

4. Nonroad Mobile Sources

4.1 Introduction

Nonroad mobile sources are defined as those that move or are moved within a 12-month period and are not licensed or certified as highway vehicles. Nonroad mobile sources are vehicles and engines that fall under the following categories:

- Agricultural equipment, such as tractors, combines and balers;
- Airport ground support equipment, such as baggage tugs and terminal tractors;
- Commercial equipment, such as generators and pumps;
- Industrial equipment, such as forklifts and sweepers;
- Construction and mining equipment, such as graders, back hoes and trenchers;
- Lawn and garden equipment, such as leaf blowers and lawn mowers;
- Logging equipment (not present in Maricopa County);
- Pleasure craft, such as power boats and personal watercraft;
- Railway maintenance equipment, such as rail straighteners;
- Recreational equipment, such as all-terrain vehicles and off-road motorcycles;
- Underground mining and oil field equipment (not present in Maricopa County);
- Aircraft, such as jet and piston engines; and
- Locomotives, such as switching and line haul trains.

Emission calculations for most nonroad mobile source categories except aircraft, airport ground support equipment (GSE) and locomotives were derived using EPA's NONROAD model, ver. 2008.1.0 (Core version 2008, April 2009). Aircraft and airport GSE emission estimates were made using the Federal Aviation Administration's EDMS (Emissions Dispersion Modeling System) model, ver. 5.1.1. Locomotive emission calculations were derived from surveys of the three railroad companies that have operations in the county (Burlington Northern Santa Fe, Union Pacific and Amtrak).

County specific temperature and fuel-related inputs are required for the operation of the NONROAD model. Monthly temperature and fuel data were provided by the Arizona Department of Weights and Measures. The following table lists the local county inputs used:

Table 4.1–1. NONROAD model county temperature- and fuel-related inputs.

Month	Temperatures (°F)			Fuel	Diesel	Gasoline	Ethanol (EtOH) Blend		
	Max.	Min.	Average	RVP (psi)	Sulfur (ppm)	Sulfur (ppm)	EtOH (Vol %)	Market Share (%)	Total Oxygen (wt%)
January	64	45	54.90	8.8	6	35	9.47	100	3.49
February	69	48	58.45	8.4	6	23	9.24	100	3.42
March	79	54	66.84	8.4	7	49	9.18	100	3.41
April	87	61	74.23	7.8	7	23	5.57	100	2.06
May	91	66	78.74	6.8*	6 *	27*	0.00*	0*	0.00*
June	107	80	93.40	6.6	6	25	0.00	0	0.00
July	106	84	95.16	7.0	4	19	0.00	0	0.00
August	104	82	93.16	6.8	6	29	0.00	0	0.00
September	101	79	90.07	6.5	6	35	0.00	0	0.00
October	91	65	78.13	7.9	7 †	25	6.79	100	2.52
November	81	56	68.67	8.4	7 †	15	8.78	100	3.27
December	65	46	56.03	8.3 †	7	28 †	8.17 †	100 †	3.03 †

* Since measurements were not available, the average of June, July, August and September data was used.

† Since measurements were not available, the average of October, November, January, February, March and April data was used.

EPA recommends adjusting default NONROAD model values (such as equipment population, activity levels of equipment, growth factors, etc.) where local data is available, as the default values in the model are derived from national averages. The NONROAD model defaults were adjusted in the following manner:

- Equipment population numbers and activity levels for commercial lawn and garden equipment were adjusted based on 2003 survey results of the commercial lawn and garden industry performed by ENVIRON as part of an inventory developed to study the impact of visibility impairing pollutants (ENVIRON et al., 2003). Survey results show that for most categories of lawn and garden equipment, the equipment populations for Maricopa County are significantly lower than EPA default values, while the average annual hours of operation for most equipment types are slightly higher than EPA's values. Using these new local data results is a considerable decrease in emissions from this category, compared with earlier results using EPA default data.

The NONROAD model does not calculate emission values for NH₃. Ammonia emission calculations for the NONROAD model were derived by using a multiplier of NO_x emissions developed by ENVIRON (2003).

Spatial allocation factors were developed (based on EPA guidance documents) to apportion non-road emissions to the PM₁₀ nonattainment area. The approaches used are described in each section of this chapter.

Temporal allocations (used to calculate PM₁₀ average-day emissions) for nonroad equipment categories modeled in the NONROAD model come from EPA recommendations on weekday and weekend day activity levels for each nonroad equipment category (US EPA, 1999). Table 4.1–2 lists the weighted activity level allocation fractions for each equipment class for weekdays and weekend days. For this report, the most conservative (highest) allocation fraction in each nonroad equipment class was used to calculate average-day emissions.

Table 4.1–2. Default weekday and weekend day activity allocation fractions.

Equipment category	Weekday	Weekend day
Agricultural	0.1666667	0.0833334
Airport ground support	0.1428571	0.1428571
Commercial	0.1666667	0.0833334
Construction and mining	0.1666667	0.0833334
Industrial	0.1666667	0.0833334
Lawn and garden (residential)	0.1111111	0.2222222
Lawn and garden (commercial)	0.1600000	0.1000000
Logging	0.1666667	0.0833334
Pleasure craft	0.0600000	0.3500000
Railway maintenance	0.1800000	0.0500000
Recreational	0.1111111	0.2222222

4.2 Agricultural equipment

Annual emissions from agricultural equipment in Maricopa County were calculated using EPA's NONROAD model as discussed above. County-wide results are shown in Table 4.2–1.

