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FINAL
1997 GRIDDED AMMONIA EMISSION INVENTORY UPDATE FOR THE SOUTH COAST AIR BASIN

Prepared by

Mark Chitjian and James Koizumi
AVES, an Affiliate of ATC Associates Inc.
50 East Foothill Boulevard
Arcadia, CA 91006
(626) 447-5216

Charles W. Botsford, P.E.
Parsons/Engineering Science

Dr. Gerard Mansell
ENVIRON International Corporation

Dr. Eric Winegar
Applied Measurement Science

Prepared Under Contract #99025 for the

South Coast Air Quality Management District
21865 E. Copley Drive
Diamond Bar, CA 91765
(Contact: Dr. Julia Lester, Program Supervisor)

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EXECUTIVE SUMMARY

AVES was retained by the South Coast Air Quality Management District (AQMD) to update the Air Quality Management Plan (AQMP) ammonia inventory. The 1997 AQMP ammonia inventory (1993 base year) was an update of an earlier study performed by the Radian Corporation in 1991 (Radian Study) (1987 base year). The Update included a correction to publicly-owned treatment works emissions and updates to dairy emission factors and livestock populations.

This current ammonia inventory update will be used in the development of an ammonia inventory for the Year 2000 AQMP. This report includes:

- Reviews of appropriate ammonia sources for inclusion into the inventory,
- Reviews of the methodology used by the Radian Study,
- Reviews of relevant literature published since the compilation of the Radian Study,
- Selection of the most appropriate methodology for the update, and
- Description of the compilation of the gridded inventory.

For most categories, this inventory used the same sources of activity data as the Radian Study (1997 AQMP). However, differences in information sources and changes in emission factors and activity occurred in the Livestock category.

The dairy cattle ammonia emission factor was revised from 20 lbs./head/yr. to 51 lbs./head/yr. based on an analysis performed by Dr. Eric Winegar and recent source test results. A change in the activity data came from checking the 1997 cattle population (dairy and non-dairy) data from United States Department of Agriculture (USDA) against Santa Ana Regional Water Quality Control Board (RWQCB) data. The total cattle population activity was revised upward by 214,69 head. The effect of these changes was to substantially increase estimated ammonia emissions attributed to dairy cattle.

A substantial decrease in both the estimated horse population from 223,068 to 117,128; and horse emission factors from 52 lb/horse/year to 27 lb/horse/year, resulted in an approximately fourfold reduction in estimated emissions for this source.

Another large effect on the ammonia inventory update resulted from an increase in poultry population from approximately 14.7 million to 2.46 million from 1993 to 1997 and a decrease in emission factor estimates. The emission factors used in the Radian Study were 1.60 lbs/layer/yr, 1.20 lbs/pullet/yr, and 0.79 lbs/broiler/yr. AVES used emission factors from Battye et al. (1.32 lb/layers/yr, 0.672 lb/pullet/yr, and 0.368 lb/broiler/yr). Activity data from the U.S. Department of Agriculture's Census of Agriculture did not distinguish between layers and pullets. These reduced emission factors resulted in a 6.2-ton/day decrease in the year 2000 AQMP ammonia inventory.

Emission factors for dogs and cats were revised downward from 5.5 and 1.8 to 2.17 and 0.348 lbs./animal/yr. respectively. The cigarette emission factor was revised downward from $2.07x10^{-05}$ to $2.2x10^{-07}$ lbs./cigarette.

The largest change in estimated emissions came from mobile sources. The Radian Study built up emissions from emission factors specific to vehicle category, fleet mix information and a number of other parameters. This method required many assumptions. AVES used a bulk emission factor based on a tunnel study, which was approximately four times greater than previously estimated. This emission factor is based on testing specific to the South Coast Air Basin and only requires Vehicle Miles Traveled (VMT) activity data to calculate emissions. This inventory does not include mobile source emissions. The SCAQMD will develop the required VMT data and add the mobile source emissions. For purposes of reporting, emissions have been estimated based on the emission factor used for this study and VMT data, by county, provided by the SCAQMD. Estimated emissions from this source increased from 7.1 tons/day to 33.2 tons/day.

The methodology used to estimate ammonia emissions from Industrial Sources (Section 9) was changed to more completely capture the total ammonia supplied to industrial users. The Radian Study estimated emissions from toxic release inventory databases such as ARBS's EDS or 1987/1988 SARA reports. The SARA reports are limited to facilities that manufactured or used in manufacturing process 50,000 pounds or more of ammonia or otherwise used 10,000 pounds of ammonia. AVES contacted the three major ammonia suppliers, Unocal, Hill Brothers Chemical Corporation and LaRoche Industries Incorporated and obtained records for ammonia supplied to each zip code by industry type. By using ammonia suppliers AVES was able to capture ammonia emissions not accounted for by Radian. The emissions were assigned to zip codes to protect the confidentiality of the ammonia suppliers customers. Each industry type was assigned a specific emission factor (e.g., refrigeration usage equals emissions) to compile the ammonia emissions contribution of this source.

The publicly-owned treatment works (POTWs) emission factor was revised downward to 0.118 lbs./million gallons of wastewater. This resulted in a nearly 4 tons/day ammonia emission reduction from the 1997 AQMP.

The soils emission factors and activity data remained largely unchanged.

Sources of ammonia included in the year 2000 AQMP inventory that were not included in the Radian Inventory are native animal waste, landfills, and composting operations. Composting emissions in particular were found to be significant (on the order of 9 tons/day). Other sources considered by AVES but not included in the updated ammonia inventory were prescribed burns, home composting, and oceans and other bodies of water.

The inventory was spatially allocated the 1 km x 1 km grid. The inventory was based on the 1997 calendar year.

The compilation of the gridded inventory includes selection of emission factors and activity data to estimate the magnitude of ammonia emissions as well as appropriate surrogate data to allocate the emissions spatially and temporally.

As with activity data, AVES conducted spatial and temporal allocation, consistent with the 1997 AQMP. One major change was allocating Industrial Sources as area sources because the activity data was received as sales data from the ammonia suppliers segregated by zip code.

A summary of the annual average emissions by source category is presented in Table ES-1. A comparison of ammonia emissions by source for the 1997 SoCAB and the 2000 SoCAB is presented in Table ES-2. A summary of ammonia emissions by source per county is presented in Table ES-3. Charts 1 and 2 present pie graphs of ammonia per source for the 1997 SoCAB and 2000 SoCAB respectively. Chart 3 presents ammonia emission by county for the 2000 SoCAB.

Table ES-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

	SCAB Activity			Emission Factor			Emissions, t/d	
Source Category	1997 SoCAB[a]	2000 SoCAB	Units	1997 SoCAB[b]	2000 SoCAB	Units	1997 SoCAB[a]	2000 SoCAB
Livestock							**56.57**	**60.37**
Horses and Ponies	223,068	117,128	head	52	26.9	lb/head/yr	15.89	4.32
Beef Cows	15,353	20,020	head	102	87.6	lb/head/yr	2.15	2.40
Milk Cows	314,571	302,899	head	20	51.0	lb/head/yr	8.62	21.2
Heifers and heifer calves	NA	167,367	head	NA	28.8	lb/head/yr	NA	6.59
Steers, steer calves, bulls, and bull calves	NA	54,328	head	NA	30.4	lb/head/yr	NA	2.26
Hogs and pigs	17,260	18,059	head	15	20.3	lb/head/yr	0.35	0.50
Layers	NA	NA	head	1.6	NA	lb/head/yr	NA	NA
Pullet	NA	NA	head	1.2	NA	lb/head/yr	NA	NA
Layers and pullets	NA	16,190,673	head	NA	0.996	lb/head/yr	NA	22.1
Broilers and other meat-type chickens	NA	969,847	head	0.79	0.368	lb/head/yr	NA	0.49
Poultry	14,697,683	NA	head	1.43	NA	lb/head/yr	28.79	NA
Sheep and Lambs	63,545	52,070	head	8.8	7.43	lb/head/yr	0.77	0.53
Goats, Total	NI	3,980	head	NA	1.28	lb/head/yr	NI	0.0070
Rabbits	NI	25,183	head	NA	0.37	lb/head/yr	NI	0.013
Mules, Burros and Donkeys		299	head		26.9	lb/head/yr		0.011
Soil							**39.00**	**34.24**
Urban	land use	2,078	$miles^2$	various	1	kg/km^2-day	land use	5.93
Agricultural	land use	1,414	$miles^2$	various	3.7	kg/km^2-day	land use	14.9
Rangeland/Pasture	land use	1,701	$miles^2$	various	1.5	kg/km^2-day	land use	7.28
Wetland	land use	60	$miles^2$	various	1	kg/km^2-day	land use	0.17
Forest Land	land use	1,425	$miles^2$	various	1	kg/km^2-day	land use	4.07
Barren Land	land use	654	$miles^2$	various	1	kg/km^2-day	land use	1.87

Table ES-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

Source Category	SCAB Activity			Emission Factor			Emissions, t/d	
	1997 SoCAB[a]	2000 SoCAB	Units	1997 SoCAB[b]	2000 SoCAB	Units	1997 SoCAB[a]	2000 SoCAB
Fertilizer (TOTAL)							**10.98**	**7.68**
On Farm Liquid	14,350	10,604	tons as N	0.02	0.02	% of total N	0.95	0.71
On Farm Dry	11,090	5,226	tons as N	0.1	0.1	% of total N	3.69	1.74
Non-Farm	5,887	3,639	tons as N	0.3	0.3	% of total N	5.88	3.63
Anhydrous Ammonia	8,414,000	NA	lb/yr	0.04	NA	% of total N	0.46	0.00
Domestic							**29.07**	**25.87**
Cats	1,082,323	1,401,184	cats	1.8	0.348	lb N/cat/yr	2.67	0.76
Dogs	1,595,686	2,074,120	dogs	5.50	2.17	lb N/dog/yr	12.0	7.05
Cigarette Smoking	12,618,588	14,882,918	people	0.022	0.00023	lb/person/yr	0.38	0.0048
Household Ammonia Use	12,618,588	14,882,918	people	0.05	0.05	lb/person/yr	0.86	1.02
Human Perspiration	12,618,588	14,882,918	people	0.55	0.55	lb/person/yr	9.51	11.2
Human Respiration	12,618,588	14,882,918	people	0.0035	0.0035	lb/person/yr	0.06	0.07
Untreated Human Waste, Homeless	129,888	134,636	homeless	11	11	lb/homeless/yr	1.96	~~740.50~~ 2.03
Cloth Diapers	56,783.6	100,807	infants	6.9	6.9	lb/infant/yr	0.54	0.95
Disposable Diapers	511,052	907,259	infants	0.36	0.36	lb/infant/yr	0.25	0.45
Untreated Human Waste, Other	12,050,752	14,882,918	people	0.05	0.05	lb/person/yr	0.83	1.02
On-Road Mobile	VMT	307,043,000	VMT/day	various	61	mg/km	**7.10**	**33.2**
Industrial Sources							**9.00**	**13.16**
Refrigeration	NA	1,789	tons/yr	NA	1	ton/ton	NA	4.90
NOx Control	NA	2,268	tons/yr	NA	0.1	ton/ton	NA	0.62
Metal Treating	NA	9,825	tons/yr	NA	0.1	ton/ton	NA	2.68
Blue Printing	NA	75	tons/yr	NA	1	ton/ton	NA	0.20
Wastewater Treatment (non-POTW)	NA	306	tons/yr	NA	0.15	ton/ton	NA	0.13
Traditional Point Sources (Radian Report[c])	NA	NA	NA	NA	various	NA	9.00	4.62
Composting	NI	2,445,599	tons/yr	NA	various	various	**0.00**	**9.69**
Landfills	NI	362	tons CH_4/yr	NI	0.007	lb/lb methane	**0.00**	**0.0069**

Table ES-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

	SCAB Activity			Emission Factor			Emissions, t/d	
Source Category	1997 SoCAB[a]	2000 SoCAB	Units	1997 SoCAB[b]	2000 SoCAB	Units	1997 SoCAB[a]	2000 SoCAB
Sewage Treatment (POTW)	mass balance	1,382	MMgals	various	0.118	lb/MMgal	**3.94**	**0.08**
Mobile - Other	various	NI	VMT	various	various	lb/VMT	**0.08**	**0.08**
Native Animal Waste							**0.00**	**0.16**
Deer	NI	9,713	head	NI	11.11	lb/head/yr	0.00	0.15
Bear	NI	307	head	NI	42.0	lb/head/yr	0.00	0.018
Prescribed burning	NI	4,164	acre/yr	N/A	various	various	**NI**	**NA**
SoCAB TOTAL							**155.74**	**184.55**

[a] No values or documentation were included in the 1997 AQMP[b]. The ammonia emisisons for the 1997 AQMP were generally based on the Radian Study[c], except for POTW dairy and beef cattle emissions.

[b] South Coast Air Quality Management District (SCAQMD). (1996) 1997 Air Quality Management Plan, November, 16.

[c] Dickson R.J. et al. (1991) Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board, Sacramento CA by Radian Corporation., Sacramento CA.

NA - Not applicable; category did not exist in report, but emissions were included in a separate category.

NI - Not inventoried in the report.

Various - More than one source

Land use - based on the amount of land associated with the category

Table ES-2. Emission Summary by Source

Source	1997 SoCAB Emissions (tons/day)	1997 SoCAB Percent of Total	2000 SoCAB Emissions (tons/day)	2000 SoCAB Percent of Total
Livestock	56.6	36.6%	60.4	32.72%
Soil	39.0	25.2%	34.2	18.55%
Fertilizer (TOTAL)	11.0	7.10%	7.68	4.16%
Domestic	28.1	18.1%	25.9	14.02%
On-Road Mobile	7.10	4.59%	33.2	17.99%
Industrial Sources	9.00	5.82%	13.2	7.13%
Composting	0	0.00%	9.69	5.25%
Landfills	0	0.00%	0.007	0.00%
Sewage Treatment	3.94	2.55%	0.082	0.04%
Mobile - Other	0.080	0.05%	0.080	0.04%
Native Animal Waste	0	0.00%	0.163	0.09%
Prescribed burning	0	0.00%	0	0.00%
SoCAB TOTAL	**155**	**100.00%**	**185**	**100.00%**

Table ES-3 Ammonia Emissions by Category per County

Category	Los Angeles County Emissions, tons/day	Orange County Emissions, tons/day	Riverside County Emissions, tons/day	San Bernardino County Emissions, tons/day	Total SoCAB Emissions, tons/day
Livestock	2.30	0.46	30.6	27.0	60.4
Soil	10.0	2.92	13.3	8.01	34.2
Fertilizer	2.26	1.56	1.90	0.35	6.1
Domestic	14.8	4.16	2.62	2.94	24.6
Industrial	7.01	0.63	0.13	0.77	8.5
Composting	0.80	2.07	3.84	2.98	9.7
Landfills	0.0015	0.004	0.0012	0.0001	0.0
POTWs	0.054	0.017	0.0026	0.008	0.1
Native Animals	0.005	0.0004	0.003	0.012	0.020
Combustion					4.62
On-Road Mobile					33.2
Other Mobile					0.08
Total	37.3	11.8	52.4	42.1	181.50

Chart 1. Pie Graph of 1997 SoCAB Ammonia Emissions by Source

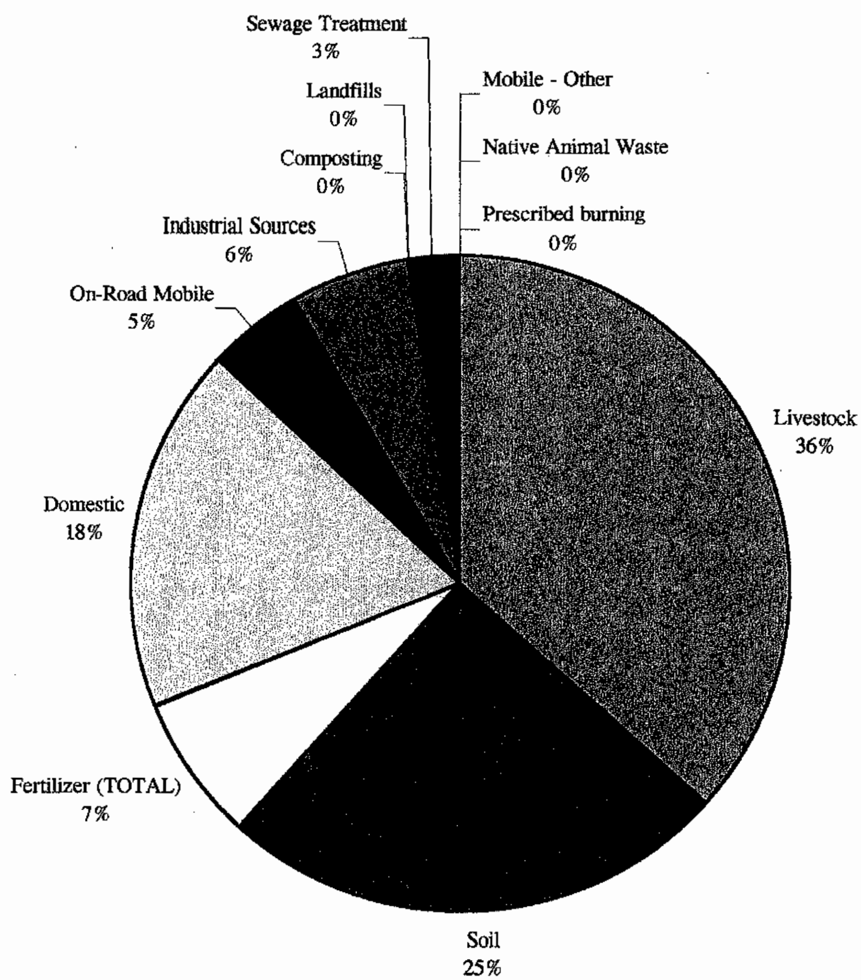


Chart 2. Pie Graph of 2000 SoCAB Ammonia Emissions by Source

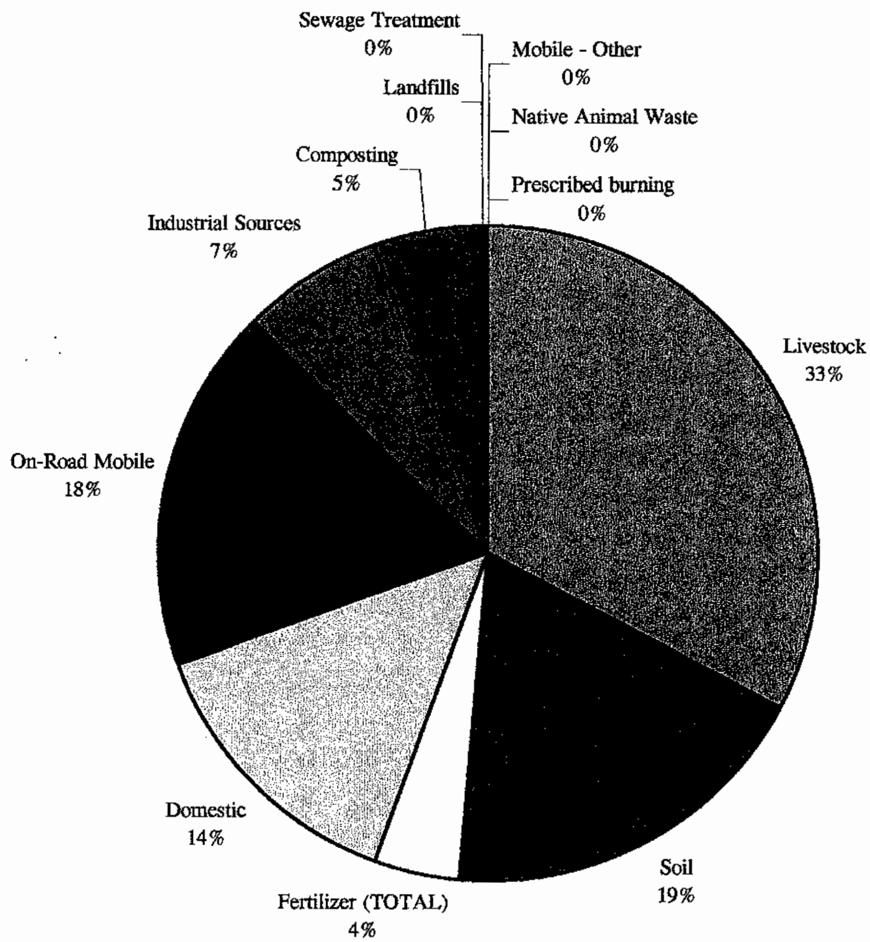
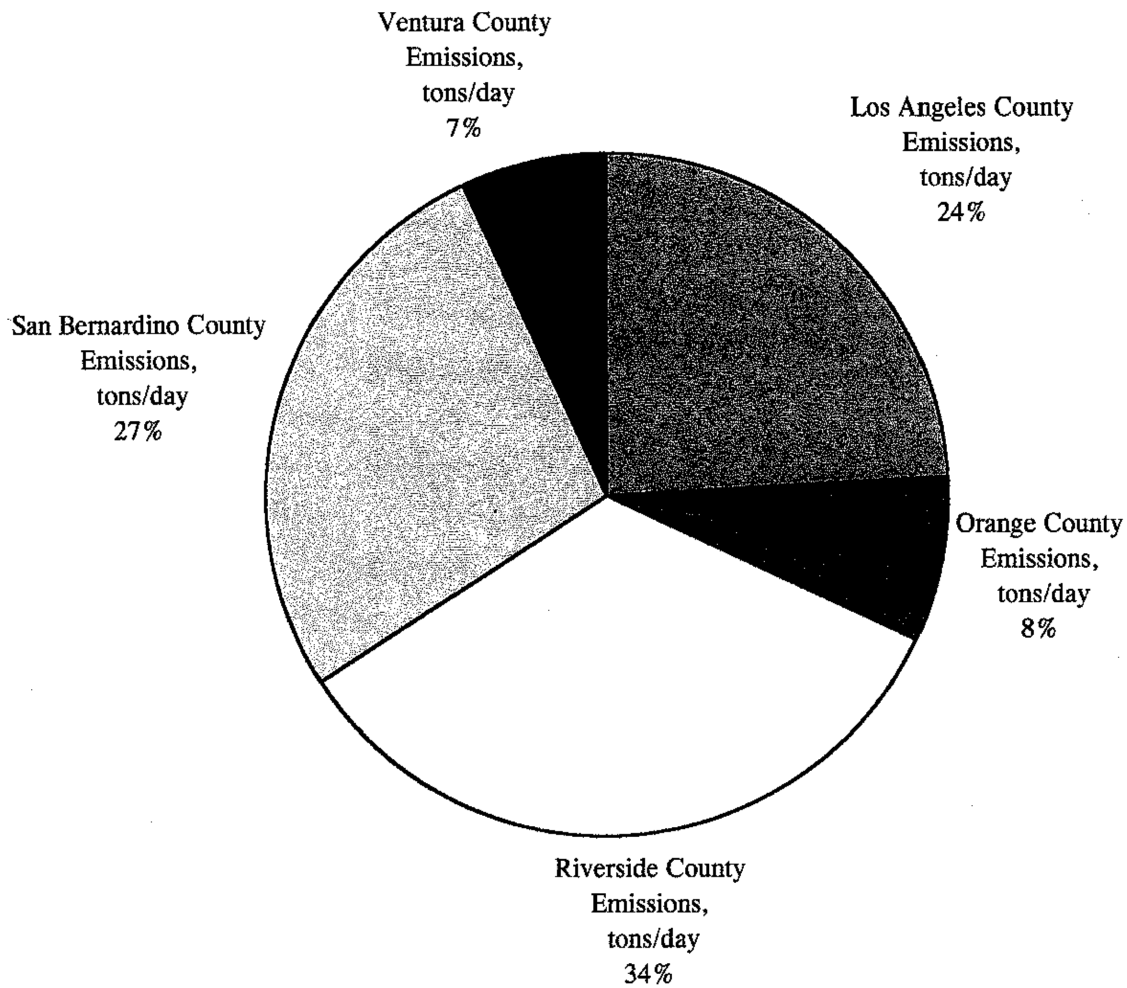


Chart 3. Pie Graph of SCAB Ammonia Emissions per County



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Section 1

INTRODUCTION

This report documents the update to the South Coast Air Quality Management District's (AQMD) 1997 Air Quality Management Plan (AQMP) ammonia emission inventory for the year 2000 AQMP. A comprehensive literature review was included in the scope of work.

This ammonia inventory update was prepared for the AQMD modeling domain, which includes Los Angeles, Ventura, Orange, and portions of San Bernardino and Riverside Counties.

