COMPILATION OF DIESEL EMISSIONS SPECIATION DATA

FINAL REPORT

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EXECUTIVE SUMMARY

Emissions from diesel-powered motor vehicles have substantially changed over the last decade because of new fuels, changed engine designs, and improved emission-control technology. The changing nature of diesel exhaust, the substantially lower emissions of recent models and the requirement to measure emissions components that total less than one percent of diesel exhaust mass all result in significant challenges for the scientists who make these measurements. In many situations, scientists must devise new measurement methods to meet these needs. Additional challenges exist in compiling and reporting these emissions data sets in a comprehensive, easily understood manner, since measurement and reporting methods can vary by investigator.

In order to better assess the current state of speciated diesel emissions data, the Coordinating Research Council (CRC) and the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) jointly sponsored this project with the following three objectives:

- Perform literature review of diesel speciation studies;
- Compile speciated exhaust emissions data from on-road diesel vehicles designed to meet U.S. emission standards; and
- Assess the quality and completeness of the data.

E.H. Pechan & Associates, Inc. (Pechan) reviewed studies that have recently been carried out that provided data on speciated diesel exhaust emissions from vehicles with and without the use of advanced emission reduction technologies. In performing the literature search to determine the data sets that could be incorporated into a diesel emissions database for this project, Pechan accessed peer-reviewed materials such as journal papers (e.g., Environmental Science and Technology [ES&T]) and papers and reports from the Society of Automotive Engineers (SAE), CRC, NREL, California Air Resources Board (CARB), U.S. Environmental Protection Agency (EPA), and research institutes (e.g., University of Wisconsin, West Virginia University, University of California at Riverside). After review and analysis of the report content and speciation methodology employed, the suitability of each reference was briefly summarized for this project. Over 240 references were reviewed for possible inclusion in the database. The studies for which data have been included in the Diesel Speciation Database are listed below, along with the number and types of vehicles included in the database from each study and the corresponding vehicle or engine model years:

Study Name	Vehicles Tested	Vehicle/Engine Model Years
Southwest Research Institute (SwRI) School Bus Study	2 school buses	2001
SwRI study for the Ad Hoc Diesel Fuel Test Program	1 LDDV	N/A
New York City Clean Diesel Demonstration Program	2 diesel transit buses	1999
California Institute of Technology	2 MHDDT 2 HHDDT	1995 1987
BP Southern California ultra-low sulfur diesel (ULSD)/DPF/CNG Heavy-duty study	3 HDDT 1 transit bus 1 school bus	1996-1999 1998 1998

Study Name	Vehicles Tested	Vehicle/Engine Model Years
SwRI Fischer-Tropsch study	2 HDD engines	1999, 2000
CRC Mass vehicle tests	16 LDDVs	1977-1994
CRC AVFL-10a & 10b	4 LDDV/T ~110 L/HDDV	2004 1978-2000
CE-CERT	14 HDDT 28 LDDV/T	1996-2000 1983-1999
Gasoline-diesel particulate matter (PM) Split Study	30 HDDT 2 buses	1982-2001 1982, 1992
CRC E55/59	1 MHDDT 8 HHDDT	1997 1985-2003
Desert Research Institute	4 LDDV 4 Diesel trucks	1991, 1998, 1999, 2000 N/A
Environment Canada	1 LDDT 2 urban buses	1998 1989, 1998
HDD = heavy-duty diesel HDDT = heavy-duty diesel truck HDDV = heavy-duty diesel vehicle HHDDT = heavy heavy-duty diesel truck LDDT = light-duty diesel truck LDDV = light-duty diesel vehicle MHDDT = medium heavy-duty diesel truck		

Relevant emissions data from these studies were extracted and compiled into database tables. Tables were organized by engine, fuel, and emissions data. Emissions data were subdivided into seven tables for: 1) regulated pollutants, 2) elements and inorganic compounds, 3) carbonyl compounds, 4) polycyclic aromatic hydrocarbons (PAH), 5) dioxins and furans, 6) speciated hydrocarbons (volatile organic gases), and 7) semivolatile organic compounds. Additionally, a pollutant list, a bibliography, and a data dictionary are included in the database. The database can be used to execute queries based on (where available) engine, fuel, duty cycle, and emissions parameters. The speciation database (available from CRC) is provided in two formats—Microsoft Access® and Microsoft Excel®. Both formats contain the same data and both are organized in the same manner.

The number of compiled emission tests by pollutant grouping included in the Diesel Speciation Database is as follows:

- 312 emission tests reporting carbonyls;
- 237 emission tests reporting speciated volatile organic compounds;
- 387 emission tests reporting PAHs;
- 207 emission tests reporting semivolatile organic compounds;
- 297 emission tests reporting speciated particulate matter; and
- 87 emission tests reporting dioxins or furans.

Throughout the data collection and compilation process, several issues evolved that were reviewed by the CRC Real World Vehicle Emissions & Emissions Modeling Group (the Working Group). This group provided direction and guidance in determining how data collection issues should be resolved. Several decisions made by the Working Group that affect how data are recorded in the database are as follows:

- All speciated emission rates are listed in the database as they were reported in the original project documentation and the *Phase* field in the emissions table indicates whether the data were collected in PM, gaseous, or both phases.
- Within the database, background concentration data is provided, where available, but the emission rates were not corrected for background concentrations, if this was not done in the source report.
- Organic carbon (OC) is not adjusted for other bonded elements like hydrogen or oxygen. Since there are no universal correction factors for OC, the Working Group agreed to let the users of the database decide what correction factors should be applied, if needed.

After the database was completed, Pechan's subcontractor, Energy and Environmental Analysis, Inc. (EEA), performed an independent quality assurance (QA) review of the diesel speciation database prepared by Pechan. Through this review, plots of total hydrocarbons, oxides of nitrogen, particulate matter, and carbon monoxide as a function of vehicle class and model year groupings were prepared, and several data outliers and errors were detected.

The Diesel Speciation Database prepared under this project should prove to be useful to researchers, emission modelers, and emission inventory developers. This database should also provide users with a better understanding of the nature of pollutants emitted by the current fleet of diesel vehicles and trucks.

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CONTENTS

ACRONYMS AND ABBREVIATIONS

CARB	California Air Resources Board
CAS	Chemical Abstracts Service
CBD	Central Business District
CE-CERT	Center for Environmental Research and Technology
CNG	Compressed Natural Gas
CO	carbon monoxide
CO_2	carbon dioxide
CRC	Coordinating Research Council
CRDPF	Continuously Regenerating Diesel Particulate Filters
CSHVC	City-Suburban Heavy Vehicle Cycle
CSHVR	City Suburban Heavy Vehicle Route
DDC	Detroit Diesel Corp.
DOC	diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	diesel particulate filters
DRI	Desert Research Institute
EC	elemental carbon
EEA	Energy and Environmental Analysis, Inc.
EGR	Exhaust Gas Recirculation
EMFAC	EMission FACtor mobile source model
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 1992
ES&T	Environmental Science and Technology
F-T	Fischer-Tropsch
FTP	Federal Test Procedure
HC	hydrocarbon
HHDDT	Heavy Heavy-Duty Diesel Trucks
International	International Truck & Engine Corporation
LDV	light-duty vehicle
LHDT	light heavy-duty truck
MHDT	Medium Heavy-Duty Trucks
MSOD	Mobile Source Observation Database
MTA	Metropolitan Transit Authority
NO_x	oxides of nitrogen
NPAH	nitro-polycyclic aromatic hydrocarbon
NREL	National Renewable Energy Laboratory
NYB	New York Bus
NYSDEC	New York State Department of Environmental Conservation
OC	organic carbon
OEM	original equipment manufacturer
PAHs	polycyclic aromatic hydrocarbons
Pechan	E.H. Pechan & Associates, Inc.
PM	particulate matter
ppm	parts per million

ACRONYMS AND ABBREVIATIONS (continued)

PUF	polyurethane foam
QA	quality assurance
RPECS	Rapid Prototyping Electronic Control System
SAE	Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SCR	selective catalytic reduction
SHDT	small heavy-duty truck
SO_2	sulfur dioxide
SOF	soluble organic fraction
SRS	Substance Registry System
SVOCs	semivolatile organic compounds
SwRI	Southwest Research Institute
THC	total hydrocarbon
TPM	total particulate matter
UDDS	Urban Driving Dynamometer Schedule
ULSD	ultra-low sulfur diesel
UWM	University of Wisconsin-Madison
WVU	West Virginia University

CHAPTER I. INTRODUCTION/BACKGROUND

A. INTRODUCTION

Diesel engines are used extensively in transportation, especially in heavy-duty applications, due to their power, durability, and efficiency. Emissions from diesel-powered motor vehicles have substantially changed over the last decade as engine manufacturers have significantly lowered the emissions of particles in diesel exhaust through improved engine design and emission-control technologies--in combination with new fuels. The changing nature of diesel exhaust, the substantially lower emissions of recent models and the requirement to measure emissions components that total less than one percent of diesel exhaust mass all result in significant challenges for the scientists who make these measurements. In many situations, scientists must devise new measurement methods to meet these needs. The present team of investigators discovered additional challenges in compiling and reporting these emissions data sets in a comprehensive, easily understood manner. Many investigators employ different measurement and reporting methods; therefore compiling and comparing these results on an equitable basis was a major challenge.

The Coordinating Research Council (CRC) and the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) jointly sponsored a project with the following objectives:

- Compile speciated exhaust emissions data from on-road diesel vehicles designed to meet U.S. emission standards;
- Provide average emission rates of a large number of chemical species as a function of vehicle and technology category; and
- Provide an assessment of the quality and completeness of the data.

This report describes the effort performed by E.H. Pechan & Associates, Inc. (Pechan) to conduct an in-depth literature review to identify the state of knowledge of regulated and unregulated exhaust emissions from current technology diesel vehicles. The resulting database is available, upon request, from CRC.

B. REPORT ORGANIZATION

This report is organized in seven chapters. This first chapter is the report introduction. The second chapter details the data collection effort and summarizes the primary studies included in the Diesel Speciation Database. Chapter III provides information on the database development and database structure. Chapter IV discusses issues that arose in compiling the data for this database and the resolution of those issues. Chapter V provides information on the quality assurance (QA) processes performed on the database along with general findings. Chapter VI describes potential uses for the resulting database beyond the needs of this study, and Chapter VII provides references mentioned in the report.

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CHAPTER II. DATA COLLECTION

The principal task for this project was to conduct an in-depth literature search to identify studies in which measurements of speciated diesel exhaust emissions from diesel engines were made. There were no restrictions regarding the model year of the engine. Only those emission tests conducted with diesel fuels and lubricants representative of those commercially used in the U.S. were included. In performing the literature search for this project, Pechan accessed peer-reviewed materials such as journal papers (e.g., Environmental Science and Technology [ES&T]) and papers and reports from the Society of Automotive Engineers (SAE), CRC, NREL, California Air Resources Board (CARB), EPA, and research institutes (e.g., University of Wisconsin, West Virginia University, University of California at Riverside). The bulk of the reports used in this effort were published by SAE.

Copies of the source materials identified were procured by purchase from the Internet, from interlibrary loan, or from Pechan's in-house data collections. After review and analysis of the report content and speciation methodology employed, the suitability of each reference was briefly summarized for this project in a separate spreadsheet. Data from a total of 81 out of the 243 references reviewed are included in the database. The studies for which data have been included in the Diesel Speciation Database are briefly summarized below in Table II-1, along with the corresponding Project ID of the study as included in the Diesel Speciation Database, the number and type of vehicles tested, the model years of these vehicles, and the reference citations for these studies. It should be noted that the number and types of vehicles included in this table do not necessarily represent all of the vehicles tested in a given study. Rather, this represents the vehicles included in the Diesel Speciation Database. Additional vehicles from these studies may have been excluded for a number of reasons, including: the vehicles did not meet the study criteria; speciated emissions were not collected; data for other vehicles were not available; only certain phases of project data were included; or other reasons as determined during the data review process.

A brief description of each of these studies is provided below.

Table II-1. Summary of Studies and Vehicles Included in Diesel Speciation Database

Study Name	Project ID(s)	Vehicles Tested	Vehicle/Engine Model Years	Relevant References
Southwest Research Institute (SwRI) School Bus Study	1004	2 school buses	2001	Ullman, et al., 2003
SwRI study for the Ad Hoc Diesel Fuel Test Program	1002	1 LDDV	N/A	Ball, et al., 2001a; Ball, et al., 2001b; Ball, et al., 2001c
New York City Clean Diesel Demonstration Program	1003, 1005	2 diesel transit buses	1999	Lanni, et al., 2001; Chatterjee, et al., 2002; and Lanni, et al., 2003
California Institute of Technology	1013, 1023	2 MHDDT 2 HHDDT	1995 1987	Schauer, et al., 1999; Hildemann, et al., 1991; Rogge, et al., 1993a; Rogge, et al., 1993b
BP Southern California ULSD/DPF/CNG Heavy-duty study	1001, 1012	3 HDDT 1 transit bus 1 school bus	1996-1999 1998 1998	Lev-On, et al., 2002a; Lev-On, et al., 2002b; and LeTavec, et al., 2002; Alleman, 2005
SwRI Fischer-Tropsch study	1021	2 HDD engines	1999, 2000	Fanick, et al., 2001
CRC Mass vehicle tests	1015, 0116, 1025	16 LDDVs	1977-1994	Cadle, et al., 1999; Knapp, et al., 2003
CRC AVFL-10a & 10b	1024, AVFL-10a	4 LDDV/T ~110 L/HDDV	2004 1978-2000	Merritt, 2003; Fanick, 2005
CE-CERT	1006, 1007, 1008, 1011, 1022	14 HDDT 28 LDDV/T	1996-2000 1983-1999	Durbin, 2002a; Durbin, 2002b; Durbin, et al., 2003;Cocker, et al., 2004; Shah, et al., 2004; Shah, et al., 2005; Norbeck, et al., 1998
Gasoline-diesel PM Split Study	1010	30 HDDT 2 buses	1982-2001 1982, 1992	NREL, 2005
CRC E55/59	1009, 1018	1 MHDDT 8 HHDDT	1997 1985-2003	Gautam, et al., 2003; Clark, et al., 2005
Desert Research Institute	1014, 1017	4 LDDV 4 Diesel trucks	1991, 1998, 1999, 2000 N/A	Zielinska, et al., 2004; Lowenthal et al., 1994
Environment Canada	1019, 1020	1 LDDT 2 urban buses	1998 1989, 1998	Graham et al., 1998; Graham and Welburn, 2000

A. SOUTHWEST RESEARCH INSTITUTE (SwRI) SCHOOL BUS STUDY

In late 2002, Southwest Research Institute completed a study commissioned by International Truck and Engine Corporation (International) and ConocoPhillips to characterize the regulated pollutants and toxic air contaminants for three school bus configurations. This study measured emission results for numerous chemical compounds and elements. International was interested in a comparative emissions profile of its Green Diesel Technology school bus that is certified by

EPA and CARB as meeting 2007 emission standards for particulates and hydrocarbons. ConocoPhillips was interested in knowing the impact of its ultra-low-sulfur fuel on the exhaust emissions of school buses equipped with low emitting diesel technology.

This work characterized the exhaust emissions from a diesel-powered bus, tested in a low-emitting diesel configuration (using the Green Diesel Technology) and also in a conventional diesel engine configuration. The second bus tested had a compressed natural gas engine. The conventional diesel school bus was manufactured by American Transportation and used a model year 2001 International DT530 model C275 engine. This engine is EPA 1998 certified. The low emitting school bus configurations was identical with the exception that it was equipped with an Engelhard catalyzed diesel particulate filter, and the engine control module was calibrated for low oxides of nitrogen (NO_x). This engine and filter combination meets EPA and CARB 2007 certification standards for PM and hydrocarbons (HC).

The conventional diesel configuration used Chevron Phillips number 2 diesel fuel that met the requirements of EPA certification testing. This fuel contained 371 parts per million (ppm) sulfur and 33 percent aromatics by weight. The ultra low sulfur diesel fuel used in the low emitting configuration was from ConocoPhillips and contained 14 ppm sulfur and 31 percent aromatics by weight. It was taken from a commercially available, ultra-low sulfur diesel refinery run that contained cracked stock.

This program used the City-Suburban Heavy Vehicle Cycle (CSHVC) because it was considered to be most representative of school bus operation. Three consecutive cycles of the CSHVC, totaling 85 minutes, were performed during a single test. This was necessary to accumulate adequate sample for analysis. Samples of gaseous compounds were taken from the primary dilution tunnel. Whereas, samples for semi-volatile compounds and particulate bound compounds were taken after double dilution to ensure that the sample entering the collection media was below 52°C.

The emissions measured in this study included regulated emissions, NO, methane, particulate matter sulfate and soluble organic fraction, and CO_2. In addition, 41 toxic air contaminants that CARB associates with diesel exhaust are detailed, as are many individual polycyclic aromatic hydrocarbons, dioxins, furans, chlorobenzene derivatives and elements.

B. SwRI STUDY FOR THE AD HOC DIESEL FUEL TEST PROGRAM

This aim of this study was to quantify engine-out emissions of potentially toxic compounds from a modern diesel engine. Five diesel fuels were examined in this study:

- an ultra-low sulfur (~1 ppm sulfur), low-aromatic hydrocracked diesel;
- the same ultra-low sulfur diesel containing 15 percent by volume dimethoxy methane;
- a Fischer-Tropsch diesel fuel (the Fischer-Tropsch data are included in the database, but it should be noted that this is not a commercially available fuel);
- a CARB diesel fuel (at 176 ppm sulfur); and
- an EPA number 2 certification diesel fuel (at 337 ppm sulfur).

Testing for this project was performed by Southwest Research Institute. The project included a number of sponsors: Ford Motor Company, DaimlerChysler, Equilon Enterprises, Marathon Ashland Petroleum Co., PDVSA Intevep., and the U.S. Department of Energy.

A DaimlerChrysler OM611 light-duty diesel engine was controlled with a Rapid Prototyping Electronic Control System (RPECS) that allowed variation of common rail injection parameters, pilot injection and Exhaust Gas Recirculation (EGR). Program modifications were made to the RPECS to allow individual cylinder fuel injection timing and quantity control. This allowed balancing the indicated mean effective pressure and combustion phasing of each cylinder. The engine was operated over speed/load modes representative of typical operating modes found in the US Federal Test Procedure (FTP) driving schedule. Each test point was run in triplicate. Measurements of PM, soluble organic fraction, NO_x, carbon monoxide (CO), total hydrocarbon (THC), benzene, 1,3-butadiene, formaldehyde, acetaldehyde, 17 PM bound polycyclic aromatic hydrocarbons (PAHs), and 10 gaseous phase PAHs were made. No nitro-PAHs (NPAHs) were reported.

C. NEW YORK CITY CLEAN DIESEL DEMONSTRATION PROGRAM

The New York City Metropolitan Transit Authority (MTA) initiated a Clean Diesel Demonstration Program. The Demonstration Program was aimed at implementing various diesel emission control, alternative fuel, and hybrid electric drive technologies to reduce transit bus emissions. As part of this program, emission testing was performed on several of the transit vehicles included in the Demonstration Program, under the supervision of the New York State Department of Environmental Conservation (NYSDEC), Environment Canada, and several industrial partners. NYSDEC and Environment Canada established a protocol for measuring both regulated and unregulated emissions from the selected in-use buses.

The program evaluated emissions from in-use buses powered by Detroit Diesel Corp. (DDC) Series 50 Diesel and Series 50G Compressed Natural Gas (CNG) engines. Two diesel-powered buses were tested and three CNG buses were tested. (The CNG results are not included in the diesel speciation database.) The transit buses that were evaluated were equipped with 1999 model year DDC Series 50 engines equipped with Johnson Matthey Continuously Regenerating Diesel Particulate Filters (CRDPF). They were fueled with 30 ppm sulfur, number 1 diesel fuel and driven over the Central Business District (CBD) and New York Bus (NYB) driving schedules. Some testing was also done with the standard 300 ppm sulfur, number 1 diesel fuel on these engines equipped with a diesel oxidation catalyst (DOC) that the fleet normally uses.

The emissions measured in this study included regulated pollutants, CO_2, NO_2, EC, OC, carbonyls, speciated hydrocarbons, PAHs, NPAHs, SO_4, and soluble organic fraction (SOF).

D. CALIFORNIA INSTITUTE OF TECHNOLOGY

A significant body of work initiated at the California Institute of Technology studied the composition of diesel particulate matter and other unregulated exhaust compounds. Gas and particle-phase tailpipe emissions were quantified using a two-stage dilution sampling system. Testing was performed on two pre-1998 medium-duty diesel trucks with no aftertreatment, using CARB diesel fuel. The vehicles were driven through the hot-start portion of the Federal Test

Procedure driving cycle. Emission rates of numerous gas-phase and particulate-phase alkanes, alkenes, aromatics, terpanes, hopanes and steranes, carbonyls, and acids were quantified along with fine particle mass and chemical composition (elemental and organic carbon and trace elements). High molecular weight carbonyls up to tridecanal were measured. PM was characterized using a traditional filter sampler and with a denuder/filter/polyurethane foam (PUF) sampler.

E. BP SOUTHERN CALIFORNIA ULSD/DPF/CNG HEAVY-DUTY STUDY

This project, funded in part by the South Coast Air Quality Management District (SCAQMD) and CARB and carried out in 2001, evaluated ultra-low sulfur diesel fuels and passive diesel particulate filters (DPF) in several different truck and bus fleets operating in Southern California. A chemical characterization study was carried out to compare the exhaust emissions using the test fuels with and without aftertreatment. This project included the measurement of regulated emissions and CO_2, and the speciation of VOC, particle-bound and semi-volatile organics, inorganic ions, elements, PM_{10}, and $PM_{2.5}$.

Six vehicles (4 diesel and 2 CNG) were selected for the chemical characterization phase of the study – a school bus, two grocery trucks, and three transit buses. The vehicles were tested with the original exhaust system and subsequently fitted with DPFs provided by Engelhard and Johnson Matthey. The testing was carried out using a representative California diesel fuel, Arco ECD-1, and Arco ECD. One diesel vehicle was also tested with Fischer-Tropsch (F-T) diesel fuel. The Arco ECD fuel contained 4 ppm sulfur and 8 percent aromatics by weight, ECD-1 had 13 ppm sulfur and 18 percent aromatics by weight, CARB diesel had 115 ppm sulfur and 16 percent aromatics by weight, and the F-T fuel had < 1 ppm sulfur and 0.16 percent aromatics by weight. The vehicles were all 1998 or newer.

The school bus and grocery trucks were tested on the City Suburban Heavy Vehicle Route (CSHVR) test cycle, while the CBD cycle was used for the transit buses. To ensure adequate particulate matter collection, vehicles with aftertreatment devices were tested on back-to-back cycles with a single set of filter media.

F. SwRI STUDY FOR SYNTROLEUM

This study, carried out by SwRI, was done to support a petition to the U.S DOE to include Fischer-Tropsch as an alternative fuel in the Energy Policy Act of 1992 (EPAct). It compared emissions from a Cummins B-Series engine in a heavy light-duty truck when running on four different fuels. No emission aftertreatment devices were used, but this model year 1999 engine was certified for 1999 heavy-duty emission standards. Two engines were tested—one installed in a vehicle and driven on a chassis dynamometer, and the other on an engine dynamometer. The fuels tested included a conventional low sulfur number 2 diesel fuel with 300 ppm sulfur and 28 percent aromatics by volume, a CARB diesel with 150 ppm sulfur and 8 percent aromatics by volume, a Swedish diesel with less than 10 ppm sulfur and 4 percent aromatics by volume, and a Fischer-Tropsch fuel with less than 10 ppm sulfur and less than 1 percent aromatics by volume. Measured emissions included regulated emissions, methane, 1,3-butadiene, benzene, aldehydes, CO_2, N_2O, and particulates by size distributions.

The engine mounted directly on the dynamometer was operated over the US heavy-duty transient cycle while the vehicle was driven over the Urban Dynamometer Driving Schedule (UDDS), the Highway Fuel Economy Test (HFET), and the US06 cycles.

G. CRC MASS VEHICLE TESTS

Several studies funded by the CRC and DOE have been carried out to measure unregulated exhaust emissions from large numbers of in-use light-duty vehicles. Although most of the vehicles tested were gasoline fueled, there were a few diesel-fueled vehicles included in the studies as well.

One of these studies carried out in Denver, Colorado; San Antonio, Texas; and the South Coast Air Quality Management District, California included 49 diesel-fueled vehicles. The newest vehicles tested were from the 1997 model year. In addition to regulated exhaust emissions, organic carbon, SO_4, NO_3, common elements, particulate and semi-volatile PAHs, hopanes and steranes were quantified. Hopanes and steranes are important because they are naturally present in petroleum and have been found to be present in motor oil. This has led to their use as marker compounds for PM emissions from motor vehicles in ambient PM source apportionment studies. Testing was carried out on the FTP-UDDS. It was expected that trace elements associated with catalyst attrition, could be detected if more sensitive analytical methods were employed

A second study was carried out in Cary, North Carolina using the IM240 test. This study included eight 1989 model year or older light-duty diesel vehicles. In addition to regulated emissions, measurements were made for CO_2, PM_{10}, organic and elemental carbon, carbonyls, PAH, NPAH, oxy-PAH, hopanes and steranes.

H. CRC AVFL-10a

The purpose of this study was to conduct an in-depth literature review to identify the state of knowledge of regulated and unregulated exhaust emissions from current, advanced technology diesel engines. The effort was focused on gathering engine-out emissions data without regard to engine application, fuel type, manufacturer, aftertreatment device employed, power output, or other factors. These data were used to create a relational database. This database of engine-out diesel exhaust emissions should facilitate the examination of the body of databases on different query criteria. In addition, a bibliography of each source reviewed in this project was prepared, with a brief synopsis of the content of each individual paper.

The emphasis for this project was placed initially on advanced technology engines--those developed to meet 2007 and future standards. Therefore, it was anticipated that the majority of the effort would be concentrated on reports published after the 1996 time frame. In fact, the project compiled data from sources as old as 1991. The bulk of studies, however, were published from 1998 to 2003. In total, Project AVFL-10a included a review of 155 sources and data were extracted from 72 of these. Most of the studies utilized to create the AVFL-10a database were published by the Society of Automotive Engineers (SAE), yet represent a global perspective with good representation from Asia and Europe.

I. CE-CERT

Some recent work at the Center for Environmental Research and Technology (CE-CERT), University of California has provided some unregulated emissions data from light-duty trucks. In one study, several fuel choices including CARB diesel (72 ppm sulfur, 23 percent aromatics), EC-D diesel (3 ppm sulfur, 11 percent aromatics), and three different blends of 20 percent biodiesel (two soybean methyl esters and one yellow grease methyl ester) with 80 percent CARB diesel were tested in several 1983 to 1993 light diesel trucks. Although the focus was mainly on regulated emissions, data on organic and elemental carbon as well as particle phase ions, trace elements and PAH compounds are provided in the supplemental information. Unregulated emissions presented in the supporting information of this study were not analyzed.

In another CE-CERT study, the regulated emissions as well as carbonyls, speciated hydrocarbons and PAH emissions were also quantified for 4 model year 1998 and 1999 light trucks. One of the trucks was tested with CARB diesel (17-48 ppm sulfur, 20 percent aromatics) and the other three were equipped with an Engelhard diesel particulate filter and fueled with Arco ECD diesel (13-26 ppm sulfur, 9 to 10 percent aromatics) and in one case, with commercial Arco ECD-1 diesel (15 ppm sulfur, 20 percent aromatics). Although significant hydrocarbon speciation was carried out, only results for a few species and totals for C_1 to C_{13} NMOGs are reported. Data on EC, OC, particulate bound ion, and trace elements are reported.

J. GASOLINE/DIESEL PM SPLIT STUDY

The Gasoline/Diesel PM Split Study was undertaken to evaluate the sources and range of uncertainties associated with the methods and procedures used for sample collection and chemical analysis in the process of estimating the relative contributions of gasoline and diesel tailpipe emissions to ambient fine particulate matter concentrations. This project was sponsored by the U.S. Department of Energy's Office of FreedomCAR and Vehicle Technologies. Vehicle emissions testing was performed in Riverside, CA, in 2001 by Bevilacqua-Knight, Inc. (BKI) with the U.S. Environmental Protection Agency (EPA), and by West Virginia University. Chemical analysis of the emissions was performed by both Desert Research Institute (DRI) and the University of Wisconsin-Madison (UWM). In addition to the testing of heavy-duty diesel vehicles, this project also included testing of light-duty gasoline vehicles.

For the heavy-duty diesel emissions testing, West Virginia University's (WVU's) transportable heavy-duty vehicle emissions testing laboratory was used. Thirty heavy-duty diesel trucks were tested, with vehicle model years ranging from pre-1990 through 1998 and newer model year groups. The trucks also ranged from the light-heavy vehicle class to the heavy-heavy vehicle class. Fifteen of the trucks were from well-maintained fleets and were of recent model years. The remaining trucks represented a mix of in-use vehicles. Two transit buses were also tested, representing older and newer engine technologies.

The heavy-duty diesel trucks were tested over the following driving cycles:

- the City-Suburban Heavy Vehicle Route (CSHVR);
- the highway cycle; and
- at idle operation.

The buses were tested over the following cycles:

- the CSHVR;
- an idle period; and
- the Manhattan test cycle.

One of the project objectives was to compare the analysis of organic species from multiple laboratories. To accomplish this, samples were collected in parallel by DRI and UWM for each test, and were analyzed independently. The chemical analyses of the engine emissions and ambient samples included gravimetric mass, elements, ions, EC, OC, polycyclic aromatic hydrocarbons, hopanes, steranes, alkanes, and polar organic compounds.

K. CRC E-55/59

The CRC E-55/59 test program objective was to improve the understanding of the California heavy-duty vehicle emissions inventory by obtaining emissions from a representative vehicle fleet, and to include unregulated emissions measured for a subset of the tested fleet. The challenge of measuring the wide expanse of unregulated emissions and their low levels precluded obtaining unregulated measurements for all trucks recruited for this program. Sponsors of this project include CARB, EPA, Engine Manufacturers Association, DOE/NREL, and SCAQMD. The project consisted of four segments, designated as Phases 1, 1.5, 2, and 3. Seventy-five vehicles were recruited in total for the program, and recruitment covered the model year range of 1974 through 2004. The number and types of vehicles tested in each phase are as follows:

- Phase 1: 25 heavy heavy-duty diesel trucks (HHDDT);
- Phase 1.5: 13 HHDDTs;
- Phase 2: ten HHDDTs, seven medium heavy-duty diesel trucks (MHDDT), and two medium heavy-duty gasoline trucks (MHDGT); and
- Phase 3: nine MHDDT, eight HHDDT, and two MHDGT.

The vehicles tested in this study were procured in the Los Angeles area, based on model years specified by the sponsors and by engine types determined from a survey. WVU measured regulated emissions data from these vehicles and gathered emissions samples. Emission samples from a subset of the vehicles were analyzed by DRI for chemical species detail. The California Trucking Association assisted in the selection of vehicles to be included in this study. Speciation data were obtained from a total of nine different vehicles.

Emissions were measured using WVU's Transportable Heavy-Duty Vehicle Emissions Testing Laboratory. The laboratory employed a chassis dynamometer, with flywheels and eddy-current power absorbers, a full-scale dilution tunnel, heated probes and sample lines and research grade gas analyzers. PM was measured gravimetrically. Additional sampling ports on the dilution tunnel supplied dilute exhaust for capturing unregulated species and PM size fractions. Background data for gaseous emissions were gathered for each vehicle test and separate tests were performed to capture background samples of PM and unregulated species.

The HHDDTs were tested under unladen, 56,000 lb., and 30,000 lb. truck load weights. The driving cycles used for the HHDDT testing included:

- AC50/80;
- UDDS;
- Five modes of an HHDDT test schedule proposed by CARB: Idle, Creep, Transient, Cruise, and HHDDT_S (a high speed cruise mode of shortened duration); and
- The U.S. EPA transient test.

The proposed CARB HHDDT test cycle is based on California truck activity data, and was developed to improve the accuracy of emissions inventories. It should be noted that the transient portion of this proposed CARB test schedule is not the same as the EPA certification transient test.

L. DESERT RESEARCH INSTITUTE

Researchers at DRI collected a series of emission samples for toxicity testing and detailed chemical characterization from a variety of gasoline and diesel-fueled in-use vehicles operated on the Unified Driving Cycle on a chassis dynamometer. Three current technology diesel vehicles from model years 1998, 1999, and 2000 were tested, as well as a 1991 model year diesel pick-up truck that was a high PM emitter. Emission rates of organic and elemental carbon (OC/EC), elements (metals and associated analytes), ions, and a variety of particulate and semi-volatile organic compounds (PAH, NPAH, oxy-PAH, hopanes, and steranes) were reported for these vehicles. Speciated organic analysis also was conducted on the fuels and lube oils obtained from these vehicles after the emissions testing. This work was sponsored by the DOE’s Office of Heavy Vehicle Technologies through NREL.

In a separate study performed by DRI, emissions of heavy duty diesel-powered vehicles were measured at the Phoenix Transit Yard in South Phoenix in 1992 using the West Virginia University Transportable Heavy-Duty Vehicle Emissions Testing Laboratory. Thirteen heavy-duty trucks and buses were tested over this period. The vehicles were operated with diesel No. 2 and Jet A fuels, with and without a fuel additive, and with and without particulate control traps. Vehicles were tested over the Central Business District (CBD) driving cycle. Particulate matter in the diluted exhaust was sampled proportionally from a total-exhaust dilution tunnel. Emission rates and compositions of $PM_{2.5}$ particulate mass, elements, ions, bulk organic and elemental carbon, and gaseous and particulate PAHs were averaged for various classes of fuels and PM control.

M. ENVIRONMENT CANADA

The Emissions Research and Measurement Division (ERMD) of Environment Canada tested a light duty diesel truck on a chassis dynamometer over the four-phase Federal Test Procedure (FTP). The vehicle was tested at two temperatures using a commercially available low sulfur diesel fuel (LSD) and LSD blended with 10%, 20%, and 30% soybean oil methyl ester. Samples of dilute exhaust were obtained using a constant volume sampling system and mass emission rates for the following emissions were determined:

- criteria emissions (CO, NO_x, THC) and CO_2;
- methane and non-methane organic compounds;
- methyl and ethyl esters of soybean oil;
- carbonyl compounds; and
- total particulate matter (TPM).

For another study, two in-use urban buses were tested over the Central Business District cycle at two temperatures (20 °C and –10 °C). The old technology bus was equipped with a 2-stroke diesel engine and was tested in two configurations – with the original equipment manufacturer (OEM) muffler and with a retrofit oxidation catalyst. This bus was certified to the 1988 heavy-duty diesel engine emission standards. The new technology bus was equipped with a 4-stroke diesel engine with a close-coupled oxidation catalyst and was certified to stringent 1998 urban bus emission standards. Both buses see on-road service with the local public transit authority in Ottawa, Ontario, Canada.

Emission rates were determined for the gaseous criteria pollutants (CO, NO_x, THC), CO_2, methane and non-methane hydrocarbons, carbonyl compounds, vapor phase organic acids, sulfur dioxide (SO_2), NH_3, $PM_{2.5}$ mass emissions, particle phase organic and inorganic ions, metals, organic and elemental carbon and for particle phase organic compounds.

CHAPTER III. DATABASE DEVELOPMENT

A. DEVELOPMENT OF DIESEL SPECIATION DATABASE STRUCTURE

Pechan adopted the database structure from CRC Project AVFL-10a (Merritt, 2003), thereby avoiding the necessity of creating a database from scratch. The Microsoft Access® relational database was prepared to permit analysis of emissions data reported in all the reviewed sources and to facilitate the identification of trends. The database can be used to execute queries based on (where available) engine, fuel, duty cycle, and emissions parameters. It was also highly desirable to provide the data in a format that can readily be used by the EPA and its subcontractors to update the SPECIATE database and the MSOD database.

In order to expand applications of the resulting database, Chemical Abstracts Service (CAS) numbers were added along with chemical names, which were edited to be consistent with EPA's SPECIATE database. This was an essential effort since one chemical can have multiple names. Using consistent chemical names and identification numbers facilitates future data analyses using the compiled data. For those compounds and mixtures without CAS numbers, the EPA Substance Registry System (SRS) identification numbers were applied. In cases where CAS and SRS ID are not available, Pechan generated unique numbers to identify those compounds and mixtures.

Note that the original CRC AVFL-10a database was revised with the addition of unique project numbers (Project ID) along with study numbers (Study ID) in the database. In order to consolidate datasets based on the same tests that were published in different references, Project IDs provide the users with the identification of all associated datasets. For example, several studies published regulated pollutants, speciated gaseous and PM bound emission rates in separate papers. They were assigned the same Project ID, but different Study IDs, to indicate they are based on the same project, but with data published in multiple papers.

The speciation database is provided in two formats — Microsoft Access® and Microsoft Excel®. Both formats contain all the same data, and both are organized in the manner described below.

B. DEFINITION OF DATA TABLES

Relevant data were extracted and entered into various tables. Tables were organized by engine, fuel, and emissions data. Emissions data were subdivided into seven tables for: 1) regulated emissions, 2) elements and inorganic compounds, 3) carbonyl compounds, 4) PAH and NPAH compounds, 5) dioxins and furans, 6) speciated hydrocarbons (volatile organic gases), and 7) semivolatile organic compounds (SVOC, including hopanes, steranes, nitrosamines, and heavy hydrocarbons). Additionally, a pollutant list (which includes pollutant names, alternate names, CAS, and codes), a bibliography, and a data dictionary are included in the database. The table names used in the database and a description of each are shown in Table III-1.

