Eastern Research Group, Inc.

2005 MEXICALI EMISSIONS INVENTORY

Final Report

Prepared for:

Western Governors' Association
Denver, Colorado

U.S. Environmental Protection Agency, Region 9
San Francisco, California

Secretaría de Protección al Ambiente de Baja California
Mexicali, Baja California, Mexico

February 27, 2009

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Prepared by:

Eastern Research Group, Inc. (ERG)
Sacramento, California

with

Ingeniería en Control Ambiental y Riesgo Industrial, S. de R.L. (ICAR)
Mexicali, Baja California, Mexico

and

TransEngineering
El Paso, Texas

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TABLE OF CONTENTS

Section **Page**

ES.0 EXECUTIVE SUMMARY ES-1
ES.1 Methodology ES-1
ES.2 Summary of Results ES-2

1.0 INTRODUCTION 1-1
1.1 Inventory Characteristics 1-2
1.2 Data Management and Formatting 1-5
1.3 Data Quality Objectives 1-5
1.4 Report Organization 1-7

2.0 POINT SOURCES 2-1
2.1 Federal Jurisdiction Point Source Methodology 2-1
2.2 State Jurisdiction Point Source Methodology 2-4
2.3 Results 2-7
2.4 Quality Assurance 2-8

3.0 AREA SOURCES 3-1
3.1 Methodology 3-1
3.1.1 Fuel Combustion Categories 3-5
3.1.2 Evaporative VOC Categories 3-5
3.1.3 Agricultural Categories 3-6
3.1.4 Ammonia Categories 3-8
3.1.5 Paved Road Dust 3-8
3.1.6 Unpaved Road Dust 3-12
3.1.7 Miscellaneous Burning Categories 3-13
3.1.8 Border Crossings 3-13
3.1.9 Brick Kilns 3-13
3.1.10 Charbroiling, Construction Dust, and Bakeries 3-14
3.1.11 Landfills 3-14
3.1.12 Wastewater Treatment 3-14
3.2 Results 3-14
3.3 Quality Assurance 3-19

4.0 ON-ROAD MOBILE SOURCES 4-1
4.1 Methodology 4-1
4.2 Results 4-2
4.3 Quality Assurance 4-4

5.0 NONROAD MOBILE SOURCES 5-1
5.1 Methodology 5-1

TABLE OF CONTENTS (Continued)

Section **Page**

5.1.1 Aircraft 5-1
5.1.2 Locomotives 5-2
5.1.3 Agricultural and Construction Equipment 5-2
5.2 Results 5-3
5.3 Quality Assurance 5-4

6.0 EMISSION INVENTORY RESULTS 6-1

7.0 REFERENCES 7-1

APPENDIX A: AREA SOURCE CATEGORY FORMS

APPENDIX B: TECHNICAL REPORT (DRAFT), ESTIMATION OF TRAVEL DEMAND AND VEHICULAR TRAFFIC CONGESTION OF THE MEXICALI REGION

Tables **Page**

ES-1 2005 Mexicali Emissions Inventory Summary (Tons per Year) ES-3

1-1 2005 Mexicali Emissions Inventory Summary (Tons per Year) 1-5

2-1 Listing of State Jurisdiction Point Sources 2-5

2-2 2005 Mexicali Federal Jurisdiction Point Source Emissions (Tons per Year) 2-9

2-3 2005 Mexicali State Jurisdiction Point Source Emissions (Tons per Year) 2-9

3-1 General Emission Estimation Methodologies for Area Sources in Mexicali 3-2

3-2 2005 Mexicali Area Source Emissions (Tons per Year) 3-15

4-1 2005 Mexicali On-Road Mobile Source Emissions (Tons per Year) 4-4

4-2 2005 Imperial County and Mexicali On-Road Mobile Source Emissions (Tons per Year) 4-6

5-1 2005 Mexicali Nonroad Mobile Source Emissions (Tons per Year) 5-4

6-1 2005 Mexicali Emissions Inventory Summary (Tons per Year) 6-1

Figures **Page**

1-1 State of Baja California and Five Municipalities 1-3

1-2 Municipality and Mexicali and Most Populous Localities 1-4

2-1 Location of Federal and State Jurisdiction Point Sources in the Urban Portion of Mexicali 2-3

3-1 Location of Paved and Unpaved Road Dust Sampling Sites 3-9

3-2 Pavement Coverage of Mexicali Roads 3-11

4-1 Mexicali Loaded Roadway Network Under Weekday Conditions 4-3

6-1 Mexicali NO_x Emissions 6-2

6-2 Mexicali SO_2 Emissions 6-2

6-3 Mexicali VOC Emissions 6-3

6-4 Mexicali CO Emissions 6-3

6-5 Mexicali PM_{10} Emissions 6-4

6-6 Mexicali $PM_{2.5}$ Emissions 6-4

6-7 Mexicali NH_3 Emissions 6-5

6-8 Mexicali CH_4 Emissions 6-5

ACRONYMS

AGEB	area geoestadístics básicas (basic geographic area)
ANAFAPYT	Asociación Nacional de Fabricantes de Pinturas y Tintas (National Association of Paint and Dye Manufacturers)
ARB	Air Resources Board, California
BC	Baja California
CANALAVA	Cámara Nacional de la Industria de Lavanderías (National Chamber of the Dry Cleaning Industry)
CFE	Comisión Federal de Electricidad (Federal Electric Commission)
CH_4	methane
CO	carbon monoxide
COA	Cédula de Operación Anual (Annual Operating Report)
DQOs	data quality objectives
EIIP	Emission Inventory Improvement Program
EIP	Emission Inventory Plan
ERG	Eastern Research Group, Inc.
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
GIS	geographical information system
HDDV	heavy-duty diesel vehicle
HDGV	heavy-duty gasoline vehicle
IC	internal combustion
ICAO	International Civil Aviation Organization
ICAR	Ingeniería en Control Ambiental y Riesgo Industrial, S. de R.L.
ID	identification number
INEGI	Instituto Nacional de Estadística, Geografía e Informática (National Institute of Statistics, Geography, and Computing)
kg	kilogram

km	kilometers
lb	pound
lbs	pounds
LDDT	light-duty diesel truck
LDDV	light-duty diesel vehicle
LDGT	light-duty gasoline truck
LDGV	light-duty gasoline vehicle
LPG	liquefied petroleum gas
LTO	landing and take-off
m^2	square meters
m^3	cubic meters
MC	motorcycle
Mg	megagram
mm Hg	millimeters of mercury
mph	miles per hour
NAICS	North America Industry Classification System
NEI	National Emissions Inventory
NH_3	ammonia
NIF	National Emissions Inventory Input Format
NO_x	nitrogen oxides
NPK	nitrogen-phosphorus-potassium
PEMEX	Petróleos Mexicanos
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in equivalent aerodynamic diameter.
PM_{10}	particulate matter less than 10 micrometers in equivalent aerodynamic diameter

PROAIRE	Programa para Mejorar la Calidad del Aire (Program to Improve Air Quality)
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
s	second
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food)
SCC	source classification code
scf	standard cubic feet
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Secretariat of the Environment and Natural Resources)
SENER	Secretaría de Energía (Secretariat of Energy)
SLRC	San Luis Río Colorado, Sonora
SO_2	sulfur dioxide
SPA	Secretaría de Protección al Ambiente de Baja California (Secretary of Environmental Protection of Baja California)
TDM	travel demand model
TIM	time-in-mode
TSP	total suspended particulate
U.S. EPA	United States Environmental Protection Agency
VKT	vehicle kilometers traveled
VMT	vehicle miles traveled
VOC	volatile organic compound
WGA	Western Governors' Association
WRAP	Western Regional Air Partnership
yr	year

ES.0 EXECUTIVE SUMMARY

In response to requests from the Secretary of Environmental Protection of Baja California (Secretaría de Protección al Ambiente de Baja California – SPA) and the California Air Resources Board (ARB), the Western Governors' Association (WGA), with funding from the U.S. Environmental Protection Agency (U.S. EPA), hired a contractor team to develop the 2005 Mexicali inventory. The contractor team was led by Eastern Research Group, Inc. (ERG) and supported by two Mexico-based subcontractors (i.e., Ingeniería en Control Ambiental y Riesgo Industrial, S. de R.L. [ICAR] and TransEngineering). This 2005 Mexicali emissions inventory updates previous inventories developed for Mexicali, Baja California (BC), including Mexicali's Programa para Mejorar la Calidad del Aire (PROAIRE) for a base year of 1996 (PROAIRE, 1999) and the 1999 Mexico National Emissions Inventory (NEI) Program (ERG, 2006).

The 2005 Mexicali emissions inventory was developed for the entire municipality of Mexicali. Annual emissions (both tons per year and megagrams per year) were estimated for point sources, area sources, on-road mobile sources, and nonroad mobile sources. Emissions were estimated for the following pollutants: nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOC), carbon monoxide (CO), particulate matter (PM) less than 10 micrometers (µm) in aerodynamic diameter (PM_{10}), PM less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$), ammonia (NH_3), and methane (CH_4).

ES.1 Methodology

The point source emissions inventory was developed using existing emissions data provided by the Secretariat of Environment and Natural Resources (SEMARNAT) and the Secretary of Environmental Protection of Baja California (SPA). The area source and nonroad mobile source emissions inventory were developed using activity data collected from Mexicali government agencies and other local contacts. The on-road mobile source emission inventory was developed using vehicle activity data (i.e., vehicle kilometers traveled [VKT]) obtained from traffic and congestion modeling.

ES.2 Summary of Results

Table ES-1 provides a summary of the results of the 2005 Mexicali emissions inventory, by source type and pollutant. Table ES-1 shows that:

- Emissions from federal jurisdiction point sources are considerably larger than emissions from state jurisdiction point sources, even though the ratio of state-to-federal jurisdiction point sources is greater than 10-to-1.
- NO_x and SO_2 emissions are dominated by point sources.
- VOC emissions are emitted by area (i.e., mainly various evaporative source categories) and on-road mobile sources.
- On-road mobile sources are the predominant source of CO.
- Area sources are the largest contributors of PM_{10} and $PM_{2.5}$ (i.e., due to unpaved and paved road dust), NH_3 (i.e., from livestock ammonia and fertilizer application), and CH_4 (i.e., from the landfill).

The final inventory was formatted to be compatible with U.S. EPA's National Emissions Inventory Format (NIF), and SMOKE/IDA format (i.e., used for photochemical and other modeling). In addition, spatial surrogates for gridding area source emissions into a 4 km grid system for modeling were developed. Also, geographic information system (GIS)-based shape files obtained for Mexicali's AGEBs (i.e., area geoestadístics básicas or basic geographic areas) which were used in the development of some area source category emissions, were provided along with the final inventory files for purposes of spatially distributing area source emissions over the inventory domain for purposes of air quality modeling.

Table ES-1. 2005 Mexicali Emissions Inventory Summary (Tons per Year)

Source Type	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Point – Federal	13,931.7	3,650.9	659.3	3,636.2	1,537.7	128.4		
Point – State	444.0	973.2	73.0	479.9	89.7			
Area	1,205.5	131.1	15,301.5	18,854.0	50,879.3	6,753.5	9,015.2	6,033.3
On-Road Mobile	8,570.4	168.7	8,977.1	60,603.4	765.0	665.8	252.4	144.4
Nonroad Mobile	4,485.0	60.9	542.9	3,206.9	550.2	533.3	0.0	1.5
Total	**28,636.5**	**4,984.8**	**25,553.8**	**86,780.4**	**53,821.8**	**8,081.0**	**9,267.6**	**6,179.2**

Blanks indicate that pollutant emissions were not applicable or were not estimated due to a lack of data.

1.0 INTRODUCTION

The first emissions inventory developed for Mexicali, Baja California (BC) was published as part of Mexicali's Programa para Mejorar la Calidad del Aire (PROAIRE) for a base year of 1996 (PROAIRE, 1999). The next and most recent emissions inventory for Mexicali was developed and published as part of the 1999 Mexico National Emissions Inventory (NEI) Program; however, the industrial source emissions in the 1999 Mexico NEI for Mexicali were based on the previous 1996 PROAIRE inventory (ERG, 2006).

The Secretary of Environmental Protection of Baja California (Secretaría de Protección al Ambiente de Baja California – SPA) has requested an update to the emissions inventory for the municipality of Mexicali for the year 2005. In addition, the California Air Resources Board (ARB) has requested an updated inventory for purposes of air quality modeling in the border area of Imperial County, California, and Mexicali.

In response to these needs, the Western Governors' Association (WGA), with funding from the U.S. Environmental Protection Agency (U.S. EPA), sponsored this project to update the Mexicali emissions inventory to 2005. The Contractor team, hired under Contract No. 30430-01, was led by Eastern Research Group, Inc. (ERG), and included Ingeniería en Control Ambiental y Riesgo Industrial, S. de R.L. (ICAR), and TransEngineering. ICAR was responsible for data collection related to area and point sources, and TransEngineering was responsible for estimating on-road motor vehicle activity data which were used to estimate mobile source emissions and to determine the distribution of vehicle activity over paved versus unpaved roads.

The specific objectives of the 2005 Mexicali emissions inventory were to provide a current and accurate technical basis for air quality planning in the municipality of Mexicali. Also, the results of the 2005 Mexicali emissions inventory (for the non-methane pollutants) are formatted for use in air quality modeling to better understand the contribution of Mexicali emissions to concentrations of criteria pollutant levels in that region.

1.1 Inventory Characteristics

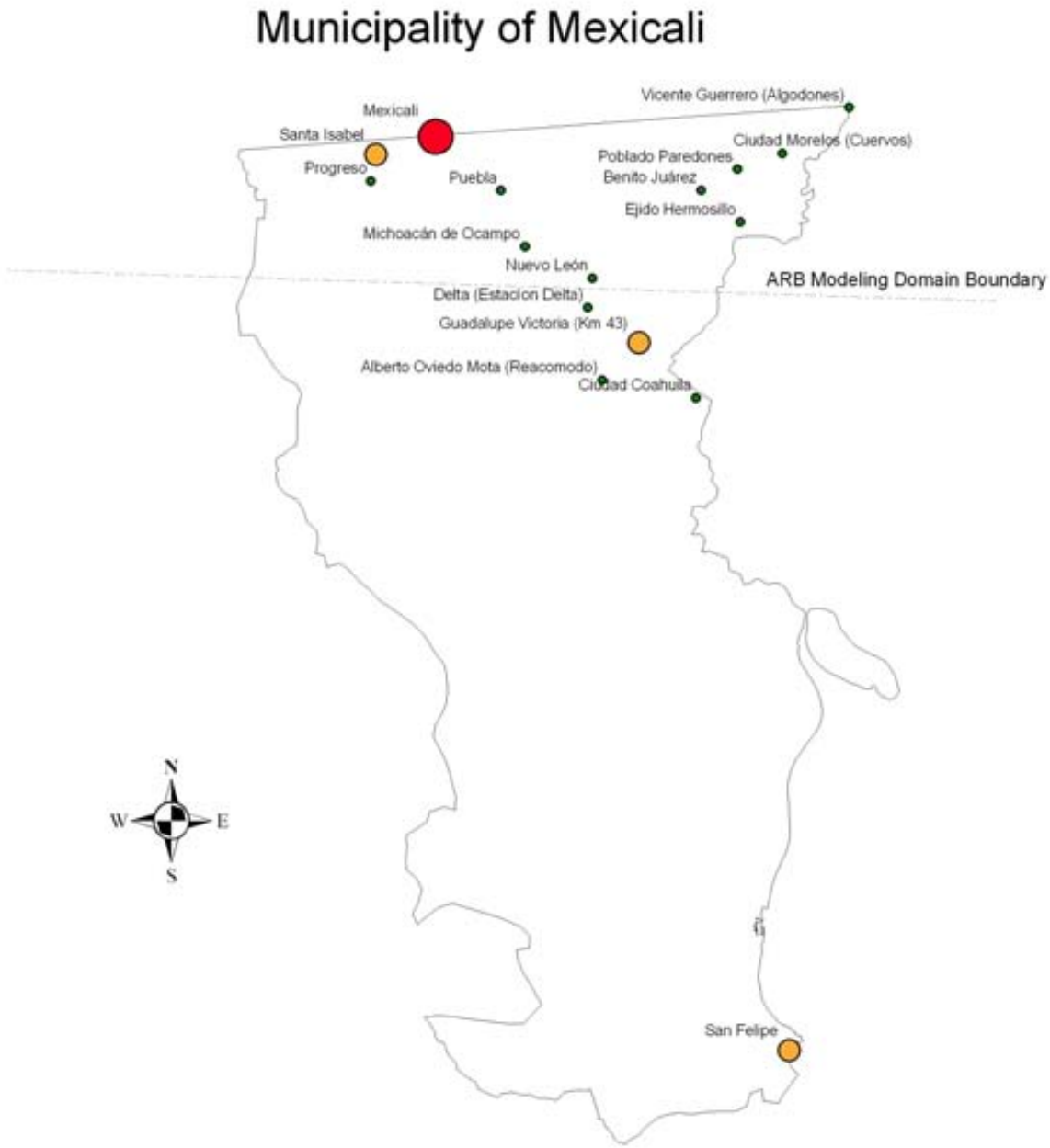
The characteristics of the 2005 Mexicali emissions inventory are as follows:

- Base year: 2005.
- Temporal resolution: Annual emissions, in terms of megagrams per year (Mg/year) and tons per year (tons/year). Some intermediate activity data are presented in Imperial units. The inventory results are presented in Imperial units (i.e., tons per year) in the English version of the final report and in metric units (i.e., megagrams [Mg] per year) in the Spanish version of the final report.
- Geographic domain: Entire municipality of Mexicali. Figure 1-1 shows the entire state of Baja California and its five municipalities (i.e., Mexicali, Tijuana, Tecate, Playas de Rosarito, and Ensenada). Figure 1-2 shows the municipality of Mexicali and location of the most populous "localities" (e.g., cities, towns, communities, etc.) with population greater than 3,000.
- Geographic Resolution: In addition to total municipality-level emissions by pollutant and source type, emissions were estimated at various other levels of detail, including:
  - Exact location (i.e., latitude/longitude) for point sources.
  - Spatial surrogates at the level of basic geographic areas (area geoestadística básica – AGEB) are also provided. An AGEB is analogous to a census tract in the U.S. These surrogates provide the spatial allocation of emissions to 4 kilometer (km) × 4 km grid cells within the ARB modeling domain (i.e., approximately 36 km to 50 km south of the California—BC border).
- Pollutants:
  - Nitrogen oxides (NO_x)
  - Sulfur dioxide (SO_2)
  - Volatile organic compounds (VOC)
  - Carbon monoxide (CO)
  - Particulate matter (PM) less than 10 micrometers (µm) in aerodynamic diameter (PM_{10})
  - PM less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$)
  - Ammonia (NH_3)
  - Methane (CH_4).
- Source Types and Categories: Point sources, area sources, on-road mobile sources, and nonroad mobile sources. Each of these source types will be discussed in their individual sections.

Figure 1-1. State of Baja California and Five Municipalities

Municipality Code	Municipality Name	2005 Population
001	Ensenada	413,481
002	Mexicali	855,962
003	Tecate	91,034
004	Tijuana	1,410,687
005	Playas de Rosarito	73,305
	Total	**2,844,469**

Figure 1-2. Municipality of Mexicali and its Most Populous Localities



Locality	2005 Population	Locality	2005 Population
Mexicali	653,046	Ejido Hermosillo	5,082
Santa Isabel	22,007	Progreso	5,071
Guadalupe Victoria (Km 43)	14,861	Benito Juárez (Ejido Tecolotes)	4,697
San Felipe	14,831	Vicente Guerrero (Algodones)	4,021
Puebla	7,014	Poblado Paredones	3,390
Ciudad Morelos (Cuervos)	6,814	Nuevo León	3,255
Alberto Oviedo Mota (Reacomodo)	5,835	Michoacán de Ocampo	3,065
Ciudad Coahuila (Km 57)	5,333	All Other Localities	92,362
Delta (Estacion Delta)	5,278	**Municipality Total**	**855,962**

1.2 Data Management and Formatting

Development of the 2005 Mexicali emissions inventory required the compilation of considerable amounts of emissions and other related inventory data. Electronic spreadsheets were used to compile, calculate, and summarize emissions data.

The final inventory was formatted to be compatible with U.S. EPA's National Emissions Inventory Format (NIF), and SMOKE/IDA format (i.e., used for photochemical and other modeling). In addition, spatial surrogates for gridding the area source emissions into a 4 km grid system for modeling will be developed. Also, geographic information system (GIS)-based shape files of the obtained for Mexicali's AGEBs, which were used in the development of some area source category emissions, will be provided along with the final inventory files for purposes of spatially distributing area source emissions over the inventory domain for purposes of air quality modeling.

1.3 Data Quality Objectives

The data quality objectives (DQOs) were established as part of the Emission Inventory Plan (EIP)/Quality Assurance Project Plan (QAPP) developed for this project. The specific DQOs, and criteria used to evaluate whether the DQOs are achieved for the 2005 Mexicali emissions inventory are as follows:

1. A comprehensive emissions inventory for all source types (i.e., point, area, on-road motor vehicle, and nonroad mobile sources) and all major categories within these source types.

   Acceptance criteria: The source types and major categories accounted for in the EIIP guidance documents are present in the Mexicali emissions inventory, and/or any differences are documented.

2. Identification of 80% of all federal jurisdiction and state jurisdiction point sources located within the municipality of Mexicali.

   Acceptance criteria: A list of point sources under the federal (SEMARNAT Delegation), and state (SPA) jurisdictions compares to the emissions data, by source, provided by those agencies.

3. Point sources: Emissions estimates with an accuracy of ± 25% for at least 10% of the facilities.

Acceptance criteria: Estimated emissions for 10% of the total facilities compare to measured emissions of all pollutants with ± 25% accuracy. The emissions data measurements will be obtained from subcontractor ICAR, and will be based on data collected over the past five years in Mexicali.

4. Area, On-Road Motor Vehicle, and Nonroad Mobile Sources: Emissions estimates with an accuracy of ±50%.

   Acceptance criteria: Estimated emissions using emission factors/models compare to emissions estimated using a fuel-balance approach for all applicable pollutants. The fuel-balance approach will use national statistics, while the preferred inventory methodology will use PEMEX and local fuel distribution data.

5. Documentation: All EI results are transparent and reproducible.

   Acceptance criteria: Written and electronic inventory documentation provides detailed explanations of data collected, data measured/analyzed, values estimated/calculated, assumptions made, and emission factors used so that the results can be duplicated.

Most of these acceptance criteria have been met, and in some cases exceeded, in the development of the 2005 Mexicali emissions inventory. Instances where the acceptance criteria could not be met are documented (i.e., see Area Sources, Section 3.3).

In general, the following quality assurance checks were performed to ensure the DQOs were achieved:

- Accuracy checks – Spreadsheets were developed to calculate emissions, and 100% of the formulas were checked for accuracy. 100% of the electronic calculations were checked (50% by hand), and any errors were corrected.

- Completeness checks – The list of pollutants and source categories for the 1999 Mexico NEI was compared against all of the inventory files to ensure that emissions are estimated for the correct pollutants and source categories. Any errors were corrected.

- Representativeness – The emission factors and activity data were reviewed to ensure they are appropriate and current for the source categories for 100% of the source categories inventories. All adjustment factors (e.g., used to allocate national activity to a state- or municipality-level rate) were reviewed to ensure they are representative of actual conditions affecting emissions generated during the base year of 2005.

Specific quality assurance procedures followed during the estimation of emissions for each source type will be described in report Sections 2.0, 3.0, 4.0, and 5.0 for point sources, area

sources, on-road mobile sources, and nonroad mobile sources, respectively, as part of the final report.

1.4 Report Organization

The remainder of this report provides a complete and detailed description of all methods, assumptions, data, and calculations used to develop the emissions inventory, along with the results by source category. The report is organized as follows:

- Section 2.0 describes the point source estimation methodology and results.
- Section 3.0 describes the area source estimation methodology and results.
- Section 4.0 describes the on-road mobile source estimation methodology and results.
- Section 5.0 describes the nonroad mobile source methodology and results.
- Section 6.0 provides the overall 2005 Mexicali emissions inventory results.
- Section 7.0 lists all references used in the development of this emissions inventory.
- Appendix A contains the forms showing how each area source category's emissions were calculated (i.e., method/emission factor/formula, reference, activity data, sample calculation).
- Appendix B contains a detailed explanation of the analysis conducted to estimate on-road mobile source activity data.

2.0 POINT SOURCES

Point sources are stationary industrial sources that release emissions from fixed points (e.g., a stack or vent). In Mexico, point source emissions data are transmitted to the federal and/or state environmental agencies (depending upon sector-based jurisdiction) by means of the Annual Operating Certificate (Cédula de Operación Annual – COA). As a result, the development of point source emissions data for the 2005 Mexicali emissions inventory relied heavily on the cooperation of the government agencies that maintain emission registries – the Secretariat of Environment and Natural Resources (SEMARNAT) for federal jurisdiction point sources and the SPA for state jurisdiction point sources. The procedures used to compile emissions from the federal and state jurisdiction point sources are described below.

2.1 Federal Jurisdiction Point Source Methodology

There are 16 federal jurisdiction point sources located in the municipality of Mexicali, which was confirmed by SEMARNAT. These point sources are listed below with their sector/subsector, as applicable:

- CFE Campo y Centrales Geotermoeléctrico de Cerro Prieto (Electricity Generation)
- CFE Central Turbo Gas (Electricity Generation)
- Dafmex, S. de R.L. de C.V. (Metallurgical/Ferrous Metal Foundry)
- Energía Azteca X, S. de R.L. de C.V. (Electricity Generation)
- Energía de Baja California, S. de R.L. de C.V., Central Termoeléctrica (Electricity Generation)
- Fábrica de Papel San Francisco, S.A. de C.V. (Pulp and Paper/Paper Production)
- Fevisa Industrial, S.A. de C.V. (Glass/Container Glass Manufacture)
- Fundiciones San Martin o Felix Jesus del Valle Zamora (Metallurgical/Iron and Steel Foundry)
- Infra, S.A. de C.V., Sucursal Mexicali (Chemical/Industrial Gases)
- Kenworth Mexicana, S.A. de C.V. (Automotive/Truck Manufacture)
- Kyowa Mexicali, S.A. de C.V. (Plastic Parts Manufacturing)

- Maquiladora San Diego, S.A. de C.V. (Metallurgical – Iron and Steel Foundry)
- Petróleos Mexicanos (PEMEX) Refinación Planta Mexicali (Petroleum/Petroleum Products Storage and Distribution
- Quimical, S.A. de C.V. (Chemical/Pesticides and Agricultural Chemicals)
- Termoeléctrica de Mexicali, S. de R.L. de C.V. (Electricity Generation)
- Vitro AFG, S.A. de C.V. (Glass/Plane Glass Manufacture)

The physical location of some of the federal jurisdiction (and state jurisdiction) point sources in the urban portion of Mexicali is illustrated in Figure 2-1. The federal jurisdiction point sources are shown as red dots (and the state jurisdiction point sources are shown as green dots). Some addition federal and state jurisdiction point sources located in the rural areas of Mexicali are not shown on Figure 2-1.

ICAR made the initial data request to SEMARNAT for existing information regarding emissions for the year 2005 from Mexicali federal jurisdiction point sources. SEMARNAT provided two electronic files in Excel format: "Empresas Comp Federal (EMIS 230108).xls" and "DATGEN_MEXICALI_05.xls". The "Empresas Comp Federal (EMIS 230108).xls" file provided a listing of all federal jurisdiction sources located in the state of Baja California, as well as those federal jurisdiction sources that reported 2005 emissions to SEMARNAT. The "DATGEN_MEXICALI_05.xls" file consisted of several sheets of which the following were most relevant for the compilation of emissions:

- Hoja1 – Complete facility description;
- EqComb – Emissions from combustion equipment;
- ActProc – Emissions from non-combustion equipment and processes;
- Chim – Stack parameters; and
- EqCont – Description of control equipment.

In general, the information contained in the "DATGEN_MEXICALI_05.xls" file was fairly complete. However, much of the data contained in this file was represented in codes,

Figure 2-1. Location of Federal and State Jurisdiction Point Sources in the Urban Portion of Mexicali

abbreviations, and acronyms. As a result, ICAR made a subsequent request to SEMARNAT to provide the relevant data dictionaries needed to decipher the file. Subsequently, SEMARNAT provided two data dictionary files associated with the "DATGEN_MEXICALI_05.xls" file: "Diccionario_Datos_Datgen.xls" and "Codigos_catalogo.xls". The "Diccionario_Datos_Datgen.xls" file provided the data dictionary and formats used by the "DATGEN_MEXICALI_05.xls" file, while the "Codigos_catalogo.xls" file provided a key for all of the codes, abbreviations and acronyms.

Using the "Empresas Comp Federal (EMIS 230108).xls" and "DATGEN_MEXICALI_05.xls", along with the data dictionary files, ICAR compiled emissions from the federal jurisdiction point sources.

2.2 State Jurisdiction Point Source Methodology

There are 173 state jurisdiction point sources located in the municipality of Mexicali. As seen in Figure 2-1, many of these state jurisdiction point sources are clustered in the city's industrial parks, which was confirmed by SEMARNAT. The names for these facilities are listed in Table 2-1.