1.1 ATMOSPHERIC AMMONIA

Atmospheric ammonia reacts with nitric acid and sulfuric acid to produce nitrate and sulfate particles. These fine particles have been shown to affect visibility, are easily respirable, and have potential health implications. This study was conducted to improve and update previous ammonia emission inventories so that AQMD staff may perform particulate modeling with greater accuracy.

1.2 EMISSION INVENTORIES

This gridded emission inventory includes emission factors, activity data and allocation data. Multiplying emission factors by activity yields emissions. The emissions were allocated to a particular place and to a particular time to allow modelers to assess how the ammonia reacts with other atmospheric compounds.

Emission Factors - Emission factors specify the rate at which a particular source emits ammonia. For example, the emission factor for composting is expressed as tons of ammonia emitted per ton of compost material processed (input). Likewise, the emission factor for chickens is expressed as pounds of ammonia emitted per chicken per year.

Most of the ammonia emission factors found in the available literature could not be rated using EPA methodology or were low-rated. This indicates either the emission factor was not based on test data (e.g., engineering calculations, mass balance, etc.) or that the test data were few in number and/or in poor agreement.

Activity - Source activity determines the capacity of the source to emit. For example, the measure of activity at a chicken ranch is the number of chickens on the ranch at any given time. When the activity (number of chickens at that farm) is multiplied by the emission factor (pounds of ammonia emitted per chicken per year), the result is pounds of ammonia per year emitted by that ranch. The units of measurement for the activity data must match the emission factor units of measurement.

Allocation - Sources emit ammonia at different times and different places. For example, automobiles with three-way catalysts emit ammonia. The highest concentration is on the major freeways during morning and afternoon rush hours. In this report, we refer to the location of the emissions as the spatial allocation and the time of the emissions as the temporal allocation.

Sources are either designated as point sources or area sources. For example, dairies were designated as point sources because their locations are known based on a specific address. Deer and bear were designated as area sources because their location within forested areas of the SoCAB is unknown.

Sources may emit ammonia at a higher rate during the day than at night. This is referred to as diurnal fluctuation. Likewise, sources may emit more in the summer than in the winter. This is referred to as seasonal fluctuation. Both of these are examples of temporal allocation.

This study provides an updated gridded ammonia emission inventory based on one-kilometer square grid cells for area sources and point sources by Universal Transverse Mercator (UTM) coordinates.

1.3 PREVIOUS WORK

This study used information and methodology primarily from four prior studies:

1. Gharib and Cass[1] at the California Institute of Technology (Cal Tech) prepared a SoCAB ammonia inventory for the 1982 inventory year. The authors compiled emission factors and activity data from nearly one hundred reports and papers to produce the inventory.

2. Radian (Radian Study[2]) used Gharib and Cass as a basis to produce the 1987 Southern California Air Quality Study (SCAQS) ammonia inventory. The SQAQS domain is somewhat larger than the SoCAB domain, taking in part of northern San Diego County. The Radian Study formed the basis for the 1997 Air Quality Management Plan (AQMP)[3] for the 1993 inventory year. Emissions from two sources, livestock (dairy emission factor and livestock populations) and wastewater treatment plants, were updated for the 1997 AQMP.

3. Sonoma Technologies Inc, et al, (San Joaquin Valley Study)[4] performed a major study in 1998 to evaluate and improve methods of inventorying ammonia sources in the San Joaquin Valley. As part of this project, testing was performed at a dairy, a farm and a wastewater treatment plant.

4. Battye et al. performed a literature survey of ammonia emission factors between 1985 and 1994 for the U.S. EPA, Office of Research and Development. Sources surveyed include the Compilation of Air Pollution Emission Factors - Volume I (AP-42)[11] for industrial sources, the National Acid Precipitation Assessment Program factors for combustion sources, human breath and perspiration, and publicly owned treatment works (POTW), European factors for agricultural sources, and Toxic Release Inventory for industrial sources. It is relevant to livestock and poultry because the study attempts to identify

emission factors that are appropriate for the entire United States and ranks them according to the AP-42 rating method.

Many other reports, studies and papers were reviewed and found useful in preparing the year 2000 AQMP ammonia inventory.

1.4 INVENTORY OBJECTIVES, METHODOLOGY AND REPORT ORGANIZATION

Inventory Objectives - The project objective was to provide the AQMD with a reliable and accurate gridded ammonia emission inventory for the SoCAB modeling domain. This was accomplished by:

1. Prioritizing ammonia source categories and considering the relative contribution to the total inventory based on the latest emission factors and activity data and the relative confidence in the emission estimate for that category.
2. Conducting an exhaustive literature search to identify new data developed by many ammonia inventory studies conducted since the Radian Study. These included the Schmidt and Winegar livestock study[5], the Sanitation District POTW study[6], the CalTech mobile source ammonia investigations[7], the University of California at Davis livestock emissions investigation[8], and many others.
3. Working closely with SCAQMD staff in making inventory improvement recommendations. Working closely with Dr. Eric Winegar of Applied Measurement Science to provide insight on the livestock emission factor issue. Consulting with Glen Cass of California Institute of Technology and other experts knowledgeable with the automotive catalyst emission factors.
4. Using the services of ENVIRON International Corporation (ENVIRON), experts in preparing gridded emission inventories.

Several major issues were investigated:

1. **Livestock-Related Emissions** - The Radian Study reported that livestock-related emissions accounted for 46 percent of the 1987 South Coast Air Basin ammonia emission inventory. However, the more recent Schmidt and Winegar study (1995) on livestock waste ammonia emissions reported greatly reduced levels (emission factor of 20 vs. 73 lbs./cow-yr.). Results from this study were used to update the 1997 AQMP. This issue was resolved by revisiting the Schmidt & Winegar Study and revising the dairy emission factor upwards to 50 lbs. lbs./cow-yr. to be specific to the SoCAB[9]. The revised emission factor is also consistent with the Asman Study[10].

2. **Publicly-Owned Treatment Works (POTWs)** - The Radian Study reported that POTW ammonia emissions accounted for 14 percent of the 1987 SCAQS ammonia emission inventory. However, a study prepared by the local sanitation districts reported levels two to four orders of magnitude less than the 1987 inventory. The sanitation district value was

used for the 1997 AQMP Inventory. A sanitation district source observed that the major SoCAB POTWs do not have significant sludge drying operations. The 1997 AQMP values were upheld.

3. **Mobile Sources** - The Radian Study reported that on-road mobile sources contributed approximately 3 percent to the 1987 ammonia inventory. Since then, the Cal Tech Tunnel Study reported an effectively fourfold higher contribution from vehicles with 3-way vehicle catalysts. This issue was resolved by discussing with vehicle emission experts at General Motors, Ford and Glen Cass of California Institute of Technology. The conclusion was to use the SoCAB-specific California Institute of Technology Tunnel Study emission factor.

Inventory Methodology - AVES's efforts were focused according to the "80/20 Rule", which says that 80 percent of the results come from 20 percent of the effort. Those sources with the highest contribution (i.e., livestock, soils, domestic, mobile, etc.) received the most attention.

Many sources from the 1997 AQMP Inventory, such as a large majority of the combustion sources, were not updated because their combined contribution was on the order of one percent of the total ammonia emission inventory.

Report Organization - After the Executive Summary and Introduction, this report is organized by sections according to ammonia source category. These source categories are:

1. Livestock
2. Native Animal Waste
3. Publicly-Owned Treatment Works
4. Soil Surface
5. Domestic Sources
6. Mobile Sources
7. Fertilizer
8. Industrial Sources
9. Landfills
10. Composting Operations
11. Oceans and Other Bodies of Water
12. Prescribed Burning

The 1997 AQMP did not inventory native animal waste, composting operations, oceans and other bodies of water, and prescribed burning.

In each section, there is:

- An introduction to the source,
- A discussion of the 1997 AQMP Inventory (for the 1993 plan year),
- A discussion of the current inventory update,
- Future research,
- And references.

The discussion of the current inventory update includes:

- Emission factors,
- Activity data, and
- Emissions allocation methods.

These data are summarized in tables specific to each source category.

The discussion on sources is followed by Emissions Gridding, which summarizes the methodology and quality assurance for spatially and temporally resolving the inventory.

The Conclusions section summarizes the differences in emission factors, activity and allocation between the 1997 AQMP Inventory and this report. The Conclusion section also summarizes recommendations for future research.

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Section 2

LIVESTOCK AND POULTRY EMISSIONS

Emissions from livestock and poultry waste are the largest contributors to the South Coast Air Basin (SoCAB) ammonia inventory—60 tons/day. The bulk of the emissions are produced in high concentrations at the dairies in the Chino area of San Bernardino County. These dairies have from a few hundred to several thousand head of cattle. However, dairies and large chicken ranches are also present in other parts of San Bernardino and Riverside Counties. Some of the larger chicken ranches have more than a million chickens. Horses are also significant contributors to this class of emissions, however their numbers are diffuse and more residential in nature. The types of livestock and poultry inventoried for this study were:

- Cattle (beef cows, milk cows, heifers and heifer calves, steers, steer calves, bulls, and bull calves)
- Horses and ponies
- Mules, burros and donkeys
- Hogs and pigs
- Sheep and lambs
- Goats
- Rabbits
- Chickens (layers, pullets, broilers)
- Turkeys
- Ducks and geese
- Other poultry

2.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP Inventory[1] primarily used livestock emission factors developed in the Radian Study[2] (1987 SCAQS Inventory), Dickson, et al.[3], and Gharib and Cass[4] (1982 SoCAB Inventory). The Gharib and Cass emission factors were used for cattle (feedlots, range), sheep, and hogs. Dickson, et al., emission factors were used for horses, chickens (broiler, laying), and turkeys.

The Radian Study collected records from Los Angeles County Veterinary Services Department for Los Angeles, the Census of Agriculture and University of California Cooperative Extension Service for Orange County, and the Riverside and San Bernardino Agricultural Commissioner's Office for Riverside and San Bernardino for activity data for cattle, horses, sheep, hogs, chickens and turkeys. The populations were adjusted because only a part of each county (with the exception of Orange County) was included in the SoCAB. The sheep population was corrected for fluctuation in flock composition in and out of the SoCAB.

Spatial resolution relied on the land use data developed by Gharib and Cass[4]. Hogs, dairy cattle and feedlot cattle were allocated to confined feeding land use. Sheep and range cattle were allocated to rangeland use. Locations of chicken ranches were specified in the modeling domain according to information obtained from each county's Agricultural Commissioner's Office in the Radian Study[1].

Temporal profiles for livestock emissions relied on the methods developed by Muck and Steenhuis[6] and Steenhuis et al.[7]

Changes between the 1997 AQMP and the Radian Study involved dairies and the implementation of a SoCAB-specific factor from a study by Schmidt and Winegar[5]. Schmidt and Winegar recommended an emission factor ranging from 11 to 20 lbs./head/year depending on diurnal and seasonal variation. The 1997 AQMP used 20 lbs./head-yr. This resulted in a large decrease in the inventory as the Radian Study used 72.8 lbs./head/year.

Activity data (population) for the 1997 AQMP inventory were based on collected records from each County Agricultural Commissioner's Office. Livestock and poultry population records from "crop reports" were used. The populations were adjusted because only a part of each county (with the exception of Orange County) was included in the SoCAB. The sheep population was corrected for fluctuation in flock composition in and out of the SoCAB.

2.2 INVENTORY UPDATE

Emission Factors

Dairy Cattle - The wide range of emission factors for dairies and the large contribution of this source warranted a detailed review of the studies. Dr. Eric Winegar performed a review to identify appropriate emission factors to represent dairies in the SoCAB, including a statistical analysis of the data available. This review is presented in Appendix B, titled "Review of Literature Sources for Emissions of Ammonia from Dairy Farms"[8]. The analysis suggests three possible emission factors and a final recommended value, which is shown on Table 2-1.

Dr. Winegar averaged non-parametric and flux chamber values to obtain a final composite emission factor of 51 lb./head/year. A description and comparison of non-parametric and flux chamber analysis is included in Appendix B. The use of these two values to produce the composite emission factor requires the least number of assumptions and uses the most conservative application of the data analysis performed. It should be noted that this is consistent with the Asman Study[9] composite cattle value of 50 lbs./head/year.

Non-Dairy Cattle, Pigs, Sheep, Horses, Mules, Burros, Donkeys, Goats, Rabbits and Poultry - In 1994, Battye et al.,[10] conducted a comprehensive study of ammonia source emission factors for the U. S. Environmental Protection Agency (EPA). One of the studies Battye reviewed was the Asman Study, a highly regarded work conducted in Europe. Battye assigned a moderately high level of confidence (B ratings) to the Asman Study emission factors (except for sheep and goats) and stated that these were the most recent and accurate emission values for animal husbandry at the time. The latter Sutton, et al. Study[11] also favors the Asman Study because of its midrange values. Because the Asman Study was considered favorably among other studies, the Asman Study emission factors cited by Battye and Sutton were used for all livestock except dairy cows. The benefits of using the Asman Study factors are: consistency with Federal studies, the high level of evaluation and review (B ratings for cattle, pigs and poultry), and use of the values by the San Joaquin Valley Study[12]. Battye's[10] emission factors, which were based on emission factors from the Asman study, were developed for use across the United States. While Asman's factors do not specifically apply to the farming practices in the SoCAB, the values have been cited and favorably approved in numerous peer reviewed papers.

A composite emission factor was produced from Battye et al.[10] for steers, bulls and calves of 30.39 lbs./head/year (18.12 lbs./head/year for steers, 61.53 lbs./head/year for bulls, and 11.53 lbs./head/year for calves), because the activity data only included a single population for these three categories.

A composite emission factor was also produced from Battye et al.[10] for layers and pullets (chickens) of 1.0 lbs./chicken/yr. (1.32 lbs./layer/year, and 0.672 lbs./pullet/year), because the activity data only included the total for these two categories. The 0.368 lb/broiler/year Battye et al.[10] emission factor was used to estimate ammonia emission from boilers.

Activity

Dairy Cattle – Original data on 1996 and 1997 dairy cattle populations were obtained by AQMD from the Santa Ana Regional Water Quality Control Board (RWQCB) and provided to AVES. AVES also contacted the RWQCB and other sources, and reviewed the United States Department of Agriculture's 1997 Agricultural Census[13], to confirm information and resolve conflicts in data sets. Some data in the USDA's 1997 Agricultural Census[13] are considered confidential because either the number of farms of the size of a single individual farm allows readers the ability to estimate populations at a specific farm. Dairy cattle populations were estimated from total and categorized cattle populations where such information was restricted by confidentiality.

Non-Dairy Cattle – Non-dairy cattle populations were obtained from the United States Department of Agriculture's 1997 Agricultural Census. Estimates of non-dairy cattle populations were developed from non-confidential total cattle populations and other specific cattle populations when data was not reported in the USDA's 1997 Agricultural Census[13] because of confidentiality.

Horse, Mule, Burro, Donkeys, Goats, Rabbits, Poultry -- Horse, mules, burros and donkeys, goats, rabbits and poultry populations were estimated from the 1997 Agricultural Census reported at the county level. The 1997 Agricultural Census included on-farm horses only, therefore horse populations were adjusted using the 1997 American Horse Council Survey[14]. This study estimated horse population by a detailed sampling of representative areas. Questionnaires and door-to-door surveys were completed. The study results were reported at the state level because the sampling strategy did not support a finer resolution. AVES used the ratio of 5.68 between the state total populations in the 1997 Agricultural Census and the 1997 American Horse Council Survey[14] to estimate total horse population by county for all five counties. The 1997 Agricultural Census population was multiplied by the 5.68 ratio to produce an adjusted population that more closely represented the total horse population. Activity data for the SoCAB were determined by the portion of land use of each county included in the SoCAB.

Livestock and poultry activity data, emission factors and emissions are presented on Table 2-2. Horse activity data, emission factors and emissions are presented on Table 2-3.

Spatial Allocation

Dairy Cattle -- Dairy emissions were spatially allocated as point sources by geocoding facility addresses obtained from the Santa Ana RWQCB. Mr. Scott Milton[15] of the USDA stated that 25% of heifers and heifer calves are kept on dairy farms and that 75% are kept as range cattle. The heifer and heifer calves populations from the Agricultural Census were allocated to dairy farm based on data from the Santa Ana RWQCB. A ratio of heifer and heifer calves was developed for each farm from the RWQCB data by dividing the number of heifer and heifer calves at each farm by the total number of heifer and heifer calves. Twenty five percent of the heifer and heifer calves populations from the USDA's 1997 Agricultural Census[13] were multiplied by the ratio developed from the RWCB data.

Beef Cattle - Rangeland cattle were allocated to rangeland in the USGS land use and land cover database[17]. Seventy-five percent of the heifer and heifer calves populations from the USDA's 1997 Agricultural Census[13] were allocated to rangeland.

Horse, Mule, Burro and Donkeys -- Horse, mule, burro and donkey emissions were spatially allocated based on the land use data developed by Aerial Information Systems (AIS)[17]. Half of the emissions were allocated to the horse ranch land use category from the AIS land use data[17] representing commercial and non-commercial ranching operations and half of the horse emissions were allocated to the low density rural land use category representing home stabled recreational horses.

Hogs, Rabbits, Sheep and Goats - Hog and rabbit populations were allocated to confined feeding in the USGS land use and land cover database[16]. Sheep and goat ammonia emissions were allocated to rangeland in the USGS land use and land cover database[15].

Poultry - Poultry emissions for Orange, Ventura, Riverside, San Bernardino, and Los Angeles Counties were allocated as point sources based on geocoding of addresses obtained from the Orange, San Bernardino, Ventura, Riverside and Los Angeles Counties Environmental Health and/or Vector Control[18,19].

Future Research

Because of the quality of the available data on ammonia emissions from dairies and the importance of accurate data to the entire ammonia inventory, it is recommended that additional studies be conducted to account for the noted discrepancies (ambient monitoring vs. mass balance vs. source test data). For example, while Dr. Winegar's analysis has made adjustments to the emission rates determined by the flux chamber method, these adjustments are based on several assumptions and extrapolations. Using the same basis for evaluating these data as stated, it is concluded that additional study is needed to completely evaluate the reasons for the discrepancies.

Although current data do not support any specific allocation profile, the temporal resolution of dairy emissions may have a significant impact on nitrate formation. In addition, existing information indicates that the temporal fluctuation may be significant. Therefore, further study of the seasonal and diurnal variation characteristics of diary emissions will greatly enhance the inventory for use in regional modeling.

Factors affecting emissions and temporal profiles include:

- Animal species, age, and weight
- Animal housing design
- Nitrogen content of feed
- Uptake efficiency of dietary nitrogen to animal tissues and milk
- Manure properties: pH, viscosity, mass fraction as dry solids
- Manure storage practices
- Amount and thickness of manure spread on land
- Method of manure spreading
- Time interval between spreading and plowing
- Meteorological conditions: temperature, turbulence, humidity, and precipitation
- Irrigation practices
- Soil properties: pH, calcium content, water content, buffer capacity, and porosity

Increased accuracy in temporal allocation needs to be coupled with increased accuracy in livestock emission factors. We believe further refinements in emission factor estimates should focus on differences in management practices that have a large effect on total emissions and can be controlled.

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Table 2-1. Composite Ammonia Emission Factors - Dairy Cattle
(lb/head/year)

Statistical Approach to Evaluate Emission Factor	Emission Factor (lb/head/yr)	Confidence in Emission Factor
Normal Distribution	63	Good
Non-parametric	52	Good
Flux Chamber Adjustment	50	High

Winegar E. (1999) Review of Literature Sources for Emissions of Ammonia from Dairy Farms. (see Appendix B)

Table 2-2. Livestock Ammonia Populations and Emissions by County

Livestock	Los Angeles Population	Orange Population	Riverside Population	San Bernardino Population	Ventura Population	Total SoCAB Population
Beef Cows	3,250	681	7,629	8,460	4,230	20,020
Milk Cows	3,250	681	113,719	185,249	4,230	302,899
Heifers and Heifers Calves (Total)	2,963	578	69,766	94,060	4,232	167,367
Dairy Heifers[a]	741	145	17,442	23,515	1,058	41,842
Beef Heifers[a]	2,222	434	52,325	70,545	3,174	125,525
Steers, Steer Calves, Bulls, and Bull Calves	2,016	152	13,854	38,306	7,459	54,328
Hogs and Pigs	1,683		2,080	14,296		18,059
Sheeps and Lambs	1,972	82	33,155	16,861	290	52,070
Layers and pullets	11,255	17	11,679,036	4,500,365	33	16,190,673
Broilers and other meat type chickens	403,330		404	566,113	252	969,847
Mules, Burros and Donkeys	76		139	84		299
Goats	704		1,657	1,619	299	3,980
Rabbits	212		24,971		71	25,183

Livestock	Emission Factor, lbs/animal	Los Angeles Emissions, tons/yr	Orange Emissions, tons/yr	Riverside Emissions, tons/yr	San Bernardino Emissions, tons/yr	Ventura Emissions, tons/yr	Total SoCAB Emissions, tons/yr	Total SoCAB Emissions, tons/dy	Emission Factor Source
Beef Cows	87.6	142.3	29.8	334	370	185	877	2.40	Battye et al. (1994)[b]
Milk Cows	51.00	82.9	17.4	2,900	4,724	108	7,724	21.2	Winegar (1999)[c]
Heifers and Heifers Calves (Total)	28.8	42.6	8.31	1,003	1,352	60.8	2,406	6.59	Battye et al. (1994)[b]
Dairy Heifers	28.8	10.6	2.08	251	338	15.2	601	1.65	Battye et al. (1994)[b]
Beef Heifers	28.8	31.9	6.23	752	1,014	45.6	1,804	4.94	Battye et al. (1994)[b]
Steers, Steer Calves, Bulls, and Bull Calves	30.4	30.6	2.31	211	582	113	826	2.26	Battye et al. (1994)[b]
Hogs and Pigs	20.3	17.1		21.1	145		183	0.50	Battye et al. (1994)[b]
Sheeps and Lambs	7.43	7.33	0.30	123	62.6	1.08	193	0.53	Battye et al. (1994)[b]
Layers and pullets	1.00	5.60	0.01	5,816	2,241	0.02	8,063	22.1	Battye et al. (1994)[b]
Broilers and other meat type chickens	0.37	74.2		0.07	104	0.05	178	0.49	Battye et al. (1994)[b]
Mules, Burros and Donkeys	26.9	1.02		1.87	1.13		4.02	0.011	Battye et al. (1994)[b]
Goats	1.28	0.45		1.06	1.03	0.19	2.54	0.0070	Bouwman, et al. (1997)[d]
Rabbits	0.37	0.04		4.62		0.01	4.66	0.013	Gharib and Cass (1984)[e]
SoCAB Total		404	58	10,415	9,584	469	20,461	62.7	

[a] Assumed 75% of heifers were dairy heifers and 25% were beef heifers based on conversation with Scott Milton of USDA, December 1999.

[b] Battye, R., W. Battye, C. Overcash, and S. Fudge (1994): Development and Selection of Ammonia Emission Factors. Final report prepared for U.S. Environmental Protection Agency.

[c] Winegar modifed results of Schmidt, C.E., and E. Winegar (1996): Results of the Measurements of PM10 Precursor Compounds from Dairy Industry Livestock Waste. Technical report prepared for the South Coast Air Quality Management District.

[d] Bouwman, A.F., Lee D.S. Asman W.A.H. Dentener F.J. and. Van Der Hoek K.W (1997): A Global High Resolution Emission Inventory for Ammonia Global Biogeochemical Cycles, Vol. II, No. 4, pp. 561-587.

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[f] Assumed horse emissions factors apply to mules, burros and donkeys.

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Beef Heifers[a]	2,222	434	52,325	70,545	125,525	3,174
Steers, Steer Calves, Bulls, and Bull Calves	2,016	152	13,854	38,306	54,328	7,459
Hogs and Pigs	1,683		2,080	14,296	18,059	
Sheeps and Lambs	1,972	82	33,155	16,861	52,070	290
Layers and pullets	11,255	17	11,679,036	4,500,365	16,190,673	33
Broilers and other meat type chickens	403,330		404	566,113	969,847	252
Mules, Burros and Donkeys	76		139	84	299	
Goats	704		1,657	1,619	3,980	299
Rabbits	212		24,971		25,183	71

Livestock	Emission Factor, lbs/animal	Los Angeles Emissions, tons/yr	Orange Emissions, tons/yr	Riverside Emissions, tons/yr	San Bernardino Emissions, tons/yr	Total SoCAB Emissions, tons/yr	Total SoCAB Emissions, tons/dy	Ventura Emissions, tons/yr	Emission Factor Source
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Broilers and other meat type chickens	0.37	74.2		0.07	104	178	0.49	0.05	Battye et al. (1994)[b]
Mules, Burros and Donkeys	26.9	1.02		1.87	1.13	4.02	0.011		Battye et al. (1994)[b]
Goats	1.28	0.45		1.06	1.03	2.54	0.0070	0.19	Bouwman, et al. (1997)[d]
Rabbits	0.37	0.04		4.62		4.66	0.013	0.01	Gharib and Cass (1984)[e]
SoCAB Total		404	58	10,415	9,584	20,461	62.7	469	

[a] Assumed 75% of heifers were dairy heifers and 25% were beef heifers based on conversation with Scott Milton of USDA, December 1999.