Table III-1. Tables Included in the Diesel Speciation Database

Table Name	Description
Tbl Aftertreatment	Lists and defines the aftertreatment codes used in emission tables
Tbl Carbonyl	Contains emission data for 47 carbonyl compounds (see Table A-1, in the appendix)
Tbl Data Dictionary	Defines all tables and fields in the database
Tbl DioxinFuran	Contains emission data for 18 dioxins and furans (see Table A-2)
Tbl Engine Data	Provides available data on the engines used in the tests by project and study ID
Tbl Fuel Data	Defines properties of the fuels used in the emission tests by project and study ID
Tbl PAH	Contains emission data for 193 PAH and NPAH compounds (see Table A-3)
Tbl PM Speciation	Contains emission data for 77 elements and inorganic compounds (see Table A-4)
Tbl Pollutant List	Lists the 924 pollutants included in the emission tables along with any alternate names of the compound, the code used in the emission tables, and the CAS number of the compound, where applicable
Tbl Regulated Pollutants	Contains emission data for 18 pollutants, including regulated pollutants (see Table A-5)
Tbl Studies	Identifies pertinent information about each study reviewed for this project, including title, author, year, and comments about the information contained in the study (a bibliography)
Tbl SVOC	Contains emission data for 416 semivolatile organic compounds (see Table A-6)
Tbl Test Cycle	Provides a description for each of the test cycle codes used in the database
Tbl Test Data	Provides information on the test program, sampling methods, and analytical methods for the various studies used in the database
Tbl TOG/VOC/NMOG	Contains emission data for 263 speciated hydrocarbon compounds (see Table A-7)

C. DEFINITION OF DATA FIELDS

Within the database, there is a Data Dictionary table that lists all fields in each table in the database. A brief definition of each field is described in this table in the database. Tables III-2 through III-8 list the field names and definitions of the tables that do not include emission values. Table III-9 lists the names and definitions of the fields included in the seven emission tables. Note that not all of the emission tables include all of these fields.

Table III-2. Definition of Fields Included in *Tbl Studies*

Field	Definition
Citation	Publication number
Comments	Comments on main topics in publication
Lead Author	First author listed
Origin	Country of publication
Project ID	Identification of study project, may encompass several publications
Publisher	Publishing organization
Study ID	Identification of study, as defined by one publication
Title	Publication title
Year	Year published

Table III-3. Definition of Fields Included in *Tbl Engine Data*

Field	**Definition**
aspirated	Aspiration
cat_type	Catalyst type
Description	Description of type of engine/vehicle
disp_liter	Engine displacement
egr_type	Exhaust Gas Recirculation
eng_cycle	Engine cycle
Engine Application	Typical application of engine
Engine ID	Identification of engine model
fi_press	Fuel injection pressure
fi_type	Fuel injection type
manufacturer	Engine manufacturer
model_name	Model name of engine
model_year	Model year of engine
No_cylinders	Number of cylinders
NO_x trap?	NO_x filter
Odometer Reading (mile)	Odometer reading of vehicle prior to test
Part_trap?	Particle filter
power	Rated power (hp or kW)
Project ID	Identification of study project, may encompass several publications
rated speed	Rated speed (rpm)
reductant_type	Catalyst reduction type
Study ID	Identification of study, as defined by one publication
Test ID	Identification of specific test run
Test_cycle	Test cycle used to test engine
torque	Engine torque (N-m)
torque_sd	Torque speed
Vehicl Model Year	Model year of vehicle
VIN	Vehicle Identification Number

Table III-4. Definition of Fields Included in *Tbl Fuel*

Field	Definition
ash	Fuel ash content
Carbon	Fuel carbon content
cet_imp_type	Cetane improvement additives
cetane_imp	Cetane improvement
cetane_in	Cetane index
cetane_num	Cetane number
Density	Fuel density
ep (final boiling point)	Final boiling point
Fuel batch ID	Fuel identification code
heat	Fuel heat content
Hydrogen	Fuel hydrogen content
ibp (initial boiling point)	Initial boiling point
Nitrogen	Fuel nitrogen content
oxy_type	Oxygenate type
Oxygen	Fuel oxygen content
P_arom (Polynuclear Aromatic Hydrocarbons)	Fuel PAH content
Project ID	Identification of study project, may encompass several publications
spec_grav	Specific gravity
Study ID	Identification of study, as defined by one publication
sulfur	Fuel sulfur content
T_arom (Total Aromatics)	Fuel total aromatics content
t10 (temp. of 10% recovery)	Temperature of 10% recovery
t50	Temperature of 50% recovery
t90	Temperature of 90% recovery
t95	Temperature of 95% recovery
Viscosity	Fuel viscosity

Table III-5. Definition of Fields Included in *Tbl Aftertreatment*

Field	Definition
Control_ID	Identification of aftertreatment
Manufacturer	Manufacturer of aftertreatment device
Notes	Additional description and notes on aftertreatment
Type	Type of aftertreatment

Table III-6. Definition of Fields Included in *Tbl Test Cycle*

Field	Definition
Description	Full name of test cycle
Test cycle code	Code used to identify test cycle

Table III-7. Definition of Fields Included in *Tbl Test Data*

Field	Definition
Analytical Methods	Methods for analyzing pollutants in exhaust
Project ID	Identification of study project, may encompass several publications
Sampling Methods	Methods for sampling exhaust
Study ID	Identification of study, as defined by one publication
Test Program	Vehicle recruitment, vehicle classifications, vehicle test matrix, geographic region, etc.

Table III-8. Definition of Fields Included in *Tbl Pollutant List*

Field	Definition
Alternate name	Alternate name of pollutant
CAS Numbers	CAS code of pollutant
Code	Unique code assigned to pollutant
Pollutant name	Name of pollutant

Table III-9. Definition of Fields Included in Emission Tables

Field	Definition
Aftertreatment	Aftertreatment identification
Analytical Methods	Methods for analyzing pollutants in exhaust
Emissions	Numeric value of pollutant emission rate in specified units
Engine ID	Identification of engine model
Fuel batch ID	Fuel identification code
Notes	Other notes related to emissions data
Phase	PM or gas phase
PM size	PM particle size cutoff (in Tbl PM Speciation only)
Pollutant code	Pollutant CAS number or other code used to identify pollutant
Pollutant Name	Name of pollutant
Project ID	Identification of study project, may encompass several publications
Study ID	Identification of study, as defined by one publication
Test ID	Identification of specific test run
Test proc	Test cycle followed in emissions test
Uncertainties	Uncertainty associated with emissions, where reported
Units	Units applicable to pollutant emission rate specified in EMISSIONS field

The number of compiled emission tests by pollutant grouping included in the Diesel Speciation Database is as follows:

- 312 emission tests reporting carbonyls;
- 237 emission tests reporting speciated volatile organic compounds;
- 387 emission tests reporting PAHs;
- 207 emission tests reporting semivolatile organic compounds;
- 297 emission tests reporting speciated particulate matter; and
- 87 emission tests reporting dioxins or furans.

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CHAPTER IV. RESOLUTION OF DATA ISSUES

Issues that evolved during the data collection process of this project and intermediate products of this project were reviewed by the CRC Real World Vehicle Emissions & Emissions Modeling Group (the Working Group). This group provided direction and guidance in determining how several data collection issues should be resolved. The Group agreed that the project resources should not be used to prepare composite emission rates (e.g., grouped by model year or technology type) or to prepare speciation profiles in weight percent format, as these are not a direct need of this project. Instead, the Working Group was interested in obtaining a high quality and well documented database containing regulated and speciated pollutant emission rates, along with test data information that was as detailed as possible. Where available, the Group requested that information on the uncertainty of the test data be included in the database. In addition, it was desired that the database indicate the test methods used. Due to the diverse nature of literature reviewed and the differing objectives of these many studies, users of the Diesel Speciation Database should exercise caution and make use of the QA observations noted in Chapter V.

The resolutions made by the group on specific data issues are summarized below.

A. PHASE OF SVOCs

Semivolatile organic compounds (SVOCs) (such as PAH, organic acids, hopanes, steranes, etc.) can be sampled and analyzed in combinations of gas phase and PM bound together, or separately. Many of the SVOC data collected in this project are reported in both the gaseous form and PM-bound, while others are reported for only one of these two phases. Tests that collected SVOC in both the PM and gaseous phases are not comparable with other studies that measured SVOC for the PM phase only, since the gaseous phase of emissions could be significant, and is not accounted for in this example. Based on the decisions of the Working Group, Pechan did not split SVOC emission rates into gas and PM phases, which are needed for preparing PM and organic gas speciation profiles. Instead, all speciated emission rates are listed in the database as they were reported in the original project documentation and the Phase field in the emissions table indicates whether the data were collected in PM, gaseous, or both phases. Thus, users of the Diesel Speciation Database should be alert to the phase of SVOCs when comparing SVOC emission rates among tests.

B. BACKGROUND CONCENTRATIONS

The Working Group also specified that, within the database, background concentration data should be provided where available, but the emission rates should not be corrected for background concentrations if this was not done in the source report. This applies to projects like E55/59. The database should use a flag to indicate whether the data were corrected for background concentration. All data from the CRC AVFL-10a are included in the database as-is for data integrity. For the tests without correction for background concentrations, Pechan included the blank data along with the exhaust results, per the Working Group's direction. There were several dilution tunnel exhaust sampling protocols found in the literature (e.g., dilution air was filtered by PM filters with and without activated charcoal filters to remove organic gases).

Most studies collected blank samples simultaneous with exhaust testing and subtracted background concentrations.

C. ORGANIC CARBON ADJUSTMENTS

The Working Group also determined that organic carbon (OC) should not be adjusted for other bonded elements like hydrogen or oxygen. Since there are no universal correction factors for OC, the Working Group agreed to let the users of the database decide what correction factors should be applied, if needed.

In general, diesel exhaust contains more EC than OC in vehicles without control devices. Control devices play a significant role by altering both pollutant emission rates and the chemical compositions of the exhaust. For example, in trucks equipped with advanced diesel particulate filters, the filters may remove over 90 percent of the exhaust PM, and the after-filter exhaust could contain more OC than EC. An explanation of this phenomenon is that EC (or soot) is trapped in the filter, leaving a higher percentage of OC in the exhaust (Chatterjee, et al., 2002). On the other hand, OC is primarily removed by catalytic oxidation, so in vehicles equipped with an oxidation catalyst, the exhaust typically contains more EC than OC.

D. STUDY-SPECIFIC DATA ISSUES AND OBSERVATIONS

In order to obtain additional data or documentation or to resolve data issues or questions related to a specific study, Pechan attempted to contact the study authors to resolve these issues. Table IV-1 summarizes the additional follow-up performed by Pechan with specific authors or organizations regarding data questions.

Additional information obtained regarding the data for several studies, or observations Pechan noted about the data, are summarized below. These notes are important to properly interpret the data included in the Diesel Speciation Database for these studies.

1. Notes on the Gasoline/Diesel PM Split Study Data

Data from the Gasoline/Diesel Split Study includes 76 records (species) that are larger than 100 percent of the reported $PM_{2.5}$. All, except two records, are either OC, EC, or total carbon. These anomalies are due to adsorption artifacts that occur during sampling.

In the DRI analyses, the background data were subtracted from the source tests. In cases where the background levels were higher than the source test data, the result was a negative value. In these cases, DRI replaced the negative data with a 0 and used the detection limit as the uncertainty field. In the UWM analyses, the background data were not subtracted from the source test data.

Table IV-1. Contacts Made for Resolving Data Issues in Specific Studies

Organization	Person Contacted	Reason for Contact	Outcome
National Renewable Energy Laboratory	Douglas Lawson	Needed documents for the Diesel-gasoline PM Split Study	Provided draft final report which was not available on the NREL websites.
National Renewable Energy Laboratory	Teresa Alleman	Needed numerical values and discussions of EC and OC emissions.	Provided spreadsheets; concluded that the diesel PM filters have preference in removing EC. Therefore, the exhaust had more OC than EC which is reverse of current diesel exhaust profiles without diesel PM filters.
West Virginia University	Nigel Clark, Mridul Gautam	Needed speciation data and numerous discussions of abnormal hexane emission rates. Also, needed explanation of mg/mi units for idle tests.	Received data. The high hexane emission factors could be due to contamination in the dilution air which was not filtered by charcoal. Provided explanation of idle units.
California Air Resources Board	William Vance, Hector Maldonado, Paul Rieger, Alberto Ayala, Jerry Ho	Needed E55/59 speciation data and numerous discussions of abnormal hexane emission rates. Requested diesel data.	Received data. The high hexane emission factors could be due to contamination in the dilution air which was not filtered by charcoal. CARB did not test for diesel speciation data.
New York State Department of Environmental Conservation	Thomas Lanni, Shida Tang	Requested speciation data	Received data and discussions of their studies on transit buses.
Southwest Research Institute	Patrick M. Merritt	Questions on missing units and data in the AVFL-10 A database	Provided the missing units and explained the database.
UC Riverside, CE-CERT	Tom Durbin, David Cocker	Requested reports (E-24) and data. Discussions on the abnormal hexane in E55/59 study	Received as requested. Confirmed that hexane in diesel exhaust should be very trace.
University of Wisconsin, Madison	Jamie Schauer, David Foster	Requested reports and data. Discussions on the abnormal hexane in E55/59 study	Received as requested. Confirmed that hexane in diesel exhaust should be in trace amounts which is consistent with his study for CARB.
Desert Research Institute	Barbara Zielinska	Clarifications on chemical names and duplicate records	Resolved.
Desert Research Institute	Anthony Chen	Clarifications on zero in the reports	Explained zeros mean those chemicals were measured and gave zero emissions.
Clean Air Vehicle Technology Center, Inc.	Richard Snow	Requested data for the Central Carolina Vehicle Particulate Emission Study	Received reports.
Environment Canada	Lisa Graham, Peter Howes, Greg Rideout	Requested reports and numerous discussions on E55/59 hexane emission rates issue. Clarifications on chemical names.	Received a number of reports and confirmed that hexane in diesel exhaust should be in trace amounts. Resolved chemical names.
EPA	Carl Fulper, Charles Lewis	Requested EPA MSOD database and related information.	Received MSOD database and confirmed there was no diesel exhaust data in it.
GM	Steven Cadle	Requested reports.	Received.
Cleaire Advanced Emission Controls, LLC	Tim Taylor	Discussion on diesel exhaust control devices.	Resolved.

2. Notes on the California Institute of Technology Data

Schauer did not use zeros in his organic gases speciation data in this study. He used some 0.00 + - standard deviation for inorganic elements and those values represent true zero.

3. Notes on the SwRI Syntroleum Study Data

In Study ID 53 by Southwest Research Institute, "trace" is reported for some records and "zero" for others, when concentrations were very low. "Trace" is assumed to mean lower than detection limit, while "zeros" are assumed to indicate zero or no emissions of a given species.

4. Notes on the WVU E-55/59 Data

This data set included some idle testing. While the idle test data for regulated pollutants were reported in units of mass per cycle, the speciated data from the idle testing were reported in units of mg/mile. WVU converted the idle emissions data from mass/time to mass/mile, in order to make the units consistent with other driving phases. This was done by dividing the mass/time emissions by the distance the vehicle would typically have traveled in the duration of the idle test. However, upon further review of the report, emissions were available in units of mg/mode for idling. These are now the units reported in the final speciation database.

Three or four of the vehicles in this study appear to be outliers due to engine malfunctions leading to low NO_x and high PM emissions. While these are not properly functioning vehicles, they may be representative of some in-use vehicles. It should be noted that vehicles or tests that may have been identified as outliers in the Diesel Speciation Database have not been discarded, and are included in the database. Researchers using this database must determine on a case-by-case basis whether the data are useful for their individual needs.

The emissions from Studies 213 and 215 (Gautam, et al., 2003 and Clark, et al., 2005) were not background corrected. The rationale for this decision was that the sampling train had a HEPA filter to remove background PM; thus, background concentrations should be insignificant. Data are included in the Diesel Speciation Database as reported by the study authors. It should be noted that some background concentrations are higher than exhaust in the E55-59 study. Also, it should be noted that WVU did not use charcoal filters to remove VOC from the dilution air. As a result, this study had very high hexane and acetone levels in the samples.

In this study, uncertainty is calculated as three times the standard deviations of the background level. Duplicate analyses were performed for every 10 samples. The testing protocols generally call for 10 percent replicate analyses. These are applied to determine replicate precision that allows the researchers to calculate sample uncertainty.

CHAPTER V. QA OF DATABASE

A. EXTERNAL QA REVIEW OF DATABASE

As part of the QA for this project, Pechan's subcontractor, Energy and Environmental Analysis, Inc. (EEA), performed an independent review of the diesel speciation database prepared by Pechan. The stated objectives of this QA review were as follows:

1. Review the ranges of predominant species and regulated pollutant emission rates for reasonableness, noting any unreasonably high or low emission rates;
2. Identify outliers (e.g., typos, poor tests, gross polluters);
3. Assess whether the variation in emission rates and composition by model years and vehicle weight classes follows expected patterns;
4. Note any important uncertainties or limitations of the data; and
5. Report conclusions/findings.

EEA's methodology for analyzing the database and the findings of their analysis are summarized here.

1. Analysis Methodology

As a first step in this analysis, EEA first added a new vehicle category to each observation in the "tbl Engine Data." The following vehicle categories were used: heavy-heavy duty truck (HHDT), medium-heavy duty truck (MHDT), light-heavy duty truck (LHDT), small-heavy duty truck (SHDT), or light duty vehicle (LDV) (with only a handful remaining unclassified or listed as 1-CYL or Marine). These classifications correspond to the EPA classification with the sole exception of SHDT which refers to a unique class of delivery trucks that use small diesel engines relative to the typical engines in that class of vehicle (10,000 to 14,000 lb. GVW) and are typically Japanese imports. Each observation was categorized based on specific knowledge of engine models, as well as horsepower ratings. This type of distinction can be important for analytical purposes because, for example, LHDT engines used pre-chamber combustion prior to 1991 while MHDT and HHDT engines used direct injection. Identifying the technologies employed within each of these categories can be useful in attributing cause to changes in pollutant emission test results.

To link pollutant data to the corresponding engines, the tables "tbl Engine Data" and "tbl Regulated Pollutants" were linked on the field "Test ID." Using this relational link, the information contained in a given observation in "tbl Engine Data" was appended to the related observation in "tbl Regulated Pollutants." It should be noted that the observations within "tbl Engine Data" with no value for "Test ID" could not be linked to pollutant values in "tbl Regulated Pollutants."

This new query-generated table was extracted for further manipulation and analysis into spreadsheet format. To assess the quality of the pollutant data of interest, several categorizations were created with the intention of comparing similar engines in order to detect significantly dissimilar data points. The data were broken into engine use categories (as defined above), model year categories to correspond to different regulatory specifications (pre-1990 model years; model years 1991 through 1993; and post-1993 model years), and pollutant categories (CO, NO_x, PM, and THC). Table V-1 shows where the EEA classification differs from the original engine classification.

Table V-1: Observations in which EEA Engine Classification Differs from Original

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		LHDT
AVFL-10a 1	Airport Ground Support		1-CYL
AVFL-10a 136	Aux Power unit		1-CYL
AVFL-10a 137	AUX. POWER UNIT		1-CYL
1013199, 201, 221	Heavy-Duty Diesel Trucks	Average of two heavy-duty diesel trucks	HHDT
AVFL-10a 127	Heavy-Duty Off-Road		SHDT
AVFL-10a 79	Heavy-Duty On-Road		MHDT
AVFL-10a 116	Heavy-Duty On-Road		
AVFL-10a 33	Heavy-Duty On-Road		MHDT
AVFL-10a 121	Heavy-Duty On-Road		MHDT
AVFL-10a 137	Heavy-Duty On-Road		HHDT
AVFL-10a 137	Heavy-Duty On-Road		HHDT
AVFL-10a 131	Heavy-Duty On-Road		HHDT
AVFL-10a 43	Heavy-Duty On-Road		HHDT
AVFL-10a 136	Heavy-Duty On-Road		HHDT
AVFL-10a 136	Heavy-Duty On-Road		HHDT
AVFL-10a 66	Heavy-Duty On-Road		HHDT
Freightliner 8 cold	Heavy-Duty On-Road	Freightliner 8	HHDT
Freightliner 8 creep	Heavy-Duty On-Road	Freightliner 8	HHDT
Freightliner 8 transient	Heavy-Duty On-Road	Freightliner 8	HHDT
Freightliner 8 cruise	Heavy-Duty On-Road	Freightliner 8	HHDT
Freightliner 9 cold	Heavy-Duty On-Road	Freightliner 9	HHDT
Freightliner 9 creep	Heavy-Duty On-Road	Freightliner 9	HHDT
Freightliner 9 transient	Heavy-Duty On-Road	Freightliner 9	HHDT
Freightliner 9 cruise	Heavy-Duty On-Road	Freightliner 9	HHDT
Freightliner tractor ULSD	Heavy-Duty On-Road	Freightliner tractor	HHDT
Freightliner tractor ULSD	Heavy-Duty On-Road	Freightliner tractor	HHDT
Freightliner tractor ULSD	Heavy-Duty On-Road	Freightliner tractor	HHDT
Freightliner tractor ULSD	Heavy-Duty On-Road	Freightliner tractor	HHDT
Freightliner 10 cold	Heavy-Duty On-Road	Freightliner 10	HHDT
Freightliner 10 creep	Heavy-Duty On-Road	Freightliner 10	HHDT
Freightliner 10 transient	Heavy-Duty On-Road	Freightliner 10	HHDT
Freightliner 10 cruise	Heavy-Duty On-Road	Freightliner 10	HHDT
AVFL-10a 136	Heavy-Duty On-Road		HHDT
AVFL-10a 62	Heavy-Duty On-Road		LHDT
AVFL-10a 77	Heavy-Duty On-Road		LHDT
AVFL-10a 35	Heavy-Duty On-Road		LHDT
AVFL-10a 108	Heavy-Duty On-Road		MHDT

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
Refuse Hauler CARB	Heavy-Duty On-Road	Refuse Hauler	HHDT
Refuse Hauler ECD	Heavy-Duty On-Road	Refuse Hauler	HHDT
Refuse Hauler ECD+CRT	Heavy-Duty On-Road	Refuse Hauler	HHDT
Refuse Hauler ECD-1	Heavy-Duty On-Road	Refuse Hauler	HHDT
Refuse Hauler ECD-1+CRT	Heavy-Duty On-Road	Refuse Hauler	HHDT
AVFL-10a 42	Heavy-Duty On-Road		HHDT
AVFL-10a 56	Heavy-Duty On-Road		HHDT
AVFL-10a 49	Heavy-Duty On-Road		HHDT
AVFL-10a 49	Heavy-Duty On-Road		HHDT
AVFL-10a 49	Heavy-Duty On-Road		HHDT
AVFL-10a 49	Heavy-Duty On-Road		HHDT
Pre-1993	Heavy-Duty On-Road	Cummins L10	HHDT
Low Aromatic	Heavy-Duty On-Road	Cummins L10	HHDT
Reformulated	Heavy-Duty On-Road	Cummins L10	HHDT
AVFL-10a 104	Heavy-Duty On-Road		HHDT
AVFL-10a 109	Heavy-Duty On-Road		HHDT
AVFL-10a 111	Heavy-Duty On-Road		HHDT
AVFL-10a 115	Heavy-Duty On-Road		HHDT
Tanker Truck CARB	Heavy-Duty On-Road	Tanker Truck	HHDT
Tanker Truck ECD	Heavy-Duty On-Road	Tanker Truck	HHDT
Tanker Truck ECD+CRT	Heavy-Duty On-Road	Tanker Truck	HHDT
Internation truck cold	Heavy-Duty On-Road	International truck	HHDT
Internation truck creep	Heavy-Duty On-Road	International truck	HHDT
Internation truck transient	Heavy-Duty On-Road	International truck	HHDT
Internation truck cruise	Heavy-Duty On-Road	International truck	HHDT
AVFL-10a 42	Heavy-Duty On-Road		HHDT
AVFL-10a 120	Heavy-Duty On-Road		HHDT
AVFL-10a 135	Heavy-Duty On-Road		HHDT
Freightliner 2 cold	Heavy-Duty On-Road	Freightliner 2	HHDT
Freightliner 2 creep	Heavy-Duty On-Road	Freightliner 2	HHDT
Freightliner 2 transient	Heavy-Duty On-Road	Freightliner 2	HHDT
Freightliner 2 cruise	Heavy-Duty On-Road	Freightliner 2	HHDT
Freightliner 3 cold	Heavy-Duty On-Road	Freightliner 3	HHDT
Freightliner 3 creep	Heavy-Duty On-Road	Freightliner 3	HHDT
Freightliner 3 transient	Heavy-Duty On-Road	Freightliner 3	HHDT
Freightliner 3 cruise	Heavy-Duty On-Road	Freightliner 3	HHDT
AVFL-10a 62	Heavy-Duty On-Road		HHDT
AVFL-10a 137	Heavy-Duty On-Road		HHDT
AVFL-10a 140	Heavy-Duty On-Road		HHDT
Bus CARB	Heavy-Duty On-Road	Bus	MHDT
Bus ECD+CRT	Heavy-Duty On-Road	Bus	MHDT
Bus ECD-1	Heavy-Duty On-Road	Bus	MHDT
Bus ECD-1+CRT	Heavy-Duty On-Road	Bus	MHDT
Bus CARB	Heavy-Duty On-Road	Bus	MHDT
Bus ECD+CRT	Heavy-Duty On-Road	Bus	MHDT
Bus ECD-1-a	Heavy-Duty On-Road	Bus	MHDT
Bus ECD-1+CRT	Heavy-Duty On-Road	Bus	MHDT
Bus LSD	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD + CRT	Heavy-Duty On-Road	Bus	MHDT
Bus LSD	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT	Heavy-Duty On-Road	Bus	MHDT
Bus LSD pre	Heavy-Duty On-Road	Bus	MHDT
Bus LSD post	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD pre	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD post	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD + CRT pre	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT post	Heavy-Duty On-Road	Bus	MHDT

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
Bus LSD pre	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT pre	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT post	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT CBD 6019	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD CBD 6019	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT CBD 6065	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD CBD 6065	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD NYB 6019	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT NYB 6019	Heavy-Duty On-Road	Bus	MHDT
AVFL-10a 62	Heavy-Duty On-Road		MHDT
AVFL-10a 116	Heavy-Duty On-Road		MHDT
Bus ULSD NYB 6065	Heavy-Duty On-Road	Bus	MHDT
Bus ULSD+CRT NYB 6065	Heavy-Duty On-Road	Bus	MHDT
Truck CARB	Heavy-Duty On-Road	Truck	HHDT
Truck ECD+CRT	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1+CRT	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1+DPX	Heavy-Duty On-Road	Truck	HHDT
Truck CARB	Heavy-Duty On-Road	Truck	HHDT
Truck ECD+CRT	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1+CRT	Heavy-Duty On-Road	Truck	HHDT
Truck ECD-1+DPX	Heavy-Duty On-Road	Truck	HHDT
Freightliner tractor ULSD cold	Heavy-Duty On-Road	Freightliner 1	HHDT
Freightliner tractor ULSD creep	Heavy-Duty On-Road	Freightliner 1	HHDT
Freightliner tractor ULSD transient	Heavy-Duty On-Road	Freightliner 1	HHDT
Freightliner tractor ULSD cruise	Heavy-Duty On-Road	Freightliner 1	HHDT
Freightliner 4 cold	Heavy-Duty On-Road	Freightliner 4	HHDT
Freightliner 4 creep	Heavy-Duty On-Road	Freightliner 4	HHDT
Freightliner 4 transient	Heavy-Duty On-Road	Freightliner 4	HHDT
Freightliner 4 cruise	Heavy-Duty On-Road	Freightliner 4	HHDT
Freightliner 5 cold	Heavy-Duty On-Road	Freightliner 5	HHDT
Freightliner 5 creep	Heavy-Duty On-Road	Freightliner 5	HHDT
Freightliner 5 transient	Heavy-Duty On-Road	Freightliner 5	HHDT
Freightliner 5 cruise	Heavy-Duty On-Road	Freightliner 5	HHDT
Freightliner 6 cold	Heavy-Duty On-Road	Freightliner 6	HHDT
Freightliner 6 creep	Heavy-Duty On-Road	Freightliner 6	HHDT
Freightliner 6 transient	Heavy-Duty On-Road	Freightliner 6	HHDT
Freightliner 6 cruise	Heavy-Duty On-Road	Freightliner 6	HHDT
Freightliner 7 cold	Heavy-Duty On-Road	Freightliner 7	HHDT
Freightliner 7 creep	Heavy-Duty On-Road	Freightliner 7	HHDT
Freightliner 7 transient	Heavy-Duty On-Road	Freightliner 7	HHDT
Freightliner 7 cruise	Heavy-Duty On-Road	Freightliner 7	HHDT
AVFL-10a 42	Heavy-Duty On-Road		HHDT
AVFL-10a 44	Heavy-Duty On-Road		HHDT
AVFL-10a 52	Heavy-Duty On-Road		HHDT
AVFL-10a 55	Heavy-Duty On-Road		HHDT
AVFL-10a 100	Heavy-Duty On-Road		HHDT
AVFL-10a107	Heavy-Duty On-Road		HHDT
AVFL-10a 118	Heavy-Duty On-Road		HHDT
AVFL-10a 118	Heavy-Duty On-Road		HHDT
AVFL-10a 136	Heavy-Duty On-Road		HHDT
AVFL-10a 136	Heavy-Duty On-Road		HHDT
AVFL-10a 137	Heavy-Duty On-Road		HHDT
AVFL-10a 137	Heavy-Duty On-Road		HHDT
AVFL-10a 98	Heavy-Duty On-Road		HHDT
AVFL-10a 98	Heavy-Duty On-Road		HHDT

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
New 20C	Heavy-Duty On-Road	New bus	HHDT
New -10C	Heavy-Duty On-Road	New bus	HHDT
Muffler 20C	Heavy-Duty On-Road	Old bus	MHDT
Muffler -10C	Heavy-Duty On-Road	Old bus	MHDT
OxyCat 20C	Heavy-Duty On-Road	Old bus + added catalyst	MHDT
OxyCat -10C	Heavy-Duty On-Road	Old bus + added catalyst	MHDT
AVFL-10a 64	Heavy-Duty On-Road		MHDT
AVFL-10a 74	Heavy-Duty On-Road		MHDT
AVFL-10a 74	Heavy-Duty On-Road		HHDT
AVFL-10a 126	Heavy-Duty On-Road		MHDT
AVFL-10a 64	Heavy-Duty On-Road		HHDT
AVFL-10a 64	Heavy-Duty On-Road		SHDT
AVFL-10a 64	Heavy-Duty On-Road		MHDT
Schoolbus CARB	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD+DPX	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD-1	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD-1+DPX	Heavy-Duty On-Road	School bus	MHDT
Schoolbus F-T	Heavy-Duty On-Road	School bus	MHDT
Schoolbus F-T+DPX	Heavy-Duty On-Road	School bus	MHDT
Schoolbus CARB	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD+DPX	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD-1	Heavy-Duty On-Road	School bus	MHDT
Schoolbus ECD-1+DPX	Heavy-Duty On-Road	School bus	MHDT
Schoolbus F-T	Heavy-Duty On-Road	School bus	MHDT
Schoolbus F-T+DPX	Heavy-Duty On-Road	School bus	MHDT
AVFL-10a 120	Heavy-Duty On-Road		MHDT
Schoolbus CD	Heavy-Duty On-Road		MHDT
Schoolbus LED	Heavy-Duty On-Road		MHDT
AVFL-10a 97	Heavy-Duty On-Road		MHDT
AVFL-10a 98	Heavy-Duty On-Road		MHDT
AVFL-10a 107	Heavy-Duty On-Road		MHDT
AVFL-10a 56	Heavy-Duty On-Road		MHDT
AVFL-10a 73	Heavy-Duty On-Road		MHDT
AVFL-10a 75	Heavy-Duty On-Road		MHDT
AVFL-10a 89	Heavy-Duty On-Road		MHDT
AVFL-10a 64	Heavy-Duty On-Road		HHDT
AVFL-10a 123	Heavy-Duty On-Road		HHDT
AVFL-10a 64	Heavy-Duty On-Road		MHDT
AVFL-10a 78	Heavy-Duty On-Road		MHDT
AVFL-10a 123	Heavy-Duty On-Road		MHDT
AVFL-10a 64	Heavy-Duty On-Road		LHDT
AVFL-10a 64	Heavy-Duty On-Road		MHDT
AVFL-10a 59	Heavy-Duty On-Road		HHDT
AVFL-10a 103	Heavy-Duty On-Road		HHDT
AVFL-10a 31	Heavy-Duty On-Road		HHDT
AVFL-10a 31	Heavy-Duty On-Road		HHDT
AVFL-10a 22	Heavy-Duty On-Road		MHDT
AVFL-10a 138	Heavy-Duty On-Road		
AVFL-10a 61	Heavy-Duty On-Road		MHDT
AVFL-10a 61	Heavy-Duty On-Road		MHDT
AVFL-10a 86	Heavy-Duty On-Road		MHDT
AVFL-10a 51	Light-Duty (Passenger)		LHDT
AVFL-10a 35	Light-Duty (Passenger)		LHDT
AVFL-10a 35	Light-Duty (Passenger)		LHDT

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
AVFL-10a 35	Light-Duty (Passenger)		LHDT
AVFL-10a 50	Light-Duty (Passenger)		LHDT
Heavy duty F-T	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy duty Swedish	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy duty CARB	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy duty D2	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy light-duty F-T	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy light-duty Swedish	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy light-duty CARB	Light-Duty (Passenger)	Cummins B-series	LHDT
Heavy light-duty D2	Light-Duty (Passenger)	Cummins B-series	LHDT
LSD Cold Start 24C Transient	Light-Duty (Passenger)	Cummins Turbo	LHDT
LSD Cold Start 24C Stabilized	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 24C Transient	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 24C Stabilized	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Cold Start 0C Transient	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Cold Start 0C Stabilized	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 0C Transient	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 0C Stabilized	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Cold Start 24C	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 24C	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Cold Start 0C	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
LSD Hot Start 0C	Light-Duty (Passenger)	Cummins Turbo Diesel	LHDT
AVFL-10a 25	Light-Duty (Passenger)		SHDT
AVFL-10a 144	Light-Duty (Passenger)		SHDT
AVFL-10a 105	Light-Duty (Passenger)		SHDT
AVFL-10a 106	Light-Duty (Passenger)		SHDT
AVFL-10a 106	Light-Duty (Passenger)		SHDT
AVFL-10a 39	Light-Duty (Passenger)		LDV
1990 Chevy Pickup CARB	Light-Duty (Passenger)	1990 Chevy Pick-up	LHDT
1990 Chevy Pickup EC-D	Light-Duty (Passenger)	1990 Chevy Pick-up	LHDT
1989 Chevy Pickup CARB	Light-Duty (Passenger)	1989 Chevy Pickup	LHDT
1989 Chevy Pickup EC-D	Light-Duty (Passenger)	1989 Chevy Pickup	LHDT
1987 Chevy Pickup CARB	Light-Duty (Passenger)	1987 Chevy Pick-up	LHDT
1987 Chevy Pickup EC-D	Light-Duty (Passenger)	1987 Chevy Pick-up	LHDT
1985 Chevy Pickup CARB	Light-Duty (Passenger)	1985 Chevy Pick-up	LHDT
1985 Chevy Pickup EC-D	Light-Duty (Passenger)	1985 Chevy Pick-up	LHDT
AVFL-10a 155	Light-Duty (Passenger)		LHDT
AVFL-10a 155	Light-Duty (Passenger)		LHDT
1993 Ford Pickup CARB	Light-Duty (Passenger)	1993 Ford Pick-up	LHDT
1993 Ford Pickup EC-D	Light-Duty (Passenger)	1993 Ford Pick-up	LHDT
1990 Ford Van CARB	Light-Duty (Passenger)	1990 Ford Van	LHDT
1990 Ford Van EC-D	Light-Duty (Passenger)	1990 Ford Van	LHDT
1983 Ford Pickup CARB	Light-Duty (Passenger)	1983 Ford Pick-up	LHDT
1983 Ford Pickup EC-D	Light-Duty (Passenger)	1983 Ford Pick-up	LHDT
F-250 ARCO ECD Round 1	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F- 250 ARCO ECD Round 2	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F- 250 CARB Round 1	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F-250 CARB Round 2	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F-250 CARB Control	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F-250 ECD-1 + DPX Round 1	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F-250 ECD-1 + DPX Round 2	Light-Duty (Passenger)	Ford F-250 Pick-up	LHDT
F-450 ECD	Light-Duty (Passenger)	Ford F-450 Pick-up	LHDT
F-450 CARB	Light-Duty (Passenger)	Ford F-450 Pick-up	LHDT
F-450 ECD-1+DPX	Light-Duty (Passenger)	Ford F-450 Pick-up	LHDT
Dodge Sprinter FTP Composite	Light-duty diesel	Dodge Sprinter	SHDT
HD	Light-duty diesel	Diesel high PM emitter at 72 °F	LHDT
Summer Average	Light-duty diesel	Average of 10 vehicles	LHDT

Test ID[1]	Engine Application	Description	EEA DESCRIPTOR
D	Light-duty diesel	Average of three light duty vehicles -current-technology diesel vehicles at 72 °F	LHDT
D30	Light-duty diesel	Average of three light duty vehicles -current-technology diesel vehicles at 30 °F	LHDT
107	Light-duty diesel	LDDV=Light-duty diesel vehicle	LHDT
HCS-8R	Medium Heavy-Duty	Box Truck	SHDT
MDD Trucks	Medium-duty	Average of 2 Medium Duty Diesel Truck	LHDT
E55CRC-41	Medium-heavy duty truck	Box	LHDT
E55CRC-41	Medium-heavy duty truck	Box	LHDT
E55CRC-41	Medium-heavy duty truck	Box	LHDT
9125		SEDAN	LDV
33060		PICKUP	LHDT
Low Aromatic		Cummins L10	HHDT
Pre-1993		Cummins L10	HHDT
Reformulated		Cummins L10	HHDT
ID-II		Composite of 9 box trucks, 1 flat bed, and 1 van	
33061		SEDAN	LDV
9077		SEDAN	LDV
9080		WAGON	LDV
33062		WAGON	LDV
9114		SEDAN	LDV
9085		PICKUP	LDV

[1]Values in italics are used for observations in which the field “Test ID” is missing. For these observations the values of the field “Project ID” and “Study ID” are concatenated and provided here to identify the observation referenced. Since these concatenated values are not, necessarily, unique values to the table “tbl EEA Engine Data”, they are among the observations that are not included in the query-generated table.

A relatively small, but not insignificant, proportion of the observations could not be classified into one of the model year categories. This occurred when the data were reported as averages of tests from multiple engines covering a variety of model years that spanned more than one of the model year categories. This also resulted from cases where no model year was reported. Observations for which no model year categorization could be assigned are provided in Table V-2.

