3. RECOMMENDATIONS FOR FURTHER RESEARCH

This study resulted in significant improvements to the 2002 emission inventories for on-road and off-road mobile sources and for sources of agricultural fugitive dust in the CENRAP region. Emission inventories were prepared on highly region-specific or even county-specific bases and adhered closely to EPA's recommended guidance for inventory development. Additional refinements and improvements should be incorporated as the products of ongoing research into emission factors and updates to activity data sets become available. Additionally, we identified the following potential sources of uncertainty in the inventories (roughly in order of importance):

1. Unusual vehicle age distributions and duplicate VIN records were observed in DMV databases of vehicle registrations.
2. The inventories of non-road mobile sources could benefit from additional bottom-up data collection efforts.
3. Existing VMT distributions could be refined to better represent the increasing popularity of SUVs and light trucks.
4. Fuels testing programs could be deployed or improved to better represent fuels characteristics.
5. VIN decoding yielded too few records corresponding to alternative-fueled vehicles to allow improvements to this component of the inventory (though this affects future-year projections more than the 2002 inventory).
6. Day-specific inventories (e.g., Monday, Tuesday, etc.) may be superior to assuming all weekdays are the same and both weekend days are the same for photochemical modeling purposes.
7. The inventories of agricultural fugitive dust sources could benefit from additional bottom-up data collection efforts.

This section briefly discusses recommendations for addressing these issues.

3.1 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF ON-ROAD MOBILE SOURCES

3.1.1 Incorporate New Data and Information as They Become Available

Emission inventories operate best as dynamic databases—subject to continuous refinements, additions, and improvements as research develops and activity data are updated. The electronic file systems of the activity data and emission inventories developed for the CENRAP, which were delivered as products of this project, are likely to be revised and improved as new information becomes available. Examples of recently developed or soon-to-be-available data sets that could be incorporated to further improve the CENRAP's inventories include (1) locally generated VMT estimates for Kansas City, Minneapolis-St. Paul, and Little

Rock; (2) results of the fuels testing program of the Texas Department of Agriculture; and (3) reports of fuels sulfur contents that refiners will be submitting to EPA beginning in February 2005 for diesel and February 2007 for gasoline. In addition, we recommend encouraging fuel testing programs in states where they are not yet planned—Louisiana, Arkansas, Iowa, and Nebraska—and encouraging the Oklahoma Department of Agriculture to archive and maintain records of their existing fuels testing program.

3.1.2 Investigate Databases of Vehicle Registrations

Unusual features in several states' databases of vehicle registrations were noted, including (roughly in order of importance) unexpected numbers of duplicate VINs, unusually large proportions of old light-duty vehicles, and unexpectedly small numbers of light-duty vehicles less than 2-3 years in age. High frequencies of duplicate VINs are sources of error in fleet distributions in and of themselves—particularly in Iowa, where the frequency of duplicates could only be reduced to 6%. However, high frequencies of duplicate records may only be one symptom of general database maintenance problems—such as retention of outdated records, mis-assignment of records, etc.—that cannot be easily recognized and remedied without in-depth review and diagnosis. The possibility that unidentified errors in the vehicle registration databases are related to unusual vehicle age distributions in some states is a cause for concern. MOBILE6 models older vehicles with higher emission rates due to their levels of deterioration and outdated emissions control technologies. Therefore, errors in this component of the vehicle population distributions exert significant impacts on the emission inventories of on-road mobile sources. In addition, errors across all age ranges can significantly impact projections of emission inventories to future years.

3.1.3 Use Fleet Distributions to Refine VMT Distributions

Patterns of SUVs and light-duty-truck use have been shifting rapidly in recent years. However, for this study, VMT distributions by vehicle type for many areas of the CENRAP were based on EPA defaults, which are based on predictions and data from a number of years ago. Errors in the VMT distributions by vehicle type can be significant because emissions standards vary across the classes of light-duty vehicles, and emissions from gasoline-fueled vehicles differ considerably from those of diesel-fueled vehicles. VMT distributions could be refined or adjusted by using vehicle registration data. This approach is based on an assumption, which we believe is well-founded, that due to recent trends in vehicle ownership and driver behavior, many light-duty trucks (e.g., SUVs) are now driven very similarly like passenger vehicles. Thus, the proportions of VMT that should be assigned to each vehicle type and fuel type are approximately equal to the proportions of vehicles registered in each vehicle- and fuel-type category. (Note that this assumption has already been applied in EPA Region I.) Alternatively, the VMT mix could be calculated from registration data using the vehicle type-specific assumptions about annual mileage accumulation rates that are part of the MOBILE6 model.

3.1.4 Prepare Inventories Specific to the Days of the Week

Driving activities for on-road motor vehicles appear to vary with each day of the week. Therefore, a day-specific approach may be preferable to a simple weekday-weekend approach for some photochemical modeling applications. In general, urban VMT declines on Sundays below average weekday levels to an even greater extent than on Saturdays. Friday evening VMT is somewhat higher than on other weekday evenings, and daily total VMT on Mondays is usually somewhat below average for weekdays in urban areas. Day-specific patterns are also likely to occur in rural areas. The 2002 CENRAP inventories reflect the most significant weekday-weekend patterns supported by research results from other areas of the United States. However, further improvements could be made by investing in research projects that investigate region-specific, day-of-week patterns for both rural and urban areas.

3.1.5 Improve Inventories for Alternative-Fueled Vehicles

VIN decoding yielded too little information to support improvements to the inventory of alternative-fueled vehicles. In addition, fuels characteristics of alternative fuels are rarely tested, and no region-specific data were identified. While these uncertainties have little effect on the 2002 inventory, they may become more important when future-year emission inventories are projected to 2018 and beyond. Alternative-fueled vehicles may compose significantly larger proportions of vehicle fleets in the future and trace levels of sulfur in alternative fuels may become more important as sulfur levels in diesel and gasoline fuels continue to decline as a result of existing regulations.

3.2 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF NON-ROAD MOBILE SOURCES

A survey of representative groups of recreational boat owners in the CENRAP region produced dramatic revisions to the emission inventories for this source category. Emissions estimates were revised by factors of 3 or more, on average. Further improvements in the non-road component of the inventory could be made by gathering bottom-up activity data for the next-largest non-road mobile source categories, including agricultural equipment and construction and mining equipment (which are significant sources of NO_x, $PM_{2.5}$, and SO_2 emissions) and/or recreational or lawn and garden equipment (which are important sources of VOC emissions).

3.3 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF SOURCES OF AGRICULTURAL DUST

3.3.1 Research and Develop Process-Based Emissions Estimation Methods

The limited body of research into emission factors and emission processes represents the most significant weakness in the emission inventories of sources agricultural fugitive dust. Investment in the development of emissions measurement programs and process-based

approaches that account for soil moisture, meteorological conditions, and agricultural practices would produce substantial improvements to the accuracy and certainty of this component of the inventory.

3.3.2 Prepare Bottom-Up Inventories for Additional Source Categories

A survey of agricultural extension offices and the use of bottom-up animal population data produced significantly altered spatial allocations and emissions estimates for sources of agricultural fugitive dust. State-level emissions estimates were revised by 25% to 50%, and CAFO emissions were displaced to entirely different geographic areas of the CENRAP. Further modest improvements could be made by gathering bottom-up activity data for the next-largest sources of agricultural fugitive dust, including cotton ginning operations and/or crop transport. However, emissions from these types of sources are likely to be dwarfed by emissions from agricultural tilling dust and are likely to be of significance in only a few areas of the CENRAP where cotton ginning occurs.

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APPENDIX A

EMISSION ESTIMATION METHODS FOR MOBILE SOURCES AND AGRICULTURAL DUST SOURCES IN THE CENTRAL STATES (STI-903574-2610-MD)

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EMISSION ESTIMATION METHODS FOR MOBILE SOURCES AND AGRICULTURAL DUST SOURCES IN THE CENTRAL STATES

METHODS DOCUMENT
STI-903574-2610-MD

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QUALITY ASSURANCE STATEMENT

This report was reviewed and approved by the project Quality Assurance (QA) Officer or his delegated representatives, as provided in the project QA Plan (Sullivan, 2004).

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1. INTRODUCTION

The Central States Regional Air Planning Association (CENRAP) is developing a regional haze plan in response to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas. To develop an effective regional haze plan, the CENRAP ultimately must develop a conceptual model of the phenomena that lead to episodes of low visibility in the CENRAP region. Thus, the CENRAP is researching visibility-related issues for its region, which includes the states of Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota. Both primary particulate matter (which is emitted directly to the atmosphere in particulate form) and the formation of secondary particulate matter (which is generated from chemical transformations in the atmosphere of gaseous precursor species such as ammonia, nitrogen oxides, sulfur oxides, and volatile organic compounds [VOCs]) contribute to episodes of regional haze and low visibility in the CENRAP region. Mobile sources and sources of agricultural fugitive dust are thought to be significant sources of these pollutants (as illustrated in **Figure 1-1**). In recognition of these issues, the CENRAP sponsored the development of improved emission inventories for mobile sources and sources of agricultural dust. The project objectives were to improve or develop activity data for off- and on-road mobile sources and sources of agricultural dust throughout the nine CENRAP states; to prepare the activity data in formats compatible for reprocessing and use with MOBILE6, NONROAD, and SMOKE 1.5 (which runs MOBILE6 internally); and/or to prepare the emission inventories in the latest version of the National Emission Inventory Input Format (NIF).

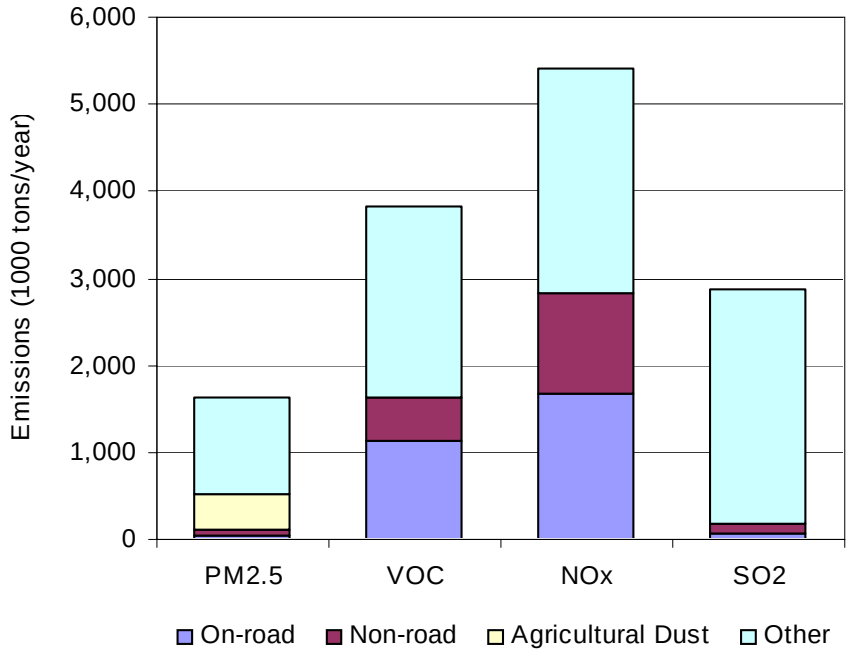

Figure 1-1. Estimated emissions for the CENRAP region. Source: 1999 NEI (U.S. Environmental Protection Agency, 1999c).

1.1 BRIEF OVERVIEWS OF EMISSIONS MODELING METHODS

1.1.1 Overview of Methods to Prepare Emission Inventories of On-Road Mobile Sources

The EPA's MOBILE6 model—an emission factor model that estimates emission factors for on-road mobile sources—and SMOKE were used to generate and prepare emission inventories of on-road mobile sources for photochemical modeling. SMOKE processes and prepares on-road mobile source emission inventories for photochemical air quality modeling by applying temporal profiles, speciation profiles, and gridding surrogates to county-level emissions estimates. In addition, SMOKE self-contains MOBILE6. Thus, SMOKE has the added capability of generating county-level emission inventories for on-road mobile sources by estimating MOBILE6 emission factors and matching these to county-level activity data. MOBILE6 requires a variety of inputs, including temperatures, fleet distributions, vehicle speeds, regulatory controls settings, and fuels characteristics. **Figure 1-2** illustrates the general processes of using MOBILE6 within SMOKE to generate on-road mobile source emission inventories. Figure 1-2 also illustrates the MOBILE6/SMOKE activity data, input files, and outputs that were prepared as products of this project. The products of these inventory development efforts are highly region-specific, or even county-specific, emission inventories that adhere to EPA's recommended guidance for the development of emission inventories for on-road mobile sources.