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[r] Assumed horse emissions factors apply to mules, burros and donkeys.

Table 2-3 Horse Populations and Ammonia Emissions

State Population

Source	Population	Ratio
1997 Agricultural Census[a]	113,110	
1997 American Horse Council Surv	642,000	5.68

On-Farm Horse Populations

County	Population[a]	Adjusted Population	EF[c], lb/head/yr	Emissions, tons/yr	Emissions, tons/day
Los Angeles	5,716	32,443	26.9	436	1.20
Orange	1,429	8,111	26.9	109	0.30
Riverside	9,778	55,499	26.9	746	2.05
San Bernardino	3,713	21,075	26.9	283	0.78
Ventura	3,008	17,073	26.9	230	0.63
SoCAB Total	20,636	117,128	26.9	1,575	4.32

[a] 1997 Agricultural Census (on-farm only)

[b] American Horse Council Foundation (1998) The Economic Impact of the Hourse Industry in the United States.

[c] Battye, R., W. Battye, C. Overcash, and S. Fudge (1994): Development and Selection of Ammonia Emission Factors. Final report prepared for U.S. Environmental Protection Agency.

Assumed the ratio of on-farm populations to total populations were consistant across all counties.
Applied the difference between on-farm populations from the 1997 American Horse Council Survey.

Section 3

NATIVE ANIMAL WASTE

Animals native to the SoCAB, such as deer and bear, generate ammonia emissions primarily from waste, in the same manner as livestock and poultry. Other emission mechanisms such as digestion, respiration, and perspiration are minor in comparison.

Native animal waste emissions, as inventoried, account for only 0.16 tons/day of ammonia and are considered a relatively minor source. It is not likely that a more complete inventory would bring this source into more prominence.

3.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP inventory[1], which was based on the Radian Study[2], did not consider native animal waste.

3.2 INVENTORY UPDATE

Emission Factors

Native animal wastes degrade into the soil. Thus, there is a possibility of double counting emissions with those from the various soil types. Small animals (e.g., rats, birds, ants, bacteria) are ubiquitous as is their waste which degrades easily into the soil. The rate or degree of ammonia loss by volatilization was not found in the literature reviewed, therefore for purposes of the 2000 AQMP inventory, AVES assumes that small animal emissions are included in the soil emission factor.

AVES also assumes that large game (e.g., deer, and bear) wastes are not included in the soils emission factors, because of their lower population density and the larger length of time for degradation. Available emission factors for native animals are summarized in Appendix A. Activity data was only found for deer, and bear (see below), emission factors developed by Warn[3] were used (0.14 lb./ kg-herbivore-yr.). When the Warn emission factor for herbivores is multiplied by the weight of deer (11 lbs./head/yr.), it is close to the emission factor provided by Dickson et al. (10 lbs./head/yr.) (see Table 3-1). The herbivore emission factor was also used for bear emissions. The Warn emission factors were favored because the emission factors are EPA accepted and rated values.

Activity Data

Activity data for large game was obtained from the California Department of Fish and Game (CDFG). Deer populations were obtained from conversations with Jane McKeever[4] of the CDFG. Bear populations were estimated from the 0.25 bear per square mile density estimated by CDFG[5] and total forested area from the USGS land use database. The total game bagged by county and type of game in 1997 was obtained from the Report of the 1997 Game Take

Hunter Survey[6]. Good population estimates could not be developed from the number of game bagged, therefore, these numbers were not used.

AVES only developed emissions for deer and bear, because of low confidence in populations for other native animals. Emission factors, activity data and emissions are shown on Table 3-2.

Spatial Allocation

Native animal waste will be allocated to range and forest land in the USGS land use database[7].

Future Research

It was assumed that small native animal waste emissions were included in soil emissions. This assumption may not be valid if ammonia flashes or evaporates before soil samples are analyzed. Further research into the volatilization of small animal waste is need.

Emission estimates for large native animal waste are based on domestic animal analogs. There are two major difficulties with this approach. First, a consensus in the scientific community has not been reached on domestic animal emission estimates (see Section 6 for a discussion on domestic animals). There is a great breadth in emission values for any given domestic animal. Secondly, domestic animals may not adequately represent native animals. The diets of the domestic animals are well regulated. The diets of native animals are not regulated and may vary by season and territory. The efficiency of digestion may cause variation in the emission factors.

AVES recommends that soil emissions be further investigated by conducting field test studies (see Section 5 for a discussion on soil surfaces). One phase of these studies would be to determine the effect of native animal waste.

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7. USGS Land Use Database

Table 3-1. Native Animal Waste Ammonia Emissions

Game	Total	Warn et. al. (1990) Emisison Factor, lb/kg-head-yr	Weight[a] kg	Adjusted Warn et al. Emission Factor[b], lb/head-yr
Deer	13,500	0.14	79.4	11.1
Bear	0.25/ sq. mile[d]	0.14	300	42.0
SoCAB Total				

Native Animals	Los Angeles Population	Riverside Population	San Bernardino Population	Ventura Population	SoCAB Population
Bear	90	50	167	120	307
Deer	2,854	1,591	5,268	3,787	9,713

Native Animals	Los Angeles Emissions, tons/yr	Riverside Emissions, tons/yr	San Bernardino Emissions, tons/yr	Ventura Emissions, tons/yr	SoCAB Emissions Tons/yr	SoCAB Emissions Tons/dy
Bear	1.90	1.06	3.50	2.52	6.46	0.018
Deer	15.6	8.68	28.7	20.7	53.0	0.15

[a] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. EPA-600/7-90-014. Final Report Prepared for Office of Reasearch and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corporation, Chapel Hill, N.C., EPA Contract No. 68-02-4374, Work Assignment No. 43 , June.

[b] Weight of white-tail deer taken from http://www.thewildones.org/CHA.Animals97/deer.html. Weight of bears taken from http://www.bearden.org/blkbear.html.

[c] Adjusted Warn et al. Emission Factor = Warn et al. Emission Factor x Weight, kg.

[d] Bear Density from Department of Fish and Game, Black Bear Management Plan, July 1998

ADD Population Notes for DEER.

Section 4

PUBLICLY-OWNED TREATMENT WORKS

Emissions from publicly owned treatment works (POTW) arise from process equipment and fugitive emissions. Kogan and Torres describe the sources and sinks of ammonia in the wastewater treatment process in their paper presented at the 1997 Air and Waste Management Association[1]. Ammonia from household and industrial sources enters the POTW and is emitted throughout the wastewater treatment process. Additional ammonia is generated during anaerobic digestion of sludge. Dewatering filtrate recycled through the primary clarifiers increases the ammonia concentration in the effluent. Nitrification in secondary treatment and in the air activated sludge process, consumption by bacteria, and loss of nitrogen in residual sludge solids all reduce the potential amount of ammonia emitted from the wastewater process. Traditionally, the largest POTW source of ammonia emissions is sludge drying operations.

The Radian Study[2] estimated a relatively high contribution of ammonia from POTWs. This was amended downward in the 1997 AQMP inventory[3] after new test information became available. These test results demonstrated that the POTW ammonia contribution was essentially negligible. The year 2000 AQMP inventory also uses these more recent test results.

4.1 1997 AQMP AMMONIA INVENTORY

The Radian Study used influent and effluent nitrogen compound concentrations to perform a simple nitrogen balance across each facility. The nitrogen loss to atmosphere as ammonia or nitrogen gas was calculated between influent, effluent and bacterial nitrogen fluxes. The data were obtained from a limited survey of publicly owned sewage treatment facilities. Ammonia losses attributed to sludge processing were estimated using an emission factor presented in the 1982 inventory. This factor assumes that a fixed amount (13.5%) of ammonia-nitrogen in digested sludge is lost to the atmosphere. For undigested sludge, a loss of 5.2% was assumed[1]. The Radian Study estimated 29 tons/day emitted from POTWs.

The 1997 AQMP updated the Radian Study by incorporating test data produced by Kogan and Torres[1]. These data demonstrated that the nitrogen balance method drastically overestimated POTW emissions.

The 1997 AQMD treated POTW emissions as point sources for each facility.

4.2 INVENTORY UPDATE

Emission Factors

Kogan and Torres[1] reported emission factors derived from source test data, mass balance and Toxchem+ modeling. The emission factors presented by Kogan and Torres do not include sludge handling. The Kogan and Torres value of 0.118 lb./MMgal was used for the updated inventory because it is in agreement with the San Joaquin Valley Study[5], is based on actual source test data, and reflects emissions from treatment plants located in the South Coast Air Basin (see Table 4-1).

The San Joaquin Valley Study[5] hypothesized that sludge drying operations would be a significant source of ammonia emissions, overshadowing all other POTW sources. However, the larger POTWs in the SoCAB do not have available land area for sludge drying operations nor the capacity to handle odor complaints. SoCAB POTW sludge is sent either to compost facilities or landfills[6].

Activity Data

POTW flow rates were used for activity data. The POTW emissions were calculated for each facility from flow rate data listed in the Radian Study. Flow rates and emissions are shown for each facility on Table 4-2.

Spatial Allocation

Addresses for each facility were geocoded and the emissions were distributed as point sources in the modeling domain. No temporal resolution was made.

Future Research

Data regarding temporal shifts in wastewater plant processes can be obtained from wastewater flow rates. However, more research is needed for considering other factors such as meteorology, treatment processes, temperatures, etc. Research into emission factors that are specific to certain processes would allow the consideration of plant design when estimating emissions. However, future research does not appear warranted based on the low significance of this source.

The potential for ammonia emissions from waste stream collection networks upstream of POTWs has not been explored or considered in previous studies.

4.3 REFERENCES

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2. Dickson R.J. et al. (1991) *Development of the Ammonia Emission Inventory for the Southern California Air Quality Study Report* prepared for the California Air Resources Board, Sacramento CA by Radian Corporation, Sacramento CA, Sept.

3. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

4. Knapp, T.E., and G.M. Adams (1997): *Ammonia Emissions from POTW Air Activated Sludge Secondary Treatment: Regulator Estimation vs. Source Testing*. Paper presented at the California Water Environment Association, 60th Annual Conference, Long Beach, CA, April 23-35.

5. Coe, D., Chinkin, L., Loomis,C., Wilkinson, J., Zwicker, J., (1998): *Technical Support Study 15: Evaluation and Improvement of Methods for Determining Ammonia Emissions in the San Joaquin Valley*. Prepared for the California Air Resources Board by Sonoma Technology, Inc., January.

6. Torres, E.M., of Orange County Sanitation Districts, telephone conversation with C.W. Botsford of AVES, May 19, 1999.

Table 4-1. POTW Source Test Results

Test	Ammonia Emissions (lb/yr)	1997 Flow (MMgal/yr)	Emission Factor (lb/Mmgal)
Plant 1	4,400	29,200	0.15
Plant 2	5,176	60,225	0.09
Average			0.12

Kogan, V., and E.M. Torres (1997): Ammonia Emissions from Publicly-Owned Treatment Works. Paper presented at the AWMA 90th Annual Meeting and Exhibition, Toronto, Ontario, Canada, June 8-13.

Table 4-2. POTW Flow Rates and Ammonia Emissions

Facility	County	Emission Factor lb/mmgal	Flowrate MMgal/ day	Emissions ton/day	Emissions tons/yr
Joint Plant	Los Angeles	0.12	366	0.022	7.88
Hyperion Plant	Los Angeles	0.12	361	0.021	7.77
San Jose Creek	Los Angeles	0.12	63.2	0.0037	1.36
Los Coyotes	Los Angeles	0.12	35.9	0.0021	0.77
L.A. Glendale Reclamation Plant	Los Angeles	0.12	20.8	0.0012	0.45
Terminal Island	Los Angeles	0.12	20.2	0.0012	0.44
Long Beach	Los Angeles	0.12	19.8	0.0012	0.43
Whittier Narrows	Los Angeles	0.12	14.3	0.0008	0.31
Pomona	Los Angeles	0.12	9.6	0.0006	0.21
Los Angeles County Totals			**911**	**0.0537**	**19.61**
Huntington Beach	Orange County	0.12	192	0.011	4.13
Fountain Valley	Orange County	0.12	56	0.0033	1.21
South Coast County Water District	Orange County	0.12	5	0.0003	0.11
Laguna Hills Sanitary District	Orange County	0.12	4.5	0.0003	0.10
Water Factor 21 Reclamation Plant	Orange County	0.12	8.8	0.0005	0.19
South East Regional Reclamation Auth.	Orange County	0.12	8.64	0.0005	0.19
Irvine Ranch Water District	Orange County	0.12	6.99	0.0004	0.15
Aliso Water Mngmt District	Orange County	0.12	4.4	0.0003	0.09
City of San Clemente	Orange County	0.12	3.47	0.0002	0.07
Los Alisos Water District	Orange County	0.12	3	0.0002	0.06
Capistrano Beach Sanitary District	Orange County	0.12	1.1	0.0001	0.02
Moulton-Niguel Water District	Orange County	0.12	0.4	0.0000	0.01
Orange County Totals			**294**	**0.0174**	**6.34**
Hemet Treatment Plant	Riverside	0.12	7.15	0.0004	0.15
Palm Springs	Riverside	0.12	6.46	0.0004	0.14
City of Riverside	Riverside	0.12	28.2	0.0017	0.61
Sunnymead Treatment Plant	Riverside	0.12	1.25	0.0001	0.03
Sun City Treatment Plant	Riverside	0.12	0.93	0.0001	0.02
Riverside County Totals			**44**	**0.0026**	**0.95**
City of San Bernardino	San Bernardino	0.12	87.5	0.0052	1.88
Chino Basin Regional Plant #1	San Bernardino	0.12	28.9	0.0017	0.62
Chino Basin Regional Plant #2	San Bernardino	0.12	4.4	0.0003	0.09
City of Redlands	San Bernardino	0.12	4.4	0.0003	0.09
City of Rialto	San Bernardino	0.12	3.85	0.0002	0.08
City of Colton	San Bernardino	0.12	3.74	0.0002	0.08
San Bernardino County Totals			**133**	**0.0078**	**2.86**
SoCAB Totals			**1,382**	**0.0815**	**29.76**

Emission factors obtained from Kogan, Vladimir, and Edward Torres, *Ammonia Emissions from Publicly Owned Treatement Works (POTWs),* presented at the Air & Waste Management Association's 90th Annual Meeting and Exhibition, June 8-13, 1997, Toronto, Ontario, Canada.

Section 5

SOIL SURFACES

Soil surface ammonia emissions are the second largest contributor to the inventory approximately 34 tons/day. Soil is an amalgam of organic and inorganic material. Soil ammonia emissions are dependent on the contents of the soil. Because of this, vegetation, animals, bacteria, and geological characteristics effect soil ammonia emissions. Soil ammonia emissions may also include emissions from animal waste and fertilizer application. This causes uncertainty regarding double counting of emissions.

The six types of soil surfaces inventoried for the year 2000 AQMP are:

- Urban
- Agricultural
- Rangeland
- Wetlands
- Forest Land
- Barren Land

5.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP inventory[1], which was based on the Radian Study[2], reported that soil surface emissions contributed approximately 25 percent to the inventory (39 tons per day). The calculations were based on the emission factors and land use for the 1984 inventory[3]. Radian Corp. stated that no new emission factors for soil were found while preparing the Radian Study[2].

5.2 INVENTORY UPDATE

Emission Factors

Additional literature on ammonia emissions from soil has been published, but the uncertainty in the papers is high. The uncertainty arises because soil and vegetation can act as both sources and sinks of ammonia.[4,5] The emission factor ranges provided by Schlesinger and Hartley[6] were recommended by literature reviews[4,5]. A detailed discussion is included in Appendix A. The 1997 AQMP emission factors fell within the ranges provided by Schlesinger and Hartley[6], therefore these emission factors, originally complied by Gharib and Cass and shown on Table 5-1, were used for the 2000 AQMP ammonia inventory.

Activity Data

The activity data was based on soil surface area (acres) by land type from the USGS land use database[7]. Activity (acreage) and total emissions are shown on Table 5-2.

Spatial Allocation

Spatial allocation was based on the USGS land use data.

Future Research

Soil parameters are limited as to soil type. This is a very simplistic division. It is reasonable to assume that other parameters such as temperature and wind speed affect the volatilization rate, too.

A change in the magnitude of emissions or the spatial and/or temporal allocation of the emissions will have a significant effect on the overall quality of the inventory. There are currently no data to temporally allocate the emissions and the spatial allocation is based on only six soil types in conjunction with emission factors which are essentially the same for all land types except agricultural.

Research into vegetation and soil as a sink has developed since the Radian Study[2], however, there is still large uncertainty in the current literature. Further developments should be tracked.

One issue, which warrants further clarification, is the influence of fertilizer application and native animal waste on the ammonia emission rate from agricultural soils. AVES assumed that fertilizer and large game native animal waste (deer and bear) ammonia emissions are in addition to agricultural soil emissions, but that small native animal waste emissions are already included.

5.3 REFERENCES

1. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

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5. Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom, *Atmospheric Environment*, (29):1393-1411.

6. Schlesinger W.H. and Hartley A.E. (1992), A Global Budget for Atmospheric NH_3. *Biogeochemistry* 15, pp. 191-211.

7. USGS Land Use Database.

Table 5-1. Soils Ammonia Emission Factors

Source Category	Emission Factor kg/km^2-day	Reference
Cropland	3.7	Gharib and Cass, 1984
Lawn Surface	1	Gharib and Cass, 1984
Bare Soil	1	Gharib and Cass, 1984
Ungrazed Grass Clover	5.8	Gharib and Cass, 1984
Forest Land	1	Gharib and Cass, 1984
Pasture Grass > 30 m from Manure Source	1.5	Gharib and Cass, 1984
Grassland Near Swine Barn with No Manure	2.5	Gharib and Cass, 1984

Table 5-2. Soils Ammonia Emissions

Source Category	Emission Factor kg/km^2-day	Emission Factor tons/miles^2-day	Area[a] miles^2
Urban	1	0.0029	2,078
Agricultural	3.7	0.0106	1,414
Rangeland/Pasture	1.5	0.0043	1,701
Wetland	1	0.0029	60
Forest Land	1	0.0029	1,425
Barren Land	1	0.0029	654
SoCAB Total			**7,331**

Soils	Los Angeles Area, miles^2	Orange Area, miles^2	Riverside Area, miles^2	San Bernardino Area, miles^2	Ventura Area, miles^2	SoCAB Area[a] miles^2
Urban	1,104	314	244	416	123	2,078
Agricultural	330	105	765	214	257	1,414
Rangeland/Pasture	509	176	828	188	253	1,701
Wetland	5	4	29	22	12	60
Forest Land	360	30	203	832	480	1,425
Barren Land	56	22	114	462	31	654

Soils	Los Angeles Emissions, tons/yr	Orange Emissions, tons/yr	Riverside Emissions, tons/yr	San Bernardino Emissions, tons/yr	Ventura Emissions, tons/yr	SoCAB Emissions tons/year
Urban	1,150	327	255	433	128	2,165
Agricultural	1,271	406	2,947	824	989	5,449
Rangeland/Pasture	796	275	1,293	294	396	2,657
Wetland	5	4.0	30	23.1	12	62
Forest Land	375	31	211	867	500	1,485
Barren Land	58	23	119	481	33	681
						12,498

Soils	Los Angeles Emissions, tons/dy	Orange Emissions, tons/dy	Riverside Emissions, tons/dy	San Bernardino Emissions, tons/dy	Ventura Emissions, tons/dy	SoCAB Emissions tons/day
Urban	3.15	0.90	0.70	1.19	0.35	5.93
Agricultural	3.48	1.11	8.07	2.26	2.71	14.9
Rangeland/Pasture	2.18	0.75	3.54	0.81	1.08	7.28
Wetland	0.01	0.01	0.08	0.06	0.03	0.17
Forest Land	1.03	0.09	0.58	2.38	1.37	4.07
Barren Land	0.16	0.06	0.33	1.32	0.09	1.87
						34.2

Section 6

DOMESTIC SOURCES

Domestic ammonia emissions are developed from population activity. Domestic sources of ammonia are the fourth largest contributor to the inventory, on the order of 26 tons/day. These sources are:

- Pets (dogs and cats)
- Cigarette Smoke
- Untreated Human Waste (homeless and other)
- Untreated Human Waste (diapered population)
- Perspiration and Respiration
- Household Ammonia

Ammonia emissions from pets are primarily from pet waste. Because of the large human population, ammonia emissions from people include perspiration, and respiration losses in addition to human waste. Human waste is divided by method of disposal. Treated human waste is covered under Section 4 Publicly-Owned Treatment Works. Emissions from diapers are treated separately and divided into disposable and cloth diapers. Disposable diapers are sent to landfills and cloth diapers are laundered. A portion of human waste is left untreated (i.e., homeless, portable toilets, etc.). Household ammonia emissions originate from cleaning solutions and other chemicals used at home. Ammonia emissions from cigarettes are a result of the combustion process.

6.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP inventory[1], which was based on the Radian Study[2], used ammonia emissions factors from Gharib and Cass[3] for dogs, cats, human respiration, human perspiration and household ammonia use. The Radian Study developed additional emission factors for untreated human waste and cigarette smoke.

6.2 INVENTORY UPDATE

Pets

<u>Emission Factors</u> – For the 2000 AQMP inventory, AVES used Sutton's[4] adjustment (2.17 lbs NH_3/dog/yr and 0.348 lbs NH_3/cat/yr) of the Gharib and Cass emission factors for pets (5.5 lbs NH_3/dog/yr and 1.8 lbs NH_3/ cats/yr). As discussed in Appendix A – Literature Review, the Sutton adjustment is applicable to the SoCAB (see Appendix A). Table 6-2 includes a summary of emission factors.

Activity Data - Total pet population was used as activity data. Total pet population was estimated by the multiplying the ratio of per capita pets that was developed by the Radian Study by the human population (0.083 urban and 0.111 suburban for cats and 0.122 urban and 0.167 suburban for dogs). A summary of the ratios can be found on Table 6-2. Human populations were determined from 1990 census data[5] updated to 1997 by the U.S. Bureau of the Census[6] for Los Angeles, San Bernardino, Riverside, Ventura and Orange Counties.

Spatial Allocation - Emissions were allocated to total population using 1990 census data[5].

Cigarettes

Emission Factors - A cigarette emission factor developed by Warn, et al[7], was used for the updated inventory. The Warn et al. emission factor, 100 ug/cigarette (2.20×10^{-7} lbs NH_3/cigarette), is a factor of 50 lower than the factor used in the 1997 AQMP/Radian Study (0.011 lbs NH_3/cigarette), making cigarette smoke an insignificant contributor to the inventory. It was chosen because it was based on several peer-reviewed studies more recent than the single report cited by the 1997 AQMP (see Table 6-2).

Activity Data - Average per capita cigarette consumption (53 packages consumption per capita between 1996 and 1998[8] and assuming 20 cigarettes per pack[2]) was multiplied by the population to obtain activity data. Human populations were determined from 1990 census data[5] updated to 1997 by the U.S. Bureau of the Census[6].

Spatial Allocation - Cigarette emissions were allocated to total population using 1990 census data[5].

Untreated Human Waste - Homeless and Other

Emission Factors - No new emission factors were found in the available literature. Emission factors developed for untreated human waste for the Radian Study were used for the homeless populations and other untreated human waste (see Table 6-2).

Activity Data - The Community Services Department of San Bernardino County[9] based homeless populations on results from the 1990 national telephone survey by the National Coalition for the Homeless[10]. The survey found that 7% of the respondents reported they were homeless at some point in their lives and 3% had been homeless over a five-year period. Using census figures (1,616,000) it was estimated that 16,158 individuals were homeless in San Bernardino County. Populations were determined from 1990 census data[5] updated to 1997 by the U.S. Bureau of the Census[6].

The Los Angeles Homeless Services Authority estimates 89,000 homeless in Los Angles County[11].

The Department of Community Action, Riverside estimates 1% of the population is homeless at any given time. Based on the 1997 population, they assumed there were 14,478 homeless[12] in Riverside County. The Ventura County homeless population of 7,218 was estimated from the 1% factor from the Department of Community Action, Riverside.

Orange County relies on numbers provided by the United Way's Homeless Issues Task Force, an independent agency[13]. AVES has not been able to obtain data from them, therefore AVES used the Orange County Rescue Mission (OCRM) estimate of 15,000 homeless in Orange County[14].