Table 4.2–1. Annual emissions (tons/yr) from agricultural equipment in Maricopa County.

PM₁₀	PM_{2.5}	NO_x	SO_x	NH₃
34.27	33.24	365.55	0.14	0.67

Annual emissions for the PM₁₀ nonattainment area were calculated based on EIIP guidance (US EPA, 2002) which recommends using the ratio of agricultural land inside the nonattainment area to agricultural land inside the county. See Section 1.5.2 for a discussion of land use data used.

$$\begin{aligned}
 \text{PM}_{10} \text{ NAA emissions from agricultural equipment} &= \text{Total County PM}_{10} \text{ emissions from agricultural equipment} \times \text{Agricultural land use allocation factor} \\
 &= 34.27 \text{ tons} \times 44.14\% \\
 &= 15.13 \text{ tons PM}_{10} / \text{yr}
 \end{aligned}$$

Table 4.2–2. Annual emissions (tons/yr) from agricultural equipment in the PM₁₀ NAA.

PM₁₀	PM_{2.5}	NO_x	SO_x	NH₃
15.13	14.67	161.35	0.06	0.30

County average-day emissions were calculated by multiplying annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for agricultural equipment listed in Table 4.1–2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999), as follows:

$$\begin{aligned}
 \text{Average County PM}_{10} \text{ daily emissions (lbs/day)} &= \text{Annual PM}_{10} \text{ emissions (tons/yr)} \times \text{daily activity allocation factor for agricultural equipment (week/day)} \times 2000 \text{ (lbs/ton)} \div 52 \text{ (wks/yr)} \\
 &= 34.27 \times 0.166667 \times 2000 \div 52 \\
 &= 219.7 \text{ lbs/day}
 \end{aligned}$$

Table 4.2–3. Typical daily emissions (lbs/day) from agricultural equipment in Maricopa County.

PM₁₀	PM_{2.5}	NO_x	SO_x	NH₃
219.7	213.1	2,343.3	0.9	4.3

PM₁₀ nonattainment area average-day emissions were calculated by multiplying County average-day emissions by the agricultural land use allocation factor:

$$\begin{aligned}
 \text{PM}_{10} \text{ NAA average-day emissions} &= \text{Maricopa County PM}_{10} \text{ average-day emissions} \times \text{Agricultural land use allocation factor} \\
 &= 219.7 \text{ lbs/day} \times 44.14\% \\
 &= 100.4 \text{ lbs/day}
 \end{aligned}$$

Table 4.2-4. Typical daily emissions (lbs/day) from agricultural equipment in the PM₁₀ nonattainment area.

PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
97.0	94.0	1,034.3	0.4	1.9

4.3 Airport ground support equipment and auxiliary power units

Annual emissions from airport ground support equipment (GSE) and auxiliary power units (APUs) at most airports in the county were estimated using the Emissions Dispersion Modeling System (EDMS, v. 5.1.1) from the U.S. Federal Aviation Administration (FAA). The model can estimate emissions from affiliated ground support equipment (GSE) and auxiliary power units (APUs), by using either default equipment profiles, or user-specified data on equipment populations and activity patterns. In most cases, activity data on 2008 aircraft operations and GSE / APU usage was obtained from individual airport surveys issued by MAG and/or MCAQD. Where survey responses were incomplete or information was otherwise unavailable, activity data was estimated using commercially available data, and EDMS default assumptions where appropriate. Further details concerning the modeling input data and results are presented in Section 4.11 of this report.

For Luke Air Force Base (AFB), emissions estimates for ground support equipment were obtained from a recent base-wide mobile source emissions inventory for calendar year 2008 that had recently been completed for the US Air Force (Weston, 2010). Using data on the frequency and intensity of usage for each type of equipment, annual emissions were calculated as in the following example for a light cart equipped with a diesel engine:

$$E_{\text{pol}} = \text{ELHP} \times \text{OT} \times \text{LF} \times \text{EF} / \text{CF}$$

where:

E _{pol} = Annual emissions of a particular pollutant (lb/yr)	
ELHP = Maximum horsepower rating of engine (hp)	e.g. 10.7 hp
OT = Operating time (hr/yr)	e.g. 52,560 hr/yr
LF = Typical load factor that the engine operates (% of max)	e.g. 51%
EF = Emission factor (g/hp-hr)	e.g. 7.8 g/hp-hr
CF = Conversion factor to convert grams to pounds	(453.59 g/lb)

Thus, total annual NO_x emissions all similar pieces of this type of GSE was calculated as:

$$\begin{aligned}
 E_{\text{NO}_x} &= 10.7 \text{ (hp)} \times 52,560 \text{ (hrs/yr)} \times 51\% \times 7.8 \text{ (g/hp-hr)} / 453.59 \text{ (g/lb)} \\
 &= 4,932 \text{ (lb/yr)} / 2,000 \text{ (lb/ton)} \\
 &= 2.47 \text{ tpy}
 \end{aligned}$$

GSE emissions from the Luke AFB study were added to the EDMS-estimated emissions from the other airports in the County. (The Luke study assumed APU usage, and thus emissions, to be negligible.) A simplifying assumption was made for all airports; i.e., that activity is spread fairly evenly throughout the week and year; thus daily emissions were estimated by dividing annual totals by 366 (= days/yr in 2008). Tables 4.3–1 and 4.3–2 below present the totals for all airport GSE and APU usage within both Maricopa County and the PM₁₀ nonattainment area, on an annual and typical daily basis, respectively.