ICAR made an initial request to SPA for existing information regarding emissions for the year 2005 from Mexicali state jurisdiction point sources. SPA provided two electronic files: "2-REGISTROS (2005).xls" and "SIARE.mdb". The "2-REGISTROS (2005).xls" file provided a listing of all companies that submitted 2005 emission estimates to SPA and identified the paper file location within SPA offices of these emission submittals. The "SIARE.mdb" file is an Access database which contains such information as:

- Facility name
- File number
- Inventory year
- Type and number of process that generate emissions
- Emission controls (if any)
- Pollutant type (in units of kg/hr and kg/year)

Table 2-1. Listing of State Jurisdiction Point Sources

Facility Name	Facility Name	Facility Name
Accuride International, S.A. de C.V. (Nelson 6)	Cervecería de Baja California, S.A. de C.V.	Expopartes, S.A. de C.V.
Accuride International, S.A. de C.V. (Pta-Oeste, Nelson-12)	Chromalloy, S.A. de C.V. (Planta 1)	Fabricaciones y Montajes Metálicos, S.A. de C.V.
Agribrands Purina México, S.A. de C.V.	Chromalloy, S.A. de C.V. (Planta Ii)	Fanosa, S.A. de C.V.
Alimentos y Frituras de Baja California, S.A. de C.V.	Cias. Periodísticas del Sol de Pacífico, S.A. de C.V.	Femsa, S. de R.L. de C.V.
American Meter de Mexico, S.A. de C.V.	Compre Block Sucursal Criba	Fetasa Culiacán, S.A. de C.V.
Amp Industrial Mexicana, S.A. de C.V.	Compre Block, S.A. de C.V.	Fetasa Industrial, S.A. de C.V
Arrendadora del Colorado del Norte, S.A. de C.V.	Con Mex de Mexicali, S.A.	Fetasa Mexicali, S.A. de C.V.
Ascotech, S.A. de C.V.	Concretos Apasco, S.A. de C.V.	Flexcel-Mexicali, S.A. de C.V.
Asociacion Rural de Interes Colectivo de Baja California ´80 de R.I.	Concretos Bajanor de Mexicali, S.A. de C.V.	Frituras de Mexicali, S.A. de C.V.
Benq Mexicana, S.A. de C.V.	Constructora Gallego, S.A. de C.V. (Planta 1)	Fruvemex Mexicali, S.A. de C.V.
Bi Technologies, S.A. de C.V.	Constructora Gallego, S.A. de C.V. (Planta 2)	Furukawa Mexico, S.A.de C.V.
Bimbo, S.A. de C.V.	Constructora Gusa, S.A. de C.V.	Grayline de México, S.A. de C.V.
Black & Decker Hhi México, S. de R.L. de C.V. (Pta-2)	Controles de Mexicali, S. de R.L.	Grupo Industrial Persal, S.A. de C.V.
Black & Decker Hhi México, S. de R.L. de C.V. K1	Dafmex, S. de R.L. de C.V.	Guaycan Quimicos y Petroliferos, S.A. de C.V.
Black & Decker Hhi México, S. de R.L. de C.V. K2	Dataproducts Imaging Solution, S.A. de C.V.	Harinera de Maíz de Mexicali, S.A. de C.V.
Black & Decker Hhi México, S. de R.L. de C.V. P1	Delivamex, S. de R.L. de C.V.	Helados y Mezclas, S.A. de C.V.
Block Centinela, S.A. de C.V.	Display Orion Mexicana, S.A. de C.V.	Honeywell Aerospace de México, S.A. de C.V.
Bloquera Moderna, S.A. de C.V.	Eco Constructora, S.A. de C.V.	Honeywell Productos Automotrices, S.A. de C.V. (Radiadores)
Blue Star, S.A. de C.V.	Electronica Vanguard, S.A. de C.V.	Honeywell Productos Automotrices, S.A. de C.V. (Turbos)
Breg México, S. de R.L. de C.V.	Embotelladora de Mexicali, S.A. de C.V.	Hykam Electronica de Mexico, S.A. de C.V.
Cajas Agricolas, S.A. de C.V.	Emermex, S.A de C.V.	Ideas Y/O Enrique Hernández Santiago
Calidad Internacional de Pulido, S.A. de C.V.	Emermex, S.A. de C.V. (Edif-3)	Iluminación Cooper de Las Californias, S. de R.L. de C.V.
Carley de México, S.A. de C.V.	Empaques de Cartón Titán	Impresora y Editorial, S.A. de C.V.
Cd Electrónica de Mexico, S.A de C.V.	Empresas L.M., S. de R.L. de C.V.	Industria de Refrescos del Noreste, S. de R.L. de C.V.
Cementos Químicos Industriales, S.A. de C.V.	Energéticos y Grasas del Norte, S.A. de C.V.	Industrial Vallera de Mexicali, S.A. de C.V. (Coto Technologies)
Cemex Concretos, S.A. de C.V.	Ensambladores Electrónicos de México, S.A.	Industrial Vallera de Mexicali, S.A. de C.V. (Div. Vishay)
Cemex México, S.A. de C.V.	Ensambles de Mexicali, S.A. de C.V.	Industrial Vallera de Mexicali, S.A. de C.V. (Loveday)
Centro Camionero de Mexicali, S.A. de C.V.	Ensambles de Silleria Mexicana, S.A. de C.V.	Industrial Vallera de Mexicali, S.A. de C.V. (Manik Motors)

Table 2-1. Continued

Facility Name	Facility Name	Facility Name
Industrial Vallera de Mexicali, S.A. de C.V. (Martech-Mdi West)	Mextearinas, S.A. de C.V.	Sabritas, S. de R.L. de C.V.
Industrial Vallera de Mexicali, S.A. de C.V. (Másimo)	Molinerea del Valle, S.A. de C.V.	Sánchez Quiñónez César (Servicios y Acabados Industriales)
Industrial Vallera de Mexicali, S.A. de C.V. (Merchants Metals)	Muebles y Diseños El Bajio, S.A. de C.V.	Sds de Mexico, S.A. de C.V.
Industrial Vallera de Mexicali, S.A. de C.V. (Taymar Plastics)	Navarrete Rayos Noel Alejandro	Service Container de Baja, S. de R.L. de C.V.
Industrias SL, S.A. de C.V.	North Safety de Mexicali, S. de R.L. de C.V.	Sigma Lapos, S.A. de C.V.
Industrias Zahori, S.A. de C.V.	Novamex México, S.A. de C.V.	Sigma Lapos, S.A. de C.V. (Sucursal)
Inovación en Concretos, S.A. de C.V.	NSF Mexicali, S. de R.L. de C.V.	Skyworks Solutions, S.A. de C.V.
International Assembly Specialists, S.A. de C.V.	Nutricion Maxima de Baja California, S.A. de C.V.	Solís Meraza María de La Cruz (Transformadora de Maderas Satélite)
Isoclima de México, S.A. de C.V.	Nutrimentos Mexicanos, S.A. de C.V.	SPG de México, S.A. de C.V.
Isoclima de México, S.A. de C.V.	Omega Industries, S.A. de C.V.	Stone Container de México, S. de R.L. de C.V.
J. Cox de México, S.A. de C.V.	Operaciones de Clase Mundial, S.A. de C.V.	Strategic Materials Mexicana, S.A. de C.V.
Jean Charles Mexicali, S.A. de C.V.	Orthodental, S.A. de C.V.	Sukarne Produccion, S.A. de C.V.
Jumex Mexicali, S.A. de C.V.	Panasonic Electric Works Mexicana, S.A. de C.V.	Suntek Manufacturing Technologies, S.A. de C.V.
Kang Seo Mexicana, S.A. de C.V.	Partes Remanufacturadas de México, S.A. de C.V.	Super Muros, S.A. de C.V.
Kb Foam de Mexicali, S.A. de C.V.	Pegamentos Industriales Galileo, S.A. de C.V.	Technologies Solutions And Services, S.A. de C.V.
Kerns Beverages de México, S. de R.L. de C.V.	Pims, S.A. de C.V.	Tecnologías Internacionales de Manufactura, S.A. de C.V.
Kwang Sung Electronics México, S.A. de C.V. (Pta-1)	Placas Termodinámicas, S.A. de C.V.	Tecnomex Industrial, S.A. de C.V.
Kyowa Mexicali, S.A. de C.V.	Ponce Elizalde Armida (Transformadora de Maderas Tramex)	Tecnomex Industrial, S.A. de C.V.
L.G. Innotek Mexicali, S.A. de C.V.	Procesadora y Empacadora de Carnes del Norte, S.A. de C.V.	Temcomex, S.A. de C.V.
Lam-Mex, S.A.	Prodofi, S. de R.L. de C.V.	Teradyne Connection Systems de México, S.A. de C.V.
Lancer Orthodontics de México, S.A. de C.V.	Productos de Acero de Baja, S.A. de C.V.	Thomson
Lechera Mexicana, S.A. de C.V.	Productos de Barro, S.A. de C.V.	Tri-State de Mexico, S.A. de C.V.
LG Electronics Mexicali, S.A. de C.V.	Productos Hola del Noroeste, S.A. de C.V.	Tubos de Acero Internacional, S.A. de C.V.
L-N Safety Glass, S.A. de C.V.	Productos Urólogos de Mexico, S.A de C.V.	Valutech Out Sourcing, S.A. de C.V.
Lopez Cazares Rafael	Promotora Industrial Per, S.A. de C.V.	Veladoras del Pacifico, S.A. de C.V.
Lopez Cazares Rafael (Rancho)	Pulidora de Baja California, S.A. de C.V.	Vimifos, S.A. de C.V.
Maquiladora San Diego, S.A. de C.V.	Pulidora Los Ángeles, S.A. de C.V.	Wabash Technologies de México, S. de R.L. de C.V.
Marko de México, S. de R.L. de C.V.	Puligamex, S.A. de C.V.	Yiro Fabrica, S. de R.L. de C.V.
Masterwork Electronics de México, S.A. de C.V.	Rheem Mexicali, S. de R.L. de C.V.	Zahori, S.A. de C.V.
Megaplast, S.A. de C.V.	Robert Bosch Tool de México, S.A. de C.V.	

- Type of fuel combusted
- Number of stacks

It should be noted that emissions were reported at the facility-level, but not at the process- or equipment-level. Also, stack parameters (i.e., stack coordinates, stack height, stack diameter, exit gas velocity, and exit gas temperature) were not included in the "SIARE.mdb" file.

Based upon information contained in these two files, ICAR developed an Excel spreadsheet ("state_point_source_R0.xls") that compiled the following data for each facility:

- Facility name
- Facility identification number (ID)
- Main activity
- Facility address
- Facility point of contact
- SCIAN code
- Emission quantification (kg/year)
- Type of control
- Facility latitude
- Facility longitude
- Emission points (i.e., the quantity and type of processes that generate emissions)
- Material type (i.e., type of fuel used)
- Basis of emissions estimate.

All of these data were based upon information obtained from the "SIARE.mdb" file.

2.3 Results

The federal jurisdiction point source emissions are shown in Table 2-2. Some conclusions that can be drawn from Table 2-2 are that the power plants are the largest sources of NO_x, CO, and PM_{10}. The PEMEX facility is the largest source of VOC emissions, while the

glass plants (i.e., Fevisa and Vitro AFG) and the paper plant (i.e., Fábrica de Papel San Francisco) are the three largest sources of SO_2. It should be noted that there are no emissions reported from the Federal Electric Commission (Comisión Federal de Electricidad-CFE) geothermal power plant in Cerro Prieto.

Emissions for the 173 state jurisdiction point sources are shown in Table 2-3, by industry group. From Table 2-3, it is clear that the Petroleum and Coal Products Manufacturing sector is the largest emitter of SO_2 and a significant contributor of NO_x. The Other Industrial Manufacturing sector has the largest NO_x emissions. Computer, Communication, and Electronic Manufacturing is the largest emitter of VOC, while Food Manufacturing and Primary Metals are the primary contributors of CO emissions. Emissions for $PM_{2.5}$, NH_3, and CH_4 are not included in Table 2-2 because emissions of these pollutants were not estimated by SPA.

2.4 Quality Assurance

After compiling emissions for federal jurisdiction and state jurisdiction point sources, ICAR conducted quality assurance (QA) of these emissions. ICAR's QA of the federal jurisdiction point sources used a QA checklist that focused on the following aspects:

- Facility information (i.e., North American Industry Classification System [NAICS] codes, address, latitude and longitude)
- Process/equipment information (i.e., process/equipment description, source classification code [SCC], stack assignment)
- Emissions (i.e., pollutant completeness, emissions contribution, particulate matter, hydrocarbons, emission units, emission reasonableness)
- Stack parameters (i.e., stack height, stack diameter, exit gas temperature, exit gas velocity, stack latitude and longitude)
- Operating schedule (i.e., days per week, hours per day)
- Controls (i.e., control device, control efficiency)

Overall, ICAR's QA evaluation indicated fairly complete data for the federal jurisdiction point sources. However, a few specific data elements needed to satisfy the required characteristics of the Mexicali inventory were missing from some or all of the federal jurisdiction

Table 2-2. 2005 Mexicali Federal Jurisdiction Point Source Emissions (Tons per Year)

Facility Name	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$
CFE Central Turbo Gas Mexicali	27.4	11.8		1.9	2.4	
CFE Campo y Centrales Geothermoeléctrico de Cerro Prieto						
Dafmex, S. de R.L. de C.V.	0.4	0.1	0.0	0.3	0.0	0.0
Energía Azteca X, S. de R.L. de C.V.	5,757.9	7.5	12.4	1,433.2	548.4	
Energía de Baja California, S. de R.L. de C.V. Central Termoeléctrica	2,385.5	3.1	5.1	593.8	227.2	
Fevisa Industrial, S.A. de C.V.	277.4	2,500.2	0.5	29.0	140.2	91.6
Fábrica de Papel San Francisco, S.A. de C.V.	206.8	788.6	0.5	80.6	44.7	29.3
Infra, S.A. de C.V. Sucursal Mexicali			0.2			
Kyowa Mexicali, S.A. de C.V.	0.1	0.0	76.3	0.1	0.0	0.0
Kenworth Mexicana, S.A. de C.V.	9.4	1.8	75.6	1.3	0.1	0.1
Maquiladora San Diego, S.A. de C.V.	0.9	0.4	0.2	30.0	2.4	2.2
PEMEX Refinación Planta Mexicali			458.9			
Quimical, S.A. de C.V.	0.0	0.0	0.0	0.0	0.0	0.0
Termoeléctrica de Mexicali, S. de R.L. de C.V.	4,664.2	6.1	10.1	1,161.0	444.2	
Vitro AFG, S.A. de C.V.	601.4	330.1	19.4	233.9	128.0	5.1
Fundiciones San Martin o Felix Jesus del Valle Zamora	0.2	1.1	0.1	71.1	0.0	0.0
Total	**13,931.7**	**3,650.9**	**659.3**	**3,636.2**	**1,537.7**	**128.4**

Table 2-3. 2005 Mexicali State Jurisdiction Point Source Emissions (Tons per Year)

3-Digit NAICS	NAICS Description	NO_x	SO_2	VOC	CO	PM_{10}
212	Mining (metallic and nonmetallic)	1.47	0.00	0.00	0.09	12.92
311	Food industry	70.11	60.84	0.00	243.61	22.53
312	Beverages/tobacco industry	1.80	0.00	0.00	0.23	0.00
321	Wood products industry	0.00	0.00	0.00	0.00	0.72
322	Paper industry	5.58	0.00	3.35	2.67	2.80
323	Publishing industry	0.00	0.00	0.14	0.00	0.00
324	Petroleum and coal products manufacturing	133.76	732.91	0.00	10.07	2.71
325	Chemical industry	0.31	0.00	0.00	0.03	0.00
326	Plastics and rubber industry	27.22	116.90	2.08	9.03	7.97
327	Nonmetallic materials manufacturing	11.04	0.12	4.48	7.06	3.27
331	Primary metals industry	11.31	19.95	0.00	121.58	0.24
332	Metal products manufacturing	4.81	0.00	7.64	16.05	6.89
333	Equipment and machinery manufacturing	5.94	0.00	2.36	7.48	0.48
334	Computer, communication, electronics manufacturing	2.13	0.19	33.98	16.09	9.45
335	Electricity generation equipment manufacturing	0.00	0.00	0.03	0.00	0.02
336	Transportation equipment manufacturing	0.71	0.00	1.42	12.90	12.28
337	Furniture manufacturing	1.99	0.00	14.53	6.06	1.28
339	Other industrial manufacturing	157.76	0.00	3.22	26.85	5.99
493	Storage service	8.02	42.27	0.00	0.08	0.00
	Total	**443.97**	**973.19**	**73.23**	**479.88**	**89.55**

point sources. The first data element was process/equipment SCC, which was missing from all sources; this was gap filled using engineering judgment based upon the specific process equipment description and fuel type. The stack latitude and longitude coordinates were also missing from a number of the sources. In most cases, these coordinates were for sources with a large number of processes that typically did not have well-defined stacks (e.g., vents, etc.). For these sources, the facility latitude and longitude coordinates were assigned to the stack(s).

The most significant data problem identified by ICAR's QA evaluation of the state jurisdiction point sources was that none of the facilities had process- or stack-level emissions. After identifying this issue, ERG and ICAR focused on the seven most significant state jurisdiction point source emitters (i.e., Bimbo, Chromalloy, Sabritas, Sukarne, Temcomex, Thomson, and Zahori). ICAR searched the SPA paper files to obtain process- and stack-level emissions for these seven sources. Data obtained from the SPA paper files included the following:

- Number of sources
- Process/equipment description and codes
- Stack assignment
- Emission units
- Stack coordinates
- Stack height
- Stack diameter
- Exit gas velocity
- Exit gas temperature
- Operating schedule (days/year, hours/day)
- Controls (device and efficiency)

In addition to the detailed data collected for the seven most significant state jurisdiction point source emitters listed above, similar process- and stack-level data from the SPA files were

subsequently researched for another 85 state jurisdiction point sources. However, project constraints prevented similar data collection for the remaining 81 facilities.

Two of the five data quality objectives (DQOs) for the Mexicali inventory project are applicable to point source emissions. These are as follows:

1. Identification of 80% of all federal jurisdiction and state jurisdiction point sources located within the municipality of Mexicali.

   Acceptance criteria: A list of point sources under the federal (SEMARNAT Delegation), and state (SPA) jurisdictions compares to the emissions data, by source, provided by those agencies.

2. Point sources: Emissions estimates with an accuracy of ± 25% for at least 10% of the facilities.

   Acceptance criteria: Estimated emissions for 10% of the total facilities compare to measured emissions of all pollutants with ± 25% accuracy. The emissions data measurements will be obtained from subcontractor ICAR, and will be based on data collected over the past five years in Mexicali.

Based on the federal jurisdiction and state jurisdiction point source methodologies and quality assurance used, both DQOs were met. With regard to DQO #1, all federal jurisdiction and state jurisdiction point sources were included. The lists of federal jurisdiction and state jurisdiction point sources were checked multiple times with SEMARNAT and SPA to ensure completeness. For DQO #2, ICAR checked process- and stack-level data obtained from SEMARNAT electronic files (for federal jurisdiction sources) and from SPA paper files (for state jurisdiction sources) against information they had previously obtained from their industrial clients (2 federal jurisdiction sources and 38 state jurisdiction sources). Overall, emissions data were within ± 25% accuracy.

3.0 AREA SOURCES

Area sources are sources that are too numerous and dispersed to be effectively included in the point source inventory. Area sources include some commercial and/or industrial sources such as autobody shops and dry cleaners, fugitive sources such as paved and unpaved road dust, and fuel combustion in small boilers. The methodology used to estimate the 2005 Mexicali area source emissions is described below.

3.1 Methodology

Wherever possible, local activity data were collected in Mexicali and used to estimate area source emissions. Local activity data collection was facilitated by ICAR, who are conveniently located in Mexicali. ICAR contacted some local sources of activity data directly (e.g., PEMEX, fire departments, etc.); in other situations, ICAR worked through SPA to reach these contacts (e.g., natural gas and LPG distributors, Department of Health, etc.).

If local activity data could not be collected from local contacts, then data from publicly available government agencies were used. In addition, some methodologies and data from the development of the 1999 Mexico NEI and recent emissions inventory work conducted in 2007 in San Luis Río Colorado, Sonora and the northeastern (agricultural) portion of Mexicali were also used (ERG, 2006; ENVIRON and ERG, 2008).

General estimation methodologies for related groups of area source categories are described below and summarized in Table 3-1. Detailed documentation for each area source category is provided through the Area Source Category Forms, which are located in Appendix A. The Area Source Category Forms succinctly summarize the following for each source category: category description, pollutants, method, activity data, emission factors, notes and assumptions, emission calculations, and spatial allocation surrogates.

Table 3-1. General Emission Estimation Methodologies for Area Sources in Mexicali

Source Category	Pollutants	Methodology	Activity Data	Spatial Allocation	Notes
Industrial Fuel Combustion – Distillate & Residual Fuel Oil, Natural Gas, LPG	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4	AP-42 emission factors	Local use statistics	Employee data by sector	Reconciled with point sources.
Commercial/Institutional Fuel Combustion – Natural Gas & LPG	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4	AP-42 emission factors	Local use statistics	Employee data by sector	
Residential Fuel Combustion – Natural Gas & LPG	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4	AP-42 emission factrs	Local use statistics	Household data	
Architectural Coating	VOC	Mexico-specific per capita emission factors	Population	Population	Emissions estimated for solvent- and water-based coatings.
Industrial Surface Coating	VOC	Mexico-specific per employee emission factors	Employment data by sector	Employee data by sector	Seven subcategories. Reconciled with point sources.
Autobody Refinishing	VOC	Mexico-specific per employee emission factors	Employment data	Employee data	
Graphic Arts	VOC	Mexico-specific per capita emission factors	Population	Population	
Dry Cleaning	VOC	Mexico-specific per employee emission factors	Employment data	Employee data	Petroleum-based solvents only; no perchloroethylene
Degreasing	VOC	EIIP per employee emission factors	Employment data by sector	Employee data	Four subcategories. Reconciled with point sources.
Consumer Solvents	VOC	EIIP per capita emission factors (slightly adjusted)	Population	Population	U.S. emission factors – household and automotive factors modified to represent Mexican conditions.
Traffic Markings	VOC	1999 Mexico NEI results	N/A	Paved road network	Local applied quantities were unavailable. Used information from 1999 Mexico NEI.
Asphalt Application	VOC	1999 Mexico NEI results	N/A	Paved road network	Local applied quantities were unavailable. Used information from 1999 Mexico NEI.

Table 3-1. Continued

Source Category	Pollutants	Methodology	Activity Data	Spatial Allocation	Notes
Petroleum Transport and Distribution	VOC	EIIP emission factors	Local fuel throughput	Population	Stage I controls (submerged with vapor balance; no Stage II controls)
Agricultural Burning	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$	ARB emission factors	Burned acreage	Agricultural land use data	Burning limited to wheat, sorghum, and weeds in irrigation canals and ditchbanks.
Agricultural Tilling	PM_{10}, $PM_{2.5}$	ARB emission factors	Planted acreage	Agricultural land use data	
Agricultural Harvesting	PM_{10}, $PM_{2.5}$	ARB emission factors	Harvested acreage	Agricultural land use data	
Agricultural Pesticides	VOC	EIIP emission factors	Harvested acreage, type and quantity of pesticides applied	Agricultural land use data	Pesticide application rates limited to eight crop types
Beef Cattle Feedlots	PM_{10}	ARB emission factors	Number of slaughtered cattle	Agricultural land use data	
Livestock VOC	VOC	ARB emission factors	Number of livestock head	Agricultural land use data	
Livestock Ammonia	NH_3	WRAP NH_3 model emission factors	Number of head	Agricultural land use data	
Fertilizer Application	NH_3	WRAP NH_3 model emission factors	Planted acreage, type and quantity of fertilizers applied	Agricultural land use data	Fertilizer application rates limited to eight crop types
Paved Road Dust	PM_{10}, $PM_{2.5}$	AP-42 emission factor equation	Local VKT, silt loading, vehicle speed, precipitation	Paved road network	VKT to be developed in conjunction with motor vehicle emissions/ consideration of silt loading samples
Unpaved Road Dust	PM_{10}, $PM_{2.5}$	AP-42 emission factor equation	Local VKT, silt content, moisture content, vehicle weight and speed, precipitation	Unpaved road network	VKT to be developed in conjunction with motor vehicle emissions/ consideration of silt content and moisture content samples
Structural Fires	NO_x, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4	EIIP emission factors	Number of houses burned	Population	

Table 3-1. Continued

Source Category	Pollutants	Methodology	Activity Data	Spatial Allocation	Notes
Border Crossing (idling vehicles from Mexicali to California)	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, NH_3	MOBILE6-Mexico emission factors	Local traffic counts, idling times	Border crossing	Emission factors from MOBILE6-Mexico
Brick Kilns	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$	Utilization of previous inventory	Not applicable	Brick kiln locations	
Charbroiling/Street Vendors	NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$	1999 Mexico NEI results	N/A	Population	Local data were unavailable. Used information from 1999 Mexico NEI grown based on population.
Construction Dust	PM_{10}, $PM_{2.5}$	1999 Mexico NEI results	N/A	Population	Local data were unavailable. Used information from 1999 Mexico NEI grown based on population.
Landfills	VOC, CH_4	AP-42 emission factors	Annual quantity of waste landfilled, opening year	Landfill location	
Wastewater Treatment Plant	VOC	U.S. EPA emission factor	Wastewater flow rates	Plant location	Local data unavailable to run model.

3.1.1 Fuel Combustion Categories

Fuel combustion categories include industrial fuel combustion, commercial/institutional fuel combustion, and residential fuel combustion. Wherever possible, local collected data were used to estimate emissions. If local data were unavailable, publicly available government fuel statistics at the national- and regional-level were disaggregated down to the Mexicali municipality.

Industrial fuel combustion includes distillate fuel oil, residual fuel oil, liquefied petroleum gas (LPG), and natural gas while the commercial/institutional and residual fuel combustion source categories are limited to LPG and natural gas. Attempts were made by SPA and ICAR to contact all of the Mexicali fuel distributors. Natural gas statistics were obtained from Ecogas Mexico, S. de R.L. de C.V. (Vivo, 2008). Four LPG distributors were contacted; three of these distributors provided 2005 sales information (Álvarez Sánchez, 2008; Escalante, 2008; Félix Robles, 2008). Sales information from the three LPG distributors that provided information were averaged together and then applied to the LPG distributor that did not provide information.

The PEMEX terminal in Mexicali provided sales information regarding gasoline and distillate fuel (including motor vehicle, agricultural, and industrial uses), but did not respond to requests for information regarding residual fuel oils (Parra Armenta, 2008). Residual fuel oil information was obtained from the PEMEX terminal in Rosarito, which markets residual fuel oil in Mexicali (Miranda Palazuelos, 2008).

Biomass combustion appears to be virtually nonexistent; most heating during the mild winters is electric heating (Martinez, 2007).

3.1.2 Evaporative VOC Categories

Evaporative VOC categories include the following area source categories: architectural surface coating, industrial surface coating, degreasing, graphic arts, traffic markings, dry cleaning, consumer products, asphalt application, and gasoline distribution.

The development of Mexico-specific emission factors as part of the 1999 Mexico NEI for architectural surface coating, industrial surface coating, graphic arts, and dry cleaning was a

significant advance. These emission factors were based upon data from the National Association of Paint and Dye Manufacturers (Asociación Nacional de Fabricantes de Pinturas y Tintas – ANAFAPYT) and the National Chamber of the Dry Cleaning Industry (Cámara Nacional de la Industria de Lavanderías – CANALAVA) (ANAFAPYT, 2003; ANAFAPYT, 2004; CANALAVA, 2002). These Mexico-specific emission factors were combined with Mexicali population and sector-specific employee counts. The industrial surface coating emissions were also reconciled with emissions from point source industrial surface coating operations

Because Mexico-specific emission factors were not developed for degreasing and consumer products, per capita and per employee emission factors were obtained from the Emission Inventory Improvement Program (EIIP) guidance documents (EIIP, 1996; EIIP, 1997). However, recent health survey data collected in San Luis Río Colorado, Sonora indicate lower usage of household products corresponding to increased usage of bleach and a virtual absence of windshield fluid (Fierro and O'Rourke, 2007; Fierro, 2007; Gonzalez-Ayala, 2007); the EIIP emission factors were adjusted to account for these findings. The degreasing emissions were also reconciled with emissions from point source degreasing operations.

Traffic markings and asphalt application quantities were requested from the Mexicali Public Works Department; however, these quantities were not available (Reynoso Ambriz, 2008). As a result, the emission estimates for traffic markings and asphalt application from the 1999 Mexico NEI were used for the municipality of Mexicali.

Gasoline sales statistics were obtained from PEMEX (Parra Armenta, 2008), while gasoline distribution emission factors were obtained from EIIP guidance (EIIP, 2001a).

3.1.3 Agricultural Categories

The northeast portion of Mexicali has significant agricultural activity. Activity data for four specific agricultural categories (i.e., pesticides, burning, tilling, and harvesting) were requested from both the state and federal agricultural agencies. These four agricultural categories were previously estimated for the 2005 San Luis Río Colorado and northeastern Mexicali inventory (ENVIRON and ERG, 2008). Originally, it was anticipated that improved information could be collected from the state and federal agricultural agencies for Mexicali; however, the only useful agricultural information that could be obtained was estimates of

burning of wheat residues, sorghum residues, and weeds in irrigation canals and drainages (Rodríguez Hernández, 2008; López Bojorques, 2008). Agricultural burning methodologies from the California Air Resources Board (ARB) were used to estimate emissions (ARB, 2005).

Crop acreage information was provided for the agricultural tilling and harvesting source categories; however, this information had previously been obtained from a government database (SAGARPA, 2007a). For the previous inventory work in San Luis Río Colorado and northeastern Mexicali, municipality-level emissions for agricultural tilling and harvesting were spatially allocated in order to estimate the portion of emissions that were contained within that project's modeling domain (ENVIRON and ERG, 2008). For the 2005 Mexicali inventory, the previously estimated municipality-level emissions were simply used without the modeling domain spatial allocation. The previous agricultural tilling and harvesting estimates were based upon ARB methodologies (ARB, 2003a; ARB, 2003b).

Emissions from agricultural pesticides were estimated by applying pesticide-specific emission factors to the quantities of pesticides applied. Typical crop-specific pesticide application rates were obtained from state-specific cost production estimates (SAGARPA, 2007b). However, the application rates were only available for a limited number of crops (i.e., garlic, green alfalfa, cotton, broccoli, asparagus, tomatoes [green and red], and wheat). These pesticide application rates were applied to the crop-specific planted acres. specific pesticide application rates. Pesticide emission factors were obtained from EIIP guidance (EIIP, 2001b). Active ingredients were identified based upon Mexico's Registry of Authorized Pesticides (COFEPRIS, 2007). Formulation types were also assumed based upon the predominant formulation types listed in the Registry. Active and inactive ingredient fractions, as well as inert ingredient VOC fractions, were obtained from the EIIP guidance. Pesticide information (i.e., density, % active ingredient, and vapor pressure) was obtained from various databases maintained by California's Department of Pesticide Regulation (DPR, 2007).

Beef cattle feedlots are a source of fugitive dust caused by cattle movement over dusty ground. Slaughter statistics were used to estimate the number of cattle in feedlots. There are approximately 11 feedlots in Mexicali, all located outside of the urban area (Rodríguez Hernández, 2008). It has been estimated that cattle stay in the feedlots for approximately 90

days prior to being slaughtered (Sukarne, 2008). The beef cattle feedlot emission factor was obtained from ARB (ARB, 2004).

VOC emissions from livestock (i.e., beef cattle, dairy cattle, swine, sheep, and goats were also estimated. State- and district-level livestock headcounts were obtained from a SAGARPA database and then allocated to the municipality-level based on slaughter statistics (SAGARPA, 2007c). The livestock VOC emission factors were obtained from ARB (ARB, 2004).

3.1.4 Ammonia Categories

Two important ammonia area source categories in a regional inventory are typically livestock ammonia and agricultural fertilizers. State- and district-level livestock headcounts were obtained from a SAGARPA database and then allocated to the municipality-level based on slaughter statistics (SAGARPA, 2007c). The livestock ammonia emission factors were based on information gathered from literature reviews that is currently being implemented in the latest Western Regional Air Partnership (WRAP) NH_3 modeling (Chinkin et al., 2003).

Emissions from agricultural fertilizers were estimated by applying fertilizer-specific emission factors to the quantities of fertilizer applied. Similar to agricultural pesticides, typical crop-specific fertilizer application rates were obtained from state-specific cost production estimates (SAGARPA, 2007b). As with the pesticides, application rates were only available for a limited number of crops (i.e., garlic, green alfalfa, cotton, broccoli, asparagus, tomatoes [green and red], and wheat). Ammonia emission estimates from fertilizer application were developed using emission factors from the European Environment Agency (EEA, 2002) as recommended in the development and application of the WRAP NH_3 model.

3.1.5 Paved Road Dust

Paved road dust emissions were estimated using the most recent emission factor equation presented in the U.S. EPA Compilation of Air Pollutant Emission Factors (AP-42), Section 13.2.1 (revised November 2006) (U.S. EPA, 1995). Silt samples were collected at 10 locations in Mexicali by ICAR in July 2008. The 10 locations are shown in Figure 3-1 (numbered 1 through 10) and are as follows:

- 1 – Calzada Lázaro Cárdenas between Calzada Benito Juárez and Calzada Venustiano Carranza

Figure 3-1. Location of Paved and Unpaved Road Dust Sampling Sites

1. Calz. Lazaro Cardenas (between Calz. Benito Juarez and Calz. Venustiano Carranza).
2. Calz. Independencia (between Calz. Lopez Mateos and Calz. Rio Culiacan).
3. Calz. Industrial Palaco (between Calz. Gomez Morin and Calz. Lazaro Cardenas).
4. Av. Cristobal Colon or Francisco I. Madero (between Garita and Calz. Justo Sierra).
5. Calz. Anahuac (between Av. Gobernador and Av. Torino).
6. Av. Oaxaca (between C. Uxmal and Heroica Colegio Militar).
7. C. Rio Mocorito (between Calz. Cuahutemoc and Av. F. Montes de Oca).
8. Calz. Laguna de Xochimilco (between Calz. Anahuac and Granada).
9. Av. Rio Verde (between C. Novena and C. Cuarta).
10. C. Centauro del Norte (between Calz. Lazaro Cardenas and Calz. Hector Teran Teran).