Table V-2: Test IDs with No Year Classification

tbl Regulated Pollutants Test ID
ID-III*
Pre-1993
Low Aromatic
Reformulated
Car Engine DF-2
Car Engine CARB
Car Engine ALS
Car Engine ADMM-15
Car Engine FT-100
Summer Average*
Low Aromatic
Pre-1993
Reformulated

*Year values are included for these Test IDs, but they span more than one of the year categories as defined above.

For the pollutant groups, different values for NO_x were collapsed into a single group (i.e., this group includes NO_x, NO, and NO_2). Finally, the unit values for the pollutants were standardized to grams per mile from the various native unit specifications provided (except idling tests which were translated into grams per minute). The following conversions, many of which are based on approximate factors, were used to identify outliers in the data:

g/kW * 0.746 → g/bhp*hr
g/bhp*hr * 0.6 → g/mile for SHDT
g/bhp*hr * 0.9 → g/mile for LHDT
g/bhp*hr * 2.3 → g/mile for MHDT
g/bhp*hr * 3.3 → g/mile for HHDT

With the data prepped for cross-observation comparison, charts were created for each categorical specification (e.g., “HHDT, pre-1990, CO” and “LDV, 1991-1993, THC”) for which there were at least two data points. These charts are included in Appendix B. Each data point was then labeled and the charts were checked for extreme data values (indicating either bad data or a possible unit error) and consistency among the same engine between pollutant categories. Table V-3 contains data points that were identified for these extreme values. The “Categorization” column in Table V-3 identifies which charts in Appendix B are relevant for that particular Test ID. Additionally, charts plotting NO_x versus PM were created to detect observations that deviate from the typical NO_x / PM emissions tradeoff. The observations identified in Table V-4 appear within a reasonable range, but have been identified as “high” emitters as a result of one or more of the pollutant test results. They have been identified as “high” from comparison to similarly categorized test results. Again, the “Categorization” column helps to identify which charts in Appendix B are relevant for each listed Test ID.

Table V-3: Extreme (High and Low) Data Values that are Possibly in Error

Test ID	Categorization	Notes
CID-9E	HHDT pre1990	The data associated with this entry is an order of magnitude lower than other similarly classified observations
MC-13.1	HHDT 1990-1993	Pollutant values are approximately double other comparable observations
1797 (E55CRC-1)	HHDT pre1990	Values for NO_x (72.34 g/mile) are nearly double the next highest observation, CO is also high
New 20C	HHDT post1993	Extremely high values for $PM_{2.5}$ (197 g/mile)
New -10C	HHDT post 1993	Extremely high values for $PM_{2.5}$ (167 g/mile)
Muffler 20C	MHDT pre1990	Extremely high values for $PM_{2.5}$ (2826 g/mile)
Muffler -10C	MHDT pre1990	Extremely high values for $PM_{2.5}$ (2215 g/mile)
OxyCat 20C	MHDT pre1990	Extremely high values for $PM_{2.5}$ (1112 g/mile)
OxyCat -10C	MHDT pre1990	Extremely high values for $PM_{2.5}$ (916 g/mile)
Schoolbus ECD+DPX	MHDT post1993	Value of 0 for THC
Schoolbus ECD+DPX	MHDT post1993	Value of 0 for THC
Truck ECD-1	HHDT post1993	Values for $PM_{2.5}$ an order of magnitude lower than other observations
Truck ECD+CRT	HHDT post1993	Values for $PM_{2.5}$ and THC order of magnitude lower than other observations
Truck ECD-1+CRT	HHDT post1993	Values for $PM_{2.5}$ and THC order of magnitude lower than other observations
1983 Ford Pickup CARB	LHDT pre1990	Total Particulate Matter value of 650.2 g/mile
1983 Ford Pickup EC-D	LHDT pre1990	Total Particulate Matter value of 590 g/mile
1993 Ford Pickup CARB	LHDT 1990-1993	Total Particulate Matter value of 530 g/mile
1993 Ford Pickup EC-D	LHDT 1990-1993	Total Particulate Matter value of 330 g/mile
1987 Chevy Pickup CARB	LHDT pre1990	Total Particulate Matter value of 320 g/mile

Table V-4. Engines Identified as High Emitters

Test ID	Categorization	Notes
CCS-11N	HHDT post1993	Low CO levels, but high values for NO_x, PM, and THC
HCSF-3	HHDT post1993	High CO and mid THC – PM and NO_x missing
HCSF-4	HHDT post1993	Mid CO, high $PM_{2.5}$ and THC
HCS-11	HHDT post1993	High CO and THC, mid THC – no data for NO_x
CCS-12	HHDT post1993	Mid-range for NO_x, among highest elsewhere
HCS-12	HHDT post1993	High CO and THC, mid NO_x
1802 (E55CRC-2)	HHDT post1993	
1826 (E55CRC-3)	HHDT pre1990	Highest values in class for CO, THC, and NO_x - no data for PM_{10}
Refuse Hauler CARB	HHDT post1993	High THC, mid CO and NO_x - no data PM
Refuse Hauler ECD	HHDT post1993	
Refuse Hauler ECD-1	HHDT post1993	Highest THC value
Tanker Truck CARB	HHDT post1993	Very high THC - mid CO and NO_x
Bus CARB (Study ID 10)	MHDT post1993	
Bus ECD-1	MHDT post1993	
Bus CARB (Study ID 29)	MHDT post1993	
Bus LSD	MHDT post1993	Among highest values for CO, THC and NO_x
Bus LSD pre	MHDT post1993	Among highest values for CO, THC, and NO_x
Truck CARB (Study ID 10)	HHDT post1993	High CO and NO_x, mid $PM_{2.5}$ and THC - identical to other 'truck CARB'?
Truck ECD-1 (Study ID 10)	HHDT post1993	High CO and NO_x - mid PM_{10} and THC (low $PM_{2.5}$ - order of magnitude low) - same as identical 'truck ECD-1'?
truck CARB (Study ID 29)	HHDT post1993	High CO and NO_x, mid $PM_{2.5}$ and THC - identical to other 'truck CARB'?
truck ECD-1 (Study ID 29)	HHDT post1993	High CO and NO_x - mid PM_{10} and THC (low $PM_{2.5}$ - order of magnitude low) - same as identical 'truck ECD-1'?
HCS-5	MHDT pre1990	Highest CO in class, mid $PM_{2.5}$ and NO_x
CCSF-1	MHDT pre1990	Highest CO and $PM_{2.5}$ in class, mid NO_x
HCSF-1	MHDT pre1990	High CO and mid NO_x

In the charts shown in Appendix B, each emission record from the Diesel Speciation Database included in the specified vehicle class/model year/pollutant category is plotted as an individual point at the reported emission level. This allows the reader to visually identify both the range of reported emission rates for each vehicle class/model year/pollutant category, as well as the number of occurrences of that vehicle class/model year/pollutant category in the database. The plots also enable the identification of cases where multiple tests have resulted in similar emission rates and cases where there is no observed trend in the emission rates for that vehicle/pollutant category.

The data illustrated in Figures B-1 through B-50 were summarized in Figures B-51 and B-52. These figures show the range of the emission factors for a given pollutant and vehicle category, along with the total number of observations. In Figure B-51, the highest and lowest data values were omitted from each data set. Figure B-52 includes all data points.

2. Data Observations

- There are 4,143 records in the table “tbl Regulated Pollutants.” As a result of missing data for “Test ID” in both the “tbl Regulated Pollutants” and “tbl Engine Data” tables, only 1,353 of these records could be successfully matched between these two tables.
- As a result of the missing/unlinked data, several of the categorized charts lack sufficient data points to make definitive comparisons.
- Pollutants NO, NO_2, and NO_x are all used. It is not clear if these are being used interchangeably, or if they are, in fact, used as labeled. For the purposes of pollutant analysis, it might be useful to use NO_x only, though if this labeling does represent accurate specificity that information should not be lost.
- It is not clear how the pollutant “Total Particulate Matter” is defined. (It is not the sum of PM_{10} and $PM_{2.5}$, nor is it always greater than those values.)

B. GENERAL FINDINGS

Pechan reviewed several of the original reports that included data identified by EEA as potential outliers or errors. Through this process, Pechan identified several studies that had been incorporated into the AVFL-10a database, and subsequently into the diesel speciation database, where the units in the AVFL-10a database differed from those in the original SAE papers documenting the data collected in those studies. Pechan determined that emissions data for several studies in the AVFL-10a database are reported in units of grams per kilometer, while the original papers show the units as mg/km. Table V-5 shows examples where N_2O emissions are reported in g/km, but should be in mg/km. These units have been corrected in the database.

Table V-5. Example of Data Determined to Have Incorrect Units

Study ID	test_id	fbatch_id	engine id	test_proc	N_2O	$C0_2$	THC	CO	NO_x
35	FTP D2	D2	Cummins	FTP-75	4.0 g/km	374.4 g/km	0.24 g/km	0.9 g/km	5.67 g/km
35	US06 D2	D2	Cummins	US06	3.4 g/km	335.2 g/km	0.12 g/km	0.4 g/km	3.26 g/km
35	FTP F-T	F-T	Cummins	FTP-75	3.1 g/km	359.5 g/km	0.16 g/km	0.4 g/km	4.38 g/km

35	US06 F-T	F-T	Cummins	US06	2.9 g/km	324.0 g/km	0.12 g/mi	1.58 g/mi	1.65 g/mi
35	HFET D2	D2	Cummins	HFET	2.5 g/km	212.2 g/km	0.12 g/km	0.3 g/km	3.17 g/km

Review of several of the original figures aided in identifying several extreme PM2.5 emission outliers. Pechan reviewed the source data for these points and noted that the emission units in the database were incorrect. The units were listed as grams/mile. In actuality, based on the data in the original report, the correct units are mg/mile. These emission units have been corrected in the final database, and are shown correctly in the figures in Appendix B.

Another potential cause for some of the extreme outliers may be from special studies that resulted in extreme numbers. For example, some tests included in the diesel speciation database were performed to study selective catalytic reduction (SCR) control, which uses NH_3, EGR, and the addition of fuel to chemically reduce NO_x to N_2 and O_2 through reduction catalysts. The special conditions in these studies could affect emission rates and, consequently, speciation. Pechan also noted that the E55/59 had very high hexane which was found to be zero in other studies (e.g., Schauer, CE-CERT, Environment Canada). These high hexane levels are likely to be outliers due to errors in the field/lab.

Several observations can be made in extrapolating the analysis of high emitters of criteria pollutants to the corresponding speciations:

1) The vehicles identified as high emitters for criteria pollutants would be expected to have more organic carbon than elemental carbon, due to poor combustion efficiency; and
2) New and clean vehicles generally emit a higher percentage of methane than older or dirtier vehicles.

In general, diesel exhaust contains more EC than OC without control devices. Control devices play an important role, not only by reducing pollutant emission rates, but also by changing the chemical compositions. For example, trucks equipped with advanced diesel particulate filters, PM reduction could be over 90 percent and the exhaust could contain more OC than EC. An explanation of this phenomenon was EC (or soot) being trapped in the filter and being combusted more efficiently than the removal of OC (Chatterjee, et al., 2002). On the other hand, for vehicles equipped with an oxidation catalyst, OC was primarily removed by catalytic oxidation on the catalyst section and the exhaust contained more EC than OC.

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CHAPTER VI. POTENTIAL USES OF DIESEL SPECIATION DATABASE

The Diesel Speciation Database prepared under this project should find additional uses beyond the specified purposes of this study. This database should prove to be useful to researchers, emission modelers, and emission inventory developers. The EPA SPECIATE Workgroup has expressed interest in incorporating the database into the SPECIATE database (Beck, 2006). In order to incorporate the information from the Diesel Speciation Database into the SPECIATE database, additional work will be needed to convert the data to weight percent format by normalizing speciated emission rates by either PM or VOC. Other mobile source emissions models like EPA's Mobile Source Observation Database (MSOD) and CARB's EMission FACtors (EMFAC) mobile source emission model currently have limited—or no—speciated onroad diesel emissions, and could benefit from this database by enhancing their toxic emissions inventory capabilities.

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CHAPTER VII. REFERENCES

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APPENDIX A. POLLUTANTS INCLUDED IN DIESEL SPECIATION DATABASE EMISSIONS TABLES

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Table A-1. Compounds Included in Tbl Carbonyl

Pollutant Name	Pollutant Code
1,4-benzenedicarboxaldehyde	623278
2,3-dihydroxy-lh-indan-l-one	83330
2,5-dimethylbenzaldehyde	5779942
acetaldehyde	75070
acetone	67641
acetophenone	98862
acrolein	107028
benzaldehyde	100527
biacetyl	431038
butyraldehyde	123728
crotonaldehyde	4170303
decanal	112312
decanoic acid	334485
dimethylbenzaldehyde	C49
dodecanal	112549
formaldehyde	50000
glyoxal	107222
heptanal	111717
hexanaldehyde	66251
isobutyraldehyde	78842
isovaleraldehyde	590863
lauric acid	143077
m/p-tolualdehyde	C48
methacrolein	78853
methyl 4-hydroxy-3-methoxybenzoic acid	3943746
methyl ethyl ketone	78933
methyl isobutyl ketone	108101
methylbenzoic acid	12167747
methylglyoxal	78988
m-tolualdehyde	620235
myristic acid	544638
nonanal	124196
nonanoic acid	112050
octanal	124130
octanoic acid	124072
o-tolualdehyde	529204
pinacolone	75978
propionaldehyde	123386
p-tolualdehyde	104870
tolualdehyde	1334787
total Carbonyls	C47
tridecanal	10486198
tridecanoic acid	638539
trimethylacetaldehyde; 3-methyl-2-butanone	C50
undecanal	112447
undecanoic acid	112378
valeraldehyde	110623

Table A-2. Compounds Included in Tbl DioxinFuran

Pollutant Name	Pollutant Code
1,2,3,4,6,7,8-HpCDD	35822469
1,2,3,4,7,8,9-HpCDF	55673897
1,2,3,7,8-PeCDD	40321764
2,3,4,6,7,8-HxCDF	60851345
2,3,7,8-TCDD	1746016
2,3,7,8-TCDF	51207319
2,3-benzofuran	271896
dibenzofuran	132649
OCDD	3268879
OCDF	39001020
total HpCDD	C193
total HpCDF	C196
total HxCDD	C192
total HxCDF	C197
total PeCDD	C191
total PeCDF	C195
total TCDD	C190
total TCDF	C194

Table A-3. Compounds Included in Tbl PAH

Pollutant Name	Pollutant Code
1,2,8-trimethylnaphthalene	C51
1,2-dimethylnaphthalene	573988
1,3+1,6+1,7-dimethylnaphthalene	C52
1,3+1,6+2,3-dimethylnaphthalene	C53
1,3-dinitronaphthalene	606371
1,3-dinitropyrene	75321209
1,4,5-trimethylnaphthalene	2131411
1,4+1,5+2,3-dimethylnaphthalene	C55
1,4-chrysenequinone	C124
1,5-dinitronaphthalene	605710
1,6+1,8-dinitropyrene	C56
1,6-dinitropyrene	42397648
1,7-dimethylphenanthrene	C57
1,8-dimethylnaphthalene	569415
1,8-dinitronaphthalene	602380
1,8-dinitropyrene	42397659
1+2-ethylnaphthalene	C58
12-ethyl-6-nitrochrysene	C59
1-ethyl-2-methylnaphthalene	C60
1-methylfluoranthene, C-methylpyrene/fluoranthene	C61
1-methylfluoranthene+C-methylfluoranthene	C146
1-methylfluorene	1730376
1-methylnaphthalene	90120
1-methylphenanthrene	832699
1-methylpyrene	2381217
1-nitrobenzo[e]pyrene	C62
1-nitronaphthalene	86577
1-nitropyrene	5522430
1-phenylnaphthalene	605027
2,3,5+I-trimethylnaphthalene	C121
2,3,5-trimethylnaphthtalene	2245387
2,4,5-trimethylnaphthalene	C63
2,6+2,7-dimethylnaphthalene	C64
2,6-dimethylnaphthalene	581420
2,7-dinitrofluorene	5405538
2-benzylnaphthalene	C136
2-ethyl-1-methylnaphthalene	C65
2-methylanthracene	613127
2-methylbiphenyl	643583
2-methylfluorene	1430973
2-methylnaphthalene	91576
2-methylnitronaphthalene	C144
2-methylphenanthrene	2531842
2-nitroanthracene	C66
2-nitrobenzo[a]pyrene	C67
2-nitrobiphenyl	86000
2-nitrofluoranthene	C68
2-nitrofluorene	607578
2-nitronaphthalene	581895
2-phenylnaphthalene	612942
3,6-dimethylphenanthrene	1576676

Table A-3 (continued). Compounds Included in Tbl PAH

Pollutant Name	Pollutant Code
3-methylbiphenyl	C69
3-methyl-phenanthrene	832713
3-nitrobenzo[a]pyrene	C70
3-nitrobenzo[e]pyrene	C71
3-nitrobiphenyl	2113588
3-nitrofluoranthene	892217
3-nitrofluorene	C72
3-nitrophenanthrene	C73
4-methylbiphenyl	644086
4-methylpyrene	C74
4-nitrobenzo[e]pyrene	C75
4-nitrobiphenyl	92933
4-nitrophenanthrene	C76
4-nitropyrene	57835924
5+6-methylchrysene	C77
6-nitrobenzo[a]pyrene	63041907
6-nitrochrysene	7496028
7-methylbenz[a]anthracene	2541697
7-methylbenzo[a]pyrene	C78
7-nitro-12-methylbenzo[a]anthracene	C79
7-nitrobenz(a)anthracene	20268513
9,10-dinitroanthracene	C122
9-anthraldehyde	642319
9-methylanthracene	779022
9-methylphenanthrene	883205
9-nitroanthracene	602608
9-nitrophenanthrene	954461
acenaphthene	83329
acenaphthenequinone	82860
acenaphthylene	208968
Acephenanthrylene	201069
A-dimethylphenanthrene	C80
A-methylfluorene	C81
A-methylphenanthrene	C82
A-methylpyrene	C128
A-methylpyrene/fluoranthene	C147
anthanthrene	191264
anthracene	120127
anthraquinone	84651
anthrone	90448
A-trimethylnaphthalene	C83
B-dimethylphenanthrene	C84
benz[a]anthracene	56553
benz[a]anthracene-7,12-dione	2498660
benzacenaphthylene	C135
benzanthone	82053
benzo[a]fluorene	238846
benzo[a]fluorene/ benzo[b]fluorene	C138
benzo[a]pyrene	50328
benzo[b]chrysene	214175
benzo[b]fluoranthene	205992
benzo[b]fluorene	243174
benzo[b]triphenylene	215587

Table A-3 (continued). Compounds Included in Tbl PAH

Pollutant Name	Pollutant Code
benzo[bkj]fluoranthene	C85
benzo[c]chrysene	194694
benzo[c]phenanthrene	195197
benzo[e]pyrene	192972
benzo[ghi]fluoranthene	203123
benzo[ghi]perylene	191242
benzo[i]fluoranthene	C141
benzo[k]fluoranthene	207089
benzonaphthothiophene	C86
bibenzyl	103297
biphenyl	92524
B-methylfluorene	C87
B-methylphenanthrene	C88
B-methylpyrene	C129
B-methylpyrene/methylfluoranthene	C118
B-trimethylnaphthalene	C89
C1-MW 202 PAH	E17151234
C1-MW 228 PAH	E17151259
C2-MW 178 PAH	E17151267
C2-naphthalenes	E17074915
C3-MW 178 PAH	E17151275
C3-naphthalenes	E17074964
C4-naphthalenes	E17074998
C-dimethylphenanthrene	C90
chrysene	218019
chrysene+triphenylene	C91
C-methylfluorene	C127
C-methylphenanthrene	C92
C-methylpyrene	C130
C-methylpyrene/methylfluoranthene	C120
coronene	191071
C-trimethylnaphthalene	C93
cyclopenta[cd]pyrene	27208373
D-dimethylphenanthrene	C94
dibenz[ah]anthracene	53703
dibenz[ah+ac]anthracene	C95
dibenz[aj]anthracene	224419
dibenzo[ae]pyrene	C97
dibenzo[ah]pyrene	189640
dibenzo[ai]pyrene	191300
dibenzo[al]pyrene	C96
dibenzofuran	132649
dimethylfluoranthenes, -pyrenes	C140
dimethylnaphthalenes	C98
dimethylphenanthrenes	C99
dimethylphenanthrenes, -anthracenes	C134
D-MePy/MeFl	C123
D-methylpyrene	C131
D-methylpyrene/fluoranthene	C100
E-dimethylphenanthrene	C101
E-methylpyrene	C132
E-trimethylnaphthalene	C102
fluoranthene	206440

Table A-3 (continued). Compounds Included in Tbl PAH

Pollutant Name	Pollutant Code
fluorene	86737
fluorenone	486259
F-methylpyrene	C133
F-trimethylnaphthalene	C103
G-trimethylnaphthalene	C125
H-trimethylnaphthalene	C126
indeno[123-cd]fluoranthene	C104
indeno[123-cd]pyrene	193395
J-trimethylnaphthalene	C105
methylbenz[a]anthracenes, -chrysenes, -triphenylen	C143
methylbenzofluoranthenes, -benzopyrenes, -perylene	C142
methylbiphenyl	28652724
methylfluorene	26914170
methylnaphthalene	1321944
methylnitronaphthalene	C145
methylphenanthrenes	C106
methylphenanthrenes/anthracenes	C107
methylpyrenes/fluoranthenes	C108
naphthalene	91203
nitro-benzo(a)anthracene	C151
nitrobenzo[a]pyrene	C152
NO_2 PAH	C109
PAH	C110
perinaphthenone	548390
perylene	198550
phenanthrene	85018
pyrene	129000
retene	483658
total nitro-C13 PAH	C111
total nitro-C14 PAH	C112
total nitro-C16 PAH	C113
total nitro-C18 PAH	C114
total nitro-C20 PAH	C115
trimethylnaphthalenes	C116
triphenylene	217594
xanthone	90471

Table A-4. Compounds Included in Tbl PM Speciation

Pollutant Name	Pollutant Code
Ag	7440224
Al	7429905
As	7440382
Au	7440575
Ba	7440393
Br	7726956
Ca	7440702
Cd	7440439
Ce	7440451
chloride	16887006
chlorine	22537151
Cl	22537151
Cl^-	16887006
cobalt	7440484
Cr	7440473
Cs	7440462
Cu	7440508
cyanide compounds	E17000282
elemental carbon	C157
elemental carbon rraction 1	C159
elemental carbon rraction 2	C160
elemental carbon rraction 3	C161
Fe	7439896
Ga	7440553
Hg	7439976
I	7553562
In	7440746
K	7440097
La	7439910
Mg	7439954
Mg^{2+}	C169
Mn	7439965
Mo	7439987
Na	9440235
Na^+	C170
Nb	7440031
Nd	378782286
NH_4^+	14798039
Ni	7440020
NO_2-	14797650
NO_3-	14797558
organic carbon	C158
organic carbon fraction 1	C162
organic carbon fraction 2	C163
organic carbon fraction 3	C164
organic carbon fraction 4	C165
other elements	C171
P	7723140
Pb	7439921
Pd	7440053
PO_4^{3-}	14265442

Table A-4 (continued). Compounds Included in Tbl PM Speciation

Pollutant Name	Pollutant Code
Pr	22095530
pyrolyzed organic carbon	C166
Rb	7440177
S	7704349
Sb	7440360
Sc	14276610
Se	7782492
Si	7440213
Sn	7440315
SO_4^{2-}	14808798
SOF	SOF
soluble potassium	C167
Sr	7440246
sulfate	14808798
Te	13494809
Ti	7440326
Tl	15720577
total C	C156
U	7440611
V	7440622
W	7440337
Y	7440655
Zn	7440666
Zr	7440677

Table A-5. Compounds Included in Tbl Regulated Pollutants

Pollutant Name	Pollutant Code
CO	CO
CO_2	CO2
N_2O	10024972
NO_2	10102440
NH_3	7664417
non-methane hydrocarbons	E755363
NO	10102439
NO_2	10102440
NO_x	NO_x
PM 0.09 - 0.17 um (PM 0.1 for E55-59)	C457
PM greater than 6.2 um	C450
PM_{10}	PM_{10}
$PM_{2.5}$	$PM_{2.5}$
SO_2	SO_2
SOF	SOF
THC	308067530
total particulate matter	TPM

Table A-6. Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
(20s and R)-5a(H),14P(H),17P(H)-cholestanes	C350
(22R)-17a(H),21/3(H)-30-bishomohopane	C367
(22S)-17a(H),21~(H)-30-bishomohopane	C366
1,11-undecanedicarboxylic acid	505522
1,12-dodecanedicarboxylic acid	821385
1,2,3,4-tetrahydronaphthalene	119642
1,2,3,4-tetramethylbenzene	488233
1,2,3,5-tetramethylbenzene	527537
1,2,3-trimethylbenzene	526738
1,2,4,5-tetramethylbenzene	95932
1,2,4-butanetriol	3068006
1,2,4-triethylbenzene	95636
1,2-dichlorobenzene	95501
1,2-diethylbenzene	135013
1,2-dihydronaphthalene	447530
1,2-dimethyl-4-ethylbenzene	934805
1,2-dimethylnaphthalene	573988
1,3,5-trimethylbenzene	108678
1,3+1,6+1,7-dimethylnaphthalene	C52
1,3-dichlorobenzene	541731
1,3-diethylbenzene	141935
1,3-diisopropylbenzene	99627
1,4+1,5+2,3-dimethylnaphthalene	C55
1,4-diisopropylbenzene	100185
1+2-ethylnaphthalene	C58
17a(H),18a(H),21ß(H)-25,28,30-trisnorhopane	C208
17a(H),18a(H),21ß(H)-28,30-bisnorhopane	65636262
17a(H),21ß(H)-22,29,30-trisnorhopane	C209
17a(H),21ß(H)-hopane	13849962
17a(H),21b(H)-29-norhopane	C354
17a(H),21fl(H)-29-norhopane	C369
17a(H),21ß(H)-22,29,30-trisnorhopane	C209
17a(H),21ß(H)-30-norhopane	53584604
17a(H),21ß(H)-hopane	138499621
17a(H)-22,29,30-trisnorhopane	53584591
17A(H)-2BA(H)-30-hopane	C500
17ß(H),21a(H)-30-norhopane	C334
17ß(H),21a(H)-hopane	1176449
17ß(H),21ß(H)-hopane	471625
17α(H)-22,29,30-trisnorhopane	C371
18a(H),21a(H)-22,29,30-trisnorhopane	C506
18a(H),21ß(H)-22,29,30-trisnorhopane	C207
18a(H),21ß(H)-30-norneohopane	119613717
18α(H)-22,29,30-trisnorneohopane	C370
1-decene	872059
1-methyl-2-pyrrolidinone	872504

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
1-methylindan	767588
1-methylindane	C35
1-methylnaphthalene	90120
1-nonene	124118
1-undecene	821954
2-(2-butoxyethoxy)ethanol	112345
2,3- and 3,5- dimethylbenzoic acid	C245
2,3-benzofuran	271896
2,3-dihydroxy-IH-indan-I-one	83330
2,3-dimethoxybenzoic acid	1521386
2,4-dimethoxybenzoic acid	91521
2,4-dimethylbenzoic acid	611018
2,5-dimethoxybenzoic acid	2785980
2,5-dimethylbenzoic acid	610720
2,6,10,14-tetramethylpentadecane, pristane	C252
2,6,10-trimethylpentadecane, norpristane	C251
2,6,10-trimethyltridecane	3891994
2,6+2,7-dimethylnaphthalene	C64
2,6-dimethoxybenzoic acid	1466768
2,6-dimethylbenzoic acid	632462
20R,5A(H),14B(H),17B(H)-sitostane	C501
20R-13ß(H),17α(H)-diacholestane	C373
20R-5α(H),14α(H),17α(H)-cholestane and 20S-13ß(H),	C378
20R-5α(H),14α(H),17α(H)-ergostane	C381
20R-5α(H),14β(H),17ß(H)-cholestane	C376
20R-5α(H),14β(H),17ß(H)-ergostane	C379
20R-aaa-ethylcholestane	62446144
20R-aBB-ethylcholestane	71117925
20S&R-5a(H),14b(H),17b(H)-sitostane	E17150186
20S,5A(H),14B(H),17B(H)-sitostane	C502
20S-13B(H),17a(H)-diacholestane	56975849
20S-13ß(H),17α(H)-diacholestane	C372
20S-13ß(H),17α(H)-diaergostane	C374
20S-5α(H),14α(H),17α(H)-cholestane	C375
20S-5α(H),14β(H),17ß(H)-cholestane	C377
20S-5α(H),14β(H),17ß(H)-ergostane and 20R-13α(H),	C380
20S-aaa-ethylcholestane	C322
20S-aBB-(20R-Baa)-ethylcholestane	C324
22,29,30-trisnorneohopane	55199729
22R-17a(H),21ß(H)-30,31,32-trishomohopane	C221
22R-17a(H),21ß(H)-30,31-bishomohopane	C219
22R-17a(H),21ß(H)-30-homohopane	60305228
22S&R17a(H),21b(H)-30-bishomohopane	C356
22S&R-17a(H),21b(H)-30-homohopane	C355
22S-17a(H),21ß(H)-30-homohopane	E17150277
22S-17a(H),21ß(H)-30,31,32-trisomohopane	C220
22S-17a(H),21ß(H)-30,31-bishomohopane	C218
22S-17a(H),21ß(H)-30-homohopane	60305239
2-decanone	693549
2-ethyl-p-xylene	1758889
2-heptanone	110430
2-isopropyltoluene	527844
2-methylbenzofuran	4265252
2-methylfluoren-9-one	C360
2-methylglutaric acid	18069175

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
2-methylindan	C36
2-methylnaphthalene	91576
2-methyloctane	3221612
2-n-propyltoluene	1074175
2-pentylfuran	3777693
3-, 6-methylpicolinic acid	C244
3,4-dimethoxybenzoic acid	93072
3,4-dimethylbenzoic acid	619045
3,5-dimethoxybenzoic acid	1132214
3-isopropyltoluene	535773
3-methyladipic acid	3058013
3-methylglutaric acid	626517
3-methyloctane	2216333
4-allyl-guaiacol	97530
4-cyclopenta[def]phenanthren-4-one	C362
4-ethyl-guaiacol	2785899
4-ethyl-o-xylene	934805
4-formyl-guaiacol	C240
4-isopropyltoluene	99876
4-methylguaiacol	93516
4-methylstyrene	622979
4-methyl-syringol	6638057
4-n-propyltoluene; 1,4-diethylbenzene	C6
4-tert-butyltoluene	98511
5-ethyl-m-xylene	934747
5-isopropyl-m-xylene	4706892
5-methyl-1 (3H)-isobenzofuranone	C368
6H-benzo[cd]pyren-6-one	C365
7H-benz[delanthracen-7-one	C364
7-oxodehydroabietic acid	18684554
8,14-abietenic acid	C249
8,15-pimaradien-18-oic acid	C246
8-abietic acid	C248
8B,13a-dimethyl-14B- [3'-methylbutyl]-podocarpane	E17150293
8B,13a-dimethyl-14B-n-butylpodocarpane	E17150301
9,IO-phenanthrenedione	84117
abietic acid	514103
aB-norhopane	C281
acenaphthene	83329
acenaphthylene	208968
Acetophenone	98862
acetovanillone	498022
A-dimethylindane	C37
alpha-pinene	80568
azelaic acid	123999
Ba-norhopane	3258875
B-dimethylindane	C38
benzaldehyde	100527
benzoic acid	65250
beta-pinene	127913
biphenyl	92524
butylbenzene	104518
C19-tricyclic terpane	C260
C20-aaa-sterane	C296
C20-tricyclicterpane	C261

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
C21-aaa-sterane	C299
C21-aBB-sterane	C298
C21-Baa-sterane	C297
C21-tricyclicterpane	C262
C22-aBB-sterane	C300
C22-tricyclicterpane	C263
C23-aB-dimethyl-a-butylpodocarpane	C264
C24-aB-dimethyl-a-methylbutylpodocarpane	C265
C25-tricyclicterpane	C266
C26-tricyclicterpane	C267
C26-tricyclictriterpane-22R	C268
C26-tricyclictriterpane-22S	C269
C27 20R-13B,17B-diasterane	C327
C27-20R-13ß(H),17a(H)-diasterane	C224
C27-20R-13a(H),17ß(H)-diasterane	C226
C27-20R5a(H),14a(H),17a(H)-cholestane	481210
C27-20R5a(H),14a(H),17a(H)-cholestane&C29-20S13ß(H	C241
C27-20R5a(H),14ß(H)-cholestane	C230
C27-20R-aBB-cholestane	C312
C27-20R-Baa-cholestane	481209
C27-20S-13a(H),17ß(H)-diasterane	C225
C27-20S-13ß(H),17a(H)-diasterane	C223
C27-20S5a(H),14a(H)-cholestane	C229
C27-20S5a(H),14ß(H),17ß(H)-cholestane	E17150582
C27-20S-aaa-cholestane	C311
C27-aaB-trisnorhopane	C275
C27-aB-trisnorneohopane	C274
C27-tetracyclic terpane	C204
C27-tetracyclicterpane-22R	C270
C27-tetracyclicterpane-22S	C271
C28-20R/S?-Ba-diasterane	C307
C28-20R5a(H),14a(H),17a(H)-ergostane	C235
C28-20R5a(H),14ß(H),17ß(H)-ergostane	C234
C28-20R-aaa-methylcholestane	C321
C28-20R-aBB-methylcholestane	71117903
C28-20R-Ba-diasterane	C306
C28-20S-13ß(H),17a(H)-diasterane	C227
C28-20S5a(H),14a(H),17a(H)-ergostane	C233
C28-20S5a(H),14ß(H),17ß(H)-ergostane	C242
C28-20S-aaa-methylcholestane	C317
C28-20S-aBB-methylcholestane	C319
C28-20S-Ba-diasterane	C309
C28-aaB-bisnorhopane	C279
C28-tetracyclic terpane	C205
C28-tetracyclicterpane-22R	C272
C28-tetracyclicterpane-22S	C273
C29-20R-13a(H),17□H)-diasterane	C228
C29-20R-13a(H),17ß(H)-diasterane	C228
C29-20R5a(H),14a(H),17a(H)-stigmastane	C239
C29-20R5a(H),14ß(H),17ß(H)-stigmastane	C237
C29-20S5a(H),14a(H),17a(H)-stigmastane	C236
C29-20S5a(H),14ß(H),17ß(H)-stigmastane	C238
C29-20S-Ba-diasterane	C315
C29-aB-norneohopane	C282
C30-tricyclicterpane-22R	C277

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
C30-tricyclicterpane-22S	C278
C32-22R-aB-bishomohopane	C289
C32-22S-aB-bishomohopane	C288
C33-22R-aB-trishomohopane	C291
C33-22S-aB-trishomohopane	C290
C34-22R-aB-tetrakishomohopane	C293
C34-22S-aB-tetrakishomohopane	C292
C35-22R-aB-pentakishomohopane	C295
C35-22S-aB-pentakishomohopane	C294
C-dimethylindane	C39
cholestane	C357
cholestanol	80977
cholesterol	57885
cis-pinonic acid	473723
C-methylpyrene/methylfluoranthene	C120
cumene	98828
cyclohexanone	108941
d-dimethylindan	C202
d-dimethylindane	C40
decanal	112312
decane	124185
decanoic acid	334485
decylcyclohexane	1795160
dehydroabietic acid	1740198
dibenzofuran	132649
dihydroisopimaric acid	C247
dimethyloctane	C44
docosane	629970
docosanoic acid	112856
dodecane	112403
dodecanedioic acid	693232
dodecene	25378227
dodecylcyclohexane	1795171
eicosane	112958
eicosanoic acid	506309
eicosylcyclohexane	4443554
elaidic acid	112798
ergostane	511206
ergosterol	57874
ethylbenzene	100414
farnesane	3891983
fluorene	86737
glutaric acid	110941
glycerol	56815
guaiacol	90051
heneicosane	629947
heneicosanoic acid	2363715
heneicosylcyclohexane	26718821
heptacosane	593497
heptadecane	629787
heptadecane & pristane	C400
heptadecanoic acid	506127
heptadecylcyclohexane	19781738
heptanal	111717
heptanedioic acid	111160

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
heptanoic acid	111148
heptylcyclohexane	5617414
hexacosane	630013
hexadecane	544763
hexadecane & norpristane	C401
hexadecylcyclohexane	6812380
hexanedioic acid	124049
hexanoic acid	142621
homovanillic acid	306081
ih-benz[de] anthracen-1-one	C363
indan	496117
indene	95136
isoamylbenzene	2049947
Isobutylbenzene	538932
isoeugenol	97541
isophthalic acid	121915
isopimaric acid	5835267
isopropyltoluene	25155151
isoquinoline	119653
isostearic acid	2724585
lauric acid	143077
levoglucosan	498077
levopimaric acid	C250
m/p-cresol	C7
m/p-methylphenol	C203
m/p-xylenes	C1
maleic acid	110167
methyl malonic acid	516052
methyl succinic acid	498215
methylbenzoic acid	12167747
m-ethyltoluene	620144
m-tolualdehyde	620235
m-toluic acid	99047
myristic acid	544638
myristic acid	544649
myristoleic acid	544649
n,n-dibutylformamide	761659
naphthalene	91203
n-dotriacontane	544854
neoabietic acid	471772
n-hentriacontane	630046
nitrosodibutylamine	924163
nitrosodiethylamine	55185
nitrosodimethylamine	62759
nitrosodipropylamine	62164
nitrosomorpholine	59892
nitrosopiperidine	100754
nitrosopyrrolidine	930552
n-nonacosane	630035
NO_2^-	14797650
nonadecane	629925
nonadecanoic acid	646300
nonadecylcyclohexane	22349037
nonanal	124196
nonane	111842