1.1.2 Overview of Methods to Prepare Emission Inventories of Non-Road Mobile Sources

The EPA's NONROAD model was used to estimate emissions for most non-road mobile sources. The NONROAD model applies equipment populations, activity data (e.g., hours of operation, load factors, etc.), emission factors, and growth factors to estimate emissions for non-road mobile sources. Default input files accompany the model, which are sufficient to estimate emissions for the entire United States at the county level. However, many of the default values are based on national defaults or general assumptions and can be improved with region-specific data, if available. Improved activity data were collected throughout the CENRAP region for recreational boating, which is considered to be one of the most important non-road mobile source categories in the region. These efforts resulted in emission inventories that are much improved over those generated by using the national default values. The most significant improvements included the hours of operation, load factors, spatial distributions, and temporal patterns of recreational boating.

Emissions from locomotives and commercial marine vessels, which are excluded from the NONROAD model, were estimated according to EPA guidance documents and using bottom-up activity data to the extent available. Aircraft emissions, which are also excluded from the NONROAD project, were considered to be a lower priority and were not included in the scope of this project.

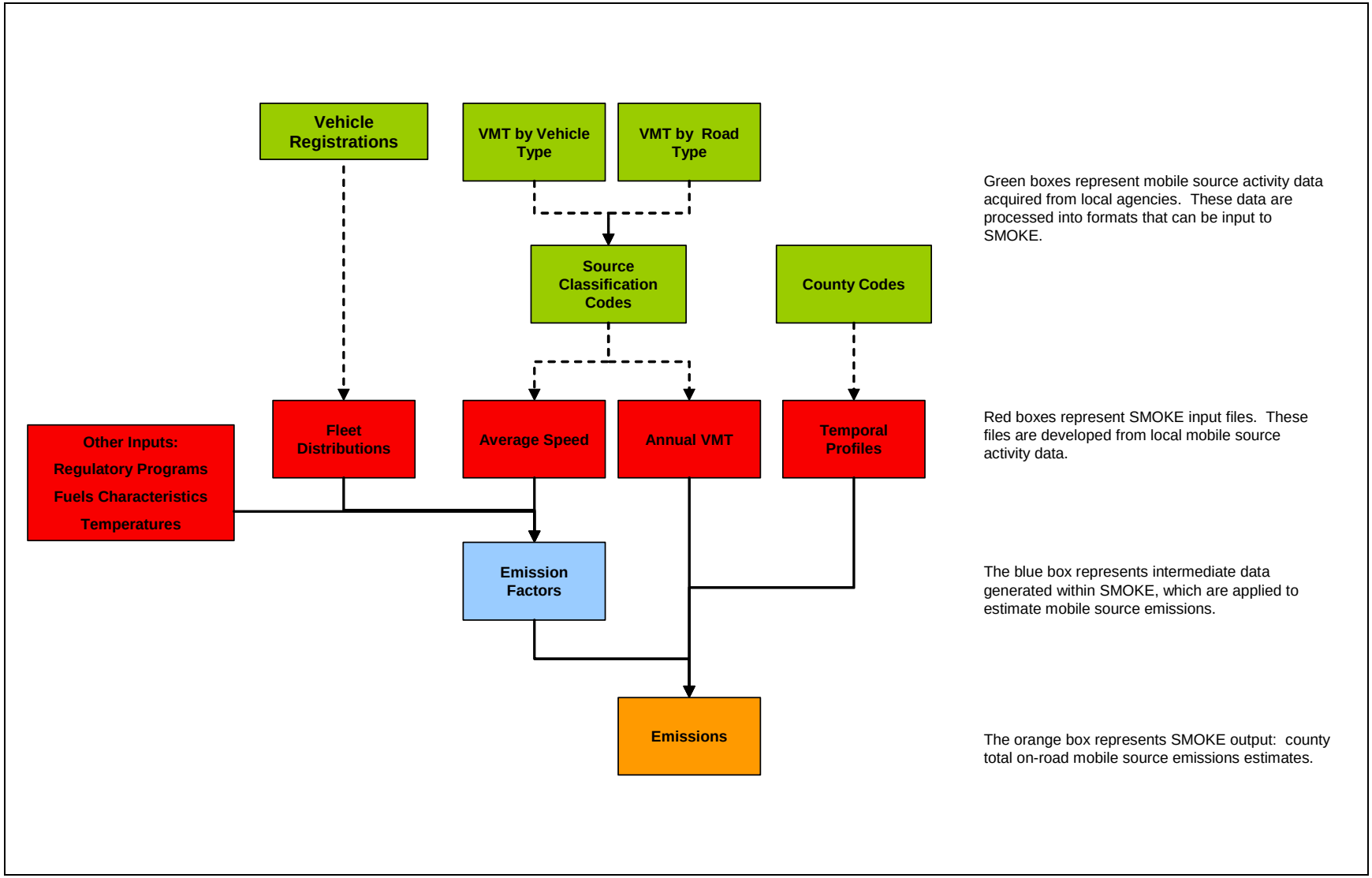

Figure 1-2. General illustration of the overall process and files used by SMOKE to generate on-road mobile source emissions output files.

1.1.3 Overview of Methods to Prepare Emission Inventories for Sources of Agricultural Dust

Emissions from agricultural fugitive dust sources were estimated according to EPA guidance documents or published literature. Bottom-up activity data were used to the extent available, including facility-specific animal populations for confined animal feeding operations (CAFOs) and activity data to describe agricultural tilling operations. Up-to-date GIS databases of soil characteristics and crop types were also used to improve the inventories. These activity data represent a significant improvement over inventories developed by applying national default assumptions. The most significant improvements include the CAFO animal populations, the geographic distributions of CAFO populations, the estimates of the number of tilling passes completed for each crop type, the representative soil silt content for each county, and the temporal patterns of agricultural tilling activities.

1.2 IMPORTANT ASSUMPTIONS

The methods employed to estimate emissions relied on several fundamental assumptions:

- Monthly fuel consumption data from the Federal Highway Administration (FHWA) and Energy Information Administration are representative of monthly patterns of on-road motor vehicle activity.
- Day-of-week and diurnal patterns of on-road motor vehicle activities observed in rural and urban geographic areas of the United States (such as Texas, California, or the national average) are reasonably representative of urban and rural areas of the CENRAP region.
- Rail link-specific traffic density data (ton-miles of cargo moved) is a reasonable surrogate for allocating locomotive fuel usage to the county level.
- The characteristics and speeds of marine vessels at key ports in the CENRAP region can be extrapolated to other ports for which detailed vessel data are not available.

Surveys were conducted to collect bottom-up information for recreational boating and agricultural dust source categories. In those cases, it was assumed that

- Recreational boat owners were capable of providing survey responses that could be interpreted to reasonably represent recreational boating activities across the CENRAP region. Techniques to eliminate or minimize the effects of over-reporting biases were sufficient.
- County agricultural extension service agents were capable of providing survey responses that reasonably represent agricultural tilling activities in the CENRAP region.
- In some cases, incomplete data were recovered. Thus, extrapolation or aggregation of bottom-up observations was assumed to produce reasonably representative results when data were missing, incomplete, or uncertain. A few examples of affected data sets include age distributions for vehicle types that appear with very low frequencies in the vehicle population, reported numbers of tilling passes for rarely grown crop types,

reported hours of use for recreational boats with inboard motors, and others as discussed in the main body of the Final Report.

- Lastly, we relied on state motor vehicle departments' databases of vehicle registrations to represent the 2002 vehicle populations in each county. In some cases, unusual features in vehicle distributions appeared (e.g., larger than expected populations of old vehicles), but no reasons to discount these phenomena could be determined.

2. METHODS TO PREPARE ACTIVITY DATA FOR ON-ROAD MOBILE SOURCES

This section describes the information sources used and the data processing steps followed to prepare activity data for on-road mobile sources, including vehicle miles traveled (VMT), speed distributions, and temporal distributions. VMT, speed distributions of VMT, and temporal distributions of VMT are critical input variables for emission inventories of on-road mobile sources and photochemical air quality models. VMT is a measure of on-road vehicle activity, which is often used as the foundation of emission inventories of on-road mobile sources, including those prepared with MOBILE6. Speed distributions of VMT significantly affect emission rates, while the timing of vehicle activities by season, day, or hour also significantly influences emissions (which vary with temperature).

The SMOKE emissions processor uses VMT, distributions of VMT by speed bin, and temporal distributions of VMT to estimate on-road motor vehicle emissions and to prepare emission inventories for use with photochemical air quality models. The objective of this task was to develop the SMOKE inputs for the CENRAP domain, including county-level VMT, speed distributions, and temporal profiles, which were used to model and prepare emission inventories of on-road mobile sources for the year 2002 (as discussed in Section 8).

2.1 BACKGROUND AND TECHNICAL ISSUES

The FHWA maintains the Highway Performance Monitoring System (HPMS) database, which contains estimates of VMT for all U.S. states and counties. The HPMS database is updated periodically with VMT data submitted by states. However, VMT data developed at the local or state level are preferable because they generally better represent regional or local conditions, are often more current than the data in the HPMS database, and, therefore, result in better quality emissions inventories. Therefore, locally or regionally developed mobile source activity data were given preference, were acquired whenever available from state and local transportation or air quality management agencies, and were used preferentially over the national default VMT estimates.

The availability of local- or state-level data varied geographically within the CENRAP domain and depended on the area's attainment status and level of urbanization. **Figure 2-1** depicts non-attainment areas, urban attainment areas, Class I areas, and tribal lands in the CENRAP region. Areas for which data existed at the local level included five non-attainment areas, which had previously performed emissions modeling with MOBILE6 or MOBILE5, as well as some urban attainment areas. Although none of the urban attainment areas had prepared VMT for emissions modeling, most had VMT data for transportation planning purposes. Thus, for all non-attainment and most urban attainment areas, locally developed VMT, speed distributions, and temporal distributions were acquired. For all other areas (i.e., rural attainment areas and some urban attainment areas), data that had been developed at the state level were acquired.

