Appendix C

On-Road Mobile Source Emissions Inventory for Southeast Michigan PM2.5 Redesignation Request

On-Road Mobile Source Emissions Inventory for Southeast Michigan
PM2.5 Redesignation Request

January 27, 2011

Prepared by the
Southeast Michigan Council of Governments (SEMCOG)
535 Griswold, Suite 300
Detroit, MI 48226

(313) 961-4266

Table of Contents

List of Tables

On-Road Mobile Source Emissions Inventory for Southeast Michigan PM2.5 Redesignation Request

I. Emissions Inventory Summary

Below are the annual and daily on-road mobile source emission inventories for fine particulate (PM2.5), nitrogen oxide (NOx) and sulfur dioxide (SO2). The daily inventory reflects average winter weekday conditions because the highest PM2.5 concentrations generally occur during the winter season.

Table 1: Annual and 24-Hour PM2.5 On-Road Emissions Inventories for Southeast Michigan

Year	Vehicle Population	Annual Inventory				Average Winter Weekday Inventory			
		Vehicle Miles of Travel (millions)	PM2.5 (tons)	NOx (tons)	SO2 (tons)	Vehicle Miles of Travel (millions)	PM2.5 (tons)	NOx (tons)	SO2 (tons)
2005	3,660,074	44,187	5,323	154,294	3,809	126.1	19.2	460.8	8.6
2008	3,647,666	44,156	4,360	119,194	1,066	125.6	15.7	365.3	3.1
2018	3,667,667	44,279	1,633	37,847	310	126.3	6.6	117.8	0.9
2022	3,687,940	44,523	1,311	28,044	294	127.0	5.6	88.1	0.8
2035	3,795,289	45,819	1,123	21,791	283	130.7	4.9	69.2	0.8

II. On-Road Mobile Emissions Inventory Development

The PM2.5 on-road emissions inventories were developed using the U.S. EPA's new Motor Vehicle Emission Simulator (MOVES) model. The analysis used version MOVES2010a, which was released in August 2010. MOVES is EPA's successor to the Mobile6 model. However, in addition to generating mobile emission rates, MOVES also has the capability to calculate on-road mobile emissions inventories, thus eliminating the need for most of the post-processing that was necessary with Mobile6.

To prepare a regional emissions inventory, the user has the choice of modeling each county separately or combining counties to form a custom domain. SEMCOG has chosen the latter option for two reasons. First and foremost, staff believe that traffic count and vehicle population data used in the emissions modeling process are more robust at the regional level and more accurately reflect the travel patterns in the region, which are not confined within county boundaries. For example, the age distribution of vehicles registered within a specific county may not reflect the age distribution of vehicles traveling on that county's roads because of the high amount of inter-county travel in the region. The second reason for choosing the custom domain option is that it saves a significant amount of time. A single MOVES run, whether by county or custom domain, takes approximately one hour. Thus, a typical conformity analysis which

requires two separate runs for each of four required analysis years, would take 56 hours if run at the county level but only 8 hours using the custom domain.

MOVES includes default data for many of its necessary data inputs. However, wherever possible SEMCOG has incorporated local data in order to develop the most accurate emissions inventory for Southeast Michigan. These local data inputs are described below. To ease the transition from Mobile6 to MOVES, EPA has provided a number of "conversion tools" that allow users to convert local data inputs used in Mobile6 to the MOVES input format. SEMCOG has taken advantage of several of these tools. Their use is noted under the appropriate sections below.

A. Local Travel Data Inputs

1. Demographic Data

Travel forecasts used to develop the on-road mobile source emissions inventory were based on demographic data from SEMCOG's 2035 Regional Development Forecast (RDF), which was adopted in early 2008. A three-step process was used to develop this forecast.

1) Regional forecast totals of population, households and jobs were generated from the REMI (Regional Economic Models, Inc.) model which forecasts Southeast Michigan's ability to attract and retain population and jobs relative to all other parts of the United States. Regional totals are developed in five-year intervals from the 2005 base year to 2035;

2) The regional totals were then used to develop a small-area forecast that disaggregates regional population, households and jobs into five-acre grid cells using the UrbanSim model. UrbanSim is a computer simulation model for planning and analysis of urban development. It incorporates the interaction between land use, transportation, and public policy. In doing so, it puts future population and jobs into the most desirable grid cells and models residential and nonresidential developments as demand arises.

