

Chapter 2: Modeling Methodology and Assumptions

This chapter presents an overview of the modeling approach including key input data and assumptions as applied for the regional conformity analysis for the 2035 LRTP and FY 09-12 TIP for the Fredericksburg 8-hour ozone maintenance area.

General Emission Calculation Methodology

Emission forecasts for the Fredericksburg maintenance area were developed using a traditional four-step transportation planning model (CUBE Voyager), the latest EPA approved emission factor model (MOBILE6.2), and a post-processor developed by VDOT to combine the modeled vehicle miles traveled (VMT) and emission factors to generate emission forecasts.

Figure 2-1 below summarizes the key steps in the development of regional emission forecasts for the conformity analysis. The process begins with development of forecasts for traffic volumes on the regional transportation network, for which key inputs include the latest available socioeconomic forecasts (including population and employment) and LRTP and TIP project lists. Traffic forecast volumes for the horizon year (2035) of the LRTP were developed with a standard four-step model developed and maintained by VDOT.

The travel model networks include all functionally classified roadways: interstates, freeways, expressways, principal arterials, minor arterials, and collector streets as specified in the LRTP and TIP for the maintenance area. In addition a small number of local streets necessary to maintain roadway network connectivity are also coded. For each conformity analysis year (2009, 2015, 2025 and 2035), estimates of socioeconomic growth were prepared, significant highway and transit projects were coded, and model runs were performed. The networks are developed for conformity analysis years selected to meet specific requirements of the transportation conformity rule. The selection of years to be analyzed is based on federal conformity regulation requirements and must include years for which regional emission budgets are specified in the applicable maintenance plan, which was reviewed in the previous chapter.

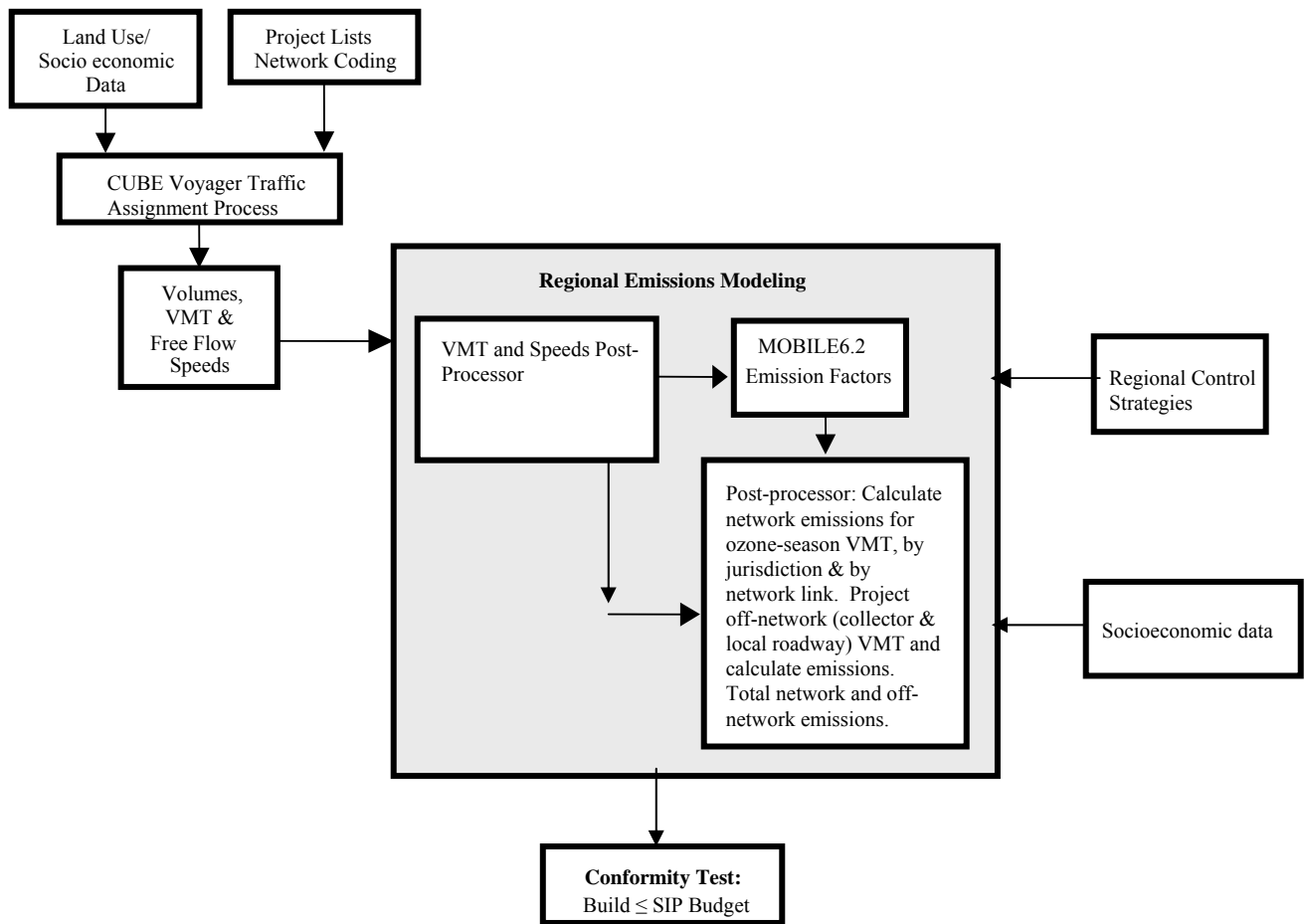
Concurrently, forecasts for emission factors are developed using the latest EPA-approved emission factor model (currently MOBILE6.2) for each forecast year. For each year, emission factors are generated (in units of grams of pollutant emitted per mile) for each pollutant to be modeled, roadway class or facility type, and jurisdiction for speeds ranging from 2.5 to 65 miles per hour.