Table 4.3–1. Annual emissions (tons/yr) from all airport ground support equipment (GSE) and auxiliary power units (APUs).

	Maricopa County					PM ₁₀ nonattainment area				
	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
GSE	14.92	14.39	497.97	13.62	*	14.72	14.21	490.28	13.42	*
APUs	12.29	12.29	88.76	12.82	*	12.27	12.27	88.68	12.80	*
Total:	27.21	26.68	586.73	26.43		26.99	26.48	578.95	26.22	

* At present, EDMS does not include calculation of ammonia emissions from aircraft operations.

Table 4.3–2. Typical daily emissions (lb) from airport GSE and APU usage.

	Maricopa County					PM ₁₀ nonattainment area				
	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
GSE	81.5	78.7	2,721.1	74.4	*	80.4	77.7	2,679.1	73.3	*
APUs	67.1	67.1	485.0	70.0	*	67.1	67.1	484.6	70.0	*
Total:	148.7	145.8	3,206.1	144.4		147.5	144.7	3,163.7	143.3	

* At present, EDMS does not include calculation of ammonia emissions from aircraft operations.

4.4 Commercial equipment

Annual emissions from commercial equipment in Maricopa County were calculated using EPA’s NONROAD model, as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of industrial employment in the nonattainment area to Maricopa County-level totals, as data on the number of wholesale establishments recommended by EIIP guidance (US EPA, 2002) was not available. See Section 1.5.1 for a discussion of the industrial employment data used.

Table 4.4–1. Annual emissions (tons/yr) from commercial equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
117.97	112.98	1,395.23	2.40	21.12	117.66	112.69	1,391.61	2.39	21.06

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for commercial equipment (0.1666667) listed in Table 4.1–2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on industrial employment ratios as described above.

Table 4.4–2. Typical daily emissions (lbs/day) from commercial equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
756.2	724.2	8,943.8	15.4	135.4	754.2	722.4	8,920.6	15.3	135.0

4.5 Construction and mining equipment

Annual emissions from construction and mining equipment in Maricopa County were calculated using EPA's NONROAD model as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of construction employment in the nonattainment area to Maricopa County-level totals as a conservative estimate, as the EIIP-recommended allocation factor of total dollar value of construction was unavailable (US EPA, 2002). See Section 1.5.1 for a discussion of the employment data used.

Table 4.5-1. Annual emissions (tons/yr) from construction and mining equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
1,260.98	1,220.75	14,796.63	6.60	28.10	1,249.88	1,210.00	14,666.42	6.55	27.85

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for construction/mining equipment (0.1666667) listed in Table 4.1-2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on population ratios as described above.

Table 4.5-2. Typical daily emissions (lbs/day) from construction and mining equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
8,083.2	7,825.3	94,850.2	42.3	180.1	8,012.1	7,756.4	94,015.6	42.0	178.5

4.6 Industrial equipment

Annual emissions from industrial equipment in Maricopa County were calculated using EPA's NONROAD model, as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of industrial employment in the nonattainment area to Maricopa County-level totals as a conservative estimate, as the number of employees in manufacturing recommended by EIIP guidance (US EPA, 2002) was unavailable. See Section 1.5.1 for a discussion of the industrial employment data used.

Table 4.6-1. Annual emissions (tons/yr) from industrial equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
101.69	98.96	2,593.13	3.22	56.23	101.42	98.71	2,586.39	3.21	56.09

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for industrial equipment (0.1666667) listed in Table 4.1-2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on industrial employment ratios as described above.

Table 4.6-2. Typical daily emissions (lbs/day) from industrial equipment usage.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
651.8	634.4	16,622.7	20.6	360.5	650.1	632.7	16,579.4	20.6	359.5

4.7 Lawn and garden equipment

Annual emissions from lawn and garden equipment in Maricopa County were calculated using EPA's NONROAD model, as described in Section 4.1. These results reflect revised equipment population and usage estimates from survey work done in early 2003 for the Arizona Department of Environmental Quality (discussed in further detail in Section 4.1). Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of population in the nonattainment area to Maricopa County-level totals (since data on housing units was unavailable, it was not possible to implement the EIIP-recommended calculation approach (US EPA, 2002). See Section 1.5.1 for a discussion of the population data used.

Table 4.7-1. Annual emissions (tons/yr) from lawn and garden equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
182.28	168.79	798.14	3.16	19.63	183.02	169.48	801.41	3.17	19.71

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for lawn and garden equipment (0.1600000 for the commercial segment, 0.2222222 for residential) listed in Table 4.1-2, and dividing the product by 52 (the number of weeks in a year; US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated by applying a population-based ratio as described in Section 4.7 above.

Table 4.7-2. Typical daily emissions (lbs/day) from lawn and garden equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
1,250.1	1,156.9	5,571.5	23.1	144.6	1,255.3	1,161.6	5,594.4	23.2	145.2

4.8 Pleasure craft

Annual emissions from pleasure craft equipment in Maricopa County were calculated using EPA's NONROAD model, as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of water surface area in the nonattainment area to Maricopa County-level totals, as recommended by EIIP guidance (US EPA, 2002). See Section 1.5.2 for a discussion of the land use data used.

Table 4.8-1. Annual emissions (tons/yr) from pleasure craft equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
9.25	8.54	77.74	0.85	1.73	7.02	6.48	59.03	0.64	1.32

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for pleasure craft (0.3500000) listed in Table 4.1-2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on water surface area as described above.