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
nonanoic acid	112050
nonylcyclohexane	2883025
norfarnesane	6864535
norpristane	3892000
octacosane	630024
octadecane	593453
octadecylcyclohexane	4445061
octanal	124130
octanoic acid	124072
octylcyclohexane	1795159
o-ethyltoluene	611143
oleic acid	112801
o-methylphenol	95487
o-toluic acid	118901
o-xylene	95476
palmitic acid	57103
palmitoleic acid	373499
paulustric acid	1945535
pentacosane	629992
pentadecane	629629
pentadecanoic acid	1002842
pentadecylcyclohexane	6006957
pentamethylbenzene	700129
pentylbenzene	538681
p-ethyltoluene	622968
phenanthrene	85018
phenanthronelanthrone	C361
phenol	108952
phenylacetic acid	103822
phthalic acid	88993
phytane	638368
picolinic acid	98986
pimaric acid	510394
pristane	1921706
propylbenzene	103651
propylcylcohexane	1678928
p-toluic acid	99945
quinoline	91225
salicylic acid	69727
sandaracopimaric acid	23527108
s-butylbenzene	135988
sebacic acid	11206
Sitostane	C325
sitosterol	83465
stearic acid	57114
stigmasterol	83487
styrene	100425
suberic acid	505486
succinic acid	110156
syringaldehyde	134963
syringic acid	530574
syringol	91101
t-2-heptenal	18829555
t-butylbenzene	98066
tetracosane	646311

Table A-6 (continued). Compounds Included in Tbl SVOC

Pollutant Name	Pollutant Code
tetracosanoic acid	557595
tetradecane	629594
tetradecylcyclohexane	1795182
tetratriacontane	14167590
trans-2-decenoic acid	334496
traumatic acid	6402364
triacontane	638686
tricosane	638675
tricosanoic acid	2433967
tridecane	629505
tridecanoic acid	638539
tridecylcyclohexane	6006333
trisnorhopane	C276
tritriacontane	630057
undecane	1120214
undecanedioic acid	1852046
undecanoic acid	112378
undecylcyclohexane	54105667
vanillic acid	121346

Table A-7. Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
1,1,2-trimethylcyclopentane; 2-methyl-3-ethylpenta	C13
1,1,4-trimethylcyclohexane	7094271
1,1-dimethylcyclopentane	28729524
1,1-dimethylcycohexane; 1-octene	C16
1,2,3,4-tetramethylbenzene	488233
1,2,3,5-tetramethylbenzene	527537
1,2,3-trimethylbenzene	526738
1,2,4,5-tetramethylbenzene	95932
1,2,4-triethylbenzene	95636
1,2,4-trimethylbenzene; t-butylbenzene	C32
1,2,4-trimethylbenzene; t-butylbenzene; 1-decene	C28
1,2-butadiene	590192
1,2-diethylbenzene	135013
1,3,5-triethylbenzene	102250
1,3,5-trimethylbenzene	108678
1,3-butadiene	106990
1,3-diethylbenzene	141935
1,3-dimethyl-2-ethylbenzene	2870044
1,3-dimethyl-4-ethylbenzene	874419
1,3-hexadiene (trans)	20237347
1,4-diethylbenzene	105055
1,4-pentadiene	591935
1-butene	25167673
1-butene; isobutene	C3
1-butyne	107006
1-ethyl-1-methylcyclopentane; 2,2,4-trimethylhexan	C17
1-heptene	592767
1-hexene	592416
1-methylcyclopentene	693890
1-methylindane	C35
1-nonene	124118
1-pentene	109671
1-t-butyl-4-ethylbenzene	7364194
2,2,3-trimethylbutane	464062
2,2,4-trimethylpentane	540841
2,2,5-trimethylhexane	3522949
2,2-dimethylbutane	75832
2,2-dimethylhexane	590738
2,2-dimethyloctane	15869871
2,2-dimethylpentane	590352
2,2-dimethylpropane	463821
2,3,3-trimethylpentane	560214
2,3,4-trimethylpentane	565753
2,3,5-trimethylhexane	1069530
2,3-dimethyl-2-pentene	10574375
2,3-dimethylbutane	79298
2,3-dimethylheptane	3074713
2,3-dimethylhexane	584941
2,3-dimethylpentane	565593
2,4,4-trimethyl-1-pentene	107391
2,4,4-trimethyl-2-pentene	107404

Table A-7 (continued). Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
2,4,4-trimethylhexane; isopropylcyclopentane	C19
2,4,6-trimethylhexane	C46
2,4-dimethylheptane	2213232
2,4-dimethylhexane	589435
2,4-dimethyloctane	C43
2,4-dimethylpentane	108087
2,5-, 2,4-, 3,3-dimethyl-hexane; trans/cis-1,2,4-t	C11
2,5-dimethylheptane, 3,5-dimethylheptane	C117
2,5-dimethylheptane; 3,5-dimethylheptane; 3,3-dime	C22
2,5-dimethylhexane	592132
2,6,10-trimethyltridecane	3891994
2,6-dimethylheptane, propylcyclopentane	C119
2-butyne	503173
2-ethyl-p-xylene	1758889
2-isopropyltoluene	527844
2-methyl-1,3-butadiene	78795
2-methyl-1-butene	563462
2-methyl-1-pentene	763291
2-methyl-2-butene	513359
2-methyl-2-pentene	625274
2-methylbutane	78784
2-methyl-butylbenzene	1595115
2-methylheptane	592278
2-methylhexane	591764
2-methylindan	C36
2-methylnonane	871830
2-methyloctane	3221612
2-methylpentane	107835
2-methylpropane	75285
2-methylpropene	115117
2-n-propyltoluene	1074175
3,3-dimethyl-1-butene	558372
3,3-dimethylhexane	563166
3,3-dimethyloctane	4110445
3,3-dimethylpentane	562492
3,5-dimethylheptane	926829
3-ethyl-2-pentene	816795
3-ethyloctane	5881174
3-ethylpentane	619998
3-isopropyltoluene	535773
3-methyl-1-butene	563451
3-methyl-1-hexene	3404613
3-methyl-cis-2-pentene	922623
3-methylheptane	589811
3-methylheptane; 3-ethylhexane; cis-trans-1,2,4-tr	C15
3-methylhexane	589344
3-methylnonane	5911046
3-methyloctane	2216333
3-methyloctane; 3,3-diethylpentane; 3-ethylheptane	C24
3-methylpentane	96140
3-methyl-trans-2-pentene	922612
3-n-propyltoluene	1074437

Table A-7 (continued). Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
4,4-dimethylheptane	1068195
4,4-dimethylheptane; 2,2-dimethylheptane; 2,6-dime	C20
4-ethyl-o-xylene	934805
4-ethyltoluene; 2,3-dimethyloctane	C27
4-isopropyltoluene	99876
4-methyl-1-pentene	691372
4-methyl-1-pentene; 3-methyl-1-pentene	C8
4-methylheptane	589537
4-methylheptane; 3-methyl-3-ethylpentane; methylcy	C14
4-methyl-t-2-pentene	4461487
4-n-propyltoluene; n-butylbenzene; 1,3-dimethyl-5-	C29
8B,13a-dimethyl-14B- [3'-methylbutyl]-podocarpane	E17150293
8B,13a-dimethyl-14B-n-butylpodocarpane	E17150301
acetylene	74862
alpha-pinene	80568
benzene	71432
beta-pinene	127913
bis[2-ethylhexyl]phthalate	117817
BTEX	C2
butane	106978
butylbenzene	104518
butylcyclohexane	1678939
butylcyclopentane	2040951
C5 olefin	68527117
C6 olefin	68526523
cis,trans-1,2,3-trimethylcylcopentane	15890401
cis,trans-1,2,4-trimethylcylcohexane	7667585
cis/trans-4-methyl-2-pentene	C9
cis-1,2-dimethylcyclohexane	2207014
cis-1,3-dimethylcyclohexane	638040
cis-1,3-dimethylcyclopentane	2453001
cis-1,4-dimethylcyclohexane	624293
cis-1-ethyl-2-methylcyclopentane	930892
cis-1-methyl-3-ethylcyclopentane	2613663
cis-2-butene	590181
cis-2-heptene	6443921
cis-2-hexene	7688213
cis-2-nonene	6434771
cis-2-pentene	627203
cis-3-nonene; isobutylcyclopentane	C26
cresol	1319773
cumene	98828
cyclohexane	110827
cyclohexene	110838
cyclopentadiene	542927
cyclopentane	287923
cyclopentene	142290
decane	124185
decylcyclohexane	1795160
dibenzothiazine	92842
dibenzothiophene	132650
dibutyl phthalate	84742

Table A-7 (continued). Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
diethylbenzene	25340174
dimethyl ethylbenzenes	C5
dimethylheptane	30498669
dimethyloctane	C44
dodecane	112403
dodecene	25378227
Dodecylcyclohexane	1795171
Eicosane	112958
ethane	74840
ethene	74851
ethyl t-butyl ether	637923
ethylbenzene	100414
ethylcyclohexane	1678917
farnesane	3891983
heneicosane	629947
heptadecane	629787
heptane	142825
heptylcyclohexane	5617414
hexadecane	544763
hexane	110543
hexylcyclohexane	4292755
indan	496117
iso-butane	72285
Isobutylbenzene	538932
isopropylcyclohexane	696297
isopropyltoluene	25155151
limonene	138863
m/p-xylene; 3,4-dimethylheptane	C23
m/p-xylenes	C1
methane	74828
methanol	67561
methylcyclohexane	108872
methylcyclohexane; 2,2-dimethylhexane	C10
methylcyclopentane	96377
methylethylbenzene	25550145
methylheptane	50985847
m-ethyltoluene	620144
MTBE	1634044
n-hexylbenzene	1077163
n-octane; trans-1,2-dimethylcyclohexane	C18
nonadecane	629925
nonane	111842
nonene	27215958
nonylcyclohexane	2883025
norfarnesane	6864535
norpristane	3892000
n-pentylbenzene; trans-1-methyl-2-(4-methylpentyl)	C31
n-propylcyclopentane; ethylcyclohexane; cis-cis-1,	C21
n-undecane; 1,2-dimethyl-3-ethylbenzene; 1,2,4,5-t	C30
octadecane	593453
octane	111659
octylcyclohexane	1795159

Table A-7 (continued). Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
o-ethyltoluene	611143
olefin C2-C5	C33
o-tert-butyltoluene	1074926
o-xylene	95476
o-xylene; 1,1,2-trimethylcyclohexane	C25
pentadecane	629629
pentadecylcyclohexane	6006957
pentane	109660
pentylbenzene	538681
pentylcyclohexane	4292926
p-ethyltoluene	622968
phenol	108952
phytane	638368
POM	E17000340
pristane	1921706
propadiene	463490
propane	74986
propene	115071
propylbenzene	103651
propyltoluene	28729546
propyne	74997
s-butylbenzene	135988
styrene	100425
t-1,3-dichloropropene	10031026
tert-butyl-m-xylene	98191
tetradecane	629594
tetradecylcyclohexane	1795182
tetramethylbenzene	25619607
toluene	108883
toluene; 2,3,3-trimethylpentane	C12
trans,cis-1,2,3-trimethylcyclopentane	C120
trans,cis-1,2,3-trimethylcylcopentane	19374460
trans,cis-1,2,4-trimethylcylcohexane	7667609
trans-1,2-dimethylcyclohexane	6876239
trans-1,3-dimethylcyclohexane	2207036
trans-1,4-dimethylcyclohexane	2207047
trans-2-butene	624646
trans-2-heptene	14686147
trans-2-hexene	4050457
trans-2-nonene	6434782
trans-2-octene	13389429
trans-2-pentadiene	C507
trans-2-pentene	646048
trans-3-nonene	20063927
tridecane	629505
tridecylcyclohexane	6006333
trimethylbenzene	25551137
trimethylhexene	30498636
trimethylpentane	29222488
undecane	1120214
undecylcyclohexane	54105667
unidentified C7	93924379

Table A-7 (continued). Compounds Included in Tbl TOG/VOC/NMOG

Pollutant Name	Pollutant Code
unidentified C8	93924380
unknown (c1-c4)	C41
unknown (c4-c12)	C42
unknown C9-C12+	C45