J

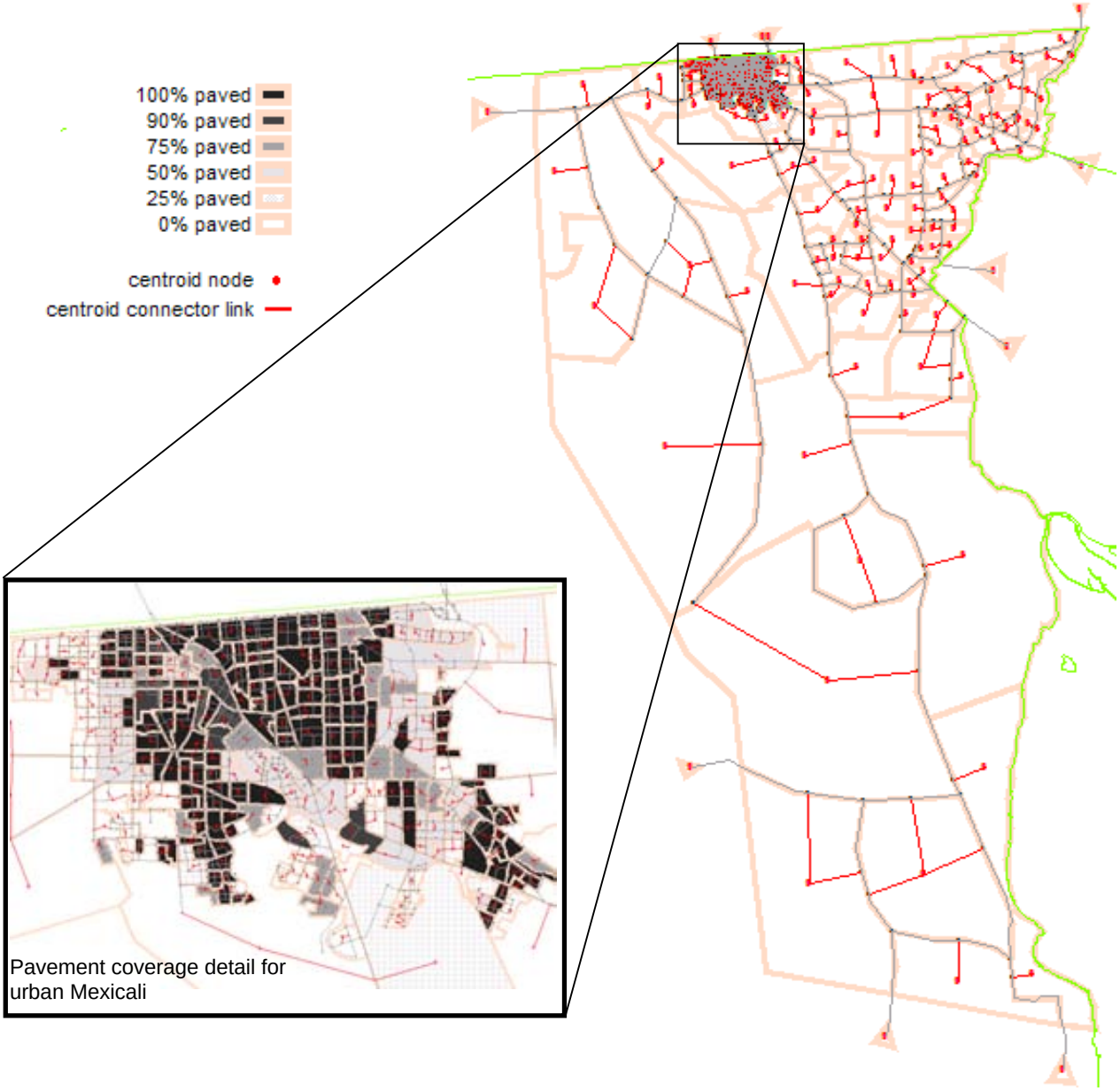
A. Col. El Robledo/El Cipres/Los Encinos (road with bus).
B. Col. Santa Clara/Pueblo Nuevo.
C. Col. Gonzalez Ortega.
D. Fracc. Laguna Campestre.
E. Fracc. Xochicalli.
F. Joaquin Murrieta/Pedro Moreno.
G. Col. Alianza para la Produccion (between PIMSA I and PIMSA IV).
H. Col. Independencia/Benito Juarez/Santa Rosalia.
I. Progreso.
J. Road to Hipolito Landfill.

- 2 – Calzada Independencia between Boulevard Adolfo López Mateos and Calle Río Culiacán
- 3 – Calzada Industrial Palaco between Calzada M. Gómez Morin and Calzada Lázaro Cárdenas
- 4 – Francisco I. Madero between Calle Justo Sierra and Calle "F"
- 5 – Calzada Anahuac between Avenida Torino and Avenida Gobernador
- 6 – Avenida Oaxaca between Calle Uxmal and Heroico Colegio Militar
- 7 – Calle Río Mocorito between Calzada Cuauhtémoc and Avenida F. Montes de Oca
- 8 – Calzada Laguna de Xochimilco between Calzada Anahuac and Granada
- 9 – Avenida Río Verde between Calle Cuarta and Calle Novena
- 10 – Avenida Centauro del Norte between Calzada Lázaro Cárdenas and Calzada Héctor Terán Terán

All samples were collected according to the sampling procedures presented in Appendix C.1 of AP-42 (U.S. EPA, 1995). The samples were analyzed by a laboratory in Tijuana, Laboratorio de Muestreo y Análisis, S.A. de C.V., according to the analytical procedures presented in Appendix C.2 of AP-42 (LMA, 2008a). The paved road dust emission factors (PM_{10} and $PM_{2.5}$) were calculated using the AP-42 methodology; emission factors were calculated for each sampling site and then averaged together. A precipitation adjustment factor of 0.98562 corresponding to 21 "wet" days was also used (NWS, 2005).

The vehicle kilometers traveled (VKT) estimate used to estimate paved road dust emissions was developed in conjunction with the on-road mobile source VKT development (see Section 4.0 of this report for details). Figure 3-2 demonstrates a portion of the analysis to determine the split of paved and unpaved analysis; further details are located in Appendix B, Section VI, of this report. The estimated paved road dust emission factors were then combined with the link-level paved road VKT to obtain link-level paved road dust emissions (Gonzalez-Ayala, 2008a).

Figure 3-2. Pavement Coverage of Mexicali Roads



3.1.6 Unpaved Road Dust

Unpaved road dust emissions were estimated using the most recent emission factor equation presented in AP-42, Section 13.2.2 (revised November 2006) (U.S. EPA, 1995). Silt samples were collected at 10 locations in Mexicali by ICAR in July 2008. The 10 locations are shown in Figure 3-1 (marked with letters A through J) and are as follows:

- A – Calle Caoba between Calle Mauto and Calle Olivo
- B – Calle Mérida between Avenida Nayarit and Avenida Puebla
- C – Avenida Río Atoyac between Calle Onceava and Calle Terceava
- D – Avenida Camino Real between Avenida Campestre and Avenida Valle Verde
- E – Calle Texcoco between Calzada Laguna de Xochimilco and Avenida Acolman
- F – General Jesus M. Garza at Calle Federación
- G – Avenida Ricardo Flores Magón between Calle Bernardo Reyes and Calle Filomeno Mata
- H – Calle de las Delicias between Avenida de los Insurgentes and Avenida Juan Álvarez
- I – Calle Venustiano Carranza between Avenida Nuevo León and Avenida Querétaro
- J – Carretera Relleno Sanitario (on the road to Hipolito Landfill; location in Figure 3-1 is not to scale)

All samples were collected according to the sampling procedures presented in Appendix C.1 of AP-42. The samples were analyzed by Laboratorio de Muestreo y Análisis, S.A. de C.V. in Tijuana according to the analytical procedures presented in Appendix C.2 of AP-42 (LMA, 2008b). The unpaved road dust emission factors were calculated using the AP-42 methodology. Three different emission factors were calculated at each sampling site using different vehicle speeds: urban (11 miles per hour [mph]), suburban (18 mph), and rural (25 mph). Three average emission factors (i.e., urban, suburban, and rural) were then calculated by averaging together the emission factors over all of the sites. A precipitation adjustment factor of 0.94247 corresponding to 21 “wet” days was also used (NWS, 2005).

Three different sets of unpaved emission factors (PM_{10} and $PM_{2.5}$) were estimated for urban, suburban, and rural unpaved roads. The estimated unpaved road dust emission factors were then combined with the link-level unpaved road VKT to obtain link-level unpaved road dust emissions (Gonzalez-Ayala, 2008b).

The VKT estimate used for estimating paved road dust emissions was developed in conjunction with the on-road mobile source VKT development (see Section 4.0 of this report). Figure 3-2 demonstrates a portion of the analysis to determine the split of paved and unpaved analysis; further details are located in Appendix B, Section VI, of this report.

3.1.7 Miscellaneous Burning Categories

Area source inventories can potentially have a number of miscellaneous burning categories. These include wildfires, prescribed fires, on-site incineration, open burning, and structural fires. Based on site visits and interviews, the only miscellaneous burning activity that occurs in Mexicali is structural fires. The number of structural fires was obtained from the Mexicali fire department (Ruiz Burgueño, 2008), while the appropriate emission factors were obtained from EIIP guidance (EIIP, 2001a).

3.1.8 Border Crossings

Emissions from idling vehicles queued to enter the United States were estimated as an area source, and were not included in the on-road mobile sources estimates. There are three border crossings in Mexicali: Calexico and Calexico East (both across from urban Mexicali) and Andrade (across from Algodones). Vehicle count and queue waiting times were obtained from the Bureau of Transportation Statistics (BTS, 2008). Emission factors were estimated using the MOBILE6-Mexico emission factor model (ERG, 2003).

3.1.9 Brick Kilns

The municipality of Mexicali has two distinct brick kiln areas. The first area is in Colonia Campestre and the second area is in Algodones (i.e., northeast Mexicali). Emissions from the Algodones brick kiln area were previously estimated as part of the 2007 inventory work in San Luis Río Colorado and northeastern Mexicali (ENVIRON and ERG, 2008); these emissions were re-used for the Mexicali inventory. Accurate activity data could not be collected at Colonia Campestre, therefore emission estimates from the smaller San Luis Río Colorado

brick kiln area (i.e., Colonia La Grullita) were assumed to be representative of the Colonia Campestre brick kiln emissions.

3.1.10 Charbroiling, Construction Dust, and Bakeries

Detailed Mexicali-specific activity data for charbroiling (restaurants and street vendors), construction dust, and bakeries could not be obtained. Emissions for these area source categories were extrapolated from the 1999 Mexico NEI (ERG, 2006). Construction dust emissions were disaggregated into two categories: residential construction and industrial/commercial construction.

3.1.11 Landfills

The municipality of Mexicali has one landfill (Hipolito landfill) which is located south of the urban area. Emissions were estimated using U.S. EPA's theoretic first order kinetic model of methane production (U.S. EPA, 1995). Many of the site-specific data needed to make an accurate estimation of emissions (e.g., methane generation potential, methane generation rate constant, temperature, etc.) were not available. The only information that was obtained regarding the landfill was the year it opened and the daily quantity of waste landfilled (Villegas Ibarra, 2008). Default values were used for all other necessary parameter variables.

3.1.12 Wastewater Treatment

The municipality of Mexicali has eight wastewater treatment facilities: four in Mexicali and single facilities in Ciudad Morelos (Cuervos), Guadalupe Victoria (Km. 43), Vicente Guerrero (Algodones), and San Felipe. These facilities have a combined installed capacity of 2.964 cubic meters per second (m^3/s) with an actual treatment rate of 1.8494 m^3/s (CNA, 2007). This treatment rate translates to an annual flow of 58,322,678,400 liters. The VOC emission factor for wastewater treatment was then applied to this annual flow (U.S. EPA, 1991).

3.2 Results

The 2005 Mexicali area source emissions inventory is presented in Table 3-2. Examination of Table 3-2 indicates the following regarding area source emissions in Mexicali in 2005:

- Agricultural field burning is the largest source of NO_x followed by industrial natural gas combustion and residential LPG combustion.

Table 3-2. 2005 Mexicali Area Source Emissions (Tons per Year)

Source Category	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Industrial Distillate Combustion	66.47	2.29	0.67	0.00	3.27	0.82	0.00	0.17
Industrial Residual Combustion	0.00	0.00	1.58	0.00	11.06	10.45	0.00	5.64
Industrial Natural Gas Combustion	279.79	0.00	6.30	0.00	8.40	8.73		4.45
Commercial Natural Gas Combustion	2.58	0.02	0.14	2.17	0.20	0.20		0.06
Residential Natural Gas Combustion	7.33	0.05	0.43	3.12	0.59	0.59		0.18
Industrial LPG Combustion	56.33	0.16	3.43	32.09	3.02	3.02		0.82
Commercial LPG Combustion	23.63	0.07	1.44	13.46	1.27	1.27		0.34
Residential LPG Combustion	102.97	0.29	6.27	58.65	5.52	5.52		1.49
Paved Road Dust					4,609.79	422.18		
Unpaved Road Dust					42,331.35	4,209.66		
Charbroiling/Street Vendors	2.77		9.69	150.18	75.44	60.21		
Bakeries			117.94					
Construction Activities – Residential					16.77	3.49		
Construction Activities – Industrial/Commercial					118.59	24.65		
Architectural Surface Coating (Solvent-based)			311.48					
Architectural Surface Coating (Water-based)			167.27					
Autobody Refinishing			78.74					
Traffic Markings			57.06					
Industrial Surface Coating - Wood Furniture			64.78					
Industrial Surface Coating - Other Metallic Products			1,007.07					

Table 3-2. Continued

Source Category	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Industrial Surface Coating – Electronics			32.47					
Industrial Surface Coating – Automotive			1,281.22					
Industrial Surface Coating - Other Transportation			327.24					
Industrial Surface Coating - Other Manufacturing			1,262.62					
Industrial Surface Coating - Industrial Maintenance			433.48					
Degreasing (Vapor and In-line cleaning - Other)			323.47					
Degreasing (Vapor and In-line cleaning – Electronics			284.68					
Degreasing (Cold Cleaning – Other)			744.18					
Degreasing (Cold Cleaning - Automotive Repair)			565.11					
Dry Cleaning			145.74					
Graphic Arts			346.90					
Consumer Solvents - Personal Care			993.18					
Consumer Solvents – Household			84.62					
Consumer Solvents - Automotive Aftermarket			67.61					
Consumer Solvents – Coatings			242.98					
Consumer Solvents - Adhesives and Sealants			761.13					
Consumer Solvents - Federal Insecticide, Fungicide and			409.59					

Table 3-2. Continued

Source Category	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Rodenticide Act (FIFRA) Products								
Consumer Solvents - Miscellaneous			29.58					
Asphalt Application			145.97					
Agricultural Pesticides			216.60					
Gasoline Distribution – Stage I			12.72					
Gasoline Distribution – Stage II			419.88					
Gasoline Distribution - Spillage			25.45					
Underground Tank Breathing			38.17					
Tank Truck Transit			4.45					
Landfills			235.46					6,019.90
Wastewater Treatment			835.76					
Agricultural Tilling					929.76	206.13		
Agricultural Harvesting					767.74	170.21		
Agricultural Field Burning	621.30	126.57	1,078.07	17,384.11	1,596.17	1,521.23		
Fertilizer application – Anhydrous ammonia							660.75	
Fertilizer application – Urea							4,878.75	
Fertilizer application – N-P-K							436.84	
Fertilizer application – Calcium nitrate							2.69	
Fertilizer application – Diammonium phosphate							1.38	
Beef cattle feedlots					290.72			
Livestock – Dairy Cattle (NH_3 and VOC)			322.77				1,389.78	
Livestock –Beef Cattle (NH_3 and VOC)			1,025.42				1,589.51	
Livestock – Swine (NH_3 and VOC)			10.92				36.65	

Table 3-2. Continued

Source Category	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Livestock – Sheep (NH_3 and VOC)			4.43				13.63	
Livestock – Goats (NH_3 and VOC)			2.77				3.70	
Structure Fires	0.11		0.85	4.64	0.82	0.76		0.22
Border Crossing	20.65	0.41	46.86	428.04	2.28	1.91	1.56	
Brick Kilns	21.55	1.23	704.91	777.55	106.51	102.50		
Total	**1,205.48**	**131.09**	**15,301.55**	**18,854.02**	**50,879.89**	**6,753.65**	**9,015.23**	**6,033.28**

Blanks indicate pollutant(s) are not applicable; 0.00 indicates pollutant emissions are insignificant.

- Agricultural field burning is also the largest source of SO_2. Typically, there would be high SO_2 emissions from industrial residual combustion, but reconciliation with the point source inventory reduced the area source industrial residual combustion emissions to zero. In fact, the estimated SO_2 emissions from industrial residual combustion were 3,275 tons.

- There are a number of VOC sources that emit approximately 1,000 tons per year: agricultural field burning, several types of industrial surface coating, several types of consumer solvents, wastewater treatment, and dairy cattle. However, if some of these subcategories are aggregated together, then overall, industrial surface coating and consumer solvents are the most significant area source emitters of VOC.

- Paved and unpaved road dust are the most important PM_{10} and $PM_{2.5}$ sources, while agricultural field burning is also an important source of $PM_{2.5}$.

- Fertilizer application and livestock ammonia are the predominant NH_3 sources, while the landfill is the largest CH_4 source.

3.3 Quality Assurance

Several general quality assurance checks were conducted for the entire Mexicali inventory. These checks (including hand calculations, completeness checks against the 1999 Mexico NEI, emission factor checks, etc.) were conducted for all area source categories. In addition, two of the overall five DQOs for the Mexicali inventory project are applicable to area source emissions:

1. A comprehensive emissions inventory for all source types (i.e., point, area, on-road motor vehicle, and nonroad mobile sources) and all major categories within these source types.

   Acceptance criteria: The source types and major categories accounted for in the EIIP guidance documents are present in the Mexicali emissions inventory, and/or any differences are documented.

2. Area, On-Road Motor Vehicle, and Nonroad Mobile Sources: Emissions estimates with an accuracy of ±50%.

   Acceptance criteria: Estimated emissions using emission factors/models compare to emissions estimated using a fuel-balance approach for all applicable pollutants. The fuel-balance approach will use national statistics, while the preferred inventory methodology will use PEMEX and local fuel distribution data.

The Mexicali area source inventory meets DQO #1. The area source inventory categories were based upon the area source categories previously inventoried in the 1999 Mexico NEI. The

1999 Mexico NEI area source categories were selected by reviewing all source categories included in Emission Inventory Improvement Program (EIIP) and other U.S. EPA guidance documents; Mexican federal environmental staff then identified those categories that either did not exist in Mexico or could be considered to be insignificant. Based upon comments to the draft inventory report, one area source category was added (i.e., VOC from beef cattle feedlots) and one area source category was disaggregated into two (i.e., construction activities into residential construction activities and industrial/commercial construction activities).

With regard to DQO #2, most area source fuel combustion emissions could not be assessed using a fuel-balance approach due to the lack of specific fuel usage data. However, the accuracy of the border crossing emission estimates was evaluated. Border crossing emissions (i.e., idling emissions) are typically not estimated in the U.S. since the wait times resulting in increased emissions generally occur on the Mexican side of the border. The preferred estimation methodology is to obtain queue waiting times and then calculate the distance based upon the lowest allowable vehicle speed in the MOBILE6 emission factor model (i.e., 2.5 miles per hour or 4 kilometers per hour). This calculated distance is then multiplied by the emission factor corresponding to the lowest allowable vehicle speed (Brzezinski, 2009). This methodology was used to estimate border crossing emissions in Mexicali. All inputs to the model and all subsequent post-model emission calculations were rechecked and no errors were found.

Besides the methodology used to estimate border crossing emissions, accurate idling emissions data are relatively unavailable (Brzezinski, 2009). Only one somewhat relevant source of data (i.e., a guidance document related to “long duration idling” for heavy-duty diesel vehicles) was identified (U.S. EPA, 2004). The typical hourly idling emission factors for heavy-duty diesel vehicles identified from this guidance document were 135 g NO_x/hour, and 3.68 g PM_{10}/hour and g $PM_{2.5}$/hour. The heavy-duty diesel vehicle emission factors used in the Mexicali emission estimates were 15.96 g NO_x/mile, 1.27 g PM_{10}/mile, and 1.14 g $PM_{2.5}$/mile. At 2.5 miles per hour, these emission factors translate to 39.9 g NO_x/hour, 3.18 g PM_{10}/hour, and 2.85 g $PM_{2.5}$/hour. Although the PM_{10} and $PM_{2.5}$ emission factors are comparable with those in the guidance document, the NO_x emission factor differs by a factor of over 3.

However, discussions with U.S. EPA staff familiar with idling emissions indicated that long duration idling does not correspond with border crossing idling. Long duration idling involves engine idling of long-haul heavy-duty diesel trucks during mandated rest periods (i.e., typically overnight or 10 hours rest for every 14 hours of driving) to operate air conditioning, heat, or on-board appliances (e.g., televisions, computers, microwaves, etc.). This type of idling occurs with higher engine loads and is fundamentally different than idling that occurs at border crossings (Brzezinski, 2009). In addition, queue waiting times for the three Mexicali border crossings were considerably shorter than the overnight (or long duration) idling (BTS, 2008). Thus, it is not unexpected that the NO_x emissions during long duration idling would be substantially greater than emissions from idling at border crossings. Given these findings, the border crossing emissions were not adjusted.

4.0 ON-ROAD MOBILE SOURCES

On-road mobile sources include all motor vehicles that are allowed to operate on public roadways (e.g., cars, trucks, buses, motorcycles). On-road mobile source emissions include exhaust emissions, as well as various types of evaporative emission processes. Several other types of emissions are caused by on-road mobile sources, including paved and unpaved road dust, Stage II vehicle refueling, and emissions from vehicles idling at the border crossings; these source categories are estimated as area sources and are addressed in Section 3.0 of this report.

Based upon previous experience from developing the 1999 Mexico NEI, availability of the VKT data needed to estimate emissions from on-road motor vehicles at the municipality-level is very limited in Mexico (with the exception of Mexico City, Guadalajara, and other large metropolitan areas). Therefore, traffic and congestion modeling were used to estimate VKT by road segment (i.e., link) for the municipality of Mexicali. The link-level VKT estimates were combined with emission factors generated by the MOBILE6-Mexico model (i.e., a Mexico-specific version of the MOBILE6 emission factor model) to estimate on-road motor vehicle emissions (ERG, 2003). The methodology is described below, and a more detailed explanation of the methodology is presented in Appendix B.

4.1 Methodology

The traffic volume and congestion modeling used a simplified road network, which included freeways, main arterials, collector roads, and “connectors” (i.e., artificial links that modeled local traffic flows). Although the road network was simplified, the road network consisted of 3,603 individual links. In general, the road network is primarily concentrated in the Mexicali urban area, but Federal Highway 2 (connecting Mexicali to Tijuana and San Luis Río Colorado), Federal Highway 5 (connecting Mexicali to Ensenada and San Felipe), as well as rural roads in the agricultural areas in the northeast and rural areas in the south, are also modeled.

The traffic modeling relied upon known Mexican trip generation rates combined with demographic and socio-economic information (i.e., population, household size, income, and employment) for each AGEB (i.e., Mexican equivalent of a census tract). The traffic modeling resulted in daily VKT estimates for daily traffic volumes for each link in the roadway network.

Link-level VKT was then estimated by multiplying each link's daily traffic volume by its length in kilometers. Figure 4-1 shows the Mexicali roadway network and traffic volume intensity during a typical week day.

The traffic volumes for individual roadway network links were assigned to corresponding link-specific congested speed emissions factors from MOBILE6-Mexico in order to estimate daily link-level emissions. Several sets of emission factors were developed to account for different congested speeds (i.e., from 3 to 65 miles per hour [mph]), variations in ambient temperature, and seasonality. Overall emissions were estimated by summing the link-level emissions over the entire Mexicali road network.

Emissions were estimated for the following seven vehicle classifications:

- Light-Duty Gasoline Vehicles (LDGV)
- Light-Duty Gasoline Trucks (LDGT)
- Heavy-Duty Gasoline Vehicles (HDGV)
- Light-Duty Diesel Vehicles (LDDV)
- Light-Duty Diesel Trucks (LDDT)
- Heavy-Duty Diesel Vehicles (HDDV)
- Motorcycles (MC)

4.2 Results

The annual on-road mobile source emissions are presented in Table 4-1. Examination of Table 4-1 indicates the following regarding on-road mobile source emissions in Mexicali in 2005:

- Light-duty gas vehicle and trucks are the primary sources of VOC, CO, NH_3, and CH_4.
- Heavy-duty diesel vehicles are the major sources of NO_x, SO_2, PM_{10}, and $PM_{2.5}$.
- Light-duty diesel vehicles and trucks, as well as motorcycles are relatively insignificant contributors of all pollutants - primarily due to their comparatively small fraction of the overall VKT.

Figure 4-1. Mexicali Loaded Roadway Network Under Weekday Conditions

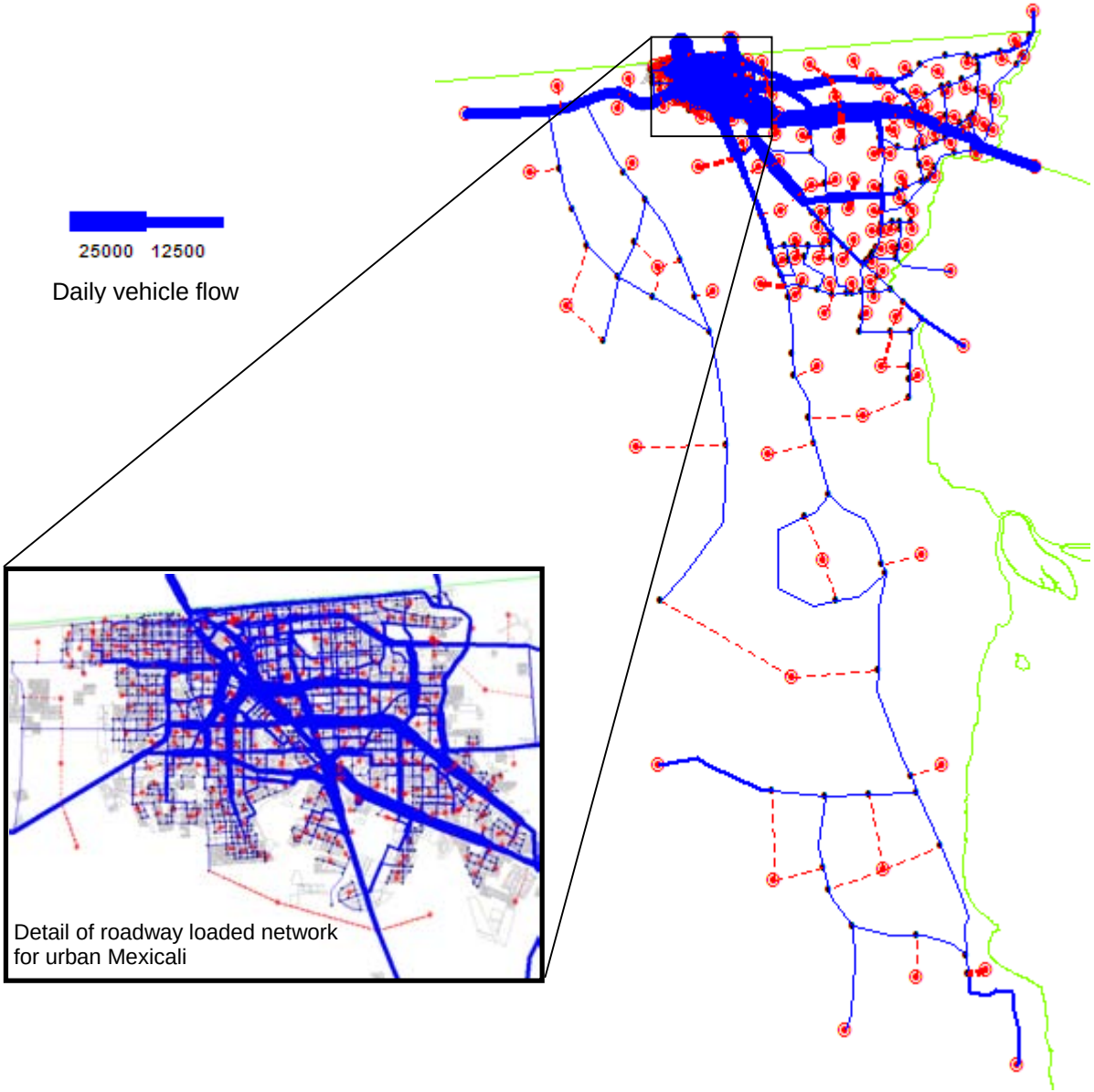


Table 4-1. 2005 Mexicali On-Road Mobile Source Emissions (Tons per Year)

	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
LDGV	1,151.9	25.4	4,550.3	29,441.3	143.3	117.9	124.6	58.4
LDGT	1,523.4	33.1	3,594.6	26,650.3	184.1	155.4	113.5	61.7
HDGV	374.8	4.4	393.5	2,475.8	8.8	6.6	3.3	6.6
LDDV	12.1	0.0	9.9	18.7	2.2	2.2	0.0	0.0
LDDT	7.7	0.0	5.5	11.0	1.1	1.1	0.0	0.0
HDDV	5,463.0	105.8	340.6	1,574.1	424.4	382.5	11.0	13.2
MC	37.5	0.0	82.7	432.1	1.1	0.0	0.0	4.4
Total	**8,570.4**	**168.7**	**8,977.1**	**60,603.4**	**765.0**	**665.8**	**252.4**	**144.4**

4.3 Quality Assurance

As discussed in Section 1.3, a number of general quality assurance checks were conducted for the entire Mexicali inventory. These checks (including hand calculations, completeness checks against the 1999 Mexico NEI, emission factor checks, etc.) were conducted for all on-road mobile source categories. In addition, two of the five data quality objectives (DQOs) for the Mexicali inventory project are applicable to on-road mobile source emissions:

1. A comprehensive emissions inventory for all source types (i.e., point, area, on-road motor vehicle, and nonroad mobile sources) and all major categories within these source types.

   Acceptance criteria: The source types and major categories accounted for in the EIIP guidance documents are present in the Mexicali emissions inventory, and/or any differences are documented.

2. Area, On-Road Motor Vehicle, and Nonroad Mobile Sources: Emissions estimates with an accuracy of ±50%.

   Acceptance criteria: Estimated emissions using emission factors/models compare to emissions estimated using a fuel-balance approach for all applicable pollutants. The fuel-balance approach will use national statistics, while the preferred inventory methodology will use PEMEX and local fuel distribution data.