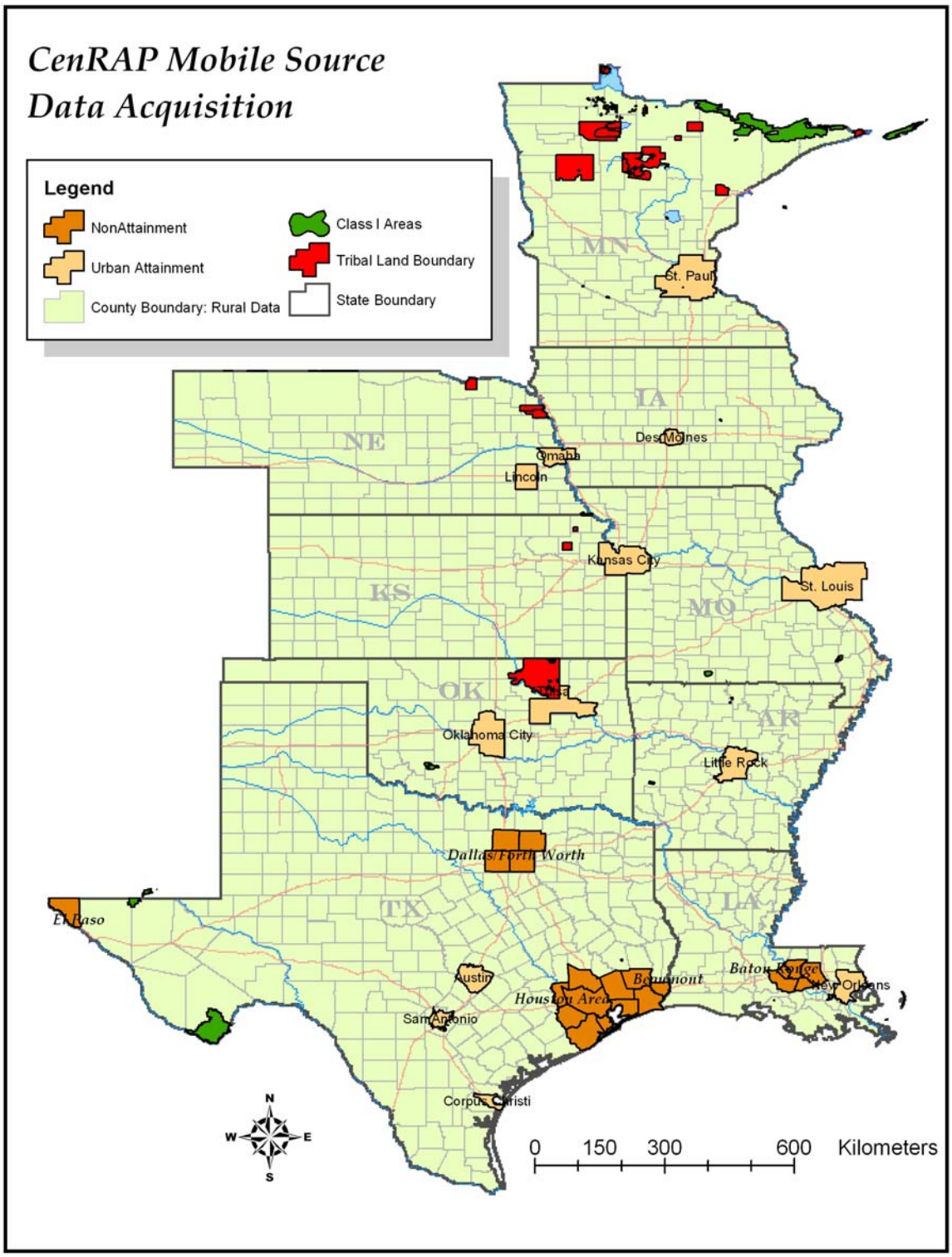

Figure 2-1. Non-attainment areas, urban attainment areas, Class I areas, and tribal lands in the CENRAP region.

To ensure effective use of project resources, we identified areas to be given highest priority according to the following criteria:

1. Magnitude of each region's VMT, population, and proximity to Class I areas.
2. Availability of MOBILE input data.
3. Availability of state or local mobile source activity data to represent the year 2002.

2.2 DATA ACQUISITION

Urban areas often maintain state-generated or locally generated VMT and speed or temporal distributions for the purposes of emissions assessments, air quality modeling, or transportation planning. In addition, the FHWA maintains the national Highway Performance Monitoring System (HPMS) database of VMT on major U.S. roadways. The HPMS data are reported at the county or sub-county level by road type (i.e., freeway, highway, major arterial).

Sonoma Technology, Inc. (STI) requested locally developed on-road mobile source activity data for all non-attainment areas in the CENRAP region and for urban attainment areas located near Class I areas. When locally developed mobile source activity data were not available, Metropolitan Planning Organizations (MPOs) and state departments of transportation (DOTs) were contacted with requests for data. For all other areas, state DOTs were contacted for the most up-to-date HPMS data. **Table 2-1** summarizes the mobile source activity data acquired for each area of the CENRAP domain.

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.

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Area	Data Acquired	Year	Source of Data
Non-Attainment Areas			
Houston/Galveston, Beaumont/Port Arthur, and El Paso, Texas	MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions	2002	Texas Transportation Institute (TTI)
Dallas/Forth Worth, Texas	VMT by vehicle/road type, temporal/speed distributions	1999	Texas Commission on Environmental Quality (TCEQ)
Baton Rouge, Louisiana	MOBILE6 input files, VMT by road type	2002	Louisiana Department of Environmental Quality (LDEQ)

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.

Urban Attainment Areas – Within 500 km of a Class I Area			
Attainment counties, Dallas/Ft. Worth, Texas	VMT by vehicle/road type, temporal/speed distributions	1999	TCEQ
New Orleans, Louisiana	MOBILE6 input files, VMT by road type	2002	LDEQ
St. Louis, Missouri	VMT by vehicle/road type, temporal distributions	2004	East-West Gateway Coordinating Council
Kansas City, Missouri -Kansas	VMT by road type	2002	Kansas Highway Department (KHD) and Missouri Department of Transportation (MoDOT)
Topeka and Wichita, Kansas	VMT by road type	2002	KHD
Little Rock, Arkansas	VMT by road type	2002	Arkansas Highways and Transportation Department (AHTD)
Minneapolis/St. Paul, Duluth, and St. Cloud, Minnesota	VMT by road type	2002	Minnesota Department of Transportation (MnDOT)
Lincoln, Nebraska	VMT by road/vehicle type and speed	2002	Lincoln-Lancaster Metropolitan Planning Organization
Oklahoma City and Tulsa, Oklahoma	VMT by road type	2002	Oklahoma State Highway Department (OSHD)

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.

All Other Areas			
Texas	MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions	2002	TTI
Louisiana	MOBILE6 input files, VMT by road type	2002	LDEQ
Arkansas	VMT by road type	2002	AHTD
Iowa	VMT by road type	2002	Iowa Department of Transportation
Kansas	VMT by road type	2002	KHD
Minnesota	VMT by road type	2002	MnDOT
Missouri	VMT by road type	2002	MoDOT
Nebraska	VMT by road type	2002	Nebraska Department of Transportation
Oklahoma	VMT by road type	2002	OSHD

2.2.1 Details of Data Acquisition for Non-attainment Areas

The CENRAP region currently has five non-attainment areas: four in Texas and one in Louisiana. The El Paso, Texas, non-attainment area (designated as serious) consists of El Paso County and is within about 150 km of the Guadalupe Mountains and Carlsbad Caverns National Parks and within about 400 km of Big Bend National Park. The Dallas-Ft. Worth and Baton Rouge non-attainment areas are located within about 300 kilometers of Class I areas. Houston-Galveston and Beaumont-Port Arthur are at least 500 km distant from any Class I area.

For the non-attainment areas in Texas, MOBILE6-compatible files were acquired from the TTI and the TCEQ. TTI provided hourly and annual VMT and average speed distributions for 2002 by road type and vehicle type. The TCEQ provided MOBILE6-compatible files for 1999, which were grown to 2002 based on additional information provided by the TCEQ. For Baton Rouge, the LDEQ supplied 2002 MOBILE6 input files, as well as 2002 VMT data from the Louisiana Department of Transportation Development (LDOTD).

2.2.2 Details of Data Acquisition for Urban Attainment Areas within 500 km of Class I Areas

Several urban attainment areas in the CENRAP domain are within 500 km of Class I areas (identified in Table 2-1). Of these, three provided locally developed activity data for mobile sources: (1) New Orleans, Louisiana; (2) St. Louis, Missouri; and (3) Lincoln, Nebraska. Other urban areas were unable to provide locally developed activity data within the time available for data acquisition; therefore, VMT data were acquired for these areas from state DOTs. Activity data for a few urban attainment areas have become available very recently or will become available soon (e.g., Kansas City, Missouri-Kansas; Minneapolis-St. Paul, Minnesota). These locally developed data are recommended for use during future inventory development projects.

2.2.3 Details of Data Acquisition for All Other Areas

Texas and Louisiana provided MOBILE6 inputs and activity data for all counties or parishes within those states. Mobile source activity data for 2002 were acquired from the state DOTs in Arkansas, Missouri, Iowa, Minnesota, Oklahoma, Nebraska, and Kansas. In all cases, the data acquired from the state DOTs contain the same type of information as the national HPMS database. However, in some cases, the data supplied by states were more up to date than the latest version of the national HPMS database.

2.3 DATA PREPARATION

A broad array of data types and formats were acquired for this task, which necessitated a strategic data processing scheme to assemble, process, and format the data for use with SMOKE/MOBILE6. The processing scheme was carried out for the following data types:

1. Data acquired for non-attainment areas (MOBILE-compatible inputs)
2. Data acquired for urban attainment areas (MOBILE-compatible inputs or transportation model data)
3. Data acquired for all other areas (HPMS)

Two standardized data processing algorithms were developed to process (1) MOBILE-compatible inputs and transportation demand model data or (2) national HPMS data. **Figure 2-2** illustrates the processing scheme applied to the MOBILE-compatible input data and transportation model data. **Figure 2-3** illustrates the processing scheme applied to the HPMS data. These algorithms included functions to process VMT data into the formats required by SMOKE and to process and calculate average speed distributions and temporal profiles. The outputs of the data processing schemes were SMOKE-ready input files suitable for use with MOBILE6 running within the SMOKE emissions processor.

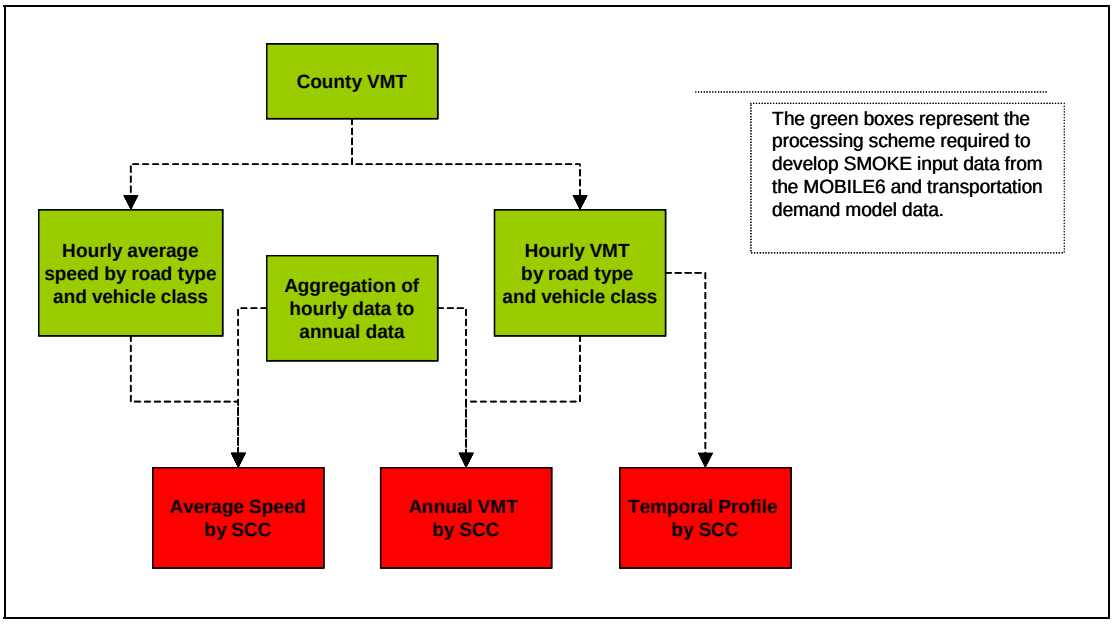

Figure 2-2. Illustration of the processing scheme applied to the MOBILE-compatible input data and transportation model data to develop SMOKE input files.