Table 4.8-2. Typical daily emissions (lbs/day) from pleasure craft equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
124.5	114.9	1,046.5	11.4	23.3	94.5	87.3	794.6	8.6	17.7

4.9 Railway maintenance equipment

Annual emissions from railway maintenance equipment in Maricopa County were calculated using EPA's NONROAD model, as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of population in the nonattainment area to Maricopa County-level totals, as recommended by EIIP guidance (US EPA, 2002). See Section 1.5.1 for a discussion of the population data used.

Table 4.9–1. Annual emissions (tons/yr) from railway maintenance equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
1.13	1.09	9.23	0.00	0.02	1.13	1.10	9.26	0.00	0.02

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for railway maintenance equipment (0.1800000) listed in Table 4.1–2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on the population ratio as described above.

Table 4.9–2. Typical daily emissions (lbs/day) from railway maintenance equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
7.8	7.6	63.9	0.0	0.1	7.8	7.6	64.1	0.0	0.1

4.10 Recreational equipment

Annual emissions from recreational equipment in Maricopa County were calculated using EPA's NONROAD model, as described in Section 4.1. Annual emissions for the PM₁₀ nonattainment area for this category were derived by applying the ratio of passive open space and vacant land use in the nonattainment area to Maricopa County-level totals as recommended by EIIP guidance (US EPA, 2002). See Section 1.5.2 for a discussion of the land use data used.

Table 4.10–1. Annual emissions (tons/yr) from recreational equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
45.58	41.98	63.80	0.42	2.10	7.68	7.08	10.76	0.07	0.35

County average-day emissions were calculated by multiplying Maricopa County annual emissions (generated by the NONROAD model) by the most conservative weekday/weekend day activity allocation factor for recreational equipment (0.2222222) listed in Table 4.1–2, and dividing the product by the number of weeks (52) in the year (US EPA, 1999). PM₁₀ nonattainment area average-day emissions were calculated based on land use as described above.

Table 4.10–2. Typical daily emissions (lbs/day) from recreational equipment.

Maricopa County					PM ₁₀ nonattainment area				
PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
389.6	358.8	545.3	3.6	18.0	65.7	60.5	91.9	0.6	3.0

4.11 Aircraft

Emissions from aircraft operations at the largest civilian airports in Maricopa County were estimated using the Federal Aviation Administration's Emissions and Dispersion Model (EDMS, v. 5.1.1). The EDMS model combines specified aircraft type and activity levels with default emission factors in order to estimate annual emissions inventories for a specific airport. The model calculates emissions of sulfur oxides (SO_x), oxides of nitrogen (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC), and, for a small subset of aircraft and engine types), PM₁₀ and PM_{2.5} as well. The model also estimates emissions from affiliated ground support equipment (GSE) and auxiliary power units (APUs); these emissions are reported separately and are summarized in Section 4.3.

MCAQD surveyed all medium and large airports in Maricopa County to gather data on aircraft type and activity level of aircraft operations. Specifically, the number of landing and takeoff cycles (LTO's) or touch and go operations (TGOs), along with information on the types of aircraft that comprise the airport's typical fleet mix, and other operational data, such as typical usage patterns of ground support equipment (GSE) and auxiliary power units (APUs), average taxi/idle times, etc. Where survey responses were unavailable or incomplete, aircraft activity data from publicly accessible databases, such as the FAA's Air Traffic Activity System (ATADS) and Enhanced Traffic Management System Counts (ETMSC), were used.

All emission estimates in this section have been developed using the EDMS model, with the exception of Luke Air Force Base (AFB), whose emissions calculations have been prepared as part of a base-wide 2008 mobile source emissions inventory that has recently been completed (Weston, 2010). Luke AFB's emissions reported as 'aircraft activity' actually comprise three distinct, though related, types of activity: (1) the operation of aircraft stationed at the base, (2) a much smaller level of "transient" aircraft traffic within Luke's airspace, and (3) emissions produced during on-wing engine testing – considered a "mobile source" emission category. As with all other airports included in this inventory, emissions from ground support equipment (GSE) at Luke AFB are addressed in Section 4.3, Airport ground support equipment and auxiliary power units.

In addition to the LTOs (and occasional TGO activity) reported by other airports in the area, Luke reported two additional, types of aircraft operations: aircraft low fly bys (LFB), and aircraft low fly patterns (LFP). Each of these types of operations can be characterized by a distinctive combination of the times in mode (TIM); (e.g., approach, taxi in/out, takeoff and climb out.)

Luke AFB's emissions are not based on the number of LTOs, but rather the aggregate annual operational time in modes (TIMs) for all aircraft of similar type. For the F-16, an LTO cycle includes five modes of operation: idle (taxi in/out), intermediate, approach, military and after-burner. The F-16 emissions were estimated using the annual TIMs provided by Luke AFB and emission factors from military guidance documents.

Table 4.11–1 lists the data sources for each airport's activity level, as well as fleet mix. The total number of aircraft operations in 2008 is also listed. For all airports other than Luke AFB, aircraft emissions were estimated for four aircraft categories:

- Air carriers (abbreviated "AC"): Larger commercial aircraft with at least 60 seats or 18,000 lbs payload capacity, used for scheduled service to transport passengers and/or freight;

- Air taxis (“AT”): Smaller commercial turbine- or piston-powered aircraft with less than 60 seats or 18,000 lbs payload capacity;
- General aviation (“GA”): Aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel; and
- Military (“ML”): Aircraft used to support military operations.