Total homeless population for all five counties was estimated to be 141,854.

Spatial Allocation - Homeless human waste emissions were allocated to total population using 1990 census data[5], updated to 1997 by the Bureau of Census[6].

Untreated Human Waste - Infants

Emission Factors - No new emission factors were found in the available literature. Emission factors developed for untreated human waste for the Radian Study were used for the infant population (see Table 6-2).

Activity Data - The total percent population of infants under three years old were calculated as the sum of the under 1 year old, 1-2 year old and half of the 3-4 year old categories from the 1990 census[5], updated to 1997[6] by the Bureau of Census. The data were used to calculate the percentage of infants in the total population. Radian's ratio of disposable to cloth diapers was used. These data were used for the estimation and allocation of diaper emissions in the updated inventory. The development of infant population data is shown on Table 6-1.

Diaper emissions from the elderly populations were not available.

Spatial Allocation - Infant human waste emissions were allocated to total population using 1990 census data.

Perspiration-Respiration

Emission Factors - No new emission factors were found in the available literature. Emission factors developed for the Radian Study[2] were used for perspiration and respiration (see Table 6-2).

Activity Data - Population was used as activity data and was determined from 1990 census data[5] updated to 1997 by the U.S. Bureau of the Census[6].

Spatial Allocation - The human respiration/perspiration emissions were spatially allocated to total population using 1990 census data[5].

Household Ammonia

Emission Factors – No new emission factors were found in the available literature. Emission factors developed for household ammonia for the Radian Study were used for the updated inventory (see Table 6-2).

Activity Data – Population was used as activity data and was determined from 1990 census data updated to 1997 by the U.S. Bureau of the Census[5].

Spatial Allocation – The household ammonia emissions were spatially allocated to total population using 1990 census data.

Table 6-2 shows emission factors, activity data, and total emissions for all domestic categories for the updated inventory.

Future Research

The contribution of pets is significant. However, the activity data were based on a per capita ratio to the general population and not based on a direct pet count. A resource-intensive way to obtain this information would be to approach each city for pet registration information and make an assumption regarding unregistered pets.

6.3 REFERENCES

1. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

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Table 6-1. Infant Populations

County	1990 Population[a]	Under 1	1 and 2	3 and 4	0 to 3	Percentage of Total Population
Los Angeles	8,863,164	132,518	317,611	286,156	593,207	6.69%
Riverside	1,170,413	17,517	45,389	41,899	83,856	7.16%
Orange	2,410,556	34,293	79,599	70,981	149,383	6.20%
San Bernardino	1,418,380	24,603	59,208	54,531	111,077	7.83%
Ventura	669,016	9,721	22,515	21,542	43,007	6.43%

[a] Census of Population and Housing, 1990: Summary Tape File 1 on U.S. Census Bureau Web Site (Summary Level: State-County) [machine-readable data files] / prepared by the Bureau of the Census.--Washington: The Bureau, 1991.

County	1997 Population[a]	Percentage of Total Population	1997 Infant Population
Los Angeles	9,145,219	6.69%	612,085
Riverside	1,447,791	7.16%	103,729
Orange	2,674,091	6.20%	165,714
San Bernardino	1,615,817	7.83%	126,538
Ventura	727,200	6.43%	46,747
SoCAB Total	15,610,118	6.76%	1,054,813

[a] Census of Population and Housing, U.S. Bureau of the Census, Current Population Reports, Series P23-194, Popluation Profile of the United States: 1997. U.S. Government Printing Office, Washington, D.C., 1998.

Table 6-2. Domestic Ammonia Emissions

Respiration

County	1997 Population[a]	Respiration Emission Factor,[e] lb. NH_3/ person-yr	Respiration Emissions, tons/day	Respiration Emissions ton/year
Los Angeles	9,145,219	0.004	0.044	16.0
Riverside	1,447,791	0.004	0.007	2.5
Orange	2,674,091	0.004	0.013	4.7
San Bernardino	1,615,817	0.004	0.008	2.8
Ventura	721,806	0.004	0.003	1.3
SoCAB TOTAL	**14,882,918**		**0.07**	**26.0**

Perspiration

County	1997 Population[a]	Perspiration Emission Factor,[e] lb. NH_3/ population	Perspiration Emissions, tons/day	Perspiration Emissions ton/year
Los Angeles	9,145,219	0.55	6.89	2,515
Riverside	1,447,791	0.55	1.09	398
Orange	2,674,091	0.55	2.01	735
San Bernardino	1,615,817	0.55	1.22	444
Ventura	721,806	0.55	0.54	198
SoCAB TOTAL	**14,882,918**		**11.2**	**4,093**

Household Use

County	1997 Population[a]	Household Use Emission Factor,[e] lb. NH_3/ population	Household Use Emissions, tons/day	Household Use Emissions ton/year
Los Angeles	9,145,219	0.05	0.63	229
Riverside	1,447,791	0.05	0.10	36.2
Orange	2,674,091	0.05	0.18	66.9
San Bernardino	1,615,817	0.05	0.11	40.4
Ventura	721,806	0.05	0.05	18.0
SoCAB TOTAL	**14,882,918**		**1.02**	**372**

Table 6-2. Domestic Ammonia Emissions

Other Untreated Human Waste

County	1997 Population[a]	Other Untreated Human Waste Emission Factor,[e] lb. NH_3/preson-yr	Other Untreated Human Waste Emissions, tons/day	Other Untreated Human Waste Emissions ton/year
Los Angeles	9,145,219	0.050	0.63	229
Riverside	1,447,791	0.050	0.10	36.2
Orange	2,674,091	0.050	0.18	66.9
San Bernardino	1,615,817	0.050	0.11	40.4
Ventura	721,806	0.050	0.05	18.0
SoCAB TOTAL	**14,882,918**		**1.02**	**372**

Cigarettes

County	1997 Population[a]	Average Per Capita Consumption in Packages (1996-98)[c]	Cigarettes Per Package	Emission Factor, lb/cigarette[d]	Cigarette Emissions, tons/day	Cigarette Emissions ton/year
Los Angeles	9,145,219	53.0	20	2.20E-07	0.0029	1.07
Riverside	1,447,791	53.0	20	2.20E-07	0.0005	0.17
Orange	2,674,091	53.0	20	2.20E-07	0.0009	0.31
San Bernardino	1,615,817	53.0	20	2.20E-07	0.0005	0.19
Ventura	721,806	53.0	20	2.20E-07	0.0002	0.08
SoCAB TOTAL	**14,882,918**			**2.20E-07**	**0.0048**	**1.74**

Infant - Cloth Diapers

Cloth Diapers	Infant Population[a]	EF,[b] lb /infant population	% Diaper Type[b]	Cloth Wearing Infant Population[a]	Cloth Diaper Emissions ton/day	Cloth Diaper Emissions ton/year
Los Angeles	612,085	6.9	10%	61,208	0.58	211
Riverside	103,729	6.9	10%	10,373	0.10	35.8
Orange	165,714	6.9	10%	16,571	0.16	57.2
San Bernardino	126,538	6.9	10%	12,654	0.12	43.7
Ventura	46,747	6.9	10%	4,675	0.04	16.1
SoCAB TOTAL	**1,008,065**			**100,807**	**0.95**	**348**

Infant - Disposable Diapers

Disposable Diapers	Infant Population[a]	EF,[b] lb /infant population	% Diaper Type[b]	Disposable Wearing Infant Population[a]	Disposable Diaper Emissions ton/day	Disposable Diaper Emissions ton/year
Los Angeles	612,085	0.36	90%	550,876	0.27	99.2
Riverside	103,729	0.36	90%	93,356	0.05	16.8
Orange	165,714	0.36	90%	149,142	0.07	26.8
San Bernardino	126,538	0.36	90%	113,884	0.06	20.5
Ventura	46,747	0.36	90%	42,073	0.02	7.57
SoCAB TOTAL	**1,008,065**			**907,259**	**0.45**	**163**

Table 6-2. Domestic Ammonia Emissions

Cats

County	1997 Population[a]	Cat Emission Factor,[e] lb. NH_3/cat-yr	Pet Ratio[b]	Cat Population	Cat Emissions, tons/day	Cat Emissions ton/year
Los Angeles	9,145,219	0.35	0.08	759,053	0.44	160
Riverside	1,447,791	0.35	0.11	160,705	0.09	34.0
Orange	2,674,091	0.35	0.08	221,950	0.13	46.9
San Bernardino	1,615,817	0.35	0.11	179,356	0.10	37.9
Ventura	721,806	0.35	0.11	80,120	0.05	16.9
SoCAB TOTAL	**14,882,918**			**1,401,184**	**0.76**	**279**

Dogs

County	1997 Population[a]	Dog Emission Factor,[e] lb. NH_3/dog-yr	Pet Ratio[b]	Dog Population	Dog Emissions, ton/day	Dog Emissions ton/year
Los Angeles	9,145,219	2.17	0.12	1,115,717	4.02	1.469
Riverside	1,447,791	2.17	0.17	241,781	0.87	318
Orange	2,674,091	2.17	0.12	326,239	1.18	430
San Bernardino	1,615,817	2.17	0.17	269,841	0.97	355
Ventura	721,806	2.17	0.17	120,542	0.44	159
SoCAB TOTAL	**14,882,918**			**2,074,120**	**7.05**	**2,572**

Homeless

County	Homeless Population[f]	EF,[b] lb NH_3/ population	Homeless Emissions, tons/day	Homeless Emissions, tons/year
Los Angeles	89,000	11	1.34	490
Riverside	14,478	11	0.22	79.6
Orange	15,000	11	0.23	82.5
San Bernardino	16,158	11	0.24	88.9
Ventura	7,218	11	0.11	39.7
SoCAB TOTAL	**134,636**		**2.03**	**740.5**

SoCAB TOTAL DOMESTIC	**24.57**	**8,967.4**

[a] Census of Population and Housing, U.S. Bureau of the Census, Current Population Reports, Series P23-194, Popluation Profile of the United States: 1997. U.S. Government Printing Office, Washington, D.C., 1998.

[b] Radian, 1987 Ammonia Emission Inventory (1991), September.

[c] California State Board of Equilization, "Table 30B - Cigarette Distributions and Per Capita Consumption, 1959-60 to 1997-98." 1997 Annual Report, A-41.

[d] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. Final Report Prepared for Office of Reasearch and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corperation, Chapel Hill, N.C., PB90-235094, EPA-600/7-90-014, June.

[e] Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom, Atmospheric Environment, (29):1393-1411.

[f] The homeless populations were obtained by county from different agencies.
- Department of Community Action Riverside (DCAR) estimates 1% of the population is homeless at any given time.
- The DCAR estimate of 1% was used for San Bernardino County .
- The Orange County Rescue Mission estimates 15,000 homeless in Orange County.
- The Los Angeles Homeless Services Authority estimates 89,000 homeless.

Section 7

MOBILE SOURCES

The Radian Study[1] defined mobile source as any vehicle powered by combustion. Ammonia emissions are a result of the combustion process. These emissions fluctuate with size of the engine, the amount of load placed upon the engine, type of fuel, temperature at start, and control technology applied.

For the purpose of this inventory, AVES concentrated on mobile sources with 3-way catalysts because these are thought to overshadow the contribution of all other mobile sources. Based on the Radian Study, all other mobile sources accounted for approximately 0.2 percent of the inventory at 0.08 tons/day. Therefore, AVES used the Radian Study values for all other mobile sources as default.

7.1 1997 AQMP AMMONIA INVENTORY

The mobile source section of the 1997 AQMP inventory[2], which was based on the Radian Study, was developed using a bottom up approach based on:

- Vehicle miles traveled (VMT),
- Fraction per model year,
- Failure rate per model year from ARB roadside inspection,
- Percent catalyst from various sources,
- Emission factors for properly operating vehicles from Gharib and Cass[3] , and
- Emission factors for improperly operating vehicles from various studies conducted in the 1980s.

The Radian Study based allocations on light duty exhaust particulate emissions from the ARB gridded, hourly inventory. The Radian Study states that use of the Caltrans Transportation Impact Model (CTIM) is preferable but too cost intensive considering the small relative contribution of mobile sources.

7.2 INVENTORY UPDATE

Emission Factors

AVES used the Fraser and Cass[4] Tunnel Study vehicle fleet average emission factor, 61 mg/km driven, for the year 2000 AQMP inventory. This emission factor is approximately three and a half times larger than the average of the emission factors used in the Radian Study. The emission factor was derived from measurements taken inside a tunnel in Van Nuys, California, therefore reflects the fleet average as represented by the vehicles passing through the tunnel. To use this vehicle fleet average emission factor, it is not necessary to use the myriad number of assumptions required by the Radian Study's bottom-up approach. Instead of individual vehicle emission factors, the Fraser and Cass Tunnel Study allows use of a bulk (vehicle fleet average) emission factor. Mobile source ammonia emissions, predominantly from vehicles with 3-way catalystic converters, are the third largest contributor to the inventory, on the order of 33 tons/day.

Activity Data and Spatial Allocation

The AQMD will perform transportation modeling using VMT data to determine emissions and allocation. This approach is simple and avoids the pitfalls of collecting representative data to implement the bottom up approach used in the Radian Study and is more representative of actual emissions. VMT was supplied electronically by the SCAQMD (see Table 7-1) for Los Angeles, Orange, Riverside, San Bernardino Counties for reporting purposes only. The AQMD will add mobile source emissions to the gridded inventory when the transportation modeling is complete.

Future Research

The Fraser and Cass study is based on limited data, therefore AVES conducted additional further literature review and contacted Dr. Cass, Dr Steven Cadle of General Motors, and Robert Gorse of Ford[5,6]. It is anticipated that ammonia emissions testing by Ford will be added to a future tailpipe study, however this data will not reflect improperly operating vehicle emissions, which may drive the inventory. Dr. Cass has also recently completed a new tunnel study—final results were not available at time of publication.

7.3 REFERENCES

1. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

2. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

3. Gharib, S., and G.R. Cass (1984*): Ammonia Emissions in the South Coast Air Basin.* Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

4. Fraser, M.P., Cass G.R. (1998): Detection of Excess Ammonia Emissions from In-Use Vehicles and the Implications for Fine Particle Control, *Environmental Science and Technology*, Vol. 32, No. 8, pp. 1,053-1,057, April.

5. Cadle, S., of General Motors, (1999), telephone conversation with C.W. Botsford of AVES, on March 9.

6. Gorse, R., of Ford Motor Company (1999), telephone conversation with C.W. Botsford of AVES, on March 18.

Table 7-1 1997 VMT by County Provided by the SCAQMD

Location	Daily VMT
Los Angeles	177,252,000
Orange	64,334,000
Riverside	33,145,000
San Bernardino	32,312,000
TOTAL SoCAB	307,043,000

Out of SoCAB	Daily VMT
Antelope Valley	9,289,000
Coachella Valley	13,271,000

Section 8

FERTILIZER

Ammonia emissions from the application of fertilizer to land surfaces for agricultural purposes are approximately 8 tons/day. Fertilizer types can range from manure to specialty mixtures developed for specific crops. Like soils, fertilizer ammonia emissions are dependent on the fertilizer ingredients. In addition, there is the possibility of double counting emissions with soil surfaces (see Section 5 discussion). Most inventories, including this one have assumed that ammonia emissions from fertilizer application are in addition to emissions from soil surfaces.

8.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP inventory[1], which was based on the Radian Study[2], reported 11 tons per day of ammonia emissions from fertilizer. This is seven percent of the total inventory. Gharib and Cass[3] also reported that fertilizer application and handling emissions accounted for approximately five percent of the total ammonia emissions. For both inventories, fertilizer application was categorized into cropland, orchard, and non-farm use to apply emission factors and usage rates for dry and liquid fertilizers. Emission factors used in the Radian Study are the same as those used by Gharib and Cass.

Fertilizer usage for farm and non-farm use was obtained from California Department of Food and Agriculture (CDFA) Tonnage Report[4]. Fertilizer consumption was categorized by acquiring crop acreage data from each county's Agriculture Commissioners Office[5,6,7,8].

Seasonal and diurnal profiles were not addressed in the Radian Study.

8.2 INVENTORY UPDATE

Emission Factors

New emission factors with better resolution have been developed since the Radian Study[2] for specific fertilizer types (see Appendix A). No further resolution was found in the activity data. The newer emission factors could not be applied to the activity found in the CDFA Tonnage Report[4] because data was not provided for these specific fertilizer types for the modeling domain. Therefore, AVES retained the emission factors used by the 1997 AQMP[1]. These factors are presented in Table 8-1. The emissions factors are 10% by weight for dry fertilizer application on farms, 20% by weight for liquid fertilizer application on farms, and 30% by weight for dry and liquid application on non-farms[2].

Activity Data

Activity data were based on dry and liquid fertilizer usage as reported in CDFA Fertilizing Materials Tonnage Report[9] by county: Los Angeles County - 3,570 ton/yr, Orange County - 2,700 tons/yr, San Bernardino County - 536 ton/yr, Ventura County- 7,832 tons/yr and Riverside County 12,662 tons/yr). Fertilizer application and was distributed between farm and non-farm using the ratios developed for the 1987 SCAQS inventory[1] as shown on Table 8-2.

Spatial Allocation

On-farm fertilizer emissions were spatially allocated based on agricultural lands in the USGS land use database[10]. Non-farm fertilizer emissions were allocated to single family residential, golf courses, local parks, developed regional parks and cemeteries. The emissions for the SoCAB were allocated by USGS land use database[10] for each county then scaled by the SoCAB boundaries. Radian Study[2] applied the fertilizer tonnage by county by crop with a fertilizer application emission factor (lbs N/acre/yr), but fertilizer is applied differently even for similar crops. Because of the uncertainty, AVES assumed that the fertilizer tonnage for each county was applied evenly over the agricultural land use in each county.

Future Research

The available literature did not establish whether ammonia emissions are truly linear with respect to the quantity of fertilizer applied. More research is needed to investigate the factors affecting ammonia emissions from fertilizer application and handling including environmental conditions and farm management practices. Several factors that may influence fertilizer emissions are:

- Soil properties
- Fertilizer type
- Application technique
- Application schedules and cycles
- Meteorological conditions

Understanding the effects of these factors will help to precisely estimate the magnitude, location, and timing of ammonia emissions due to fertilizer application. In addition, it is important to understand whether soil emission factors include the application of fertilizer.

Better activity data is also needed. Improved emission factors were unusable because corresponding categories were unavailable in the activity data.

8.3 REFERENCES

1. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

2. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

3. Gharib, S., and G.R. Cass (1984*): Ammonia Emissions in the South Coast Air Basin*. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

4. California Department of Food and Agriculture (1987): *Fertilizing Materials Tonnage Report,* Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California.

5. County of Los Angeles, Department of Agriculture Commissioners and Weight and Measures, 1997 Crop Report.

6. County of Orange County, Department of Facilities and Resources Department, 1997 Orange County Crop Report.

7. Riverside County Agriculture Commissioners Office.

8. County of San Bernardino County, 1997 Crop Acreage and Value by Area.

9. California Department of Food and Agriculture (1998): *Fertilizing Materials Tonnage Report, July - December 1998,* Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California.

10. USGS land use database

Table 8-1. Fertilizer Usage

County	Fetilizer Usage (tons/yr)								
	Total Dry[a]	Total Liquid[a]	Farm Total Fertilizer N (tons/yr)	Non-Farm Total Fertilizer N (tons/yr)	Non-Farm/Farm Ratio[c]	Farm Dry Fertilizer N (tons/yr)	Farm Liquid Fertilizer N (tons/yr)	Non-Farm Dry Fertilizer N (tons/yr)	Non-Farm Liquid Fertilizer N (tons/yr)
Los Angeles County	3,206	364	3,603	3,229	0.90	1,691	192	1,515	172
Orange County	1,883	817	2,261	1,750	0.77	1,061	461	822	356
San Bernadino County	534	2	16,076	672	0.98	269	1	265	1
Riverside County	2,296	10,366	379	372	0.04	2,204	9,950	92	416
Ventura County	3,565	4,267	9,689	204	0.02	3,491	4,179	74	88
SoCAB TOTAL	**7,919**	**11,549**	**22,319**	**6,023**		**5,226**	**10,604**	**2,693**	**945**

[a] California Department of Food and Agriculture (1999): Fertilizing Materials Tonnage Report, July - December 1998, Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California.

[b] Radian, 1987 Ammonia Emission Inventory (1991), September.

[c] Non-Farm/Farm Ratio = Non-Farm Total Fertilizer (tons/yr)/ Farm Total Fertilizer (tons/yr).

Table 8-2. Fertilizer Ammonia Emissions

Los Angeles County

	Usage[a] (tons N/yr)	Emission Factor[b] (NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	1,690.75	0.10	205	0.56
Farm Liquid	191.96	0.02	5	0.01
Non-Farm Dry	1,515.25	0.30	552	1.51
Non-Farm Liquid	172.04	0.30	63	0.17
Total	**3,570**		**824.62**	**2.26**

Orange County

	Usage[a] (tons N/yr)	Emission Factor[b] (tons NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	1,061.45	0.10	129	0.35
Farm Liquid	460.54	0.02	11	0.03
Non-Farm Dry	821.55	0.30	299	0.82
Non-Farm Liquid	356.46	0.30	130	0.36
Total	**2,700**		**569.21**	**1.56**

San Bernadino County

	Usage[a] (tons N/yr)	Emission Factor[b] (tons NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	269.49	0.10	33	0.09
Farm Liquid	1.01	0.02	0.02	0.0001
Non-Farm Dry	264.51	0.30	96	0.26
Non-Farm Liquid	0.99	0.30	0.36	0.001
Total	**536**		**129.47**	**0.35**

Riverside County

	Usage[a] (tons N/yr)	Emission Factor[b] (tons NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	2,204	0.10	268	0.73
Farm Liquid	9,950	0.02	242	0.66
Non-Farm Dry	92	0.30	34	0.09
Non-Farm Liquid	416	0.30	152	0.42
Total	**12,662**		**694.33**	**1.90**

Ventura County

	Usage[a] (tons N/yr)	Emission Factor[b] (tons NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	3,491	0.10	424	1.16
Farm Liquid	4,179	0.02	101	0.28
Non-Farm Dry	74	0.30	27	0.07
Non-Farm Liquid	88	0.30	32	0.09
Total	**7,832**		**584.29**	**1.60**

Table 8-2. Fertilizer Ammonia Emissions

SoCAB	Usage[a] (tons N/yr)	Emission Factor[b] (tons NH_3/ton)	Emissions (tons/yr)	(tons/day)
Farm Dry	5,226	0.10	635	1.74
Farm Liquid	10,604	0.02	258	0.71
Non-Farm Dry	2,693	0.30	981	2.69
Non-Farm Liquid	945	0.30	344	0.94
Non-Farm Total[c]	**15,829**		**892**	**2.44**
Non-Farm Total[d]	**3,639**		**1,326**	**3.63**
Total	**19,468**		**2,218**	**6.08**

[a] See Table 8-2

[b] California Department of Food and Agriculture (1999): Fertilizing Materials Tonnage Report, July - December 1998, Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California.

[c] Farm Total is the sum of Farm Dry and Farm Liquid.

[d] Non-Farm Total is the sum of Non-Farm Dry and Non-Farm Liquid.

Section 9

INDUSTRIAL SOURCES

Ammonia emissions from industrial sources are produced from a variety of processes and are approximately 13 tons/day. Fugitive ammonia emissions occur during ammonia use in refrigeration, metal heat treating, blueprinting production and water treatment processes. NOx control (ammonia slip), combustion, ammonia production, ammonia nitrate/phosphate production, urea production, and fertilizer production also produce ammonia emissions.

For the purpose of this inventory, AVES concentrated on industrial sources that used ammonia supplied by an outside vendor rather than combustion or otherwise produced ammonia. Based on the Radian Study, combustion-produced ammonia sources accounted for approximately one percent of the inventory, or 4.6 tons/day. Therefore, AVES used the Radian Study values for these sources as a default.

9.1 1997 AQMP AMMONIA INVENTORY

The 1997 AQMP inventory[1], which was based on the Radian Study[2], used point source information gathered from the 1987 SARA 313 Toxics Release Inventory[3] (TRI) ammonia emissions reported for the SoCAB. The fugitive emissions (non-point source) data were used directly.

As part of the Radian Study ten facilities, comprising approximately 75 percent of the total emissions, were contacted to check stack parameters. The check included modeling parameters and ammonia emissions listed in the TRI. The remaining 25% of the emissions were treated as ground level area sources.

The Radian Study removed ammonia from fuel combustion and ammonia slip to prevent double counting. Facilities reporting under the lower 1988 TRI threshold were added to the Radian inventory.

9.2 INVENTORY UPDATE

For this inventory, industrial sources not associated with combustion were investigated in detail. These sources are:

- Refrigeration – Fugitive emissions from ammonia refrigeration occur as a result of system leaks. Therefore, by mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage.