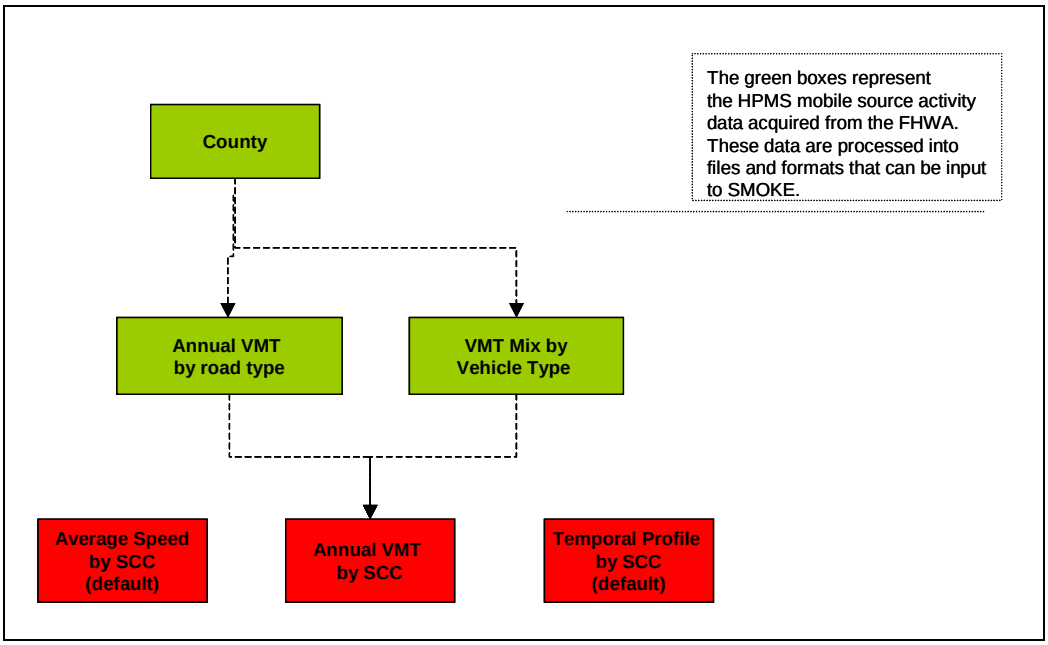

Figure 2-3. Illustration of the processing scheme applied to the national HPMS data.

2.3.1 Details of Data Preparation for Mobile Source Activity Data

SMOKE requires VMT data distributed by 96 standard source classification codes (SCC). Each SCC denotes a vehicle type and a road type combination of those listed in **Table 2-2**. For each state in the CENRAP domain, STI compiled SMOKE inputs for the 96 SCCs using the data sets discussed in Section 2-2.

Table 2-2. Definitions of the 8 vehicle types and 12 road types used by SMOKE.

Vehicle Types	Road Types
LDGV - Light Duty Gasoline Vehicles	Rural Interstate
LDGT1 - Light Duty Gasoline Trucks 1	Rural Principal Arterial
LDGT2 - Light Duty Gasoline Trucks 2	Rural Minor Arterial
HDGV - Heavy Duty Gasoline Vehicles	Rural Major Collector
LDDV - Light Duty Diesel Vehicles	Rural Minor Collector
LDDT - Light Duty Diesel Trucks	Rural Local
HDDV - Heavy Duty Diesel Vehicles	Urban Interstate
MC - Motorcycles	Urban Freeway
	Urban Principal Arterial
	Urban Minor Arterial
	Urban Collector
	Urban Local

2.3.2 Details of Data Preparation for Temporal Profiles

SMOKE uses a default library (data file) of monthly, weekly, and diurnal temporal profiles for all emissions source categories. STI reviewed and revised the default SMOKE/EPA profiles to better represent the temporal patterns of on-road mobile emissions in the CENRAP domain. For Texas and parts of Missouri, where locally developed temporal data were available, local temporal profiles were added to the SMOKE profile library. For other areas, representative temporal profiles were selected. Day-of-week temporal profiles were adopted from a recent study of traffic activity patterns (Coe et al., 2004). Monthly temporal profiles were based on the 1995 National Personal Transportation Survey (Federal Highway Administration, 1995). Diurnal profiles were based on the SMOKE/EPA default profiles for counties inside metropolitan statistical areas (MSAs) and other relatively urbanized counties. For other counties, where population densities or urban populations fell below established thresholds, diurnal profiles were based on Texas' profiles for groups of counties sharing similar population characteristics. (Population demographics were acquired from the U.S. Census Bureau.)

2.4 QUALITY ASSURANCE

On completion of the development of the VMT data, speed distribution data, and temporal profiles, the following quality assurance/quality control (QA/QC) reviews were

conducted, and graphical illustrations were included as an appendix to the Final Report. In addition, the procedures outlined in the project Quality Assurance Project Plan (QAPP) were followed (Sullivan, 2004).

- Examine county-level total VMT estimates and their relative magnitudes and distributions throughout the domain.
- Examine VMT fractions by road type and vehicle type.
- Examine maps, plots, and graphs of VMT by county, road type, and vehicle type.
- Examine graphs of speed distributions by road type and region.
- Examine graphs of temporal profiles for each region.

3. METHODS TO PREPARE FLEET CHARACTERISTICS FOR ON-ROAD MOBILE SOURCES

Emission factors for on-road mobile sources vary with the following fleet characteristics, which are derived from state transportation departments' vehicle registration records.

- *The vehicle age distribution* determines (1) the estimated proportion of the fleet that has been designed to meet certain emissions standards, and (2) the estimated average deterioration level of on-board emissions control devices. Vehicle design standard and deterioration level, in turn, are variables that govern the choice of emission factor.
- The *fractions of the vehicle fleet that are powered by different fuels* (e.g., gasoline or diesel) affect the choice of appropriate emission factors.

Registration distributions vary widely across regions, and Giannelli et al. (2002) indicated that registration distributions exert a major influence (i.e., potentially more than a 20% change) on MOBILE6-modeled emission factors. Therefore, the application of county-specific registration distributions is essential to the development of accurate emission inventories for on-road mobile sources. This section describes the information sources used and the data processing steps followed to prepare fleet characteristics, including vehicle age distributions and vehicle fuel fractions.

3.1 DATA ACQUISITION

Seven state DOTs in the CENRAP region provided extracts of their vehicle registration databases, which were decoded and processed to prepare MOBILE6-ready fleet-age distributions and fuel fractions for light-duty vehicles. The DOTs provided vehicle identification numbers (VIN) and county codes for every vehicle registered in their states on a specified date. The VIN records were decoded to yield vehicle ages and fuel types, which were used to calculate county-specific fleet characteristics. **Table 3-1** provides details about each of the acquired vehicle registration databases.

Texas provided ready-made MOBILE6 inputs, including fleet characteristics, for use in this project. Arkansas was excluded from development of fleet characteristics because the state is currently developing an on-road mobile source inventory, which is expected to be available in 2004. Instead, MOBILE6 default fleet characteristics were used for the state of Arkansas. Fleet characteristics were developed for light-duty vehicles only because heavy-duty vehicles are often used for interstate travel; therefore, national average fleet distributions (i.e., MOBILE6 defaults) are reasonably representative.

Table 3-1. Descriptions of acquired vehicle registration databases and related information.

State	Vehicle Registration Database Characteristics		Contact Information	Comments
	Number of Records	Date Represented		
Texas	n/a	n/a	Mary McGarry-Barber and Chris Kite, Texas Commission on Environmental Quality	Texas provided ready-made fleet characteristics.
Louisiana	2,941,066	July 1, 2002	Cecile Bush and Ray Thomas, Louisiana Department of Public Service	
Arkansas	n/a	n/a	Mary Pettyjohn, Arkansas Department of Environmental Quality and Charles Beaver, Arkansas Department of Revenue	Arkansas is currently funding a separate project to process VINs and estimate emissions from on-road mobile sources. Results will be made available to CENRAP in 2004.
Oklahoma	5,703,980	January 9, 2004	Ray Bishop, Oklahoma Department of Environmental Quality and Chuck Dusenbery, Oklahoma Tax Commission	Oklahoma's database included registrations of non-road vehicles, such as recreational boats, which were eliminated after the automated VIN decoding process.
Kansas	2,568,781	January 21, 2004	Donnita Thomas and Leonard Corkill, Kansas Department of Revenue	
Missouri	5,069,888	February 1, 2004	John Rustige and Fonda Thomas, Missouri Department of Natural Resources and	
Iowa	2,880,936	October 31, 2003	Chad Daniel and Priyanka Painuly, Iowa Department of Natural Resources	
Nebraska	1,850,509	December 11, 2003	David Brown, Nebraska Department of Environmental Quality and Deric Bloom, Nebraska Department of Motor Vehicles	Nebraska uses a state-specific system of county identification codes.
Minnesota	4,606,640	February 1, 2004	Innocent Eyoh and Chun-Yi Wu, Minnesota Pollution Control Agency and Judith Franklin, Minnesota Department of Public Safety	

3.2 DATA PREPARATION, QUALITY ASSURANCE, AND QUALITY CONTROL

The following steps were carried out to prepare, error-check, and correct the vehicle registration databases as needed before carrying out the process of VIN decoding.

- Load records into a unified database for processing.
- Translate county codes if necessary.
- Eliminate null VIN and county federal information processing standard (FIPS) codes.
- Identify and eliminate duplicate VINs.
- Independently verify the number of records.
- Export files for VIN decoding.

Load records into a unified database for processing. All vehicle registration records, including VINs and county FIPs codes, were unified into a structured query language (SQL) database. The unified SQL database supported more efficient preliminary data processing, quality assurance, and quality control procedures and permitted a running record of any changes made to the data sets. Copies of the original data sets from the states were archived before loading them into the unified database.

Translate county codes. Each state provided county information for registration records. Iowa's and Louisiana's databases included FIPS county codes. Kansas', Minnesota's, Missouri's, Nebraska's, and Oklahoma's databases contained county names or county codes that were translated to conform to the standard 5-digit FIPS format, "SSCCC", where SS are 2 integers that identify the state and CCC are 3 integers that identify the county or parish. VIN records without valid county names or codes were eliminated. For example, some of the VIN records were classified as state vehicles and were not assigned to any county. Less than one percent of the VIN records received from each state were eliminated due to unavailable county codes.

Eliminate null VIN and FIPS records. Null VIN and FIPS entries were identified, and records that contained null entries were eliminated. Less than one percent of the records from each state contained null entries. An additional 6% of the Kansas records were eliminated because they were flagged as representing trailers or mobile homes rather than on-road vehicles.

Identify and eliminate duplicate VINs. Each state's database was examined for duplicate VINs. Theoretically, no duplicates should exist because each VIN uniquely identifies a single vehicle. However, duplicate VINs may appear in a vehicle registration database for a variety of administrative reasons, such as failure to update vehicle information associated with changes of owner address or transfers of vehicle ownership. Each state DOT was contacted to discuss any duplicates in their registration databases. Duplicates that occurred within the same county were simply deleted, but cross-county duplicates were retained in most cases. The State of Missouri identified the most recent database entry associated with each duplicate VIN. Therefore, cross-county duplicates were eliminated from Missouri's database by retaining only the most recent duplicate record. The frequencies of duplicate records in the final databases were small for most of the states (i.e., less than one in ten thousand for the Kansas, Louisiana, Minnesota, Nebraska, and Oklahoma data sets). Thus, the potential errors in the vehicle age and fuel type distributions

are expected to be small or negligible. However, a significant number of duplicate records could not be eliminated from Iowa's databases and may represent a source of error in the fleet characteristics for that state. **Table 3-2** summarizes the numbers of duplicate records existing in the vehicle registration databases for each state.

Table 3-2. Summary of null and duplicate VIN record identification and elimination.

State	Original Database (as received)		Final Database	
	Total No. Records	% Duplicates	Total No. Records	% Duplicates
Texas	n/a	n/a	n/a	n/a
Louisiana	2,941,090	0.004	2,941,066	0.004
Arkansas	n/a	n/a	n/a	n/a
Oklahoma	5,704,139	0.000	5,703,980	0.000
Kansas	2,782,208	0.002	2,568,781	0.002
Missouri	5,230,782	2.960	5,069,888	3.053
Iowa	3,111,046	19.016	2,880,936	5.939
Nebraska	1,863,340	0.002	1,850,509	0.002
Minnesota	4,611,407	0.005	4,606,640	0.005

Verify the number of records. The final number of records in each state's database was compared to the number of registered vehicles reported by the FHWA (Federal Highway Administration, 2004) and the state's population as reported for the 2000 Census (U.S. Census Bureau, 2004). The population comparison was performed at a county level to ensure that the most populated counties in each state had the highest numbers of registered vehicles. When large discrepancies were observed, the appropriate state agencies were contacted to resolve the differences. For example, Oklahoma's vehicle registration database includes off-road vehicles. VINs for off-road vehicles were eliminated following VIN decoding, at which time the numbers of records compared better with the figures reported by the FHWA and the 2000 Census. Louisiana's vehicle registration database contained a relatively low number of vehicles (given the state's population and FHWA's reported number of registered vehicles); however, the Louisiana Department of Public Safety confirmed that the number of records in their database was correct.