3) Grid cells from the small-area forecast were aggregated to traffic analysis zones (TAZs) for use in SEMCOG's travel forecasting model.

As noted above, SEMCOG's RDF provides forecasts in five-year increments from 2005 to 2035. The 2008, 2018 and 2022 demographic forecasts used to develop the PM2.5 emissions inventories were interpolated using the two closest five-year forecasts for each of these years (i.e. 2008 was interpolated using the 2005 and 2010 RDF forecasts).

It should also be noted that the 2035 RDF was developed prior to the severe economic downturn in late 2008. The 2040 RDF, which is currently under development and will be completed in March 2012, will likely forecast significantly lower population and employment for the region.

2. SEMCOG's Travel Demand Forecasting Model (TDFM)

Vehicle miles of travel (VMT) forecasts for the on-road emissions inventory were developed using version E5 of SEMCOG's Travel Demand Forecasting Model (TDFM), which was implemented in 2009. The TDFM runs on the TransCAD software platform and utilizes the standard four-step travel modeling process: trip generation, trip distribution, mode choice, and traffic assignment. Detailed documentation on the model is contained in a separate SEMCOG document that is available upon request.

3. Mapping of Travel Demand Model (TDFM) Functional Classes and Area Types to MOVES Road Types

In order to use TDFM travel data in MOVES, the road types used in SEMCOG's model must be reconciled with those used in MOVES. The MOVES model uses four basic road types for on-road activities: Urban Restricted, Urban Unrestricted, Rural Restricted and Rural Unrestricted. The term restricted refers to restricted or limited access roadways. In the SEMCOG region, this includes all freeway facilities. All other roadways in the SEMCOG region are considered unrestricted facilities. The TDFM also includes several special functional classes that are not part of the regular roadway network (e.g. walk only, external zone connectors, transit-only links). These are not included in SEMCOG's emissions modeling.

As TDFM functional classes do not distinguish between urban and rural facilities, another TDFM variable, Area Type, was used as a surrogate. The TDFM defines four area types (urban business, urban, suburban and rural) and assigns one to each roadway link based on the density of households, population and employment in the traffic analysis zone in which the link resides.

Table 2 shows how each area type and functional class in SEMCOG's TDFM is mapped to the four road types used in MOVES.

Table 2: Mapping of TDFM Functional Class and Area Type to MOVES Road Type

<table>
<tr><th rowspan="2">SEMCOG TDFM Functional Class</th><th colspan="4">SEMCOG TDFM Area Type</th></tr>
<tr><th>Urban Business</th><th>Urban</th><th>Suburban</th><th>Rural</th></tr>
<tr><td>1 - Interstate Freeway</td><td colspan="3" rowspan="4">4 – MOVES Urban Restricted Road Type</td><td rowspan="4">2 – MOVES Rural Restricted Road Type</td></tr>
<tr><td>2 - Other Freeway</td></tr>
<tr><td>8 - Ramp</td></tr>
<tr><td>11 - Freeway Connector</td></tr>
<tr><td>4 - Principal Arterial</td><td colspan="3" rowspan="6">5 – MOVES Urban Unrestricted Road Type</td><td rowspan="6">3 – MOVES Rural Unrestricted Road Type</td></tr>
<tr><td>5 - Minor Arterial</td></tr>
<tr><td>6 - Collector</td></tr>
<tr><td>7 - Local</td></tr>
<tr><td>12 - Gravel Road</td></tr>
<tr><td>99 - Centroid connector (local road surrogate)</td></tr>
<tr><td>81-94 Transit Use Only</td><td colspan="4" rowspan="3">Non-road or outside region. Not used in MOVES</td></tr>
<tr><td>90 - External</td></tr>
<tr><td>96 - Walk Only</td></tr>
</table>

4. Vehicle Miles of Travel (VMT)

MOVES requires the user to input annual VMT by the six FHWA Highway Performance Monitoring System (HPMS) vehicle types:

1) Motorcycle
2) Passenger car
3) Other 4-tire, 2-axle vehicles
4) Bus
5) Single unit truck
6) Combination truck

However, local VMT data used in the MOVES model is derived from SEMCOG's Travel Demand Forecast Model, which generates average weekday VMT forecasts and does not currently have the capability to allocate this VMT to different vehicle types. Thus, some

adjustments were required to convert the TDFM data into the format required for MOVES. These adjustments are described below.