APPENDIX B. CHARTS FROM DATABASE QA ANALYSIS

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Figure B-1. HHDT CO pre1990

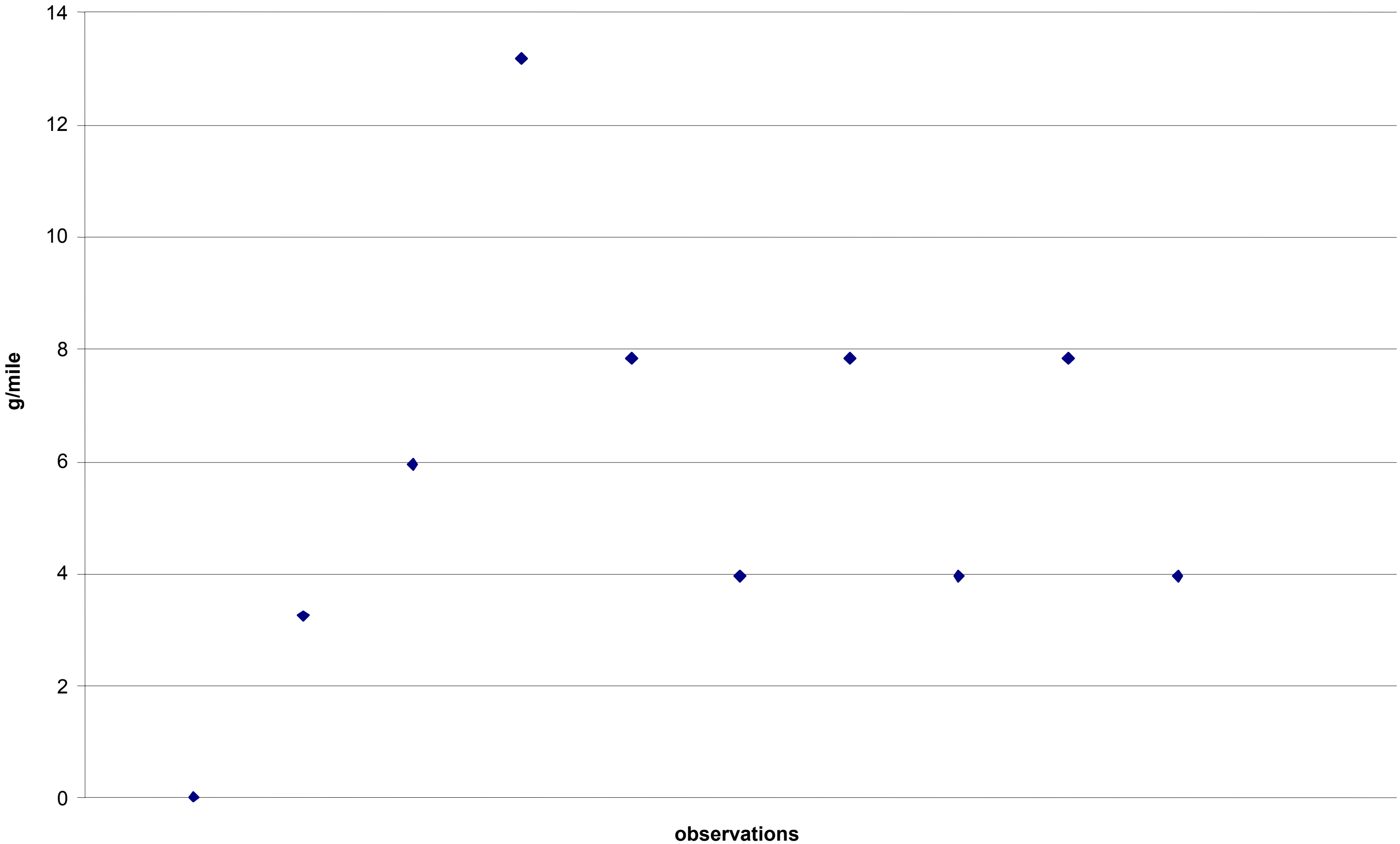


Figure B-2. HHDT CO 1990-1993

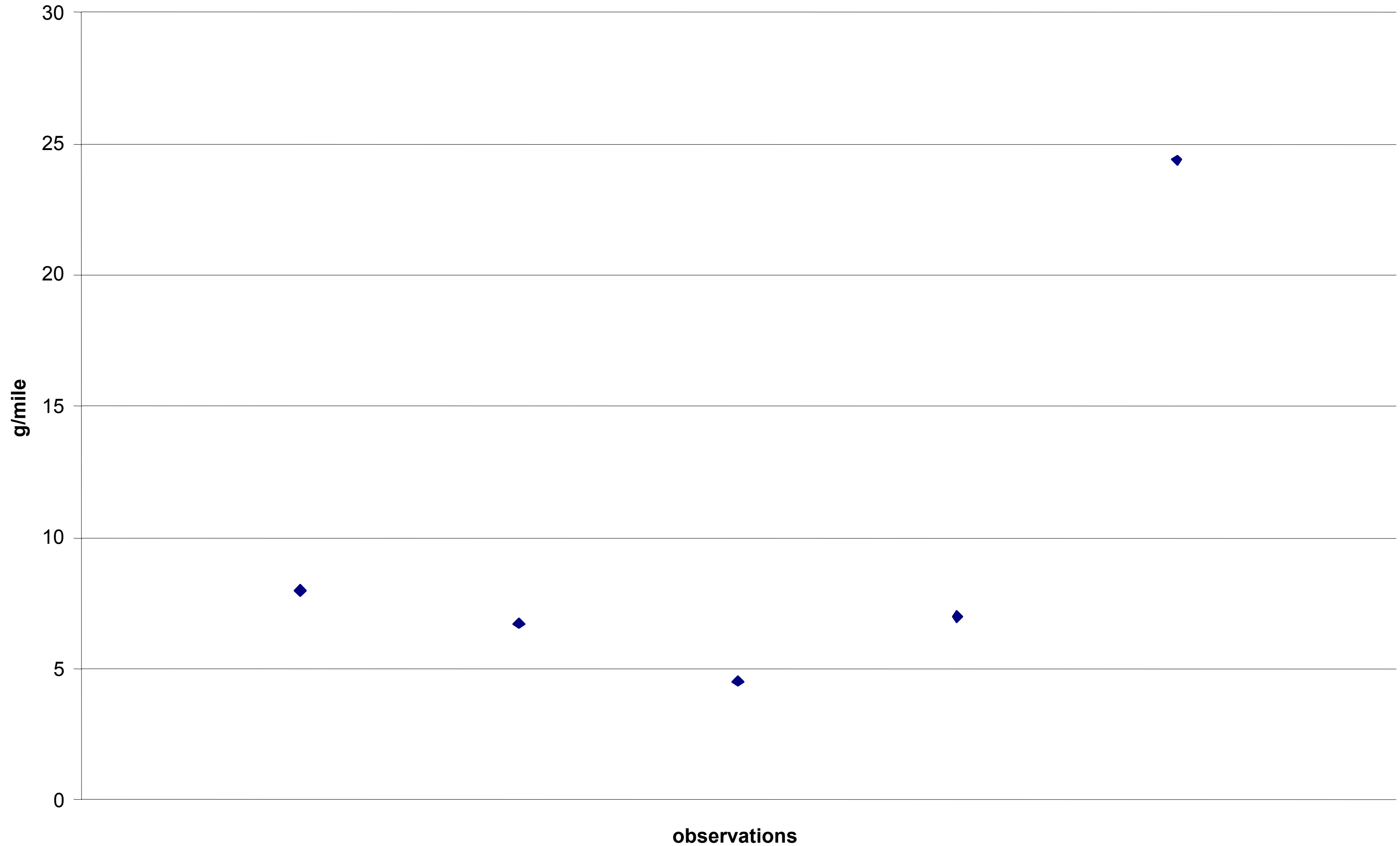


Figure B-3. HHDT CO post1993

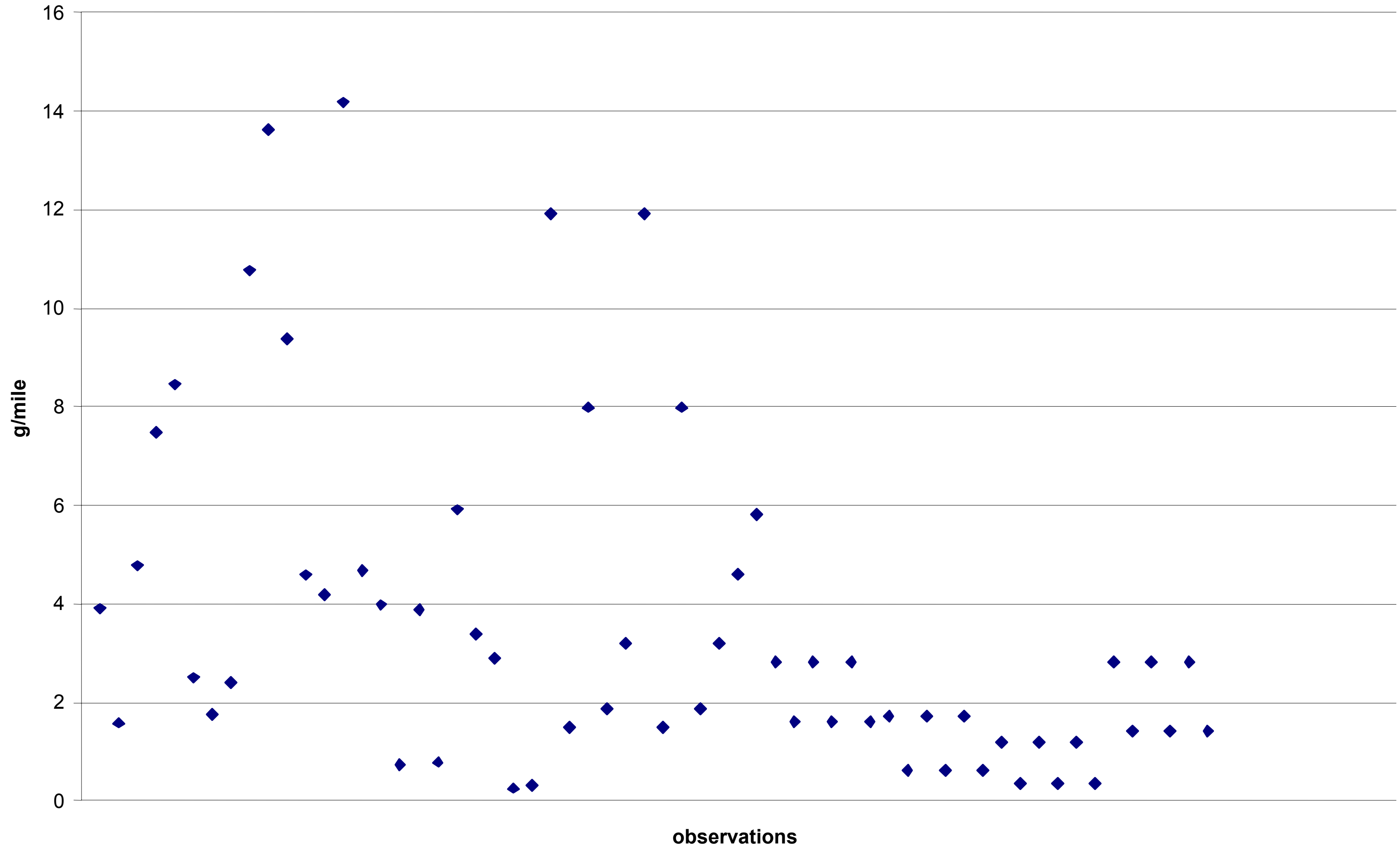


Figure B-4. HHDT PM10 post1993

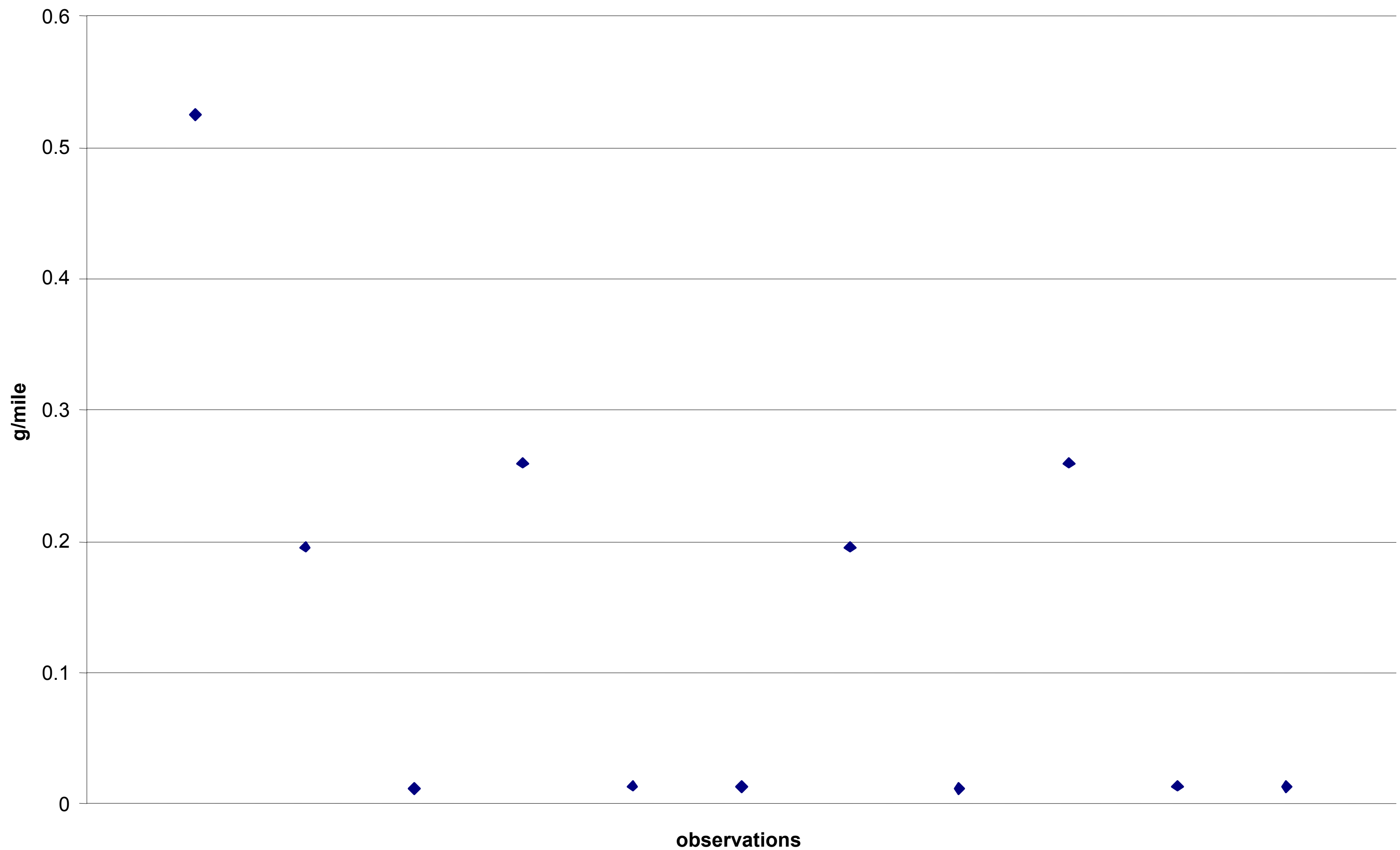


Figure B-5. HHDT THC pre1990

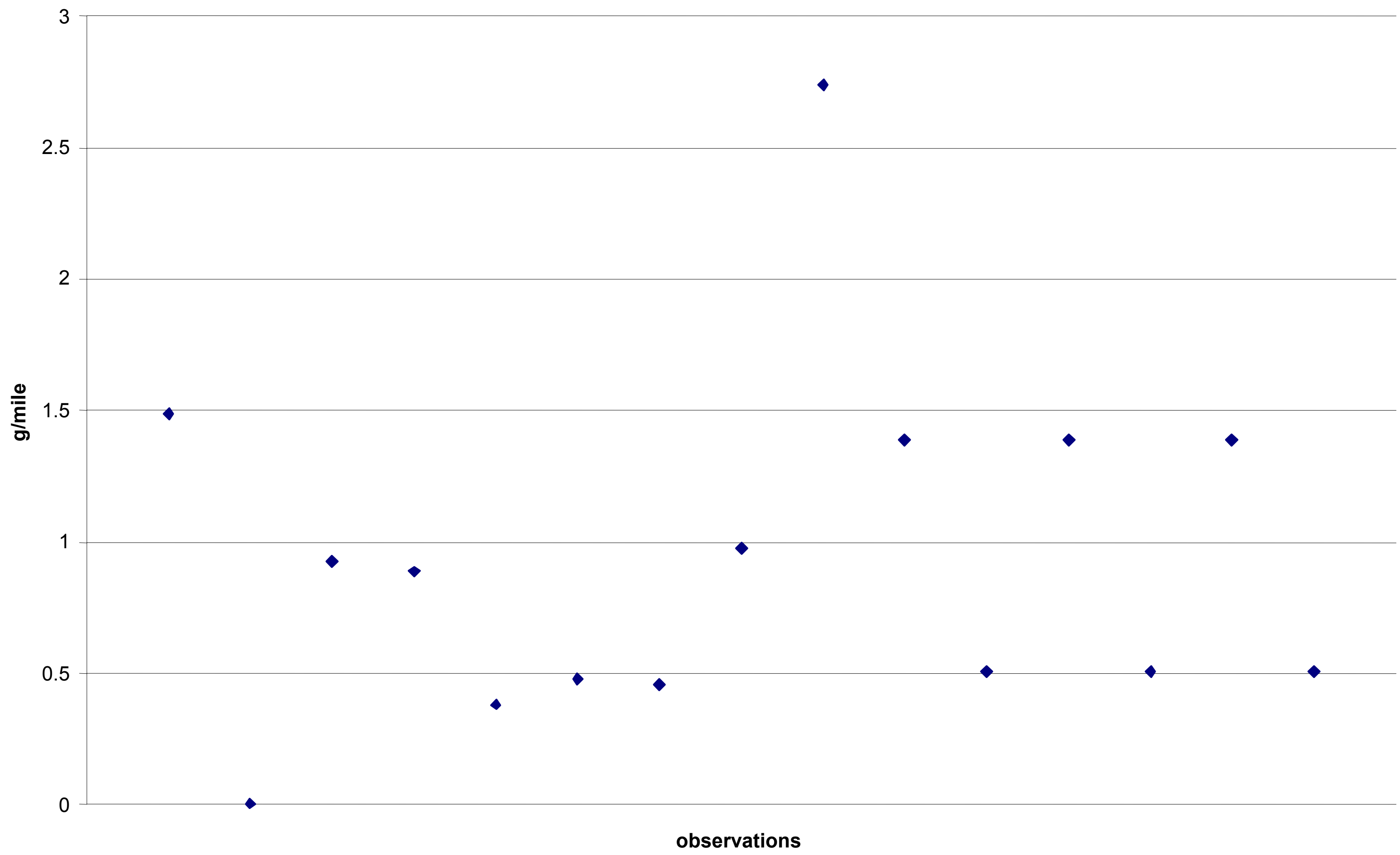


Figure B-6. HHDT THC 1990-1993

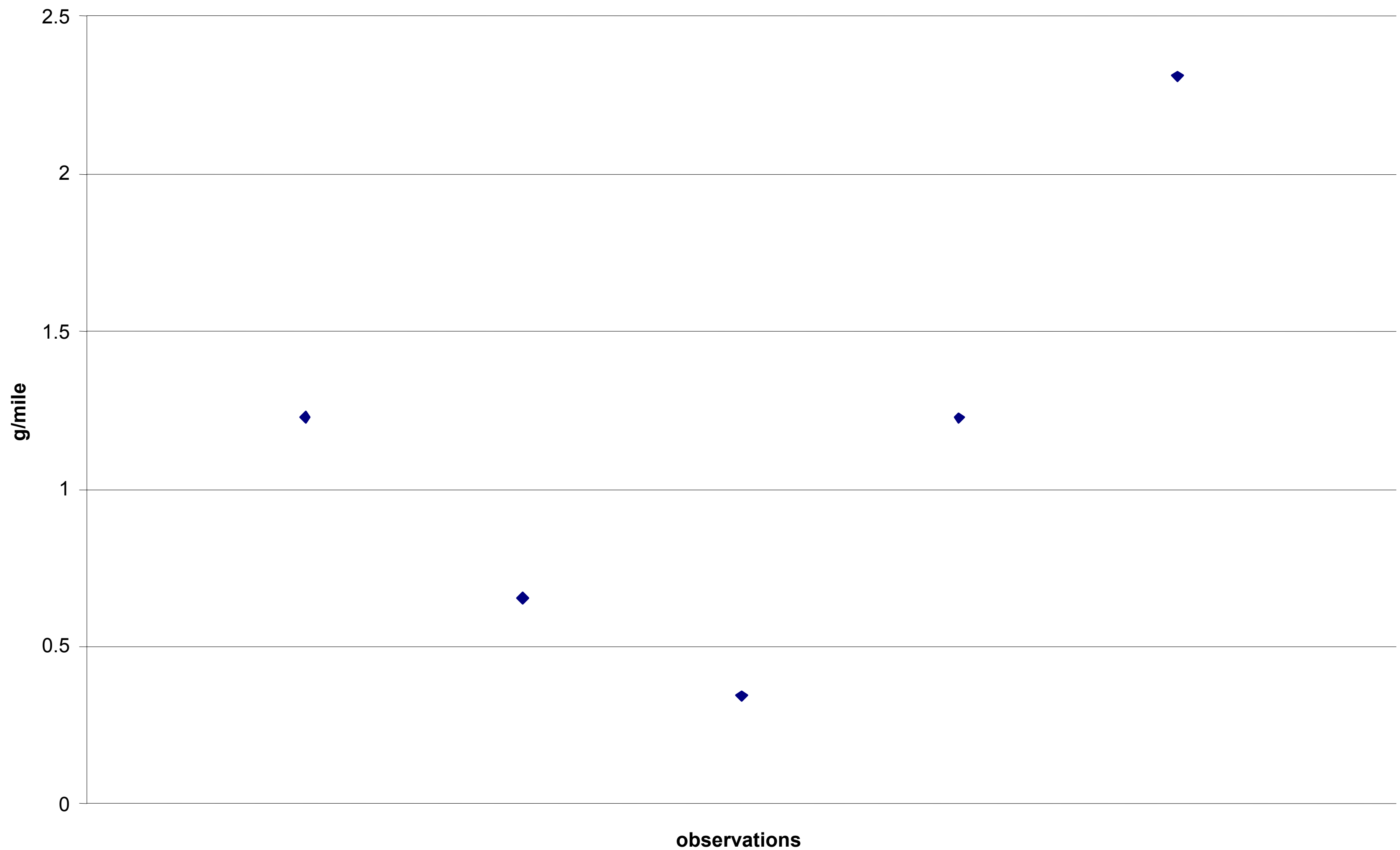


Figure B-7. HHDT THC post1993

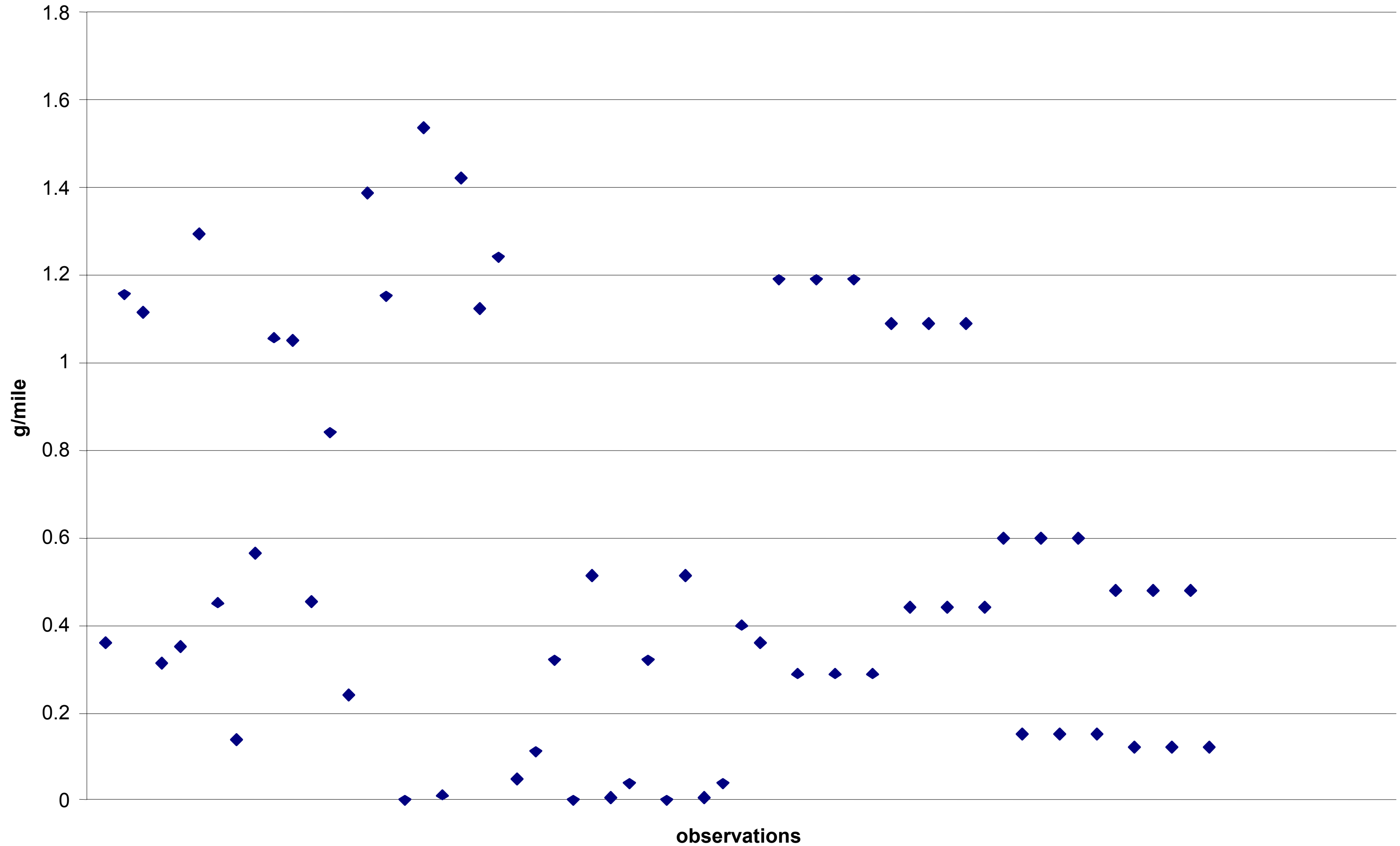


Figure B-8. HHDT NOx pre1990

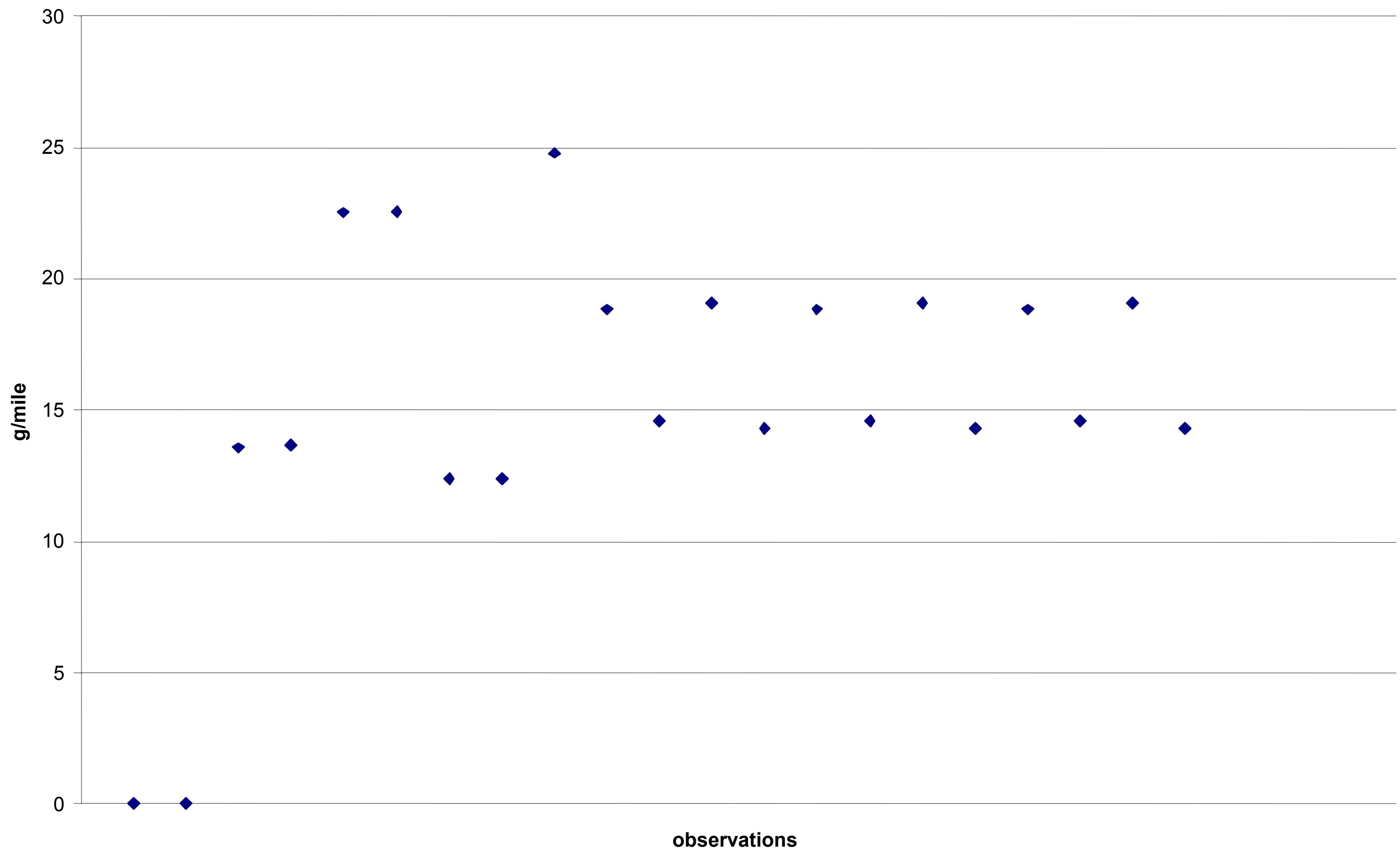
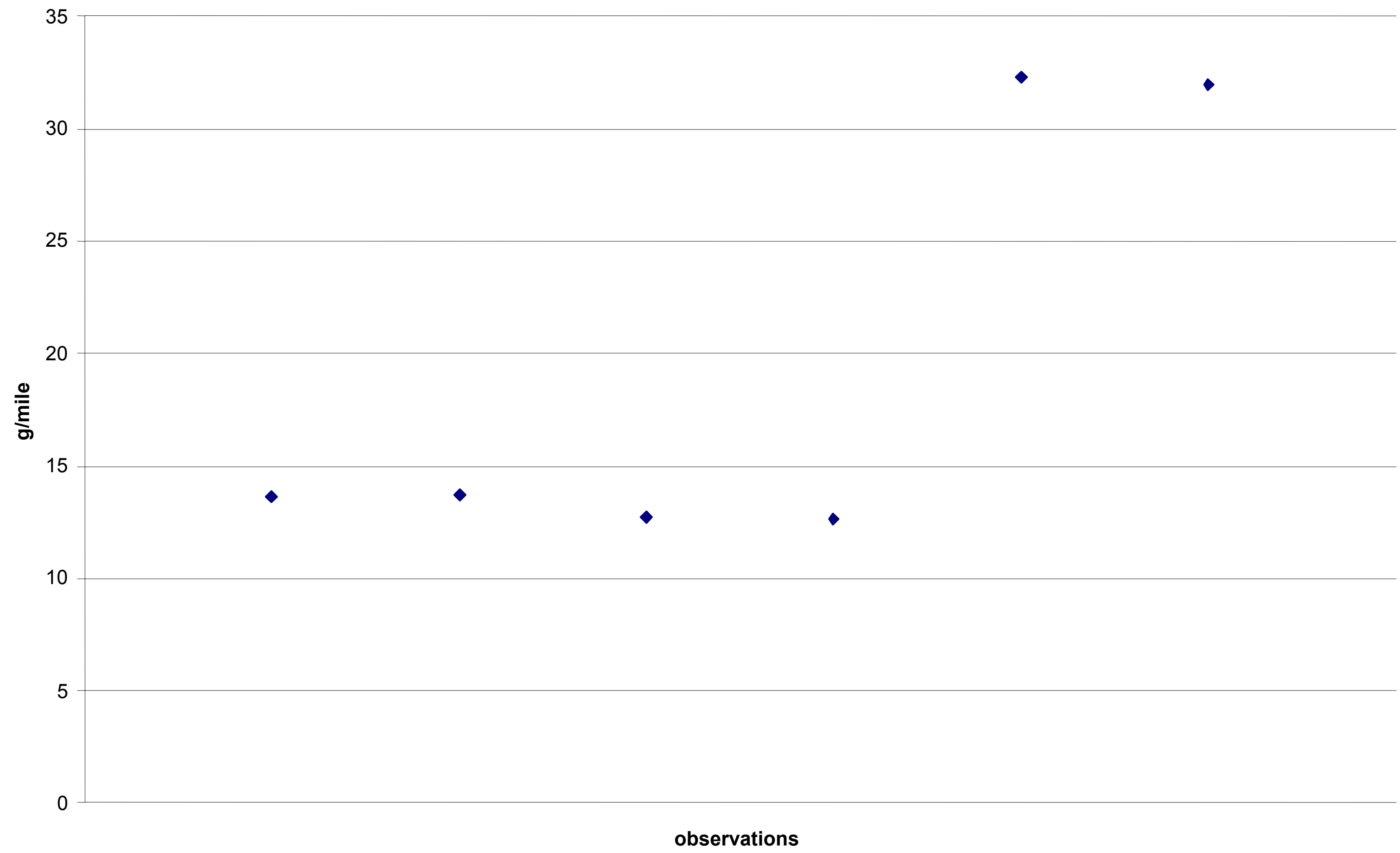


Figure B-9. HHDT NOx 1990-1993



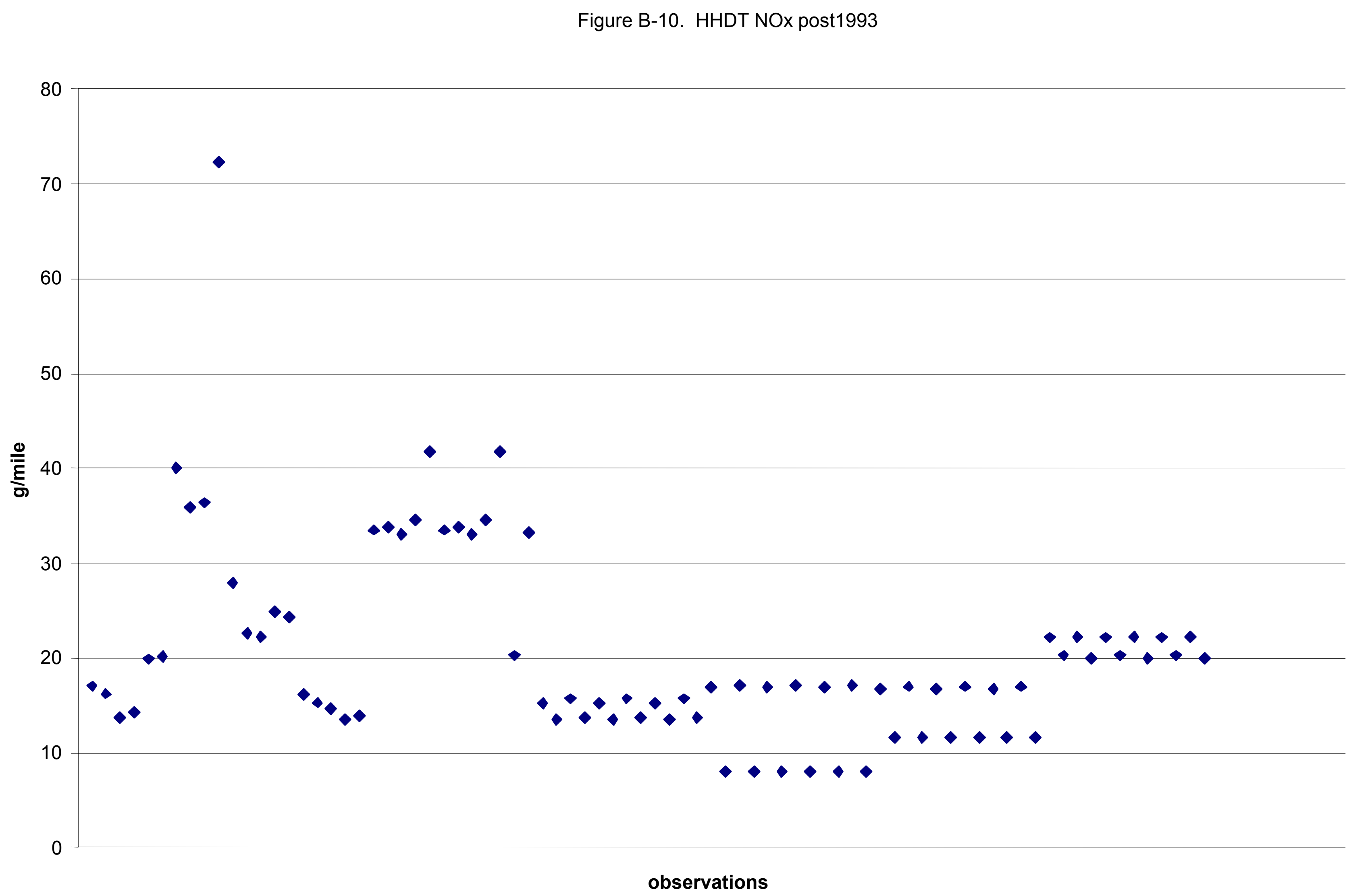


Figure B-10. HHDT NOx post1993
80
70
60
50
40
30
20
10
0
g/mile
observations

Figure B-11. LDV CO pre1990

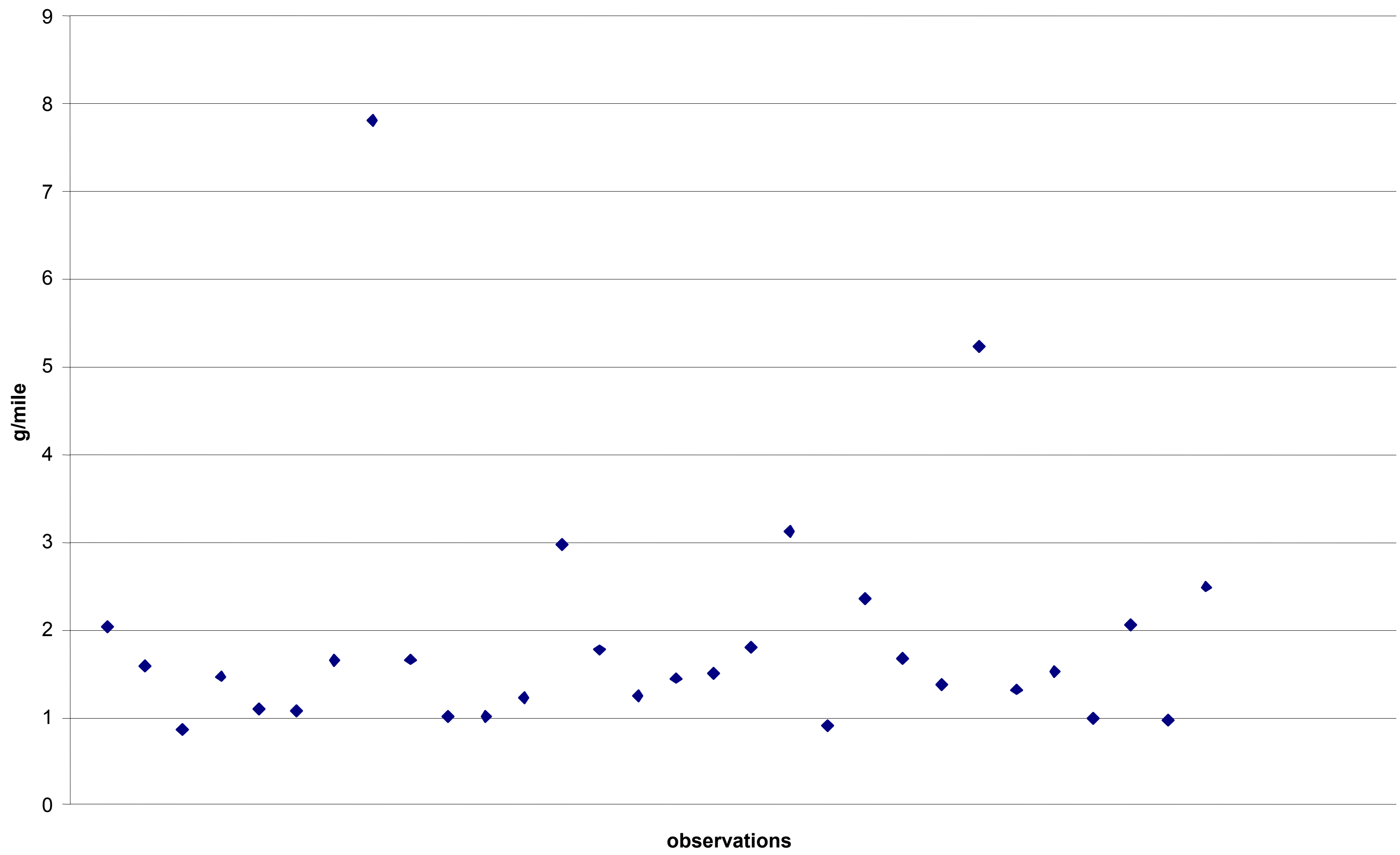


Figure B-12. LDV CO 1990-1993

Figure B-13. LDV CO post1993

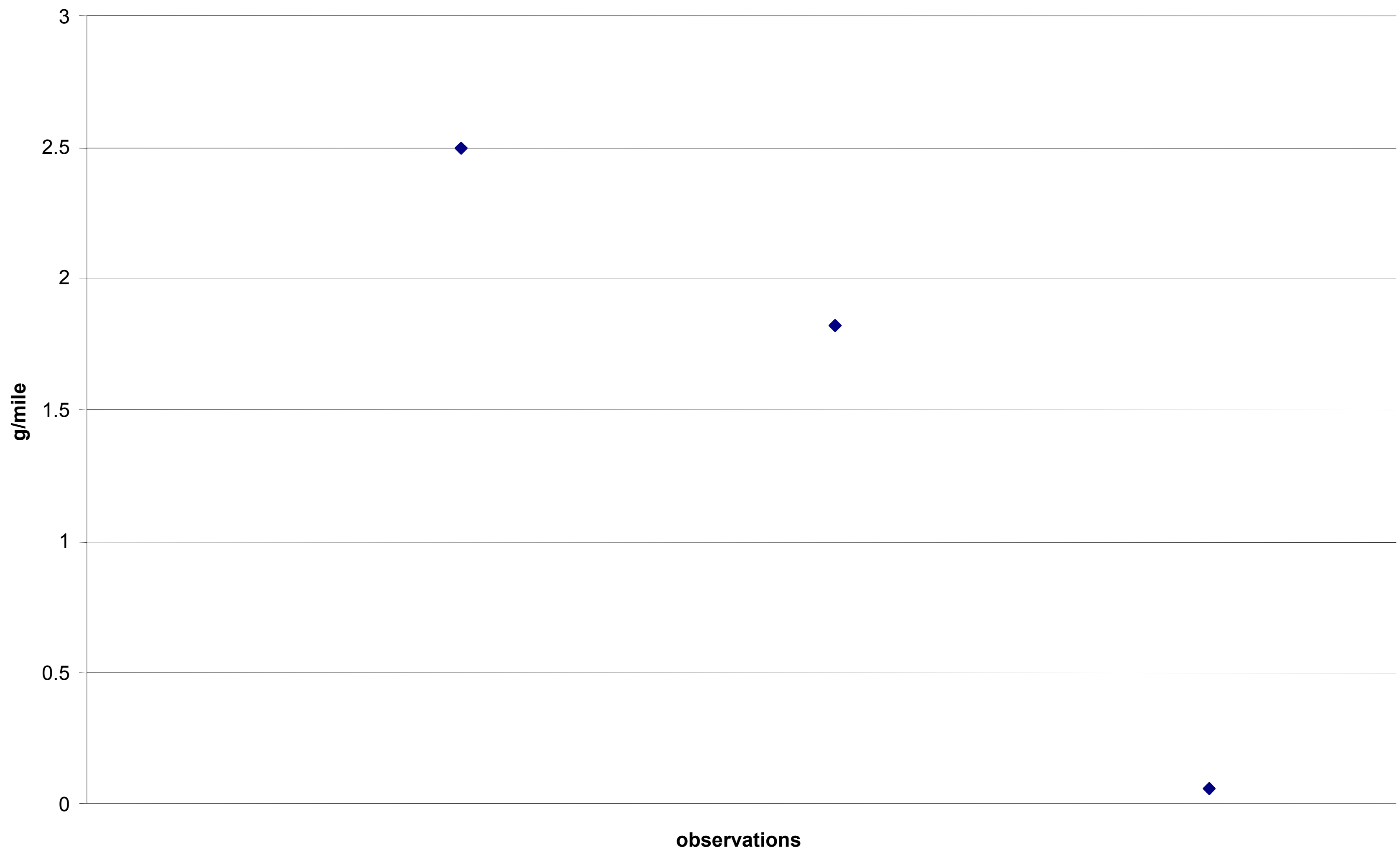


Figure B-14. LDV PM10 pre1990

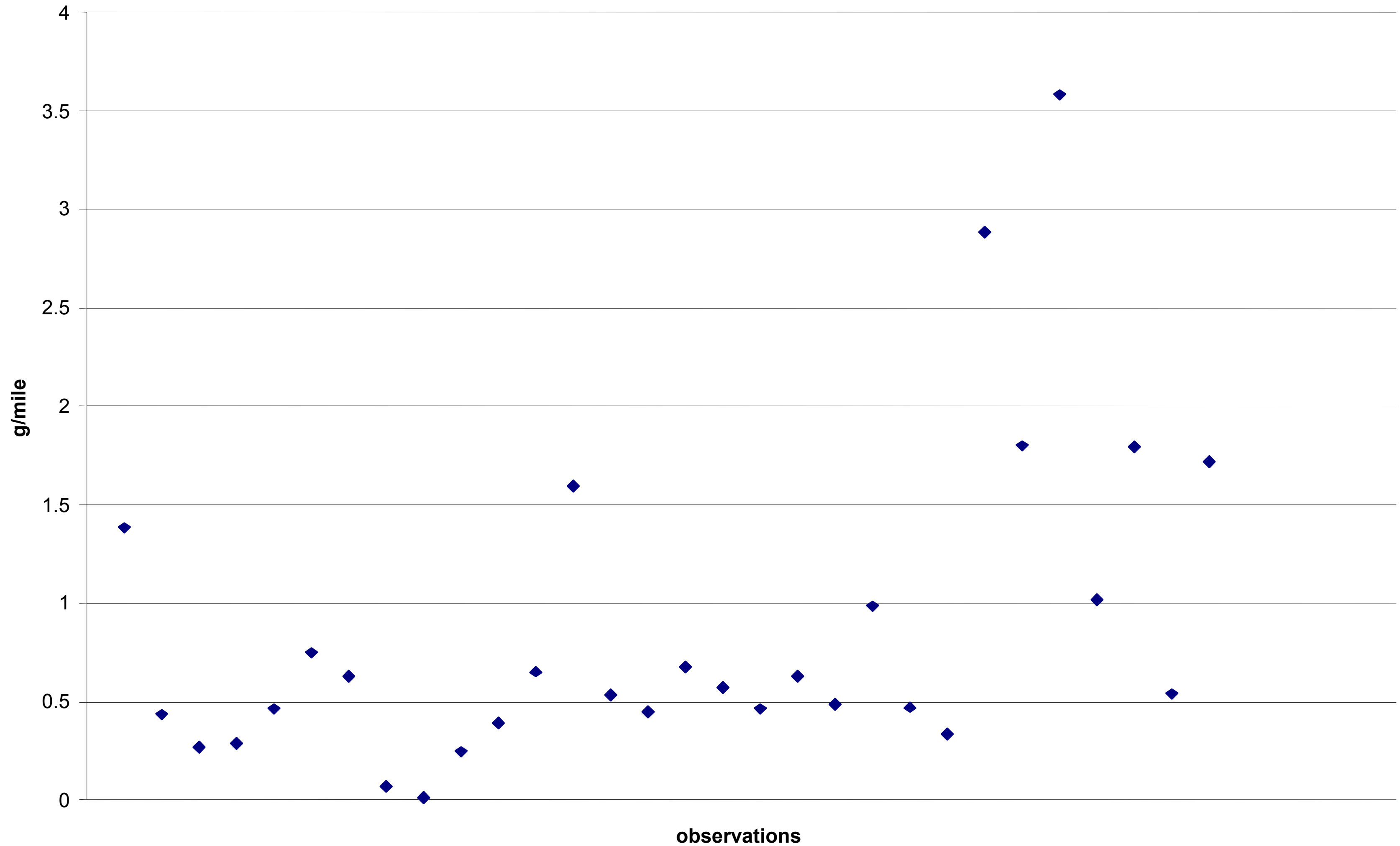


Figure B-15. LDV PM10 1990-1993

Figure B-16. LDV PM10 post1993

Figure B-17. LDV THC pre1990

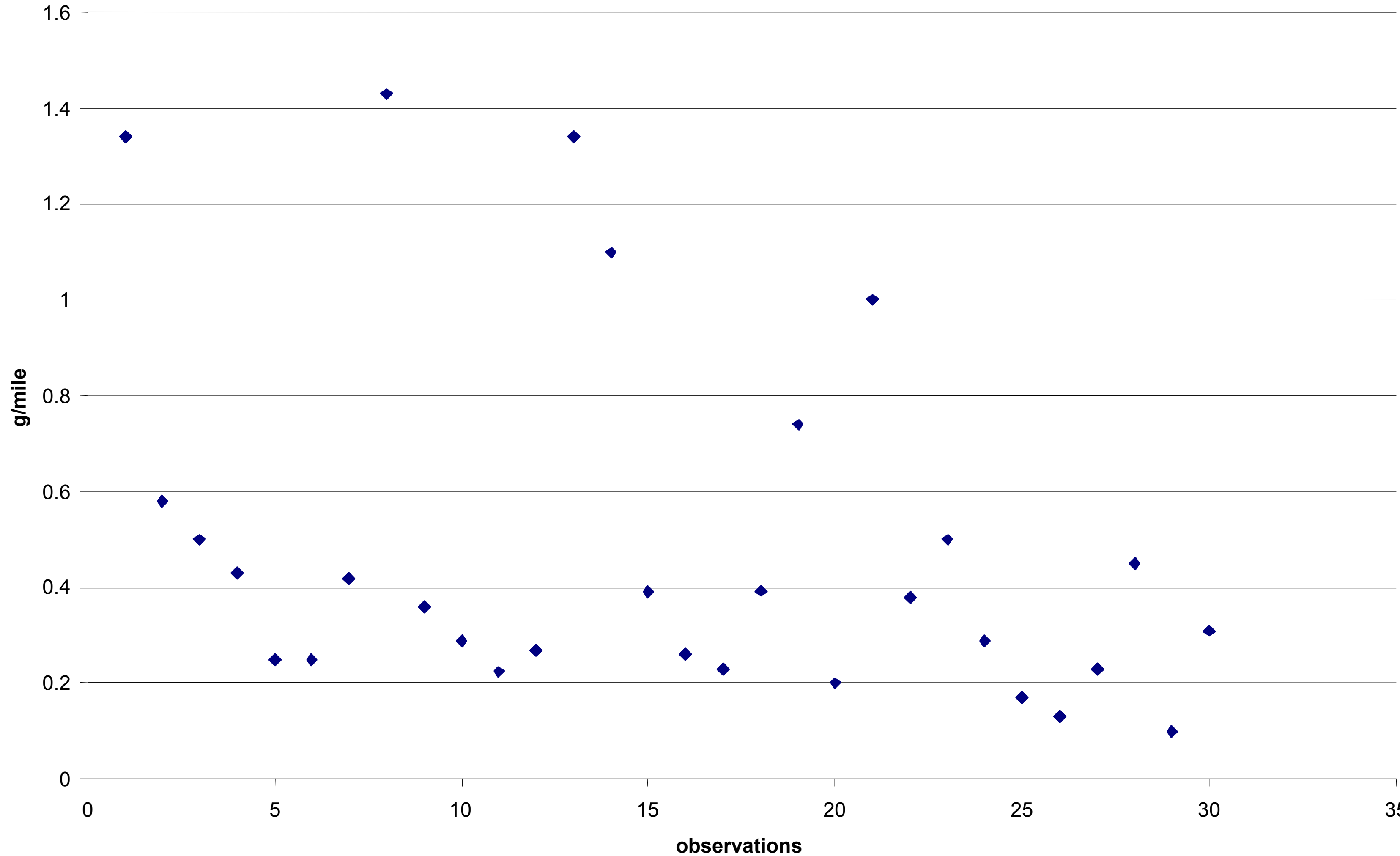


Figure B-18. LDV THC 1990-1993

Figure B-19. LDV THC post1993

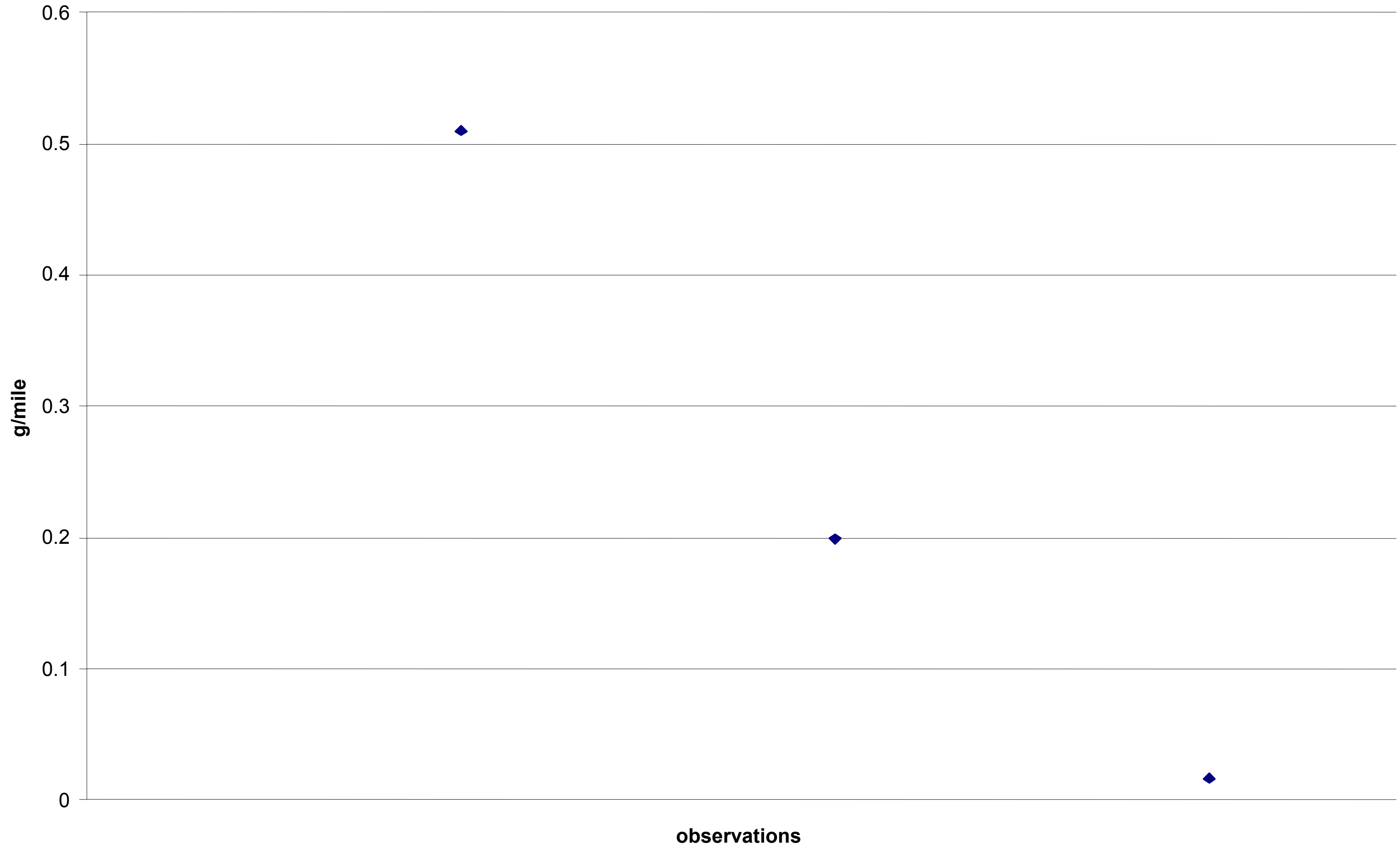


Figure B-20. LDV NOx pre1990

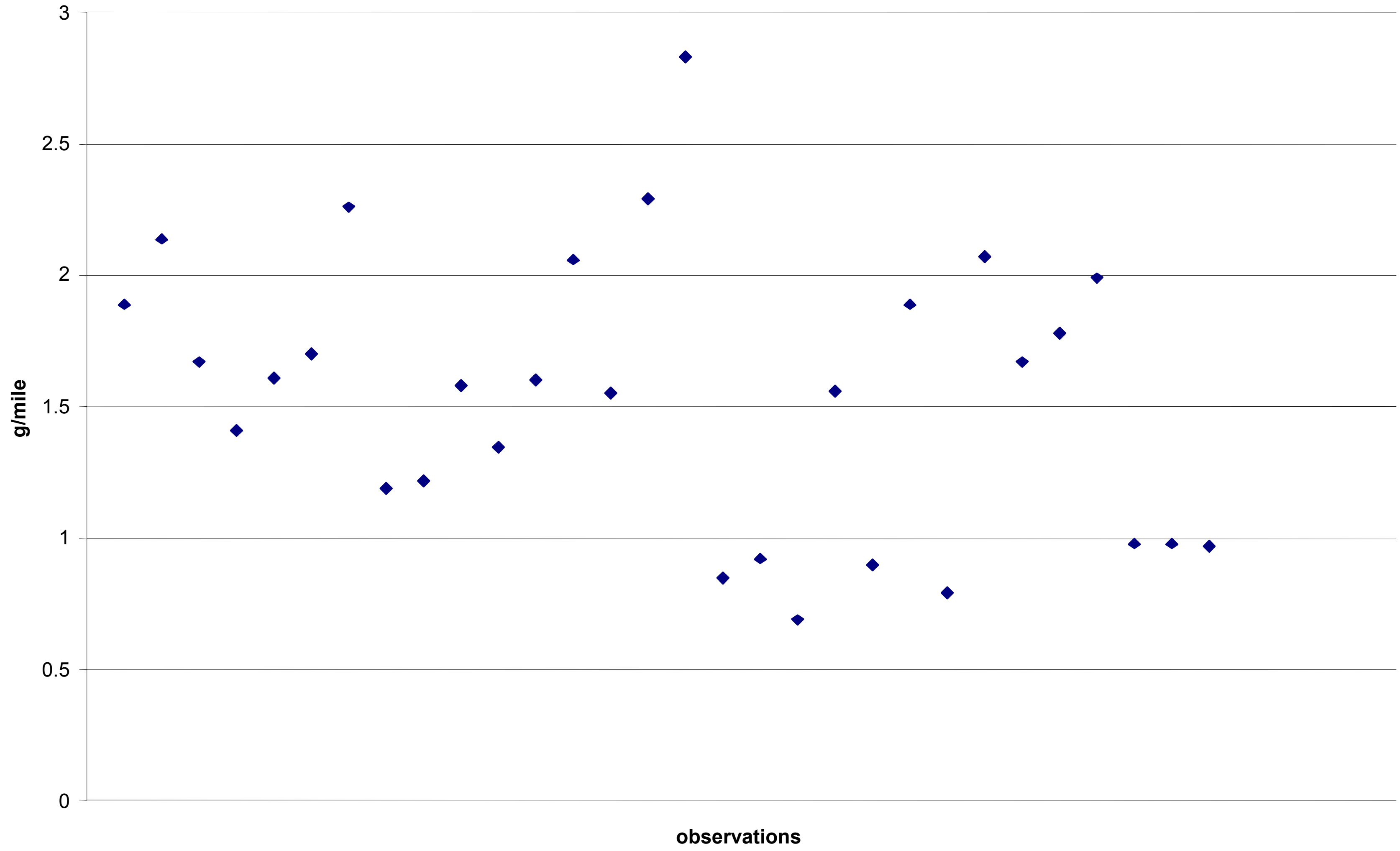
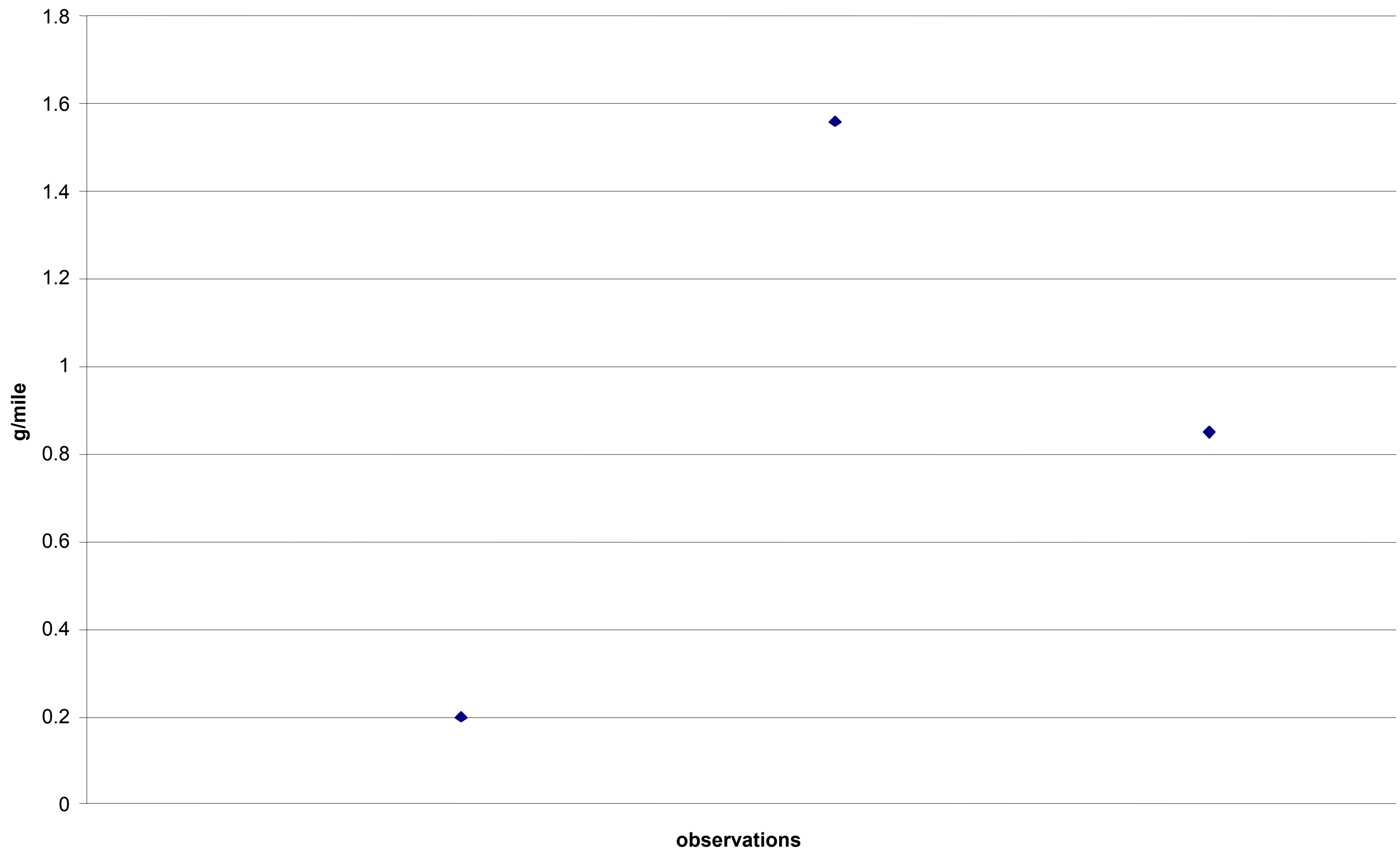


