REVISIONS TO THE STATE IMPLEMENTATION PLAN
FOR THE CONTROL OF OZONE AIR POLLUTION

ATTAINMENT DEMONSTRATION FOR THE
HOUSTON/GALVESTON
OZONE NONATTAINMENT AREA

Appendix G

Decrease in Ambient Air Concentrations of Benzene, Toluene and Total Xylenes in Southeast Texas

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
PO BOX 13087
AUSTIN, TEXAS 78711-3087

FEBRUARY 20, 1998

TNRCC

May 1997
AS-134

Decrease in Ambient Air Concentrations of Benzene, Toluene, and Total Xylenes in Southeast Texas

printed on recycled paper

Monitoring Operations Division

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Decrease in Ambient Air Concentrations of Benzene, Toluene, and Total Xylenes in Southeast Texas

Prepared by
Monitoring Operations Division
(512)239-1716

AS-134
May 1997

TNRCC

Barry R. McBee, *Chairman*
R. B. "Ralph" Marquez, *Commissioner*
John M. Baker, *Commissioner*

Dan Pearson, *Executive Director*

Authorization for use or reproduction of any original material contained in this publication, i.e., not obtained from other sources, is freely granted. The Commission would appreciate acknowledgement.

Published and distributed
by the
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

The TNRCC is an equal opportunity/affirmative action employer. The agency does not allow discrimination on the basis of race, color, religion, national origin, sex, disability, age, sexual orientation or veteran status. In compliance with the Americans with Disabilities Act, this document may be requested in alternate formats by contacting the TNRCC at (512)239-0028, Fax 239-4488, or 1-800-RELAY-TX (TDD), or by writing P.O. Box 13087, Austin, TX 78711-3087.

Texas Natural Resource Conservation Commission
Monitoring Operations Division
Monitoring Data Management & Analysis Section

Publication Review Questionnaire

The purpose of this survey is to gauge how well this publication communicates its contents and whether it is useful to the reader. Survey comments will be compiled and used to improve the production of future publications to ensure that their content and design are of high quality and that they meet the reader's information needs. Please take a few minutes to complete and return this form. Fold in thirds and staple so that the return address on the reverse appears on the outside. Please affix a first class stamp before mailing.

What is your affiliation? Government ❑ Environmental Group ❑
(select all that apply) Consulting Firm ❑ Industry ❑ Public ❑ Other ❑

Publication Reviewed *Decrease in Ambient Air Concentrations of Benzene, Toluene, and Total Xylenes in Southeast Texas (AS-134, May 1997)*

Publication Ratings

(mark appropriate boxes)

	Exceeds Expectations	Satisfactory	Needs Improvement
Clarity	❑	❑	❑
Non-Technical Content	❑	❑	❑
Technical Content	❑	❑	❑
Data Analysis	❑	❑	❑
Information is Current	❑	❑	❑
Usefulness	❑	❑	❑
Organization	❑	❑	❑
Graphics	❑	❑	❑

Would you recommend this publication to others? Yes ❑ No ❑
Do you use information from this publication? Yes ❑ No ❑
What improvements or changes would you recommend?

_____
_____
_____
_____

What air quality publications would be most useful to you in the future?

_____
_____

Reviewer Information

(Optional – May only be used to contact you for more information about your suggestions.)

Name: _____
Organization: _____
Address: _____
City/State/Zip: _____
Phone: _____

From _____

_____

_____

Affix Stamp Here

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
ATTN: PAT WOOD, MC 165
P.O. BOX 13087
AUSTIN, TEXAS 78711–3087

Contents

Abstract 1

Introduction 1

Data and Methods 2

Results 4

Conclusions 6

Future Research 7

Acknowledgment 7

Appendix A: Tables A-1

Table 1. Trends and Their Significance for Total Volatile Organic Compounds Measured in 1987–1995 ..... A-3

Table 2. Trends and Their Significance for Benzene Measured in 1987–1995 ..... A-3

Table 3. Trends and Their Significance for Toluene Measured in 1987–1995 and Isomers Measured in 1987–1994 ..... A-4

Table 4. Air Emissions in Thousands of Pounds and Average Annual Concentration in Parts per Billion by Volume A-5

Appendix B: Maps and Figures B-1

Map 1. Houston Regional Monitoring (HRM) Sites B-3

Map 2. South East Texas Regional Planning Commission (SETRPC) Sites B-4

Figure 1. Benzene Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas B-5

Figure 2. Toluene Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas B-6

Figure 3. Total Xylenes Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas B-7

Abstract

A statistical analysis of the trend in ambient, or outdoor, concentrations of volatile organic compounds measured at long-term stationary monitoring sites in southeast Texas from the late 1980s to the mid-1990s shows that there has been a significant decline in the ambient concentrations of many volatile organic compounds. In particular, levels of benzene, toluene, and total xylenes (sum of meta-, para-, and ortho-isomers) have decreased in four counties in Texas: Harris, Chambers, Orange, and Jefferson. These four counties all experienced a 50 percent to 75 percent decrease in the monitored ambient levels of benzene. These counties also experienced 70 percent to 90 percent declines in measured toluene concentrations, and a 60 percent to 100 percent decline in the measured concentrations of total xylenes.

Analysis of the self-reported air releases of toxic chemicals, collected as part of the Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI), shows that the decrease in reported industrial emissions of benzene, toluene, and xylenes, except those in Orange County, is reflected in the decline in ambient concentrations of these compounds.

The TRI reports that total xylene emissions are increasing in Orange County, yet our analysis shows that ambient concentrations of xylenes are decreasing in all four counties. The correspondence between TRI emissions and ambient concentrations emphasizes the chemical and petroleum refining industries as a significant source of airborne benzene, toluene, and xylenes in Texas. These analyses also offer evidence that federal and state legislation, and voluntary efforts by industry have reduced the public's exposure to hazardous air pollutants.