Table 4.11–1. Annual airport operations (by aircraft category), and related data sources.

Airport	Airport Code	Operations Data Source ¹	Fleet Mix Data Source ²	Aircraft Type	2008 Operations
Buckeye Municipal	BXK	airnav.com	Generic GA profile	GA	26,535
Chandler Municipal	CHD	FAA/ATADS	FAA/ETMSC	AT	2,882
				GA	233,713
				ML	247
Falcon Field	FFZ	FAA/ATADS	FAA/ETMSC	AC	6
				AT	3,813
				GA	313,448
				ML	2,152
Gila Bend Municipal	E63	airnav.com	Generic GA profile	GA	1,768
Glendale Municipal	GEU	FAA/ATADS, Survey response	FAA/ETMSC	AT	1,873
				GA	134,282
				ML	57
Luke Air Force Base	LUF	[Emission totals provided by Luke AFB are based on times-in-mode.]			
Phoenix Deer Valley	DVT	Survey response	Survey response, FAA/ETMSC	AC	284
				AT	6,217
				GA	370,003 *
				ML	130
Phoenix Goodyear	GYR	Survey response	Survey response, FAA/ETMSC	AC	140
				AT	1962
				GA	169,177 *
				ML	6,747
Phoenix-Mesa Gateway (formerly Williams Gateway)	IWA	FAA/ATADS, Survey response	FAA/ETMSC	AC	3,876
				AT	5,937
				GA	211,674
				ML	5,939
Phoenix Sky Harbor	PHX	Survey response	Survey response, FAA/ETMSC	AC	391,518
				AT	77,354
				GA	30,868
				ML	2,759
Pleasant Valley	P48	airnav.com	Generic GA profile	GA	23,535
Scottsdale	SDL	FAA/ATADS	FAA/ETMSC	AT	11,232
				GA	179,619
				ML	560
Sky Ranch at Carefree	18AZ	Survey response	Generic GA profile	GA	1,515
Stellar Airpark	P19	airnav.com	Generic GA profile	GA	19,528
Wickenburg Municipal	E25	Survey responses	Generic GA profile	GA	6,000

1. FAA/ATADS: Federal Aviation Administration’s Air Traffic Activity Data System (database); <http://aspm.faa.gov>.

2. FAA/ETMSC: Federal Aviation Administration’s Enhanced Traffic Management System Counts (database); <http://aspm.faa.gov>.

* includes touch-and-go (TGO) operations levels reported by the airport.

The following section describes how activity and emissions were estimated for a representative airport, Chandler Municipal (CHD). The FAA’s Air Traffic Activity System (ATADS, <http://www.aspm.faa.gov>) provided data on 2008 activity by aircraft type; these results are contained in Table 4.11–1. While ATADS reported a total of 233,713 general aviation operations at this airport in 2008, further information on the aircraft types comprising this activity was

needed. The FAA’s Enhanced Traffic Management System Counts (ETMSC) database was used to “grow” available aircraft-specific operational data as described below.

The ETMSC database on general aviation activity at CHD in 2008 comprises 152 different aircraft types, totaling 3,589 operations, (See Table 4.11–2). To simplify modeling input requirements, this aircraft-specific activity data was ranked in order of decreasing frequency and activity data for the most frequently reported aircraft was then grown to represent all general aviation (“GA”) activity, as shown in Table 4.11–2 below.

Table 4.11–2. Example showing how most common aircraft-specific activity was grown for EDMS modeling.

Rank	Aircraft Type	ETMSC- reported operations	% of total reported operations	Cumulative Percent	“Grown” operations for EDMS modeling
1	BE20 - Beech 200 Super King	240	6.7%		21,919
2	BE58 - Beech 58	233	6.5%		21,280
3	PA28 - Piper Cherokee	233	6.5%		21,280
4	C525 - Cessna CitationJet/CJ1	232	6.5%		21,189
5	C182 - Cessna Skylane 182	203	5.7%	31.8%	18,540
6	C172 - Cessna Skyhawk 172/Cutlass	194	5.4%		17,718
7	TBM7 - Socata TBM-7	166	4.6%		15,161
8	R22 - Robinson R-22 Mariner	138	3.8%		12,604
9	BE9L - Beech King Air 90	106	3.0%		9,681
10	BE36 - Beech Bonanza 36	97	2.7%	51.3%	8,859
11	BE55 - Beech Baron 55	90	2.5%		8,220
12	BE35 - Beech Bonanza 35	87	2.4%		7,946
13	C210 - Cessna 210 Centurion	75	2.1%		6,850
14	PA32 - Piper Cherokee Six	73	2.0%		6,667
15	P28R - Cherokee Arrow/Turbo	71	2.0%	62.4%	6,484
16	P46T - Piper Malibu Meridian	67	1.9%		6,119
17	SR22 - Cirrus SR 22	67	1.9%		6,119
18	BE30 - Raytheon 300 Super King Air	65	1.8%		5,936
19	MO20 - Mooney M-20	62	1.7%		5,662
20	C560 - Cessna Citation V/Ultra/Encore	60	1.7%	71.3%	5,480
⋮	⋮	⋮	⋮	⋮	
152	XL2 - Liberty XL-2	1	< 0.1%	100.0%	(n/a)
Totals:		3,589			233,713

This approach of ranking reported activity, and then growing the most frequently occurring subset of aircraft typically resulted in a set comprised of 10 to 30 aircraft types being modeled for each airport/aircraft class combination, representing 60 to 100% of all reported activity. Since the EDMS model includes estimates of PM₁₀ emissions only for a relatively small number of aircraft/engine types, all model output files were reviewed for missing data. For those aircraft/engine combinations for which the EDMS model indicated zero PM₁₀ emissions, the default EPA emission factors listed in Table 4.11–3 (US EPA, 2003) were incorporated into the EDMS output data files, and total PM emissions recalculated.