Figure B-21. LDV NOx 1990-1993

Figure B-22. LDV NOx post1993



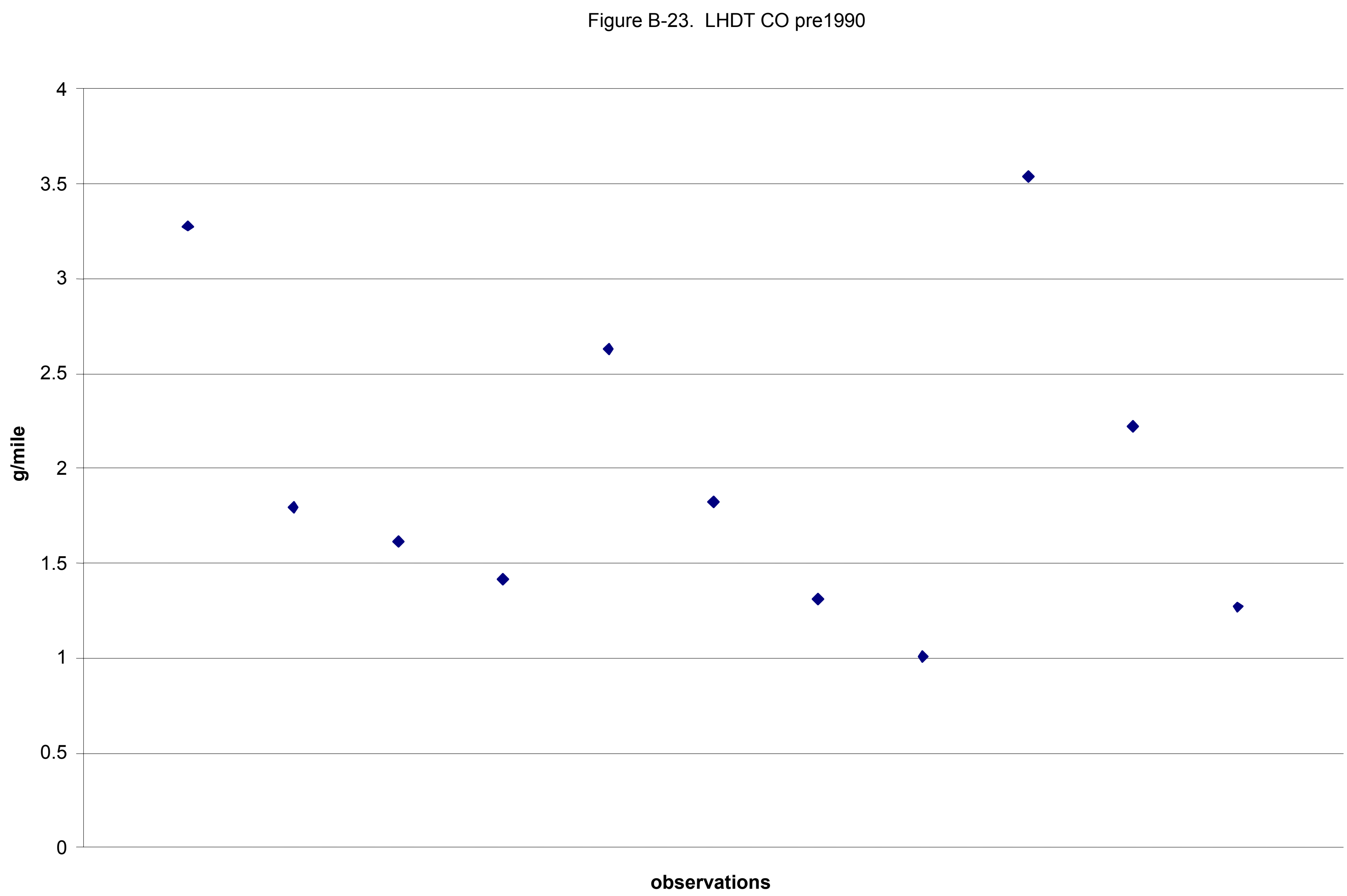


Figure B-23. LHDT CO pre1990
4
3.5
3
2.5
2
1.5
1
0.5
0
g/mile
observations

Figure B-24. LHDT CO 1990-1993

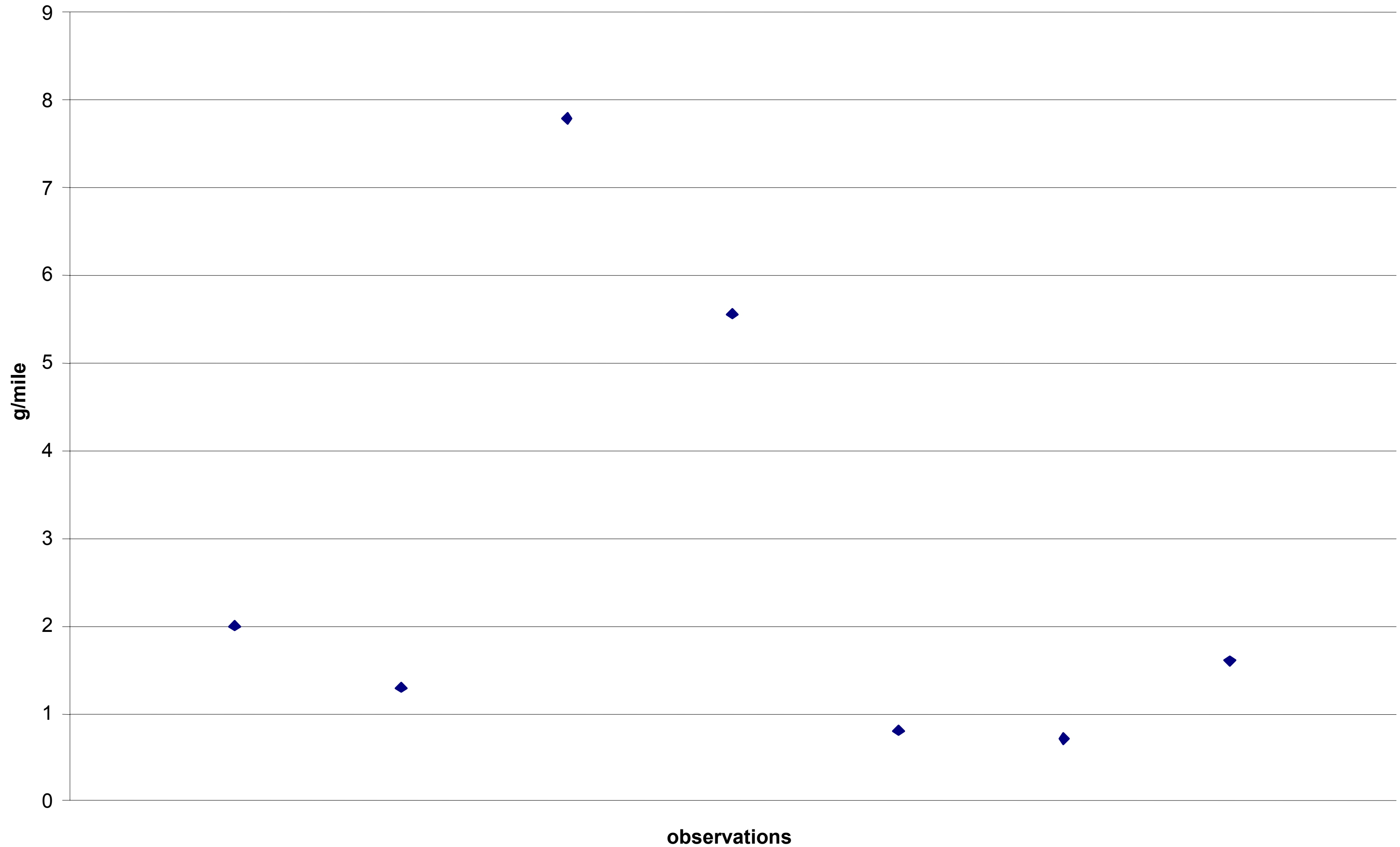


Figure B-25. LHDT CO post1993

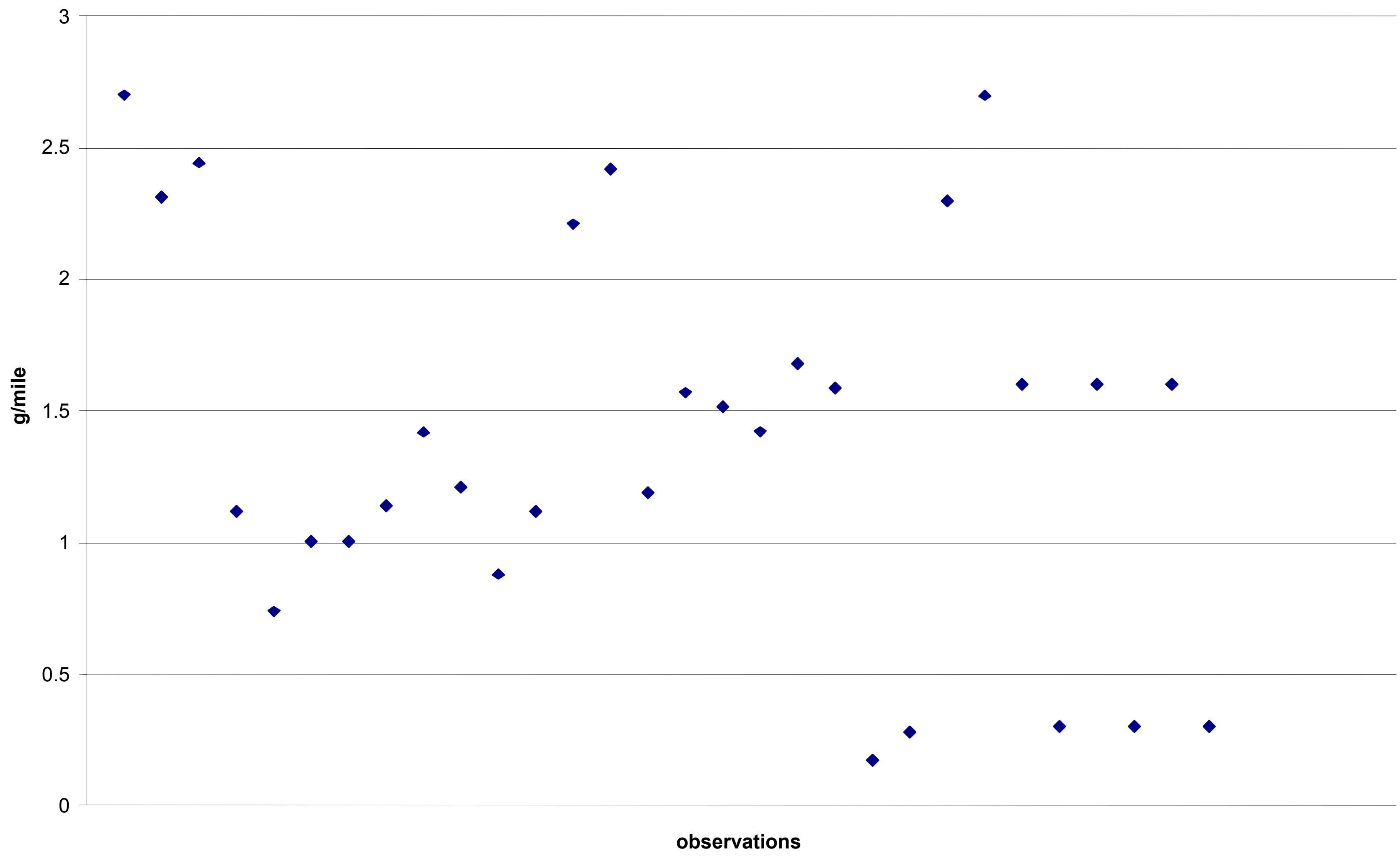


Figure B-26. LHDT THC pre1990

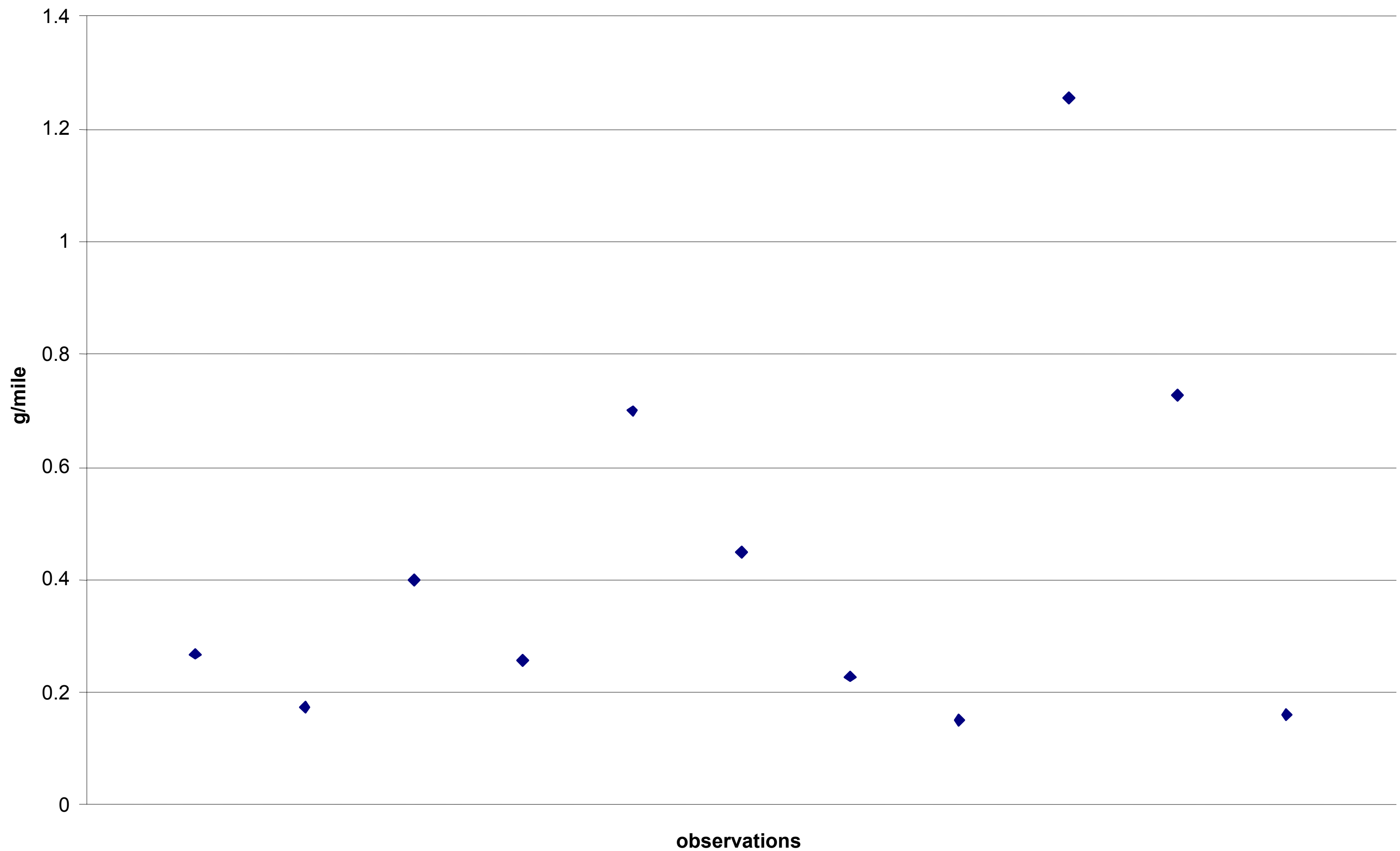


Figure B-27. LHDT THC 1990-1993

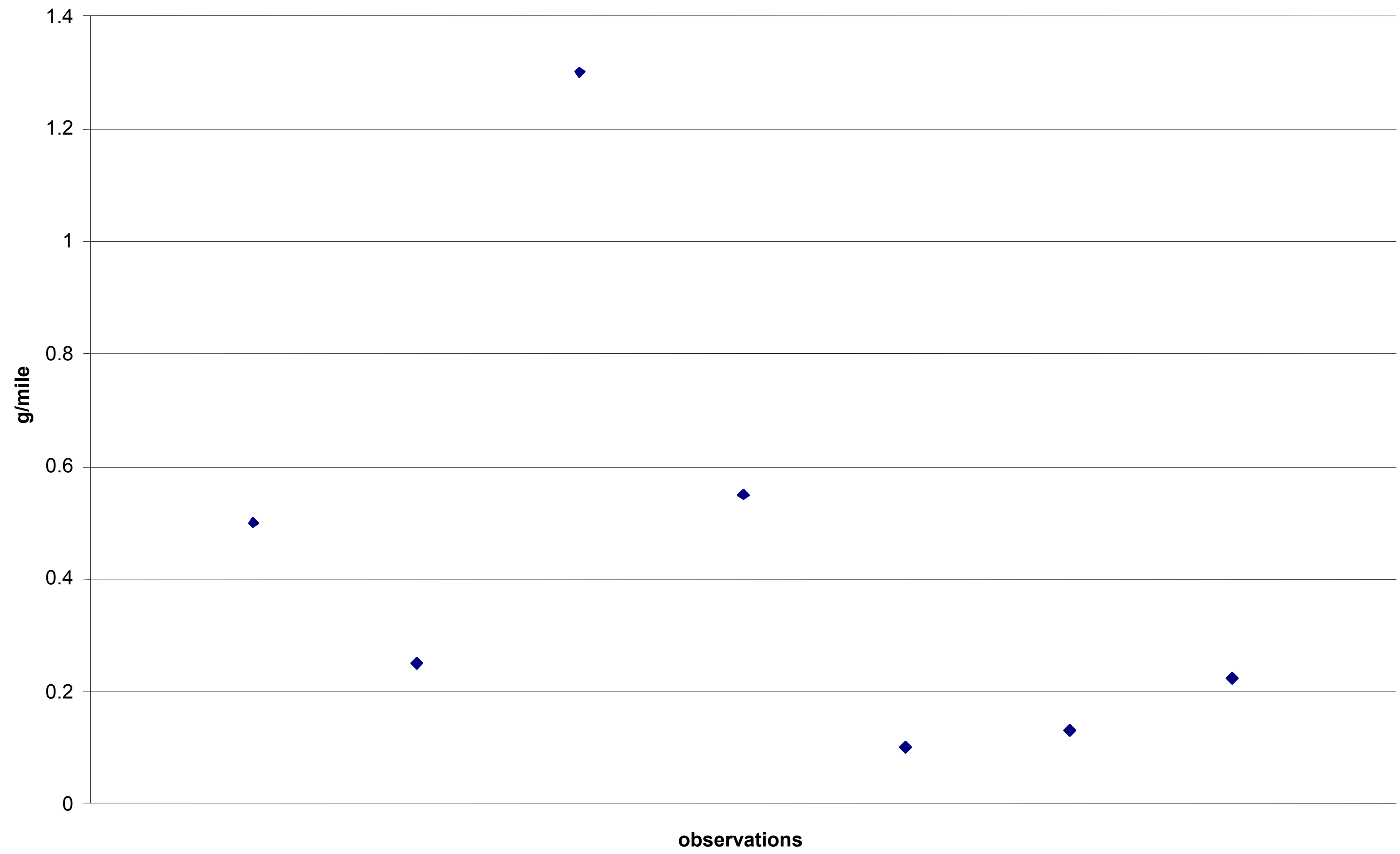


Figure B-28. LHDT THC post1993

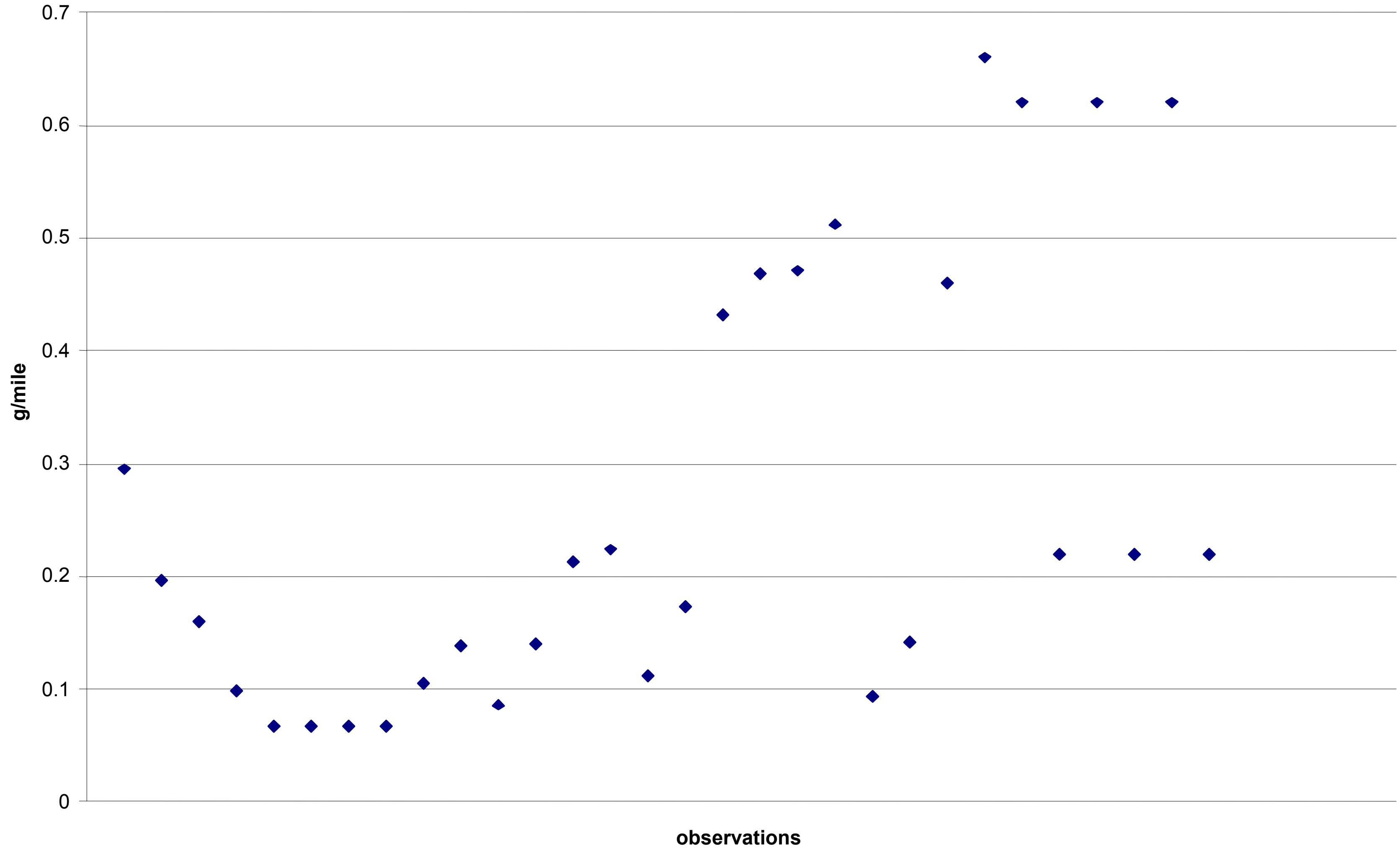


Figure B-29. LHDT NOx pre1990

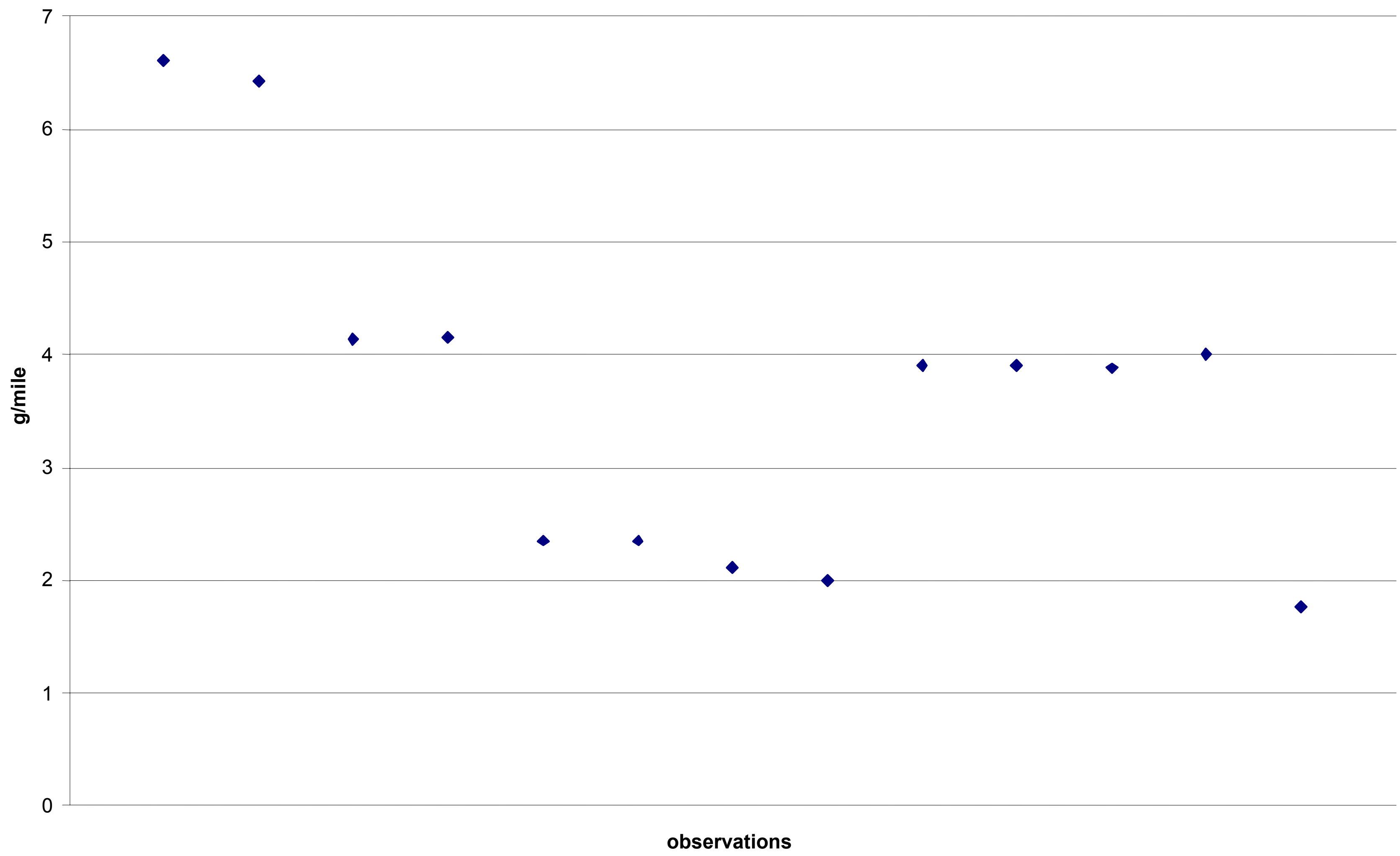


Figure B-30. LHDT NOx 1990-1993

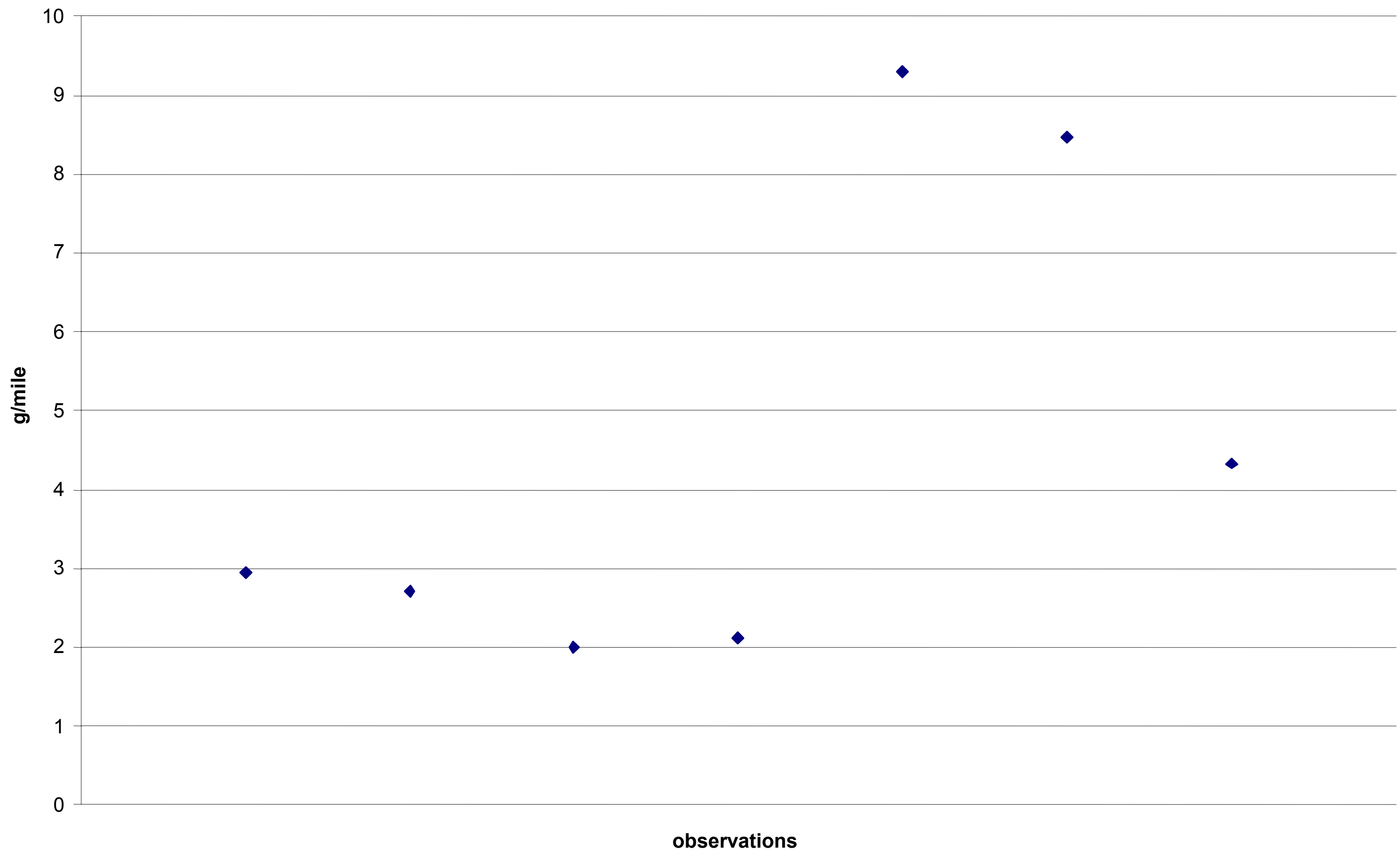


Figure B-31. LHDT NOx post1993

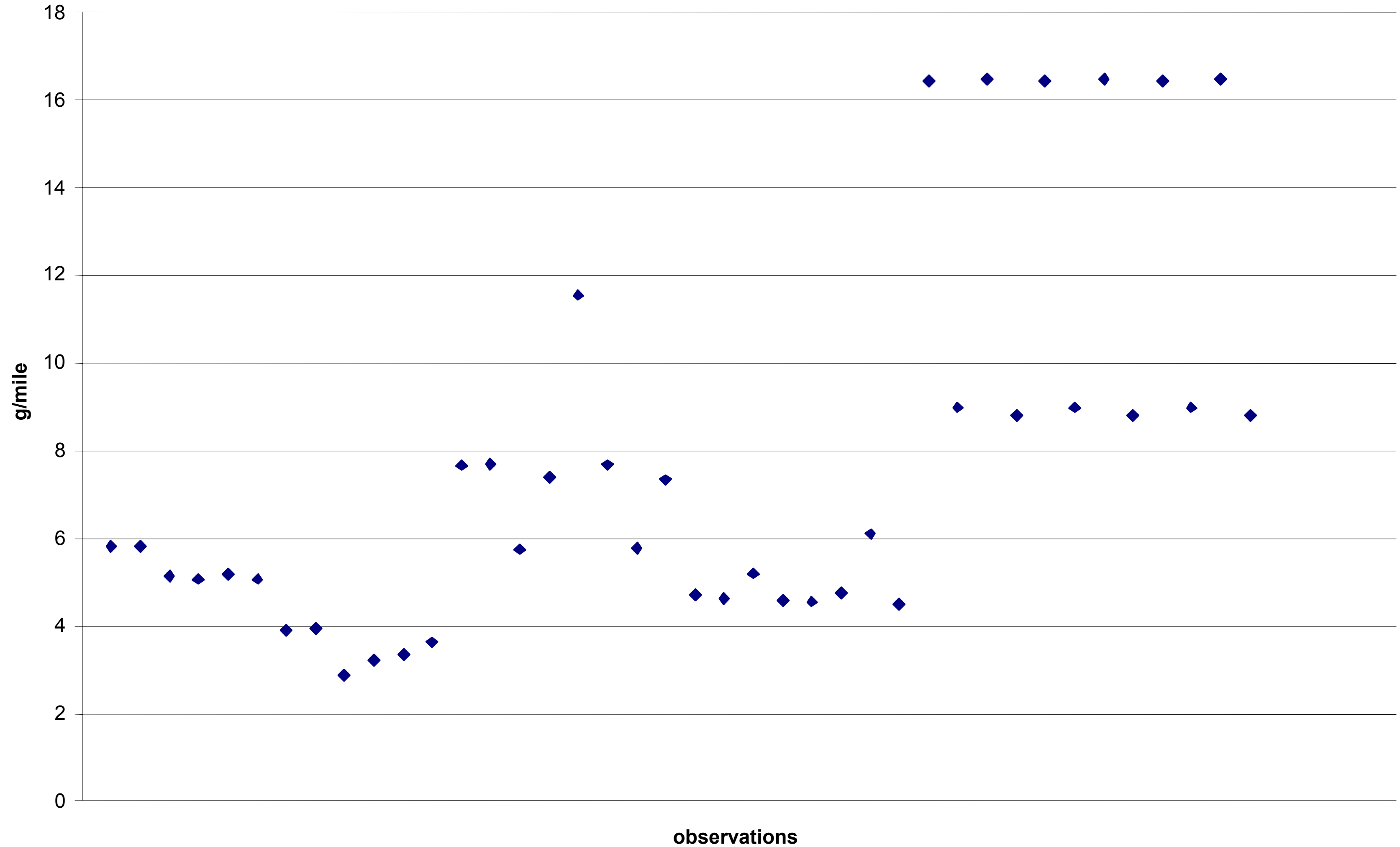


Figure B-32. MHDT CO pre1990

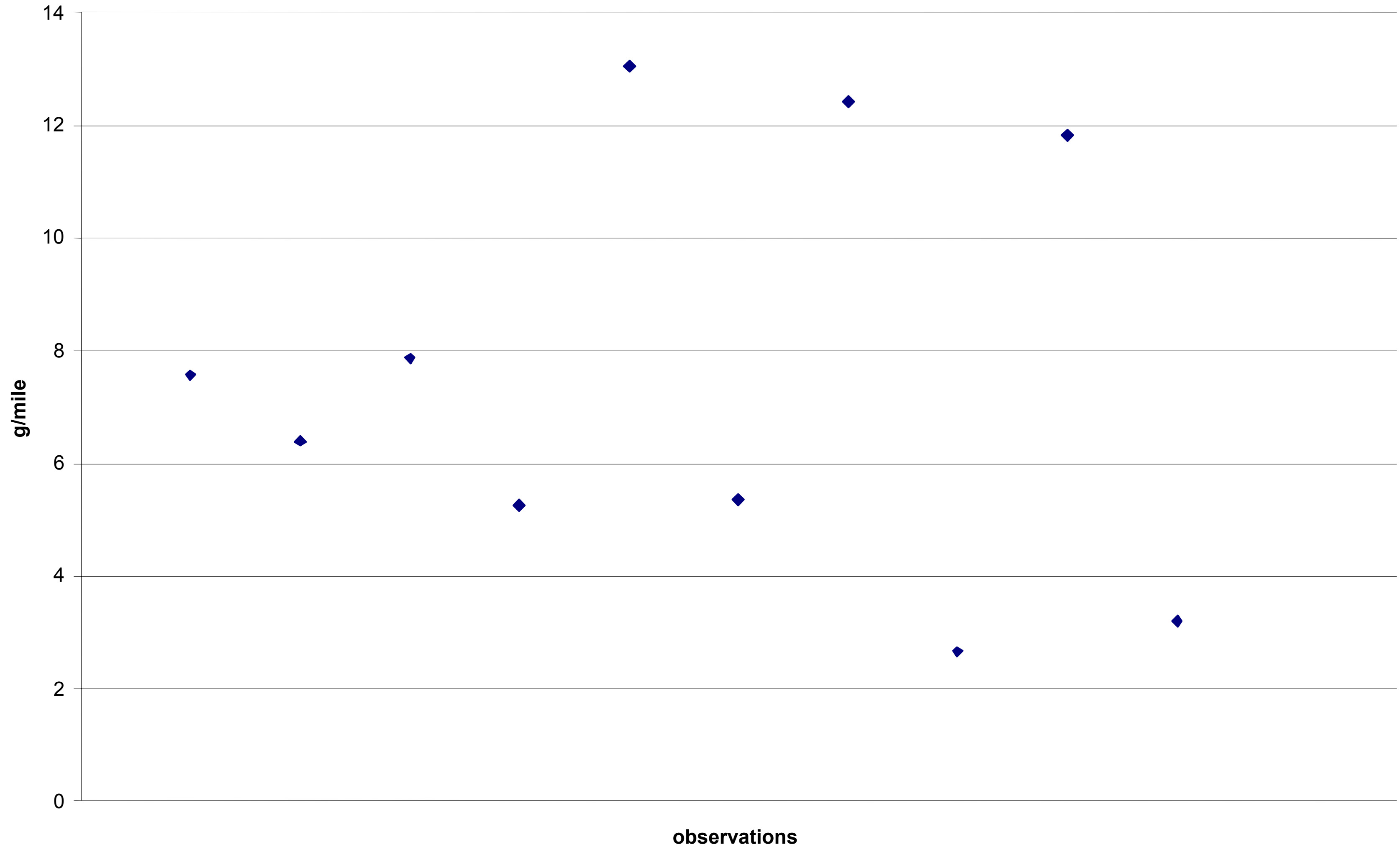


Figure B-33. MHDT CO post1993

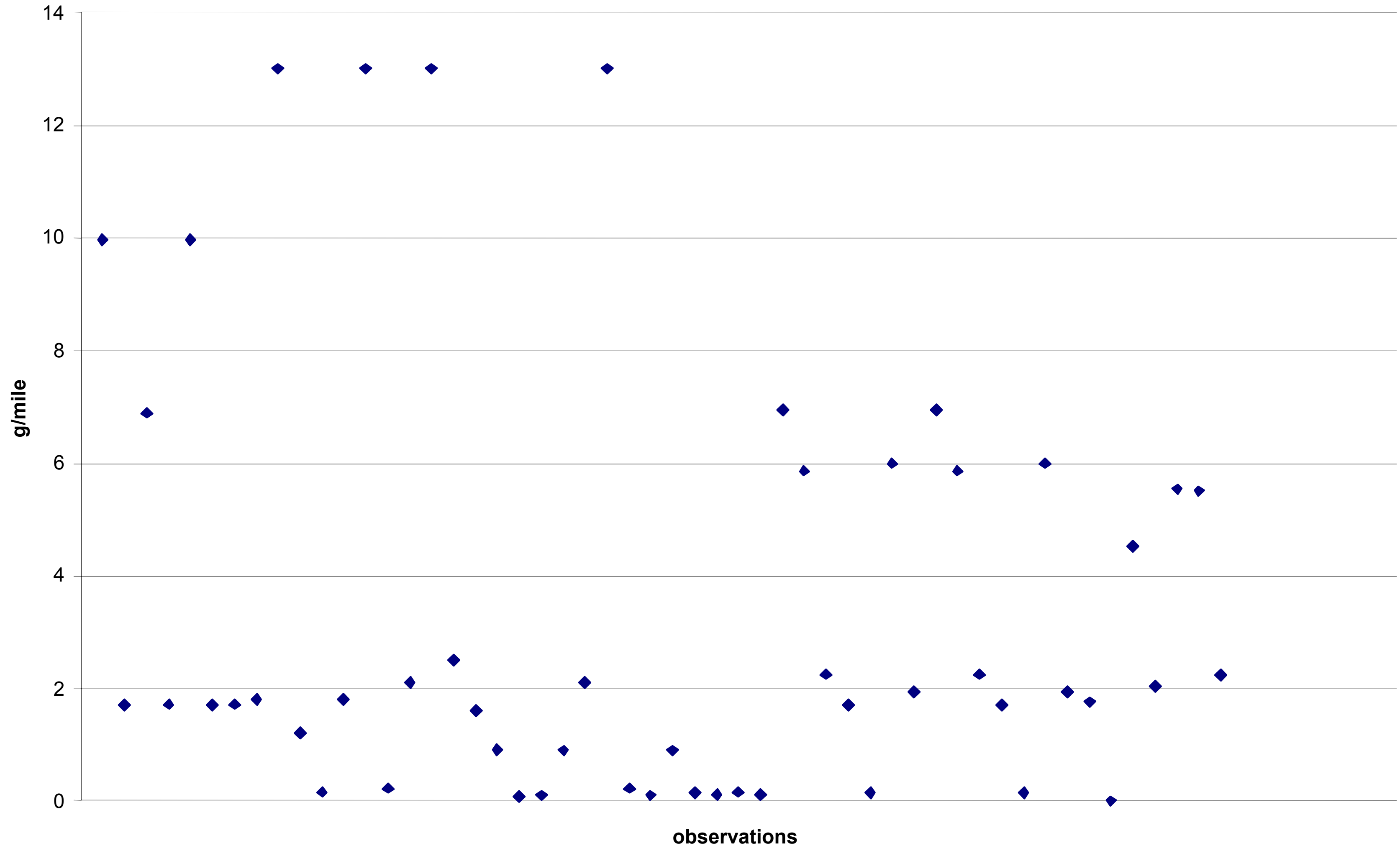