Introduction

In this report, Texas Natural Resource Conservation Commission (TNRCC) staff assess the trend in ambient concentrations of the volatile organic compounds, benzene, toluene and total xylenes, in the heavily industrialized southeast Texas counties, Harris, Chambers, Jefferson, and Orange. Each of these species is a Hazardous Air Pollutant (HAP), as defined in the 1990 Clean Air Act Amendments.[1] Harris, Chambers, Orange, and Jefferson have been among the top 20 most polluted Texas counties in total TRI releases and transfers. The chemical and petroleum refining industries accounted for approximately 96 percent of total reported releases in Jefferson County and 91 percent in Harris County in 1989. Harris, Jefferson, and Orange have been among the top five Texas counties in total pounds of TRI chemical releases to the air.[2]

These counties have also had the benefit of active industrial and governmental involvement in monitoring airborne emissions of organic compounds. In 1987, the Houston Regional Monitoring (HRM) Corporation, a consortium of chemical and petroleum refining industries in Harris and Chambers counties formed in response to Houston's failure to meet the Clean Air Act ozone standards, began monitoring organic species. In Jefferson and Orange counties, the local Planning Commission sponsored the South East Texas Regional Planning Commission (SETRPC) network starting in 1989. This network also was established because the Beaumont area failed to meet the federal ozone standard.

Ozone is a photochemical oxidant formed from volatile organic compounds and nitrogen oxides in the presence of sunlight. It can affect the respiratory system,

especially in sensitive individuals such as asthma or allergy sufferers. Because of the importance of volatile organic compounds in ozone formation, both the HRM and SETRPC networks collected extensive measurements of volatile organic compounds, meteorology, and ozone. The HRM and SETRPC networks measure for 146 and 54 compounds, respectively.

Organic compounds, rather than nitrogen oxides, have been the focus of Texas regulatory efforts to lower ozone levels in both Beaumont and Houston, the latter classified as having the nation's worst smog after Los Angeles. Organic compounds are believed to be the limiting compounds in the formation of ozone and are commonly emitted by the chemical industry and from petroleum refining. They are also significant components of automotive exhaust and gasoline vapors.

Benzene, toluene, and xylenes make up a significant percentage of the total air emissions in these four counties. Benzene, toluene, and xylenes are emitted by both large concentrated sources like chemical plants and petroleum refining plants, and small numerous sources like automobiles.

While all HAPs in Section 112 of the 1990 Clean Air Act are considered toxic, benzene generates a lot of public interest in Texas and elsewhere because it is a human carcinogen. Benzene at low concentrations is frequently measured in ambient urban air. While there is no direct evidence that benzene levels found in ambient urban air pose a significant public health risk, occupational exposures to benzene have been associated with an increased risk of leukemia[3] and certain other well-documented adverse effects on the hematopoietic system.[4]

Neither toluene nor the xylene isomers are known human carcinogens. However, they are still a public concern because adverse health effects have been reported for these compounds at levels thousands of times higher than those routinely found in urban air.[5]

Data and Methods

The HRM network consists of eight stations located east of downtown Houston in an industrial area around a shipping channel as shown in Map 1. Samples are collected using summa®-polished stainless steel canisters that draw in air over a 24-hour period at each site every sixth day, resulting in approximately 60 samples per year at every site. Further to the east in another heavily industrial area, the SETRPC network operates three toxics sites in Jefferson County and three sites in Orange County as shown in Map 2. The SETRPC samples are collected using a similar technology but only every twelfth day. Data from both monitoring networks were provided to the TNRCC by Radian Corporation (Austin, Texas), which operates the samplers and analyzes the samples.

Measured volatile organic compound data from the HRM network, taken 1987 through 1995, and data from the SETRPC network, taken 1989 through 1995, were analyzed for possible trends. The measured concentrations, in parts per billion by volume (ppbv) for a particular compound or group of compounds, were plotted as a function of time, and a straight line was fitted to the plot using classical least squares regression. The software used for the classical linear regression was JMP Statistical Visualization version 2.0 (SAS Institute Inc., Cary, North Carolina). The general formula fitted is given below:

$$(1)\ Pollutant = \alpha + \beta\,(SASDATE)$$

where,

POLLUTANT is the concentration in ppbv for a species or group of species (i.e. benzene), and,

SASDATE is given in the number of seconds since Jan. 1, 1904. This is the default date used by the statistical software in calculating the regression equation.

After calculation of the best-fit line, the coefficient of SASDATE, ß, was examined to determine its sign and significance. If the sign of the coefficient was negative and the coefficient was significant (as determined by a two-sided t-test with the probability of obtaining a larger t value less than 0.01), then the trend in the ambient concentrations of the pollutant at that site was declared to be significantly decreasing. Using the coefficient, we calculated an estimated change in daily ambient concentrations of a particular compound or group of compounds with the following formula:

$$(2)\ TREND = \frac{\hat{Y}_n - \hat{Y}_1}{\hat{Y}_1}$$

where,

$\hat{Y}_n$ is the estimated final concentration and $\hat{Y}_1$ is the estimated initial concentration. For all sites except 815 and 801, $\hat{Y}_n$ is calculated by evaluating equation (1) with a *SASDATE* of Dec. 23, 1995, which is the last sample date in the dataset. For site 801, $\hat{Y}_n$ is calculated by evaluating equation (1) with a *SASDATE* of Dec. 17, 1995. At site 815, sampling was discontinued in 1992, so a *SASDATE* for July 29, 1992 is used to calculate $\hat{Y}_n$. $\hat{Y}_1$ is calculated by evaluating equation (1) with the *SASDATE*, which corresponds to the monitor's start-up date.

Even if the coefficient is not determined to be significant, the trend is still noted from the sign of the coefficient. These non-significant trends are declared to be possibly decreasing if the sign is negative or possibly increasing if the sign is positive. If the coefficient was positive and significant, then the trend in the ambient concentrations of a pollutant would be declared to be significantly increasing. The *TREND* is estimated for every monitoring site using equation (2). The four possible classifications are significant decrease, significant increase, possible decrease, and possible increase.

TNRCC staff also applied these techniques to the sum of all organic compounds measured at each network. For the HRM network, 146 compounds were summed and analyzed for trends. For the SETRPC network, 54 compounds were summed and analyzed for trends. Many of the compounds were only found infrequently at levels above their detection limit. When a compound was not measured in a particular sample, one-half the minimum detection limit was used in the statistical calculations following standard procedures in air pollution monitoring.[6] These techniques were then applied to the pollutants benzene, toluene, and total xylenes at each of the 12 monitoring sites.

Staff also applied these techniques to county-wide averages to estimate the trend for benzene, toluene, and total xylenes in each of the four counties. To do this, first a sample day average was calculated using the

data from all sites within a county for a pollutant or group of pollutants. Then the trend was estimated using the averaged data and equations (1) and (2). By doing this, staff were able to estimate the trend in ambient concentrations of the pollutants and the significance of the trend for Harris, Chambers, Jefferson, and Orange counties. The estimate, based on the average of multiple sites, is more statistically robust than the estimates of the trend for each individual site.