Export files for VIN decoding. The final VIN data sets for each state were exported into separate ASCII text files and formatted for VIN decoding.

3.3 VIN DECODING

Eastern Research Group (ERG) developed and maintains VIN decoding software that returns model year, series, gross vehicle weight rating, fuel type, and other vehicle specifications

for all domestic and foreign light duty vehicles sold in the United States from 1972 to 2002.[1] Version 2000.01 of the ERG VIN Decoder was used to decode the VINs received from state registration databases. Before proceeding with VIN decoding, the accuracy of the VIN decoder software was validated by decoding several known VINs and verifying the results and by comparing results to the outputs of other VIN decoders.

After the VINs from each state were decoded, the age of each decoded vehicle was determined by subtracting the model year from the current year, where the current year was defined for each state as the year represented by its VIN data set (see Table 3-1). For each county and each vehicle type, the fractions of vehicles aged <1 through 24 years were calculated. Vehicles of ages greater than 24 years were assigned to age 24. The products of these calculations were county-specific fractional age distributions for light-duty vehicle classes.

In addition, the ERG VIN Decoder returned the type of fuel utilized by each decoded vehicle. The fractions of diesel-fueled vehicles in each county, vehicle class, and age group, from age <1 through 24 or greater were calculated. In some cases, vehicle populations were very small and required extrapolation or aggregation across geographic areas or vehicle classes to calculate representative diesel fractions. The results of these calculations are diesel fractions for each county, light-duty vehicle type, and age group. Too few natural-gas powered vehicles were identified to produce meaningful distributions; therefore, MOBILE6 defaults were used for this fuel type (unless locally developed MOBILE6 inputs were provided).

3.4 FINAL QUALITY ASSURANCE, QUALITY CONTROL, AND DATA PREPARATION

On completion of VIN decoding, the following QA/QC reviews and processing steps were conducted to prepare the MOBILE6-ready inputs, and graphical illustrations were included in an appendix to the Final Report. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004):

- Verify the number of decoded VIN records.
- Examine the vehicle age fractions and fuel type fractions for reasonableness.
- Independently calculate and verify a vehicle age fraction and a fuel type fraction.
- Parse the vehicle age distributions and fuel type fractions into MOBILE6-ready inputs.
- Verify correct parsing and formatting of the final deliverables.
- Test the use of these files with the SMOKE emissions processor.

Verify the number of decoded VIN records. The ERG VIN Decoder appended several fields containing vehicle information and error codes to the original data records containing the VINs and FIPS codes. The number of records contained within each decoded file was verified to be equal to the number of records originally submitted for decoding. The decoded VIN files were loaded into the unified SQL database for the final QA/QC procedures. VINs that were not

[1] A listing of the vehicle manufacturers treated by the software and more information is available online at http://www.ergweb2.com/vindecoder/index.cfm.

decoded by the software remained in the output files and were flagged with error codes for explanation.

Examine the vehicle age fractions and fuel type fractions for reasonableness. Two separate files, one containing the age distributions for all vehicle classes and counties and another containing the diesel fractions for all vehicle classes and counties, were loaded into the SQL database in order to examine the calculated fractions. The 25 vehicle fractions for each vehicle class and each county were verified to sum to one. The minimum, maximum, mean, and median fractions for each age class from all the age distributions were examined in order to identify any outlier values and assess their effects. Similarly, the minimum, maximum, mean, and median diesel fractions for each age class from all the vehicle classes and counties were examined. Pivot tables and corresponding pivot charts were also created for the default and calculated age distributions and diesel fractions in order to facilitate quick visual examinations.

Parse the vehicle age distributions and fuel type fractions into MOBILE6-ready inputs. The calculated age distributions for each vehicle class and county were contained within a single table in the SQL database that had variable character fields of character length 50 for the FIPS codes and the vehicle classes and 25 numeric fields of precision 0.0001 for the calculated age fractions. The calculated diesel fractions for each vehicle class and county were contained in a similar table in the SQL database. A separate ASCII text file containing 25 age fractions for each of the 5 decoded vehicle classes was exported from the SQL database. The space-delimited text files contained the header REG DIST on the first line followed by rows of 26 fields containing the vehicle class code and the age fractions from zero to age 24. The diesel fractions were exported into similar ASCII text files for each county. The files contained sets of 25 diesel fractions for 14 of the 16 combined MOBILE6 vehicle classes, for a total of 350 fractions. For the remaining 2 vehicle classes, MOBILE6 assumes that all motorcycles (MC) are gasoline-fueled and all urban/transit buses (HDBT) are diesel-fueled. The age distribution files were prepared as external inputs for the MOBILE6 runs, while the diesel fractions were incorporated into the MOBILE6 input files.

Verify correct parsing and formatting of the final deliverables. A random sample of registration distribution files and diesel fraction files were examined to ensure that the files were properly exported from the SQL database. The selected registration distribution files were verified to contain the appropriate heading and 25 age fractions for each of the 5 vehicle classes. The selected diesel fraction files were verified to contain 5 sets of 25 fractions with 10 fractions in the first row of each set, 10 fractions in the second row of each set, and 5 fractions in the third row of each set.

Test the use of these files with the SMOKE emissions processor. The selected registration distribution files were run through the SMOKE emissions processor using a test MOBILE6 input file with default values to ensure that the files ran properly within the framework of MOBILE6 operating within SMOKE. Similarly, the selected diesel fractions were verified with a test MOBILE6 input file. The diesel fractions were incorporated into the test input file, each in turn, and the files were run through SMOKE to ensure that the diesel fractions were formatted properly to run within the framework of SMOKE.

4. METHODS TO PREPARE FUELS CHARACTERISTICS AND IMPACTS OF REGULATORY CONTROLS FOR ON-ROAD AND OFF-ROAD MOBILE SOURCES

Fuel parameters and regulatory controls can significantly impact emission factors predicted by the MOBILE6 model (for on-road sources) and the NONROAD model (for off-road sources). This section describes the information sources used and the data processing steps followed to prepare fuels characteristics and regulatory control settings for use in MOBILE6. When appropriate, fuels characteristics were also prepared for the NONROAD model.

4.1 FUELS CHARACTERISTICS

Three characteristics of fuels significantly affect criteria pollutant emission predictions from the MOBILE6 and NONROAD models:

1. Sulfur content
2. Fuel volatility
3. Oxygenate content

Fuel sulfur content directly affects emissions of sulfates (particulate matter) and SO_2 from combustion of all fuels. In addition, sulfur's adverse effects on catalytic converters indirectly affect emissions of VOCs, CO, and NO_x from gasoline-fueled vehicles. Fuel volatility and oxygenate content are only necessary for gasoline-fueled vehicles.

EPA found that gasoline volatility can have a major effect on MOBILE6 estimates of VOC and CO emissions (Giannelli et al., 2002), although the influence diminishes at lower temperatures and has no effect at temperatures below 45°F (Tang et al., 2003). Oxygenates for gasoline fall into two classes: alcohols and ethers (see **Table 4-1)**. All are assumed to reduce emissions of CO, but ethanol can also increase the gasoline volatility.

Table 4-1. Common types of oxygenates (listed in approximate order of decreasing prevalence).

Alcohols	Ethers
Ethanol	Methyl tert-butyl ether (MTBE)
Methanol	Tert-amyl methyl ether (TAME)
Butanol	Ethyl tert-butyl ether (ETBE)
	Diisopropyl ether (DIPE)

Both MOBILE6 and NONROAD accept sulfur content information on a weight basis. MOBILE6 requires that sulfur content be specified in parts per million by weight (ppmw or sometimes just ppm), and NONROAD requires that sulfur content be expressed as a percentage by weight (wt. %). Gasoline volatility is expressed in terms of Reid Vapor Pressure (RVP), or pounds per square inch (psi). The extent to which oxygenates are present can be defined either

as the percentage of a specific oxygenate blended by volume (% vol.), or the total weight percentage (% wt.) of oxygen atoms in the blended fuel.

4.1.1 Data Acquisition

For gasoline and diesel fuel, a number of information sources exist, including EPA, commercial data sources, state departments of agriculture, and fuel associations. In addition, the American Society for Testing and Materials (ASTM) standards can be used as guidelines for areas where information is missing or incomplete. Each of these sources of information is discussed in greater detail below.

For compressed natural gas (CNG) and liquefied petroleum gas (LPG), only the NONROAD model requires fuels characteristics, and the only information required is the sulfur content. NONROAD only allows entry of a single sulfur content to describe both fuels, although CNG and LPG sulfur contents sometimes differ. However, for both fuels, the sulfur content is very low (often well below specifications), is rarely tested, and currently has a negligible impact on the overall inventory (although it may become more important in the future as sulfur levels in gasoline and diesel fuel drop). Therefore, for NONROAD, a CNG/LPG sulfur content of approximately 0.0007 wt. % was used, which is consistent with the CNG sulfur content assumed by EPA's AP-42 publication for stationary sources (U.S. Environmental Protection Agency, 1998a).[2]

U.S. Environmental Protection Agency

EPA maintains a database of reformulated gasoline (RFG) data for those areas that utilize RFG. Also, MOBILE6 allows RFG to be modeled explicitly (i.e., the model chooses appropriate values for sulfur content, volatility, and oxygen content). For future inventories, information for fuels sold in other areas may be available from EPA. Specifically, federal regulations (40 CFR 80.370 and 40 CFR 80.593) will require refiners to submit annual reports of sulfur content to EPA by February 2005 and February 2007 for gasoline and diesel fuel, respectively.

Commercially available data

Information about gasoline and diesel fuel compositions is available for purchase from Northrop Grumman and the American Association of Automobile Manufacturers (AAM). These data are the basis for fuel data estimated in EPA's National Emission Inventory (NEI) (E.H. Pechan and Associates, 2004). However, each of these data sets consists of a relatively small number of samples from relatively few areas (e.g., 1-6 cities per state, 1-20 samples per city, and 1-3 locations per city). Data are collected by these entities for winter and summer months only.

AAM can identify specific laboratories and analytical methodologies used, whereas Northrup Grumman's data are reported by a number of private companies and laboratory information cannot be readily tracked down. However, the AAM data are less extensive than the

[2] A sulfur content of 0.0007% (wt.) corresponds to 2000 gr/MMscf = 0.2 gr/100 scf. This factor includes sulfur that is added for safety purposes (odorant).

Northrop Grumman data, and costs are significantly higher. Therefore, Northrup Grumman's data were used rather than AAM's data.

State departments of agriculture

Some weights and measures divisions of state departments of agriculture test gasoline and/or diesel fuel on a regular basis and are able to provide these data electronically. These data are often far more extensive (e.g., hundreds or thousands of samples taken, throughout the entire year and the entire state) than the data available from commercial surveys. Thus, they represent a significant improvement over the commercially available data when available.

For 2002, data were available from three of the CENRAP states (Kansas, Minnesota, and Missouri), and it is likely that Texas will have data for future calendar years. Oklahoma conducts tests but currently does not maintain a database of results.[3] Other CENRAP states do not currently test for fuel parameters relevant to mobile source emissions modeling.

Oxygenated fuel and octane grade data

In several CENRAP states, blending ethanol into fuel is prevalent, even though no regulatory requirements are in effect. The U.S. Department of Energy's Energy Information Administration (EIA) tracks sales volumes of gasoline and oxygenated gasoline by state; however, these data are tracked at the refinery, whereas blending of ethanol is more likely to occur downstream of the refineries at bulk terminals (due to difficulties associated with sending ethanol-blended fuel through pipelines). For states known to blend significant amounts of ethanol, oxygenated fuel associations were contacted to determine the extent of blending.

EIA data were also collected for the purposes of obtaining information about relative sales of regular and premium gasoline. This information was used to estimate the weighted average sulfur content because sulfur contents are significantly higher for regular gasoline than premium gasoline.