Figure B-34. MHDT PM10 post1993

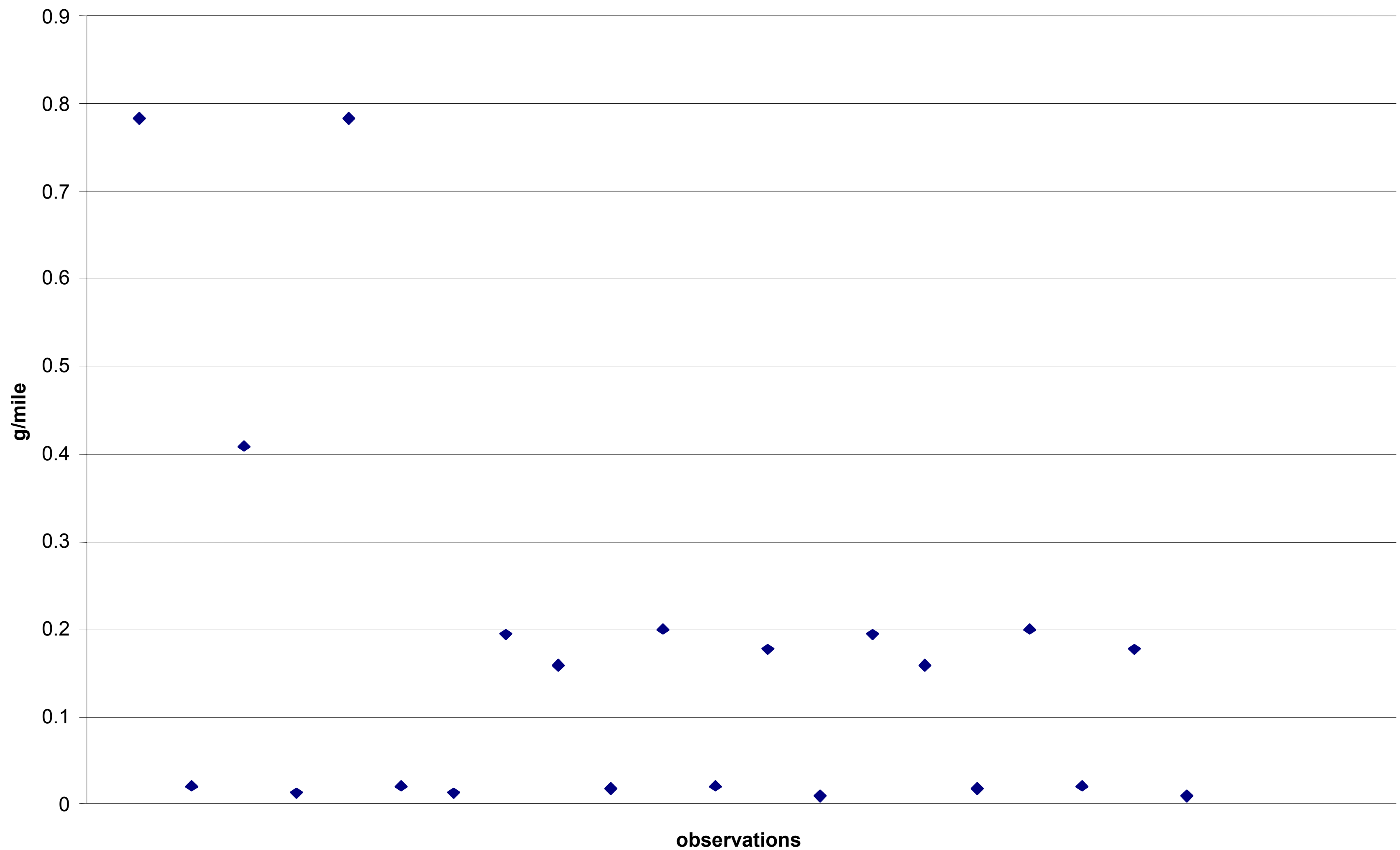


Figure B-35. MHDT THC pre1990

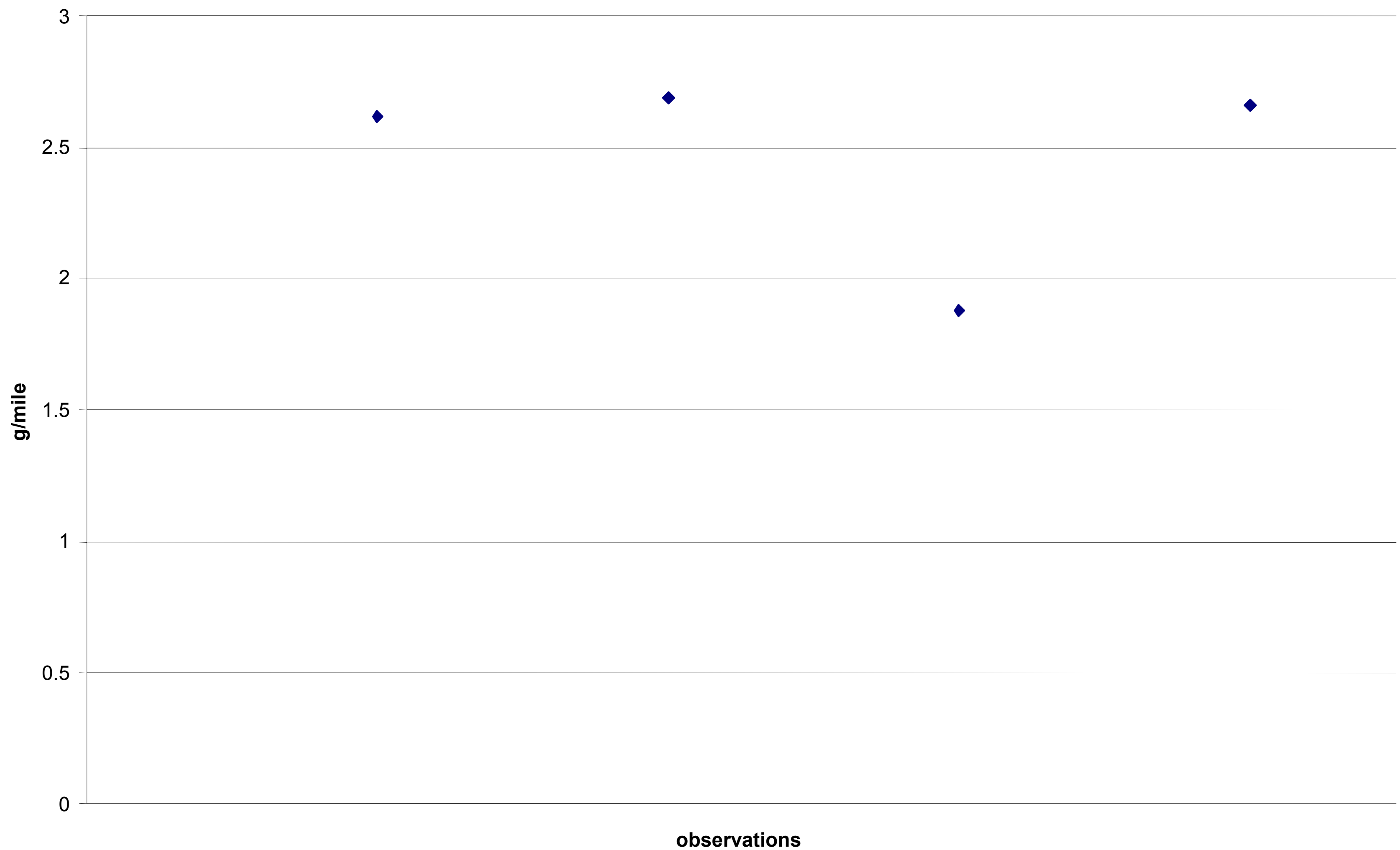


Figure B-36. MHDT THC post1993

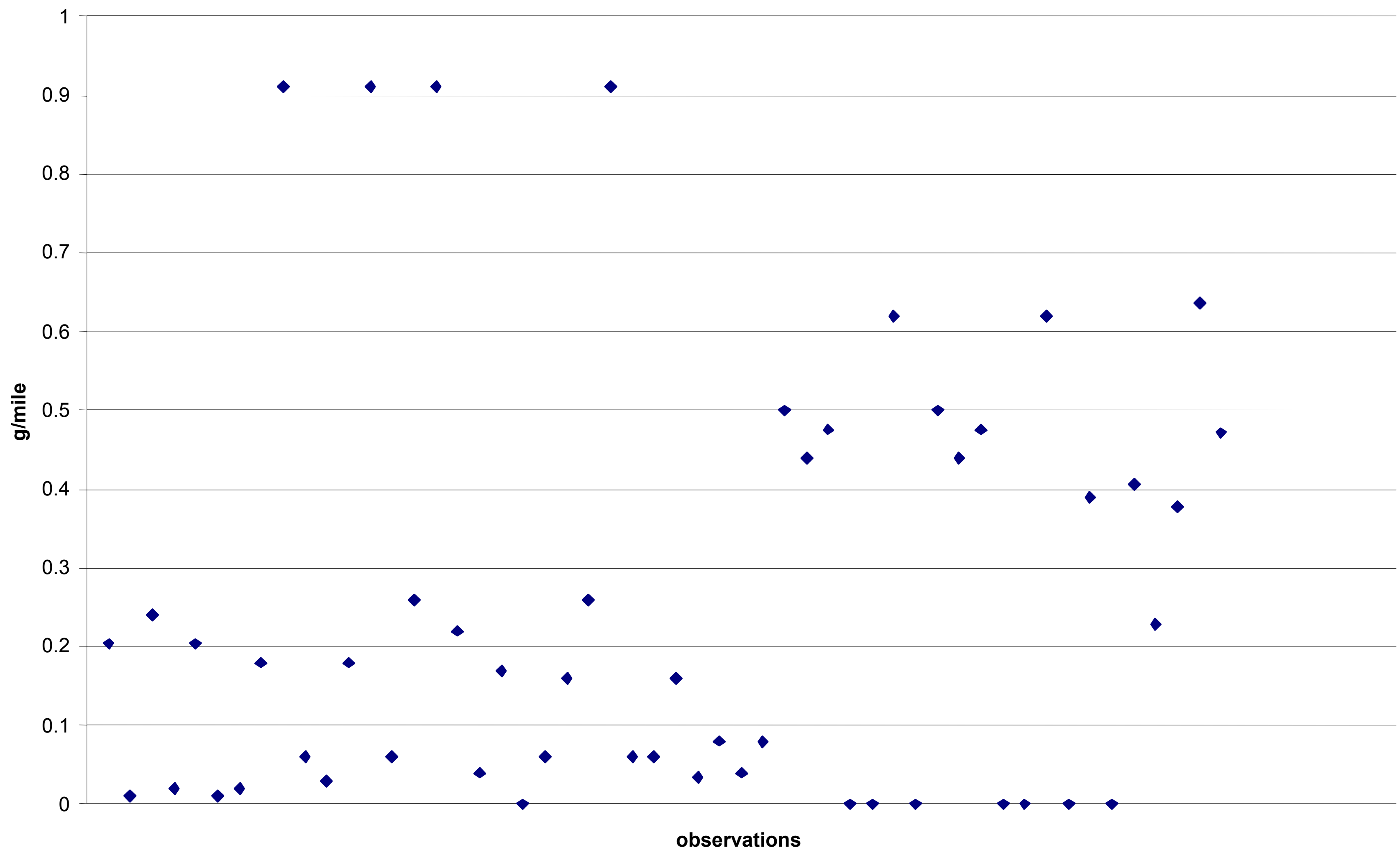


Figure B-37. MHDT NOx pre1990

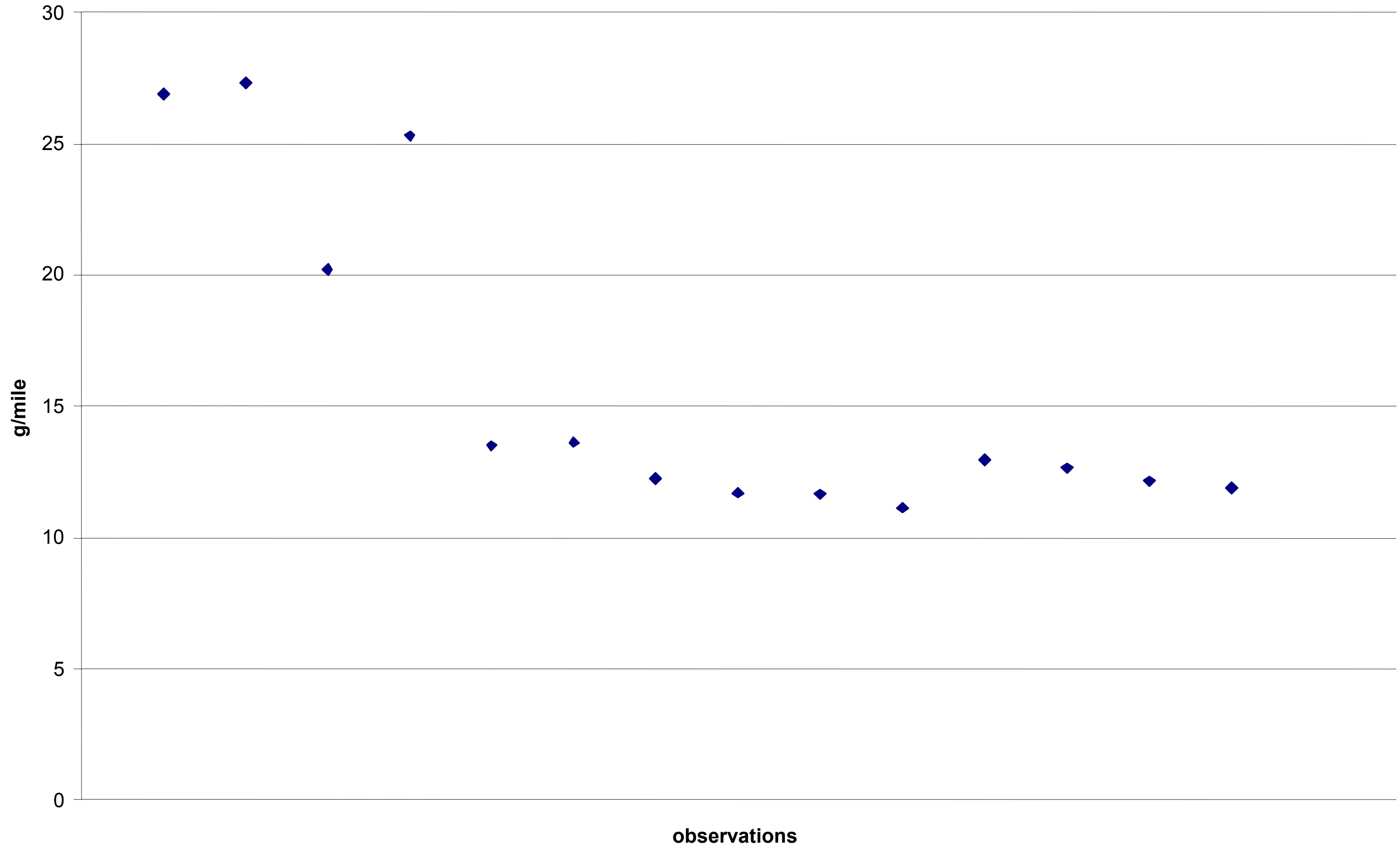


Figure B-38. MHDT NOx post1993

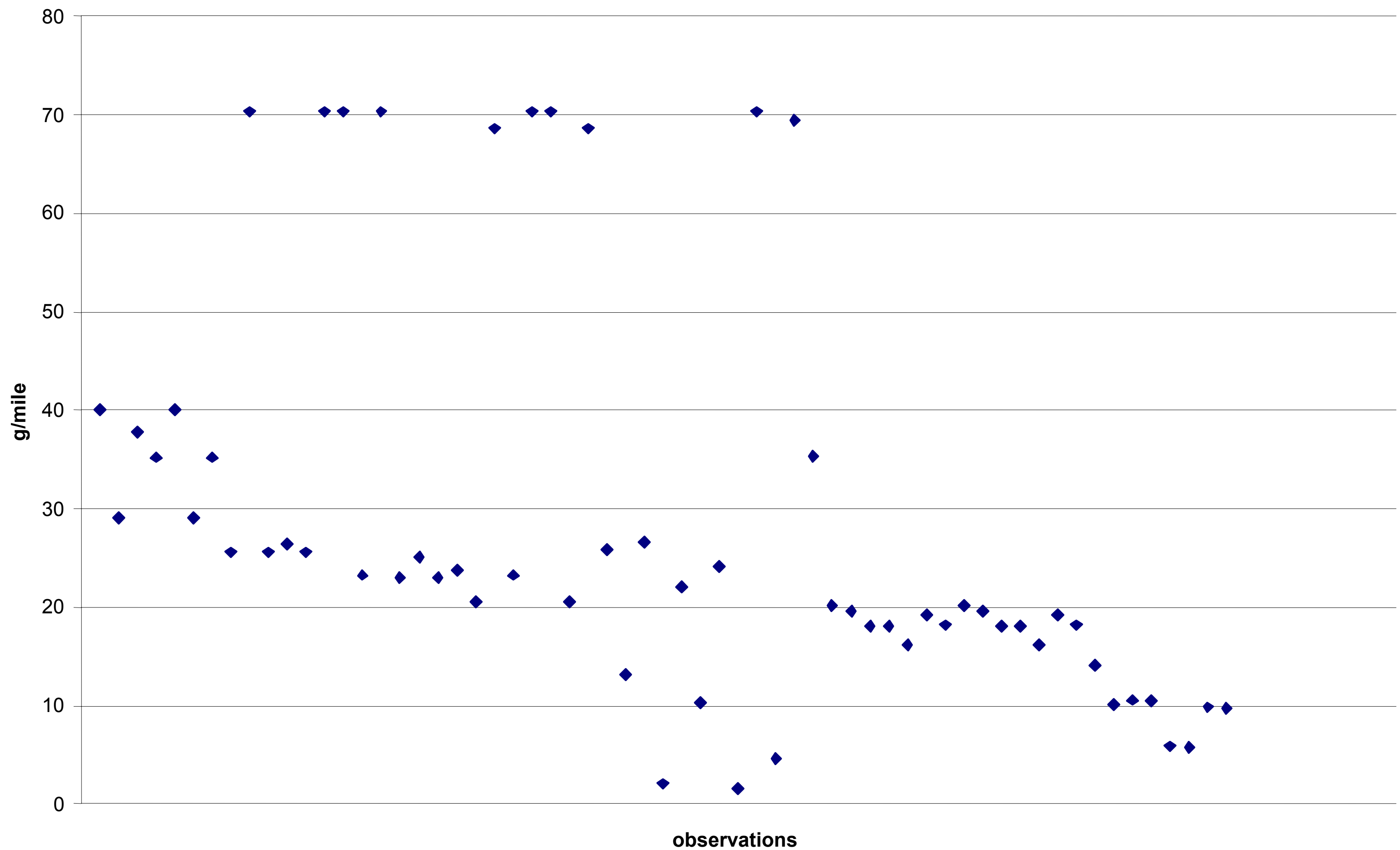


Figure B-39. SHDT CO post1993

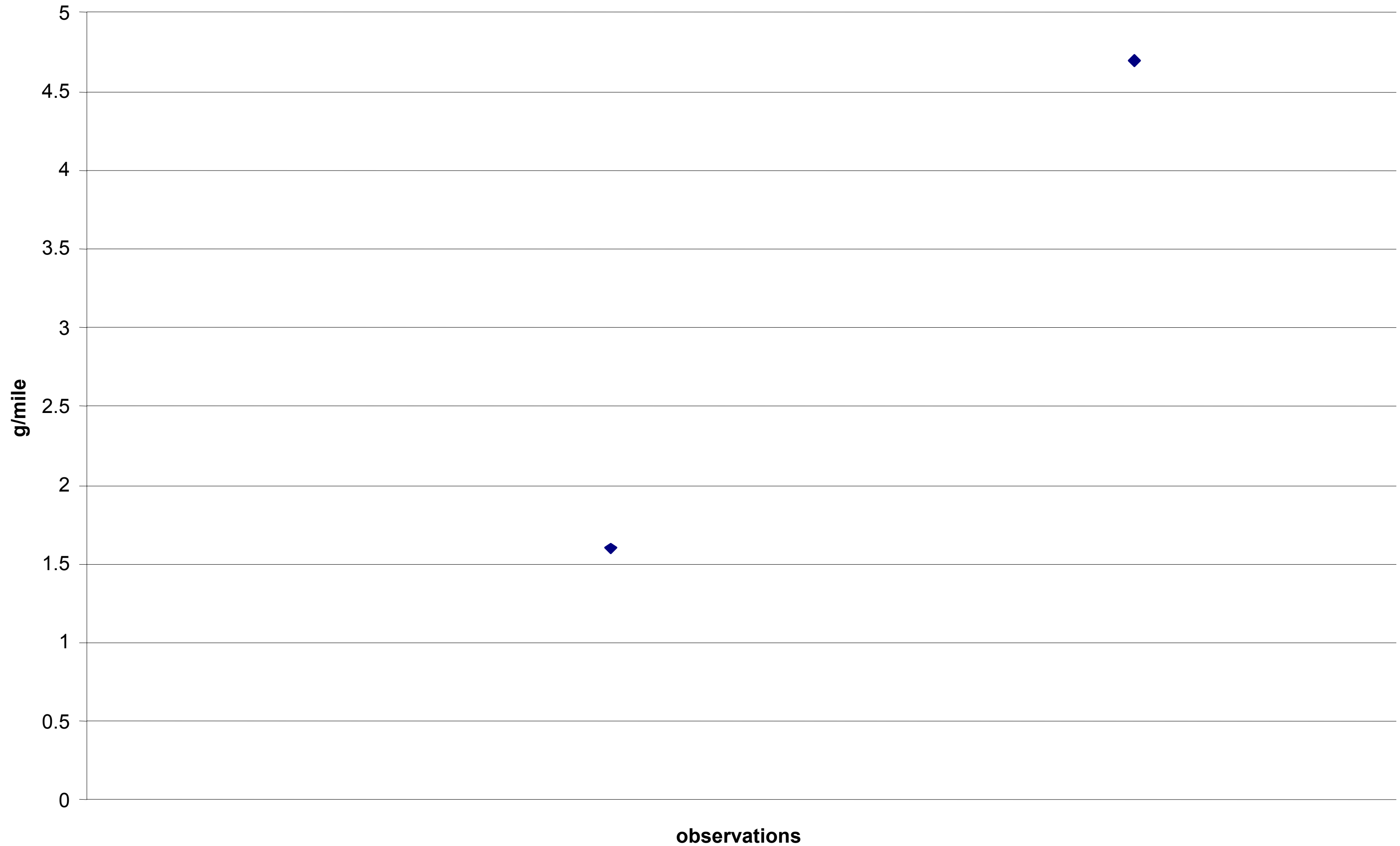


Figure B-40. SHDT THC post1993

Figure B-41. SHDT NOx post1993

Figure B-42. HHDT PM2.5 Post-1993

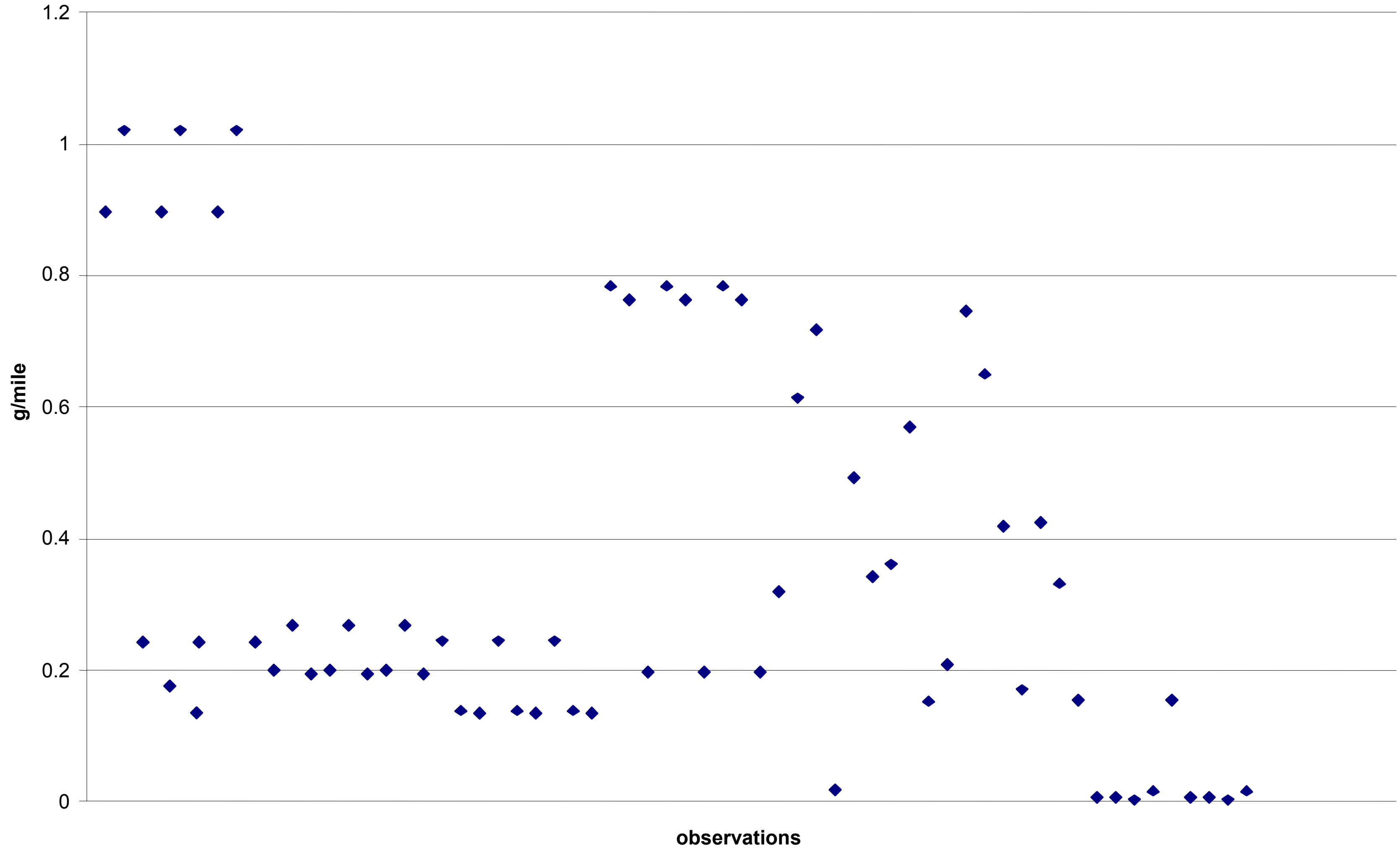


Figure B-43. MHDT PM2.5 Pre-1990

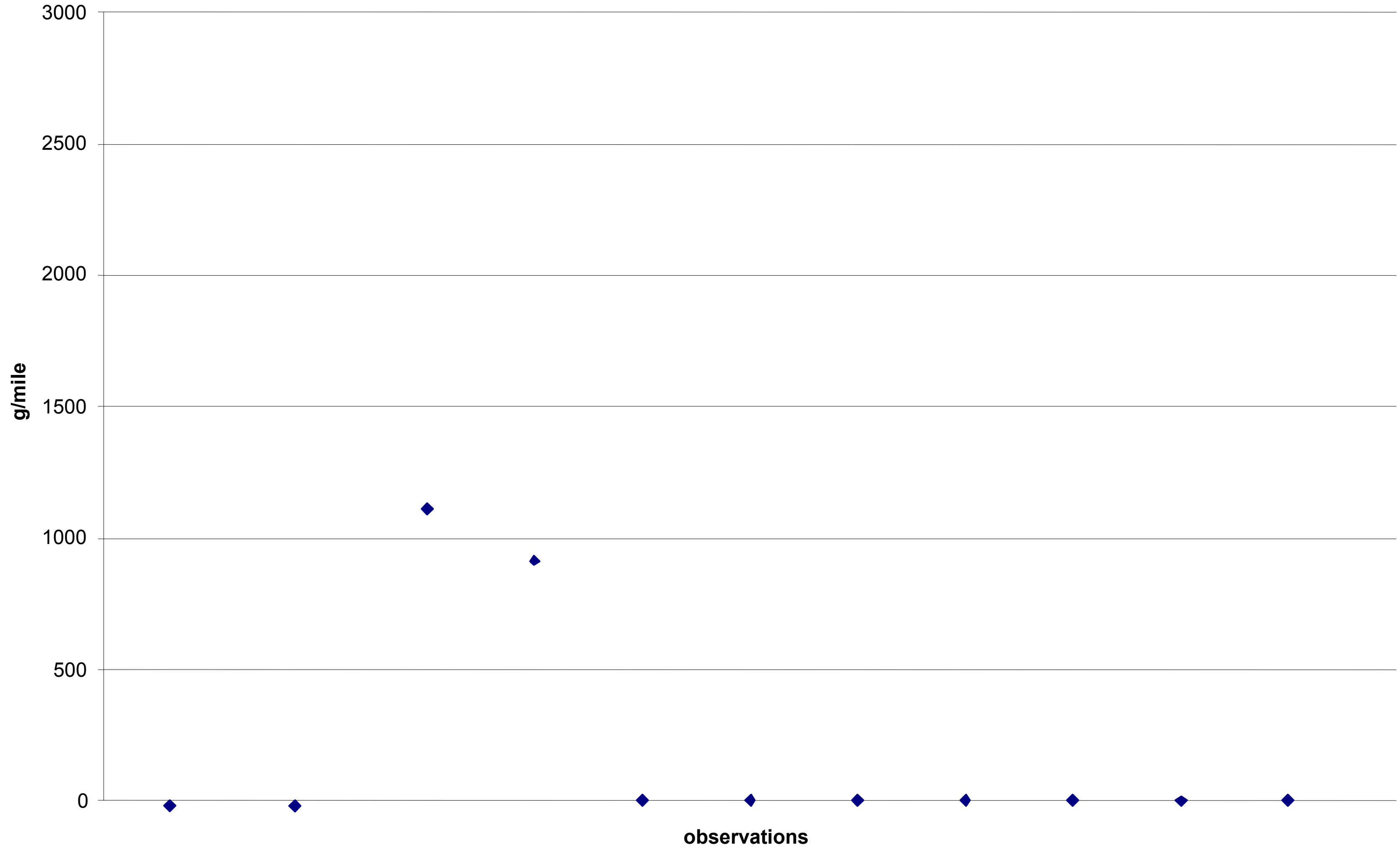


Figure B-44. MHDT PM2.5 Pre-1990

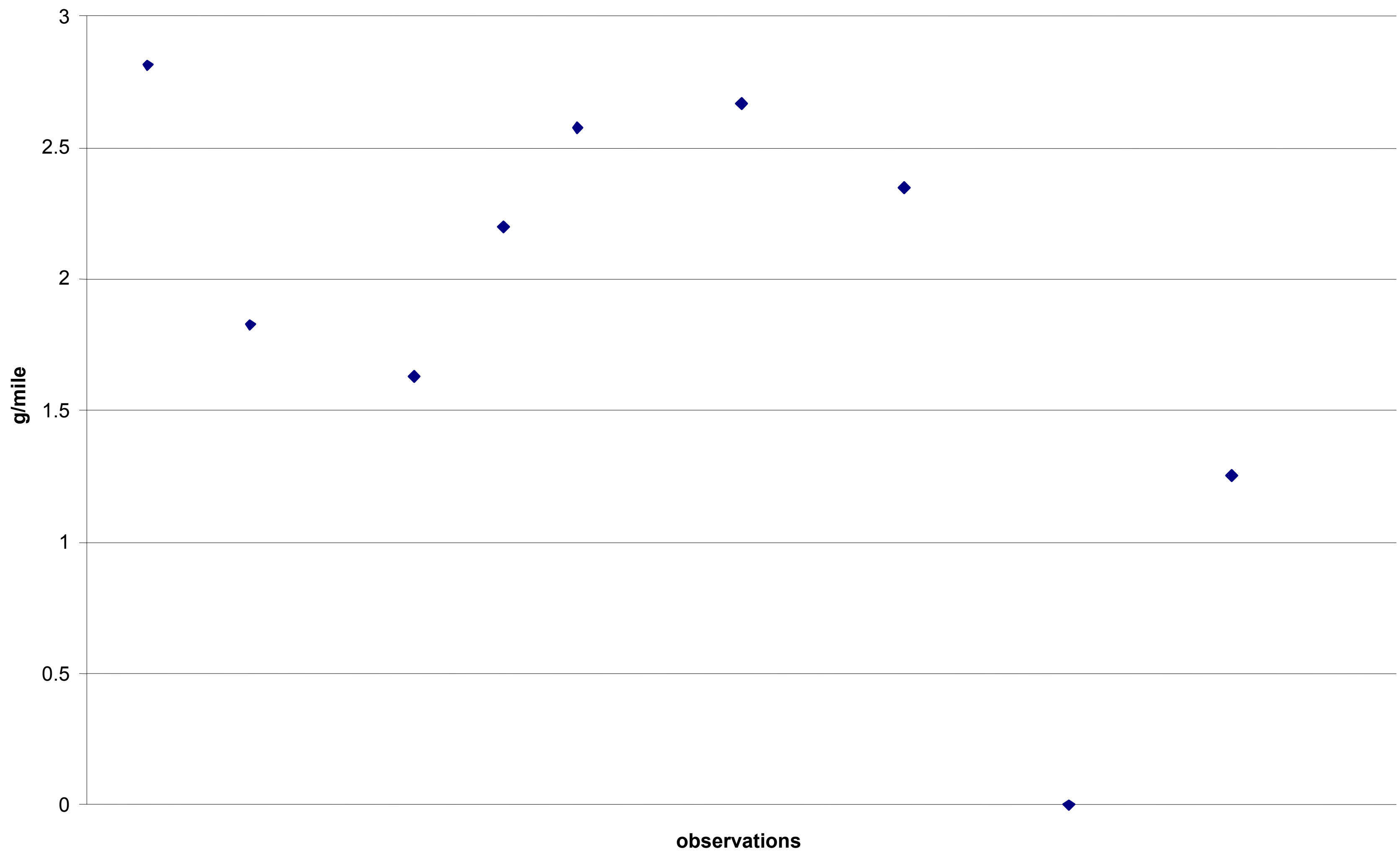


Figure B-45. MHDT PM2.5 Post-1993

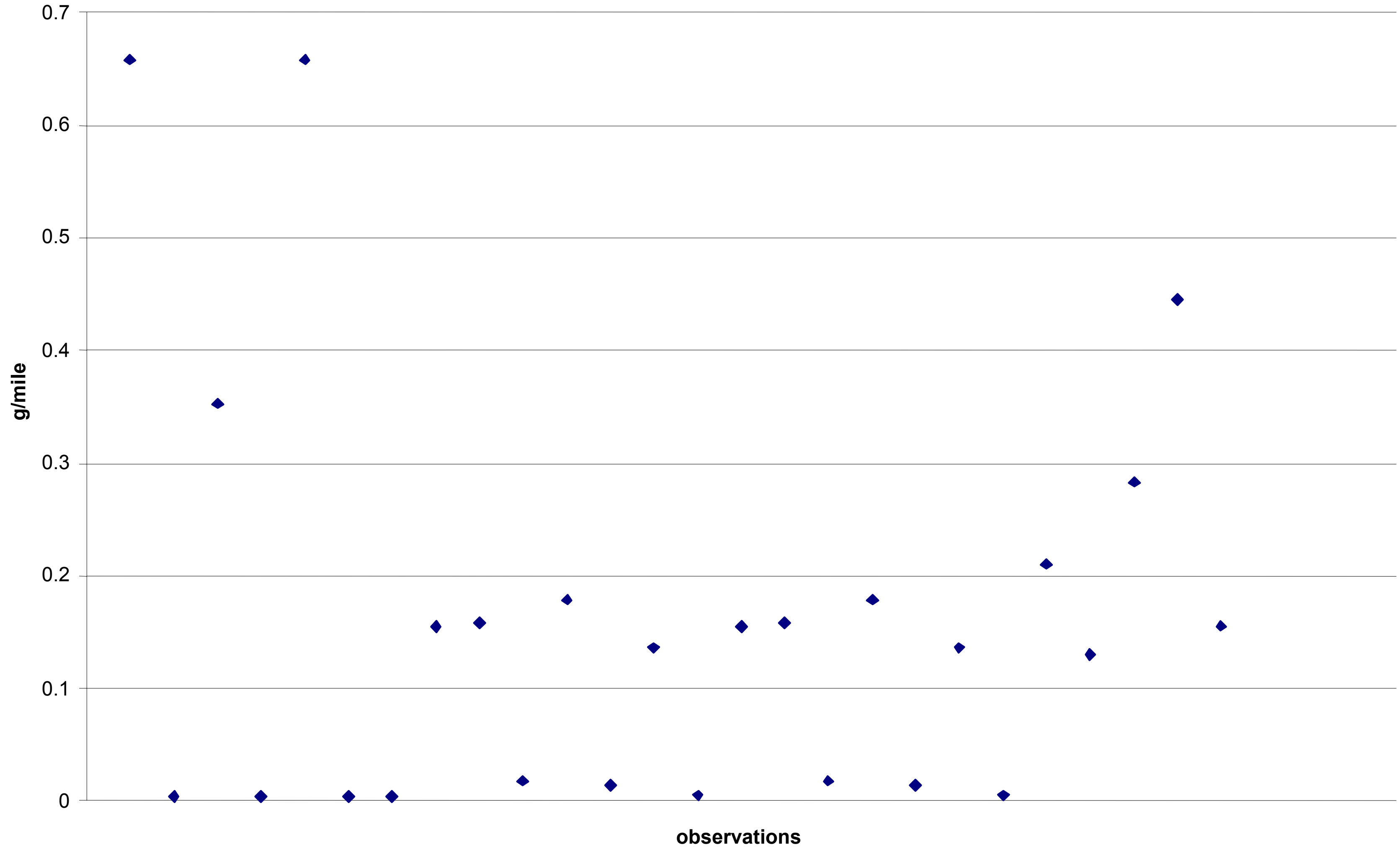


Figure B-46. HHDT post1993 - All Observations

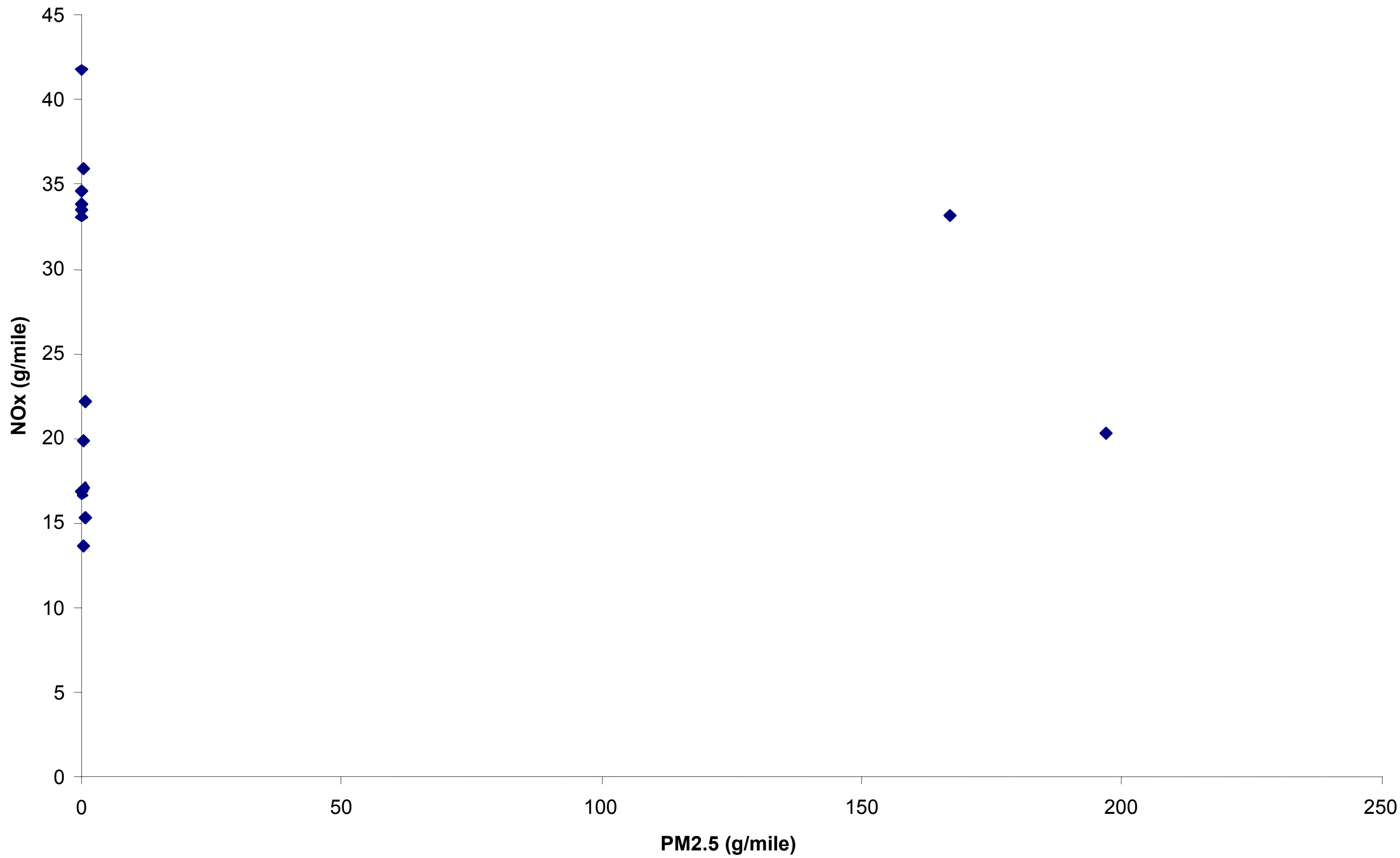