To verify these analyses for county-wide trends, staff transformed pollutant values to their natural logarithms, and measurements that fell outside of two standard deviations from the mean were deleted. On this modified data set, the calculation of trend using equations (1) and (2) was repeated. This ensured that upset conditions did not overly influence the statistical analysis. As long as the significance, relative magnitude, and direction of the trend did not change, the results of this supplemental analysis are not reported here.

To compare the trends from the monitoring data with the annual estimates of industrial emissions from the TRI, calculating a county-wide trend estimate was necessary. Since staff could only compare annual emissions estimates with annual averages over several sites, they calculated an alternative measure of the trend: the percent change. The equation for percent change is equation (2), with annual emissions or annual average concentration substituted for $\hat{Y}_1$ and $\hat{Y}_n$. Because TRI data are available only through 1994, the percent change is calculated from the first year of monitoring (either 1987 or 1989) through 1994. In mathematical terms, the data for $\hat{Y}_n$ in the percent change calculation are from 1994 and the data for $\hat{Y}_1$ come from the first year of monitoring. For the HRM and SETRPC networks, this is 1987 and 1989, respectively. Thus, the percent change between emissions and ambient concentrations is directly comparable. The results from this alternative calculation of a trend, the percent change, can be compared with results for the trend estimate calculated using the regression coefficient.

Results

1. *A statistical analysis of the trend in ambient concentrations of volatile organic compounds measured at long-term stationary monitoring sites in southeast Texas during the late 1980s and mid 1990s shows that there has been a significant decline in the ambient concentrations of many volatile organic compounds.*

First, TNRCC staff considered the trend in ambient concentrations of volatile organic compounds measured at long-term stationary monitoring sites in southeast Texas during the late 1980s and mid 1990s (Table 1).

In Harris County, all six monitors had a significant decline of the total ambient concentration of the 146 monitored compounds. In Chambers County, where there are also 146 compounds monitored, both monitors showed a significant decrease.

In Jefferson County, where 54 compounds are measured, the result was different. One of the three sites had a significant decrease, while two sites had a possible decrease. In Orange County, there was a significant decline of the total ambient concentration of the 54 measured compounds. Of the three Orange County monitoring sites, only one had been operating since 1989, and it showed a significant 79 percent decrease. The other two sites began monitoring during 1992.

The discovery that there has been a significant decline in the sum of ambient concentrations of measured volatile organic

compounds led to the study of benzene, toluene, and xylenes in more detail.

2. *These four counties all experienced a 50 percent to 75 percent decrease in the monitored ambient levels of benzene.*

For benzene, all sites in the HRM and the SETRPC networks showed a decrease in ambient levels over the period of monitoring with all but one decrease being significant. Ambient concentrations of benzene near industrial facilities in all four counties with monitors have decreased. For example, Harris County had a highly significant 65 percent benzene reduction from 1987 through 1995. In Jefferson County, there was a downward trend of 53 percent over the six-year period. The details are in Table 2.

There was only one site, site 803 in Harris County, where the ambient benzene concentration appears not to be significantly decreasing. Examination of the HRM network data showed that the third highest average level of benzene and the maximum recorded benzene level during the eight-year monitoring period occurred at 803. This site has been selected by TNRCC for additional monitoring using specialized techniques.

3. *These counties also experienced 70 percent to 90 percent declines in measured toluene concentrations and about a 60 percent to 100 percent decline in the measured concentrations of total xylenes. The percent decline of these two compounds is not as large in Harris County as in the other three counties.*

Similar results were found when classical least squares regression was applied to toluene and total xylenes data (Table 3). For toluene, there was a significant decrease at all 12 individual sites and for each of the four counties. For total xylenes, there was a significant decrease at 10 individual sites and for the four counties. For xylenes, the analysis covered the period 1987-1994 because no 1995 HRM xylenes data were available for analysis.

4. *Analysis of the air releases of toxic chemicals reported as part of the EPA's TRI shows that the decrease in reported industrial emissions of benzene, toluene, and xylenes, except for Orange County, reflects a decline in ambient concentrations of these compounds. The TRI reports that xylenes emissions are increasing in Orange County, yet our analysis shows that ambient concentrations of xylenes are decreasing in all four counties.*

Since 1986, facilities that produce or use chemicals regulated under Title III of the Superfund Amendments and Reauthorization Act are required to report annual air emissions of over 300 compounds considered potentially toxic.[7] Benzene, toluene, and xylenes have historically been among the top 25 chemicals released to the air in Texas in total weight. In 1992, benzene, toluene, and total xylenes made up approximately 15 percent of the total pounds of TRI compounds emitted to the air in Harris, Chambers, Jefferson, and Orange counties.

Table 4 shows the total yearly air emissions of benzene, toluene, and xylenes and their respective annual average measured concentrations for Harris, Chambers, Jefferson, and Orange counties. Since 1987, there is a decrease in annual emissions of benzene, toluene and xylenes, except for Orange County. Emissions of xylenes are reported to be increasing in Orange County. In all four counties, measured concentrations of benzene, toluene, and total xylenes have declined since monitoring began.

Only Harris County consistently had a clear relationship between annual emissions data and measured concentrations (as

shown for benzene in Figure 1). This may be result of a large sample size for both ambient data and emissions data. There are six monitors in Harris County and many emission sources reporting to the TRI. Visual inspection of the data showed that for the other three counties, there is some correspondence between benzene and toluene concentrations and emissions, while there is very little correspondence between total xylenes concentrations and emissions (Figures 1-3).

In the heavily industrialized Harris County, trends in emissions from companies reporting to the TRI for benzene, toluene, and total xylenes reflect the trends in ambient concentrations. In the other three counties, where there is a poorer correspondence between trends in ambient concentration and trends in TRI emissions, it may be because we only have a limited number of monitors from which to calculate the countywide trend.

5. *Automobile emissions are known to contain benzene, toluene and xylenes,*[8] *and data from the Texas Department of Transportation show that the number of vehicle miles traveled (VMT) has increased significantly since 1987 in Harris and Chambers counties.*

This would suggest that emissions from mobile sources have been increasing during this period, even though measured benzene levels have been decreasing. However, counteracting these potential mobile emissions increases is the impact of the requirement for reformulated fuels, which would lower benzene emissions, imposed by the 1990 Federal Clean Air Act. The net effect of these factors on ambient concentrations remains unclear. Although the HRM and SETRPC monitoring results reported in this paper are from sites located for maximum industrial emissions, many of these sites are near high traffic areas and also measure mobile emissions.