Standards and existing assumptions

ASTM standards provide volatility guidelines for every part of the country and every month. ASTM standards, regulations, and assumptions made by state and local agencies/MPOs were collected for the purposes of filling in gaps in fuel sampling data, quality assurance, and consistency with current inventories. However, it should be noted that average values are often below regulatory limits to allow a margin of compliance. In addition, ASTM standards are not regulatory limits, and EPA has found that RVP values can often exceed the ASTM standards (U.S. Environmental Protection Agency, 1992, pp. 25-26).

[3] Oklahoma's Department of Agriculture deferred to the Oklahoma Corporation Commission, which is the lead agency for fuel testing in that state.

4.1.2 Data Processing and Quality Assurance

In general, fuels characteristics were defined for various geographic subregions of the CENRAP region, various fuel types, and for on-road or non-road sources. Fuels characteristics were then organized and prepared for use with MOBILE6 and NONROAD. The discussions below provide the relevant factors that were considered when calculating or preparing the fuels characteristics for diesel fuel and gasoline.

Diesel fuel

As stated previously, sulfur content is the only parameter of interest for diesel fuel. In 2002, transportation-grade diesel fuel was required to have a sulfur content of no more than 500 ppmw = 0.05 wt. %, and for the 2002 NEI, EPA assumed that sulfur content was approximately 500 ppm for all areas of the United States from 1994 through 2002 (E.H. Pechan and Associates, 2004). However, average sulfur content is likely to be lower than the regulatory standard. Furthermore, EPA regulations require sulfur content to be less than 15 ppmw = 0.0015 wt. % by September 1, 2006. Thus, refineries are likely to be lowering the sulfur content of their diesel fuel already. Therefore, available diesel fuel sulfur content information for 2002 was inspected for statistically significant seasonal or regional differences, and for differences between on-road and off-road fuels.

Reformulated Gasoline (RFG)

For areas utilizing RFG (covered areas), little data processing was required because RFG can be modeled explicitly by MOBILE6 with command "FUEL PROGRAM : 2". The only areas of the CENRAP currently utilizing RFG are listed in **Table 4-2**. When RFG is modeled explicitly, user inputs for sulfur content and RVP are overridden by the program. User-supplied oxygenate levels are also overridden, with the exception of user-specified wintertime oxygen contents greater than 2.1 wt. % (U.S. Environmental Protection Agency, 2003a, 2002d). Therefore, in each covered area, the extents to which wintertime oxygen contents are above this level were examined.

Table 4-2. Listing of CENRAP areas utilizing RFG.

Metropolitan Area	Specific Counties
St. Louis, Missouri	Franklin, Jefferson, St. Charles, St. Louis
Dallas/Fort Worth, Texas	Collin, Dallas, Denton, Tarrant
Houston/Galveston, Texas	Brazoria, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller, Chambers

Source: 40 CFR 80.70.

When the "FUEL PROGRAM : 2" command is used, the user must also specify whether the RFG is being used in a southern or northern area. These are referred to as "VOC-Control Region 1" and "VOC-Control Region 2", respectively, by federal regulations (40 CFR 80.71); both Missouri and Texas are in VOC-Control Region 1, which corresponds to a MOBILE6 input of "S" (for southern).

Areas not using RFG – spatial variability and local requirements

Historically, regional differences in gasoline were modeled by dividing the country into districts on the bases of pipelines and other distribution channels. Northrop Grumman still organizes its gasoline data by these districts. Although the continued appropriateness of these divisions has not been verified (and does not account for RFG usage, localized regulations in metropolitan areas, and regional ethanol blending), the district divisions were utilized to investigate spatial differences among areas that do not have localized requirements. The five districts for various metropolitan areas within CENRAP are identified in **Table 4-3**.

Table 4-3. Gasoline distribution districts identified by Northrop Grumman.

District	CENRAP Metropolitan Areas
3 (Southeast)	Little Rock, Arkansas New Orleans, Louisiana
5 (North Central)	Minneapolis-St. Paul, Minnesota
7 (Central and Upper Plains)	Kansas City (Kansas/Missouri) Davenport, Iowa Des Moines, Iowa St. Louis, Missouri Omaha, Nebraska
8 (Oklahoma and East Texas)	Tulsa, Oklahoma Dallas-Ft. Worth, Texas Houston, Texas San Antonio, Texas
11 (New Mexico and West Texas)	Amarillo, Texas El Paso, Texas

Localized regulations restrict summertime fuel volatility, and include requirements and restrictions for oxygenate usage; but currently, there are no localized controls on gasoline sulfur content in the CENRAP region.

Sulfur content of gasoline (non-RFG)

MOBILE6 incorporates two elements of gasoline sulfur content data: (1) information about the average sulfur content existing during the calendar year of interest (for purposes of determining SO_2 and PM emissions), and (2) information about the maximum sulfur content ever experienced by vehicles in a given model year (for purposes of determining deterioration of catalysts). Available fuel data can only be utilized to modify sulfur contents for the calendar year of interest, not the lifetime maxima of fuel contents ever experienced. Data for regular and premium gasolines were averaged separately, and weighted average sulfur contents were determined based upon relative sales volumes of different grades of gasoline. Given the limited availability of data, the calculated weighted average sulfur contents were only added to MOBILE6 input files if they differed significantly from the MOBILE6 default values.

Default sulfur content data can be different for "western" areas due to a geographic phase-in of gasoline sulfur regulations. However, this only affects Nebraska (of the CENRAP states) and calendar year 2003 and later. A full listing of MOBILE6 default sulfur contents is shown in **Table 4-4**.

Table 4-4. MOBILE6 default sulfur content data for conventional gasoline (i.e., non-RFG).

Calendar Year	Average Fuel Sulfur Content (ppmw)		Vehicle Model Year	Maximum Fuel Sulfur Content Experienced (ppmw)	
	Eastern Areas[a]	Western Areas[b]		Eastern Areas[a]	Western Areas[b]
2000	300	300	2000[c]	1000	1000
2001	299	299	2001	1000	1000
2002	279	279	2002	1000	1000
2003	259	263	2003	1000	1000
2004	121	160	2004	303	325
2005	92	160	2005	303	325
2006	33	160	2006	87	325
2007	33	60	2007	87	142
2008+	30	30	2008+	80	80

[a] Within CENRAP, this includes all counties except those specifically identified as western areas.
[b] Within CENRAP, this only includes the following counties, all of which are located in western Nebraska: Banner, Box Butte, Cheyenne, Dawes, Deuel, Garden, Keith, Kimball, Morrill, Scotts Bluff, Sheridan, and Sioux (Source: 40 CFR 80.215(a)(2)(i)).
[c] Within MOBILE6, maximum sulfur content does not affect emissions from vehicles of model year 1999 and older.

RVP and oxygenate content of gasoline (non-RFG) – agriculture department data

For RVP and oxygenate, the data obtained from state departments of agriculture were analyzed. For regions where data were available, temporal variations in volatilities over the course of the year were compared with the variations in the corresponding ASTM standards for those regions. Within each state, areas known to have local regulatory requirements were examined separately from areas without such requirements, and gasoline blended with ethanol was examined separately from other gasoline. (Methodology documentation for the 2002 NEI indicates that, aside from areas with local requirements, RVP was assumed to be uniform across each state [E.H. Pechan and Associates, 2004].) The limited data obtained from Northrop Grumman were compared to the agriculture departments' data for purposes of gauging the extent to which the Northrop Grumman data are representative.

EPA and local regulations restrict the maximum RVP of some summertime gasolines. For purposes of quality assurance, summertime RVP data were compared to these requirements. However, it should be noted that EPA and many local governments grant a waiver of 1.0 psi to ethanol blends (i.e., the blends are allowed to have RVP values that are 1.0 psi higher than regulatory limits[4]), and in such cases MOBILE6 assumes that the RVP of the ethanol-blended gasoline is 1.0 psi higher than the RVP specified in the model input file. Available data from

[4] EPA's waiver (40 CFR 80.27(d)) only applies if a sufficient quantity of ethanol is used (9-10% vol.)

state agricultural departments were utilized to investigate the extent to which the RVP of ethanol blends is higher than the RVP of conventional gasoline. If differences were found to be considerably smaller than 1.0 psi, the area was modeled as one without a waiver (even if a waiver exists) to prevent MOBILE6 from increasing the RVP of the ethanol blends.

The extent to which a fuel is characterized as an "ethanol blend" depends on how this term is defined. In some cases, the blend is mandated. For example, the State of Minnesota requires that ethanol be blended into all gasoline sold in the state, year-round, to reach a level of 2.7-3.5 wt. % oxygen in the blend.[5] However, in other areas, a variety of levels of oxygenate are in use, and oxygenate analyses show a variety of oxygenate concentrations, which in some cases contain both alcohols and ethers in the same sample. Because MOBILE6 only models one oxygenate type or the other and assumes a single average oxygenate concentration, frequency plots were generated to determine the extent to which different oxygenate concentrations were present, and analytical data were screened to eliminate low data (e.g., near detection limits). It is worth noting that volatility increases due to ethanol tend to be somewhat independent of concentration above approximately 3%. This is important in areas modeled with RVP waivers, for which MOBILE6 will increase RVP by 1.0 psi for all ethanol blends, regardless of the ethanol concentration.

RVP and oxygenate content of gasoline (non-RFG) – other data

For states in which agriculture department data were not available, RVP estimates were based primarily on data obtained from Northrop Grumman in the summer and winter. These data were interpolated to different months using ASTM standards—similar to the procedure applied for the 2002 NEI (E.H. Pechan and Associates, 2004). Spatial and temporal variations were also compared to publicly available RVP data from the 1999 NEI (which was generated based upon data from Northrop Grumman and AAM). Areas with specific RVP or oxygenate restrictions were modeled to reflect those restrictions, even if no sampling data were available for those areas.

Although gasoline volatilities are highest in the winter, the extent of wintertime data analysis was tempered by two factors: (1) the effects of volatility are lessened at colder temperatures, and (2) MOBILE6 models any RVP higher than 11.7 psi as equal to 11.7 psi (U.S. Environmental Protection Agency, 2003a, 2002d).

General quality assurance

Given the recent court cases involving environmental laboratory fraud (Bureau of National Affairs, 2002a, b), particularly with respect to testing vehicle fuels (McCarthy, 2001; Bureau of National Affairs, 2002c; U.S. Department of Justice, 2002), an effort was made to determine the source of the data collected. Data from fuel testing sources known to have been indicted and/or convicted of laboratory fraud were discarded when appropriate. The methodologies utilized were also examined. For example, it is known that RVP measurements using Grabner equipment are adjusted using a variety of formulas (sometimes season-

[5] The 2.7% minimum oxygen content is identified by Section 239.791 of the Minnesota Statutes, and ethers are specifically excluded from meeting that requirement; Section 239.761 bans the use of ethers (above approximately 0.33%) and limits the maximum ethanol content to 10% vol., which corresponds to approximately 3.5 wt. % oxygen.

dependent), and gas chromatography (GC) results for oxygenates can differ from Fourier-transform infrared (FTIR) results. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004).

4.1.3 Data Preparation

Fuels characteristics were prepared as a summary data table listing gasoline volatilities as a function of county and month, and the extent to which oxygenated fuel information and fuel sulfur contents differ from MOBILE6 defaults. The tables, which are included in an appendix to the Final Report, show the appropriate MOBILE6 inputs with respect to the commands shown in **Table 4-5**. These command lines were inserted into the SMOKE input files for the complete set of geographic areas within the CENRAP and time periods within calendar year 2002.

Table 4-5. MOBILE6 input commands relevant to fuel composition.

Command	Meaning	Data
FUEL PROGRAM[a]	Identifies gasoline sulfur content, and whether RFG is being used	1 = eastern default sulfur values, 2 = RFG, 3 = western default sulfur values, 4 = user-supplied sulfur data
DIESEL SULFUR	Diesel sulfur content	Average diesel sulfur content, in ppmw
OXYGENATED FUELS[b]	Extent of oxygenate usage	% of gasoline sold that is blended with alcohols, and that is blended with ethers; average oxygen wt. % in each of those blends
FUEL RVP	Gasoline RVP (prior to ethanol addition, if any)	Average RVP, in psi
SEASON	For RFG, an identifier of which season's requirements are in effect	1 = summertime RFG, 2 = wintertime RFG

[a]Optional command; MOBILE6 default is FUEL PROGRAM = 1.
[b]Optional command; MOBILE6 default is no oxygenate.