The output from the travel model and the emission factor model serve as inputs to a post-processor that is then applied to calculate regional total emissions. The forecast VMT for each year (by link including jurisdiction, vehicle class, facility type and speed) is combined in the post-processor with the forecast emission factors for each pollutant (by facility type and speed) to generate forecast emissions for each pollutant for each network link in each jurisdiction for each analysis year.

Emissions for traffic operating on “off-network” facilities (collectors and local streets) are too small to be included in the regional transportation model networks and are estimated separately. The post-processor is applied to develop estimates of VMT for these facilities for all conformity analysis years by extrapolating current traffic counts by applying growth factors generated by the VDOT Statewide Planning System (SPS). Emission factors are applied to the projections for local and collector VMT to generate forecasts for off-network emissions by jurisdiction for each analysis year.

The network and off-network emissions are then totaled to arrive at forecasts for regional total emissions for the maintenance area for each analysis year. Emission tests as described in the previous chapter are then applied to demonstrate regional transportation conformity.

Figure 2-1: Conformity Analysis Process



The selection of analysis years and associated emission tests is presented first. The models and processors used in the analysis are reviewed, with a discussion of methodology as well as key inputs and assumptions for the modeling. The modeling discussion addresses transportation demand forecasts first, then the development of forecasts for emission factors.

The modeling results for this conformity analysis are presented in Chapter 4.

Analysis Years and Budgets

Table 2-1 presents the motor vehicle emission budgets as specified in the maintenance plan (reviewed in the previous chapter) as well as the years selected for modeling for this conformity analysis. Previously applicable budgets established for the 1-hour ozone standard are superseded by these budgets.

Table 2-1: Analysis Years and Budgets

Year	Regional Emission Budgets <i>(tons per ozone season weekday)</i>	
	NOx	VOC
2009*	8.346	13.062
2015 *	7.576	7.334
2025	7.576	7.334
2035	7.576	7.334

* Budgets specified in 70 FR 76165, effective January 23, 2006

The years selected for analysis are consistent with the requirements of Section 93.118 of the conformity rule. The maintenance plan specifies a budget for 2009 and 2015, and years for which budgets are established are required in the conformity rule to be analyzed. Additionally, the conformity rule requires modeling for the last year of the transportation plan (2035), and that years modeled be no more than ten years apart. To meet the latter requirement, the year 2025 was selected.

Note section 93.118 the conformity rule requires budgets established “for the most recent prior year” to apply for years for which budgets have not been “specifically established”. For this analysis, the 2015 budgets as listed above are applicable for the years 2025 and 2035 as well.

Transportation Demand Forecasting – Fredericksburg version 3.0 Model

The Fredericksburg travel demand model used to support the FAMPO 2035 CLRP process including the air quality conformity determination process was the Fredericksburg Version 3.0 model. This model contains many new features from that used for the last FAMPO 2030 conformity determination including a new software platform, new external trip forecasting procedure, High Occupancy Toll (HOT) lane capability, and the inclusion of Virginia Railway Express (VRE) trips in the model.

The modeling platform used by VDOT statewide is called CUBE Voyager and consists of two primary software programs: CUBE Base and CUBE Voyager. CUBE Base is used to develop a model’s organizational structure using the CUBE Catalog format and for editing files including transportation networks. CUBE Voyager, is the successor to TP+ and MINUTP, and provides the engine that actually runs the CUBE

Voyager model. Over the course of the past few years, VDOT staff have moved all travel demand models within Virginia from older platforms, e.g., MINUTP, into the new CUBE Voyager format. Using this new modeling platform, technical staff at VDOT have developed and maintain a regional travel demand model for the Fredericksburg Area MPO (FAMPO) study area. The model is a four-step travel demand model that includes trip generation, trip distribution, mode split and traffic assignment. The model includes feedback between highway assignment and trip distribution. The model covers the entire George Washington Regional Commission (GWRC) planning area which includes both the FAMPO and the Fredericksburg 8-hour ozone maintenance areas in their entirety. The jurisdictions included in the model include Stafford County, Spotsylvania County, City of Fredericksburg, King George County, and Caroline County. The CITILABS model has been validated against 2000 traffic volumes, land use, demographics, and other socio-economic factors. The validated model was then used to develop future year traffic models and volume estimates.