a. HPMS Normalization

In accordance with EPA and FHWA guidance, SEMCOG TDFM VMT was normalized to HPMS VMT by county and road type. Normalization factors were developed by dividing 2009 HPMS VMT by 2009 TDFM VMT. The resulting factors were then applied to TDFM VMT in all analysis years.

b. Distribution of VMT Among HPMS Vehicle Types

A two-step process was used to develop this distribution. First, SEMCOG's 2006 screen line traffic count database was used to develop VMT distribution factors among the six HPMS vehicle classes. This database includes 779 traffic classification counts collected throughout the seven-county SEMCOG region. When collected, the counts were classified by FHWA's standard 13 traffic bins. These bins were then aggregated to the six HPMS classifications.

The second step in the process involved adjusting for a recognized bias in the traffic count data toward undercounting the proportion of light trucks, SUVs, and vans. This bias was first recognized in 2004 when local count data was compared to both vehicle registration records and Mobile6 national default data. The bias is likely due to the inability of traffic counting equipment to correctly distinguishing these vehicles from cars, causing them to be classified under the HPMS system as "passenger cars" rather than "other 4-tire, 2-axle vehicles". To correct for this bias, the count data from these two classifications were combined and then redistributed based on the MOVES default distribution. Both the original and adjusted factors are shown in Table 3.

Table 3: VMT Distribution Factors by HPMS Vehicle Types

HPMS Vehicle Type	Before Step 2 Adjustment	After Step 2 Adjustment*
1 Motorcycle	0.011567	0.011567
2 Passenger Car	0.713678	0.534530
3 Other 4-tire, 2-axle vehicles	0.186204	0.365352
4 Bus	0.008705	0.008705
5 Single-Unit Truck	0.039116	0.039116
6 Combination Truck	0.040730	0.040730

* MOVES default split between vehicle types 2 & 3: 59.4% vs. 40.6%

c. Conversion of Average Weekday VMT to Annual VMT

Monthly and weekend day adjustment factors were developed using 2004-2006 data from the 150+ permanent traffic recording (PTR) stations in Southeast Michigan. These adjustment factors, along with the HPMS-normalized weekday VMT by

vehicle type were then entered into EPA's *aadvmtcalculator_hpms.xls* converter tool to compute the annual VMT and monthly and daily VMT fractions needed for MOVES.

5. Hourly VMT Fractions

Two different data sources were used to develop hourly VMT fractions for MOVES:

1) 2006 screen line traffic counts collected by SEMCOG - All screen line counts include classification data but were only collected on weekdays.

2) 2005 PTR counts for locations within the SEMCOG region - This data includes both weekdays and weekends but all of the count stations are on freeways and only a limited number of these stations collect classification data.

Using this data, SEMCOG was able to develop weekday hourly VMT fractions for each of the four MOVES road types and six HPMS vehicle types. However, for weekends, the count data was not robust enough to develop separate factors by road type or vehicle type so only a single set of hourly VMT factors was developed for all the road types and vehicle types.

6. Road Type Distribution

SEMCOG 2006 screen line counts were used to develop the Road Type Distribution for each HPMS vehicle type. Because these counts were not evenly distributed among the four MOVES road types, the count data was first expanded to reflect the system-wide VMT distribution by road type from the TDFM. Table 4 shows the final distribution factors used in MOVES runs for PM2.5 re-designation request. The same distributions were used for all analysis years.

Table 4: Road Type Distribution Used in MOVES

HPMS Vehicle Type	MOVES Road Type			
	Rural Restricted	Rural Unrestricted	Urban Restricted	Urban Unrestricted
Motorcycle	0.082102	0.080699	0.348661	0.488538
Passenger Car	0.051566	0.092906	0.290307	0.565221
Other 4-tire, 2-axle vehicles	0.054670	0.154881	0.258523	0.531927
Bus	0.115776	0.082206	0.365080	0.436938
Single-Unit Truck	0.080163	0.127845	0.355673	0.436318
Combination Truck	0.171595	0.066330	0.447998	0.314077

7. Average Speed Distributions

MOVES uses the distribution of vehicle hours traveled (VHT) by average speed to determine an appropriate operating mode distribution. To develop the local average speed distribution for Southeast Michigan, SEMCOG used congested speed and VHT output from the TDFM to compute the VHT fraction in each MOVES speed bin. MOVES requires the user to input hourly speed distributions by road type and vehicle class. While SEMCOG's travel model does not provide hourly speed data, it does calculate speeds by four different time periods:

1) AM peak, simulating the hours of 7:00 - 9:00 a.m.;
2) PM peak, simulating the hours of 3:00 - 6:00 p.m.;
3) Mid-day, simulating the hours of 9:00 a.m. - 3:00 p.m.;
4) Off-peak, simulating the hours of 6:00 p.m. - 7:00 a.m.