The Mexicali on-road mobile source inventory meets DQO #1. Emissions were estimated for seven on-road mobile source categories: light-duty gasoline vehicles (LDGV), light-duty gasoline trucks (LDGT), heavy-duty gasoline vehicles (HDGV), light-duty diesel vehicles (LDDV), light-duty diesel trucks (LDDT), heavy-duty diesel vehicles (HDDV), and motorcycles (MC). The MOBILE6-Mexico emission factor does provide emission factors for 28

disaggregated categories; however, the use of 7 categories is consistent with the 1999 Mexico NEI and provides easier reporting.

Also, the Mexicali on-road mobile source inventory also meets DQO #2. The on-road mobile source quality assurance took two forms: comparison of inventory VMT estimates with fuel-based VMT estimates and comparison of inventory motor vehicle activity data with Imperial County motor vehicle activity data.

The first quality assurance step was to compare the Mexicali VMT estimates derived using traffic and congestion modeling with fuel-based VMT estimates; VMT estimates were used instead of VKT estimates for ease of comparison. As part of the Mexicali traffic and congestion modeling, weekday VMT was estimated to be 7,876,541 miles (Appendix B, Table 11) and weekend day VMT was estimated to be 5,496,411 miles (Appendix B, Table 12). Assuming 52 weeks per year consisting of 5 weekdays and 2 weekend days, then annual VMT was estimated to be 2.63×10^9 miles. As described in the area source fuel combustion and evaporative VOC methodology sections of this report (Sections 3.1.1 and 3.1.2), 2005 fuel sales statistics were provided by the PEMEX Mexicali bulk terminal. Additional research conducted as part of this QA procedure indicated that a significant portion of the fuels sold by the PEMEX Mexicali bulk terminal was sold and transported for consumption in Sonora (e.g., San Luis Río Colorado, Puerto Peñasco, Sonoyta, etc.) and other parts of Baja California (i.e., Tecate and Ensenada). Therefore, PEMEX staff provided revised fuel sales statistics of the fuel actually sold in the municipality of Mexicali (i.e., 224,800,401 liters of Magna gasoline, 63,773,310 liters of premium gasoline, and 84,678,057 liters of diesel) (Parra Armenta, 2009). Based on a PEMEX assumption that 60 percent of the diesel is used in motor vehicles, there is a total of 89,664,609 gallons of motor vehicle fuel used in Mexicali. The new vehicle fuel economy for Mexico light-duty vehicles and trucks has been estimated to be 20.5 miles per gallon (mpg) (An and Blumberg, 2005); this value is likely overestimated for the overall in-use vehicle fleet, but fuel economy statistics for the overall Mexico in-use vehicle fleet could not be identified. Multiplying the motor vehicle fuel statistics by the fuel economy resulted in an annual VMT estimate of 1.84×10^9 miles. The fuel-based VMT estimate is approximately 70 percent of the VMT estimate developed using traffic and congestion modeling. Given that the Mexicali VMT estimate developed using traffic and congestion modeling has an approximate uncertainty of ±20

percent (Gonzalez-Ayala, 2008c), then the VMT estimate based on traffic and congestion modeling could potentially be overestimated slightly. This is within the 50 percent uncertainty specified by DQO #4.

The second quality assurance step was to compare Mexicali motor vehicle activity data with Imperial County motor vehicle activity data for reasonableness based upon comments regarding the draft report. Overall Imperial County and Mexicali on-road mobile source emissions data are compared in Table 4-2.

Table 4-2. 2005 Imperial County and Mexicali On-Road Mobile Source Emissions (Tons per Year)

	Imperial County (tons/day)	Imperial County (tons/year)	Mexicali (tons/year)	Ratio (Mexicali/Imperial)
NO_x	19.59	7,150.4	8,570.4	1.199
SO_2	0.14	51.1	168.7	3.301
VOC	6.41	2,339.7	8,977.1	3.837
CO	56.52	20,629.8	60,603.4	2.938
PM_{10}	0.86	313.9	765.0	2.437
$PM_{2.5}$	0.71	259.2	665.8	2.569

Imperial County emissions data were obtained from ARB's Almanac Emission Projection Data (ARB, 2007). As can be seen in the ratios in Table 4-2, the Mexicali on-road mobile source emissions exceed the Imperial County emissions by a factor of 1.2 to 3.8.

As described in the area source methodology (Section 3.0 and Appendix A), the 2005 population of the municipality of Mexicali was 855,962 people. The 2005 population of Imperial County was estimated to be 153,857 people (U.S. Census, 2008). The ratio of Mexicali population to Imperial County population is 5.563. If on-road mobile source emissions were proportional to population, then the Mexicali on-road mobile source emissions would exceed the Imperial County emissions by a similar factor of 5.563.

One potential reason why the Mexicali/Imperial County emission ratios are lower (i.e., 1.2 to 3.8) than the population ratio (i.e., 5.563) is that there is a significantly higher level of vehicle ownership in Imperial County compared to the municipality of Mexicali. Chapter 4 of the Imperial County Air Quality Management Plan (AQMP) provides a count of 121,707 vehicles for the year 2002 and an estimate of 161,231 vehicles for the year 2009 (Imperial, 2008); linear interpolation between these two data points resulted in an estimate of 138,646

vehicles for the year 2005. This results in an estimated vehicle ownership rate of 0.901 vehicles per person. Vehicle registration statistics for the municipality of Mexicali obtained from INEGI indicate a total of 422,357 vehicles registered in 2005 (INEGI, 2008), which corresponds to an estimated vehicle ownership rate of 0.493 vehicles per person. Therefore, Imperial County vehicle ownership rates are significantly higher than in Mexicali.

Chapter 4 of the Imperial County AQMP also provide estimated daily VMT for 2002 and 2009 (4.780×10^6 miles and 6.277×10^6 miles, respectively) (Imperial, 2008); linear interpolation between these two data points resulted in an estimate of 5,421,571 daily VMT in 2005, which corresponds to an annual VMT estimate of 1.98×10^9 miles. Overall Mexicali VMT is higher than overall Imperial County VMT by a factor of 1.33. Perceptions of even higher levels of vehicle activity in Mexicali compared to Imperial County are potentially due to Mexicali vehicle activity being concentrated in the urban portion of Mexicali, compared to Imperial County vehicle activity being spread among a number communities located throughout the county (e.g., El Centro, Brawley, Holtville, Calipatria, Westmorland, etc.).

Based upon these QA analyses, it was felt that the Mexicali on-road mobile source emission estimates were reasonably accurate and that additional adjustments were not needed.

5.0 NONROAD MOBILE SOURCES

Nonroad mobile sources include all equipment that move under their own power, or that are portable, and are not allowed to operate on public roadways. For the 2005 Mexicali emissions inventory, nonroad mobile sources include aircraft and airport ground support equipment and auxiliary power units, locomotives, and agricultural and construction equipment.

Another nonroad source type is commercial marine vessels; however, no major ports with significant commercial marine vessel activity exist in Mexicali. Initially, it was thought that there might be some fishing vessels in some of the communities located on the Gulf of California. However, fishing vessel activity data were not available. Some fishing occurs out of San Felipe, but this appears to consist of tourist fishing, rather than commercial fishing. Due to the lack of data and apparent insignificance of these emissions, emissions for commercial marine vessels were not estimated.

5.1 Methodology

The methodologies used to estimate emissions for the various nonroad mobile source types operating in Mexicali are described below.

5.1.1 Aircraft

There are two airports located in the municipality of Mexicali: General Rodolfo Sánchez Taboada International Airport (east of the Mexicali urban area) and San Felipe International Airport (located in the southern portion of the municipality). Operator-specific landing and takeoff (LTO) statistics and aircraft fleet composition data were obtained from local airport officials (Sanchez Resendiz, 2008). These data included information for both the Mexicali and San Felipe airports; however, the data were not associated with a particular airport. Therefore, it was assumed that all flight data were associated with the General Rodolfo Sánchez Taboada International Airport airport because it is much larger than San Felipe International Airport. Because of the large amount of agricultural activity in Mexicali, crop dusting (or aerial spraying) is a significant activity in the area. Crop dusting activity data (including LTO data, flight lengths, and fuel usage) were provided by staff from the Mexicali crop dusting industry association (Tamayo Moreno, 2008). There were also numerous other general aviation landing

strips located throughout Baja California, but these were not included in the inventory because LTO data for these landing strips were not available.

The aircraft operations information was input into the latest version of the Emissions and Dispersion Modeling System (EDMS 5.0.2, release June 29, 2007) model. The EDMS model was developed by the Federal Aviation Administration and is recommended for use by U.S. EPA. The model contains the latest emission factors from the International Civil Aviation Organization's (ICAO) Engine Exhaust Emissions Data Bank. The default time-in modes for taxi out, take off, climb out, approach, and taxi in were used to run the model. The model output included emissions by aircraft type and total emissions, including emissions for aircraft, ground support equipment, and auxiliary power units. Emissions from other airport-related activities (e.g., parking lots, roadways, stationary sources within airport boundaries, etc.) were not included in the estimates because these sources addressed within other emission inventory categories.

5.1.2 Locomotives

A railway line extends from Mexicali to Puerto Peñasco, Sonora. In order to estimate emissions for locomotives operating within the municipality of Mexicali (i.e., in the locomotive yard and from line haul activities), local locomotive fuel consumption data are needed; however, these data were not available. Visual observations ERG staff indicated that there is very limited locomotive activity in the municipality. Due to the lack of data needed to estimate these emissions for Mexicali, the emissions calculated for the 1999 Mexico NEI were used without adjustment. These are felt to be appropriate because of the observed limited locomotive activity.

5.1.3 Agricultural and Construction Equipment

As part of the 1999 Mexico NEI project, a Mexico-specific version of the U.S. EPA's NONROAD emissions model was developed (i.e., NONROAD-Mexico), which provided a streamlined way to estimate emissions from agricultural and construction equipment (ERG, 2005). To develop a Mexico-specific version of this model, various parameters were adjusted to better reflect conditions in Mexico, including: average annual temperature, altitude, and diesel sulfur content. Also, Mexican state-level agricultural and construction equipment populations were incorporated into the model. Although other nonroad equipment types (lawn and garden,

logging, etc.) exist in Mexico, agricultural and construction equipment were given highest priority during the development of the NONROAD-Mexico model because it was believed that they emitted the most emissions as compared to the other equipment types.

Because the NONROAD-Mexico model contained data which would generate emissions for 1999, only, it was desirable to update the equipment population and operation files to 2005 in order to estimate 2005 emissions for the municipality of Mexicali. However, sufficient recent data were not available.

Due to the lack of data needed to update the NONROAD-Mexico model, the municipality-level nonroad equipment emissions from the 1999 Mexico NEI generated using the NONROAD-Mexico model were extrapolated using 2005 population for Mexicali. This extrapolation method was previously used to estimate nonroad source emissions in the San Luis Río Colorado emission inventory, which included the northeast portion of the municipality of Mexicali (ENVIRON and ERG, 2008). First, for agricultural equipment, it was assumed that agricultural land area would be fairly stable over time. As a result, the agricultural equipment population would likely not grow significantly between 1999 and 2005. For construction equipment, it was assumed that equipment population growth was proportional to population growth. The population of the municipality of Mexicali grew from 764,602 to 855,962 over the same time period; this corresponds to a growth rate of 1.1195 (INEGI, 2000; INEGI, 2006). This growth factor was applied to the 1999 municipality-level emissions estimated using NONROAD-Mexico to obtain 2005 emissions for agricultural and construction equipment.

5.2 Results

The annual nonroad mobile source emissions are presented in Table 5-1; NH_3 and CH_4 emissions were not estimated for nonroad mobile sources. As seen in the table, the largest emissions are from construction and agricultural equipment. The construction and agricultural equipment are dominated by diesel-powered equipment which will cause relatively high NO_x, PM_{10}, and $PM_{2.5}$ emissions. Locomotives have infrequent activity and the portion of aircraft flight durations that occur in the inventory domain are comparatively short relative to the length of an entire flight, with the exception of cropdusters.

Table 5-1. 2005 Mexicali Nonroad Mobile Source Emissions (Tons per Year)

Source Category	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$
Aircraft – Commercial	15.2	1.9	6.8	31.7	0.3	0.3
Airport Auxiliary Power Units	3.7	0.3	1.1	32.4	0.1	0.1
Airport Ground Support Equipment	0.6	0.1	0.0	0.4	0.0	0.0
Locomotives	206.2	1.8	7.8	20.4	5.1	4.6
Construction Equipment	3,100.2	41.6	320.4	1,552.3	348.9	338.5
Agricultural Equipment	1,158.5	14.6	195.7	785.3	195.7	189.8
Aircraft – Cropdusters (General)	0.5	0.6	11.1	784.4	0.0	0.0
Total	**4,485.0**	**60.9**	**542.9**	**3,206.9**	**550.2**	**533.3**

5.3 Quality Assurance

As discussed in Section 1.3, a number of general quality assurance checks were conducted for the entire Mexicali inventory. These checks (including hand calculations, completeness checks against the 1999 Mexico NEI, emission factor checks, etc.) were conducted for all area source categories. In addition, two of the five DQOs for the Mexicali inventory project are applicable to nonroad mobile source emissions:

1. A comprehensive emissions inventory for all source types (i.e., point, area, on-road motor vehicle, and nonroad mobile sources) and all major categories within these source types.

   Acceptance criteria: The source types and major categories accounted for in the EIIP guidance documents are present in the Mexicali emissions inventory, and/or any differences are documented.

2. Area, On-Road Motor Vehicle, and Nonroad Mobile Sources: Emissions estimates with an accuracy of ±50%.

   Acceptance criteria: Estimated emissions using emission factors/models compare to emissions estimated using a fuel-balance approach for all applicable pollutants. The fuel-balance approach will use national statistics, while the preferred inventory methodology will use PEMEX and local fuel distribution data.

The Mexicali nonroad mobile source inventory meets DQO #1. The nonroad mobile source inventory categories were based upon the nonroad mobile source categories previously inventoried in the 1999 Mexico NEI. The 1999 Mexico NEI nonroad mobile source categories were selected by reviewing all source categories included in Emission Inventory Improvement Program (EIIP) and other U.S. EPA guidance documents; Mexican federal environmental staff

then identified those categories that either did not exist in Mexico or could be considered to be insignificant. Some U.S.-specific nonroad mobile source categories typically inventoried were excluded in Mexico (e.g., lawn and garden equipment, logging equipment, recreational vehicles, etc.). It should also be noted that the aircraft and locomotive categories were included as area sources in the 1999 Mexico NEI, but were classified as nonroad mobile sources for the Mexicali inventory. Also, two nonroad mobile source categories not previously inventoried in the 1999 Mexico NEI were included in the Mexico inventory (i.e., airport auxiliary power units and airport ground support equipment). Finally, based upon comments to the draft inventory report, one additional nonroad mobile source category was added (i.e., cropdusting aircraft).

With regard to DQO #2, there were insufficient fuel usage data to assess the nonroad mobile source emissions using a fuel balance approach.

6.0 EMISSION INVENTORY RESULTS

The overall 2005 Mexicali emissions inventory results are shown in Table 6-1. The results are presented by source type and pollutant. Figures 6-1 through 6-8 show the distribution of emissions by source type for each pollutant. The table and figures show that:

- Emissions from federal jurisdiction point sources are considerably larger than emissions from state jurisdiction point sources, even though the ratio of state-to-federal jurisdiction point sources is greater than 10-to-1.
- NO_x and SO_2 emissions are primarily emitted by point sources.
- VOC emissions are emitted by area (i.e., mainly various evaporative source categories) and on-road mobile sources.
- On-road mobile sources are the predominant source of CO.
- Area sources are the largest sources of PM_{10} and $PM_{2.5}$ (i.e., due to unpaved and paved road dust), as well as NH_3 (i.e., from livestock ammonia and fertilizer application) and CH_4 (i.e., from the landfill).

Table 6-1. 2005 Mexicali Emissions Inventory Summary (Tons per Year)

Source Type	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3	CH_4
Point – Federal	13,931.7	3,650.9	659.3	3,636.2	1,537.7	128.4		
Point – State	444.0	973.2	73.0	479.9	89.7			
Area	1,205.5	131.1	15,301.5	18,854.0	50,879.3	6,753.5	9,015.2	6,033.3
On-Road Mobile	8,570.4	168.7	8,977.1	60,603.4	765.0	665.8	252.4	144.4
Nonroad Mobile	4,485.0	60.9	542.9	3,206.9	550.2	533.3	0.0	1.5
Total	**28,636.5**	**4,984.8**	**25,553.8**	**86,780.4**	**53,821.8**	**8,081.0**	**9,267.6**	**6,179.2**

Blanks indicate that pollutant emissions were not applicable or were not estimated due to a lack of data.

Figure 6-1. Mexicali NO_x Emissions

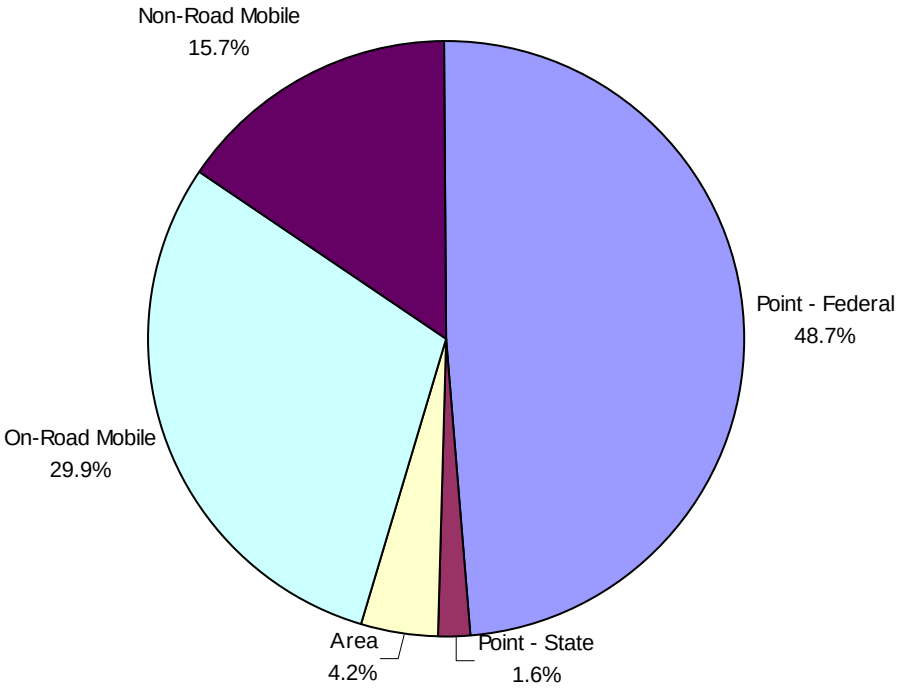


Figure 6-2. Mexicali SO_2 Emissions

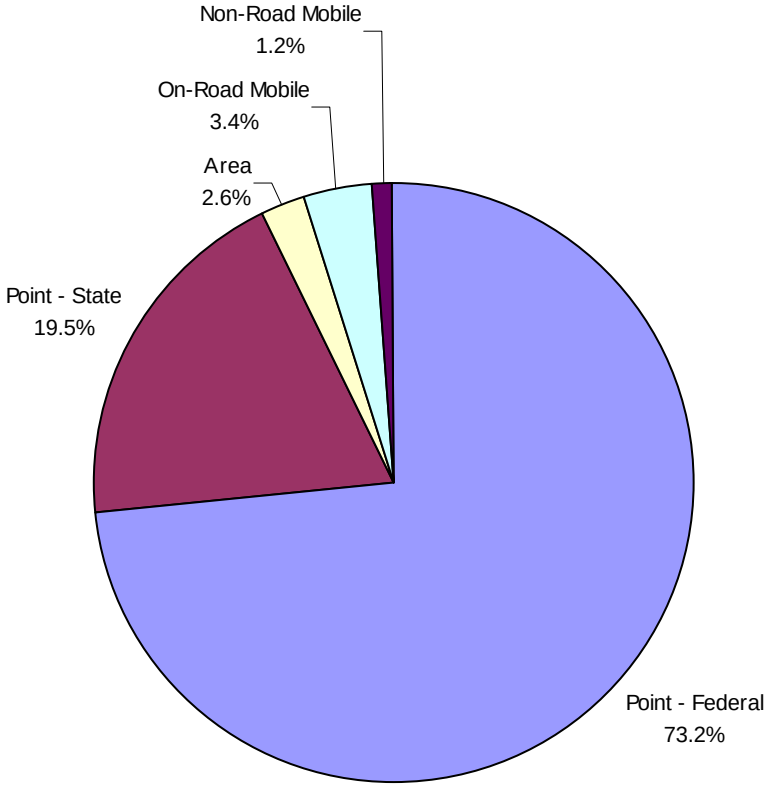


Figure 6-3.- Mexicali VOC Emissions

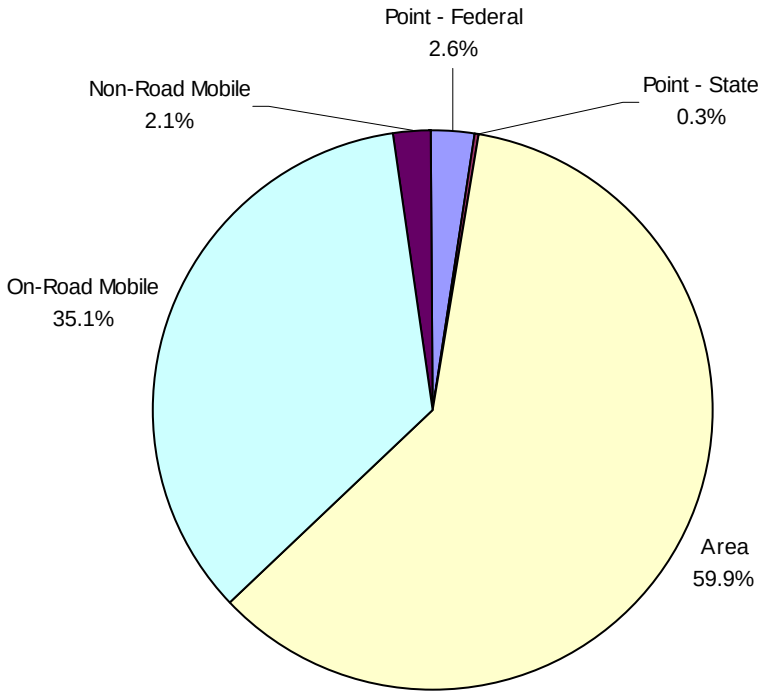


Figure 6-4. Mexicali CO Emissions

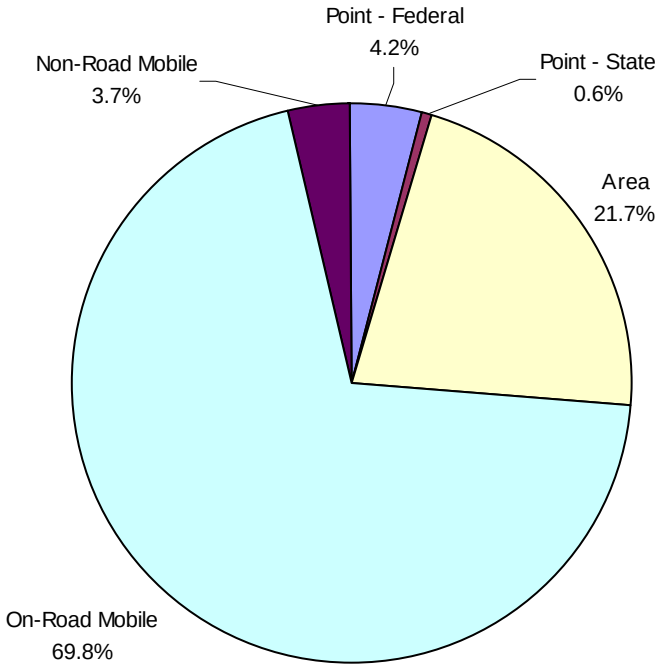


Figure 6-5. Mexicali PM_{10} Emissions

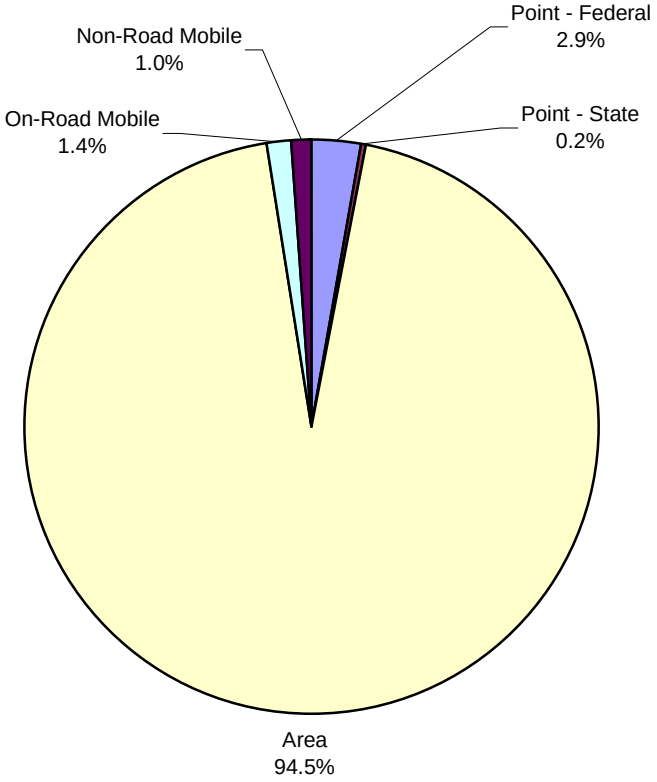


Figure 6-6. Mexicali $PM_{2.5}$ Emissions

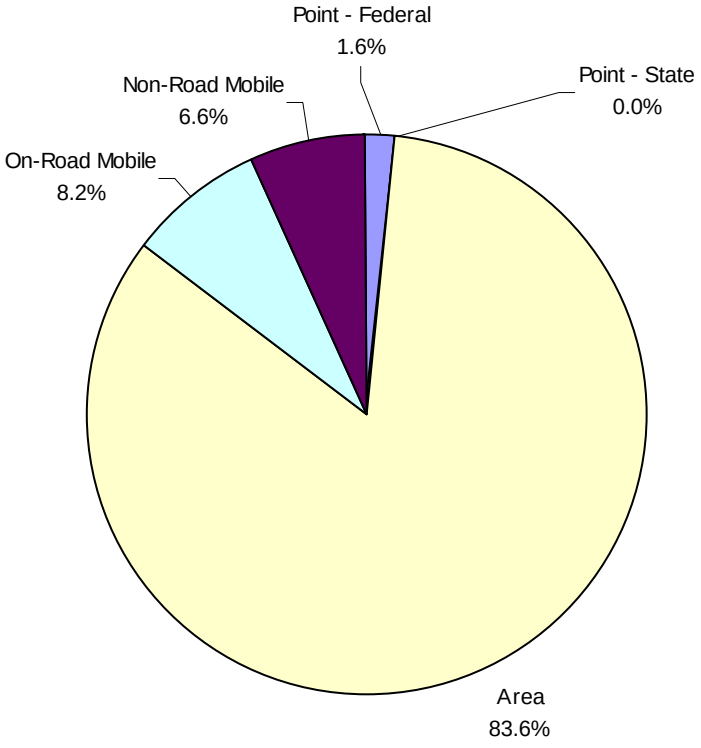


Figure 6-7. Mexicali NH_3 Emissions

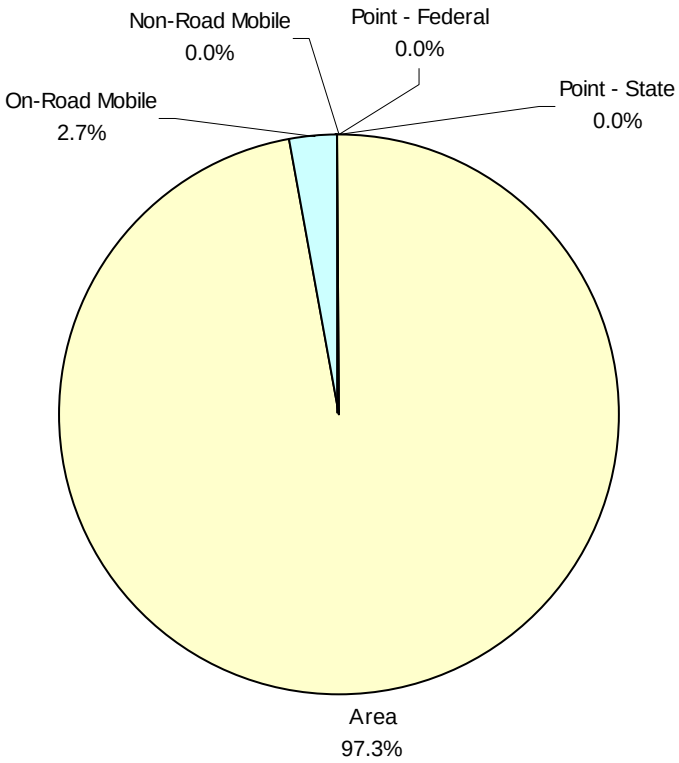
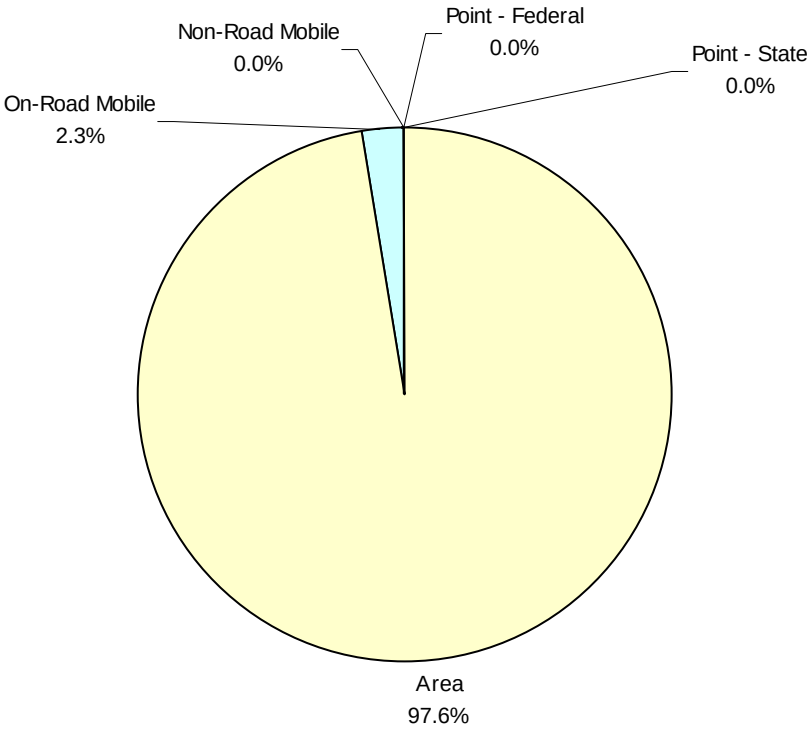


Figure 6-8. Mexicali CH_4 Emissions



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APPENDIX A:

AREA SOURCE CATEGORY FORMS

SOURCE TYPE: Area **SOURCE CATEGORY:** Industrial Fuel Combustion – Distillate

DESCRIPTION:

Industrial consumption of distillate fuel. Emission sources include boilers, furnaces, heaters, internal combustion (IC) engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, and CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Regional-level total distillate fuel usage (Parra Armenta, 2008; Parra Armenta, 2009)

EMISSION FACTORS:

- NO_x – 24 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- SO_x – 5.966 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- VOC – 0.2 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- CO – 5.0 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- PM_{10} – 1.0 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- $PM_{2.5}$ – 0.25 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- NH_3 – 0.052 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])

NOTES AND ASSUMPTIONS:

- It was assumed that 30% of the total distillate was industrial distillate.
- Bulk terminal-weighted average sulfur content of distillate fuel was calculated to be 0.038% (Valdes Cantu, 2003).
- Industrial area source distillate emissions were reconciled with the industrial point source inventory by subtracting point source inventory distillate emissions from the area source distillate emissions.