Conclusions

Both the Houston and Beaumont/Port Arthur areas are classified by the EPA as nonattainment for ozone. Volatile organic compound reductions have been targeted as a major component of the ozone control strategy in these areas. Emissions reduction programs have been in place for many years. Based on our analysis, efforts to reduce organic compound levels in the ambient air through emissions reductions have resulted in a reduction in the levels of toxic compounds such as benzene, toluene, and total xylenes. While there are some questions how effective the volatile organic compound control strategy has been in reducing ozone levels, the decreasing ambient concentrations of a known human carcinogen, benzene, can be considered a significant benefit.

The correspondence between decline of reported emissions in the TRI and the decline in ambient concentrations measured at the monitoring sites indicates that the primary sources influencing concentrations of benzene, toluene, and xylenes in the areas near these monitors are large point sources, including the petrochemical industry. One important reason for the correspondence between the ambient measurements and the reported emissions is the site locations. Since they are sponsored by industry, especially in Harris and Chambers counties, they are at the fence line or on the property of industrial facilities. However, many of these sites are also located near high traffic areas. The decline in ambient concentrations of xylenes in Orange County while industrial emissions

have reportedly increased will require further study.

Future Research

To characterize the decline in hazardous volatile organic compounds in these counties, the TNRCC anticipates conducting a more detailed trend analysis of all of the compounds monitored and a compound-by-compound comparison with TRI emissions. Staff will focus their attention on compounds that are important in ozone formation.

The research has indicated areas where emission sources are not well understood. Additional research will need to be conducted to identify the source of these emissions. Two particular instances deserve to be noted. Chambers County has reported benzene emissions (500 lbs.) only for 1994, yet benzene levels there are consistent with the levels found in the other three counties. There may be transport from nearby Harris County. In Chambers County, point sources that may be contributing to emissions may not be included in the TRI because their chemical use is below the threshhold that requires them to report. Also, the opposite direction of the trend in xylenes emissions and concentrations needs to be examined in greater detail to determine why emissions have increased while concentrations have decreased in Orange County.

Finally, additional monitoring will be conducted at HRM network site 803 to better characterize emissions in the area. Analysis showed that while site 803 in Harris County had a slight downward benzene trend, it was not significant. This site showed the third highest average level of benzene and the highest level of benzene over the seven-year monitoring period.

Acknowledgment

The authors would like to thank the TNRCC Office of Pollution Prevention and Recycling for its assistance in providing the TRI data used in this analysis.

1. Title III, Section 112(k), of the 1990 Amendments to the Clean Air Act (CAA), Public Law 101-549, Nov. 15, 1990.
2. *Toxic Release Inventory Program 1989 Texas State Report*, Texas Water Commission, #LP 92-17, Aug. 1992.
3. Infante, P.F., Rinsky, R.A., Wagner, J.K., and Young, R.J., *Leukemia Among Workers Exposed to Benzene*, National Institute for Occupational Safety and Health, April 26, 1977.
4. Toxicological Profile for Benzene, Agency for Toxic Substances and Disease Registry, U.S. Public Health Service, May 1989.
5. Sax, N.I., *Dangerous Properties of Industrial Materials*, 5th Edition, Van Nostrand Reinhold Company, p. 1035 and pp. 1094-1095.
6. U.S. EPA, 1990: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "1990 Urban Air Toxics Monitoring Program," EPA-450/4-91-024, June 1991.
7. Title III, Section 313, Superfund Amendments and Reauthorization Act, (Emergency Planning and Community Right-to-Know Act), Oct. 1986.
8. Lonneman, W.A., Sella, R.L., and Meeks, S.A., "Non-Methane Organic Composition in the Lincoln Tunnel," *Environmental Science & Technology* 1986, 20, 790-796.

Appendix A: Tables

Table 1. Trends and Their Significance for Total Volatile Organic Compounds Measured in 1987-1995

Monitor ID	Dates of Operation	Trend	Prob. Coefficient is Not Zero (P>|t|)
Harris County			
801	9/87-12/95	(-) 62%	<0.01 - significant
803	9/87-12/95	(-) 43%	<0.01 - significant
804	9/87-12/95	(-) 34%	<0.01 - significant
807	9/87-12/95	(-) 69%	<0.01 - significant
808	9/87-12/95	(-) 46%	<0.01 - significant
815	9/88- 7/92	(-) 28%	<0.01 - significant
Chambers County			
900	2/90-12/95	(-) 76%	<0.01 - significant
901	9/87-12/95	(-) 49%	<0.01 - significant
Jefferson County			
12	9/89-12/95	(-) 41%	<0.01 - significant
102	9/89-12/95	(-) 2%	0.88
2008	9/89-12/95	(-) 3%	0.93
Orange County			
100	7/89-12/95	(-) 79%	<0.01 - significant

Table 2. Trends and Their Significance for Benzene in 1987-1995

Monitor ID	Trend	Prob. Coefficient is Not Zero (P>|t|)
Harris County	(-) 65%	<0.01 - significant
801	(-) 71%	<0.01 - significant
803	(-) 13%	0.56
804	(-) 69%	<0.01 - significant
807	(-) 78%	<0.01 - significant
808	(-) 75%	<0.01 - significant
815	(-) 60%	<0.01 - significant
Chambers County	(-) 76%	<0.01 - significant
900	(-) 25%	<0.01 - significant
901	(-) 46%	<0.01 - significant
Jefferson County	(-) 53%	<0.01 - significant
12	(-) 65%	<0.01 - significant
102	(-) 34%	<0.01 - significant
2008	(-) 56%	<0.01 - significant
Orange County *	(-) 72%	<0.01 - significant
100	(-) 74%	<0.01 - significant

* The Orange County trend differs from site 100 trend because data from two additional sites, which were started in 1992, were included in the county-wide average.