Table 4.11–3. EPA’s default PM₁₀ emission factors for aircraft, by activity type.

Activity type	PM ₁₀ Emission Factor (lb/LTO)
Air Carrier, Air Taxi, Military	0.60333
General Aviation	0.2367

Following EPA guidance (US EPA, 2003), PM_{2.5} emissions were estimated to be 92% of PM₁₀ levels. For ease in modeling computation and the assessment of emissions, all activity was assumed to occur evenly throughout the year. Thus, average daily emissions were calculated by dividing annual totals by 366 (= days per year in 2008). Tables 4.11–4 and 4.11–5 list the total annual emissions and average daily emissions of each airport and aircraft type, and for airports within and outside the PM₁₀ NAA, respectively.

Table 4.11–4. Annual and average daily emissions, by airport and aircraft type, from airports within the PM₁₀ NAA.

Airport	Cate- gory	Annual emissions (tons/yr)				Typical daily emissions (lbs/day)			
		PM ₁₀	PM _{2.5}	NO _x	SO _x	PM ₁₀	PM _{2.5}	NO _x	SO _x
Chandler Municipal	AT	0.27	0.27	0.94	0.24	1.5	1.5	5.1	1.3
	GA	12.68	11.79	18.51	6.43	69.3	64.4	101.1	35.1
	ML	0.04	0.04	0.12	0.02	0.2	0.2	0.6	0.1
	Total	12.99	12.10	19.56	6.68	71.0	66.1	106.9	36.5
Falcon Field	AC	0.00	0.00	0.00	-	0.0	0.0	0.0	0.0
	AT	0.23	0.23	2.94	0.49	1.3	1.2	16.0	2.7
	GA	18.49	17.07	14.34	6.16	101.0	93.3	78.3	33.7
	ML	0.31	0.29	0.40	0.13	1.7	1.6	2.2	0.7
	Total	19.03	17.59	17.67	6.78	104.0	96.1	96.6	37.0
Glendale Municipal	AT	1.06	1.05	9.70	2.43	5.8	5.7	53.0	13.3
	GA	6.90	6.41	5.51	2.20	37.7	35.0	30.1	12.0
	ML	0.01	0.01	0.12	0.02	0.0	0.0	0.6	0.1
	Total	8.17	7.66	15.51	4.71	44.6	41.8	84.8	25.7
Luke Air Force Base†	ML	62.82	62.82	382.40	31.81	343.3	343.3	2,089.6	173.8
Phoenix Deer Valley	AC	0.04	0.04	0.05	0.01	0.2	0.2	0.3	0.1
	AT	0.41	0.41	3.97	0.76	2.2	2.2	21.7	4.2
	GA	10.10	9.43	62.81	14.61	55.2	51.5	343.2	79.8
	ML	0.02	0.02	0.07	0.02	0.1	0.1	0.4	0.1
	Total	10.57	9.90	66.91	15.40	57.8	54.1	365.6	84.1
Phoenix Goodyear	AC	0.02	0.01	0.36	0.05	0.1	0.1	1.9	0.3
	AT	0.19	0.19	1.61	0.28	1.1	1.0	8.8	1.5
	GA	0.66	0.66	18.86	5.25	3.6	3.6	103.0	28.7
	ML	0.96	0.89	3.66	1.07	5.2	4.8	20.0	5.8
	Total	1.83	1.74	24.48	6.64	10.0	9.5	133.8	36.3
Phoenix Sky Harbor Intl.	AC	22.38	22.38	1,751.85	185.77	122.3	122.3	9,573.0	1,015.2
	AT	4.24	4.02	116.92	17.51	23.2	22.0	638.9	95.7
	GA	3.37	3.21	12.81	2.83	18.4	17.6	70.0	15.4
	ML	0.45	0.43	23.48	2.34	2.5	2.4	128.3	12.8
	Total	30.45	30.05	1,905.06	208.45	166.4	164.2	10,410.2	1,139.1
Phoenix-Mesa Gateway Airport	AC	0.16	0.15	13.25	1.72	0.9	0.8	72.4	9.4
	AT	0.63	0.62	3.02	0.64	3.4	3.4	16.5	3.5
	GA	12.99	12.04	17.41	5.48	71.0	65.8	95.2	29.9
	ML	0.58	0.55	26.56	3.14	3.2	3.0	145.1	17.1
	Total	14.35	13.36	60.24	10.98	78.4	73.0	329.2	60.0
Pleasant Valley	GA	0.36	0.33	1.65	0.34	1.9	1.8	9.0	1.8
Scottsdale	AT	1.03	1.02	7.84	1.37	5.7	5.6	42.8	7.5
	GA	19.83	18.86	116.13	21.79	108.4	103.1	634.6	119.1
	ML	0.08	0.08	0.24	0.06	0.5	0.4	1.3	0.3
	Total	20.95	19.96	124.21	23.22	114.5	109.1	678.8	126.9
Skyranch at Carefree	GA	0.18	0.17	0.39	0.10	1.0	0.9	2.1	0.5
Stellar Airpark	GA	2.31	2.13	2.42	0.97	12.6	11.6	13.2	5.3
PM₁₀ NAA totals:		183.80	177.61	2,620.31	316.00	1,004.3	970.5	14,318.6	1,726.8

† Sum of emissions from the following categories, as reported in Weston (2010): (1) aircraft stationed at Luke AFB, (2) transient aircraft, and (3) on-wing aircraft engine testing.