SAMPLE CALCULATIONS:

Estimate annual emissions from distillate fuel oil combustion in the industrial sector in Mexicali.

Total distillate use (Mexicali terminal) = 84,678,057 liters/yr

Industrial fraction = 0.3 (assumed)

Total industrial distillate use = 84,678,057 liters/yr x 0.3 = 25,403,417 liters/yr = 6,711,603 gallons/yr

<u>Annual municipality-level emissions (reconciled with area sources)</u>:

NO_x emissions = 24 lbs/1,000 gallons × (6,711,603 gallons) = 80.5 tons – 14.1 tons = 66.5 tons
SO_x emissions = 5.966 lbs/1,000 gallons × (6,711,603 gallons) = 20.0 tons – 17.7 tons = 2.3 tons
VOC emissions = 0.2 lbs/1,000 gallons × (6,711,603 gallons) = 0.7 tons – 0.0 tons = 0.7 tons
CO emissions = 5.0 lbs/1,000 gallons × (6,711,603 gallons) = 16.8 tons – 75.0 tons = -58.2 tons (set to zero)
PM_{10} emissions = 1.0 lbs/1,000 gallons × (6,711,603 gallons) = 3.4 tons – 0.1 tons = 3.3 tons
$PM_{2.5}$ emissions = 0.25 lbs/1,000 gallons × (6,711,603 gallons) = 0.8 tons – 0.0 tons = 0.8 tons
CH_4 emissions = 0.052 lbs/1,000 gallons × (6,711,603 gallons) = 0.2 tons – 0.0 tons = 0.2 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Industrial Fuel Combustion – Residual

DESCRIPTION:

Industrial consumption of residual fuel. Emission sources include boilers, furnaces, heaters, internal combustion (IC) engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, and CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Regional-level residual fuel usage (Miranda Palazuelos, 2008)

EMISSION FACTORS:

- NO_x – 47 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- SO_x – 580.74 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- VOC – 0.28 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- CO – 5.0 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- PM_{10} – 32.36 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- $PM_{2.5}$ – 21.08 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])
- CH_4 – 1.0 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.3 – Updated September 1998])

NOTES AND ASSUMPTIONS:

- Bulk terminal-weighted average sulfur content of residual fuel was estimated to be 3.699% (combustóleo, Intermedio 15, and Industrial Combustible) (Valdes Cantu, 2003).
- Industrial area source residual emissions were reconciled with the industrial point source inventory by subtracting point source inventory residual emissions from the area source residual emissions.

SAMPLE CALCULATIONS:

Estimate annual emissions from residual fuel oil combustion in the industrial sector in Mexicali.

Regional residual use (Rosarito terminal) = 121,974,708 liters/yr = 32,225,815 gallons/yr

Mexicali fraction = 0.35 (assumed)

Total industrial distillate use = 32,225,815 gallons/yr x 0.35 = 11,279,035 gallons/yr

<u>Annual municipality-level emissions (reconciled with area sources)</u>:

NO_x emissions = 47 lbs/1,000 gallons × (11,279,035 gallons) = 265.1 tons – 435.6 tons = -170.5 tons (set to zero)
SO_x emissions = 580.74 lbs/1,000 gallons × (11,279,035 gallons) = 3,275.1 tons – 3,776.2 tons = -501.1 tons (set to zero)
VOC emissions = 0.28 lbs/1,000 gallons × (11,279,035 gallons) = 1.6 tons – 0.0 tons = 1.6 tons
CO emissions = 5.0 lbs/1,000 gallons × (11,279,035 gallons) = 28.2 tons – 31.9 tons = -3.7 tons (set to zero)
PM_{10} emissions = 32.36 lbs/1,000 gallons × (11,279,035 gallons) = 182.5 tons – 171.4 tons = 11.1 tons
$PM_{2.5}$ emissions = 21.08 lbs/1,000 gallons × (11,279,035 gallons) = 118.9 tons – 108.4 tons = 10.5 tons
CH_4 emissions = 1.0 lbs/1,000 gallons × (11,279,035 gallons) = 5.6 tons – 0.0 tons = 5.6 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Industrial Fuel Combustion – Natural Gas

DESCRIPTION:

Industrial combustion of natural gas. Emission sources include boilers, furnaces, heaters, IC engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Annual natural gas quantity used in the industrial sector (Vivo, 2008)

EMISSION FACTORS:

- NO_x – 280 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- SO_x – 0.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- VOC – 5.5 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CO – 84 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- PM_{10} – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- $PM_{2.5}$ – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CH_4 – 2.3 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])

NOTES AND ASSUMPTIONS:

- Industrial area source natural gas emissions were reconciled with the industrial point source inventory by subtracting point source inventory natural gas emissions from the area source natural gas emissions.

SAMPLE CALCULATIONS:

Estimate annual emissions from industrial natural gas usage in Mexicali.

Annual industrial natural gas usage = 109.6 x 10^6 m^3 = (3,871.7 x 10^6 scf)

<u>Annual municipality-level emissions – Mexicali</u>:

NO_x – (3,871.7 x 10^6 scf) x 280 lb/10^6 scf = 542.0 tons – 262.2 tons = 279.8 tons
SO_x – (3,871.7 x 10^6 scf) x 0.6 lb/10^6 scf = 1.2 tons – 1.9 tons = -0.7 tons (set to zero)
VOC – (3,871.7 x 10^6 scf) x 5.5 lb/10^6 scf = 10.6 tons – 4.3 tons = 6.3 tons
CO – (3,871.7 x 10^6 scf) x 84 lb/10^6 scf = 162.6 tons – 216.8 tons = -54.2 tons (set to zero)
PM_{10} – (3,871.7 x 10^6 scf) x 7.6 lb/10^6 scf = 14.7 tons – 6.3 tons = 8.4 tons
$PM_{2.5}$ – (3,871.7 x 10^6 scf) x 7.6 lb/10^6 scf = 14.7 tons – 6.0 tons = 8.7 tons
CH_4 – (3,871.7 x 10^6 scf) x 2.3 lb/10^6 scf = 4.5 tons – 0.0 tons = 4.5 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Commercial/Institutional Fuel Combustion – Natural Gas

DESCRIPTION:

Commercial/institutional combustion of natural gas. Emission sources include boilers, furnaces, heaters, internal combustion (IC) engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Annual natural gas quantity used in the commercial sector (Vivo, 2008)

EMISSION FACTORS:

- NO_x – 100 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- SO_x – 0.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- VOC – 5.5 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CO – 84 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- PM_{10} – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- $PM_{2.5}$ – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CH_4 – 2.3 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])

NOTES AND ASSUMPTIONS:

- None.

SAMPLE CALCULATIONS:

Estimate annual emissions from commercial natural gas usage in Mexicali.

Annual industrial natural gas usage = 1.462 x 10^6 m^3 = (51.6 x 10^6 scf)

<u>Annual municipality-level emissions – Mexicali</u>:

NO_x – (51.64 x 10^6 scf) x 100 lb/10^6 scf = 2.58 tons
SO_x – (51.64 x 10^6 scf) x 0.6 lb/10^6 scf = 0.02 tons
VOC – (51.64 x 10^6 scf) x 5.5 lb/10^6 scf = 0.14 tons
CO – (51.64 x 10^6 scf) x 84 lb/10^6 scf = 2.17 tons
PM_{10} – (51.64 x 10^6 scf) x 7.6 lb/10^6 scf = 0.20 tons
$PM_{2.5}$ – (51.64 x 10^6 scf) x 7.6 lb/10^6 scf = 0.20 tons
CH_4 – (51.64 x 10^6 scf) x 2.3 lb/10^6 scf = 0.06 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Residential Fuel Combustion – Natural Gas

DESCRIPTION:

Residential combustion of natural gas for heating and cooking.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$, CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Households

ACTIVITY DATA:

- Annual natural gas quantity used in the residential sector (Vivo, 2008)

EMISSION FACTORS:

- NO_x – 94 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- SO_x – 0.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- VOC – 5.5 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CO – 40 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- PM_{10} – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- $PM_{2.5}$ – 7.6 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])
- CH_4 – 2.3 lb/10^6 scf (U.S. EPA, 1995 [Section 1.4 – Updated July 1998])

NOTES AND ASSUMPTIONS:

- None.

SAMPLE CALCULATIONS:

Estimate annual emissions from residential natural gas usage in Mexicali.

Annual residential natural gas usage = 4.417 x 10^6 m^3 = (156.01 x 10^6 scf)

<u>Annual municipality-level emissions – Mexicali</u>:

NO_x – (156.01 x 10^6 scf) x 94 lb/10^6 scf = 7.33 tons
SO_x – (156.01 x 10^6 scf) x 0.6 lb/10^6 scf = 0.05 tons
VOC – (156.01 x 10^6 scf) x 5.5 lb/10^6 scf = 0.43 tons
CO – (156.01 x 10^6 scf) x 40 lb/10^6 scf = 3.12 tons
PM_{10} – (156.01 x 10^6 scf) x 7.6 lb/10^6 scf = 0.59 tons
$PM_{2.5}$ – (156.01 x 10^6 scf) x 7.6 lb/10^6 scf = 0.59 tons
CH_4 – (156.01 x 10^6 scf) x 2.3 lb/10^6 scf = 0.18 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Industrial Fuel Combustion – LPG

DESCRIPTION:

Industrial combustion of liquefied petroleum gas (LPG). Emission sources include boilers, furnaces, heaters, internal combustion (IC) engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$,and CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Annual LPG used in the industrial sector (Álvarez Sánchez, 2008; Escalante, 2008; Félix Robles, 2008)

EMISSION FACTORS:

- NO_x – 13.8 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- SO_x – 0.0039 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- VOC – 0.84 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CO – 7.86 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- PM (PM_{10} and $PM_{2.5}$) – 0.74 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CH_4 – 0.2 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])

NOTES AND ASSUMPTIONS:

- Three out of four LPG distributors (i.e., Gas Silza, Kino Gas del Noroeste, and Hidrocarburos del Noroeste) responded to requests for information. The fourth distributor (i.e., Gas Butano Propano de Baja California) did not respond. It was assumed that LPG distributed by Gas Butano Propano was equal to the average of the quantities distributed by Gas Silza and Kino Gas.
- LPG is assumed to contain 60% propane and 40% butane.
- Sulfur content of propane and butane is assumed to be 0.4114 gr/100 ft^3.
- Emission factor for total PM is assumed to represent PM_{10} and $PM_{2.5}$ emissions.
- Industrial area source LPG emissions were reconciled with the industrial point source inventory by subtracting point source inventory LPG emissions from the area source LPG emissions.

SAMPLE CALCULATIONS:

Estimate annual emissions from industrial LPG usage in Mexicali.

Industrial LPG usage = 8,167,952 gallons/year

Annual NO_x emissions = 13.8 lbs/1,000 gallons × (8,167,952 gallons) = 56.4 tons – 0.1 tons = 56.3 tons
Annual SO_x emissions = 0.039 lbs/1,000 gallons × (8,167,952 gallons) = 0.2 tons – 0.0 tons = 0.2 tons
Annual VOC emissions = 0.84 lbs/1,000 gallons × (8,167,952 gallons) = 3.4 tons – 0.0 tons = 3.4 tons
Annual CO emissions = 7.86 lbs/1,000 gallons × (8,167,952 gallons) = 32.1 tons – 0.0 tons = 32.1 tons
Annual PM_{10} emissions = 0.74 lbs/1,000 gallons × (8,167,952 gallons) = 3.0 tons – 0.0 tons = 3.0 tons
Annual $PM_{2.5}$ emissions = 0.74 lbs/1,000 gallons × (8,167,952 gallons) = 3.0 tons – 0.0 tons = 3.0 tons
Annual CH_4 emissions = 0.2 lbs/1,000 gallons × (8,167,952 gallons) = 0.8 tons – 0.0 tons = 0.8 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Commercial Fuel Combustion – LPG

DESCRIPTION:

Commercial combustion of liquefied petroleum gas (LPG). Emission sources include boilers, furnaces, heaters, internal combustion (IC) engines, etc.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$,and CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- Annual LPG used in the commercial sector (Álvarez Sánchez, 2008; Escalante, 2008; Félix Robles, 2008)

EMISSION FACTORS:

- NO_x – 13.8 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- SO_x – 0.0039 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- VOC – 0.84 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CO – 7.86 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- PM (PM_{10} and $PM_{2.5}$) – 0.74 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CH_4 – 0.2 lbs/1,000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])

NOTES AND ASSUMPTIONS:

- Three out of four LPG distributors (i.e., Gas Silza, Kino Gas del Noroeste, and Hidrocarburos del Noroeste) responded to requests for information. The fourth distributor (i.e., Gas Butano Propano de Baja California) did not respond. It was assumed that LPG distributed by Gas Butano Propano was equal to the average of the quantities distributed by Gas Silza and Kino Gas.
- LPG is assumed to contain 60% propane and 40% butane.
- Sulfur content of propane and butane is assumed to be 0.4114 gr/100 ft^3.
- Emission factor for total PM is assumed to represent PM_{10} and $PM_{2.5}$ emissions.

SAMPLE CALCULATIONS:

Estimate annual emissions from commercial LPG usage in Mexicali.

Commercial LPG usage = 3,424,855 gallons/year

Annual NO_x emissions = 13.8 lbs/1,000 gallons × (3,424,855 gallons) = 23.6 tpy
Annual SO_x emissions = 0.039 lbs/1,000 gallons × (3,424,855 gallons) = 0.1 tpy
Annual VOC emissions = 0.84 lbs/1,000 gallons × (3,424,855 gallons) = 1.4 tpy
Annual CO emissions = 7.86 lbs/1,000 gallons × (3,424,855 gallons) = 13.5 tpy
Annual PM_{10} emissions = 0.74 lbs/1,000 gallons × (3,424,855 gallons) = 1.3 tpy
Annual $PM_{2.5}$ emissions = 0.74 lbs/1,000 gallons × (3,424,855 gallons) = 1.3 tpy
Annual CH_4 emissions = 0.2 lbs/1,000 gallons × (3,424,855 gallons) = 0.3 tpy

SOURCE TYPE: Area **SOURCE CATEGORY:** Residential Fuel Combustion – LPG

DESCRIPTION:

Residential combustion of liquefied petroleum gas (LPG) for heating and cooking.

POLLUTANTS:

NO_x, SO_x, VOC, CO, PM_{10}, $PM_{2.5}$,and CH_4

METHOD:

Emission factors

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- Annual LPG used in the residential sector (Álvarez Sánchez, 2008; Escalante, 2008; Félix Robles, 2008)

EMISSION FACTORS:

- NO_x – 13.8 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- SO_x – 0.0039 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- VOC – 0.84 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CO – 7.86 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- PM (PM_{10} and $PM_{2.5}$) – 0.74 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])
- CH_4 – 0.2 lbs/1000 gallons (U.S. EPA, 1995 [Section 1.5 – Updated July 2008])

NOTES AND ASSUMPTIONS:

- Three out of four LPG distributors (i.e., Gas Silza, Kino Gas del Noroeste, and Hidrocarburos del Noroeste) responded to requests for information. The fourth distributor (i.e., Gas Butano Propano de Baja California) did not respond. It was assumed that LPG distributed by Gas Butano Propano was equal to the average of the quantities distributed by Gas Silza and Kino Gas.
- LPG is assumed to contain 60% propane and 40% butane.
- Sulfur content of propane and butane is assumed to be 0.4114 gr/100 ft^3.
- Emission factor for total PM is assumed to represent PM_{10} and $PM_{2.5}$ emissions.
- Residential emission factors are assumed to be identical to commercial emission factors.

SAMPLE CALCULATIONS:

Estimate annual emissions from residential LPG usage in Mexicali.

Residential LPG usage = 14,923,787 gallons/year

Annual NO_x emissions = 13.8 lbs/1,000 gallons × (14,923,787 gallons) = 103.0 tpy
Annual SO_x emissions = 0.039 lbs/1,000 gallons × (14,923,787 gallons) = 0.3 tpy
Annual VOC emissions = 0.84 lbs/1,000 gallons × (14,923,787 gallons) = 6.3 tpy
Annual CO emissions = 7.86 lbs/1,000 gallons × (14,923,787 gallons) = 58.7 tpy
Annual PM_{10} emissions = 0.74 lbs/1,000 gallons × (14,923,787 gallons) = 5.5 tpy
Annual $PM_{2.5}$ emissions = 0.74 lbs/1,000 gallons × (14,923,787 gallons) = 5.5 tpy
Annual CH_4 emissions = 0.2 lbs/1,000 gallons × (14,923,787 gallons) = 1.5 tpy

SOURCE TYPE: Area **SOURCE CATEGORY:** Architectural Surface Coatings

DESCRIPTION:
Surface coatings such as paints, paint primer, varnish, or lacquer applied to architectural surfaces.

POLLUTANTS:
VOC

METHOD:
Emission factors

SPATIAL ALLOCATION:
Population

ACTIVITY DATA:
- 2005 Mexicali population (INEGI, 2006)

EMISSION FACTORS:
- VOC (solvent-based) – 0.728 lbs/person-yr (ERG, 2006)
- VOC (water-based) – 0.391 lbs/person-yr (ERG, 2006)

NOTES AND ASSUMPTIONS:
- Mexico-specific emission factors derived as part of the development of the 1999 Mexico National Emissions Inventory using data from ANAFAPYT (ANAFAPYT, 2003).

SAMPLE CALCULATIONS:
Estimate annual emissions from architectural surface coatings in Mexicali.

Activity data:
Mexicali population = 855,962

Annual municipality-level emissions:

VOC emissions (solvent-based) = 0.728 lbs/person-yr × (855,962 people) = 311.5 tons
VOC emissions (water-based) = 0.391 lbs/person-yr × (855,962 people) = 167.3 tons

Total VOC emissions = 311.5 tons + 167.3 tons = 478.8 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Industrial Surface Coating

DESCRIPTION:
Coatings such as paints, varnish, lacquer, and paint primer. Surface coatings are applied to a wide variety of products, including furniture, cans, automobiles, airplanes and other transportation equipment, machinery, household appliances, flat wood, wire, and other miscellaneous products. In addition, coatings are used in maintenance operations at industrial facilities.

POLLUTANTS:
VOC

METHOD:
Per employee emission factors derived from Mexico paint sales.

SPATIAL ALLOCATION:
Employee data by sector

ACTIVITY DATA:

- 2005 Mexicali employee counts (INEGI, 2005)
  - Wood and metal furniture (NAICS 33711x, 33712x, 33721x)
  - Other metallic products (NAICS 332xxx, 333xxx)
  - Electronics and electrical equipment (NAICS 334xxx, 335xxx)
  - Automotive industry (NAICS 3361xx, 3362xx, 3363xx)
  - Other transportation industry (NAICS 3364xx, 3365xx, 3366xx, 3369xx)
  - Other manufacturing industries (NAICS 339xxx)
  - Industrial maintenance coatings (NAICS 31xxxx, 32xxxx, 33xxxx)

EMISSION FACTORS:

- Per employee emission factors (ERG, 2006)
  - VOC – Wood and metal furniture – 270.24 lbs/employee-yr
  - VOC – Other metallic products – 225.13 lbs/employee-yr
  - VOC – Electronics and electrical equipment – 3.33 lbs/employee-yr
  - VOC – Automotive industry – 376.19 lbs/employee-yr
  - VOC – Other transportation industry – 256.66 lbs/employee-yr
  - VOC – Other manufacturing industries – 342.82 lbs/employee-yr
  - VOC – Industrial maintenance coatings – 13.98 lbs/employee-yr

NOTES AND ASSUMPTIONS:

- Mexico-specific emission factors derived as part of the development of the 1999 Mexico National Emissions Inventory using data from ANAFAPYT (ANAFAPYT, 2003).
- Reconciliation with the point source inventory was conducted by subtracting point source emission estimates from any point sources with NAICS codes covered by the industrial surface coating area source category.

SAMPLE CALCULATIONS:

Estimate annual emissions from industrial surface coating in Mexicali.

Activity data:

Mexicali employee count = 547 (wood and metal furniture)
Mexicali employee count = 8,990 (other metallic products)
Mexicali employee count = 19,677 (electronics and electrical equipment)
Mexicali employee count = 6,812 (automotive industry)
Mexicali employee count = 2,550 (other transportation industry)
Mexicali employee count = 7,367 (other manufacturing industries)
Mexicali employee count = 62,015 (industrial maintenance coatings)

Annual municipality-level emissions:

VOC emissions = 270.24 lbs/employee-yr × (547 employees) = 73.9 tons – 9.1 tons = 64.8 tons
VOC emissions = 225.13 lbs/employee-yr × (8,990 employees) = 1,012.0 tons – 4.9 tons = 1,007.1 tons
VOC emissions = 3.33 lbs/employee-yr × (19,677 employees) = 32.8 tons – 0.3 tons = 32.5 tons
VOC emissions = 376.19 lbs/employee-yr × (6,812 employees) = 1,281.3 tons – 0.1 tons = 1,281.2 tons
VOC emissions = 256.66 lbs/employee-yr × (2,550 employees) = 327.2 tons – 0.0 tons = 327.2 tons
VOC emissions = 342.82 lbs/employee-yr × (7,367 employees) = 1,262.8 tons – 0.2 tons = 1,262.6 tons
VOC emissions = 13.98 lbs/employee-yr × (62,015 employees) = 433.5 tons – 0.0 tons = 433.5 tons

Total VOC emissions = 64.8 tons + 1,007.1 tons + 32.5 tons + 1,281.2 tons + 327.2 tons + 1,262.6 tons + 433.5 tons = 4,408.9 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Autobody Refinishing

DESCRIPTION:

Repair and restoration of automobiles, light trucks, and other vehicle bodies. Most repair jobs include refinishing on a portion of the vehicle; new vehicle coating is excluded from this source category.

POLLUTANTS:

VOC

METHOD:

Emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- 2005 Mexicali employee count (NAICS 811121) (INEGI, 2005)

EMISSION FACTORS:

- VOC – 277.25 lbs/employee-yr (ERG, 2006)

NOTES AND ASSUMPTIONS:

- Mexico-specific emission factor derived as part of the development of the Mexico National Emissions Inventory using data from ANAFAPYT (ANAFAPYT, 2003).

SAMPLE CALCULATIONS:

Estimate annual emissions from autobody refinishing in Mexicali.

Activity data:
Mexicali employee count = 568

Municipality-level emissions:

Annual VOC emissions = 277.25 lbs/employee-yr × (568 employees) = 78.7 tons

Total VOC emissions = 78.7 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Graphic Arts

DESCRIPTION:

Various graphic arts processes including typography, offset (web and sheet), rotogravure, silk screening, and flexography.

POLLUTANTS:

VOC

METHOD:

Emission factors

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- 2005 Mexicali population (INEGI, 2006)

EMISSION FACTORS:

- VOC – 0.811 lbs/person-yr (ERG, 2006)

NOTES AND ASSUMPTIONS:

- Mexico-specific emission factor derived as part of the development of the Mexico National Emissions Inventory using data from ANAFAPYT (ANAFAPYT, 2004).

SAMPLE CALCULATIONS:

Estimate annual emissions from graphic arts in Mexicali.

Activity data:
Mexicali population = 855,962

Municipality-level emissions:

Annual VOC emissions = 0.811 lbs/person-yr × (855,962 people) = 346.9 tons

Total VOC emissions = 346.9 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Traffic Markings

DESCRIPTION:

Various emission sources in this source category include painting of centerlines, edge stripes, directional markings, and paved and unpaved surfaces to improve traffic flow. These include solvent- and water-based paints.

POLLUTANTS:

VOC

METHOD:

Estimates from Mexico NEI (ERG, 2006)

SPATIAL ALLOCATION:

Paved road network

ACTIVITY DATA:

- Not applicable

EMISSION FACTORS:

- Not applicable

NOTES AND ASSUMPTIONS:

- Data request for quantities of traffic markings was made to the Mexicali Public Works, but data were not available (Reynoso Ambriz, 2008).
- Mexicali emission estimates were used from the Mexico NEI.
- Emissions from traffic markings were assumed to be unchanged from 1999 to 2005.

SAMPLE CALCULATIONS:

Estimate the total annual emissions from traffic markings in Mexicali. Calculations from 1999 Mexico NEI.

National level emissions:
Total VOC emissions = 3,031.8 Mg/year

State level emissions:
National paved road length = 237,635 km
Paved road length in Baja California = 6,805.7 km

Annual VOC emissions = (6,805.7 km/237,635 km) × 3,031.8 Mg = 86.8 Mg

Municipality level emissions – Mexicali:
State paved road length = 6,805.7 km
Paved road length in Mexicali = 4,057.4 km

Annual VOC emissions = (4,057.4 km/6,805.7 km) × 86.8 Mg = 51.8 Mg = 57.1 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Dry Cleaning

DESCRIPTION:

Solvent evaporation during dry cleaning process, from leaks in the equipment, and from solvent recovery or disposal systems.

POLLUTANTS:

VOC

METHOD:

Per employee emission factors.

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- 2005 Mexicali employee count (NAICS 81221x) (INEGI, 2005)

EMISSION FACTORS:

- VOC – 700.66 lbs/employee-yr (ERG, 2006)

NOTES AND ASSUMPTIONS:

- Only dry cleaning facilities using petroleum-based organic solvents for cleaning are included in this category; dry cleaning facilities using perchloroethylene are excluded.
- Mexico-specific emission factor derived as part of the development of the Mexico National Emissions Inventory using data from CANALAVA (CANALAVA, 2002).

SAMPLE CALCULATIONS:

Estimate annual emissions from dry cleaning in Mexicali.

Activity data:
Mexicali employee count = 416

Municipality-level emissions:

Annual VOC emissions = 700.66 lbs/employee-yr × (416 employees) = 145.7 tons

Total VOC emissions = 145.7 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Degreasing

DESCRIPTION:

Volatile organic compound emissions from surface cleaning operations. Surface cleaning operations involve the use of solvent liquids or solvent vapors to remove water-insoluble contaminants such as grease, oils, waxes, carbon deposits, fluxes, and tars from metal, plastic, glass, and other surfaces.

POLLUTANTS:

VOC

METHOD:

Per employee emission factors

SPATIAL ALLOCATION:

Employee data

ACTIVITY DATA:

- 2005 Mexicali employee counts (INEGI, 2005)
  - Cold cleaning (auto repair) (NAICS 8111xx)
  - Cold cleaning (manufacturing) (NAICS 31xxxx-33xxxx)
  - Vapor and in-line cleaning (electronics and electrical) (NAICS 334xxx-335xxx)
  - Vapor and in-line cleaning (other) (NAICS 31xxxx-33xxxx; 8111xx)

EMISSION FACTORS:

- Per employee emission factors (EIIP, 1997)
  - VOC – Cold cleaning (auto repair) – 270 lbs/employee-yr
  - VOC – Cold cleaning (manufacturing) – 24 lbs/employee-yr
  - VOC – Vapor and in-line cleaning (electronics and electrical) – 29 lbs/employee-yr
  - VOC – Vapor and in-line cleaning (other) – 9.8 lbs/employee-yr

NOTES AND ASSUMPTIONS:

- It was assumed that Mexican degreasing operations were similar to those in the U.S.
- Reconciliation with the point source inventory was conducted by subtracting point source emission estimates from any point sources with NAICS codes covered by the degreasing area source category.

SAMPLE CALCULATIONS:

Estimate annual emissions from degreasing in Mexicali.

Activity data:
Mexicali employee count = 4,186 (cold cleaning – auto repair)
Mexicali employee count = 62,015 (cold cleaning – manufacturing)
Mexicali employee count = 19,677 (vapor and in-line cleaning – electronics and electrical)
Mexicali employee count = 66,201 (vapor and in-line cleaning – other)

Annual municipality-level emissions:

VOC emissions = 270 lbs/employee-yr × (4,186 employees) = 565.1 tons – 0.0 tons = 565.1 tons
VOC emissions = 24 lbs/employee-yr × (62,015 employees) = 744.2 tons – 0.0 tons = 744.2 tons
VOC emissions = 29 lbs/employee-yr × (19,677 employees) = 285.3 tons – 0.6 tons = 284.7 tons
VOC emissions = 9.8 lbs/employee-yr × (66,201 employees) = 324.4 tons – 0.9 tons = 323.5 tons

Total VOC emissions = 565.1 tons + 744.2 tons + 284.7 tons + 323.5 tons = 1,917.4 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Consumer Solvent Use

DESCRIPTION:

Consumer use of various solvent-containing products, including: personal care products, household products, automotive aftermarket products, adhesives and sealants, FIFRA-regulated products, coatings and related products, and miscellaneous products

POLLUTANTS:

VOC

METHOD:

Emission factors

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- 2005 Mexicali population (INEGI, 2006)

EMISSION FACTORS:

- VOC (personal care products) – 2.32 lbs/person-yr (EIIP, 1996)
- VOC (household products) – 0.20 lbs/person-yr (EIIP, 1996; note 1)
- VOC (automotive aftermarket products) – 0.16 lbs/person-yr (EIIP, 1996; note 2)
- VOC (adhesives and sealants) – 0.57 lbs/person-yr (EIIP, 1996)
- VOC (FIFRA-regulated products – 1.78 lbs/person-yr (EIIP, 1996)
- VOC (coatings and related products) – 0.96 lbs/person-yr (EIIP, 1996)
- VOC (miscellaneous products) – 0.07 lbs/person-yr (EIIP, 1996)

NOTES AND ASSUMPTIONS:

- Note 1 – EIIP emission factor for household products adjusted by a factor of 0.25 based upon the pervasive use of bleach as a cleaning agent instead of typical solvent-containing products (Fierro and O'Rourke, 2007; Fierro, 2007).
- Note 2 – EIIP emission factor for automotive aftermarket products adjusted by a factor of 0.12 based upon the use of water instead of windshield fluids from the area source residual quantities (BTS, 2007; U.S. Census, 2007; Gonzalez-Ayala, 2007).

SAMPLE CALCULATIONS:

Estimate annual emissions from consumer products in Mexicali.

Activity data:
Mexicali population = 855,962

Municipality-level emissions:

Annual VOC emissions (personal care products) = 2.32 lbs/person-yr × (855,962 people) = 993.2 tons
Annual VOC emissions (household products) = 0.20 lbs/person-yr × (855,962 people) = 84.6 tons
Annual VOC emissions (automotive aftermarket products) = 0.16 lbs/person-yr × (855,962 people) = 67.6 tons
Annual VOC emissions (adhesives and sealants) = 0.57 lbs/person-yr × (855,962 people) = 243.0 tons
Annual VOC emissions (FIFRA-regulated products) = 1.78 lbs/person-yr × (855,962 people) = 761.1 tons
Annual VOC emissions (coatings and related products) = 0.96 lbs/person-yr × (855,962 people) = 409.6 tons
Annual VOC emissions (miscellaneous products) = 0.96 lbs/person-yr × (855,962 people) = 29.6 tons

Total VOC emissions = 993.2 tons + 84.6 tons + 67.6 tons + 243.0 tons +761.1 tons + 409.6 tons + 29.6 tons = 2,588.7 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Asphalt Application

DESCRIPTION:

Asphalt application to surfaces and pavements results in hydrocarbon emissions due to evaporation.