Highway and transit system data are coded by the model developers to create a representation of the regional transportation network. Highway network attributes include highway features such as number of lanes, capacity per lane, and speed. Travel time and cost data are calculated from the transportation network for use in subsequent model steps.

Trip making activity is estimated during the trip generation and trip distribution steps. Trip generation uses summary information from each traffic analysis zone (TAZ) to compute the number of trips produced in and attracted to each TAZ. The summary information includes number of households, total population, group-quarters population, retail and non-retail employment, and number of automobiles available to households. These socio-economic data are prepared by GWRC and compiled for use in the model. Trips are generated by purpose (home to work, home to non-work locations, and non-home trips). Commercial vehicle activity is accounted for through the non-home trip purpose. Trips that start or end outside the Fredericksburg region, as well as trips that simply pass through the region, are treated as separate trip purposes. These external trips were estimated from traffic counts observed at major exit stations in the year 2000 and then expanded for future years using growth trend estimates of traffic at the external stations.

The trip distribution step joins the production and attraction end of each trip using factors designed to reproduce observed traffic volumes and trip times in the base year. The trip distribution step uses a standard gravity model, with different factors for each trip purpose. The Fredericksburg model was designed to use feedback from the highway assignment into trip distribution to better approximate observed traffic conditions (and, in the future years, to better estimate the differential effects of additional trips and transportation facilities). The feedback takes into account the effect of congestion on route choice, since the most commonly chosen route to a destination will depend on whether or not a particular route is congested or free-flowing, and the level of congestion in turn depends on what route travelers are most inclined to choose.

Trip tables from trip distribution, along with network-based travel time and cost data, are input to the mode split step to estimate trip tables by trip purpose, travel period (peak or off-peak) and mode. The mode split step uses a nested logit model to allocate trips between single occupant vehicle, high occupancy 2 vehicle, and high

occupancy 3+ vehicles for automobiles and for the Virginia Rail Express (VRE) based on differences in time and cost among the modes. The new Fredericksburg version 3.0 model also can determine paying vs. non-paying users of the planned I-95 HOT lanes within the Fredericksburg region so that off-model analysis of this planned HOT lane project is no longer necessary. The final trip tables by mode and purpose are assembled for assignment to the highway and transit networks.

During the highway assignment step, trips between each zone pair are loaded onto the highway network and balanced with congestion effects. Highway assignment uses a capacity restraint formula that limits how many trips can be assigned to each roadway link based on its practical capacity. During assignment, routes are assembled between each zone pair based on the shortest routes under congested conditions. A feedback loop prior to the final assignment adjusts the trip distribution to account for the effect of congestion on travelers' likely choice of destination, so the number of trips between zones may be altered due to congestion in addition to the actual routes taken.

In transit assignment, trips are assigned to the most efficient transit route available, taking into account waiting time, travel time, transfers required, and fare. Transit assignment is based on the best route, and does not have a capacity restraint or congestion balancing component.

The output of the highway assignment process is a network file that includes forecast traffic volumes on each roadway segment, as well as an estimate of congested travel speed. That file is referred to as a "loaded network".

This overall modeling process is applied for each analysis year.

Key inputs to the network model are reviewed below.

Socioeconomic Forecasts

The GWRC provided the socioeconomic data to be used in the transportation model. The GWRC and the member governments in the counties of Spotsylvania, Stafford, King George, and Caroline as well as the city of Fredericksburg developed a distribution of the regional population and employment projections to TAZs used in the transportation model. The counties of King George and Caroline are not part of the 8-hour ozone maintenance area, but provided socioeconomic data, as they are part of the modeled region.

To estimate population and employment numbers, documentation from the 2000 US Census as well as the Virginia Employment Commission (VEC) was collected. Projections for 2035 were estimated starting with the compilation of 2006 figures in the Fredericksburg MPO area, and then a regionally collaborated estimate of figures for 2035 was developed. The forecasted numbers were prepared under the guidance of the member governments and approved by the respective MPO.

The average household size and the number of autos for the year 2035 were estimated from the 2000 Census using growth rates derived from historical trends and anticipated growth within the region.

Table 2-2 presents the socioeconomic forecast totals for the jurisdictions that lie within the 8-hour ozone maintenance area. This data was used to develop the travel demand modeling forecasts for this conformity analysis.

Table 2-2: Socioeconomic Forecasts

Year	Fredericksburg Maintenance Area Total*			
	Population	Households	Automobiles	Employment
2009	281,942	96,578	213,407	105,383
2015	334,775	118,865	253,580	123,482
2025	421,147	149,085	319,198	152,986
2035	504,942	178,408	382,848	175,829

*This summary is based on the data approved by the Fredericksburg Area MPO.