4.2 REGULATORY CONTROLS

Regulatory controls that affect engine emissions and are modeled by MOBILE6 and/or NONROAD include the following:

- Anti-Tampering Programs (ATPs)
- Inspection & Maintenance (I/M) Programs
- Stage II Refueling Controls

Stage II refueling emissions are typically excluded from mobile source emission inventories developed using MOBILE6 because they are considered to be stationary area source

emissions. Thus, refueling emissions were excluded from the CENRAP emission inventory of on-road mobile sources, and associated MOBILE6 settings were not prepared. However, the appropriate MOBILE6 commands were prepared as a table and included in an appendix to the Final Report.

4.2.1 Data Acquisition

Environmental regulatory agencies in each of the CENRAP states were contacted for information regarding ATPs, I/M programs, and Stage II controls. These agencies provided the relevant information in the form of MOBILE6 input files.

4.2.2 Data Processing and Quality Assurance

Data processing consisted primarily of quality assurance, based in part on EPA technical guidance. Information provided by regulatory agencies was reviewed for consistency with EPA guidance and for reasonableness, and was investigated further if warranted. For example, I/M program compliance rates are often assumed to be 96% prior to implementation (U.S. Environmental Protection Agency, 2002d) but should be based on operating program data after they have been implemented. In addition, if a customized I/M program effectiveness is identified (using the I/M EFFECTIVENESS command), EPA requires that the state or local agency consult with the EPA first (U.S. Environmental Protection Agency, 2002d). For Stage II vapor recovery systems, a working system is assumed to be 95% effective. However, a 95% in-use effectiveness should not be input into MOBILE6 because this does not reflect rule penetration or rule effectiveness (U.S. Environmental Protection Agency, 1991b). Appropriate values for program compliance rates and in-use effectivenesses were selected and reported in a summary data table included in an appendix to the Final Report. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004).

4.2.3 Data Preparation

Regulatory controls were prepared as a summary data table listing the counties that have ATPs, I/M programs, and/or Stage II vapor recovery, and as an electronic file with the associated MOBILE6 command lines. The tables, which are included in an appendix to the Final Report, show the appropriate MOBILE6 inputs with respect to the commands shown in **Table 4-6**. Command lines were inserted into the SMOKE input files for the geographic areas within the entire CENRAP region. (Note that the I/M commands are provided in external files that will be referenced by MOBILE6 through the “I/M DESC FILE” command.)

Table 4-6. MOBILE6 input commands relevant to non-fuel-related regulatory programs. (Command lines are needed only if programs are in place; some input files may require information for multiple ATPs and I/M programs.)

Command	Data
ANTI-TAMP PROG	Calendar years applied, vehicle model years affected, vehicle types affected, inspection frequency, compliance rate, types of components inspected
I/M PROGRAM I/M MODEL YEARS I/M VEHICLES I/M STRINGENCY[a] I/M COMPLIANCE[b] I/M WAIVER RATES[b] I/M CUTPOINTS[c] I/M EXEMPTION AGE[d] I/M GRACE PERIOD[d] NO I/M TTC CREDITS[e] I/M EFFECTIVENESS[f]	Calendar years applied, test frequency, program type, inspection test type, model years affected, vehicle types affected, failure rate, percentage of vehicles that get inspected and either comply or are waived, extent to which inspected vehicles are waived rather than being modified to comply, exempted vehicle ages, number of years that new vehicles are exempted, extent of technician training, customized program effectiveness values (pollutant-specific)
STAGE II REFUELING	Calendar year that Stage II program begins to be phased in, number of years of phase-in, in-use efficiency for light-duty vehicles, in-use efficiency for heavy-duty vehicles

[a] This command is only used for (and required for) exhaust I/M programs.
[b] This command is required for exhaust I/M programs and highly recommended for evaporative I/M programs.
[c] This command is only used (and is required) if I/M PROGRAM is IM240.
[d] This command is optional for exhaust I/M programs and highly recommended for evaporative I/M programs.
[e] This command is optional for exhaust I/M programs and is not used for evaporative I/M programs.
[f] This command is optional.

5. ADDITIONAL PARAMETERS FOR ON-ROAD MOBILE SOURCES

Additional optional inputs to MOBILE6 were prepared when readily available. These parameters are of lesser significance than VMT, fleet characteristics, fuels characteristics, or regulatory controls. However, they do have some effects and should be prepared when resources permit. In addition, consistency between the states' and the CENRAP's MOBILE6 inputs is desirable.

Examples included customized annual mileage accumulation rates, relative humidities, and/or natural gas vehicle (NGV) fractions that were provided by environmental regulatory agencies within the CENRAP region in response to other data requests. These data generally were provided in the form of MOBILE5 or MOBILE6 input files. Other inputs were relatively easy to determine. Altitude, which has been identified as having an "intermediate" (5-20%) effect upon VOC and NO_x emissions by EPA (Giannelli et al., 2002, p. iii), is easily determined from regulatory guidance and readily available geographic information systems (GIS) tools.

5.1 DATA ACQUISITION

MOBILE input files were requested from environmental regulatory agencies and/or MPOs in each of the CENRAP states, and optional input commands were reviewed and used if appropriate. Topographical GIS databases were used to determine altitudes.

5.2 DATA PROCESSING AND QUALITY ASSURANCE

Relatively little data processing was necessary, because data were in MOBILE5 or MOBILE6 format. However, consistency with applicable EPA guidance was checked.

In the case of altitude, MOBILE6 only allows the selection of "high" or "low" altitude. ("Low" is the default setting.) High altitude model outputs are based on conditions representative of approximately 5,500 feet above mean sea level (msl), and low altitude model outputs are based on conditions representative of approximately 500 feet msl (U.S. Environmental Protection Agency, 2003a, 2002d). EPA refers users to 40 CFR 86.091-30(a)(5)(ii) and (iv) for guidance. However, Section (a)(5)(ii) lists no CENRAP areas as "designated high-altitude locations" and Section (a)(5)(iv) names four counties in Nebraska (Banner, Cheyenne, Kimball, and Sioux) as specifically <u>not</u> "designated low-altitude locations." STI utilized GIS tools to determine that substantial portions of these counties <u>are</u> above 4,000 feet msl (see **Figure 5-1**) and that, therefore, they should be modeled as "high" altitude.

5.3 DATA PREPARATION

A summary data table listing the additional MOBILE6 input commands was included with an appendix to the Final Report. Command lines were inserted into the MOBILE6/SMOKE input files.

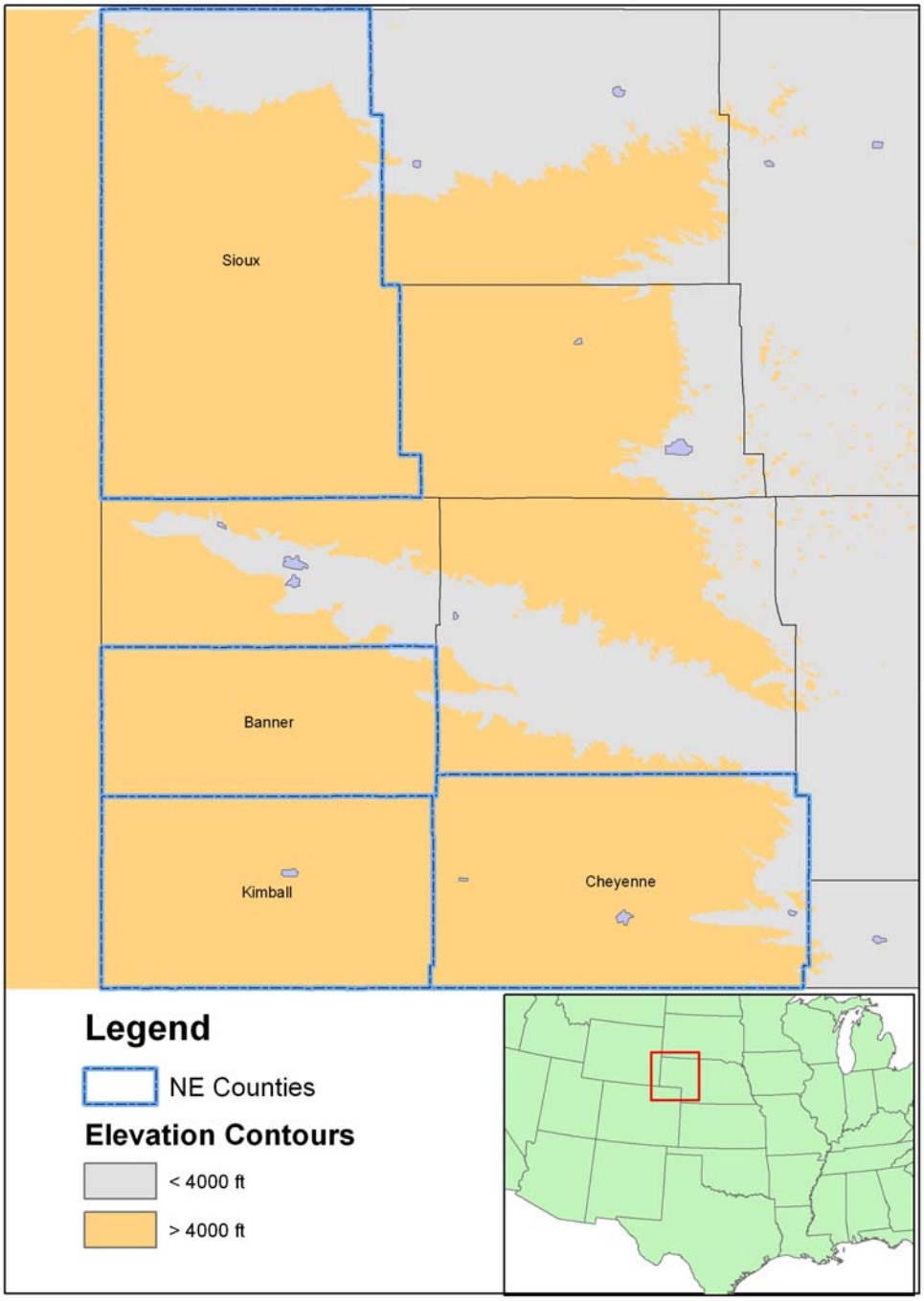

Figure 5-1. Extent to which western Nebraska counties are "high altitude" (above 4000 ft msl).

6. METHODS TO ESTIMATE EMISSIONS FOR NON-ROAD MOBILE SOURCES

Non-road mobile sources include equipment and vehicles that have internal combustion engines and are used off-road. Examples include ships, locomotives, aircraft, industrial equipment, recreational boats, and many others. This section describes information sources and methods used to prioritize efforts, gather activity data, and estimate emissions for non-road mobile sources.

6.1 PRIORITIZATION

STI reviewed the EPA's 1999 NEI (U.S. Environmental Protection Agency, 1999c) to assess the likely importance of various non-road sources to visibility in Class I areas. **Table 6-1** shows the top five non-road emitters of primary particulates and particulate precursors for counties in the CENRAP region containing or adjoining a Class I area. This review illustrated the likelihood that commercial marine vessels and railroad equipment impact visibility in the CENRAP's Class I areas more than most other non-road mobile sources. However, it also indicated that pleasure craft (recreational boats) are a much more significant source of particulates and particulate precursors than other types of recreational vehicles. It also demonstrated the importance of agricultural equipment, especially in Oklahoma and Missouri. Based on this analysis, an assessment of available resources, and consultation with the CENRAP's Emission Inventory Work Group, a decision was made to give bottom-up treatment to commercial marine vessels, locomotives, and recreational boats. These categories represent at least two-thirds of the non-road primary and precursor emissions in counties containing or adjacent to Class I areas in the CENRAP region.