Figure B-47. HHDT post1993 - Extreme Observations Omitted

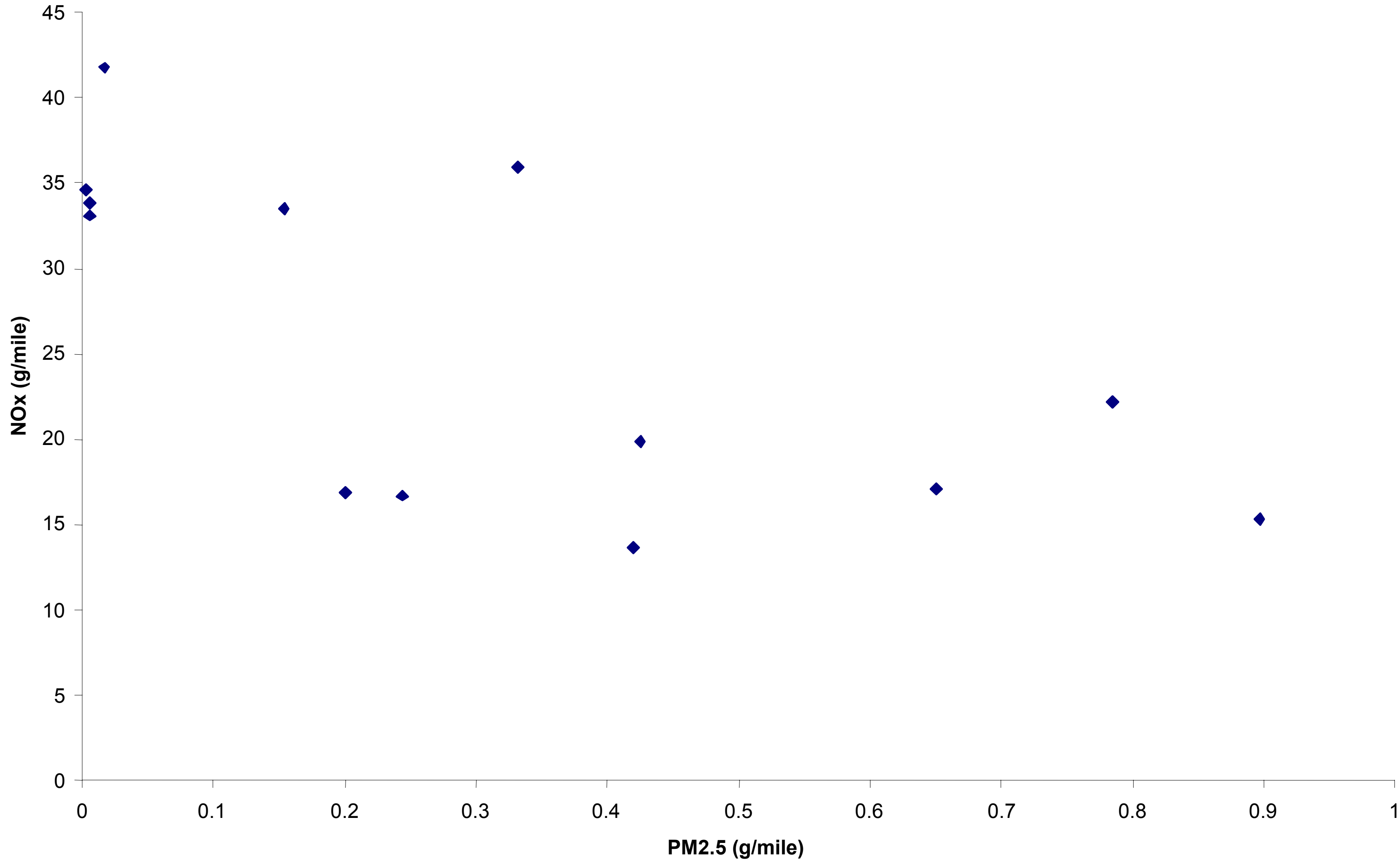


Figure B-48. MHDT pre1990

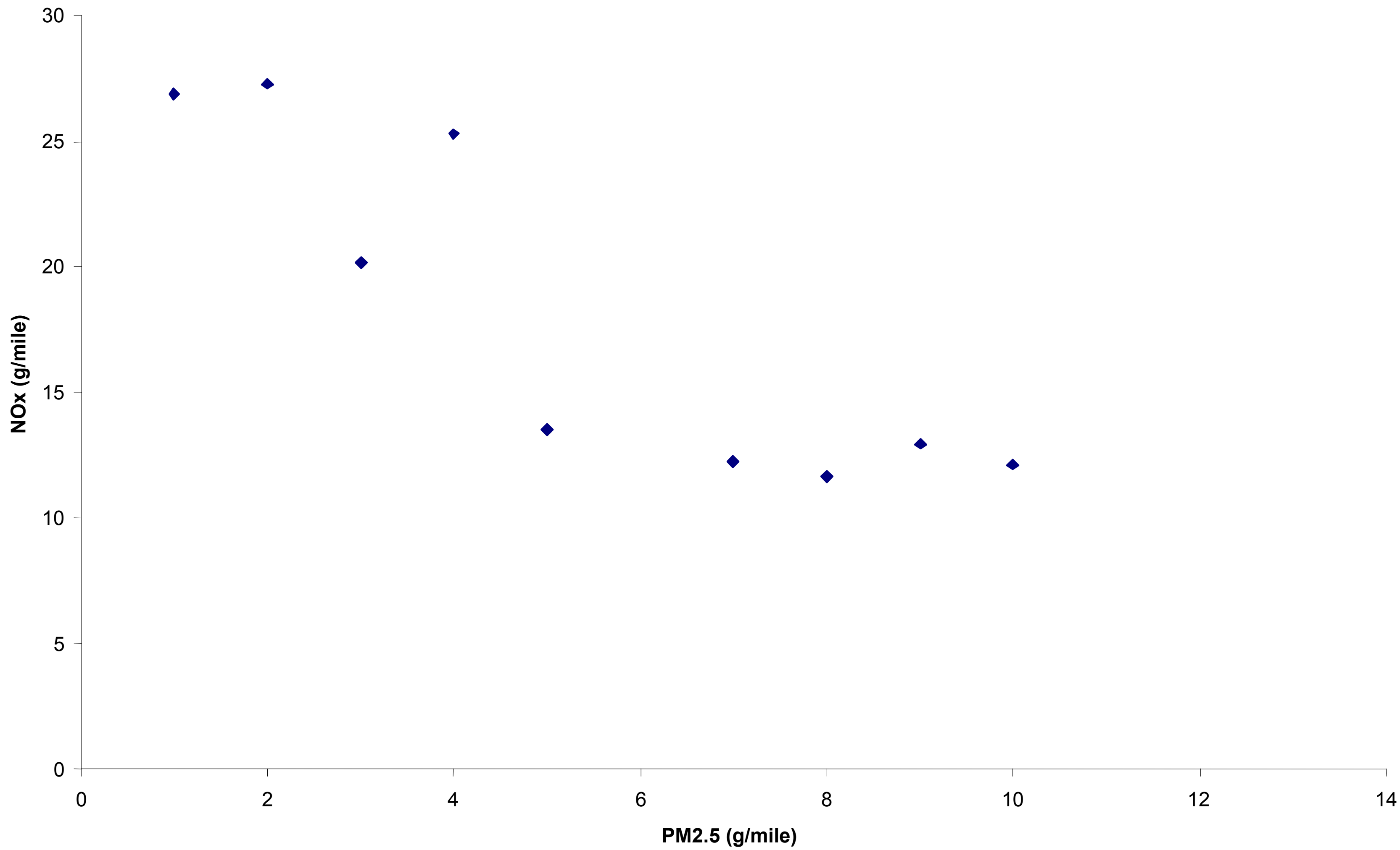


Figure B-49. MHDT post1993

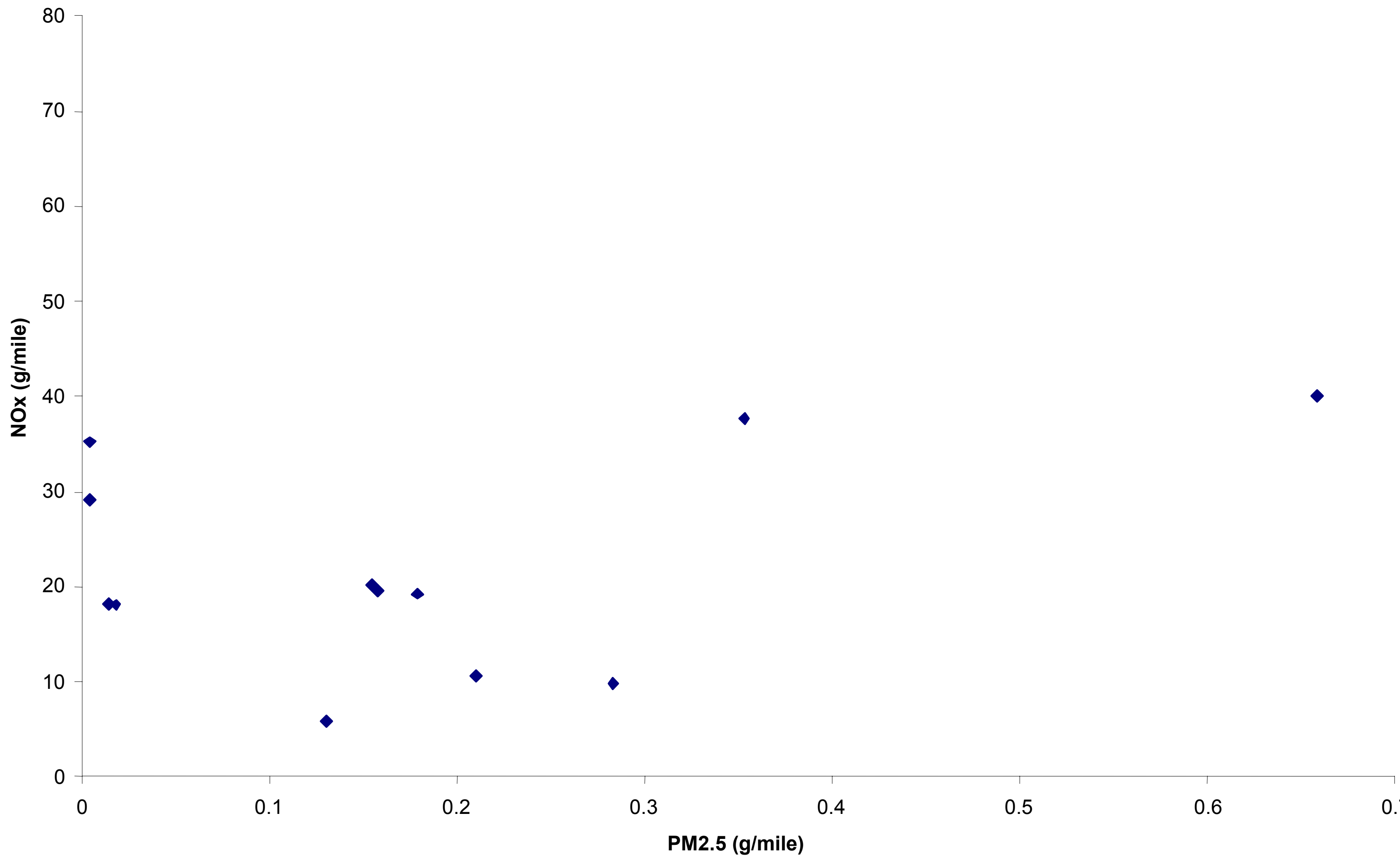


Figure B-50. LDV pre1990

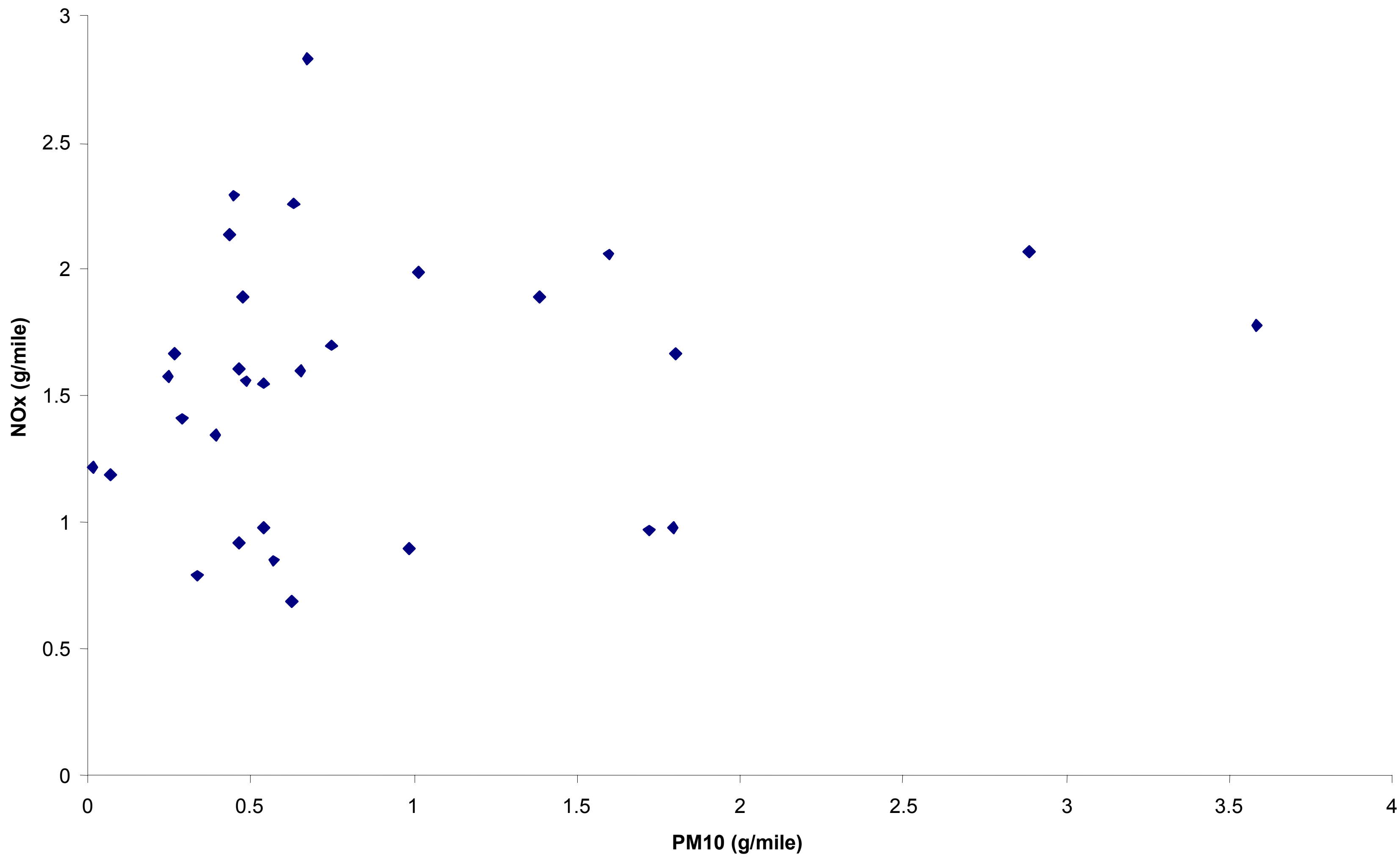


Figure B-51. Summary of Data by Pollutant and Vehicle Type with Highest and Lowest Values Omitted

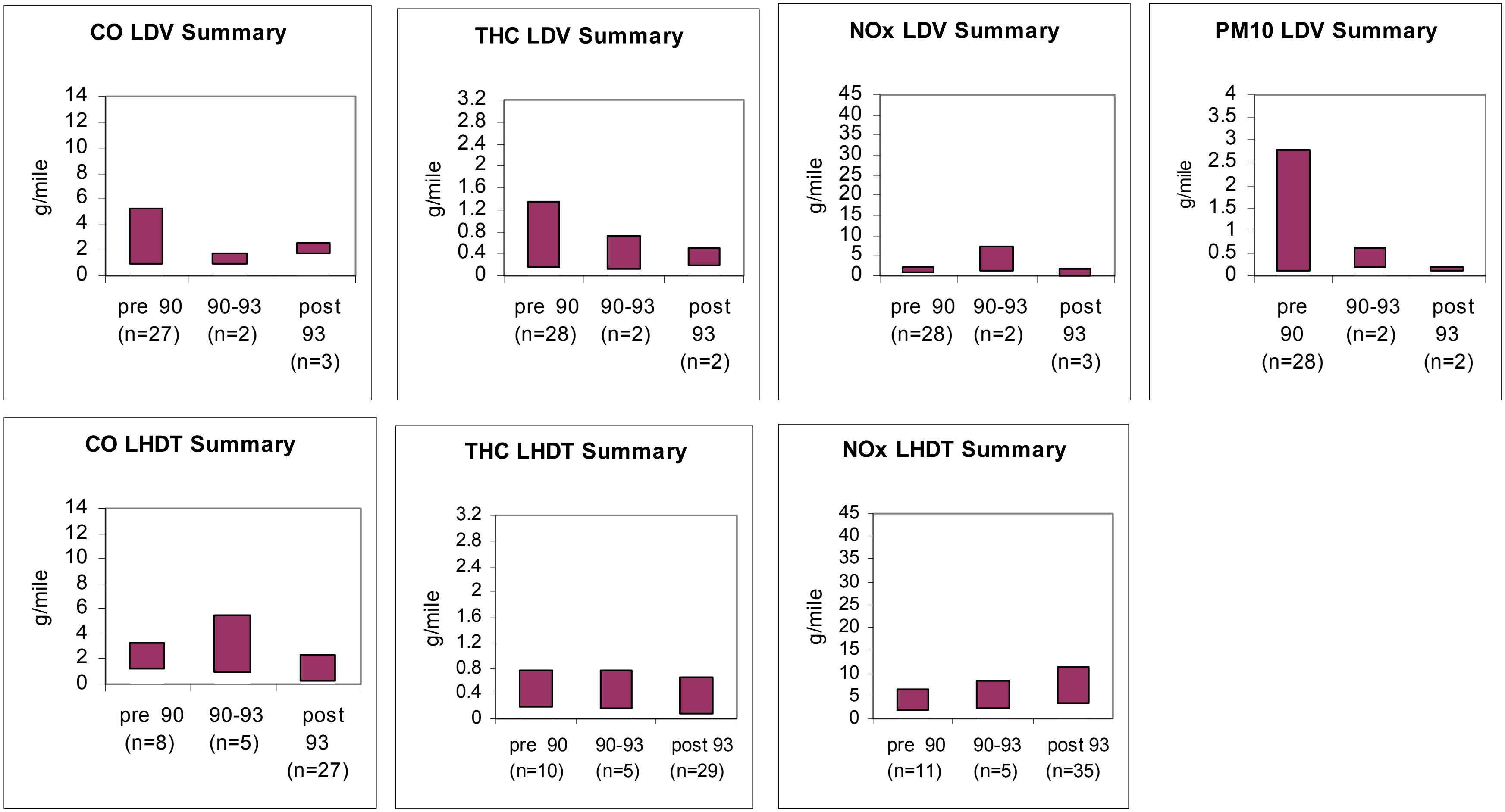


Figure B-51. Summary of Data by Pollutant and Vehicle Type with Highest and Lowest Values Omitted (cont'd)

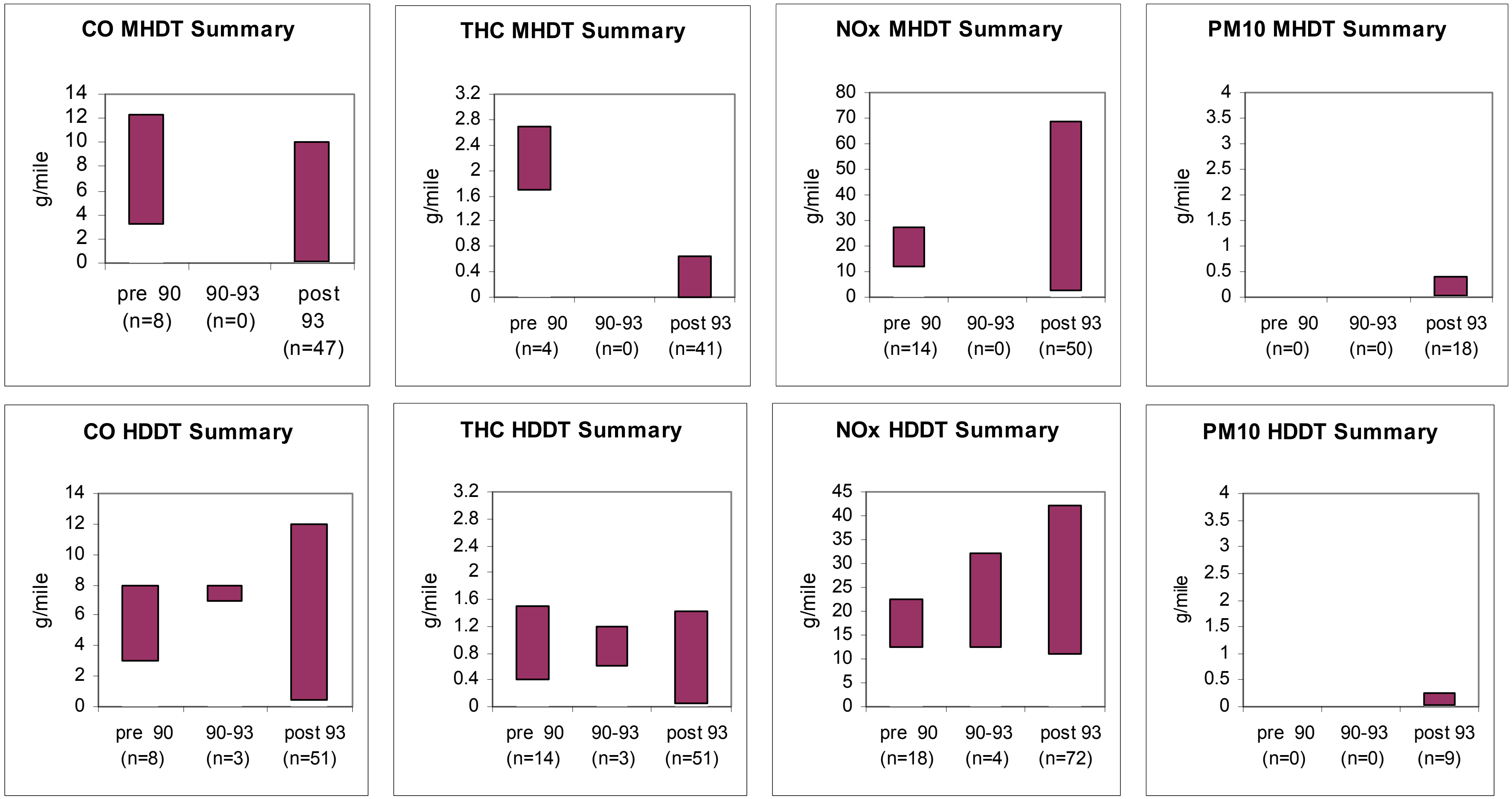


Figure B-52. Summary of Data by Pollutant and Vehicle Type Including Highest and Lowest Values

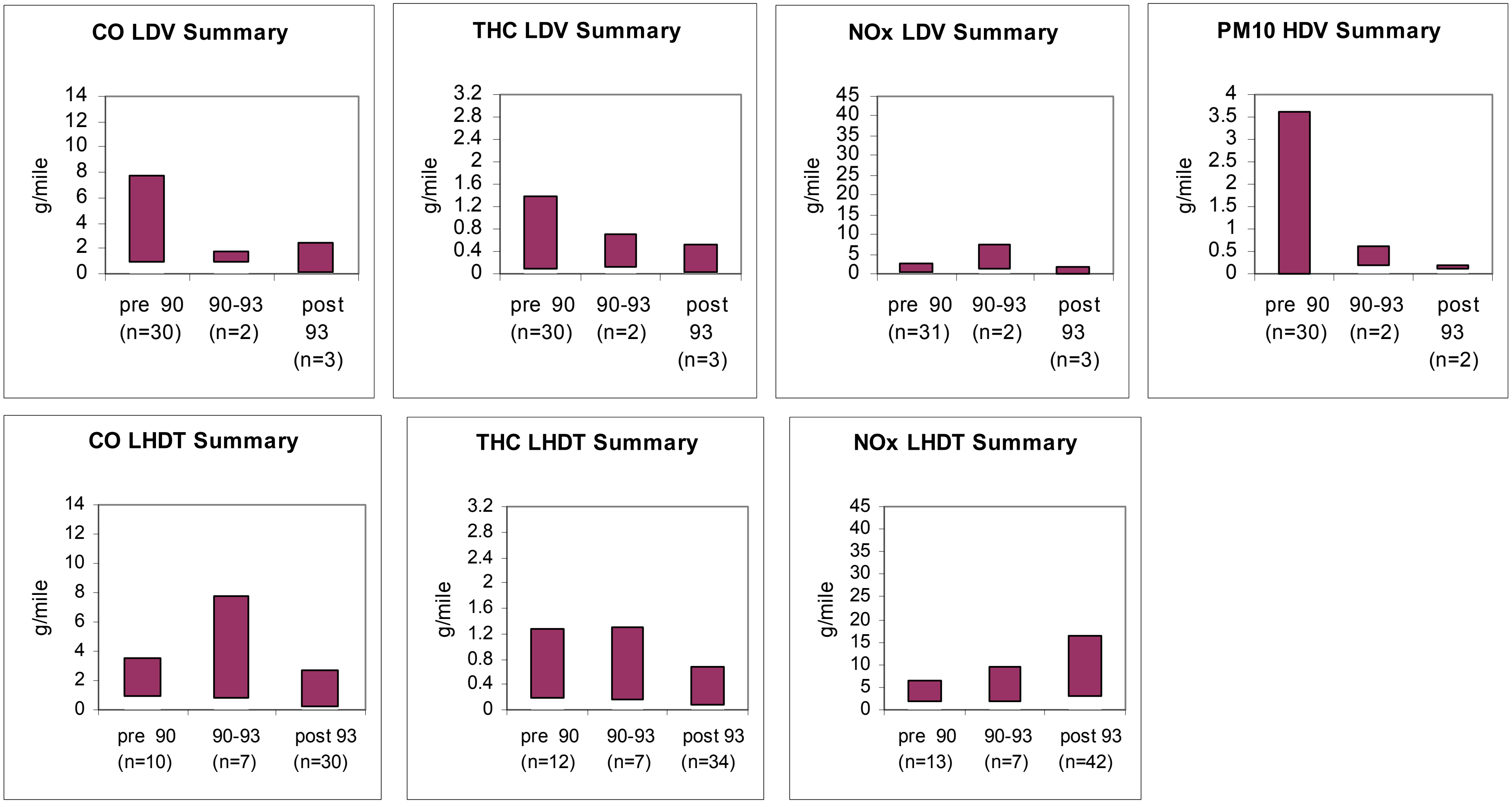
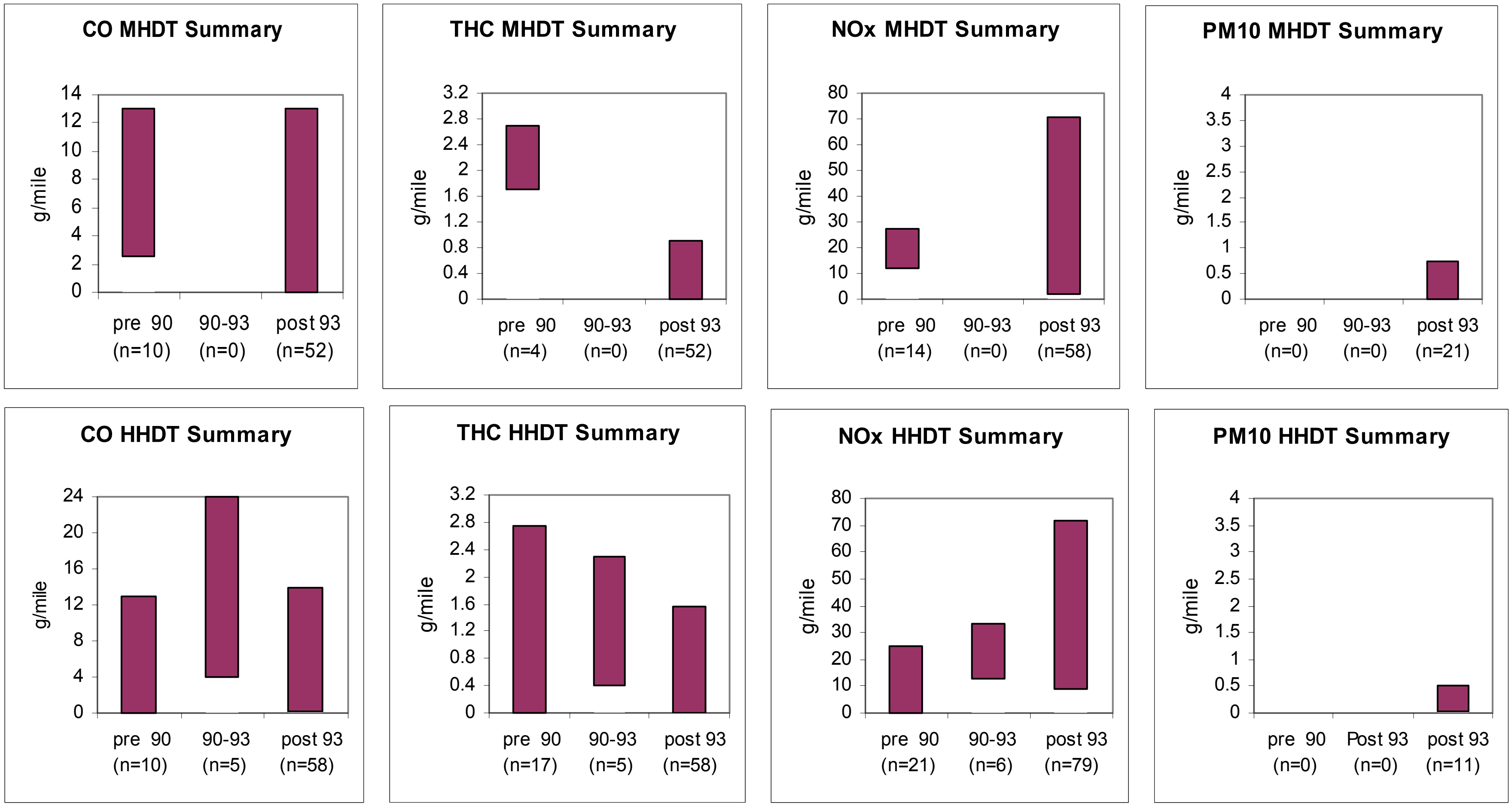


Figure B-52. Summary of Data by Pollutant and Vehicle Type Including Highest and Lowest Values (cont'd)



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