Table 3. Trends and Their Significance for Toluene Measured in 1987–1995 and Isomers Measured in 1987–1994

Monitor ID	Trend	Prob. Coefficient is Not Zero (P>|t|)
Toluene		
Harris County	(-) 69%	<0.01 - significant
801	(-) 76%	<0.01 - significant
803	(-) 50%	<0.01 - significant
804	(-) 69%	<0.01 - significant
807	(-) 73%	<0.01 - significant
808	(-) 61%	<0.01 - significant
815	(-) 55%	<0.01 - significant
Chambers County	(-) 92%	<0.01 - significant
900	(-) 80%	<0.01 - significant
901	(-) 83%	<0.01 - significant
Jefferson County	(-) 86%	<0.01 - significant
12	(-) 81%	<0.01 - significant
102	(-) 89%	<0.01 - significant
2008	(-) 88%	<0.01 - significant
Orange County	(-) 93%	<0.01 - significant
100	(-) 91%	<0.01 - significant
Total Xylenes		
Harris County	(-) 58%	<0.01 - significant
801	(-) 59%	<0.01 - significant
803	(-) 54%	<0.01 - significant
804	(-) 72%	<0.01 - significant
807	(-) 71%	<0.01 - significant
808	(-) 57%	0.87
815	(-) 13%	0.57
Chambers County	(-) 86%	<0.01 - significant
900	(-) 105%	<0.01 - significant
901	(-) 83%	<0.01 - significant
Jefferson County	(-) 100%	<0.01 - significant
12	(-) 94%	<0.01 - significant
102	(-) 100%	<0.01 - significant
2008	(-) 106%	<0.01 - significant
Orange County *	(-) 103%	<0.01 - significant
100	(-) 99%	<0.01 - significant

* The Orange County trend differs from site 100 trend because data from two additional sites, which were started in 1992, were included in the county-wide average.

Table 4. Air Emissions in Thousands of Pounds and Average Annual Concentration in Parts per Billion by Volume

Benzene

Change	1987	1988	1989	1990	1991	1992	1993	1994	Percent
Harris									
Air Emissions	2,333	2,241	1,528	1,680	1,798	1,614	1,461	1,345	(-) 42%
Avg. Concentration	3.76	3.69	3.63	2.98	2.29	2.53	2.03	1.83	(-) 51%
Chambers									
Air Emissions*	none reported							1.0	n/a
Avg. Concentration	1.13	1.41	1.32	0.95	0.83	0.66	0.70	0.56	(-) 50%
Jefferson									
Air Emissions			933.9	744.1	878.6	911.9	694.2	657.4	(-) 30%
Avg. Concentration			2.02	1.38	0.80	1.03	1.03	0.89	(-) 56%
Orange									
Air Emissions			282.4	208.3	33.4	22.8	17.1	6.1	(-) 98%
Avg. Concentration			1.92	1.50	0.62	0.72	0.77	0.57	(-) 70%

Toluene

Change	1987	1988	1989	1990	1991	1992	1993	1994	Percent
Harris									
Air Emissions	3,840	3,504	3,107	3,280	2,976	2,183	1,974	1,872	(-) 51%
Avg. Concentration	4.25	4.18	5.02	4.44	3.12	3.03	2.07	2.31	(-) 46%
Chambers									
Air Emissions	570	469	449	525	433	292	244	147	(-) 74%
Avg. Concentration	2.30	2.73	1.91	1.65	1.30	1.02	0.79	0.73	(-) 68%
Jefferson									
Air Emissions			1,419	2,918	2,719	2,414	1,793	1,257	(-) 11%
Avg. Concentration			4.11	3.06	1.94	2.01	1.23	1.15	(-) 72%
Orange									
Air Emissions			12.4	68.0	98.7	28.5	23.9	9.6	(-) 23%
Avg. Concentration			5.97	2.68	1.77	1.24	0.92	0.70	(-) 88%

Xylenes

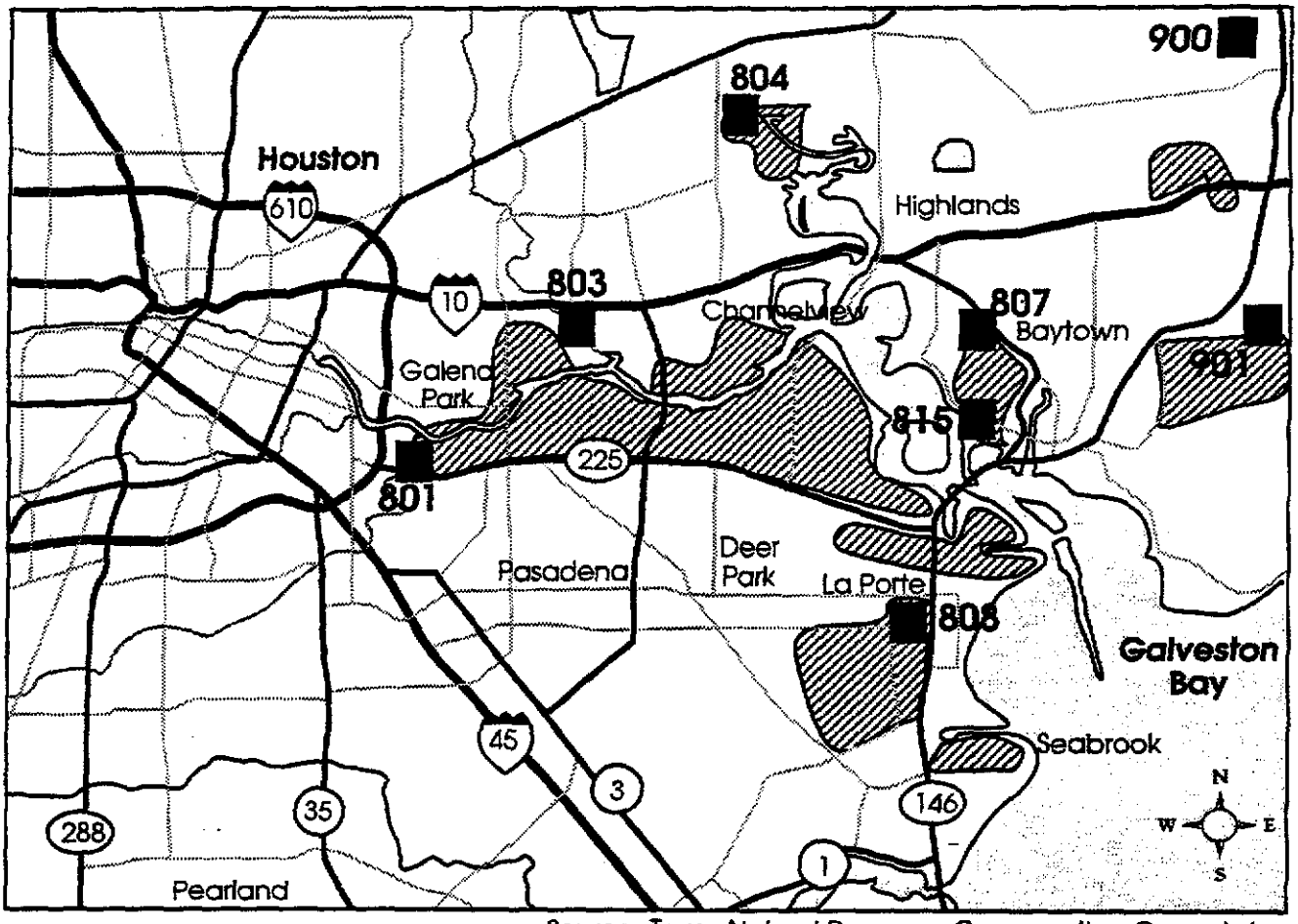
Change	1987	1988	1989	1990	1991	1992	1993	1994	Percent
Harris									
Air Emissions**	2,946	2,652	2,764	2,433	2,531	2,629	2,794	2,606	(-) 12%
Avg. Concentration	2.86	2.37	2.81	3.58	2.52	2.20	1.44	1.12	(-) 61%
Chambers									
Air Emissions	7.5	1.9	1.72	1.77	1.75	1.0	1.25	1.0	(-) 87%
Avg. Concentration	1.15	0.71	0.49	1.11	0.44	0.35	0.23	0.19	(-) 84%
Jefferson									
Air Emissions**			684.7	629.7	503.8	598.8	350.1	372.2	(-) 46%
Avg. Concentration			2.21	2.16	0.97	0.96	0.46	0.35	(-) 85%
Orange									
Air Emissions	none reported			48.0	33.4	0.006	45.5	94.0	(+) 96%***
Avg. Concentration			2.09	1.72	0.68	0.62	0.36	0.32	(-) 81%***