Table 4.11–5. Annual and average daily emissions, by aircraft type, from airports outside the PM₁₀ NAA.

Facility	Category	Annual emissions (tons/yr)				Average daily emissions (lbs/day)			
		PM ₁₀	PM _{2.5}	NO _x	SO _x	PM ₁₀	PM _{2.5}	NO _x	SO _x
Buckeye Municipal	GA	3.14	2.89	2.70	0.97	17.2	15.8	14.8	5.3
Gila Bend Municipal	GA	0.21	0.19	0.18	0.06	1.1	1.1	1.0	0.3
Wickenburg Municipal	GA	0.77	0.73	2.75	0.61	4.2	4.0	15.0	3.3
Maricopa County totals:		187.91	181.42	2,625.94	317.64	1,026.8	991.4	14,349.4	1,735.8

4.12 Locomotives

Annual emissions from locomotives were calculated based on diesel fuel usage data provided by Burlington Northern/Santa Fe Railway (BNSF), Union Pacific Railway (UP) and Amtrak. Railway operations from these companies fall into two categories: Class I haul lines and yard/switching operations. Annual emissions from these two activity categories were calculated by multiplying diesel fuel usage by the emission factors listed in Table 4.12–1 (US EPA, 2009).

Table 4.12–1. Emission factors for locomotives.

Activity type	Emission factors (lbs/gal diesel)				
	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
Class I haul line	0.015	0.014	0.394	0.004	0.0001
Yard/switch operations	0.015	0.014	0.421	0.004	0.0001

The example below illustrates how emissions were calculated for each locomotive activity type. Fuel use reported by railroads, and emission totals are summarized in Table 4.12–2.

$$\begin{aligned}
 \text{PM}_{10} \text{ emissions from UP Class I haul lines} &= \text{Diesel use (gals/yr)} \times \text{PM}_{10} \text{ emission factor (lbs/gal)} \div 2,000 \text{ lbs/ton} \\
 &= 7,780,284 \text{ gals/yr} \times 0.015 \text{ lbs/gal} \div 2,000 \text{ lbs/ton} \\
 &= 58.35 \text{ tons PM}_{10}/\text{yr}
 \end{aligned}$$

Table 4.12–2. Total diesel use and annual emissions from locomotives in Maricopa County.

Locomotive type	Diesel use (gals/yr)	Annual emissions (tons/yr)				
		PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
BNSF Class I haul line	750,094	5.63	5.25	147.77	1.50	0.36
UP Class I haul line	7,780,284	58.35	54.46	1,532.72	15.56	3.70
BNSF yard/switch operations	400,000	3.00	2.80	84.20	0.80	0.19
UP yard/switch operations	378,199	2.84	2.65	79.61	0.76	0.18
Amtrak	52,416	0.39	0.37	10.33	0.10	0.02
Totals:	9,360,993	70.21	65.53	1,854.62	18.72	4.45

PM₁₀ nonattainment area emissions were calculated by multiplying Maricopa County emissions by the percentage of track miles within the PM₁₀ nonattainment area, determined by GIS mapping. Results are shown in Table 4.12–3.

$$\begin{aligned}
 \text{PM}_{10} \text{ nonattainment area emissions from UP Class I haul lines (tons/yr)} &= \text{County PM}_{10} \text{ emissions (tons/yr)} \times \text{Percentage of track miles within the PM}_{10} \text{ nonattainment area} \\
 &= 58.35 \text{ tons PM}_{10}/\text{yr} \times 44.27\% \\
 &= 25.83 \text{ tons PM}_{10}/\text{yr}
 \end{aligned}$$

Table 4.12–3. Annual emissions (in tons/yr) from locomotives in the PM₁₀ NAA.

Locomotive type	Track in nonattainment area (%)	Annual emissions (tons/yr)				
		PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
BNSF Class I haul line	44.27	2.49	2.32	65.42	0.66	0.16
UP Class I haul line	44.27	25.83	24.11	678.53	6.89	1.64
BNSF yard/switch operations	100.00	3.00	2.80	84.20	0.80	0.19
UP yard/switch operations	100.00	2.84	2.65	79.61	0.76	0.18
Amtrak	0.00	0.00	0.00	0.00	0.00	0.00
Totals:		34.16	31.88	907.76	9.11	2.16

PM₁₀ typical daily emissions for both the county (shown in Table 4.12–4) and the PM₁₀ non-attainment area (Table 4.12–5) were calculated by dividing annual totals by 366 days (since 2008 was a leap year), as locomotive activity is assumed to be uniform throughout the year.

$$\begin{aligned}
 \text{PM}_{10} \text{ typical daily emissions from haul lines} &= \text{Annual PM}_{10} \text{ emissions (tons)} \times 2000 \text{ lbs/ton} \div 366 \text{ days} \\
 &= 58.35 \text{ tons PM}_{10}/\text{yr} \times 2000 \text{ lbs/ton} \div 366 \text{ days} \\
 &= 318.9 \text{ lbs PM}_{10}/\text{day}
 \end{aligned}$$

Table 4.12–4. Typical daily emissions (in lbs/day) from locomotives in Maricopa County.