- NO_x Control - Ammonia is injected into the exhaust of boilers, gas turbines and other process equipment to reduce NO_x emissions. The injected ammonia reacts on a 1:1 molar ratio of NH_3 to NOx. Excess ammonia is added to attempt to react all NOx. Good engineering practice results in approximately 10 ppm of unreacted NH_3 released from the stack (BACT requirement) by reducing NOx from 100 ppm to 10 ppm. The 10 ppm of excess ammonia that does not react to reduce NOx, but is emitted directly to the atmosphere is called ammonia slip. The 10 ppm ammonia slip can be correlated to 10% of the ammonia injected. The emission factor is 10 percent of usage.

- Metal Heat Treating - Ammonia is used in the nitriding process to heat treat steel. Based on minimal escape during the nitriding process, approximately 10% of ammonia supplied is emitted. The emission factor is 10 percent of usage.

- Waste Water Treatment - Ammonia is used in wastewater treatment for neutralization. Based on minimal losses during transfer, upsets and improper operation, approximately 15% of ammonia supplied is emitted because ammonia is highly soluble in water. The emission factor is 15 percent of usage[4].

- Blueprinting - Ammonia is used in blueprint processing. By mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage.

Radian Corporation developed a large database of combustion sources for the Radian Study. The total ammonia from traditional industrial combustion sources was only 6% of the overall inventory. The overall change in ammonia from traditional industrial combustion sources between 1991 and 1997 is considered to be insignificant compared to the estimate emissions from the ammonia emissions sources provided by the ammonia suppliers above. Therefore, the Radian Study ammonia emissions for industrial combustion sources were also used for this inventory.

Activity Data and Spatial Allocation

AVES contacted ammonia suppliers UNOCAL[5], LaRoche Industries Incorporated[6] and Hill Brothers Chemical Corporation[7] for activity data. Ammonia from these suppliers comprise approximately 99% of total ammonia deliveries to the SoCAB. We obtained 1998 usage information by ZIP Code and category (SCR, Refrigeration, metal treating, blueprinting and wastewater treatment). As a condition of providing the data, ammonia delivery data from each supplier was aggregated by category for each zip code to protect the proprietary nature of individual supplier information.

AVES also obtained 1996 SARA TRI data. However, these data do not include facilities with certain SIC codes and facilities handling less than 10,000 lbs./yr. of ammonia. In addition, AVES obtained data on equipment permitted by AQMD. However, there are many large ammonia users (e.g., refrigeration) that are not required to obtain permits. Therefore, the TRI and AQMD data were used only to check the supplier data by comparing the emissions of extremely large facilities (i.e., electric utilities) with the total supplier data for the ZIP code for that facility.

AVES used the ammonia supplier data for activity data because this method identifies a comprehensive universe of sources. The drawback is less spatial resolution because the data was supplied according to ZIP code. Data from each ZIP code was treated as an area source. The emissions are gridded by zip code. AVES used Source Classification Codes (SCCs) as identifiers because industrial sources have traditionally been identified by SCC.

Usage data, emission factors and emissions by use category are shown on Table 9-1.

9.3 REFERENCES

1. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

2. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

3. USEPA Office of Pollution Prevention and Toxics, 1997 State Data Files, Toxics Release Inventory (TRI) Available in Common Database Format. USEPA website.

4. Moerdyke, Donald D. (1999): UNOCAL, 376 S. Valencia Avenue, Brea, CA 92823. Phone Conversation, February.

5. Warn, T.E., Zelmanowitz, S., and Saeger, M. (1990): *Development and Selection of Ammonia Emission Factors* for Office of Research and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance EPA-600/7-90-014, June. EPA Contract No. 68-02-4374, Work Assignment No. 43.

6. Turner, Richard (1999): LaRoche Industries, Inc., 1675 N. Main Street, Orange, CA 92667-3442. Phone Conversations, April.

7. Hill, Ronald (1999): Hill Brothers Chemical Corporation, 1675 N. Main Street, Orange, CA. 92667-3442. Phone Conversation/Electronic Files, February.

Table 9-1. Industrial Source Ammonia Emissions

Category	Emission Factor (ton emitted/ ton supplied)	Usage[a] (Tons/year)	Emissions (tons/day)	Emissions (tons/year)
Refrigeration	100%	1,789	4.90	1,789
Metal Heat Treatment	10%	2,268	0.62	227
NOx Control[d]	10%	9,825	2.69	982
Blueprint	100%	74.5	0.20	74.5
Wastewater Treatment[d]	15%	306	0.13	45.9
SCAB Total		14,262	8.54	3,118

Category	Los Angeles Emissions, tons/yr	Orange Emissions, tons/yr	Riverside Emissions, tons/yr	San Bernardino Emissions, tons/yr	Ventura Emissions, tons/yr
Refrigeration	1,418	154	32.52	185	8.15
Metal Treatment	183	19.9	2.68	21.0	0.19
Flue Gas	866	42.1	7.58	63.3	3.53
Blue Print	55.3	9.13	2.66	7.36	0.06
pH Control	38.5	3.63	0.55	3.15	0.03

[a] Moerdyke, Donald D.(1999): UNOCAL, Phone Conversation, February.
Turner, Richard (1999): La Roche, Phone Conversations, April.
Hill, Ronald (1999): Hill Brothers, Phone Conversation/Electronic Files, February.

[c] SCAQMD Reg

[d] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. Final Report Prepared for Office of Reasearch and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corperation. Chapel Hill, N.C., PB90-235094, EPA-600/7-90-014, June.

Section 10

LANDFILLS

Ammonia emissions at landfills are produced by anaerobic digestion of the land filled materials, along with simple volatilization. Anaerobic digestion produces methane, ammonia, amines, reduced sulfur compounds, and other hydrocarbons. These processes occur at both active and inactive landfills. Landfill emissions as inventoried by this study and as estimated by the San Joaquin Valley Study[1] are not significant.

10.1 1997 AQMP AMMONIA INVENTORY

Landfill emissions were not quantified in the Radian Study[2] and were thus not included in the 1997 AQMP[3].

10.2 INVENTORY UPDATE

Emission Factors

Very little research has been performed to quantify ammonia emissions from landfills. The methodology used in San Joaquin Valley Study was used to update the inventory with current data. The San Joaquin Valley Study method assumes ammonia emissions are proportional to methane emissions at a ratio of 0.007 pounds ammonia per pound of methane.

Activity Data

AVES downloaded total organic gas (TOG) and reactive organic gas (ROG) emissions for landfills from the 1996 Emissions Inventory located on the California Air Resources Board (ARB) website[4]. Emissions were queried by facility name from the Emission Inventory Database (CEIDARS) under the Toxic Hot Spots webpage on the ARB website[4]. TOG includes all organic gases, and ROG excludes methane, which is non-reactive. Therefore, the ROG emissions were subtracted from TOG emissions to obtain methane emissions. ARB did not provide information for the two of the larger landfills, Chiquita Canyon and Frank Bowerman Sanitary Landfills. Methane emissions data from similar sized landfills in the ARB database were used for these landfills. Landfill sizes used for the comparison of landfill sizes were obtained from the California Integrated Waste Management Board CIWMB[5]. Table 10-1 presents the landfill emissions by facility.

Spatial Allocation

Emissions were spatially allocated as point sources with latitude/longitude values from the SWIS database[6]. As with the San Joaquin Valley Study, estimated landfill ammonia emissions using the 0.007 ammonia to methane ratio method are insignificant.

Future Research

Landfills and composting operations ammonia emissions were expected to be close to the same order of magnitude. However, landfill emissions are three orders of magnitude lower as calculated using the 0.007 ratio.

The magnitude of this difference leads one to believe that the landfill emission factor ratio is too low. For the Athens Disposal landfill that reported ammonia emissions in the CARB database, the reported emissions are much higher than the emissions estimated from the 0.007 ratio method (0.335 tons/yr vs. 0.0025 tons/yr). The CARB only reports emissions and does not detail the methodology used to obtain the emissions. Further direct ammonia emission testing is recommended.

10.3 REFERENCES

1. Coe, D., Chinkin, L., Loomis,C., Wilkinson, J., Zwicker, J., (1998): *Technical Support Study 15: Evaluation and Improvement of Methods for Determining Ammonia Emissions in the San Joaquin Valley*. Prepared for the California Air Resources Board by Sonoma Technology, Inc., January.

2. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

3. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

4. California Air Resources Board (1999), California Emissions Inventory Data Analysis and Reporting System II (CEIDARS II). ARB website, http://o2.arb.ca.gov:9000/pub/plsql/facinfo.get_req.

5. California Integrated Waste Management Board (1999), California Waste Facilities, Sites, & Operations Database Solid Waste Information System (SWIS) Database. CIWMB website, http://www.ciwmb.ca.gov/swis/SWISSrch.htm.

6. Amerine, Skip (1999), California Integrated Waste Management Board, telephone and facsimile correspondence, June 24.

Table 10-1. Landfill Ammonia Emissions

Name[a]	County	TOG,[a] tons/yr	ROG,[a] tons/yr	Methane,[b] tons/yr	Ammonia,[c] tons/yr	Ammonia, tons/dy
Azusa Gas Systems Operations	Los Angeles	1.4	0.7	0.7	5.24E-03	1.43E-05
BKK Corp.	Los Angeles	70.6	35.3	35.3	2.47E-01	6.76E-04
Browning-Ferris Industries of	Los Angeles	0.4	0.3	0.1	9.94E-04	2.72E-06
Calmat Properties Go. (Hewitt P)	Los Angeles	0.2	0.1	0.1	4.97E-04	1.36E-06
Crown Disposal Co. Inc.	Los Angeles	3.1	2.9	0.2	1.21E-03	3.32E-06
LA City, Bureau of Sanitation	Los Angeles	12.4	7.6	4.8	3.39E-02	9.28E-05
LA City, LA-Glendale Water Rec	Los Angeles	2.2	1.3	0.9	6.60E-03	1.81E-05
LA City CO, Sanitation District Uni	Los Angeles	2.2	1.9	0.3	1.97E-03	5.39E-06
LA City CO, Sanitation District	Los Angeles	4	2.3	1.7	1.16E-02	3.19E-05
LA Co. Sanitation Dist	Los Angeles	7.2	4.9	2.3	1.59E-02	4.36E-05
LA Co., Sanitation District	Los Angeles	40.4	13.0	27.5	1.92E-01	5.26E-04
LA CO., Sanitation Dist. Calabas	Los Angeles	3.4	2.8	0.6	3.94E-03	1.08E-05
Waste Management	Los Angeles	2.2	2.0	0.2	1.34E-03	3.66E-06
Waste Management Disposal Svcs.	Los Angeles	1.4	0.9	0.5	3.19E-03	8.73E-06
Waste Management of San Gabrie	Los Angeles	4.7	3.7	1.0	6.78E-03	1.86E-05
Western Waste Industries	Los Angeles	2.8	2.6	0.2	1.13E-03	3.11E-06
Whittier City	Los Angeles	0.7	0.5	0.2	1.74E-03	4.78E-06
Sakaroff Services	Los Angeles	2.2	2.1	0.1	6.65E-04	1.82E-06
Chiquita Canyon Sanitary Landfill	Los Angeles	3.4	2.8	0.6	3.94E-03	1.08E-05
Los Angeles County Total		**165**	**87.8**	**77.1**	**5.40E-01**	**1.48E-03**
Orange County of -Intg. Wst M.	Orange County	205	15.3	190.1	1.33E+00	3.65E-03
Frank Bowerman Sanitary Landfill	Orange County	40	13.0	27.5	1.92E-01	5.26E-04
Orange County Total		**246**	**28.3**	**218**	**1.52E+00**	**4.17E-03**
O'Brien Environmental Energy	Riverside	69.3	5.31	63.99	4.48E-01	1.23E-03
Western Waste Inds-(El Sobrante)	Riverside	0.4	0.26	0.14	9.94E-04	2.72E-06
Riverside County Total		**69.7**	**5.57**	**64.13**	**4.49E-01**	**1.23E-03**
San Bernardino Co. Solid Waste	San Bernardino	2.9	1.65	1.25	8.76E-03	2.40E-05
San Bernardino Co., Solid Wast	San Bernardino	2.7	1.12	1.58	1.11E-02	3.03E-05
San Bernardino County Total		**5.60**	**2.77**	**2.83**	**1.98E-02**	**5.43E-05**
Oxnard Landfill	Ventura	47.5	4.62	42.9	3.00E-01	8.22E-04
Simi Valley	Ventura	2.9	1.43	1.5	1.03E-02	2.83E-05
Ventura County Total		**50.4**	**6.05**	**44.4**	**3.10E-01**	**8.51E-04**
SoCAB Total		**486**	**124**	**362**	**2.53**	**6.93E-03**

[a] CARB (1999). California Emissions Inventory Data Analysis and Reporting System II (CEIDARS II).

[b] Methane, tons/yr = TOG, tons/yr - ROG, tons/yr

[c] Ammonia, tons/yr = Methane, tons/yr x 0.007 lb Ammonia/lb Methane

Section 11

COMPOSTING OPERATIONS

Composting is the aerobic (oxygen dependent) and anaerobic (oxygen independent) degradation of organic waste. Aerobic digestion is preferred because it primarily results in carbon dioxide. Anaerobic digestion produces methane, ammonia, amines, reduced sulfur compounds, and other hydrocarbons. The digestion reactions are exothermic (heat producing) which raise the temperature of the compost pile to 120 - 150°F. The organic end product is a stable, pathogen free soil amendment and fertilizer. Compost materials can include manure, dewatered sewage sludge from publicly owned treatment works (POTWs), wood chips, and agricultural (green) wastes.

Composting typically occurs outdoors in large piles called windrows. The carbon-nitrogen, moisture and oxygen content are monitored and adjusted to ensure sufficient microorganism activity.

Composting material has traditionally been disposed in landfills are now being sent to composting facilities. It is estimated that approximately 10% of organic waste was composted in 1990[1]. California anticipates diverting 50% of waste away from landfills by 2000[1]. Therefore, as more material is composted, emissions will be diverted from landfills to composting facilities. The ammonia emission rate is effected by composition, aeration, frequency of mechanical turning, surface area, protection from wind, moisture, and control technology (for covered windrows).

Ammonia emissions from commercial composting operations are approximately 10 tons/day.

Emissions from home composting and home fertilizer application were investigated but determined to be insignificant sources.

11.1 1997 AQMP AMMONIA INVENTORY

Emissions from composting were not inventoried in the Radian Study[2] and therefore not included in the 1997 AQMP[3].

11.2 INVENTORY UPDATE

Emission Factors

AVES applied the Synagro/Recyc emission factor, based on source test data[6], of 2.755 pounds ammonia per ton of material processed to all composting facilities that did not have facility-specific source test data. Source test data were used at EKO Systems and Rancho Las Virgenes Municipal Water District.

Activity Data

Activity data from the California Integrated Waste Management Board's California Waste Facilities, Sites, & Operations Database/Solid Waste Information System (SWIS) Database[8] was used to obtain the amount of material composted at each facility. Additional information was obtained by phone conversation[9]. Activity data, emission factors and emissions are shown on Table 11-1.

Spatial and Temporal Allocation

The compost facilities are treated as point sources. Facilities were geocoded from Latitude/Longitude values that were taken from SWIS database.

Future Research

Additional source testing would determine seasonal and diurnal temporal emission distributions.

11.3 REFERENCES

1. California Integrated Waste Management Board (CIWMB (1999): Waste Characterization Data Base. CIWMB website.

2. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramen.o CA by Radian Corporation., Sacramento CA.

3. South Coast Air Quality Management District (SCAQMD). (1996) 1997 Air Quality Management Plan, November, 16.

4. South Coast Air Quality Management District (1996b): Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc.

5. South Coast Air Quality Management District (1996b): Source Test Report 95-0032/96-003 Conducted at EKO Systems and Source.

6. AeroVironment, (1996). Odor Study Final Report Recyc, Inc. Composting Facility, Temescal Canyon, CA.

7. South Coast Air Quality Management District (1996b): Source Test Report 95-0034 conducted at Rancho Las Virgines Municipal Water District.

8. California Integrated Waste Management Board (1999): California Waste Facilities, Sites, & Operations Database/Solid Waste Information System (SWIS) Database. CIWMB website.

9. Rimmer, John (1996): Recyc. Inc., 22500 Temescal Canyon Road, Corona, CA. Phone Conversations, March.

Table 11-1. Compost Operations Ammonia Emission Factors

Source Test Information

Facility	Facility Type	Emissions, lb/ton mix	Emissions, lb/hr-ton mix	Emissions, lb/hr-1000 ft^2
Rancho Las Virgenes Municipal Water District[a]	Green Material/Sludge/ Saw Dust	0.7	5.80E-04	0.036
Synagro - Recyc Inc.[b]	Compost/Sludge/ Stable	2.7		0.266
EKO Systems[c]	Sludge/Manure	3.28	2.73E-03	0.175
San Joaqin Composting, Inc.[d]		2.81	2.07E-03	0.107

Assumptions

[a] AeroVironment, (1996). Odor Study Final Report Recyc, Inc. Composting Facility, Temescal Canyon, CA.

[b] Telephone conversation with John Brimmer of Recyc., Inc., March 1996.

[c] South Coast Air Quality Management District (1996b): Source Test Report 95-0032/96-003 Conducted at EKO Systems and Source.

[d] South Coast Air Quality Management District (1996b): Source Test Report 96-0007/96-0008/96-0009, conducted at San Joaquin Composting Inc.

All facilities operate 5 days/week, 52 weeks/year.

Table 11-2. Compost Operations Ammonia Emissions

Facility Name[a]	County	Throughput tons/yr[b]	Emissions, tons/day	Emissions, tons/yr	Emission Factor, lb/ton mix	Facility Type
Griffith Park Composting Facility	Los Angeles	2,078	0.008	2.9	2.755[d]	Sludge/Green/Zoo
Rancho Las Virgenes Composting Facility	Los Angeles	10,000	0.010	3.5	0.7[c]	Green Material/Sludge/Saw Dust
Whittier Fertilizer	Los Angeles	2,600	0.010	3.6	2.755[d]	Green Waste
JWPCP In-Vessel Composter Pilot Project	Los Angeles	3,900	0.015	5.4	2.755[d]	Sludge
Chiquita Canyon Landfill	Los Angeles	48,077	0.18	66.2	2.755[d]	Green Waste
Lancaster Landfill and Recycling	Los Angeles	152,880	0.58	210.6	2.755[d]	Agricultural/Wood/Solid Waste
Los Angeles County Total		**219,535**	**0.80**	**292**		
Leisure World	Orange County	1,875	0.007	2.6	2.755[d]	Green Waste
Sierra Soils	Orange County	6,250	0.024	8.6	2.755[d]	Green Waste, Manure/Waste Wood
Murai Farms	Orange County	14,423	0.054	19.9	2.755[d]	Green Waste
R&S Composting	Orange County	37,500	0.142	51.7	2.755[d]	Green Waste
Tierra Verde Industry	Orange County	109,200	0.412	150	2.755[d]	Green Waste
H&H Topsoil	Orange County	125,000	0.472	172	2.755[d]	Green Waste
Aquinaga Fertilizer	Orange County	125,000	0.472	172	2.755[d]	Green Waste
Tierra Verde La Pata Facility	Orange County	130,000	0.491	179	2.755[d]	Agricultural/Wood
Orange County Total		**549,248**	**2.07**	**757**		
B.P. John Wood Hauling	Riverside	62,500	0.236	86	2.755[d]	Green Waste
California Biomass	Riverside	75,000	0.283	103	2.755[d]	Green Waste, Wood, Paper
OLM Scotts and Sons	Riverside	78,000	0.294	107	2.755[d]	Green Waste
Synagro - Recyc Inc.	Riverside	130,000[e]	0.491	179	2.755[d]	Composte/Sludge/Stable
Whitefeather Farms	Riverside	130,000	0.491	179	2.755[d]	Green Waste
World Products Recycling	Riverside	230,769	0.871	318	2.755[d]	Green Waste
Inland Empire Composting	Riverside	312,000	1.177	430	2.755[d]	Green Waste/Food
Riverside County Total		**888,334**	**3.84**	**1,403**		
One-Stop Landscape Supply	San Bernardino	130,000	0.49	179	2.755[d]	Green Waste/Sludge
Inland Empire Composting	San Bernardino	182,000	0.69	251	2.755[d]	Green Waste
California Biomass	San Bernardino	75,000	0.28	103	2.755[d]	Green Waste, Wood, Paper
EKO Chino Basin Municipal Water Division	San Bernardino	401,482	1.52	553	3.28[f]	Sludge/Manure
San Bernardino County Total		788,482	3.0	**1,086**		

Table 11-2. Compost Operations Ammonia Emissions

Facility Name[a]	County	Throughput tons/yr[b]	Emissions, tons/day	Emissions, tons/yr	Emission Factor, lb/ton mix	Facility Type
Ojai Valley Waste Water Treatment Plant	Ventura	1,095	0.004	1.51	2.755[d]	Sludge
Ventura County Total		**1,095**	**0.004**	**1.51**		
SoCAB TOTAL		**2,445,599**	**9.7**	**3,538**		

[a] California Integrated Waste Management Board (1999), California Waste Facilities, Sites, & Operations Database Solid Waste Information System (SWIS) Database.

[b] Data in SWIS was reported in either tons/time, cubic yards/time or cubic feet/time. An average density of 2.03 tons/cubic yard calculated in Table 11-3 was used to convert volume to weight.

[c] South Coast Air Quality Management District (1996b): Source Test Report 95-0034 conducted at Rancho Las Virgines Municipal Water District.

[d] AeroVironment, (1996). Odor Study Final Report Recyc, Inc. Composting Facility, Temescal Canyon, CA.

[e] Telephone conversation with John Bremer of Recyc., Inc., March 1996.

[f] South Coast Air Quality Management District (1996b): Source Test Report 95-0032/96-003 Conducted at EKO Systems and Source.

[g] South Coast Air Quality Management District (1996b): Source Test Report 96-0007/96-0008/96-0009, conducted at San Joaquin Composting Inc.

All facilities operate 5 days/week, 52 weeks/year.

Table 11-3 Calculation of Average Density

Material	Specific Gravity*	Density of Water, tons/cubic yard	Density, tons/cubic yard
Ground Garbage	1.06	1.44	1.53
Moist Sludge Cake	1.43	1.44	2.06
Dry Sludge Cake	1.43	1.44	2.06
Vermiculite	2.5	1.44	3.60
Dry Compost	1.56	1.44	2.25
Shredded Paper	1	1.44	1.44
20 lb Garbage, 10 lb Air-Dry Sludge Cake	1.23	1.44	1.77
20 lb Garbage, 10 lb Moist Sludge Cake, 3 lb Vermiculite	1.42	1.44	2.05
20 lb Garbage, 10 lb Air-Dry Sludge Cake, 4 lb Paper	1.15	1.44	1.66
20 lb Garbage, 10 lb Moist Sludge Cake, 5 lb Paper	1.15	1.44	1.66
21 lb Garbage, 10 lb Moist Sludge Cake, 5 lb Paper, 2.5 lb Air Dry Compost	1.53	1.44	2.21
Average	**1.41**		**2.03**

*Haug, Roger Tim. (1980). Compost Engineering: Principles and Practice. Technomic Publishing Co., Inc, Lancaster.

Density, tons/cubic yard = Specific Gravity x Density of Water, tons/cubic yard

Section 12

OCEANS AND OTHER BODIES OF WATER

Oceanic ammonia chemistry is tied to nitrogen and sulfur cycles, overall water temperature, and nutrient concentrations[1].

For the SoCAB, this source was determined to be insignificant.

12.1 1997 AQMP AMMONIA INVENTORY

Ammonia emissions from the ocean were not examined in the Radian Study[2] and consequently not included in the 1997 AQMP[3].

12.2 INVENTORY UPDATE

Ammonia emissions from the ocean and/or other bodies of water should be omitted because of the great uncertainties in emission estimates, the lack of potential impact to inland areas and the very low measured concentrations in coastal regions of the SoCAB.

12.3 REFERENCES

1. Quinn, Patricia K., Timothy S. Bates, and James E. Johnson (1990): Interactions Between the Sulfur and Reduced Nitrogen Cycles Over the Central Pacific Ocean, *Journal of Geophysical Research*, Vol. 95, No. D10, pp. 16,405-16,416, September.

2. Dickson R.J. et al. (1991) *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

3. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

Section 13

PRESCRIBED BURNING

Emissions from prescribed burning are dependent on vegetation, moisture content, and soil. Vegetation with higher nitrogen content will produce more ammonia. High moisture will cause burning material to smolder, which increases emissions.