POLLUTANTS:

VOC

METHOD:

Use of 1999 Mexico National Emissions Inventory (ERG, 2006)

SPATIAL ALLOCATION:

Paved road network

ACTIVITY DATA:

- National-level emissions (ERG, 2006)
- National and municipality level paved road lengths (INEGI, 2002)

EMISSION FACTORS:

- Not applicable

NOTES AND ASSUMPTIONS:

- Cutback fraction of total asphalt is assumed to be similar to the U.S. (i.e., 3.06% of total asphalt).
- Asphalt is assumed to be a medium-cure cutback.
- Diluent content is assumed to be 35% (EIIP, 2001d).
- Diluent density is assumed to be 0.8 kg/liter (EIIP, 2001d).
- Evaporated fraction of diluent is assumed to be 75% (EIIP, 2001d).
- Emissions from hot-mix and emulsified asphalts are assumed to be negligible (EIIP, 2001d).

SAMPLE CALCULATIONS:

Estimate annual emissions from asphalt application in Baja California.

National level emissions:
National VOC emissions = 7,756.0 Mg/year

State level emissions:
National paved road length = 237,635 km
State paved road length = 6,805.7 km

Annual VOC emissions in Baja California = 7,756.0 Mg/year × (6,805.7 km/237,635 km) = 222.1 Mg

Municipality level emissions – Mexicali:
State paved road length = 6,805.7 km
Paved road length in Mexicali = 4,057.4 km

Annual VOC emissions in Mexicali = 222.1 Mg × (4,057.4 km/6,805.7 km) = 132.4 Mg = 146.0 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Gasoline Distribution

DESCRIPTION:

This source category relates to the emissions occurring during the transportation and distribution of gasoline. This category includes Stage I loading losses (from tank truck to underground tank), Stage II loading losses (from underground tank to vehicle – including spillage), underground tank breathing, and tank truck transit losses.

POLLUTANTS:

VOC

METHOD:

Emission factors

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- Gasoline (Magna and Premium) quantity sold (Parra Armenta, 2008; Parra Armenta, 2009)

EMISSION FACTORS:

- $VOC_{Stage\ I\ controlled}$ – 40 mg/liter (EIIP, 2001a)
- $VOC_{Stage\ II\ uncontrolled}$ – 1320 mg/liter (EIIP, 2001a)
- $VOC_{Spillage}$ – 80 mg/liter (EIIP, 2001a)
- $VOC_{Tank\ losses}$ – 120 mg/liter (EIIP, 2001a)
- $VOC_{Gas\ filled\ trucks}$ – 1 mg/liter (EIIP, 2001a)
- $VOC_{Vapor\ filled\ trucks}$ – 13 mg/liter (EIIP, 2001a)

NOTES AND ASSUMPTIONS:

- It was assumed that all stations in Mexicali have Stage I controls (assumed to be vapor balance) (Ruiz Méndez, 2003).
- It was assumed that all stations in Mexicali do not have Stage II controls (Ruiz Méndez, 2003).

SAMPLE CALCULATIONS:

Estimate annual VOC emissions from gasoline distribution in Mexicali.

Mexicali Magna gasoline = 224,800,401 liters
Mexicali Premium gasoline = 63,773,310 liters
Total gasoline = 224,800,401 liters + 63,773,310 liters = 288,573,711 liters

<u>Mexicali emissions</u>:

Stage I controlled emissions = 40 mg/l x 288,573,711 liters = 11.54 Mg = 12.7 tons
Stage II uncontrolled emissions = 1,320 mg/l x 288,573,711 liters = 380.92 Mg = 419.9 tons
Spillage emissions = 80 mg/l x 288,573,711 liters = 23.09 Mg = 25.4 tons
Tank losses = 120 mg/l x 288,573,711 liters = 34.63 Mg = 38.2 tons
Tank truck transit losses (gas-filled) = 1 mg/l x 288,573,711 liters = 0.29 Mg = 0.3 tons
Tank truck transit losses (vapor-filled) = 13 mg/l x 288,573,711 liters = 3.75 Mg = 4.1 tons

Total Mexicali gasoline distribution emissions = 12.7 tons + 419.9 tons + 25.4 tons + 38.2 tons + 0.3 tons + 4.1 tons = 500.7 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Agricultural Burning

DESCRIPTION:
Emissions from burning of agricultural residue.

POLLUTANTS:
NO_x, SO_2, VOC, CO, PM_{10}, and $PM_{2.5}$

METHOD:
Emission factors

SPATIAL ALLOCATION:
Agricultural land use

ACTIVITY DATA:
- Burn acreage by crop type (Rodríguez Hernández, 2008)
- Fuel loading by crop type (wheat 1.9 tons/acre, sorghum 2.9 tons/acre, miscellaneous weeds 2.175 tons/acre) (ARB, 2005)

EMISSION FACTORS:
- Wheat (NO_x – 4.3 lbs/ton, SO_2 – 0.9 lbs/ton, VOC – 7.6 lbs/ton, CO – 123.6 lbs/ton, PM_{10} – 10.6 lbs/ton, $PM_{2.5}$ – 10.1 lbs/ton) (ARB, 2005)
- Sorghum (NO_x – 4.5 lbs/ton, SO_2 – 0.6 lbs/ton, VOC – 5.10 lbs/ton, CO – 77 lbs/ton, PM_{10} – 17.7 lbs/ton, $PM_{2.5}$ – 16.9 lbs/ton) (ARB, 2005)
- Irrigation canal and ditchbank weeds (NO_x – 4.49 lbs/ton, SO_2 – 0.61 lbs/ton, VOC – 10.73 lbs/ton, CO – 113.95 lbs/ton, PM_{10} – 15.9 lbs/ton, $PM_{2.5}$ – 15.18 lbs/ton) (ARB, 2005)

NOTES AND ASSUMPTIONS:
- Only wheat, sorghum, and irrigation canal and ditch bank weeds are burned in Mexicali.

SAMPLE CALCULATIONS:
Estimate annual emissions from agricultural burning of wheat.

Area burned = 57,000 hectares = 140,847 acres
Residue burned = 140,847 acres x 1.9 tons/acre = 267,609 tons

Mexicali emissions:

NO_x – (267,609 tons) x 4.3 lb/ton = 575.4 tons
SO_x – (267,609 tons) x 0.9 lb/ton = 120.4 tons
VOC – (267,609 tons) x 7.6 lb/ton = 1,016.9 tons
CO – (267,609 tons) x 123.6 lb/ton = 16,538.3 tons
PM_{10} – (267,609 tons) x 10.6 lb/ton = 1,418.3 tons
$PM_{2.5}$ – (267,609 tons) x 10.1 lb/ton = 1,351.4 tons

Total NO_x emissions = wheat emissions + sorghum emissions + ditchbank weed emissions = 575.4 tons + 38.7 tons + 7.2 tons = 621.3 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Agricultural Tilling

DESCRIPTION:
Fugitive dust emissions from agricultural tilling.

POLLUTANTS:
PM_{10} and $PM_{2.5}$

METHOD:
Emission factors

SPATIAL ALLOCATION:
Agricultural land use

ACTIVITY DATA:
- Total planted area by crop type (SAGARPA, 2007a)

EMISSION FACTORS:
- Crop-specific emission factors (lbs/acre-yr) (ARB, 2003a).

NOTES AND ASSUMPTIONS:
- $PM_{2.5}$ particle size fraction of PM_{10} is 0.2217 (ARB, 2002).
- It is assumed that Mexican agricultural tilling practices are similar to practices in the San Joaquin Valley, California.

SAMPLE CALCULATIONS:

Estimate annual emissions from agricultural tilling operations for wheat in Mexicali.

Total planted area for wheat (average hard, soft, and crystalline varieties) = 81,111 hectares = 200,425 acres

Annual PM_{10} emissions = 200,425 acres x 3.7 lbs/acre-yr = 741,572.5 lbs/yr = 370.8 tons/yr
Annual $PM_{2.5}$ emissions = 370.8 tons PM_{10} x 0.2217 = 82.2 tons/yr

SOURCE TYPE: Area **SOURCE CATEGORY:** Agricultural Harvesting

DESCRIPTION:
Fugitive dust emissions from agricultural harvesting.

POLLUTANTS:
PM_{10} and $PM_{2.5}$

METHOD:
Emission factors

SPATIAL ALLOCATION:
Agricultural land use

ACTIVITY DATA:
- Total harvested area by crop type (SAGARPA, 2007a)

EMISSION FACTORS:
- Crop-specific emission factors (lbs/acre-yr) (ARB, 2003b).

NOTES AND ASSUMPTIONS:
- $PM_{2.5}$ particle size fraction of PM_{10} is 0.2217 (ARB, 2002).
- It is assumed that Mexican agricultural harvesting practices are similar to practices in the San Joaquin Valley, California.

SAMPLE CALCULATIONS:

Estimate annual emissions from agricultural harvest operations for wheat in Mexicali.

Total harvested area for wheat (average hard, soft, and crystalline varieties) = 80,555 hectares = 199,051 acres

Annual PM_{10} emissions = 199,051 acres x 5.8 lbs/acre-yr = 1,154,498.1 lbs/yr = 577.2 tons/yr
Annual $PM_{2.5}$ emissions = 577.2 tons PM_{10} x 0.2217 = 128.0 tons/yr

SOURCE TYPE: Area **SOURCE CATEGORY:** Pesticides

DESCRIPTION:

Volatile organic compound emissions from the active and inert ingredients in pesticides. VOC emissions can occur either during application of pesticides or as a result of evaporation.

POLLUTANTS:

VOC

METHOD:

Emission factors

SPATIAL ALLOCATION:

Agricultural land use

ACTIVITY DATA:

- Municipality level crop acreage (SAGARPA, 2007a)
- Typical application rates (SAGARPA, 2007b)

EMISSION FACTORS:

- VOC emission factors (active ingredients only) – 700 kg/Mg (vapor pressure between 0.0001 mm Hg and 0.000001 mm Hg) and 1,160 kg/Mg (vapor pressure greater than 0.0001 mm Hg) (EIIP, 2001b)

NOTES AND ASSUMPTIONS:

- Method of pesticide application was assumed to be surface application.
- Typical application rates were only available for alfalfa, asparagus, broccoli, cotton, garlic, tomatoes (red and green), and wheat.

SAMPLE CALCULATIONS:

Estimate the total annual emissions from pesticide application for wheat in Mexicali.

Wheat acreage = 81,111 hectares = 200,425 acres

Dimetoato (dimethoate) applied at a rate of 1.5 liters/hectare (converted to 1.46 lbs/acre using pesticide density)
43.5% active; 56.5% inert
Active ingredient vapor pressure – 2.5×10^{-5} mm; corresponds to emission factor of 700 lbs VOC/ton of active ingredient
Applied as an emulsified concentrate; corresponds to a inert ingredient VOC content of 56%

<u>Emissions from active ingredients</u>:

Emissions = 200,425 acres x 1.46 lbs pesticide/acre x 0.435 x 700 lbs VOC/ton of active ingredients = 44,535.2 lbs = 22.3 tons

<u>Emissions from inert ingredients</u>:

Emissions = 200,425 acres x 1.46 lbs pesticide/acre x 0.565 x 0.56 = 92,551.4 lbs = 46.3 tons

<u>Total emissions</u>:

Total emissions = active emissions + inert emissions = 22.3 tons + 46.3 tons = 68.6 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Beef Cattle Feedlots

DESCRIPTION:

Fugitive dust emissions released because cattle movement over ground.

POLLUTANTS:

PM_{10}

METHOD:

Emission factor

SPATIAL ALLOCATION:

Agricultural land use

ACTIVITY DATA:

- Number of cattle slaughtered (Rodríguez Hernández)
- Residence time in feedlot – 90 days (Sukarne, 2008)

EMISSION FACTORS:

- 28.9 lbs PM_{10}/1000 head-day (ARB, 2004)

NOTES AND ASSUMPTIONS:

-

SAMPLE CALCULATIONS:

Estimate the total annual emissions from beef cattle feedlots.

Cattle slaughtered = 223,545
Residence time = 90 days

Emissions = 223,545 head x 90 days x 28.9 lbs PM_{10}/1000 head-day = 581,440.5 lbs PM_{10} = 290.7 tons PM_{10}

SOURCE TYPE: Area **SOURCE CATEGORY:** Livestock Ammonia and VOC

DESCRIPTION:

The sources of emissions in this category are livestock and domesticated farm and dairy animals.

POLLUTANTS:

VOC and NH_3

METHOD:

Emission factors

SPATIAL ALLOCATION:

Agricultural land use

ACTIVITY DATA:

- Livestock population (SAGARPA, 2007c)

EMISSION FACTORS:

- VOC: Beef cattle – 12.8 lb/head-year; dairy cows – 12.8 lb/head-year; pigs – 4.6 lb/head-year; sheep – 0.96 lb/head-year; goats – 0.96 lb /head-year (ARB, 2004)
- NH_3: Beef cattle – 9.0 kg/head-year; dairy cows – 25.0 kg/head-year; pigs – 7.0 kg/head-year; sheep – 1.34 kg/head-year; goats – 0.58 kg/head-year (Chinkin et al., 2003)

ASSUMPTIONS:

- Livestock statistics represent year-round livestock populations.
- Poultry and horse populations were not found in Mexicali.

SAMPLE CALCULATIONS:

Estimate the total annual livestock ammonia emissions in Mexicali.

Municipality level VOC emissions – Mexicali:

Emissions from beef cattle = (160,221 head) × (12.8 lb VOC/head-year) = 1,025.4 tons
Emissions from dairy cows = (50,432 head) × (12.8 lb VOC/head-year) = 322.8 tons
Emissions from pigs = (4,750 head) × (4.6 lb VOC/head-year) = 10.9 tons
Emissions from sheep = (9,227 head) × (0.96 lb VOC/head-year) = 4.4 tons
Emissions from goats = (5,781 head) × (0.96 lb VOC/head-year) = 2.8 tons

Total annual VOC emissions = 1,025.4 + 322.8 + 10.9 + 4.4 + 2.8 = 1,366.3 tons

Municipality level NH_3 emissions – Mexicali:

Emissions from beef cattle = (160,221 head) × (9.0 kg NH_3/head-year) = 1,441,989 kg = 1,589.5 tons
Emissions from dairy cows = (50,432 head) × (25.0 kg NH_3/head-year) = 1,260,800 kg = 1,389.8 tons
Emissions from pigs = (4,750 head) × (7.0 kg NH_3/head-year) = 33,250 kg = 36.7 tons
Emissions from sheep = (9,227 head) × (1.34 kg NH_3/head-year) = 12,364 kg = 13.6 tons
Emissions from goats = (5,781 head) × (0.58 kg NH_3/head-year) = 3,353 kg = 3.7 tons

Total annual NH_3 emissions = 1,589.5 + 1,389.8 + 36.7 + 13.6 + 3.7 = 3,033.3 tons

Area **SOURCE CATEGORY:** **Fertilizer Application**

DESCRIPTION:

Ammonia emissions from the application of nitrogen based fertilizers. The amount of ammonia emissions depend on the nitrogen content of the fertilizer.

POLLUTANTS:

NH_3

METHOD:

Emission factors

ACTIVITY DATA:

- Municipality level crop acreage (SAGARPA, 2007a)
- Typical application rates (SAGARPA, 2007b)

EMISSION FACTORS:

- NH_3 emission factors (kg NH_3/kg fertilizer): anhydrous ammonia – 0.04857; urea – 0.18214; NPK, calcium nitrate, diammonium phosphate – 0.02428 (EEA, 2002)

NOTES AND ASSUMPTIONS:

- Typical application rates were only available for alfalfa, asparagus, broccoli, cotton, garlic, tomatoes (red and green), and wheat.

SAMPLE CALCULATIONS:

Estimate the total annual fertilizer emissions for wheat in Mexicali.

Planted wheat area = 81,111 hectares
Application rates = anhydrous ammonia 125 kg/hectare, urea 252 kg/hectare, 11-52-00 (N-P-K) 100 kg/hectare

NH_3 emissions = (81,111 hectares x 125 kg/hectare x 0.04857 kg NH_3/kg fertilizer) + (81,111 hectares x 252 kg/hectare x 0.18214 kg NH_3/kg fertilizer) + (81,111 hectares x 100 kg/hectare x 0.02428 kg NH_3/kg fertilizer) = 4,412,319 kg NH_3 = 4,863.7 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Paved Road Dust

DESCRIPTION:

Re-entrained road dust from vehicle activity on paved roads.

POLLUTANTS:

PM_{10}, $PM_{2.5}$

METHOD:

Emission factor equations

SPATIAL ALLOCATION:

Paved road network

ACTIVITY DATA:

- Paved road VMT (Gonzalez-Ayala, 2008a)

EMISSION FACTORS:

- Predictive emission factor equation (U.S. EPA, 1995)
  - k = particle size multiplier – 0.016 lb/VMT (PM_{10}); 0.0024 lb/VMT ($PM_{2.5}$)
  - sL = silt loading – derived from Mexicali paved road dust sampling at 10 locations
  - W = average vehicle weight
  - C = exhaust emission correction – 0.00047 lb/VMT (PM_{10}); 0.00036 lb/VMT ($PM_{2.5}$)
  - P = number of wet days (>0.01 in) = 21
  - N = number of days in averaging period = 365

NOTES AND ASSUMPTIONS:

- It was assumed that the average vehicle weight was 3.18 tons.
- Emission factors were calculated for each of the 10 locations and then averaged together.
- Negative emission factors calculated with the predictive emission factor equation were set to zero.

SAMPLE CALCULATIONS:

Estimate PM_{10} emission factor for Avenida Oaxaca between Calle Uxmal and Heroico Colegio Militar

Length sampled = 216 feet
Width sampled = 10 feet
Sample weight = 681.5 g
Silt content = 2.68%

Emission factor = $[k(sL/2)^{0.65}(W/3)^{1.5} – C] \times (1 – P/4N)$

sL = silt/area = (681.5 g x 0.0268)/(216 feet x 10 feet) = 0.091025 g/m^2

$EF(PM_{10}) = [(0.016) \times (0.091025/2)^{0.65} \times (3.18/3)^{1.5} – 0.00047] \times (1 – 21/[4 \times 365]) = 0.00185$ lbs/VMT

SOURCE TYPE: Area **SOURCE CATEGORY:** Unpaved Road Dust

DESCRIPTION:

Re-entrained road dust from vehicle activity on unpaved roads.

POLLUTANTS:

PM_{10}, $PM_{2.5}$

METHOD:

Emission factor equations

SPATIAL ALLOCATION:

Unpaved road network

ACTIVITY DATA:

- Unpaved road VMT (Gonzalez-Ayala, 2008b)

EMISSION FACTORS:

- Predictive emission factor equation (U.S. EPA, 1995)
  - k = empirical constants – 1.8 lb/VMT (PM_{10}); 0.18 lb/VMT ($PM_{2.5}$)
  - a = empirical constant – 1 (PM_{10} and $PM_{2.5}$)
  - c = empirical constant – 0.2 (PM_{10} and $PM_{2.5}$)
  - d = empirical constant – 0.5 (PM_{10} and $PM_{2.5}$)
  - s = surface material silt content (%) – derived from Mexicali unpaved road dust sampling at 10 locations
  - S = mean vehicle speed (mph) – 11 mph urban; 18 mph suburban; 25 mph rural
  - M = surface material moisture content average vehicle weight (%)
  - C = exhaust emission correction – 0.00047 lb/VMT (PM_{10}); 0.00036 lb/VMT ($PM_{2.5}$)
  - P = number of wet days (>0.01 in) = 21
  - N = number of days in averaging period = 365

NOTES AND ASSUMPTIONS:

- Urban, suburban, and rural emission factors were calculated for each of the 10 locations and then averaged to obtain average urban, suburban, and rural emission factors.
- Negative emission factors calculated with the predictive emission factor equation were set to zero.

SAMPLE CALCULATIONS:

Estimate PM_{10} emission factor (urban at 11 mph) for Calle Texcoco between Calzada Laguna de Xochimilco and Avenida Acolman

Silt content = 1.66%
Moisture content = 0.29%

Emission factor = $\{[k(s/12)^a(S/30)^d] / [(M/0.5)^c] - C\} \times (1 - [P/N])$

$EF(PM_{10}) = \{[(1.8) \times (1.66/12)^1 \times (11/30)^{0.5}] / [(0.29/0.5)^{0.2}] - 0.00047\} \times (1 - [21/365]) = 0.15802$ lbs/VMT

SOURCE TYPE: Area **SOURCE CATEGORY:** Structure Fires

DESCRIPTION:

Structure fires include the unintentional burning of the structure material and building contents.

POLLUTANTS:

NO_x, VOC, CO, PM_{10}, and $PM_{2.5}$

METHOD:

Emission factors

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- Fires (Ruiz Burgueño, 2008)

EMISSION FACTORS:

- NO_x – 1.4 lbs/ton of material (EIIP, 2001c)
- VOC – 11 lbs/ton of material (EIIP, 2001c)
- CO – 60 lbs/ton of material (EIIP, 2001c)
- PM_{10} – 10.6 lbs/ton of material (EIIP, 2001c)
- $PM_{2.5}$ – 9.9 lbs/ton of material (EIIP, 2001c)
- CH_4 – 2.9 lbs/ton of material (EIIP, 2001c)

NOTES AND ASSUMPTIONS:

- Average content loss was assumed to be 7.3% (EIIP, 2001c).
- Average amount of combustible contents in the structure was assumed to be 38.62 kg/m^2 (EIIP, 2001c).
- Average area of a structure was assumed to be 100 m^2.
- Only residential building fires were considered.
- Combustible building material was assumed to be 0 Mg (masonry construction).
- $PM_{2.5}$ size fraction of PM_{10} = 0.9327 (ARB, 2002).

SAMPLE CALCULATIONS:

Estimate the total annual emissions from structure fires in Mexicali.

<u>Annual municipality level emissions</u>:
Number of fires = 498
Total combustible material = number of fires × structural loss × (combustible building material + combustible building contents) = 498 × (0.073) × (0 + 100 m^2 × 38.62 kg/m^2) = 140,399 kg = 154.8 tons

NO_x emissions = 154.8 tons × 1.4 lbs/ton = 217 lbs = 0.1 tons
VOC emissions = 154.8 tons × 11 lbs/ton = 1,703 lbs = 0.9 tons
CO emissions = 154.8 tons × 60 lbs/ton = 9,288 lbs = 4.6 tons
PM_{10} emissions = 154.8 tons × 10.6 lbs/ton = 1,641 lbs = 0.8 tons
$PM_{2.5}$ emissions = 154.8 tons × 9.9 lbs/ton = 1,533 lbs = 0.8 tons
CH_4 emissions = 154.8 tons × 2.9 lbs/ton = 449 lbs = 0.2 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Border Crossings

DESCRIPTION:

Emissions from motor vehicles idling at border crossings.

POLLUTANTS:

NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, NH_3

METHOD:

Emission factors derived from MOBILE6-Mexico (ERG, 2003)

SPATIAL ALLOCATION:

Border crossing location

ACTIVITY DATA:

- Monthly average minimum and maximum temperatures
- Number of vehicles at border crossing points (BTS, 2008)
- Vehicle wait times at various border crossing ports (BTS, 2008)

EMISSION FACTORS:

- MOBILE6-Mexico (ERG, 2003)

NOTES AND ASSUMPTIONS:

- Average vehicle speed at border crossing points is assumed to be 4 km/hr.
- Emissions were only estimated for vehicles entering from Mexico into the United States.

SAMPLE CALCULATIONS:

Estimate NO_x emissions from Calexico border crossing in January

Number of LDGVs = 268,892
Number of LDGTs = 250,583
Number of MCs = 7,261
Number of HDDVs = 125

Speed – 0.0414 miles/minute (4 km/hour)
Wait times – 43 minutes for LDGVs, LDGTs, and MCs; 2 minutes for HDDVs

LDGV emission factor = 1.08 g NO_x/mile
LDGT emission factor = 1.328 g NO_x/mile
MC emission factor = 1.34 g NO_x/mile
HDDV emission factor = 15.959 g NO_x/mile

Emissions = (268,892 x 43 min x 0.0414 miles/min x 1.08 g/mile) + (250,583 x 43 min x 0.0414 miles/min x 1.328 g/mile) + (7,261 x 43 min x 0.0414 miles/min x 1.34 g/mile) + (125 x 2 min x 0.0414 miles/min x 15.959 g/mile) = 1.127 Mg = 1.243 tons

SOURCE TYPE: Area **SOURCE CATEGORY:** Brick Kilns

DESCRIPTION:

Emissions released during the firing of brick kilns.

POLLUTANTS:

NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, NH_3

METHOD:

Utilization of previous emission estimates from 2005 San Luis Río Colorado (SLRC)/Mexicali emissions inventory (ENVIRON and ERG, 2008)

SPATIAL ALLOCATION:

Brick kiln location

ACTIVITY DATA:

- Not applicable

EMISSION FACTORS:

- Not applicable

NOTES AND ASSUMPTIONS:

- The 2005 SLRC/Mexicali inventory included three brick kiln areas: Colonia Mezquite in SLRC (the largest brick kiln area), Colonia La Grullita in SLRC (a smaller brick kiln area), and south of Algodones in northeast Mexicali (firing bricks and tile shingles).
- Mexicali includes two brick kiln areas – Algodones and Colonia Campestre
- Accurate activity data could not be collected at Colonia Campestre
- The emissions from the Algodones brick kiln area were used.
- The emissions from the Colonia La Grullita area in SLRC were assumed to be equivalent to the Colonia Campestre area in Mexicali.

SAMPLE CALCULATIONS:

Not applicable

SOURCE TYPE: Area **SOURCE CATEGORY:** Charbroiling/Street Vendors

DESCRIPTION:
Emissions from charbroiling of meat.

POLLUTANTS:
NO_x, VOC, CO, PM_{10}, $PM_{2.5}$

METHOD:
Estimates from Mexico NEI (ERG, 2006)

SPATIAL ALLOCATION:
Population

ACTIVITY DATA:
- Not applicable

EMISSION FACTORS:
- Not applicable

NOTES AND ASSUMPTIONS:
- Data request for meat quantities, but adequate data were not available.
- Mexicali emission estimates were used from the 1999 Mexico NEI.
- Emissions were grown from 1999 to 2005 using population.

SAMPLE CALCULATIONS:
Estimate the total annual emissions from charbroiling in Mexicali.

1999 annual CO emissions = 121.7 Mg/yr

1999 population 764,602
2005 population 855,962
Growth factor = 855,962/764,602 = 1.1195

2005 annual CO emissions = 121.7 Mg x 1.1195 = 136.2 Mg/yr = 150.2 tons/year

SOURCE TYPE: Area **SOURCE CATEGORY:** Construction Dust

DESCRIPTION:

Dust emitted from earthmoving and other construction activities.

POLLUTANTS:

PM_{10} and $PM_{2.5}$

METHOD:

Estimates from 1999 Mexico NEI (ERG, 2006)

SPATIAL ALLOCATION:

Population

ACTIVITY DATA:

- Not applicable

EMISSION FACTORS:

- Not applicable

NOTES AND ASSUMPTIONS:

- Mexicali emission estimates were used from the 1999 Mexico NEI.
- Emissions were grown from 1999 to 2005 using population.

SAMPLE CALCULATIONS:

Estimate the total annual emissions from construction dust in Mexicali.

1999 annual PM_{10} emissions = 110.2 Mg/yr

1999 population 764,602
2005 population 855,962
Growth factor = 855,962/764,602 = 1.1195

2005 annual PM_{10} emissions = 110.2 Mg x 1.1195 = 123.4 Mg/yr = 136.0 tons/year

SOURCE TYPE: Area **SOURCE CATEGORY:** Bakeries

DESCRIPTION:
Emissions from bakeries.

POLLUTANTS:
VOC

METHOD:
Estimates from 1999 Mexico NEI (ERG, 2006)

SPATIAL ALLOCATION:
Population

ACTIVITY DATA:
- Not applicable

EMISSION FACTORS:
- Not applicable

NOTES AND ASSUMPTIONS:
- Mexicali emission estimates were used from the 1999 Mexico NEI.
- Emissions were grown from 1999 to 2005 using population.

SAMPLE CALCULATIONS:
Estimate the total annual emissions from bakeries in Mexicali.

1999 annual PM_{10} emissions = 95.6 Mg/yr

1999 population 764,602
2005 population 855,962
Growth factor = 855,962/764,602 = 1.1195

2005 annual PM_{10} emissions = 95.6 Mg x 1.1195 = 107.0 Mg/yr = 117.9 tons/year

SOURCE TYPE: Area **SOURCE CATEGORY:** Landfills

DESCRIPTION:

Landfill gases emission by anaerobic processes in landfills.

POLLUTANTS:

VOC and CH_4

METHOD:

Theoretical first-order kinetic model of methane production

SPATIAL ALLOCATION:

Landfill location

ACTIVITY DATA:

- Average refuse acceptance rates (R) – 880 Mg/day or 321,200 Mg/yr (Villegas Ibarra, 2008)

EMISSION FACTORS:

- Calculated values

NOTES AND ASSUMPTIONS:

- Methane generation potential (Lo) – 100 m^3 CH_4/Mg refuse.
- Methane generation rate constant (k) – 0.02 yr^{-1}.
- Time since landfill closure (c) – 0 years.
- Time since initial refuse placement (t) – 15 years (Villegas Ibarra, 2008)
- Molecular weight of CH_4 (MW_{CH4})– 16.04 g/gmol
- Molecular weight of NMOC (MW_{NMOC}) (expressed as hexane) – 86.18 g/gmol.
- Temperature of landfill gas – 25 ºC.
- Concentration of NMOC in landfill gas (C_{NMOC})– 4000 ppmv.
- VOC is assumed to be equivalent to NMOC.

SAMPLE CALCULATIONS:

Estimate annual VOC and CH4 emissions from the Mexicali landfill.

Q_{CH4} (methane generation, m^3/yr) = $L_oR(e^{-kc} – e^{-kt})$ = 100 x 321,200 x ($e^{[-0.02 \times 0]} – e^{[-0.02 \times 15]}$) = 8,324,919 m^3 CH_4/yr

M_{CH4} = Q_{CH4} x {[MW($_{CH4}$) x 1 atm]/[(8.205 x 10^{-5} m^3-atm/gmol-K) x (1000 g/kg) x (273 + T)]} =
8,324,919 m^3 CH_4/yr x {[16.04 g/gmol x 1 atm]/[(8.205 x 10^{-5} m^3-atm/gmol-K) x (1000 g/kg) x (298 K)]} =
5,461,218 kg/yr = 6,019.9 tons CH_4/yr

Q_{NMOC} (NMOC generation, m^3/yr) = 1.82 x Q_{CH4} x C_{NMOC}/(1 x 10^6) =
1.82 x 8,324,919 m^3 CH_4/yr x 4000/(1 x 10^6) = 60,605 m^3/yr

M_{NMOC} = Q_{NMOC} x {[MW($_{NMOC}$) x 1 atm]/[(8.205 x 10^{-5} m^3-atm/gmol-K) x (1000 g/kg) x (273 + T)]} =
60,605 m^3 NMOC/yr x {[86.18 g/gmol x 1 atm]/[(8.205 x 10^{-5} m^3-atm/gmol-K) x (1000 g/kg) x (298 K)]} =
213,611 kg/yr = 235.5 tons NMOC/yr

SOURCE TYPE: Area **SOURCE CATEGORY:** Wastewater Treatment

DESCRIPTION:

Volatile organic compound emissions from collection, contaminant treatment, and/or storage of industrial wastewater streams. These streams are discharged into either a receiving body of water or a municipal treatment plant.