Locomotive type	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
BNSF Class I haul line	30.7	28.7	807.5	8.2	1.9
UP Class I haul line	318.9	297.6	8,375.5	85.0	20.2
BNSF yard/switch operations	16.4	15.3	460.1	4.4	1.0
UP yard/switch operations	15.5	14.5	435.0	4.1	1.0
Amtrak	2.1	2.0	56.4	0.6	0.1
Totals:	383.6	358.1	10,134.5	102.3	24.3

Table 4.12–5. Typical daily emissions (in lbs/day) from locomotives in the PM₁₀ nonattainment area.

Locomotive type	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
BNSF Class I haul line	13.6	12.7	357.5	3.6	0.9
UP Class I haul line	141.2	131.8	3,707.8	37.6	8.9
BNSF yard/switch operations	16.4	15.3	460.1	4.4	1.0
UP yard/switch operations	15.5	14.5	435.0	4.1	1.0
Amtrak	0.0	0.0	0.0	0.0	0.0
Totals:	186.7	174.2	4,960.4	49.8	11.8

4.13 Summary of all nonroad mobile source emissions

Table 4.13–1 summarizes annual and daily emissions of PM₁₀, PM_{2.5}, NO_x, SO_x and NH₃ from nonroad mobile sources in Maricopa County. Table 4.13–2 shows annual and typical daily emissions for these pollutants for the PM₁₀ nonattainment area.

Table 4.13–1. Annual and typical daily emissions from nonroad mobile sources in Maricopa County.

Category	Annual emissions (tons/yr)					Typical daily emissions (lbs/day)				
	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
Agricultural	34.27	33.24	365.55	0.14	0.67	219.7	213.1	2,343.3	0.9	4.3
Airport GSE	27.21	26.68	586.73	26.43		148.7	145.8	3,206.1	144.4	
Commercial	117.97	112.98	1,395.23	2.40	21.12	756.2	724.2	8,943.8	15.4	135.4
Construction & mining	1,260.98	1,220.75	14,796.63	6.60	28.10	8,083.2	7,825.3	94,850.2	42.3	180.1
Industrial	101.69	98.96	2,593.13	3.22	56.23	651.8	634.4	16,622.7	20.6	360.5
Lawn & garden	182.28	168.79	798.14	3.16	19.63	1,250.1	1,156.9	5,571.5	23.1	144.6
Pleasure craft	9.25	8.54	77.74	0.85	1.73	124.5	114.9	1,046.5	11.4	23.3
Railway maintenance	1.13	1.10	9.23	0.00	0.02	7.8	7.6	63.9	0.0	0.1
Recreational	45.58	41.98	63.80	0.42	2.10	389.6	358.8	545.3	3.6	18.0
Aircraft	187.91	181.41	2,625.94	317.64		1,026.8	991.3	14,349.4	1,735.8	
Locomotives	70.21	65.53	1,854.62	18.72	4.45	383.6	358.1	10,134.5	102.3	24.3
Totals:	2,038.46	1,959.95	25,166.75	379.58	134.06	13,042.0	12,530.3	157,677.4	2,099.8	890.6

Table 4.13–2. Annual and typical daily emissions from nonroad mobile sources in the PM₁₀ NAA.

Category	Annual emissions (tons/yr)					Typical daily emissions (lbs/day)				
	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃	PM ₁₀	PM _{2.5}	NO _x	SO _x	NH ₃
Agricultural	15.13	14.67	161.35	0.06	0.30	97.0	94.0	1,034.3	0.4	1.9
Airport GSE	26.99	26.48	578.95	26.22		147.5	144.7	3,163.7	143.3	
Commercial	117.66	112.69	1,391.61	2.39	21.06	754.2	722.4	8,920.6	15.3	135.0
Construction & mining	1,249.88	1,210.00	14,666.42	6.55	27.85	8,012.1	7,756.4	94,015.6	42.0	178.5
Industrial	101.42	98.71	2,586.39	3.21	56.09	650.1	632.7	16,579.4	20.6	359.5
Lawn & garden	183.02	169.48	801.41	3.17	19.71	1,255.3	1,161.6	5,594.4	23.2	145.2
Pleasure craft	7.02	6.48	59.03	0.64	1.32	94.5	87.3	794.6	8.6	17.7
Railway maintenance	1.13	1.10	9.26	0.00	0.02	7.8	7.6	64.1	0.0	0.1
Recreational	7.68	7.08	10.76	0.07	0.35	65.7	60.5	91.9	0.6	3.0
Aircraft	183.80	177.60	2,620.31	316.00		1,004.3	970.5	14,318.6	1,726.8	
Locomotives	34.16	31.88	907.76	9.11	2.16	186.7	174.2	4,960.4	49.8	11.8
Totals:	1,927.89	1,856.17	23,793.26	367.42	128.87	12,275.2	11,811.9	149,537.7	2,030.5	852.9

4.14 Quality assurance procedures

Established procedures were used to check, and correct when necessary, the nonroad mobile sources emissions estimates. All NONROAD model input and output files, and Excel spreadsheets used to calculate the emissions, were checked by personnel not involved in developing the modeling inputs/outputs and spreadsheets being reviewed. In addition, the emissions estimates were reviewed for reasonableness by external agency staff.

4.15 References

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