Project Lists & Regional Network Development

A project list was generated to develop the transportation networks by analysis year, and to identify projects that are regionally significant (or otherwise subject to transportation conformity analysis). All projects occurring on roadway segments bearing a Federal Functional Classification were coded, provided that the nature of the project was amenable to network coding. In general, changes were coded for new facilities, road widenings that increase the number of through travel lanes and new interchanges on limited access facilities. Turn lanes and at-grade intersection improvements were not included in the model network; as such improvements are not amenable to modeling at a regional scale.

This conformity analysis is based on the region’s 2035 LRTP and FY 09-12 TIP. Consistent with the requirements of the transportation conformity rule, regional emission analyses were performed for 2009, 2015, 2025 and 2035. The CUBE voyager transportation networks for each of the four analysis years include all regionally significant projects included in the TIP and LRTP, and coded into the appropriate year based on anticipated construction completion dates. Where possible, completion dates reflect estimates included in the TIP project descriptions or in VDOT’s six-year plan. For future projects, completion dates were determined by adding three years to the anticipated project start date when more specific anticipated completion dates were unavailable.

The modeled network for each analysis year reflects the travel conditions expected to be in place during that analysis year. For example, the 2009 network includes existing roadways as well as projects listed in the 2035 LRTP and FY 09-12 TIP that are anticipated to be complete by 2009. Subsequent networks include existing networks plus completed projects from earlier analysis years. Thus, the 2015 network includes all the 2009 projects plus additional projects expected to be complete by 2015.

Appendix E presents the final project lists used to develop the LRTP and TIP networks, including the first analysis year for all regionally significant projects.

Travel Demand Forecast Model Output

The Fredericksburg travel demand model generates estimates of VMT for all major roadway classes (minor arterial and above). Collector and local roadway VMT are estimated through off-model procedures. The final assigned volumes from the Fredericksburg transportation model are extracted from the loaded network that is computed during the highway assignment step. Vehicle miles traveled are computed within the model by multiplying the volume estimated for each network link by the length of the link. The post processor uses the loaded network volumes and capacities, along with other relevant travel information such as number of lanes, free flow speed, and link length to calculate congested speeds for each of the highway functional classes. The VMT and congested speed results are then used as input to MOBILE6.2 to calculate emission factors. Appendix B contains VMT estimates by jurisdiction, roadway class, and time of day for each analysis year.

The roadway capacity per lane, which is used for capacity restraint in the travel demand model, is extracted from the model network, and is used along with traffic volumes and number of lanes to compute congested roadway speeds in the post-processor.

Off-Line Analyses

Some transportation projects that have a potentially significant impact on regional air quality cannot be coded into the transportation modeling network. These are categorized as “off-line projects” and are analyzed using a variety of methodologies that include elasticity/pivot-point analysis and the use of traffic engineering principles to estimate their traffic and emission impacts.

Off-line analysis for Fredericksburg can also include Congestion Mitigation and Air Quality (CMAQ) funded projects such as van pools, transit bus replacements, and park-and-ride lots. Since additional air quality credits were not needed to demonstrate conformity for this update of the LRTP and TIP, they were not applied in the emissions analysis.

Emission Factor Forecasting (US EPA MOBILE6.2 Model)

MOBILE6.2 is the current version of the MOBILE emission factor modeling software application developed and required by EPA for use in conformity determinations and the development of SIPs and associated revisions. The model was designed to be used to develop estimates of historic, current and future emission factors for area-wide (e.g., regional) on-road motor vehicle fleets. MOBILE6.2 can calculate in-use fleet average emission factors for:

- Criteria pollutants: hydrocarbons, carbon monoxide, nitrogen oxides, exhaust particulate, hazardous air pollutants (HAP), and carbon dioxide.
- Gas, diesel, and natural gas-fueled cars, trucks, buses and motorcycles.
- Calendar years between 1952 and 2050.

Emission factors are generated by the model in units of grams of pollutant per

vehicle mile of travel. As noted previously, emission factors are combined with VMT projections obtained from the regional travel demand model to generate estimates of regional emissions. Modeled emission factors vary with vehicle class, age (registration distribution by vehicle class), humidity, ambient temperatures, fuel specifications, and operation (speed, by roadway functional class).

For this analysis, both national default data and region-specific inputs were used with MOBILE6.2 to determine emission factors for this analysis. The effects of reformulated gasoline (RFG) and an Inspection and Maintenance (I/M) program were modeled in Stafford County for all analysis years, as Virginia regulations require RFG and I/M in Stafford dating back to its inclusion in the Northern Virginia 1-hour Ozone Nonattainment area. Fredericksburg City and Spotsylvania County were modeled with conventional gasoline. Additional input data applied for this analysis that are specific to the Fredericksburg area include: jurisdiction-specific registration distributions, VMT fraction by vehicle and roadway class, average congested speed for each roadway link, hourly temperatures, hourly relative humidity values, and average barometric pressure.