For MOVES, a separate speed distributions was developed for each of these time periods and applied to all hours within that period. This was done as follows:

- For each time period, the directional congested speed of each roadway link was assigned to one of MOVES 13 speed bins;
- The associated directional VHT on the links was then aggregated by speed bin and MOVES road type;
- Then, for each road type, the VHT fraction in each speed bin was computed.

As no local data is currently available on speed differentiation between vehicle classes, the same distributions were applied to all vehicle types.

Note: Ramp data was not included in the development of the above speed distributions as it was assumed that MOVES makes an internal adjustment for ramps using the user-supplied ramp fractions.

8. Ramp Fractions

Ramp fractions used in MOVES were derived from SEMCOG's Travel Demand Forecast Model. Table 4 shows the TDFM ramp fractions for each of the years modeled in SEMCOG's long-range transportation plan. While the fractions show little variation over time, there is a significant difference between urban and rural areas. Thus, SEMCOG decided to use separate ramp fractions for urban and rural areas in MOVES. Rather than select the fraction associated with any one TDFM forecast year, the average of all six years was chosen. The specific fractions used in MOVES are shown in the far right column of Table 5.

Table 5: Urban and Rural Ramp Fractions

Area Type	TDFM Forecast Year							
	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**MOVES**
2-Rural Ramp	0.0412	0.0408	0.0397	0.0398	0.0398	0.0395	0.0393	**0.04**

4-Urban Ramp	0.0795	0.0807	0.0814	0.0812	0.0809	0.0837	0.0843	**0.08**

9. Vehicle Population

Year 2010 vehicle registration data from the Michigan Department of State (DOS) was used to develop the base year vehicle population inputs for MOVES. This data was supplemented with vehicle title data to capture information on public sector fleet vehicles (e.g. those owned and operated by cities, counties, universities, etc.) that do not appear in the registration database. The body style and plate type fields in the DOS database were used to determine the MOVES source type of each vehicle. Table 6 shows how each DOS body style and plate type was mapped to the MOVES source types. Where DOS data did not provide sufficient detail, the data was supplemented with information from other sources including local transit agencies, the National Transit Database, and MOVES default distributions for Southeast Michigan counties.

Table 6. Mapping between MOVES Vehicle Types and Michigan DOS Body Style

MOVES Vehicle Type	Michigan DOS Body Style
11 – Motorcycle	Motorcycle
21 – Passenger Car	2-door; 4-door; Convertible
31 – Passenger Truck	Station Wagon; Non-Commercial Pick-up/Van
32 – Light Commercial Truck	Ambulance; Hearse; Panel; Commercial Pick-up/Van
41 – Intercity Bus	Bus (Apportioned this data between MOVES M41 and M43 vehicle types using split factors from MOVES 2010 default run; data for M42-transit buses was added using local fleet data from local transit providers)
42 – Transit Bus	
43 – School Bus	
51 – Refuse Truck	Dump Truck; Mixer; utility; Wrecker; Stake; Tank (Apportioned this data MOVES M51, M52 and M53 vehicle types using split factors from MOVES 2010 default run.)
52 – Single-unit Short-haul Truck	
53 – Single–unit Long-haul Truck	
54 – Motor Home	Motor Home
61 – Combination Short-haul Truck	Tractor (Apportioned this data between MOVES M61 and M62 vehicle types using split factors from MOVES 2010 default run)
62 – Combination Long-haul Truck	

To generate future year vehicle population data, it was assumed that this population would grow at the same rate as forecasted vehicle miles of travel from the TDFM. The rate of growth between 2010 and each future analysis year was calculated. This rate was then uniformly applied to all 2010 vehicle population source types to generate the future year population.

Detailed documentation on the development of SEMCOG's vehicle population data is contained in a separate SEMCOG mobile emissions model development memo.