* There were no benzene emissions reported in Chambers County from 1987-1993.
** Xylenes emissions are the sum of m-, p-, o-, and mixed isomers of xylene from TRI.
*** Calculation is for 1990 through 1994 only.

Data Source:
Emissions from the Toxic Release Inventory (TRI) for 1987 through 1993. Ambient concentrations calculated from monitoring data supplied by Radian, Inc., Austin, Texas.

Appendix B: Maps and Figures

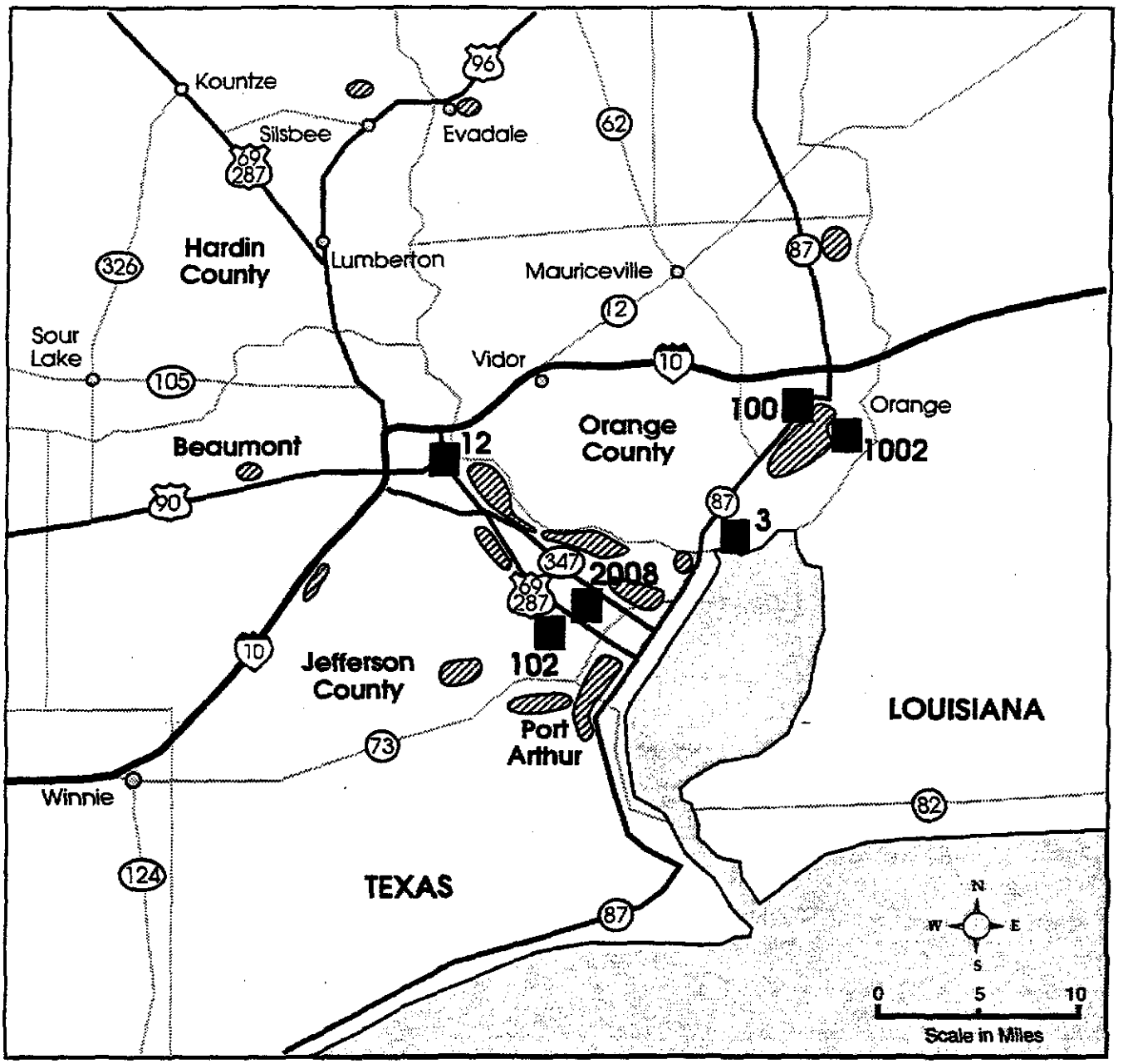
Map 1. Houston Regional Monitoring (HRM) Sites