Table 6-1. 1999 non-road emissions (tons/year) by state and source category for counties in the CENRAP region containing or adjoining a Class I area (U.S. Environmental Protection Agency, 2004b).

Page 1 of 2

Poll.	Source Category	AR	LA	MN	MO	OK	TX	Total
$PM_{2.5}$	Pleasure Craft	52.3	403.5	700.3	150.4	31.1	3.2	1,340.8
	Commercial Marine Vessels	0.0	151.6	771.6	151.3	0.0	0.0	1,074.5
	Agricultural Equipment	71.4	1.0	27.3	404.5	280.2	8.8	793.2
	Construction & Mining Eq.	49.3	45.0	56.5	73.1	58.1	16.6	298.6
	Railroad Equipment	24.4	0.5	5.1	57.2	9.3	127.2	223.7
	Other Sources	52.2	9.0	144.9	56.0	32.0	2.9	297.0
	Total – All Sources	249.6	610.6	1,705.7	892.5	410.7	158.7	4,027.8
VOC	Pleasure Craft	1,197.9	9,434.0	15,418.6	3,338.8	707.9	74.7	30,171.9
	Recreational Equipment	1,102.7	250.7	5,448.3	1,603.8	154.5	94.4	8,654.4
	Lawn & Garden Equipment	319.8	91.5	463.5	660.3	341.9	48.1	1,925.1
	Agricultural Equipment	89.9	1.2	34.4	507.5	352.3	11.1	996.4
	Commercial Marine Vessels	0.0	114.5	615.9	114.2	0.0	0.0	844.6
	Other Sources	440.0	161.8	405.4	592.9	309.9	264.7	2,174.7
	Total – All Sources	3,150.3	10,053.7	22,386.1	6,817.5	1,866.5	493.0	44,767.1

Table 6-1. 1999 non-road emissions (tons/year) by state and source category for counties in the CENRAP region containing or adjoining a Class I area (U.S. Environmental Protection Agency, 2004b).

NO_x	Commercial Marine Vessels	0.0	3,665.1	19,700.1	3,657.6	0.0	0.0	27,022.8
	Railroad Equipment	1,074.9	14.0	212.5	2,533.2	399.1	5,694.0	9,927.7
	Agricultural Equipment	557.7	7.5	213.8	3,160.6	2,188.3	69.1	6,197.0
	Construction & Mining Eq.	531.5	483.4	607.9	786.6	625.1	179.0	3,213.5
	Pleasure Craft	79.4	634.9	1,119.2	229.0	47.6	4.0	2,114.1
	Other Sources	885.5	135.5	610.9	850.9	341.6	25.4	2,849.8
	Total – All Sources	3,129.0	4,940.4	22,464.4	11,217.9	3,601.7	5,971.5	51,324.9
SO_2	Commercial Marine Vessels	0.0	714.6	2,978.5	713.1	0.0	0.0	4,406.2
	Agricultural Equipment	62.5	0.8	23.9	353.8	245.4	7.7	694.1
	Construction & Mining Eq.	71.1	64.9	80.7	104.5	83.8	24.0	429.0
	Railroad Equipment	32.1	0.5	6.5	75.2	12.1	168.6	295.0
	Pleasure Craft	7.5	61.0	103.1	21.7	4.5	0.4	198.2
	Other Sources	66.9	10.5	70.5	59.8	25.7	2.7	236.1
	Total – All Sources	240.1	852.3	3,263.2	1,328.1	371.5	203.4	6,258.6

6.2 RECREATIONAL BOATS

6.2.1 Emissions Modeling with NONROAD

Emissions from recreational boats were modeled with the latest version of the EPA's NONROAD model. NONROAD categorizes equipment types by SCC code, and the codes pertaining to recreational boats are listed in **Table 6-2**.

Table 6-2. NONROAD source categories related to recreational boats.

SCC code[a]	Equipment Description
22-82-yyy-005	Pleasure Craft: Inboard Engine
22-82-yyy-010	Pleasure Craft: Outboard Engine
22-82-yyy-015	Pleasure Craft: Personal Watercraft
22-82-yyy-025	Pleasure Craft: Sailboat Auxiliary Engine

[a] In each code, the letters "yyy" refer to fuel type: 2-stroke gasoline (005), 4-stroke gasoline (010), or diesel (020).

For each of these source categories, the NONROAD model provides exhaust emission factors in units of grams of emissions per horsepower-hour (g/hp-hr) that are a function of engine types and sizes. Activity data include size-dependent engine populations, the load on the engines (hp) while they are in use, and the number of hours that the engines are in use per year. (These data are in turn utilized to calculate fuel consumption, which is needed for the calculation of

evaporative emissions.) Sources of these model inputs are primarily activity data collected by Power Systems Research, Inc. (PSR) and methodological information from a previous EPA non-road engine and vehicle study (U.S. Environmental Protection Agency, 1991a).

NONROAD includes the following default databases of recreational boating activity. Each may be updated with bottom-up or region-specific activity data, if available.

- NONROAD's default engine populations are based on 1998 PSR national surveys of engine manufacturer sales. The national population estimate was disaggregated to the state level by using a fuel consumption distribution developed by the Oak Ridge National Laboratory (ORNL). State-level populations were further disaggregated to the county level by using the total water surface area contained in each county (U.S. Environmental Protection Agency, 2002a).
- Default temporal profiles are based on two sources of information. Monthly allocation factors are derived from a boat usage survey done for the National Marine Manufacturers Association (NMMA) (U.S. Environmental Protection Agency, 2002c). Weekday-weekend allocation factors were derived from a survey of recreational marine use conducted in California during 1993 and 1994. These weekday-weekend factors are specific to equipment type only and do not vary geographically (U.S. Environmental Protection Agency, 1999b).
- Annual equipment usages (hours of use) are based on a 1998 PSR equipment activity database. The application-specific estimates in this database were based on several yearly surveys of equipment owners conducted by PSR (U.S. Environmental Protection Agency, 2002b).
- Default engine load factors were based on a simplifying assumption that the EPA's recreational marine engine test cycle is representative of load factors for engines in use. Although PSR survey results for load factors exist, they are not represented in the NONROAD model because the EPA considered them to be insufficiently documented (U.S. Environmental Protection Agency, 2002b).

Because NONROAD relies primarily on national-level activity data, some regional and/or local equipment population and usage characteristics are likely not properly represented in the model. Moreover, the use of water surface area as a geographic allocation surrogate does not account for the navigability of a given body of water or its popularity. Improving the various types of activity data utilized by NONROAD required gathering additional information about the ownership and use of recreational boats within the CENRAP region.

6.2.2 Acquisition of Activity Data

The activity data needed to update the NONROAD inputs for recreational boats were gathered through a bottom-up survey of representative groups of recreational boat owners. The survey was designed to gather data on vessel characteristics, hours of use, fuel consumptions, engine loads, and temporal and geographic usage patterns in each CENRAP state. A representative pool of nearly 1,400 registered boat owners was recruited by telephone to participate in the study. A survey questionnaire and an incentive for participation was mailed to

each participant, followed one week later by a reminder postcard. For the purposes of study design, a 50% return rate was anticipated for the mail survey; however, a significantly better response rate—more than 70%—was actually achieved. Geographic coverage and representativeness of the survey results were considered to be excellent for all states of the CENRAP region. Survey results were analyzed and used to estimate annual hours of use and engine load factors for each state and each type of boat. Survey questionnaires, results, and raw data files are included as an appendix to the Final Report.

6.2.3 Spatial Allocation

In order to spatially allocate emissions, the counties where recreational boats are used should be determined (i.e., the county where the boat is registered is not a good spatial surrogate). The survey questionnaire included one or more maps detailing the navigable waterways in the respondents' region, which allowed respondents to easily identify the counties in which they typically operate their boats. (Participants indicated their regions during telephone recruitment.) These responses were converted and used to calculate county-level activity for recreational boats.

6.2.4 Temporal Allocation

The survey questionnaire also queried how recreational boat activity is distributed across the months of the year, the days of the week, and the hours of the day. Large variances in climate and boating habits throughout the CENRAP region meant that these temporal patterns were likely to vary greatly from state to state. Responses to these questions were analyzed and used to calculate seasonal, day-of-week, and diurnal temporal profiles for each state and type of boat.

6.2.5 Data Preparation

Deliverables for this source category included the updated input files used to run the NONROAD model, as well as county-level emission estimates derived from outputs of the latest version of NONROAD (NONROAD 2004). These emission estimates were provided in both NIF 3.0 format and the IDA format used by the SMOKE emissions model. The temporal allocation profiles and cross-reference files used by SMOKE were also provided.

6.3 MARINE VESSELS

Emissions estimates were prepared for commercial marine vessels operating in commercially active waterways in the CENRAP region. This inventory included river barges and other commercial vessels operating in inland waterways, as well as ocean-going ships, harbor tugboats, and other commercial vessels operating in the Gulf Intracoastal Waterway (GIWW). These waterways can be seen in **Figure 6-1** (U.S. Army Corps of Engineers, 1997).

Figure 6-1. Map of commercially active inland and intracoastal waterways in the United States.

6.3.1 Emission Factors

In 1999, the EPA released a Regulatory Impact Analysis (RIA) on commercial marine vessel emissions (U.S. Environmental Protection Agency, 1999e). This report estimated emissions for the three categories of marine engines shown in **Table 6-3**:

Table 6-3. EPA marine engine categories.

Category	Displacement per Cylinder	Description
1	disp. < 5 liters power ≥ 37 kW	Similar to land-based non-road engines. Used in smaller tugboats, ferries, fishing vessels, and dredges. Fueled by marine diesel oil.
2	5 ≤ disp. < 30 liters	Similar to engines used in locomotives. Used in smaller ocean-going vessels, as well as large tugboats, towboats, ferries, and fishing vessels. Fueled by marine diesel oil.
3	disp. ≥ 30 liters	Used primarily for propulsion in large, ocean-going vessels. Usually fueled by residual oil, which has a higher sulfur content than diesel oil.

In addition to the uses cited in Table 6-3, all three categories of engines can be used for "auxiliary" purposes (such as electrical generation) on larger vessels, though Category 2 engines are used in this way more often than the other types. The EPA RIA estimated emission factors for Category 1 marine engines and cited emission factors for Category 2 and 3 marine engines from a previous EPA report (U.S. Environmental Protection Agency, 1998c). **Tables 6-4 and 6-5** show the emission factors for marine engines in each category.

Table 6-4. Emission factors for Category 1 marine engines.

Power Range (kW)	HC (g/kW-hr)	NO_x (g/kW-hr)	CO (g/kW-hr)	PM (g/kW-hr)
37 – 75	0.27	11	2.0	0.9
75 – 130	0.27	10	1.7	0.4
130 – 225	0.27	10	1.5	0.4
225 – 450	0.27	10	1.5	0.3
450 – 560	0.27	10	1.5	0.3
560 – 1000	0.27	10	1.5	0.3
1000+	0.27	13	2.5	0.3

Table 6-5. Emission factors for Category 2 and 3 marine engines.

Engine Speed[1]	HC (g/kW-hr)[2]	NO_x (g/kW-hr)	CO (g/kW-hr)	PM (g/kW-hr)
Medium[2]	0.5	12	1.6	0.25
Slow[2]	0.5	17	1.4	1.48

[1] Category 2 and smaller Category 3 engines are medium speed (2-stroke). Larger Category 3 engines are slow speed (4-stroke).
[2] Emission factors converted from kilograms per ton of fuel consumed to gram per kilowatt-hour using fuel consumption estimates of 195 g/kW-hr for slow speed engines and 210 g/kW-hr for medium speed engines (Pollack et al., 2004).

Emission factors for SO_2 were calculated using Equation 6-1, an algorithm that is based on fuel sulfur content (U.S. Environmental Protection Agency, 2000). **Table 6-6** lists the assumed fuel sulfur content (U.S. Environmental Protection Agency, 2003b) for marine diesel oil and residual oil, as well as the SO_2 emission factors calculated for each engine type.

Emission rate (g/kW-hr) =
2.3735* [Fuel Consumption (in g/kW-hr) * Fractional Fuel Sulfur content] **(6-1)**