10. Vehicle Age Distribution

Year 2010 DOS vehicle registration and title data were also used to develop the vehicle/source type age distribution used in MOVES. The DOS body style field was used to assign each vehicle to one of six HPMS vehicle types (see Table 7 below). Once HPMS vehicle types had been assigned, the data was aggregated by model year and assigned to the appropriate age category. Model years 2010 and 2011 were considered age 0, 2009 was considered age 1 and so on. Model years 1980 and older were grouped into the age 30+ category. The age distribution for each HPMS vehicle type was then computed. The same distributions are used for all analysis years.

Table 7: Mapping between HPMS Vehicle Types and Michigan DOS Body Styles

HPMS Vehicle Type	Michigan DOS Body Style
Motorcycle	Motorcycle
Passenger Car	2-door; 4-door; Convertible
Other 4-tire, 2-axle vehicles	Station Wagon; Non-Commercial Pick-up/Van; Ambulance; Hearse; Panel;
Bus	Bus
Single-unit Short Truck	Dump Truck; Mixer; Utility; Wrecker; Stake; Tank , Motor Home
Combination Truck	Tractor

B. Other Local Data Inputs

1. Temperature and Humidity Data

Temperature and humidity data are required inputs for MOVES. For the PM2.5 on-road mobile emissions inventories, local temperature profiles were developed for each month of the year. To generate these profiles, the average minimum and maximum daily temperatures for each month in Southeast Michigan were computed using 2007-2009 National Weather Service (NWS) local climatological data reports. This data was provided by the Michigan Department of Environmental Quality (MDEQ). EPA's *MeteorologicalDataConverter_Mobile6.xls* tool was then used to convert the average minimum and maximum temperatures to the required hourly temperature inputs for MOVES. Table 8 shows the average min/max temperatures that were used to develop each month's hourly profile.

Table 8: Monthly Average Min/Max Temperatures for PM2.5

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	18.4	17.2	28.6	39.5	48.7	60.0	61.4	62.9	56.6	44.1	34.3	22.7
Max	32.2	31.5	46.2	60.0	70.2	79.8	81.2	81.8	76.1	62.4	48.6	34.8

SEMCOG's emissions analysis used MOVES default humidity data for Southeast Michigan as no other local data was available.

2. Barometric Pressure

The barometric pressure used for Southeast Michigan was the average of the MOVES default values for SEMCOG's seven counties. Table 9 below shows each county's default value and the resulting average used for the emissions inventory.

Table 9: Barometric Pressure Data used in MOVES

SEMCOG County	MOVES Default Barometric Pressure (inches of Mercury, inHg)
26093 - Livingston	29.113
26099 - Macomb	29.144
26115 - Monroe	29.173
26125 - Oakland	29.146
26147 - St. Clair	29.172
26161 - Washtenaw	29.095
26163 - Wayne	29.069
Average	**29.130**

3. Fuel Supply/Fuel Formulation

In transitioning its mobile emissions modeling from Mobile6 to MOVES, SEMCOG reviewed both the Fuel Supply and Fuel Formulation default values contained in MOVES for counties in Southeast Michigan (Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw and Wayne counties). Only 2005 and later years were reviewed. Earlier years will be reviewed in future if there is a need to model them.

Several adjustments were made to accurately reflect observed ethanol market share data from the Michigan Department of Agriculture as well as State regulation on permitted oxygenates and maximum allowable summertime Reid vapor pressure (RVP) in Southeast Michigan. These adjustments are documented below.

- Corrected the 2012 summertime gasoline RVP for all SEMCOG Counties to reflect the State's legal limit for Southeast Michigan (7.0 psi).

- Zeroed out any market share for gasoline with MTBE or TAME since neither has been used in Michigan since 2003.
- Adjusted the ethanol market share for all SEMCOG counties to match observed data from the Michigan Department of Agriculture's *Consumer Protection Section Annual Reports* for years 2005-2009.
- Set the ethanol market share for all SEMCOG counties to 100% in years 2010 and later. This was the observed share in 2009 and is expected to continue in future due to federal requirements for increased use of biofuels.

The resulting RVP and ethanol market share values used in MOVES after the above corrections are shown in Table 10 below.

Table 10: Revised RVP and Ethanol Market Shares used in MOVES

Year	**Summer RVP** (months 5-9)	**Ethanol Market Share** (all months)
2005	7.8 psi	39.5%
2006	7.8 psi	58.4%
2007	7.0 psi	80.3%
2008	7.0 psi	98.9%
2009	7.0 psi	100.0%
2010 and later	7.0 psi	100.0%

.