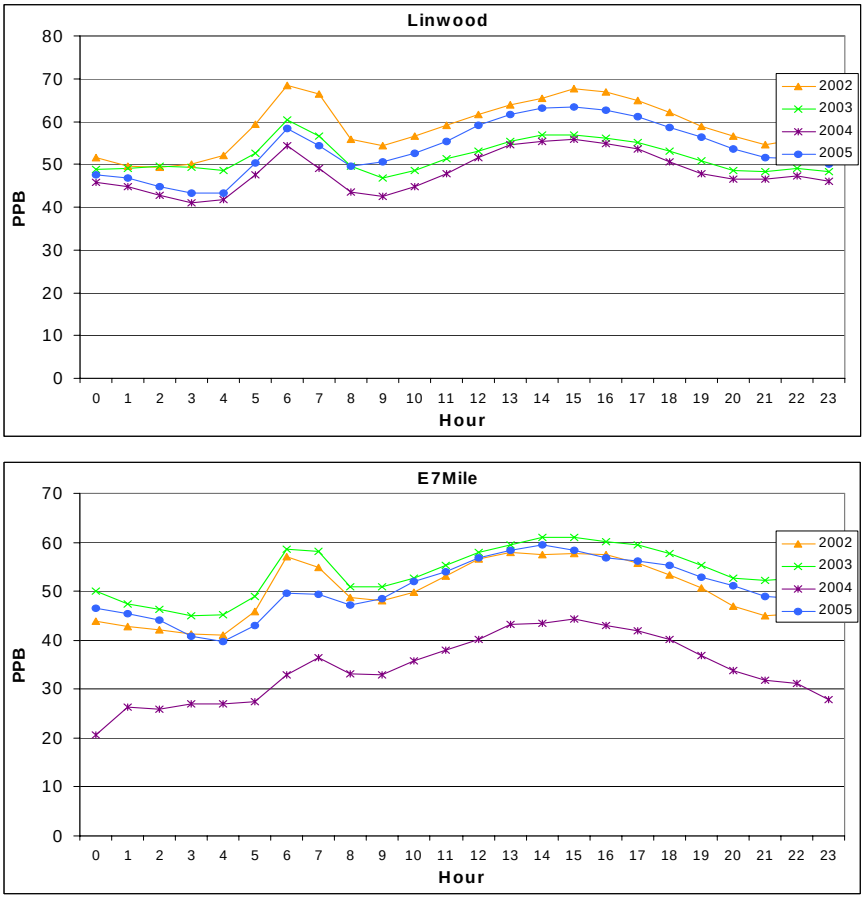


Figure A-13. O_x (ozone + NO_x) diurnal profile by year at Detroit area sites.