Key MOBILE6.2 input data for the Fredericksburg 8-hour ozone maintenance area are summarized below and in Appendix C.

Emission Control Programs

Table 2-4 lists emission control programs in effect for the Fredericksburg area as input to the MOBILE6.2 model. The locality-specific MOBILE input parameters are consistent with the approved maintenance SIP and are based on the latest planning assumptions.

The programs include:

- Reformulated gasoline (RFG), and gasoline Reid Vapor Pressure (RVP): RFG was modeled for Stafford County, whereas Fredericksburg City and Spotsylvania County were modeled with conventional gasoline. Where applicable, RFG benefits were modeled for all analysis years after 1996, consistent with Virginia regulations requiring RFG.

RFG Phase 2, which is currently in effect, has a summertime Reid vapor pressure (RVP) of approximately 6.8 pounds per square inch (PSI). For the County of Spotsylvania and the City of Fredericksburg, the summertime RVP of conventional gasoline was taken as 8.4 PSI.

- 2007 Heavy Duty Diesel Vehicle (HDDV): The 2007 Heavy Duty Diesel Vehicle (HDDV) program including the implementation of ultra low sulfur diesel was specified for the emission factor modeling for the conformity analysis. From the regulatory announcement¹:

New Standards for Heavy-Duty Highway Engines and Vehicles

[EPA is] finalizing a PM emissions standard for new heavy-duty engines of 0.01 grams per brake-horsepower-hour (g/bhp-hr), to take full effect for diesels in the

¹ EPA Office of Transportation and Air Quality, December 2000, “Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements”, EPA420-F-00-057.

2007 model year. [EPA is] also finalizing standards for NOx and non-methane hydrocarbons (NMHC) of 0.20 g/bhp-hr and 0.14 g/bhp-hr, respectively. These NOx and NMHC standards will be phased in together between 2007 and 2010, for diesel engines. The phase-in will be on a percent of-sales basis: 50 percent from 2007 to 2009 and 100 percent in 2010. Gasoline engines will be subject to these standards based on a phase in requiring 50 percent compliance in the 2008 model year and 100 percent compliance in the 2009 model year.

The program includes flexibility provisions to facilitate the transition to the new standards and to encourage the early introduction of clean technologies, and adjustments to various testing and compliance requirements to address differences between the new technologies and existing engine based technologies.

New Standards for Diesel Fuel

Refiners will be required to start producing diesel fuel for use in highway vehicles with a sulfur content of no more than 15 parts per million (ppm), beginning June 1, 2006. At the terminal level, highway diesel fuel sold as low sulfur fuel will be required to meet the 15 ppm sulfur standard as of July 15, 2006. For retail stations and fleets, highway diesel fuel sold as low sulfur fuel must meet the 15 ppm sulfur standard by September 1, 2006.

This program includes a combination of flexibilities available to refiners to ensure a smooth transition to low sulfur highway diesel fuel.

Table 2-4: Emission Control Programs

	2009	2015	2025	2035
Reformulated Gasoline	Stafford Only	Stafford Only	Stafford Only	Stafford Only
I/M Program	Stafford Only	Stafford Only	Stafford Only	Stafford Only
NLEV	Yes	Yes	Yes	Yes
2007 HDDV Standard	Yes	Yes	Yes	Yes
TIER 2/Low Sulfur Gasoline	Yes	Yes	Yes	Yes

- National Low Emission Vehicle (NLEV) program: The early implementation of the NLEV program was specified in the emission factor modeling for the conformity analysis. The NLEV program, finalized by EPA in March 1998, implemented cleaner light-duty gasoline vehicles beginning in model year 1999.
- Tier 2 Vehicle Emission Standards: EPA Tier 2 vehicle emission standards implementation beginning with the 2004 model year was specified for the modeling for the conformity analysis. Gasoline sulfur levels as required for the Tier 2 standards were incorporated into the modeling. From the supplementary information included with the final Tier 2 rule²:

² 65 FR 6698-6822, February 10, 2000, “40 CFR Parts 80, 85, and 86, Control of Air Pollution From New Motor

Highlights of the Tier2/Gasoline Sulfur Program

For cars, and light trucks, and larger passenger vehicles, the program will—

- *Starting in 2004, through a phase in, apply for the first time the same set of emission standards covering passenger cars, light trucks, and large SUVs and passenger vehicles. ...*
- *Introduce a new category of vehicles, “medium-duty passenger vehicles,” thus bringing larger passenger vans and SUVs into the Tier 2 program.*
- *During the phase-in, apply interim fleet emission average standards that match or are more stringent than current federal and California “LEV I” (Low-Emission Vehicle, Phase I) standards.*
- *Apply the same standards to vehicles operated on any fuel.*
- *Allow auto manufacturers to comply with the very stringent new standards in a flexible way while ensuring that the needed environmental benefits occur.*
- *Build on the recent technology improvements resulting from the successful National Low-Emission Vehicles (NLEV) program and improve the performance of these vehicles through lower sulfur gasoline.*
- *Set more stringent particulate matter standards.*
- *Set more stringent evaporative emission standards.*