13.1 1997 AQMP AMMONIA INVENTORY

Ammonia emissions from prescribed burning were not examined in the Radian Study[1] and consequently were not included in the 1997 AQMP[2].

13.2 INVENTORY UPDATE

Emission Factors

Based on emission factors and prescribed burning activity for Los Angeles and Riverside Counties, ammonia emissions from prescribed burning are not an important contribution to the inventory. No prescribed burning is conducted in Orange County. AVES obtained 1997 data on prescribed burning from Los Angeles[3] and Riverside Counties[4]. San Bernardino County activity is assumed to be equivalent to Riverside County. Emission factors based on type of material burned are presented in Appendix C.

Activity Data

Activity data for 1997 was used to calculate an annual, basin-wide, emission rate, which is included in the annual inventory.

Spatial Allocation

Incorporation of prescribed burn emissions into the gridded inventory for daily purposes would be misrepresentative because the location of the prescribed burns change from year to year and the burns are event oriented (i.e., they do not occur daily or at regular intervals).

13.3 REFERENCES

1. Dickson R.J. et al. (1991) *Development of the Ammonia Emission Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation., Sacramento CA.

2. South Coast Air Quality Management District (SCAQMD). (1996) *1997 Air Quality Management Plan*, November, 16.

3. Takeshita, Michael, (1999): County of Los Angeles Fire Department, Forestry Division, Vegetation Management Unit, telephone and facsimile, March, 8.

4. Pimlott, Ken (1999) California Department of Forestry and Fire Protection, Riverside Ranger Unit, telephone and facsimile, March, 11.

Section 14

EMISSIONS GRIDDING

14.1 METHODOLOGY

The final product of this study is a 1997 ammonia emissions inventory, spatially resolved and gridded on the South Coast Air Quality Management District's modeling domain. Figure 14-1 displays the modeling domain for which the gridded inventory was developed. The geographic extent of the domain is identical to the District's AQMP modeling domain, however the horizontal resolution is 1 km by 1 km. The gridded inventory was developed at the higher 1 km resolution in order to facilitate subsequent spatial aggregation and merging with existing gridded emission component data files. Although the modeling domain includes all or portions of nine counties in Southern California, the updated ammonia emission data used in this study was provided only for the following five counties within the South Coast Air Basin; Los Angeles, San Bernardino, Riverside, Orange and Ventura. Data for both area and point sources were obtained in the form of Excel spreadsheets and subsequently exported and reformatted for input in to the EPA's emission processing system, EPS2.0[1]. Note that no mobile source emissions data were used for gridding, nor was any temporal allocation considered.

Area Sources

The process of gridding area source emissions using EPS2 requires the development of spatial surrogate data in order to allocate emissions from the various sources to the appropriate grid cells in the modeling domain. Unique identification codes are assigned to each surrogate category used in the spatial allocation. In addition to spatial surrogate data, EPS2 requires that each distinct source category be identified with a unique ASC(SEC) code. Cross references tables are then used to match the emission source categories with the corresponding surrogate using these codes.

Spatial surrogates for area sources were developed from three sources of Land Use/Land Cover (LULC)[2] and population data. USGS LULC 1:100,000 scale (200 meter) resolution data were obtained in a format suitable for input to the ArcInfo GIS software system from the EPA's anonymous FTP site. These data use a 2 level Anderson classification scheme for deriving LULC codes. In addition to the USGS LULC data, land-use data from the Southern California 1990 Aerial Land Use Study[3] was obtained from the District and used for allocation of emissions from goats, horses and mules/burros/donkeys as discussed in Section 2. The emissions from mules/burros/donkeys and horses were split and allocated equally between the rural residential-low density and horse ranch AIS categories. Emissions from goats were allocated to the dairy and intensive livestock AIS category. Domestic sources were spatially allocated by population density. The 1990 US Census data[4] was obtained in

FoxPro format and processed into the appropriate file formats for use in EPS2. All other area emission sources were spatially allocated according to the USGS LULC data.

Landuse data was imported into ArcInfo, converted to polygon coverages, and projected to the UTM grid of the modeling domain. Polygon coverages for the county FIPS codes were also imported and projected to the modeling grid. A grid representing the modeling domain was then overlaid and intersected with the polygon coverages for the LULC and FIPS codes. The resultant coverage was then exported as text data file containing the fractional area of each LULC code in each grid cells referenced by FIPS codes. The resulting data was reformatted using Perl to provide the required gridded surrogate data file for input to the EPS2 GRDEM module. The 1990 Census data was processed in a similar manner to provide the density in each grid cell for each county in the domain.

Tables 14-1 through 14-3 summarize the spatial allocation data for treatment of area sources. Table 14-1 provides the description of each emission source category, the unique ASC code assigned to each and the corresponding spatial surrogate category/codes. In some cases, multiple Anderson level LULC codes are combined into a single surrogate category. For this reason, the EPS2 system requires an additional cross reference, or mapping, file to associate a single surrogate category to each unique combination of landuse codes. These codes are given in the last column of Table 14-1. Tables 14-2 and 14-3 summarize the USGS and AIS landuse classification schemes, respectively. Note that the while the USGS uses only the 2-level Anderson classification system, the AIS data provides up to 4 levels of Anderson-type classifications.

Figure 14-2 displays the distribution of the spatial surrogate data on the AQMP modeling domain. Although the surrogate data is generated on the entire domain, note that only those counties for which emission data is provided will be included in the gridded inventory.

Point Sources

Certain categories of emission data were treated as point sources and processed with the EPS2 system. These include a portion of the dairy and poultry farms, landfills, composting and publicly-owned treatment works. These categories, along with the unique SCC/CES codes for each, are summarized in Table 14-4. Since no specific stack parameters are provided, the EPS2 system treats these sources as low level point sources and allocates their emissions to the appropriate grid cell based on the geographical UTM coordinates provided for each facility.

On notable exception are the ammonia emissions from industrial sources. The sources in this category include refrigeration, NOx control, metal heat treating, waste water treatment and blueprinting. As the location of these sources is provided only by postal

ZIP Code[5] (as discussed in Section 9), they are treated as area sources using the ZIP Code as a spatial surrogate. These source categories and their corresponding ASC codes are summarized in Table 14-1 above. ArcInfo ZIP Code coverages[5] were obtained from Geographic Data Technology, Inc. and processed with the ArcInfo GIS software in a manner similar to the LULC data.

Combustion Point Sources

Combustion point source emission data from the existing SCAQMD inventory[6] were obtained from the district and remapped to the 1 km by 1 km modeling domain. Because the data was received in MEDS (Modeling Emission Data System)[7] file format, the precise location of the sources was not available. The MEDS data files contain the grid cell indices of the sources on the 5 km by 5 km AQMP modeling domain. These grid cells were recalculated based on the high resolution 1 km domain and the emissions allocated over the twenty-five 1 km grid cells corresponding to the location in the 5 km grid resolution domain. Initial examination of the existing inventory data revealed that a number of sources were located outside of the modeling domain. For these sources, the locations were remapped to the new modeling domain and flagged in the data files as being outside of the domain. Table 14-4 summarizes the emission sources categories and corresponding SCC/CES codes.

EPS2 Processing

The EPS2 modules required for gridding the ammonia inventory include PREAM, PREPNT, CHMSPL, TMPRL and GRDEM. Since no temporal allocation is being considered, it is normally not necessary to run TMPRL or CHMSPL, however, as noted below, certain restrictions inherent in the EPS2 system required their use. In order to run EPS2, the raw emissions data must be reformatted into AMS and AFS workfiles. The Perl scripting language was utilized to convert the text data files (exported from Excel) into the required AMS and AFS workfile formats.

The AMS workfiles are input to PREAM (PREprocessor for Area and Mobile sources) as the first step in the EPS2 gridding procedure. The main functions of the PREAM module are to reformat AMS files into EMBR (Emissions Model Binary Record) formatted data files, and to split out the mobile source data. As no mobile emissions data are being gridded, this second function is not utilized. In order to aid in the quality assurance of the gridding process, PREAM was first run separately for each area source category. The resulting message and report files were then checked for completeness prior to submitted the combined AMS workfiles for processing by PREAM.

AFS workfiles are input to the PREPNT (PREprocessor for PoiNT sources) module to process the point source data. As with PREAM, the main function of PREPNT is to reformat the AFS workfile data into EMBR file format. PREPNT was also run separately for each source category and the resulting message and report files checked prior to submitting the combined AFS file for final processing.

Since the EPS2 system does not recognize NH3 as a criteria pollutant, it was necessary to run the CHMSPL (CHeMical SPLit) module of EPS2 in order to input the ammonia emissions data into the processing system as CO and "speciated" into NH_3. The resulting data are "speciated" EMBR files. Similarly, the TMPRL (TeMPoRaL allocation) module was run in order to obtain hourly formatted emission records. As part of the QA process, non-MEDS (UAM) formatted hourly emissions data files were developed in order to obtained spatial plots of the gridded inventory.

The final step in the EPS2 gridding process is the GRDEM (GRiD EMissions) module. The GRDEM module performs the following functions; spatially allocate area sources based on gridded surrogate data, assign low-level point source emissions to grid cells based on source location, and create either a gridded EMBR or UAM-format low-level emission data file. For this project, a modified version of GRDEM was used to output MEDS formatted data files directly. For area sources, GRDEM spatially allocates county totaled emissions by source category based on the spatial surrogate apportionment for the source category as specified in the SCC(ASC)/gridded surrogate cross-reference file. The SCC(ASC)/gridded surrogate cross-reference file is used to assign a spatial surrogate to each SCC code. This surrogate code is then used to distribute the total county emissions into the appropriate model grid cell. GRDEM also requires the gridded surrogate file, which contains the distribution, by grid cell, of each type of surrogate within the modeling domain. Table 14-4 summarizes the emission source categories and corresponding SCC/CES codes.

The GRDEM output message files provide tabular summaries of emissions total by county and source category for both area and point sources and are provided in Table 14-5. Spatial plots of the final gridded NH_3 emission inventory are displayed in Figure 14-3.

14.2 QUALITY ASSURANCE

The EPS2 system provides a number of message and report files generated from each of the various modules used in the gridding procedure. For purposes of quality assurance, these files were evaluated at each stage of the processing to ensure that, for each source category, the total county-level emissions data were successfully ingested and written to EMBR files. Preliminary gridding of each source category was performed in order to provide spatial distribution plots of the emissions for visual inspection. Message and report files were also checked to ensure that the spatial surrogate codes were properly referenced to the appropriate emission source category for each of the five counties in the South Coast Air Basin.

Upon examination of the message and report files for the final gridding process, it was discovered that a number of emission data records for industrial point sources could not be processed due to invalid or unknown ZIP Codes within the modeling domain. The processing of the industrial sources was performed using the ZIP Codes in place of county FIPS codes in order to distribute gridded emissions spatially on the modeling domain. Since the ZIP Codes provided with these data were based on 1997 postal boundaries, they did not all match the ZIP Code coverages used, which were based on January 2000 data. A number of other ZIP codes could be located only by broad geographic regions (e.g., City of Los Angeles). For these instances, in order to prevent the loss of any emission data from the modeling domain, the data was distributed on the grid using the closest obtainable match for the unknown code based on visual inspection and/or city/county designation.

The combustion point sources obtained from the District's existing ammonia inventory also presented some possibly erroneous data. As discussed above, the data was re-mapped from the 5 km by 5 km grid domain to the 1 km by 1 km domain, spreading the emission data on the 5 km grid cells over the appropriate number of 1 km grid cells. In addition the raw data had to be shifted north by 10 km in order to allocate the data to the proper grid cells. There were, however, a number of sources, which were located outside of the modeling domain. Rather than remove the sources from the inventory, these data were retained after being flagged in the MEDS files as being outside of the domain.

REFERENCES

1. EPA, 1992. "Users Guide for the Urban Airshed Model. Volume IV: User's Manual for the Emissions Preprocessor System 2.0". USEPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. June, 1992.

2. USGS, Land Use and Cover Database.

3. AIS, 1990. "Southern California 1990 Aerial Land Use Study, Land Use Level III/IV Classification. Aerial Information Systems, 1990.

4. Census of Population and Housing, 1990: Summary Tape File 1 on U.S. Census Bureau Web Site (Summary Level: State-County) [machine-readable data files] / prepared by the Bureau of the Census-Washington: The Bureau, 1991.

5. Geographic Data Technology, Dynamap/ZIP Code Boundary & Inventory Files version 8, ARC/INFO Format, 2000.

6. Dickson R.J. et al. (1991) *Development of the Ammonia Emission Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board*, Sacramento CA by Radian Corporation, Sacramento CA.

7. California Air Resources Board, Modeling Emission Data System (MEDS), 1992

Table 14-1. Source Category Codes and Spatial Allocation for Area Sources.

Source Category	Source Category	Spatial Allocation	Anderson Landuse Codes	Surrogate mapping codes
Livestock				
Beef Cows	30417	GIS Rangeland	31,33	13
Heifers/Calves	30418	GIS Rangeland	31,33	13
Steers/Bulls	30419	GIS Rangeland	31,33	13
Hogs/Pigs	30440	GIS Confined Feedlots	23	3
Sheep/Lambs	30430	GIS Rangeland	31,33	13
Mules/Burros/Donkeys	30424/ 30423	AIS Rural Residential Low Density/Horse Ranches	1124/2700 (AIS codes)	11,10
Goats	30435	AIS Dairy & Intensive Livestock	2400 (AIS codes)	12
Rabbits	30439	GIS Confined Feedlots	23	3
Horses	30421/ 30422	AIS Rural Residential Low Density/Horse Ranches	1124/2700 (AIS codes)	11,10
Native Animals				
Bears	30592	GIS Forest	41,42,43	5
Deer	30591	GIS Forest	41,42,43	5
Soil				
Urban	30220	GIS Urban	11,12,13,14,15,16,17	1
Agriculture	30210	GIS Agriculture	21,22,23,24	2
Range/Pasture	30205	GIS Rangeland	21,31,33	4
Wetland	30230	GIS Wetland	61,62	6
Forest	30215	GIS Forest	41,42,43	5
Barren	30240	GIS Barren	71,72,73,74,75,76	7
Fertilizer				
Farm - Dry	30311	GIS Farmland	21	8
Farm - Wet	30312	GIS Farmland	21	8
NonFarm - Dry	30341	GIS Nonfarm Agriculture	22,23,24	9
NonFarm - Wet	30342	GIS Nonfarm Agriculture	22,23,24	9
Domestic				
Cat	30520	Population	1990 Census	14
Dog	30510	Population	1990 Census	14
Homeless	30561	Population	1990 Census	14
Respiration	30530	Population	1990 Census	14
Perspiration	30540	Population	1990 Census	14
Household Use	30550	Population	1990 Census	14
Other Untreated Human Waste	30562	Population	1990 Census	14
Cigarette	30570	Population	1990 Census	14
Cloth Diapers	30563	Population	1990 Census	14
Disposable Diapers	30564	Population	1990 Census	14

Table 14-1. Source Category Codes and Spatial Allocation for Area Sources.

Source Category	Source Category	Spatial Allocation	Anderson Landuse Codes	Surrogate mapping codes
Industrial Points				
Refrigeration	31505002	ZIP Code	ArcInfo ZIP Codes	15
Metal Treatment	30300934	ZIP Code	ArcInfo ZIP Codes	15
Flue Gas	10100601	ZIP Code	ArcInfo ZIP Codes	15
Blueprinting	40588801	ZIP Code	ArcInfo ZIP Codes	15
pH Control	30182002	ZIP Code	ArcInfo ZIP Codes	15

Table 14-2. USGS Anderson Land Use Classification

1 Urban or built-up land
 11 Residential
 12 Commercial and services
 13 Industrial
 14 Transportation, communication, utilities
 15 Industrial and commercial complexes
 16 Mixed urban or built-up land
 17 Other urban or built-up land
2 Agricultural land
 21 Cropland and pasture
 22 Orchards, groves, vineyards, nurseries, and ornamental horticultural
 23 Confined feeding operations
 24 Other agricultural land
3 Rangeland
 31 Herbaceous rangeland
 32 Shrub and brush rangeland
 33 Mixed rangeland
4 Forest land
 41 Deciduous forest land
 42 Evergreen forest land
 43 Mixed forest land
5 Water
 51 Streams and canals
 52 Lakes
 53 Reservoirs
 54 Bays and estuaries
6 Wetland
 61 Forested wetland
 62 Nonforested wetland
7 Barren land
 71 Dry salt flats
 72 Beaches
 73 Sandy areas not beaches
 74 Bare exposed rock
 75 Strip mines, quarries, gravel pits
 76 Transitional areas
8 Tundra
 81 Shrub and brush tundra
 82 Herbaceous tundra
 83 Bare ground
 84 Wet tundra
 85 Mixed tundra
9 Perennial snow or ice
 91 Perennial snowfields
 92 Glaciers

Table 14-3. Anderson Land Use Level III/IV Classification

1000 Urban or built-up
- 1100 Residential
  - 1110 Single Family Residential
    - 1111 High Density Single Family Residential
    - 1112 Low Density Single Family Residential
  - 1120 Multi-Family Residential
    - 1121 Mixed Multi-Family Residential
    - 1122 Duplexes, Triplexes and 2- or 3-Unit Condominiums and Townhouses
    - 1123 Low-Rise Apartments, Condominiums, and Townhouses
    - 1124 Medium-Rise Apartments and Condominiums
    - 1125 High-Rise Apartments and Condominiums
  - 1130 Mobile Homes and Trailer Parks
    - 1131 Trailer Parks and Mobile Home Courts, High Density
    - 1132 Mobile Home Courts and Subdivisions, Low Density
  - 1140 Mixed Residential
  - 1150 Rural Residential
    - 1151 Rural Residential High Density
    - 1152 Rural Residential Low Density
- 1200 Commercial and Services
  - 1210 General Office Use
    - 1211 Low- and Medium-Rise Major Office Use
    - 1212 High-Rise Major Office Use
    - 1213 Skyscrapers
  - 1220 Retail Stores and Commercial Services
    - 1221 Regional Shopping Mall
    - 1222 Retail Centers (Non-Strip With Contiguous Interconnected Off-Street Parking)
    - 1223 Modern Strip Development
    - 1224 Older Strip Development
  - 1230 Other Commercial
    - 1231 Commercial Storage
    - 1232 Commercial Recreation
    - 1233 Hotels and Motels
    - 1234 Attended Pay Public Parking Facilities
  - 1240 Public Facilities
    - 1241 Government Offices
    - **1242 Police and Sheriff Stations
    - **1243 Fire Stations
    - 1244 Major Medical Health Care Facilities
    - 1245 Religious Facilities
    - 1246 Other Public Facilities
    - 1247 Non-Attended Public Parking Facilities
  - 1250 Special Use Facilities
    - 1251 Correctional Facilities
    - 1252 Special Care Facilities
    - 1253 Other Special Use Facilities

Table 14-3. Anderson Land Use Level III/IV Classification (continued)

1260 Educational Institutions
- 1261 Pre-Schools/Day Care Centers
- **1262 Elementary Schools
- **1263 Junior or Intermediate High Schools
- **1264 Senior High Schools
- 1265 Colleges and Universities
- 1266 Trade Schools

1270 Military Installations
- 1271 Base (Built-up Area)
- 1272 Vacant Area
- 1273 Air Field

1300 Industrial

1310 Light Industrial
- 1311 Manufacturing, Assembly, and Industrial Services
- 1312 Motion Picture and Television Studio Lots
- 1313 Packing Houses and Grain Elevators
- 1314 Research and Development

1320 Heavy Industrial
- 1321 Manufacturing
- 1322 Petroleum Refining and Processing
- 1323 Open Storage
- 1324 Major Metal Processing
- 1325 Chemical Processing

1330 Extraction
- 1331 Mineral Extraction - Other Than Oil and Gas
- 1332 Mineral Extraction - Oil and Gas

1340 Wholesaling and Warehousing

1400 Transportation, Communications, and Utilities

1410 Transportation
- 1411 Airports
- 1412 Railroads
- 1413 Freeways and Major Roads
- 1414 Park and Ride Lots
- 1415 Bus Terminals and Yards
- 1416 Truck Terminals
- 1417 Harbor Facilities
- 1418 Navigation Aids

1420 Communication Facilities

1430 Utility Facilities
- 1431 Electrical Power Facilities
- 1432 Solid Waste Disposal Facilities
- 1433 Liquid Waste Disposal Facilities
- 1434 Water Storage Facilities
- 1435 Natural Gas and Petroleum Facilities
- 1436 Water Transfer Facilities
- 1437 Improved Flood Waterways and Structures
- 1438 Mixed Wind Energy Generation and Percolation Basin

Table 14-3. Anderson Land Use Level III/IV Classification (continued)

- 1440 Maintenance Yards
- 1450 Mixed Transportation
- 1460 Mixed Transportation and Utility

1500 Mixed Commercial and Industrial
1600 Mixed Urban
1700 Under Construction
1800 Open Space and Recreation

- 1810 Golf Courses
- 1820 Local Parks and Recreation
  - 1821 Local Park, Developed
  - 1822 Local Park, Undeveloped
- 1830 Regional Parks and Recreation
  - 1831 Regional Park, Developed
  - 1832 Regional Park, Undeveloped
- 1840 Cemeteries
- 1850 Wildlife Preserves and Sanctuaries
- 1860 Specimen Gardens and Arboreta
- 1870 Beach Parks
- 1880 Other Open Space and Recreation

1900 Urban Vacant
2000 Agriculture

- 2100 Cropland and Improved Pasture Land
  - 2110 Irrigated Cropland and Improved Pasture Land
  - 2120 Non-Irrigated Cropland and Improved Pasture Land
- 2200 Orchards and Vineyards
- 2300 Nurseries
- 2400 Dairy and Intensive Livestock, and Associated Facilities
- 2500 Poultry Operations
- 2600 Other Agriculture
- 2700 Horse Ranches

3000 Vacant

- 3100 Vacant Undifferentiated
- 3200 Abandoned Orchards and Vineyards
- 3300 Vacant With Limited Improvements
- 3400 Beaches (Vacant)

4000 Water

- 4100 Water, Undifferentiated
- 4200 Harbor Water Facilities
- 4300 Marina Water Facilities
- 4400 Water Within a Military Installation
- 4500 Area of Inundation (High Water)

**Critical Land Use - All critical land use is mapped. May be mapped below 2.5 acres in size down to a 1 acre minimum. Non-critical land uses are mapped at a 2.5 acre minimum mapping resolution. Non-critical land uses below the 2.5 acre size minimum are not mapped.

Table 14-4. Source Category Codes

Description	1997 AQMP SCC/CES	2000 AQMP SCC/CES
Refrigeration		31505002
Metal Treatment		30300934
Flue Gas		10100601
Blue Print		40588801
pH Control		30182002
Boiler, electrical generation natural gas	10100602	
Boiler, electrical generation natural gas	10100601	
Boiler, electrical generation natural gas	10100604	
Boiler, commercial/industrial natural gas	10300601	
Boiler, commercial/industrial natural gas	10300602	
Boiler, industrial natural gas	10200601	
Boiler, industrial natural gas	10200602	
Boiler, electrical generation processes gas	10100701	
Boiler, electrical generation processes gas	10100702	
Boiler, refinery gas	10200701	
Boiler, process gas	10201402	
Boiler, industrial process gas	10200710	
Turbine, cogeneration natural gas	20200203	
Cat	30520	30520
Dog	30510	30510
Homeless	30561	30561
Respiration	30530	30530
Perspiration	30540	30540
Household Use	30550	30550
Other Untreated Human Waste	30562	30562
Cigarette	30570	30570
Cloth Diapers		30563
Disposable Diapers		30564
Farm Dry		30311
Farm Liquid		30312
Non-Farm Dry		30341
Non-Farm Liquid		30342
Fertilizer - Farm Crop	30310	
Fertilizer - Orchards & Ornamentals	30320	
Fertilizer - Anhydrous Ammonia	30330	
Fertilizer - Non-Farm	30340	
Urban		30220
Agricultural		30210
Rangeland/Pasture		30205
Wetland		30230
Forest Land		30215
Barren Land		30240
Soil Surfaces	30200	
Bear		30592
Deer		30591
Poultry Farms		30450
Chickens - Layers	30451	

Table 14-4. Source Category Codes

Description	1997 AQMP SCC/CES	2000 AQMP SCC/CES
Chickens - Fryers	30452	
Chickens - Pullets	30453	
Turkeys	30460	
Dairy Cows		30415
Dairy Heifers		30416
Livestock Waste - Dairy Cattle	30411	
Livestock Waste - Range Cattle	30413	
Beef cows		30417
Heifers and Heifers Calves		30418
Livestock Waste - Feed Lot Cattle	30412	
Steers, Steer Calves, Bulls, and Bull Calves		30419
Hogs and Pigs	30440	30440
Sheep and Lambs		30430
Mules, Burros and Donkeys - Rural		30424
Mules, Burros and Donkeys - Ranch		30423
Goats		30435
Rabbits		30439
Horses, Rural		30421
Horses, Ranch		30422
Horses	30420	
Composting		30580
POTWs		50100701
Primary Settling Tank	50100702	
Secondary Settling Tank	50100703	
Landfills		57281

Table 14-5. Emission Summary by Area Source Category and County.