POLLUTANTS:

VOC

METHOD:

Emission factors

ACTIVITY DATA:

- Municipality level municipal treatment plant statistics (CNA, 2007)

EMISSION FACTORS:

- TOG – 1.3×10^{-5} kg/liter (U.S. EPA, 1991)

NOTES AND ASSUMPTIONS:

- VOC emissions equal TOG emissions.

SAMPLE CALCULATIONS:

Estimate the total annual VOC emissions from wastewater treatment in Mexicali.

Actual flow rate = 1.8494 m3/s = 58,322,678,400 liters/year
Annual TOG emissions = 1.3×10^{-5} kg/liter $\times$ 58,322,678,400 liters/year = 758,195 kg/year = 835.8 tons/year

APPENDIX B:

TECHNICAL REPORT (DRAFT), ESTIMATION OF TRAVEL DEMAND AND VEHICULAR TRAFFIC CONGESTION OF THE MEXICALI REGION

TECHNICAL REPORT
(DRAFT)

Estimation of Travel Demand and Vehicular Traffic Congestion of the Mexicali Region

September 2008

Prepared by:

TransEngineering

for Eastern Research Group, Inc.

I. Introduction

The present document describes the approach followed for estimation of motor-vehicle activity and related mobile source emissions for the municipality of Mexicali. As shown in Figure 1, the municipality of Mexicali is located in the State of Baja California, Mexico, and includes the city of Mexicali.

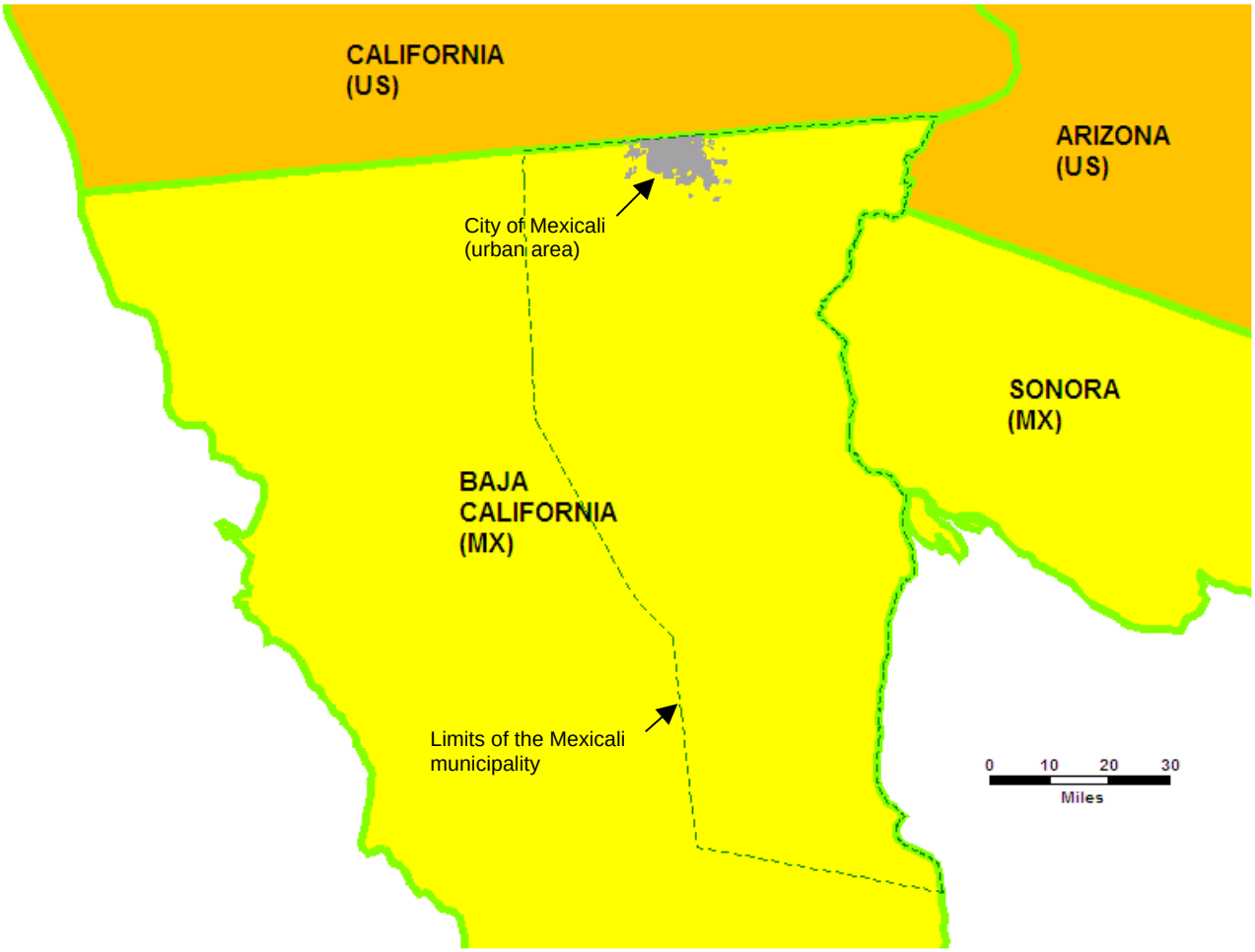

Figure 1. Geographic location of the Mexicali municipality.

The municipality of Mexicali has an area of 5,650 square-miles, while the urban area of Mexicali has only 54 square-miles, thus the urban area represents about 1% of the entire municipality area. Nevertheless, based on INEGI statistics, the 2005 population for the urban area of Mexicali was 653,000, which represents approximately 88% of the total municipality population[1].

[1] According to INEGI, the population of the municipality of Mexicali was 745,000 in 2005 (Instituto Nacional de Estadística, Geografía e Informática/ Conteo de Población 2005).

The main roadways in the Mexicali municipality have been identified, for both urban and rural areas; these roadways are depicted in Figure 2. In the rural areas, the most important roadways are Federal Highway 2 (MEX 2), which connects the city of Mexicali to the city of Tijuana (to the west), and San Luis Rio Colorado (to the east), and Federal Highway 5 (MEX 5) which connects the city of Mexicali to San Felipe (to the south) and Ensenada (to the southwest). The rest of the roadways identified in Figure 2 are state highways. As part of the roadway infrastructure, three ports-of-entry (POEs) between Mexico and the US have been identified as well: the Andrade POE in northeast corner of the municipality, and the Calexico and Calexico East POEs in the city of Mexicali. Figure 3 presents a map with details of the urban area of Mexicali.

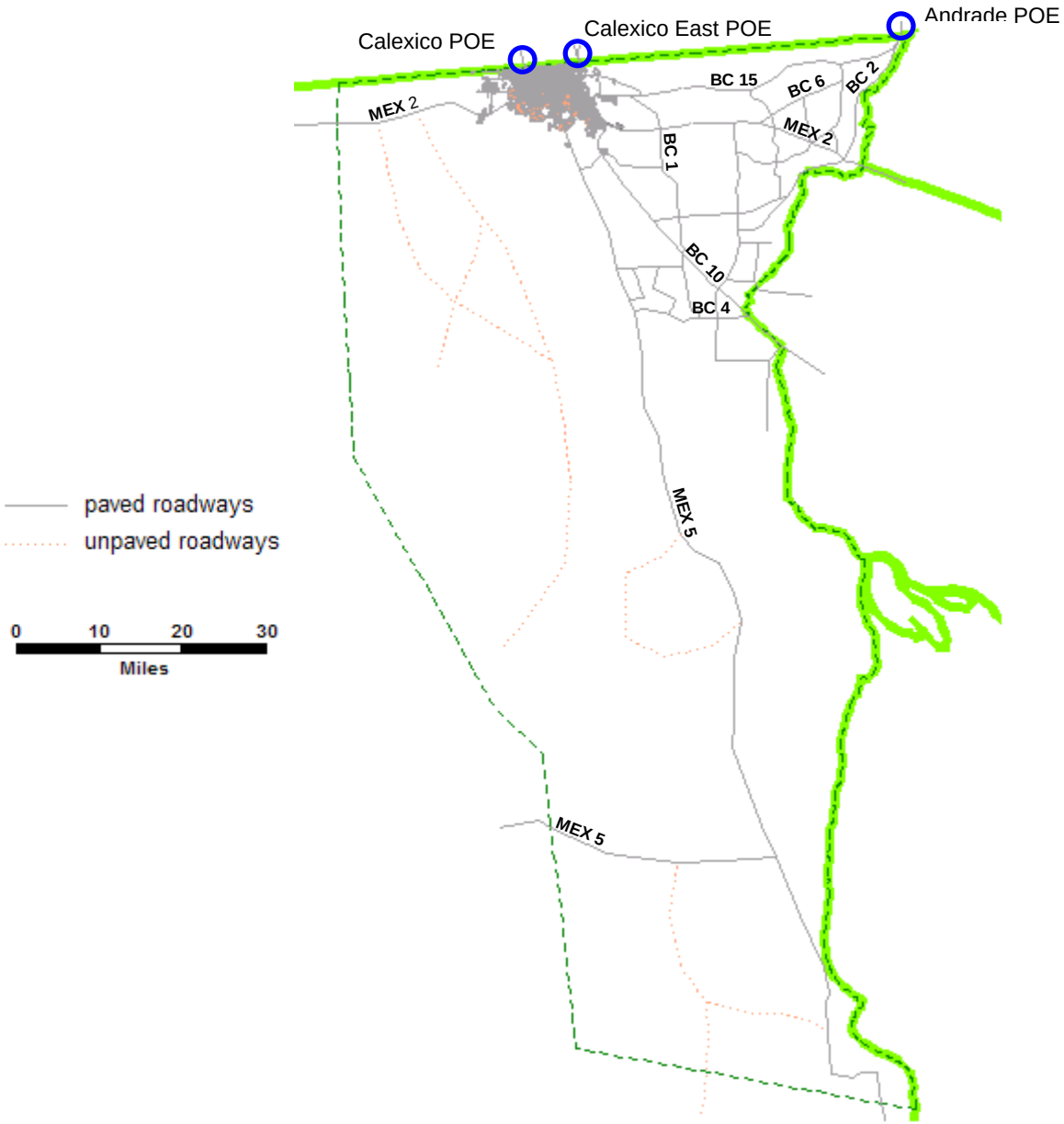

Figure 2. Main rural and urban roadways within the Mexicali municipality.

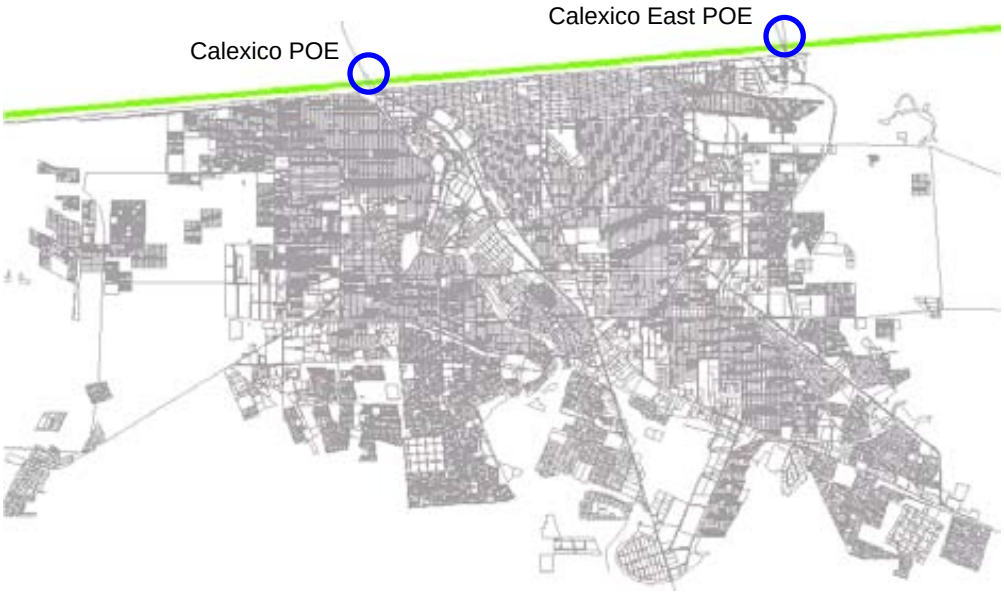

Figure 3. Detail of roadway system for the city of Mexicali (urban area).

The rural and urban roadway systems have been converted into a travel demand model to estimate daily vehicle traffic volumes. The travel demand model developed for this study has three main components:

- Trip generation
- Trip distribution
- Traffic assignment

Each of these components will be briefly described in the following pages.

II. Trip Generation

As a first step to establish traffic volumes in Mexicali, the methodology takes advantage of research in the US indicating that the values of trip generation rates across urban area locations and sizes are fairly stable when disaggregated by socioeconomic conditions of the population such as household size, income, and employment. This stability intuitively suggests the transferability of known rates from the limited case studies in Mexico to other urban areas in the country. One known and documented case study is Ciudad Juarez, and thus its disaggregate trip rates as well as other traffic patterns can be borrowed and used as a basis for estimating preliminary traffic volumes in other urban areas. For the present study, such rates will also be assumed to take place in the rural areas of the municipality.

Trip generation rates

The trip generation rates developed from the Juarez' transportation research program[2] are shown in Tables 1 and 2. Table 1 presents production rates based on household size and household income. Table 2 presents attraction rates based on area type and employment by economic activity. These rates are expressed as person-trips per day.

Table 1. Juarez' disaggregate trip production rates (daily person-trips per household).

Trip purpose	HH income	HH size					
		1	2	3	4	5	6+
HBW	(1)	0.508	1.156	1.268	1.417	1.474	2.067
	(2)	0.902	1.479	1.705	1.726	2.096	2.400
	(3)	0.875	1.522	1.581	1.698	2.247	2.987
	(4)	1.000	1.708	1.847	1.800	2.438	2.762
	(5)	0.598	1.541	1.559	2.169	2.494	3.259
	(6)	0.801	2.307	2.180	2.119	2.622	3.196
HBO	(1)	2.609	3.761	6.142	9.435	13.264	13.111
	(2)	1.647	3.792	6.005	9.294	12.064	13.730
	(3)	1.933	3.921	5.767	9.221	12.955	13.430
	(4)	2.580	3.143	4.536	11.005	12.653	17.027
	(5)	1.933	4.349	7.240	10.707	10.839	12.742
	(6)	0.769	2.675	4.957	10.475	13.960	11.975
NHB	(1)	0.435	0.560	1.484	1.252	2.604	2.396
	(2)	0.352	0.820	1.515	1.891	2.479	2.335
	(3)	1.019	0.976	2.301	2.583	2.577	2.314
	(4)	1.230	1.659	1.766	3.550	3.299	3.060
	(5)	1.230	2.167	3.890	3.198	3.587	3.060
	(6)	0.609	1.882	1.726	2.929	5.643	1.995

The income ranges are as follows:

Range Code	Household income range (1996 daily min wages)	Household income range (1996 dollars)
1	0 to 2	$ 0.00 to $ 1,374 /year
2	2 to 6	$ 1,375 to $ 4,122 /year
3	6 to 10	$ 4,123 to $ 6,870 /year
4	10 to 12	$ 6,871 to $ 8,244 /year
5	12 to 18	$ 8,244 to $12,367 /year
6	over 18	$12,368 plus

[2] Technical Memo series "Estudio Integral de Transporte/Multimodal Transportation Study: Development of Travel Demand and Mobile-Source Emission Models for base year 1996, Juarez", (IMIP 1998).

Table 2. Juarez' disaggregate trip attraction rates (daily person-trips per employee).

Trip purpose	Area Type	Household	Employment type		
			Basic	Retail	Service
HBW	CBD	0.125	2.000	1.557	1.899
	Urban	0.125	1.859	3.351	2.953
	Suburban	0.125	1.932	1.777	2.027
	Rural	0.125	1.497	1.615	2.099
HBO	CBD	0.569	0.031	22.417	36.758
	Urban	0.569	0.084	16.275	28.701
	Suburban	0.569	0.036	20.086	29.457
	Rural	0.569	0.195	3.423	2.881
NHB	CBD	0.127	0.062	14.438	0.409
	Urban	0.127	0.505	7.179	3.568
	Suburban	0.127	0.109	2.681	4.875
	Rural	0.127	0.627	10.485	2.694
TT	CBD	0.160	0.002	0.000	0.000
	Urban	0.170	0.000	0.129	0.000
	Suburban	0.180	0.012	0.549	0.102
	Rural	0.180	0.087	0.477	0.028

As depicted in these tables, the trip rates have been disaggregated into four different trip purposes:

1) Home-based-work (HBW) trips, which have the home as one of the trip ends, and work on the other, regardless of which is the origin or destination.
2) Home-based-other (HBO) trips, which have the home as one of the trip ends, and a non-work activity on the other, regardless of which is the origin or destination.
3) Non-home-based (NHB) trips, which have non-home trip ends.
4) Truck-taxi (TT) trips, which are delivery type NHB trips.

Table 2 shows in addition four different categories of Area Type. This is a measure of urban activity concentration also known as activity density. Such attribute needs to be computed for the different component zones of each urban area. Activity density is a function of the population and employment per unit area, as follows:

Activity Density = [Zone Population + (Zone Employment * F)] / Zone Acres (**Eq. 1**)

…where the normalization factor

F = Total study area Population / Total study area Employment (**Eq. 2**)

Area Type thus is categorized as follows:

Code	Area Type	Activity density
4	Rural	up to 26
3	Suburban	27 to 62
2	Urban	63 to 135
1	CBD	over 136

Zone structure

In order to develop trip generation patterns from expansion of the disaggregate trip rates, a zone structure with the required demographic variables like population, household size, income, and employment was established for the municipality of Mexicali. In this regard the Instituto Nacional de Estadística Geografía e Informática (INEGI) has demographic and socio-economic information, disaggregated in census tracts called Areas Geoestadísticas Básicas (AGEBs). These AGEB arrangements were used as reference to develop a traffic analysis zone (TAZ) structure for the urban and rural areas of the municipality. Figure 4 shows the resulting TAZ structure, which follows the alignment of the main roadway system. This TAZ structure was developed into a geographic information system (GIS) coverage, to store zonal attributes of the municipality.

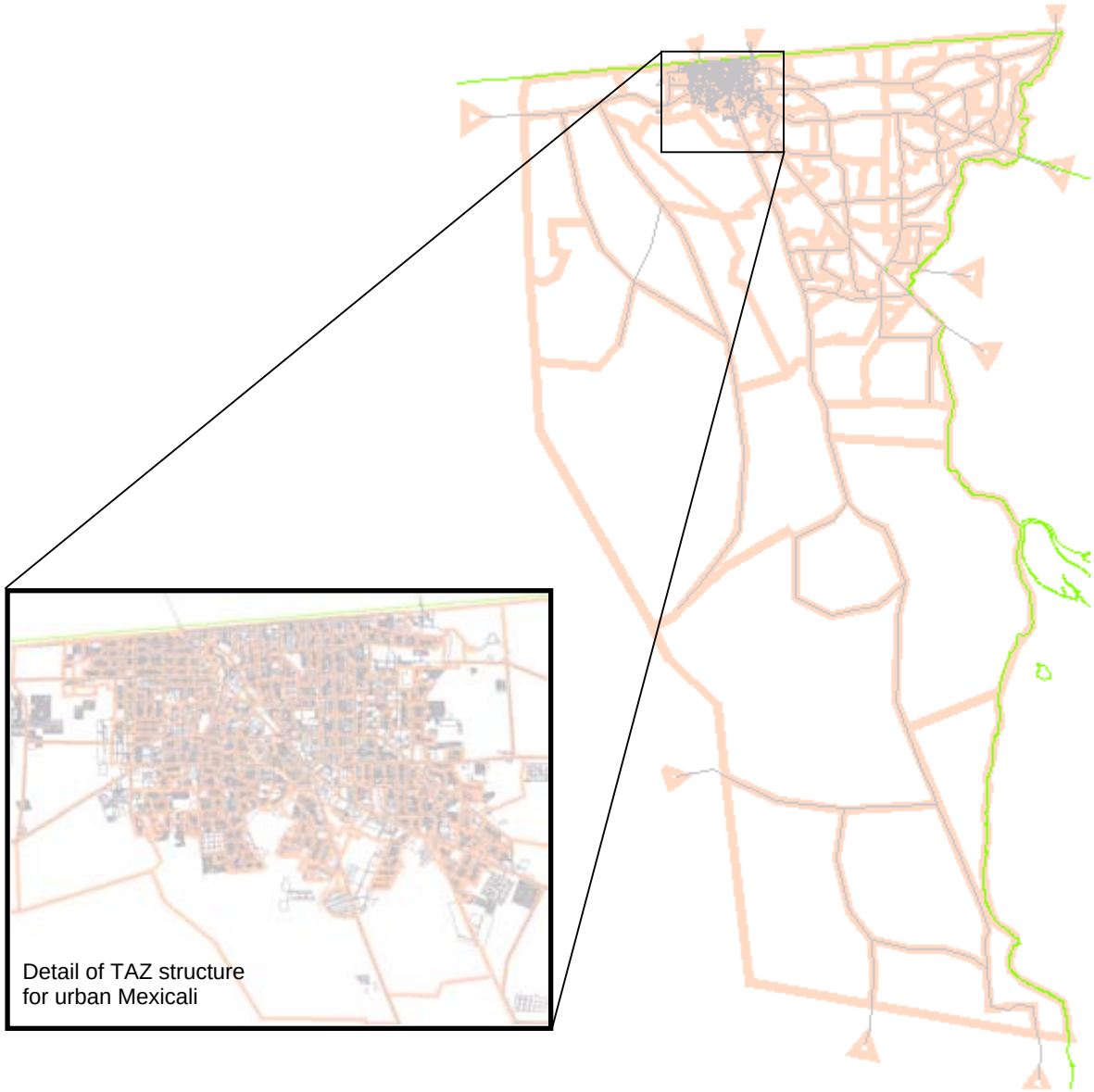

Figure 4. Traffic Analysis Zone (TAZ) structure for the Mexicali municipality.

Disaggregate household information

To develop total productions by TAZ, the trip generation model requires as input the total number of households under each category of size and income for each TAZ.

Regarding income, INEGI reports such variable on a per capita basis, so under the Juarez case study a linear regression was developed to correlate per capita income to a zonal household average income value, specially requested to INEGI from the 1990 census. The regression has the following form:

$$RelHHinc = 3.230 - 0.125*W_a - 0.078*W_b - 0.059*W_c \qquad \textbf{(Eq. 3)}$$

where:

RelHHinc: Zonal average household income/Regional average household income

W_a: Zonal Pop earning less than 1 minimum wage x100/Total zone pop

W_b: Zonal Pop earning between 1 and 2 minimum wages x100 /Total zone pop

W_c: Zonal Pop earning between 2 and 5 minimum wages x100/Total zonal pop

Household size is reported by INEGI as a zonal average at the AGEB level; this number was converted to a relative household size (RelHHsiz), dividing the zonal average household size value by the regional average household size value.

In order to convert the previously described zonal averages to actual number of households on each income and size category, the marginal curves in Figures 5 and 6 were developed. These are used by entering the relative zonal average (zonal average/regional average) on the X axis, and obtaining the percentage of households under each category, depicted by the corresponding marginal curves. The percentages are then applied to the total number of households in the TAZ.

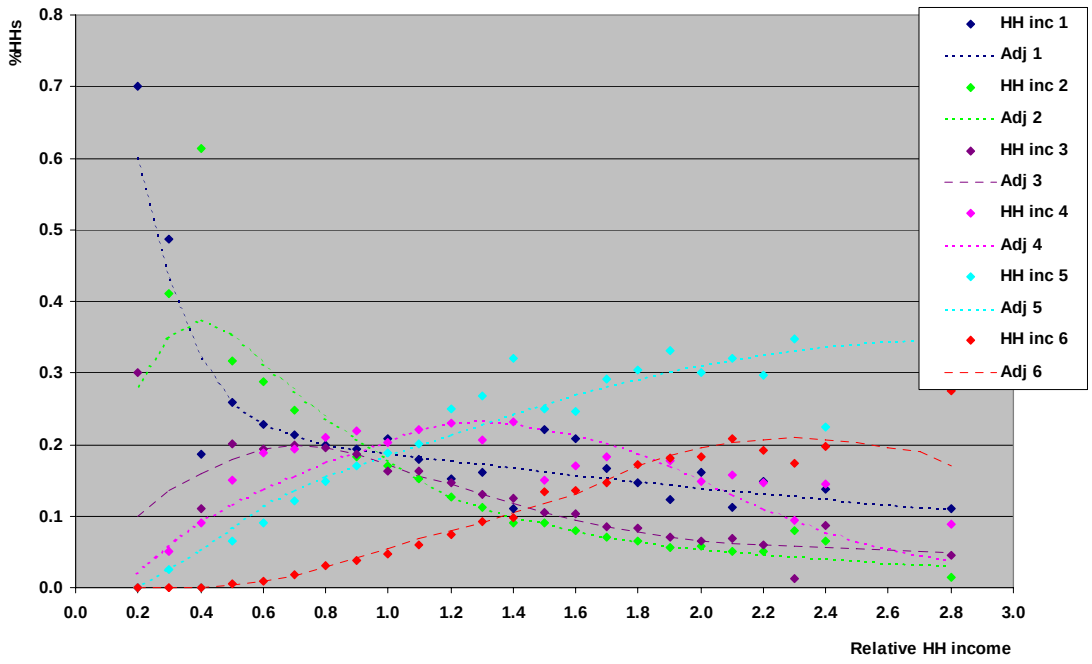

Figure 5. Distribution of households by relative household income (RelHHinc).

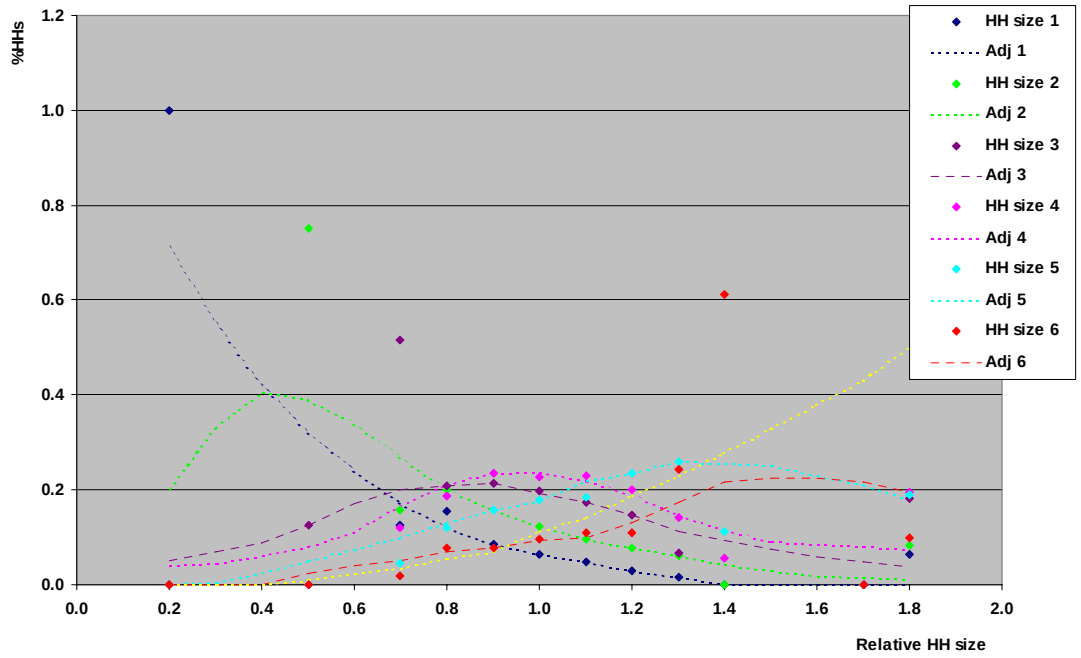

Figure 6. Distribution of households by relative household size (RelHHsiz).

The marginal curves were also developed under the Juarez' transportation research program, using extensively detailed databases specially requested to INEGI from the 1990 census.

Disaggregate employment information

Employment by economic activity for each TAZ is required by the trip generation model to establish trip attraction patterns. This information was obtained directly from the "Censos económicos 2004" (INEGI 2004) for the Mexicali area. Since this information is available only for urban areas of 50,000+ population, there is no employment information for rural areas in Mexico, and thus employment distribution for the rural area of the municipality was assumed to follow similar patterns as those observed in the urban setting; therefore an employee was allocated for every 4 people living on every rural TAZ.

Balanced trip generation totals by AGEB

As previously indicated, the production trip rates are disaggregated by household size and income, therefore the total productions for a zone were obtained simply by multiplying the production trip rates (Table 1) times the number of households under each category of household size and income.

Similarly, total attractions for each zone were obtained by multiplying the attraction trip rates (Table 2) times the number of employees under the corresponding category of area type and economic activity.

The end result of this process is a production-attraction table by zone, for each trip purpose. In theory these productions and attractions under the same trip purpose need to add up to the same number, but since their development are based on different sources (household survey for productions, and workplace survey for attractions), it is common practice to "balance" or factor one to the other, usually to the more reliable one. For the Juarez' case, and thus for the study domain, attractions were balanced to productions.

In the case of the TT trip purpose, the attractions were balanced to a control total equal of POP/20.9, which was the validated relationship in Juarez.

Table 3 shows a summary of raw production and attraction totals by trip purpose as well as the resulting balance factors.

Table 3. Resulting P-A (person-trips/day) totals for the Mexicali municipality.

		unbalanced	F_A	**balanced**
HBW	P	390,000		390,000
	A	393,676	0.9907	390,000
HBO	P	364,950		364,950
	A	311,433	1.1718	364,950
NHB	P	1,820,513		1,820,513
	A	1,352,227	1.3463	1,820,513
TT	P	35,477		35,477
	A	55,374	0.6407	35,477
	Total Ps			2,610,940
	Total As			2,610,940

The balanced P-A by TAZ was stored in the zonal (TAZ) GIS.

III. Vehicle-Trip Distribution

At the trip generation step, the total number of trips produced from, and attracted to each TAZ were estimated and presented in tabular format. This step provides a rough estimate of the trip-making potential for each zone, but does not determine the actual trip exchange with other zones.

The trip distribution step focuses on this trip exchange between zones, identifying from where and to where trips take place. Trip exchange between zones is conventionally presented as a two-dimensional matrix array, where each cell represents the number of trips produced at zone ***i*** (row ***i***) and attracted to zone ***j*** (column ***j***). Next, this Production-Attraction matrix (also referred to as the "P-A matrix") is transformed to Origin-Destination (O-D), simply by reconfiguring the cell values to produce a matrix symmetric around the main diagonal. In this regard it is important to remember that only in the case of NHB trips, Production is considered synonymous to Origin and Attraction to Destination.

<u>The traditional gravity model</u>

The traditional gravity model was originally developed from analogies with the physical world (Newton's gravity formulations), but its real strength comes from later improvements and derivation through entropy-maximizing considerations, which makes the model closely related to information theory, to error measures, and to maximum likelihood in statistics.

The doubly constrained version of the traditional gravity model has the following form:

$$T_{ij} = \beta_i * P_i * \alpha_j * A_j * f(t_{ij}) \qquad \textbf{(Eq. 4)}$$

Where:

- T_{ij}: Trips produced in zone i and attracted to zone j.
- P_i: Total trips produced in zone i.
- β_i: Balancing factor for row i (production constraint).
- A_j: Total trips attracted to zone j.
- α_j: Balancing factor for column j (attraction constraint)
- $f(t_{ij})$: Impedance (decreasing) function, based on the travel time between zone i and zone j.