For commercial gasoline, the program will—

- *Significantly reduce average gasoline sulfur levels nationwide as early as 2000, fully phased in in 2006. Refiners will generally add refining equipment to remove sulfur in their refining processes. Importers of gasoline will be required to import and market only gasoline meeting the sulfur limits.*
- ...
- *Enable the new Tier 2 vehicles to meet the emission standards by greatly reducing the degradation of vehicle emission control performance from sulfur in gasoline. Lower sulfur gasoline also appears to be necessary for the introduction of advanced technologies that promise higher fuel economy but are very susceptible to sulfur poisoning (for example, gasoline direct injection engines).*
- *Reduce emissions from NLEV vehicles and other vehicles already on the road.*

Vehicle age distributions for 2005 were incorporated into the MOBILE6.2 input files for this conformity analysis.

A sample of a MOBILE6.2 input file is provided in Appendix C.

Consistent with modeling presented in the Technical Support Document for the Fredericksburg 8-hour ozone maintenance plan, inspection and maintenance and anti-tampering programs were included in the modeling for this analysis for Stafford County only.

Ambient Conditions

Table 2-5 presents average hourly ambient temperature and relative humidity data as excerpted from the Technical Support Document for the Fredericksburg 8-hour ozone maintenance plan and applied in the MOBILE6.2 modeling in this conformity analysis. An average daily barometric pressure value of 30.019 pounds per square inch was also applied in this analysis, consistent with the maintenance plan.

Table 2-5: Ambient Conditions - Ozone Season

Time	Temperature (°F)	Relative Humidity (%)
6 AM	68	80
7 AM	69	80
8 AM	73	72
9 AM	79	64
10 AM	85	52
11 AM	90	47
12 PM	93	42
1 PM	94	39
2 PM	96	36
3 PM	95	39
4 PM	96	36
5 PM	95	36
6 PM	94	37
7 PM	92	41
8 PM	87	51
9 PM	82	60
10 PM	80	63
11 PM	77	68
12 AM	74	72
1 AM	73	74
2 AM	72	74
3 AM	71	76
4 AM	70	78
5 AM	69	78

Source: Commonwealth of Virginia, Department of Environmental Quality, "Technical Support Document for the Redesignation Request and Maintenance Plan for the Fredericksburg 8-Hour Ozone Nonattainment Area, Final"

Volume and VMT Distributions

Tables 2-6 and 2-7 present federal roadway functional classes and updated volume distributions by federal roadway functional class based on data recently published by VDOT. The volume distributions were applied in this analysis as a reasonable approximation for the corresponding VMT distributions. The reported distributions were allocated to the vehicle classes used in the MOBILE6.2 model.

Table 2-6: FHWA Roadway Functional Classes

FHWA Roadway Functional Classes	
1	Rural Interstate
2	Rural Principal Arterial
6	Rural Minor Arterial
7	Rural Major Collector
8	Rural Minor Collector
9	Rural Local
11	Urban Interstate
12	Urban Freeway/Expressway
14	Urban Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

Table 2-7: Volume Distributions by Roadway Functional Class

FHWA Functional Class		Fredericksburg Maintenance Area Volume Distributions							
		LDGV	LDGT1	LDGT2	HDTV	LDDV	LDDT	HDDV	MC
1	Rural Interstate	38.93%	31.70%	10.91%	0.87%	0.06%	0.18%	17.14%	0.23%
2	Rural Principal Arterial	40.35%	32.86%	11.31%	1.02%	0.06%	0.19%	13.89%	0.33%
6	Rural Minor Arterial	43.55%	35.47%	12.20%	1.49%	0.06%	0.20%	6.40%	0.62%
7	Rural Major Collector	44.26%	36.04%	12.40%	2.17%	0.07%	0.20%	4.16%	0.69%
8	Rural Minor Collector	44.68%	36.38%	12.52%	1.25%	0.07%	0.21%	4.47%	0.43%
9	Rural Local*	44.68%	36.38%	12.52%	1.25%	0.07%	0.21%	4.47%	0.43%
11	Urban Interstate	42.27%	34.42%	11.84%	0.78%	0.06%	0.20%	10.08%	0.35%
12	Freeway/Expressways**	na	na	na	na	na	na	na	na
14	Urban Principal Arterial	44.83%	36.51%	12.56%	1.08%	0.07%	0.21%	4.32%	0.43%
16	Urban Minor Arterial	45.77%	37.27%	12.82%	1.15%	0.07%	0.21%	2.35%	0.36%
17	Urban Collector	45.60%	37.13%	12.78%	1.18%	0.07%	0.21%	2.63%	0.41%
19	Urban Local*	45.60%	37.13%	12.78%	1.18%	0.07%	0.21%	2.63%	0.41%
All Functional Classes		44.31%	36.09%	12.42%	1.16%	0.07%	0.20%	5.36%	0.40%

* Data are unavailable for this roadway class in this area. For this analysis, data from a similar class (collectors) have been assumed.