Source Category	Description	Los Angeles AQMP Emissions, tons/yr	Orange AQMP Emissions, tons/yr	Riverside AQMP Emissions, tons/yr	San Bernardino AQMP Emissions, tons/yr	Ventura AQMP Emissions, tons/yr	Domain-wide Emissions, tons/yr	Total AQMP Emissions, tons/yr
31505002	Refrigeration	154	32.5	185	8.1	1,418		1,802
30300934	Metal Treatment	20	2.7	21.0	0.2	183		228
10100601	Flue Gas	42	7.6	63.3	3.53	866		986
40588801	Blue Print	9.1	2.7	7.36	0.06	55.3		74.8
30182002	pH Control	3.6	0.6	3.1	0.03	38.5		46
30520	Cat	161	47.1	33.5	37.5	17.0		296
30510	Dog	1,474	431	314	351	159		2,730
30561	Homeless	491	82.8	78.6	87.9	39.8		780
30530	Respiration	16.1	4.7	2.50	2.8	1.27		27.3
30540	Perspiration	2,523	738	393	439	199		4,293
30550	Household Use	229	67.1	35.7	39.9	18.1		390
30562	Other Untreated Human Waste	229	67.1	35.7	39.9	18.1		390
30570	Cigarette	1.1	0.31	0.2	0.2	0.1		1.82
30563	Cloth Diapers	212	57.4	35.3	43.2	16.2		364
30564	Disposable Diapers	99.5	26.9	16.6	20.3	7.60		171
30311	Farm Dry	206	129	200	28.0	425		989
30312	Farm Liquid	4.7	11.2	181	0.02	102		298
30341	Non-Farm Dry	554	300	31.6	96.2	26.6		1,009
30342	Non-Farm Liquid	62.9	130	143	0.4	31.9		368
30220	Urban	1,154	328	233	395	129		2,239
30210	Agricultural	1,275	408	2,340	769	988		5,780
30205	Rangeland/Pasture	798	275.5	1,061	272	394		2,802
30230	Wetland	5.2	4.0	14.6	8.5	12.1		44.4
30215	Forest Land	376	31.4	210	693	501		1,812
30240	Barren Land	58.4	22.6	98.6	250	32.7		463
30592	Bear	1.9	0.2	1.1	3.5	2.5		9.1
30591	Deer						68.5	68.5
30417	Beef cows	143	29.9	332	372	183		1,059
30418	Heifers and Heifers Calves	32.1	6.3	747	1,018	45		1,848
30419	Steers, Steer Calves, Bulls, and Bull Calves	30.7	2.3	209	584	112		938
30440	Hogs and Pigs	17.1		18.0	146			181
30430	Sheep and Lambs	7.4	0.3	122	62.9	1.1		194
30424	Mules, Burros and Donkeys - Rural	0.5		0.9	0.6			2.0

Table 14-5. Emission Summary by Area Source Category and County.

Source Category	Description	Los Angeles AQMP Emissions, tons/yr	Orange AQMP Emissions, tons/yr	Riverside AQMP Emissions, tons/yr	San Bernardino AQMP Emissions, tons/yr	Ventura AQMP Emissions, tons/yr	Domain-wide Emissions, tons/yr	Total AQMP Emissions, tons/yr
30435	Goats	0.5		1.1	1.0	0.2		2.7
30439	Rabbits	0.04		3.9		0.01		4.0
30421	Horses, Rural	219	54.7	375	142	115		906
30423	Mules, Burros and Donkeys - Ranch	0.5		0.9	0.6			2.0
30422	Horses, Ranch	219	54.7	375	142	114.8		905
	Total	10,603	3,311	7,643	6,046	3,639	3,205	34,448

Combustion and mobile sources were not included in this table please see Table E1.

Table 14-6. Emission Summary by Point Source Category and County

Source Category	Description	Los Angeles AQMP Emissions, tons/yr	Orange AQMP Emissions, tons/yr	Riverside AQMP Emissions, tons/yr	San Bernardino AQMP Emissions, tons/yr	Ventura AQMP Emissions, tons/yr	Total AQMP Emissions, tons/yr
30415	Dairy Cows	83.2	17.4	2,910	4,740	108	7,859
30416	Dairy Heifers	10.7	2.08	252	339	15.3	619
57281	Landfills	0.54	1.53	0.45	0.020	0.31	2.85
30580	Composting	293	759	1,407	1,090	1.51	3,551
30450	Poultry Farms	80.1	0.01	5,836	2,353	0.063	8,270
50100701	POTWs	19.7	6.36	0.95	2.87		29.9
Grand Totals		487	787	10,406	8,525	125	20,331

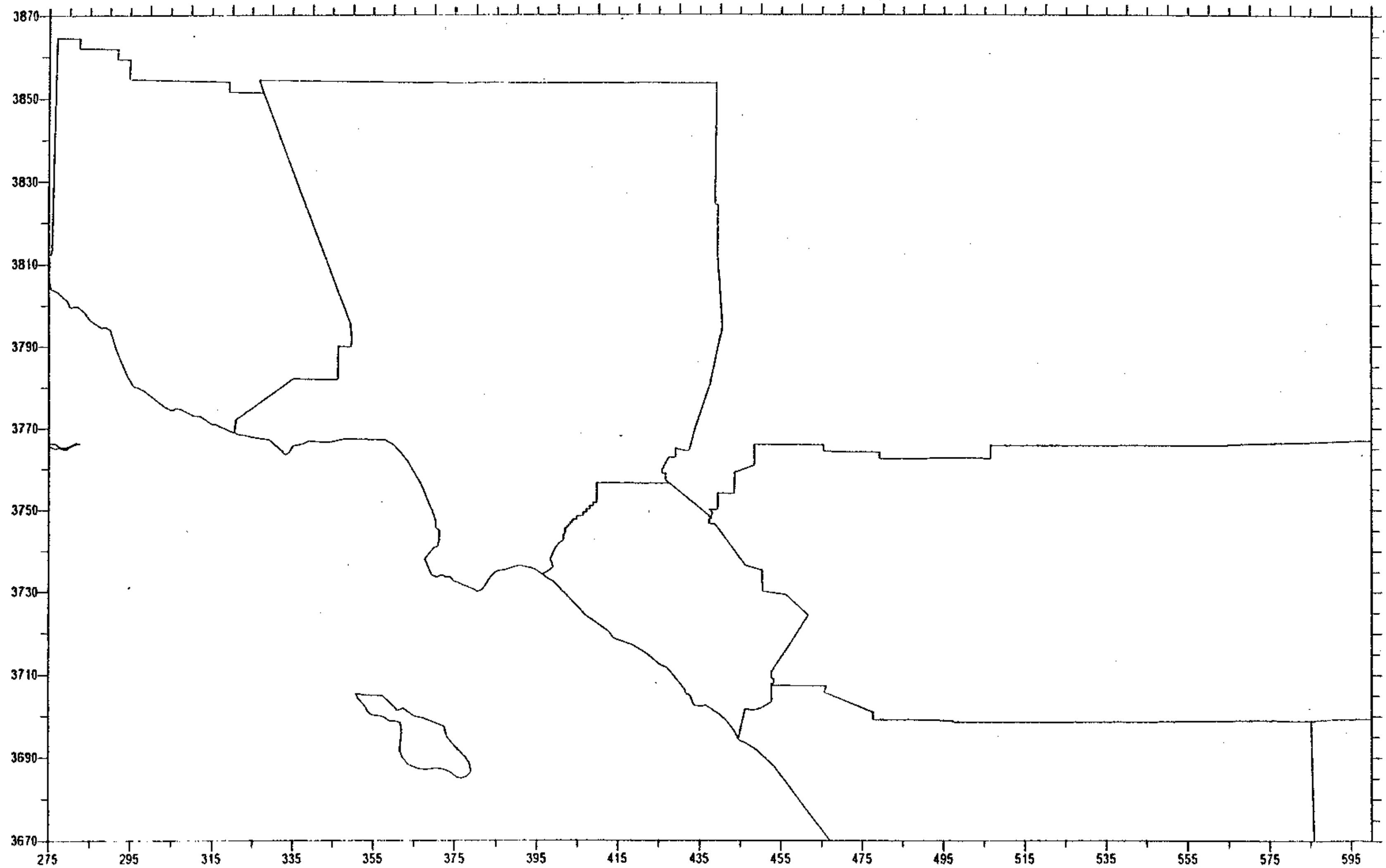
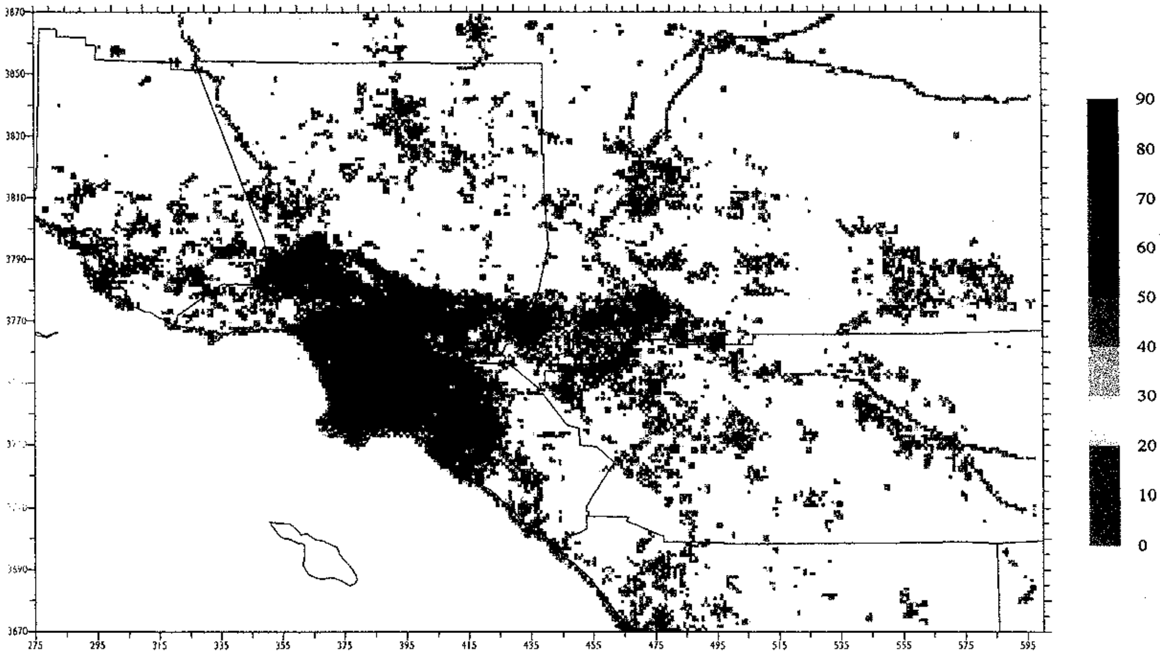
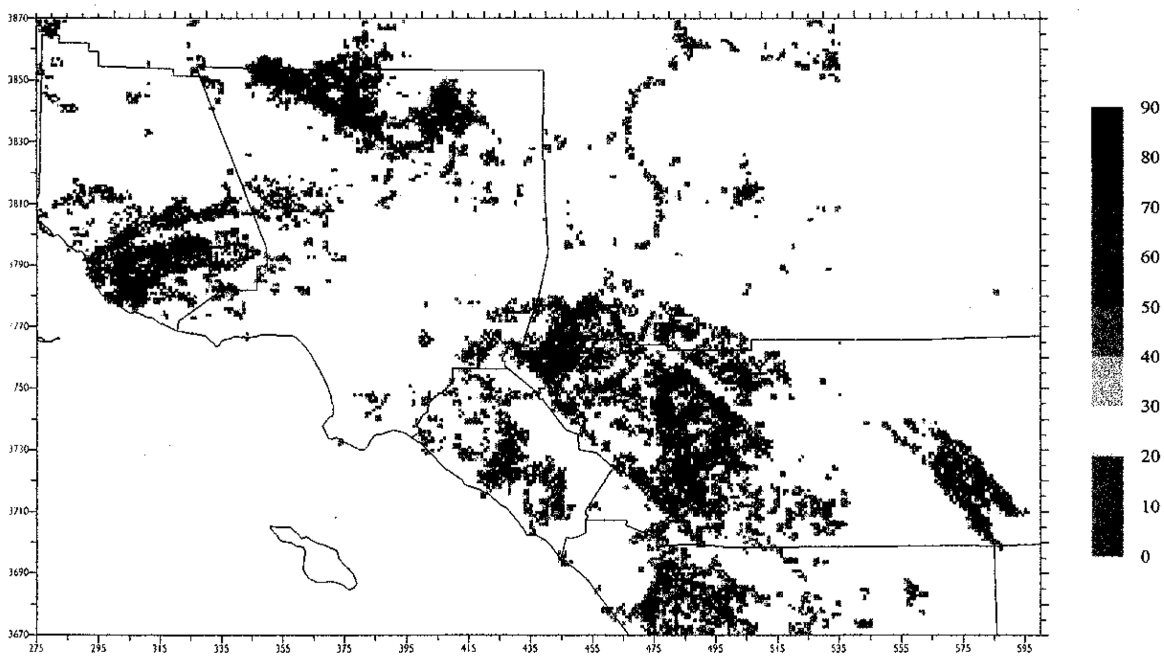


Figure 14-1. AQMP Modeling Domain.

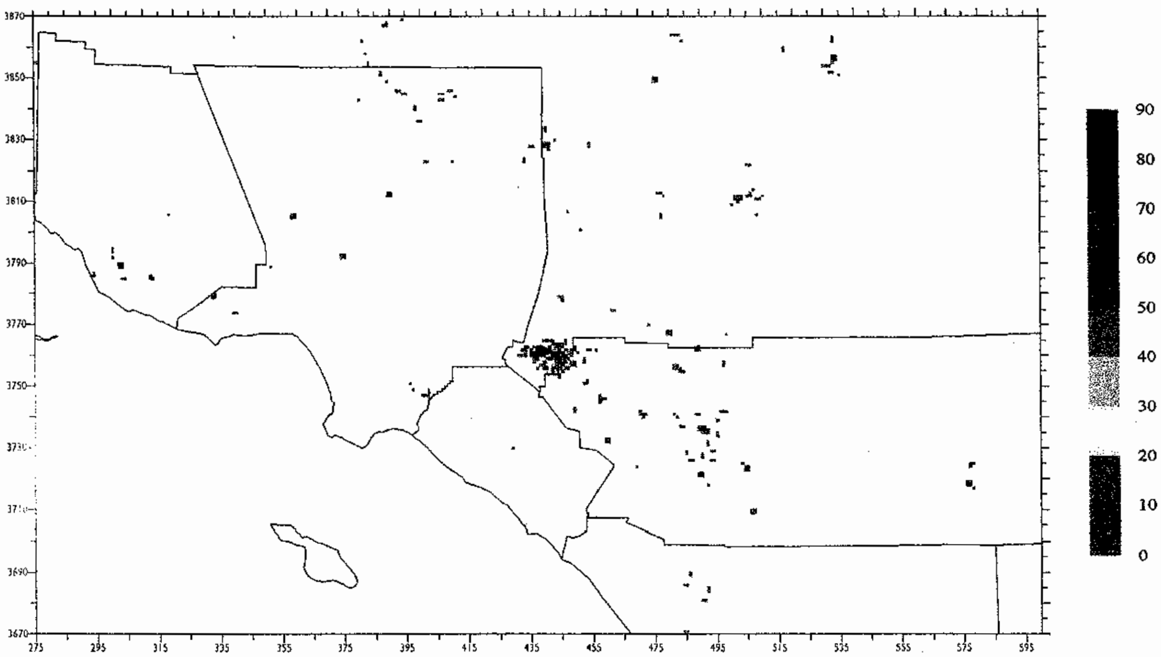


Percentage of Grid cell in Landuse Category 1: Urban
USGS LULC Codes: 11,12,13,14,15,16,17

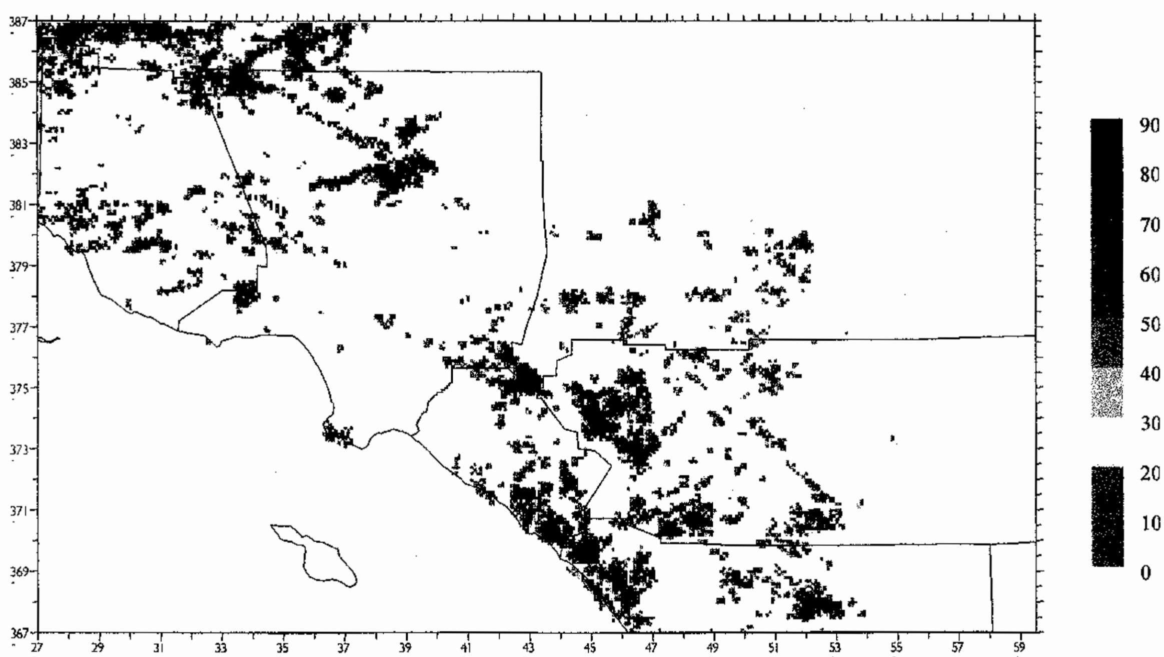


Percentage of Grid cell in Landuse Category 2: Agriculture
USGS LULC Codes: 21,22,23,24

Figure 14-2. Spatial gridding surrogates.

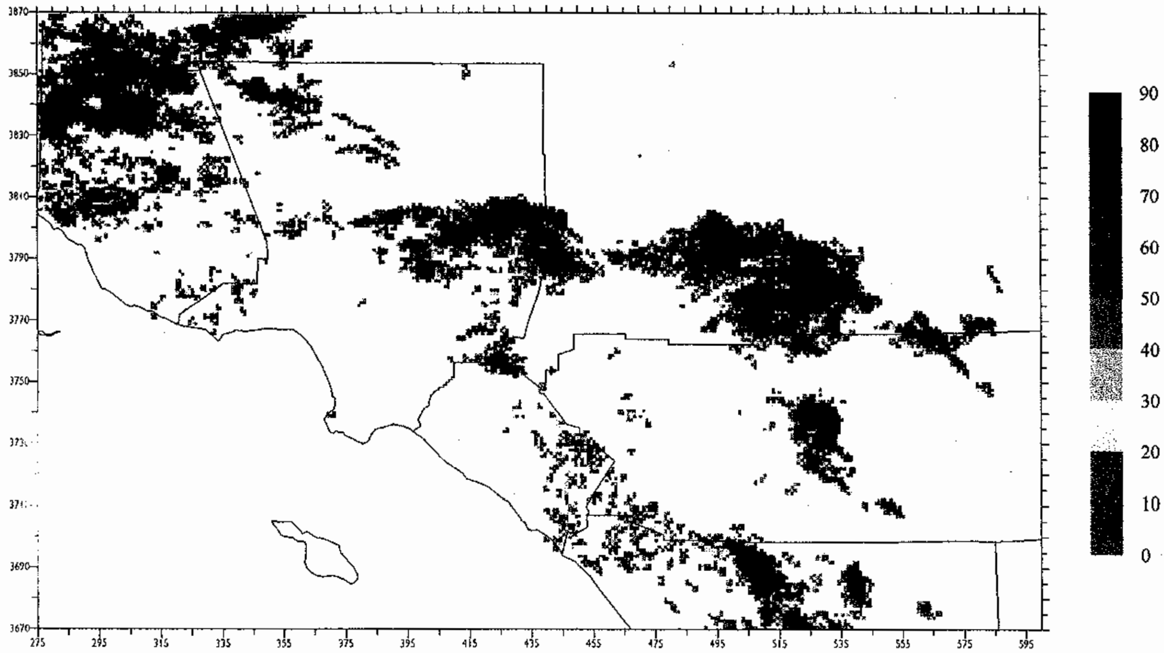


Percentage of Grid cell in Landuse Category 3: Confined Feed Lots
USGS LULC Codes: 23

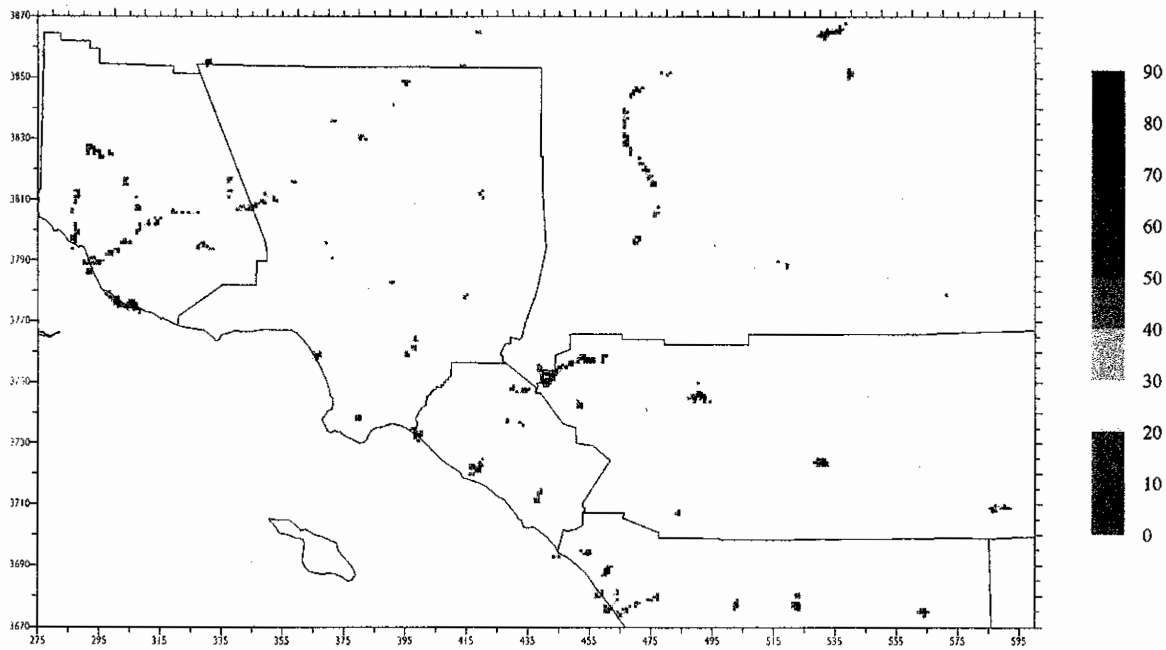


Percentage of Grid cell in Landuse Category 4:
USGS LULC Codes:

Figure 14-2. Continued.