The two constraints that the model is required to meet are 1) that the sum of trips in any specific row of the matrix should equal the total number of trips produced in that zone, and 2) that the sum of trips in any specific column should correspond to the number of trips attracted to that zone (refer back to Figure 5). The two conditions can be written as:

$$\sum_j T_{ij} = P_i \qquad \textbf{(Eq. 5)}$$

$$\sum_i T_{ij} = A_j \qquad \textbf{(Eq. 6)}$$

The expression of both balancing factors β_i and α_j can thus be derived through simple algebraic manipulations of Equations 4 to 6. These have the following forms:

$$\beta_i = \frac{1}{\sum_j \alpha_j * A_j * f(t_{ij})} \qquad \textbf{(Eq. 7)}$$

$$\alpha_j = \frac{1}{\sum_i \beta_i * P_i * f(t_{ij})} \qquad \textbf{(Eq. 8)}$$

As shown here, the balancing factors are interdependent, meaning that the calculation of one set requires the values of the other set, furthermore suggesting an iterative process until convergence is achieved. Thus, the practical approach to solving this formulation is to specify separate singly constrained models to both productions (Eq. 9) and to attractions (Eq. 10). The first one is obtained by making $\alpha_j = 1$ since in this case the columns are not being balanced. Similarly, the second one is obtained by making $\beta_i = 1$ since in this other case the rows are the ones not being balanced.

$$T_{ij} = P_i * \frac{A_j * f(t_{ij})}{\sum_j A_j * f(t_{ij})} \qquad \textbf{(Eq. 9)}$$

$$T_{ij} = A_j * \frac{P_i * f(t_{ij})}{\sum_i P_i * f(t_{ij})} \qquad \textbf{(Eq. 10)}$$

The solution for the doubly constrained model can then be converged upon by iteratively applying Eq. 9 to balance the productions (rows), and Eq. 10 to balance attractions (columns).

Transportation networks

In order to perform trip distribution, a roadway network needs to be developed for each urban area selected. This network is a simplified version of the current roadway infrastructure layout, including only the main roadways, federal and state highways in the rural setting, and from principal arterials to collector roads in the urban setting. Local roadways and streets are modeled by artificial links called connectors, which allow for the channeling of flows between the TAZs (TAZ centroids) and the network system. The networks were drawn from available maps, and organized in a roadway GIS. Figure 7 shows such primary roadway network developed for the Mexicali municipality.

Each link in the network was initially provided with attributes of functional class (generic type of infrastructure facility), and direction of flow. This information on the urban setting was provided by Mexicali's IMIP (Instituto Municipal de Investigación y Planeación), while for the rural setting this information was established through visual interpretation of satellite images. From this information, a second set of network link attributes was established, based on average conditions developed for the Ciudad Juarez case study. This information was link capacity and average daily speed, corresponding to functional class and area type where individual links are located, as depicted in Table 4. Link travel time was then computed using the assigned link speed.

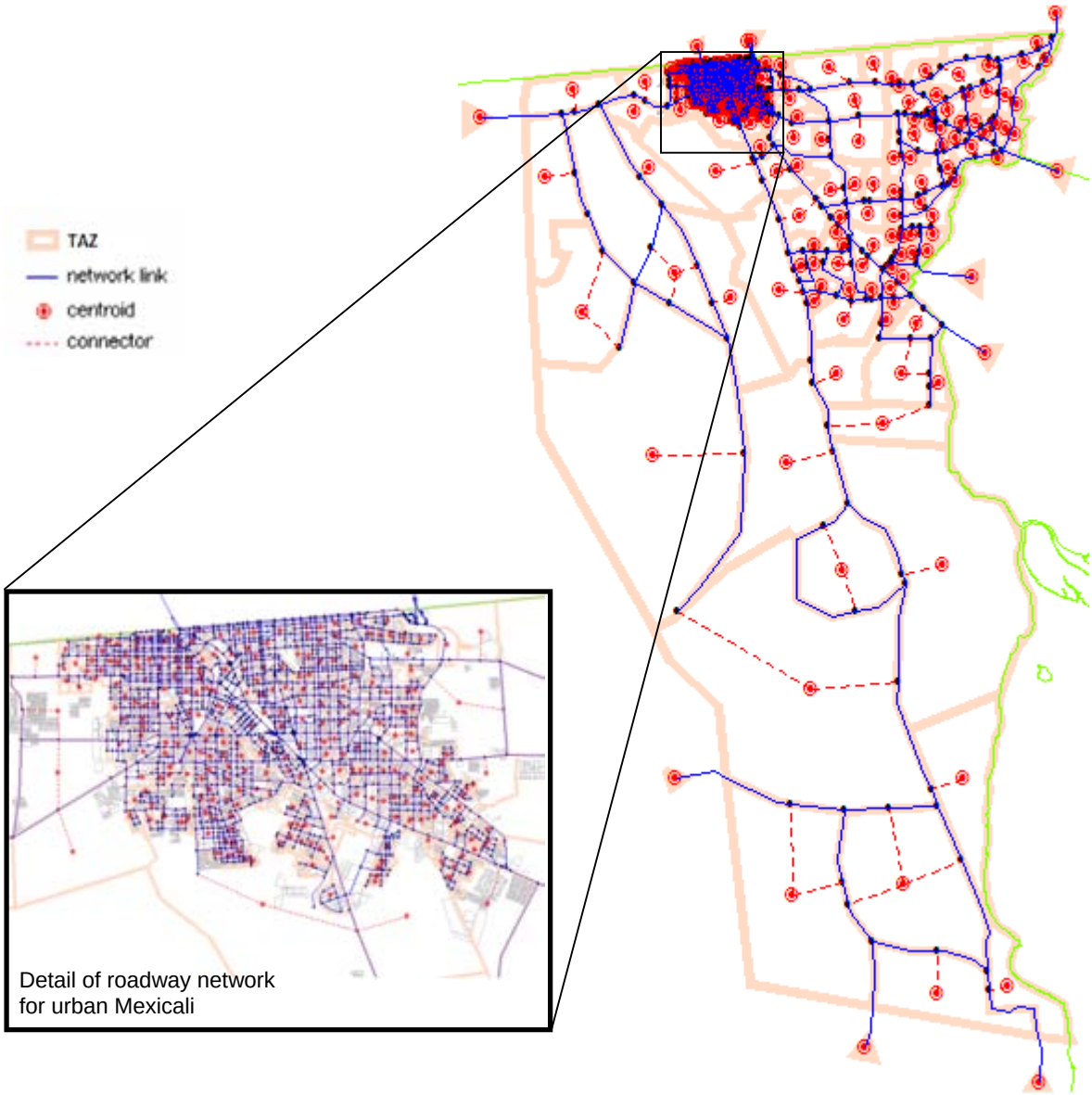

Figure 7. Roadway network model for the Mexican domain.

Table 4. Speed & capacity (daily per lane) lookup table developed for Juarez.

Speed (mph) / Capacity (vpl)		Area Type			
		CBD (1)	Urban (2)	Suburban (3)	Rural (4)
Functional Classification	Conn (0)	15 30,000	15 30,000	25 30,000	35 30,000
	Fwy (2)	29 17,250	29 17,250	31 14,750	38 11,750
	Expy (3)	25 13,100	25 13,100	29 11,750	36 10,250
	PartD (4)	17 8,350	17 8,350	26 7,500	33 6,250
	PartU (5)	17 7,550	17 7,550	25 6,800	32 5,600
	MartD (6)	14 7,250	14 7,250	24 6,500	28 4,050
	MartU (7)	14 6,600	14 6,600	24 5,950	28 3,750
	MartUnp (8)	11 6,200	11 6,200	18 5,550	25 3,350
	Ramp (12)	17 18,000	17 18,000	24 18,000	34 18,000

Roadway networks are needed at this stage of the modeling process mainly to establish travel times between TAZs, since this will feed into the gravity-model evaluation. Using the network travel times, a skim matrix was developed for the domain. This skim matrix depicts the shortest travel time (in minutes) between all TAZs in the study area.

Evaluation of gravity model

The end result of the gravity-model estimation-calibration process, is the definition of the impedance function (the $f(t_{ij})$ term). For the Juarez case study, doubly-constrained gravity models were estimated and calibrated for the four trip purposes, yielding impedance functions in the form of friction factor (FF) tables. Under the current project, these FF tables were borrowed to evaluate gravity models for each of the selected urban areas, using the corresponding set of skim matrices and P-A tables. The result of this evaluation, was the development of trip distribution P-A matrices by trip purpose, for the Mexicali municipality.
The FF tables for each trip purpose are shown in Appendix A.

Development of vehicle-trip OD matrices

As a final task of the trip distribution process, the all-mode person-trip P-A matrices needed to be converted into vehicle-trip O-D matrices.

First, this requires the application of mode shares (specifically AUTO mode), to the total number of person-trips by trip purpose.

Secondly, person-trips on AUTO need to be converted into vehicle-trips, by applying a passenger occupancy rate to the person-trip figure.

From the Juarez research, these AUTO shares and occupancy rates were observed as follows:

	person-trip AUTO share	average veh occupancy
HBW purpose	57.7%	1.09 pax/veh
HBO purpose	44.4%	1.39 pax/veh
NHB purpose	66.1%	1.22 pax/veh
TT purpose	100.0%	1.00 pax/veh

In the Juarez Case study, vehicle-miles traveled (VMT) from TRANSIT mode represents in the order of 2% of the total daily VMT, thus such vehicle activity has been emulated in the VMT mix at the emission modeling stages. The same approach has been followed for the initial six urban area categories.

Finally, in addition to the four generic trip purposes characterizing local (internal to the area) trips, an additional trip purpose was added at this stage, depicting external trips (EXT). This trip purpose actually includes all external-external and external-local trips, that is, trips that have at least one of their trip-ends outside of the study area. In order to develop the corresponding O-D matrix for EXT trip purpose, counts were obtained as control totals for the two POEs[3] and the most important highways connecting the Mexican municipality to other points outside the study area. Table 5 presents a summary of daily vehicle-trips estimated for the Mexican domain.

Table 5. Summary of daily vehicle-trips estimated for the Mexicali municipality.

	daily vehicle-trips
HBW	193,189
HBO	582,286
NHB	211,303
TT	35,477
EXT	104,200
TOTAL	**1,126,455**

[3] In year 2005, the Calexico, Calexico East and Andrade POEs had daily averages of 17000, 9900 and 2000 northbound vehicle crossings, respectively.

IV. Traffic Assignment

The final step in the travel demand modeling process and traffic congestion estimation is traffic assignment. In this step, the final OD vehicle-trip matrix for each urban area was assigned to the corresponding network system, using a user-equilibrium (UE) algorithm. Such algorithm assigns volumes to the network links, and through iteration balances congestion levels between similar cost (time) alternatives. The process involves re-computation of travel speeds to account for congestion levels as traffic volumes accumulate. The result of this step yielded "loaded" networks for the selected urban areas with traffic volumes and speeds at each of the links of the network.

A separate assignment was obtained for weekday and weekend conditions. The weekend assignment was established by applying a factor of 0.7 to the weekday OD matrix. Figure 8 shows a thematic map of the loaded network for the Mexicali municipality under weekday conditions.

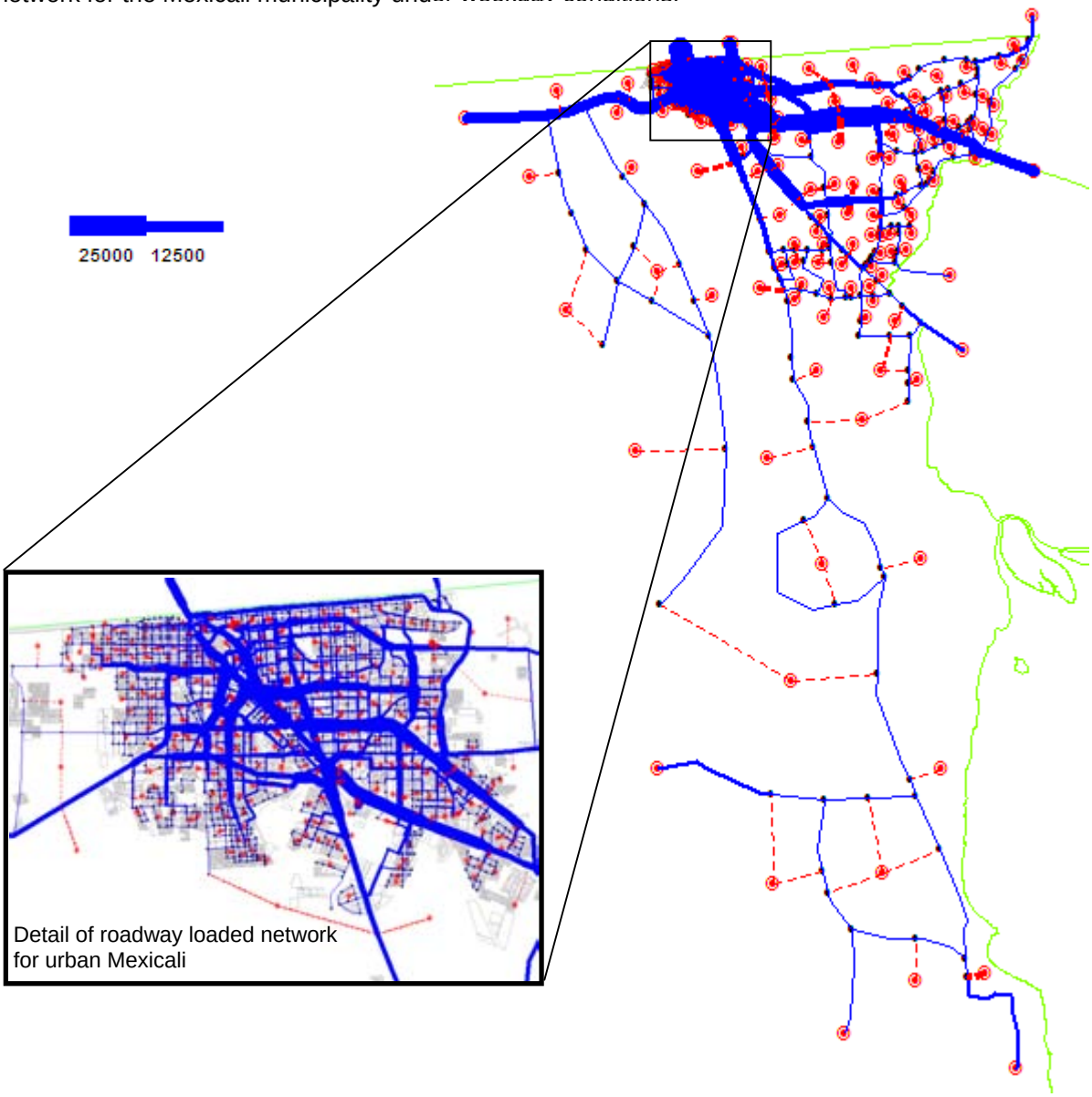

Figure 8. Loaded roadway network under weekday conditions for the Mexican domain.

This information was used to estimate on-road mobile source emissions by link, an then aggregated at the municipality level.

V. On-road mobile source emissions

Having completed the travel demand modeling part of the study, the final task requires converting the resulting daily vehicle activity (motorized travel) into total daily on-road mobile source emissions, for the entire Mexicali municipality. .

Base emission rates

Emission rates in grams/mile-of-travel (or grams/VMT) for VOC, CO, NOx, SO_2, NH_3, $PM_{2.5}$, and PM_{10}, have been obtained through the use of Mobile6-Mexico, for a combination of vehicle speeds going from 3 to 65mph. In addition, emission rates have been obtained for a range of temperatures depicting average ambient conditions at four different time-of-day periods, during four generic seasons of the year.
The time-of-day periods considered were:

period 1	7am to 9am
period 2	9am to 4pm
period 3	4pm to 8pm
period 4	8pm to 7am

The four generic seasons were designed to represent spring, summer, fall, and winter.

Emissions by link

Having developed the base emission rates for the resulting combinations of speeds and temperatures, these were assigned to each link in the transportation networks, based on the prevailing "congested" speed at a specific point in time during the day. For this, the daily non-directional traffic and 24-hour average speeds assigned to each link in the travel models needed to be converted to time-of-day directional traffic and time-of-day directional speeds. To do this a special computer program labeled PrepinPlus was coded in Visual Basic (VB) language, following the methodology developed by the Texas Transportation Institute on its software PREPIN. The following sequence summarizes the process, which needs to be done for each of the four time-of-day periods:

a) The 24-hour non-directional traffic assigned to each network link is distributed over the four time-of-day periods, based on information from ground counts. For Mexican roadway networks the daily traffic volumes have been distributed as follows, based on the Juarez case study:

period 1	9.8% over a 2-hour period
period 2	39.8% over a 7-hour period
period 3	26.0% over a 4-hour period
period 4	24.4% over an 11-hour period
	100.0%

b) To establish the directional split, the period non-directional traffic volume on each link is then applied a factor, which depends on the specific time-of-day period being analyzed. These factors vary also depending on the area type and functional classification of the roadway. Table 6 shows the average directional factors used for the AB link direction; the complement to 1 is applied to the BA direction of each link. At this point then every link in the network has directional traffic volumes for the time-of-day period being evaluated.

Table 6. Directional split factors used for Juarez.

period 1

Area Type	Functional classification 0	1	2	3	4	5	6	7	8	9	10	11	12
1	0.540	0.650	0.500	0.650	0.650	0.650	0.580	0.580	0.645	0.645	0.500	0.500	0.500
2	0.540	0.650	0.500	0.650	0.650	0.650	0.580	0.580	0.645	0.645	0.500	0.500	0.500
3	0.870	0.600	0.500	0.600	0.600	0.600	0.590	0.590	0.630	0.630	0.500	0.500	0.500
4	0.760	0.620	0.630	0.665	0.665	0.665	0.650	0.650	0.738	0.738	0.630	0.630	0.630

periods 2 and 4

Area Type	Functional classification 0	1	2	3	4	5	6	7	8	9	10	11	12
1	0.540	0.550	0.510	0.550	0.550	0.550	0.550	0.550	0.545	0.545	0.510	0.510	0.510
2	0.540	0.550	0.510	0.550	0.550	0.550	0.550	0.550	0.545	0.545	0.510	0.510	0.510
3	0.540	0.540	0.510	0.540	0.540	0.540	0.550	0.550	0.530	0.530	0.510	0.510	0.510
4	0.540	0.565	0.510	0.565	0.565	0.565	0.565	0.565	0.555	0.555	0.510	0.510	0.510

period 3

Area Type	Functional classification 0	1	2	3	4	5	6	7	8	9	10	11	12
1	0.550	0.620	0.540	0.620	0.620	0.620	0.520	0.520	0.575	0.575	0.540	0.540	0.540
2	0.550	0.620	0.540	0.620	0.620	0.620	0.520	0.520	0.575	0.575	0.540	0.540	0.540
3	0.720	0.590	0.540	0.590	0.590	0.590	0.530	0.530	0.645	0.645	0.540	0.540	0.540
4	0.715	0.615	0.665	0.615	0.615	0.615	0.645	0.645	0.648	0.648	0.665	0.665	0.665

c) Next, the average directional 24-hour link capacities provided as attributes of the roadway network are converted into directional hourly capacities. This is done through another set of conversion factors that also depend on the area type and functional classification of the link. Table 7 shows the factors used; these remain constant during the day.

Table 7. Conversion factors for 24-hour to hourly capacities.

Area Type	Functional classification 0	1	2	3	4	5	6	7	8	9	10	11	12
1	N/A	0.063	0.104	0.063	0.066	0.066	0.076	0.076	0.073	0.070	0.070	0.066	0.061
2	N/A	0.063	0.104	0.063	0.066	0.066	0.076	0.076	0.073	0.070	0.070	0.066	0.061
3	N/A	0.077	0.081	0.077	0.080	0.081	0.092	0.092	0.086	0.083	0.083	0.080	0.067
4	N/A	0.106	0.166	0.106	0.116	0.121	0.173	0.167	0.164	0.159	0.159	0.112	0.078

By multiplying the directional hourly capacities by the hours in each period, these are then turned into directional link capacities for the entire time-of-day period.
Having established both directional traffic volume and capacity for each link, for a specific time-of-day period, the link's v/c ratio on each direction can be computed.

d) To establish the directional time-of-day speed, the DFW algorithm in the PREPIN methodology was used. For this algorithm the free-flow speed for each link needs to be established, and for that purpose Table 8 provide average values depending on the link's specific area type and functional classification. For each link, this free-flow speed goes into the DFW algorithm together with the average 24-hour speed, and the directional v/c ratio, thus yielding the directional congested speed.

Table 8. Free-flow speeds in mph.

Area Type	Functional classification 0	1	2	3	4	5	6	7	8	9	10	11	12
1	15.00	50.00	55.00	50.00	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	16.90
2	15.00	50.00	55.00	50.00	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	16.90
3	25.00	50.00	55.00	50.00	25.40	25.40	20.00	20.00	19.40	19.40	25.40	25.40	30.40
4	35.00	51.00	57.00	51.00	36.40	36.40	31.30	31.30	30.00	30.00	30.00	36.40	41.40

Converting link congestion into emissions by-link

The directional speed on each link (established for specific time-of-day periods) is then used to establish the link's emissions rate to use for VOC, CO, NOx, SO_2, NH_3, $PM_{2.5}$, and PM_{10}. These Mobile6-Mexico rates are provided as a lookup table on the VB code and used to assign the resulting rates to each link.

Having established the emission rates for each link, these are then multiplied by the link's length and traffic volume (i.e. link VMT) in the period to obtain the link's emissions concentration per time-of-day.

Annual mobile source emissions estimation

The PrepinPlus code was run using the traffic loaded networks, under each of the seasonal temperatures, as well as for weekday and weekend conditions. The resulting emissions-by-link were added for the four time-of-day periods to establish daily emissions-by-link. These total daily emissions-by-link were aggregated for the entire Mexicali municipality. Finally the weekday and weekend emissions were aggregated by season, considering 13 weeks per season, and within each week, 5 weekdays and 2 weekend days. The seasonal emissions for spring, summer, fall and winter were added to establish annual emissions.

The annual on-road mobile source emissions estimated for the Mexicali municipality are summarized by pollutant on Table 9.

Table 9. Annual on-road mobile source emissions (8 vehicle classes) for the Mexican municipality (2005)

	LDGV [Tm/year]	LDGT12 [Tm/year]	LDGT34 [Tm/year]	HDGV [Tm/year]	LDDV [Tm/year]	LDDT [Tm/year]	HDDV [Tm/year]	MC [Tm/year]	**ALL** [Tm/year]
VOC*	4,128	2,163	1,098	357	9	5	309	75	8,143
CO	26,709	15,943	8,234	2,246	17	10	1,428	392	54,979
NOx	1,045	1,019	363	340	11	7	4,956	34	7,775
SO_2	23	21	9	4	0	0	96	0	154
NH_3	113	79	24	3	0	0	10	0	229
CH_4	53	39	17	6	0	0	12	4	132
$PM_{2.5}$	107	104	37	6	2	1	347	0	604
PM_{10}	130	123	44	8	2	1	385	1	694

* Emissions for VOC include exhaust and evaporative

VI. Paved and Unpaved Road Dust

In addition to the particulate matter (PM) emissions estimated from vehicle exhaust and tire/break wear (shown in Table 9), in a separate exercise PM was also estimated from roadway dust airborne by vehicle movement. The amount of airborne dust is a function of the amount of dust on the roadway, and also of the vehicle traffic volume (VMT: vehicle-miles of travel) and average vehicle speed of a roadway, which are conditions estimated from the travel demand model.

In most cases, the functional class of each link will indicate if it is paved or unpaved (FUNCL=8 indicates unpaved condition), and therefore which PM emission factor is appropriate. Yet, in the special case of centroid connector links (FUNCL=0), this requires an additional task, since centroid connectors are virtual links representing multiple local roadways within a TAZ. If a proportion of such local roadways in a given TAZ are unpaved, this needs to be represented in the selected emission factors for the TAZ's centroid connector link.

Figure 9 presents a map of the TAZs with categories of roadway pavement coverage[4].

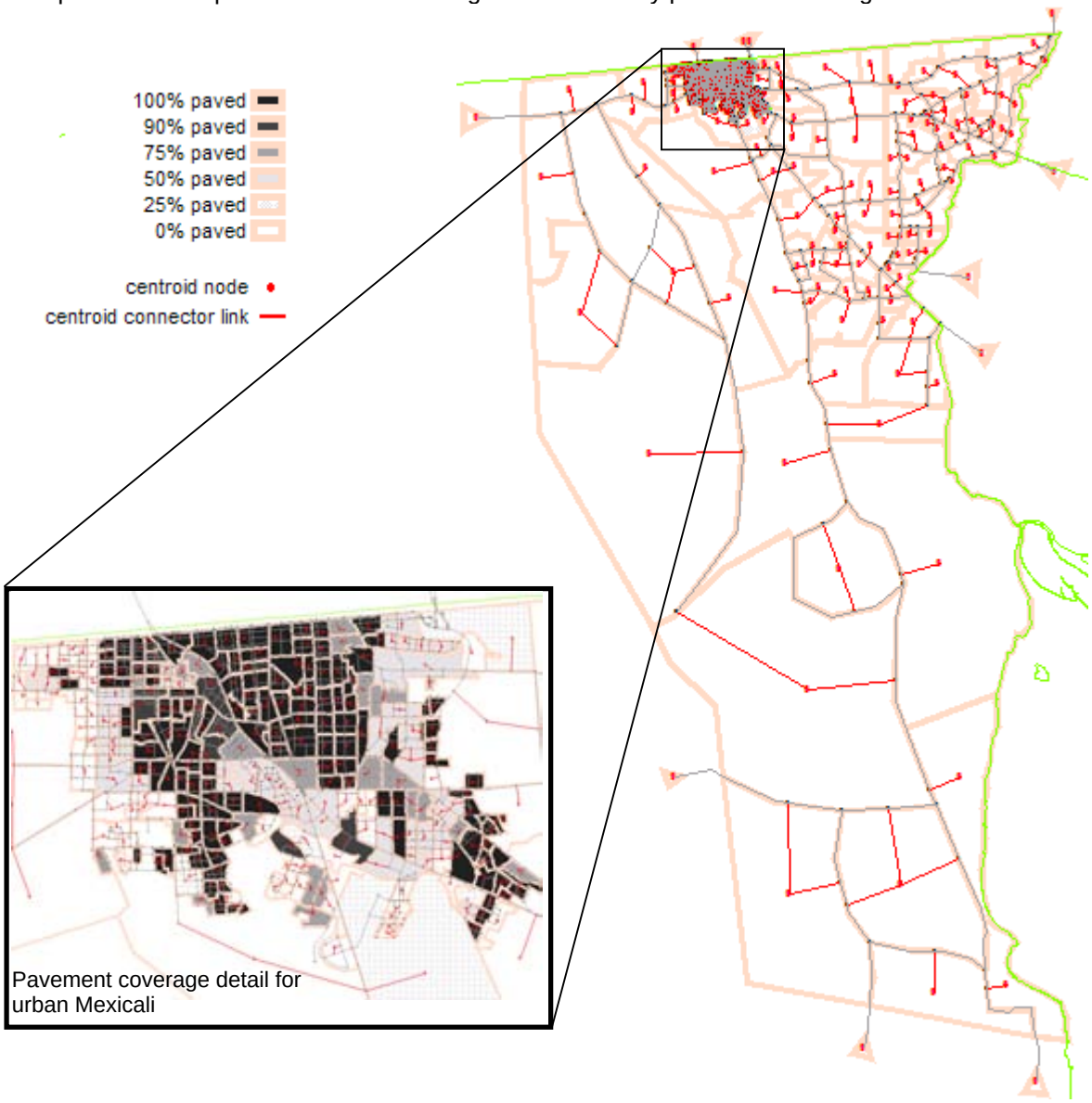

Figure 9. Roadway pavement coverage of TAZs in the Mexicali municipality.

[4] Coverage by zone provided by the Mexicali IMIP.

Paved and unpaved VMT

For proper characterization of PM from paved and unpaved roadways, the VMT obtained with the travel demand model was also identified by the paved/unpaved categories.

On the one hand, the VMT on all centroid connector links (red links in Figure 9) was divided between paved and unpaved conditions proportionally to the roadway pavement coverage of the corresponding TAZ. In addition, some of the on-system links (gray links in Figure 9) were identified as unpaved as well (refer to Figure 2), and therefore the VMT over on-system links was also categorized as paved or unpaved. Table 10 provides a summary of VMT over paved and unpaved roadways in the Mexicali municipality.

Table 10. Summary of modeled VMT on paved and unpaved roadways for the Mexciali municipality (2005)

	area [sq-miles]	daily VMT	%VMT	
			paved	unpaved
Urban Mexicali	54	3,965,327	98.0%	2.0%
Rural Mexicali	5,563	3,911,214	89.7%	10.3%
Mexicali Municipality	5,617	7,876,541	93.9%	6.1%

Even though the apparent surface of TAZs with no paved roadways seems to dominate over the study area, the actual miles of roadways in these TAZs is minimal. In terms of vehicle activity the effect is equivalent, and thus over 90% of the VMT in the Mexicali municipality takes place over paved roadways.

Paved and unpaved PM emissions from roadway dust

Based on the dust sampled from roadways in the Mexicali municipality, the following emission factors were estimated with Mobile6-Mexico:

Paved roads, at any vehicle speed:

- PM_{10} of 0.00377 lbs/VMT[5]
- $PM_{2.5}$ of 0.00034 lbs/VMT

Unpaved roads, at 11mph (average speed on urban settings):

- PM_{10} of 0.35442 lbs/VMT
- $PM_{2.5}$ of 0.03515 lbs/VMT

Unpaved roads, at 18mph (average speed on suburban settings):

- PM_{10} of 0.45350 lbs/VMT
- $PM_{2.5}$ of 0.04505 lbs/VMT

Unpaved roads, at 25mph (average speed on rural settings):

- PM_{10} of 0.53453 lbs/VMT
- $PM_{2.5}$ of 0.05316 lbs/VMT

Once every roadway link in the municipality was assigned and emission factor, and multiplied by its corresponding VMT, total PM for weekday and weekend day was estimated, as summarized in Tables 11 and 12.

[5] Link VMT is estimated by multiplying the daily traffic volume of each link by the link's length (in miles).

Table 11. Weekday PM emissions from roadway dust in the Mexicali municipality (2005)

	VMT	PM_{10} [metric Tons]	$PM_{2.5}$ [metric Tons]
paved roadways	7,395,242	12.5	1.1
unpaved roadways	481,299	115.0	11.4
all roadways	7,876,541	127.5	12.6

Table 12. Weekend day PM emissions from roadway dust in the Mexicali municipality (2005)

	VMT	PM_{10} [metric Tons]	$PM_{2.5}$ [metric Tons]
paved roadways	5,158,478	8.7	0.8
unpaved roadways	337,933	80.8	8.0
all roadways	5,496,411	89.5	8.8

Using the daily emissions from Tables 11 and 12, yearly PM emissions from roadway dust is summarized on Table 13.

Table 13. Yearly PM emissions from roadway dust in the Mexicali municipality (2005)

	paved roadways [metric Tons/yr]	unpaved roadways [metric Tons/yr]	**ALL roadways** [metric Tons/yr]
$PM_{2.5}$	383	3,819	4,202
PM_{10}	4,182	38,403	42,586

It can be seen that the PM emission factors for unpaved roadways are considerably higher than paved roadways, thus explaining why the amount of PM from unpaved roadways overpasses by far the PM from paved roadways, even though the VMT on paved roadways is much larger.

Compared to PM from vehicle exhaust (Table 9), PM from roadway dust is considerably higher.