** There is no highway segment with a functional class of 12 in the Fredericksburg 8-hour Ozone Maintenance Area.

Source: VDOT, 2007, "Traffic Trends and Characteristics for the 2005 Highway Emissions Inventory"

Post-Processing

An overview of the general approach applied in the analysis for calculating regional total emissions from on-road motor vehicles emission was provided at the beginning of this chapter. This section summarizes specific adjustments made in the post-processor to the travel demand forecasts to improve the emission forecasts.

The post-processor first adjusts travel demand forecasts and related parameters as needed for the emission calculations, and then generates the emission estimates using the forecast VMT by roadway type and jurisdiction with the emission factors that were generated using MOBILE6.2. The specific adjustments to the traffic forecasts are reviewed in turn below.

The post-processor was developed using accepted transportation engineering methods based on the 2000 *Highway Capacity Manual (HCM)* and *National Cooperative Highway Research Program (NCHRP) Report 387*.

Congested Speed Calculation

The post-processor estimates congested speeds using standard Bureau of Public Roads (BPR) formulae that are based upon free flow speeds, volumes and capacity. Free flow speed is the speed at which a vehicle on the roadway segment would travel given no conflict with other traffic, i.e., no congestion. As traffic volumes increase and the carrying capacity of the roadway is reached (i.e. congestion increases), average speeds decrease. The free flow speeds used are consistent with those used in the CUBE Voyager model.

The formulae originally developed by the BPR to describe the relationship between congested speeds and roadway free flow speeds, volumes and capacities are now applied in transportation models as standard practice. The post-processor uses two forms of the BPR equation. The first is for non-signalized roadway segments:

$$\text{speed for unsignalized facilities} = \frac{\text{corridor free flow speed}}{1 + 0.2(\text{volume} / \text{capacity})^{10}}$$

The second is for signalized roadway segments, defined as signalized facilities on which traffic signals are spaced two miles or less apart:

$$\text{speed for signalized facilities} = \frac{\text{corridor free flow speed}}{1 + 0.05(\text{volume} / \text{capacity})^{10}}$$

Emission factors calculated using MOBILE6.2 are imported into the post-processor and applied with the VMT and speed data for both network and off-network facilities to generate estimates of emissions by jurisdiction and facility type for the maintenance area.

Traffic Adjustment Factors

The vehicle activity estimates were forecast through the CUBE voyager model, and are reported as Vehicle Miles Traveled (VMT). As previously noted, the roadway network representing the transportation conditions for each analysis year forms the basis for the estimation of highway volumes. The model produces VMT estimates that correspond to average annualized daily traffic (AADT).

Table 2-8 presents average ozone season and weekday adjustment factors for the Fredericksburg area. The appropriate adjustment factors are applied to the forecast VMT to more accurately account for observed summertime traffic levels, and are based upon HPMS data for 2005 as presented in "Traffic Trends and Characteristics for the 2005 Highway Emissions Inventory (VDOT, 2007).

The tabulated factors were obtained as the average for the values reported for June, July and August (the peak ozone season) for the Fredericksburg area. The factors are presented by FHWA roadway functional class.

Table 2-8: Traffic Adjustment Factors

FHWA Roadway Functional Class		Ozone Season	Week Day
1	Rural Interstate	1.1395	1.0564
2	Rural Principal Arterial	1.0738	1.0681
6	Rural Minor Arterial	1.0237	1.0502
7	Rural Major Collector	1.0370	1.0784
8	Rural Minor Collector	1.0370	1.0784
9	Rural Local	1.0000	1.0000
11	Urban Interstate	1.0916	1.0523
12	Urban Freeway/Expressway	1.0916	1.0523
14	Urban Principal Arterial	1.0279	1.0943
16	Urban Minor Arterial	1.0257	1.1076
17	Urban Collector	1.0316	1.0955
19	Urban Local	1.0000	1.0000

Source: VDOT, 2007, "Traffic Trends and Characteristics for the 2005 Highway Emissions Inventory"

Hourly Traffic Volumes

Table 2-9 presents the hourly traffic volumes applied for this analysis. The data were obtained from "Traffic Trends and Characteristics for the 2005 Highway Emissions Inventory" (VDOT, 2007). The hourly data are presented by federal roadway functional class.