Source: Texas Natural Resource Conservation Commission

Primarily Industrial | Bay Water | Site

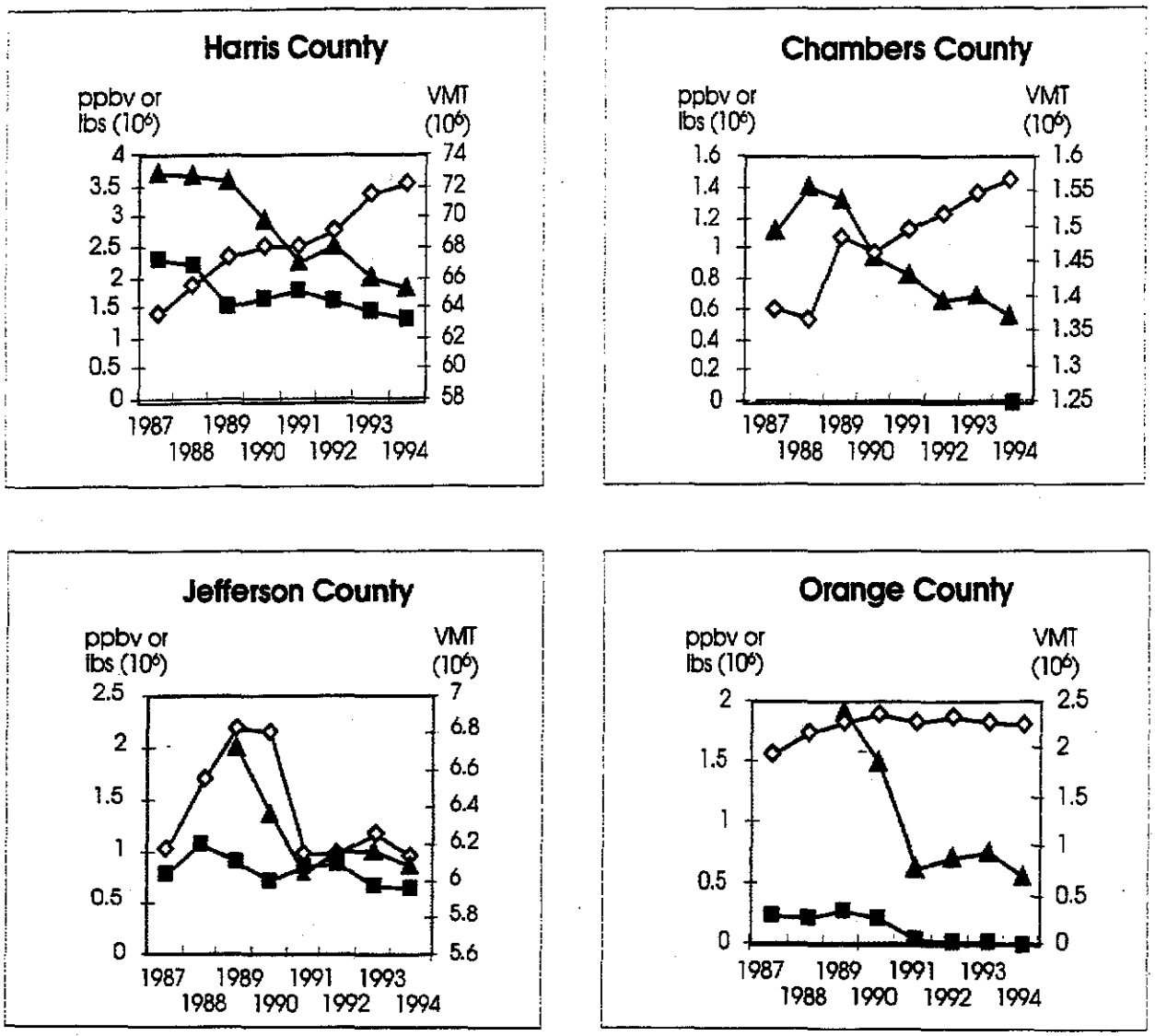
Map 2. South East Texas Regional Planning Commission (SETRPC) Sites



Source: Texas Natural Resource Conservation Commission

Primarily Industrial | Gulf Water | Site

Figure 1. Benzene Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas



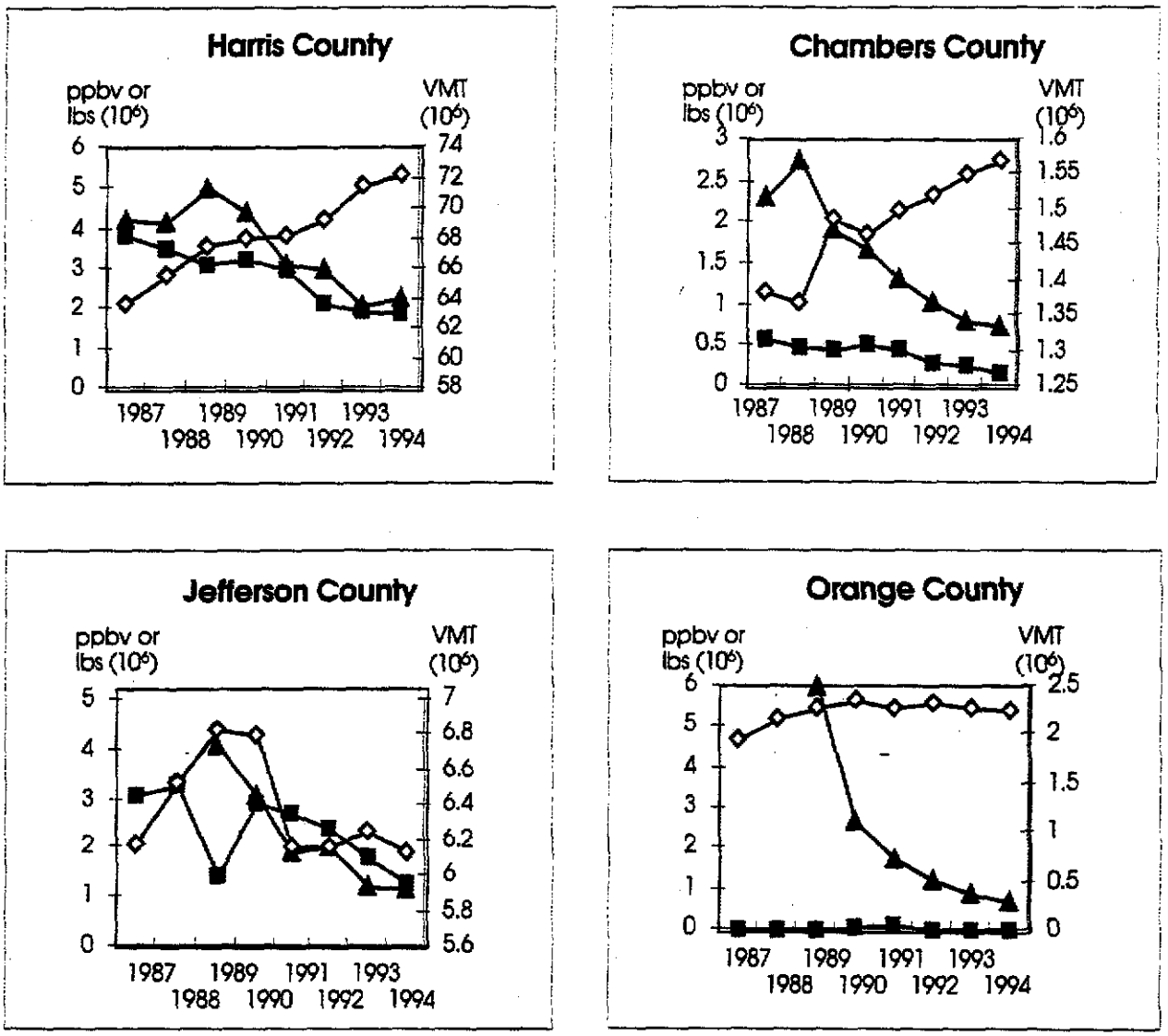
Sources: Houston Regional Monitoring Network, South East Texas Regional Planning Commission, and Texas Department of Transportation