Table 2-9: Hourly Traffic Distribution by Roadway Functional Class

Time Period	Hour	rural Interstate	Rural Prin. Arterial	Rural Minor Arterial	Rural Major Collector	Rural Minor Collector	Rural Local	urban interstate	freeway	Urban Prin. Arterial	Urban Minor Arterial	Urban Collector	Urban local
FC		1	2	6	7	8	9	11	12	14	16	17	19
Night	0	1.67%	0.97%	0.54%	0.59%	0.54%	0.54%	1.47%	1.47%	0.57%	0.55%	0.58%	0.58%
Night	1	1.33%	0.69%	0.42%	0.38%	0.26%	0.26%	1.10%	1.10%	0.37%	0.34%	0.35%	0.35%
Night	2	1.22%	0.60%	0.32%	0.36%	0.40%	0.40%	0.98%	0.98%	0.34%	0.29%	0.26%	0.26%
Night	3	1.34%	0.68%	0.60%	0.60%	0.70%	0.70%	1.11%	1.11%	0.45%	0.39%	0.38%	0.38%
Night	4	1.78%	1.24%	1.46%	1.63%	0.93%	0.93%	2.27%	2.27%	1.25%	1.05%	1.09%	1.09%
Night	5	2.20%	2.34%	3.10%	3.25%	1.99%	1.99%	3.41%	3.41%	2.61%	2.11%	2.39%	2.39%
Night	6	3.26%	3.90%	5.96%	5.86%	4.89%	4.89%	4.33%	4.33%	4.93%	3.92%	4.29%	4.29%
AM Peak	7	4.25%	5.19%	7.94%	6.91%	6.52%	6.52%	4.94%	4.94%	6.77%	5.78%	6.61%	6.61%
AM Peak	8	4.68%	5.30%	5.62%	5.58%	5.12%	5.12%	4.85%	4.85%	6.08%	6.25%	5.74%	5.74%
AM Peak	9	5.05%	5.49%	4.59%	4.60%	6.56%	6.56%	5.06%	5.06%	5.20%	5.63%	4.91%	4.91%
Midday	10	5.70%	5.78%	4.49%	4.33%	4.45%	4.45%	5.34%	5.34%	5.15%	5.18%	4.64%	4.64%
Midday	11	6.03%	6.01%	4.59%	4.65%	6.59%	6.59%	5.46%	5.46%	5.29%	5.70%	5.01%	5.01%
Midday	12	5.98%	6.07%	4.72%	5.02%	6.76%	6.76%	5.56%	5.56%	5.72%	6.30%	5.64%	5.64%
Midday	13	6.23%	6.28%	4.91%	5.14%	6.53%	6.53%	5.73%	5.73%	5.66%	5.96%	5.42%	5.42%
Midday	14	6.54%	6.94%	5.92%	5.62%	6.21%	6.21%	6.17%	6.17%	6.29%	6.24%	6.12%	6.12%
Midday	15	6.55%	7.24%	7.42%	6.82%	8.53%	8.53%	6.37%	6.37%	7.43%	7.24%	7.14%	7.14%
PM Peak	16	6.33%	7.44%	8.03%	7.91%	6.60%	6.60%	6.40%	6.40%	7.99%	7.94%	8.17%	8.17%
PM Peak	17	6.10%	7.18%	8.72%	8.46%	7.89%	7.89%	6.20%	6.20%	8.15%	8.50%	9.01%	9.01%
PM Peak	18	5.61%	5.95%	6.81%	7.01%	5.65%	5.65%	5.62%	5.62%	6.44%	6.87%	7.32%	7.32%
Night	19	4.98%	4.66%	5.03%	5.18%	4.58%	4.58%	4.98%	4.98%	4.68%	4.85%	5.33%	5.33%
Night	20	4.37%	3.65%	3.68%	4.01%	4.29%	4.29%	4.26%	4.26%	3.39%	3.63%	3.95%	3.95%
Night	21	3.69%	2.87%	2.69%	3.03%	1.98%	1.98%	3.56%	3.56%	2.67%	2.71%	2.91%	2.91%
Night	22	2.91%	2.10%	1.55%	1.87%	1.49%	1.49%	2.77%	2.77%	1.57%	1.54%	1.69%	1.69%
Night	23	2.20%	1.42%	0.90%	1.18%	0.53%	0.53%	2.04%	2.04%	1.01%	1.01%	1.04%	1.04%

Source: Data presented in VDOT, February 2007, "Traffic Trends and Characteristics for the 2005 Highway Emissions Inventory"

VMT Growth Rates for Local and Collector Roads

Forecasts are required for VMT for local and collector roads that are not captured by the regional network model. The required forecasts are obtained by applying expected average annual growth rates for traffic on these facilities to specific base year data for the area.

For this analysis, the base year VMT data for local and collector roads were obtained from the VDOT 2006 Highway Performance Monitoring System (HPMS) database. The growth rates were obtained as the annual average growth rates for auto ownership in the Fredericksburg maintenance area, and are based on the socioeconomic forecasts for auto ownership as reported in Table 2-2.

Table 2-10 presents forecasts annual average growth rates for local and collector road VMT for the Fredericksburg area. Forecast VMT generated based on these rates are included with Appendix B.

Table 2-10: Annual Growth Rates for Local and Collector Road VMT

Jurisdiction	Annual Growth Rate*
Fredericksburg	1.00855
Stafford	1.02590
Spotsylvania	1.02411

* Based on forecasted growth in auto ownership between 2006 and 2035