■ Toxic Release Inventory Air Emissions in millions of pounds

▲ Average Ambient Concentration in parts per billion by volume (ppbv)

◇ Vehicle Miles Traveled (VMT) in millions

Figure 2. Toluene Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas



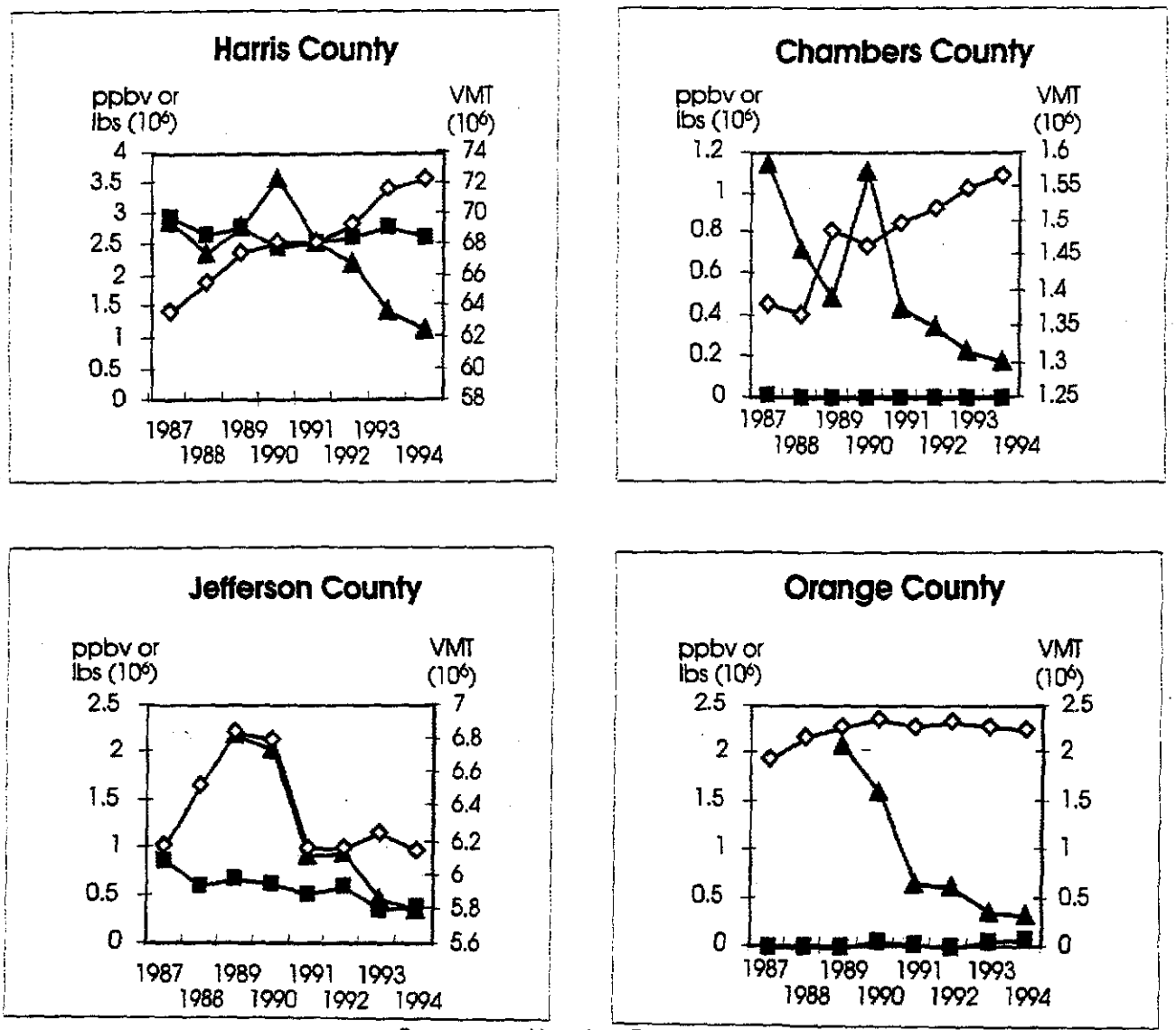
Sources: Houston Regional Monitoring Network, South East Texas Regional Planning Commission, and Texas Department of Transportation

■ Toxic Release Inventory Air Emissions in millions of pounds

▲ Average Ambient Concentration in parts per billion by volume (ppbv)

◇ Vehicle Miles Traveled (VMT) in millions

Figure 3. Total Xylenes Emissions and Ambient Concentrations versus Vehicle Miles Traveled in Southeastern Texas



Sources: Houston Regional Monitoring Network, South East Texas Regional Planning Commission, and Texas Department of Transportation

■ Toxic Release Inventory Air Emissions in millions of pounds

▲ Average Ambient Concentration in parts per billion by volume (ppbv)

◇ Vehicle Miles Traveled (VMT) in millions

Total xylenes emissions are calculated from the TRI as the sum of ortho-, meta-, para-, and mixed isomers of xylene.