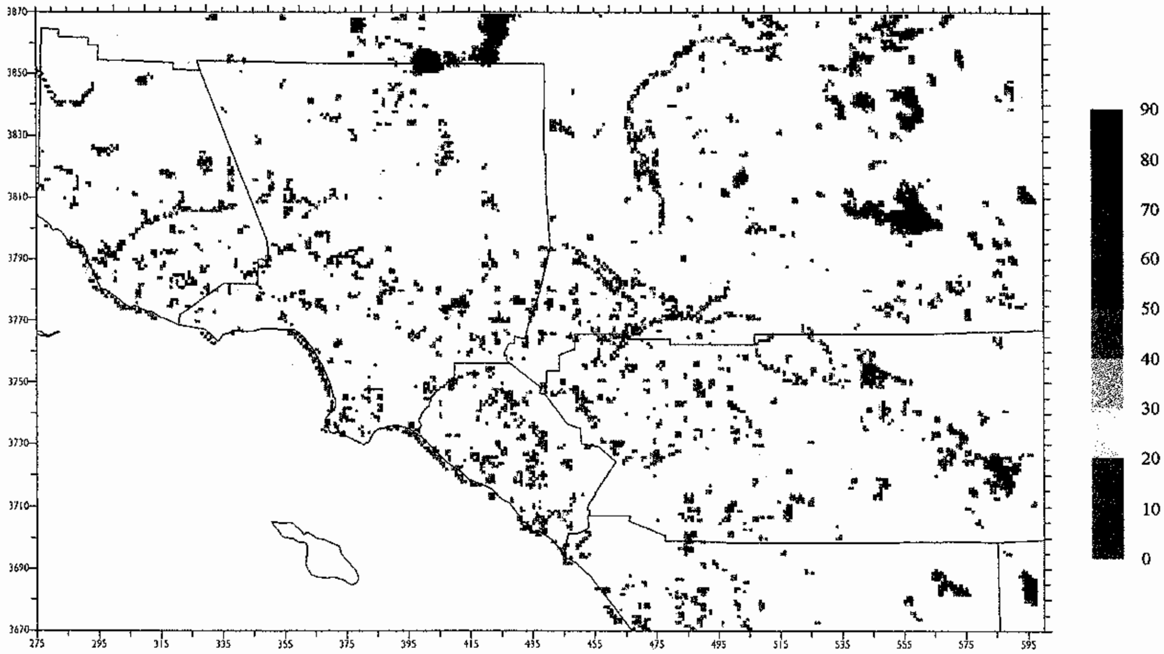


Percentage of Grid cell in Landuse Category 5: Forest
USGS LULC Codes: 41,42,43

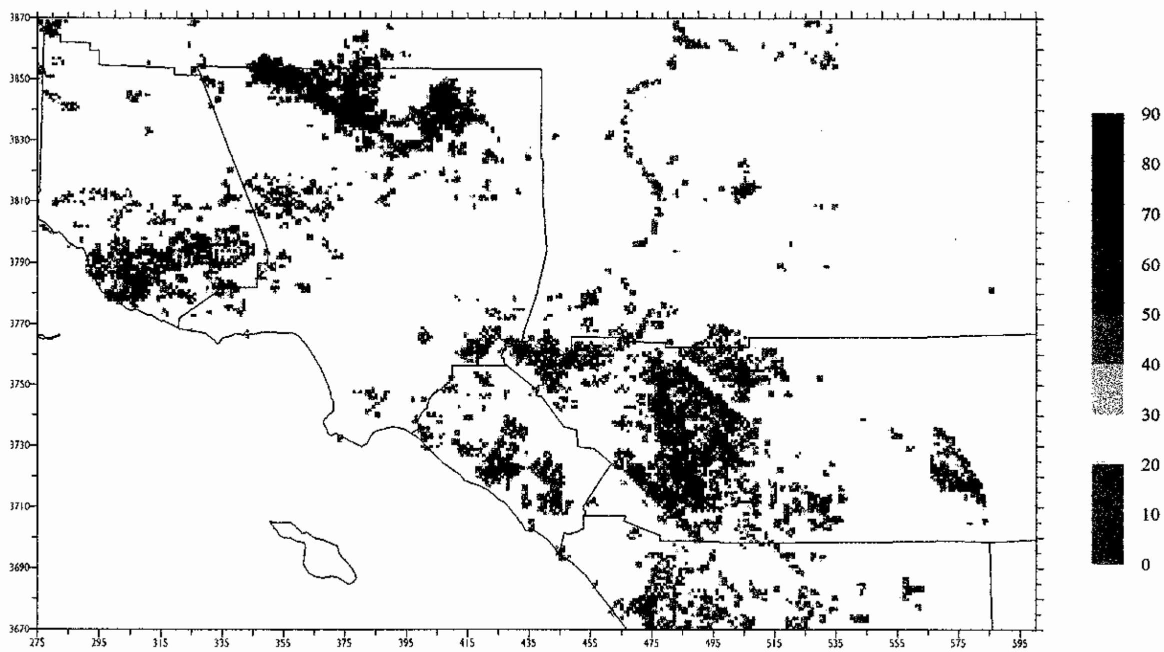


Percentage of Grid cell in Landuse Category 6: Wetland
USGS LULC Codes: 61,62

Figure 14-2. Continued.

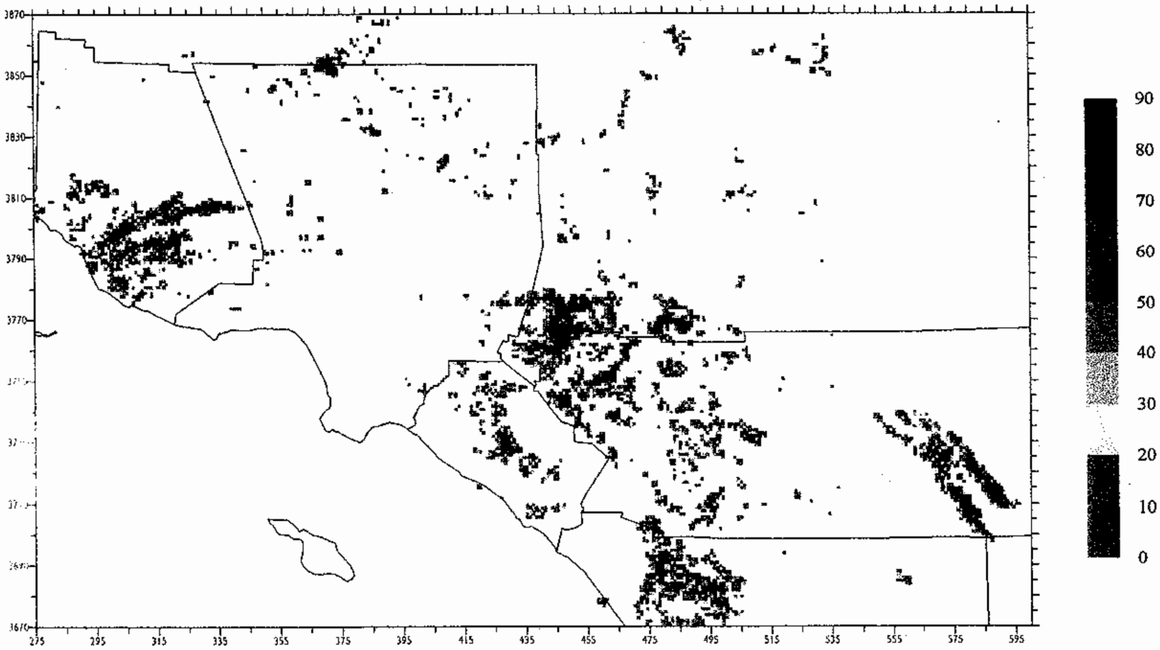


Percentage of Grid cell in Landuse Category 7: Barren Land
USGS LULC Codes: 71,72,73,74,75,76

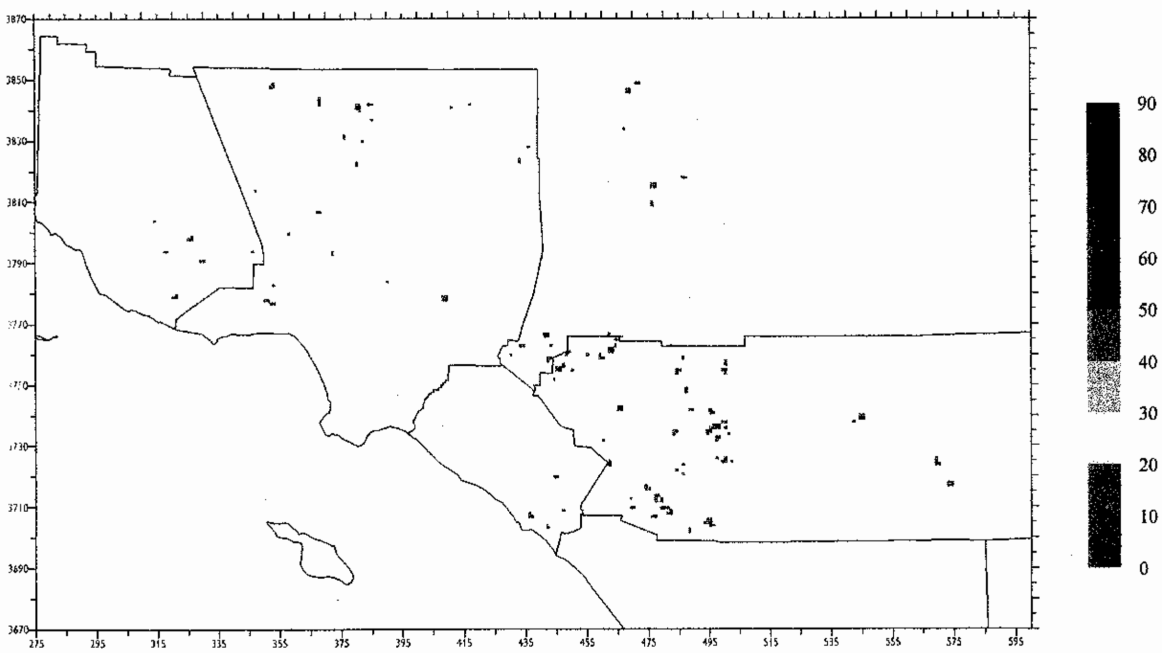


Percentage of Grid cell in Landuse Category 8: Farmland
USGS LULC Codes: 21

Figure 14-2. Continued.

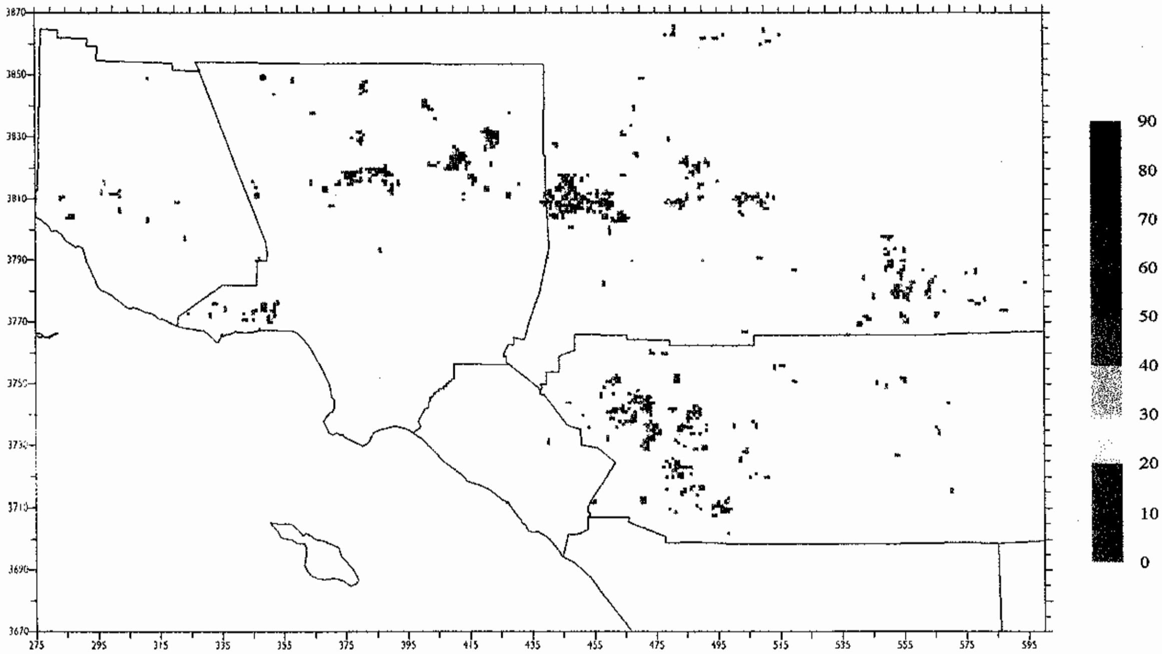


Percentage of Grid cell in Landuse Category 9: Non-Farm Agriculture
USGS LULC Codes: 22,23,24

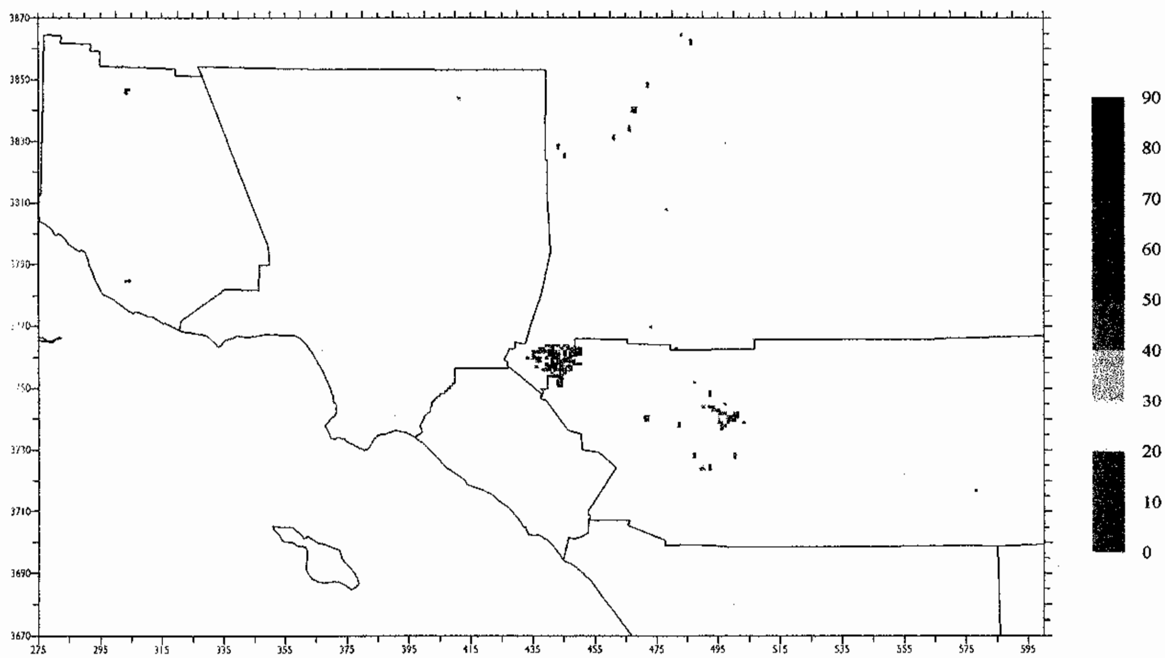


Percentage of Grid cell in Landuse Category 10: Horse Ranches
AIS LULC Codes: 2700

Figure 14-2. Continued.

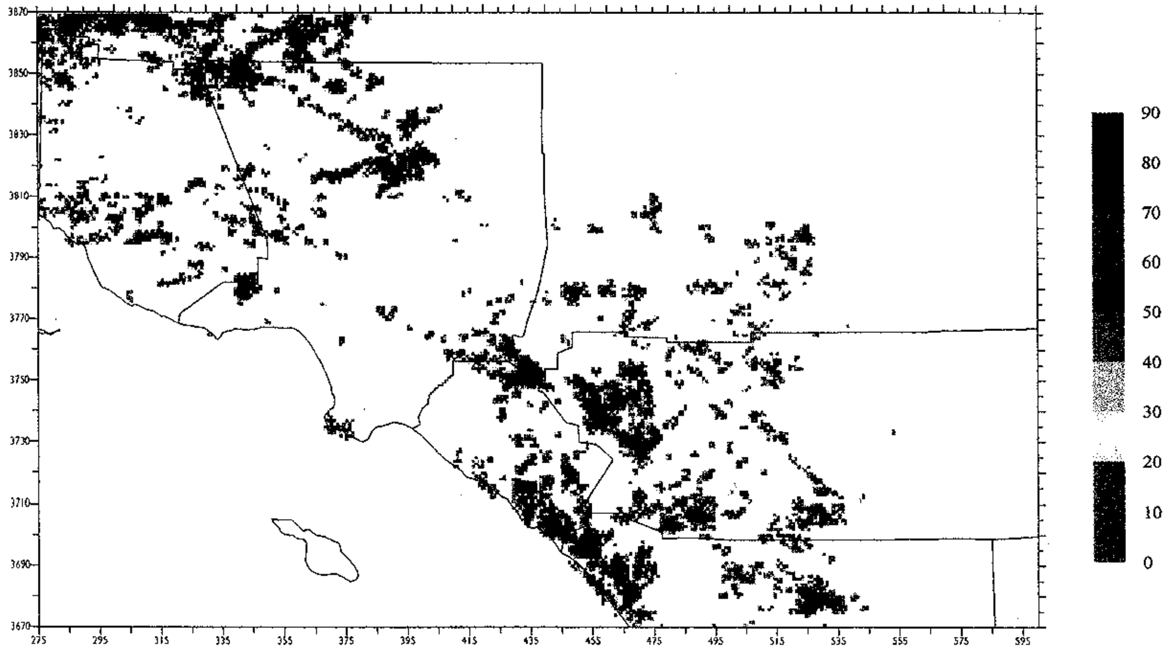


Percentage of Grid cell in Landuse Category 11: Rural Residential Low Density
AIS LULC Codes: 1124

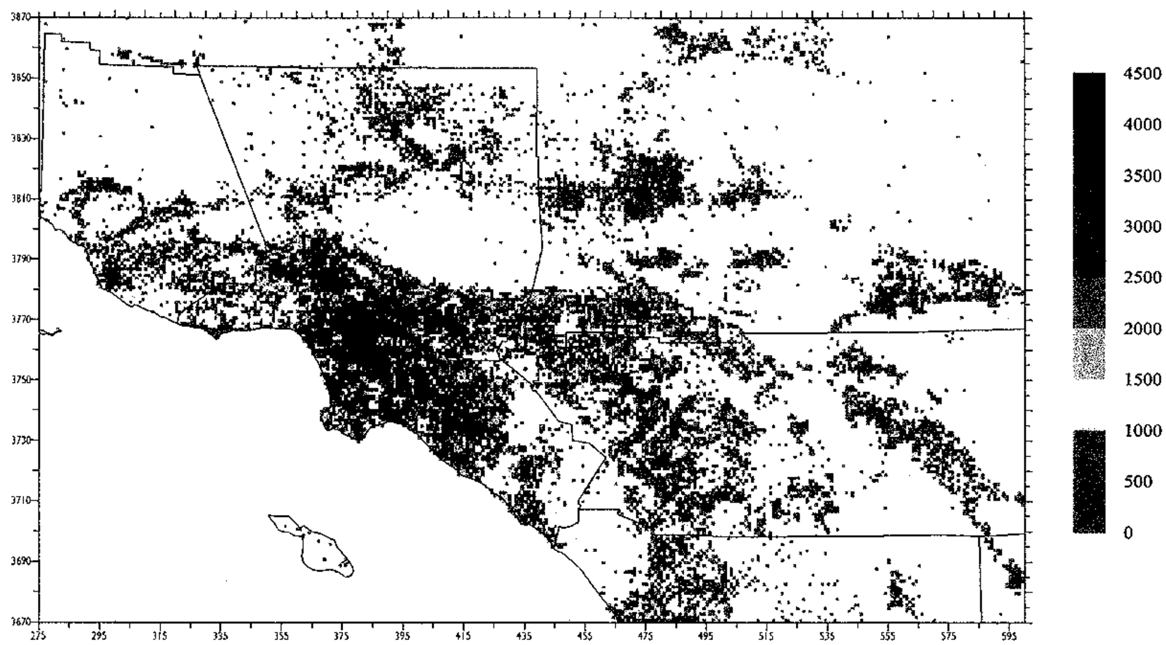


Percentage of Grid cell in Landuse Category 12: Dairy and Intensive Livestock
AIS LULC Codes: 2400

Figure 14-2. Continued.

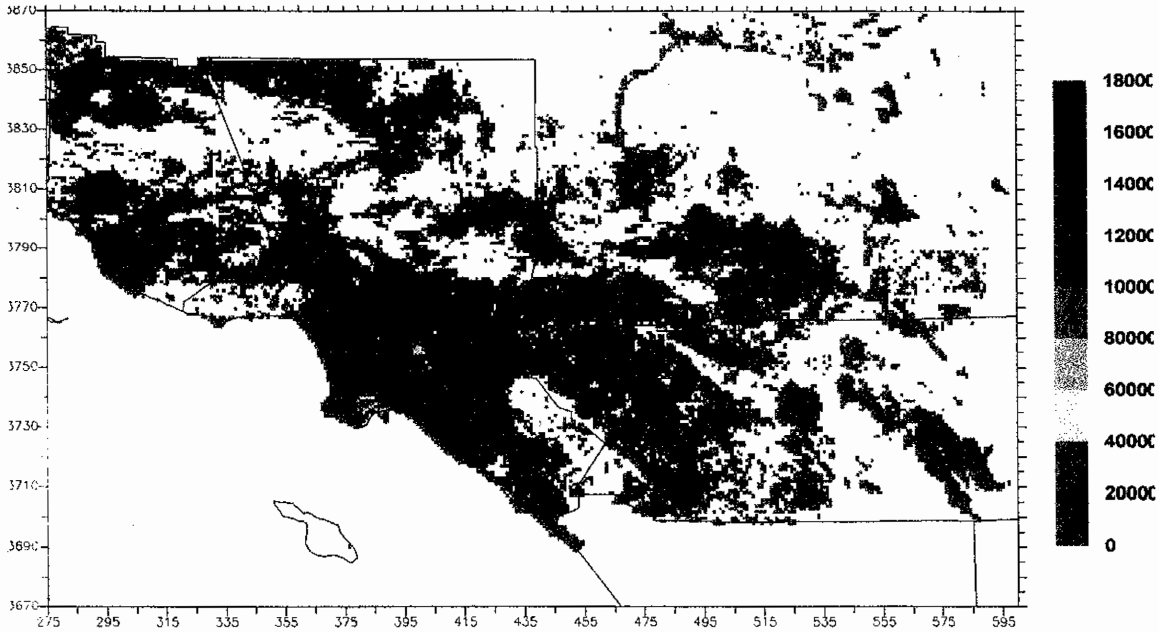


Percentage of Grid cell in Landuse Category 13: Rangeland
USGS LULC Codes: 31,33

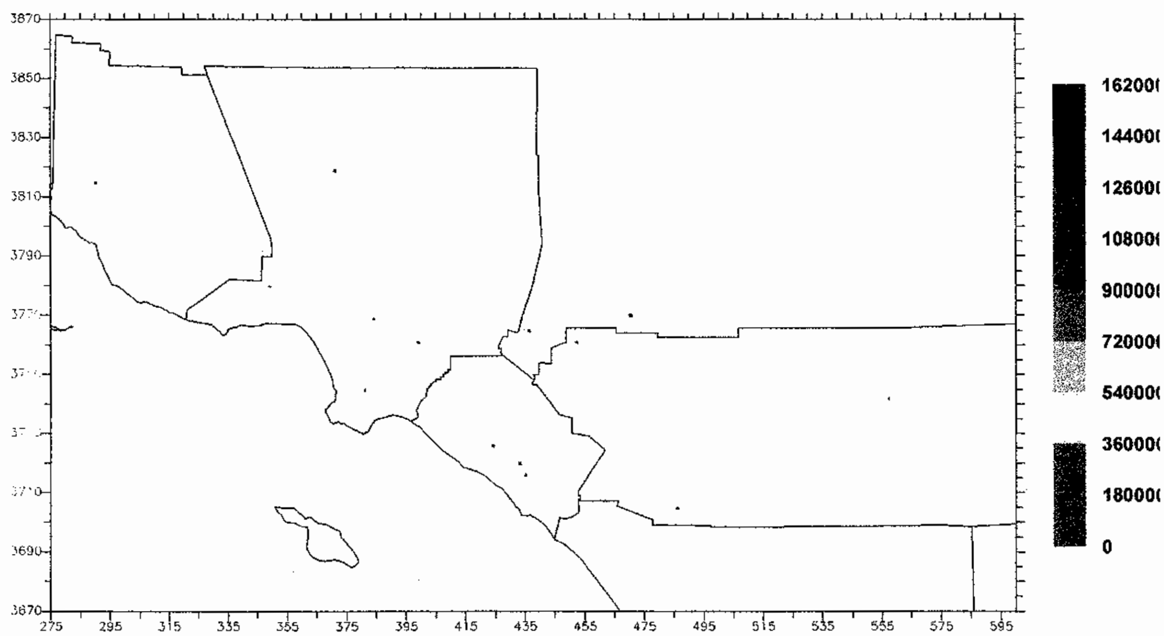


1990 Census Population Density

Figure 14-2. Concluded.

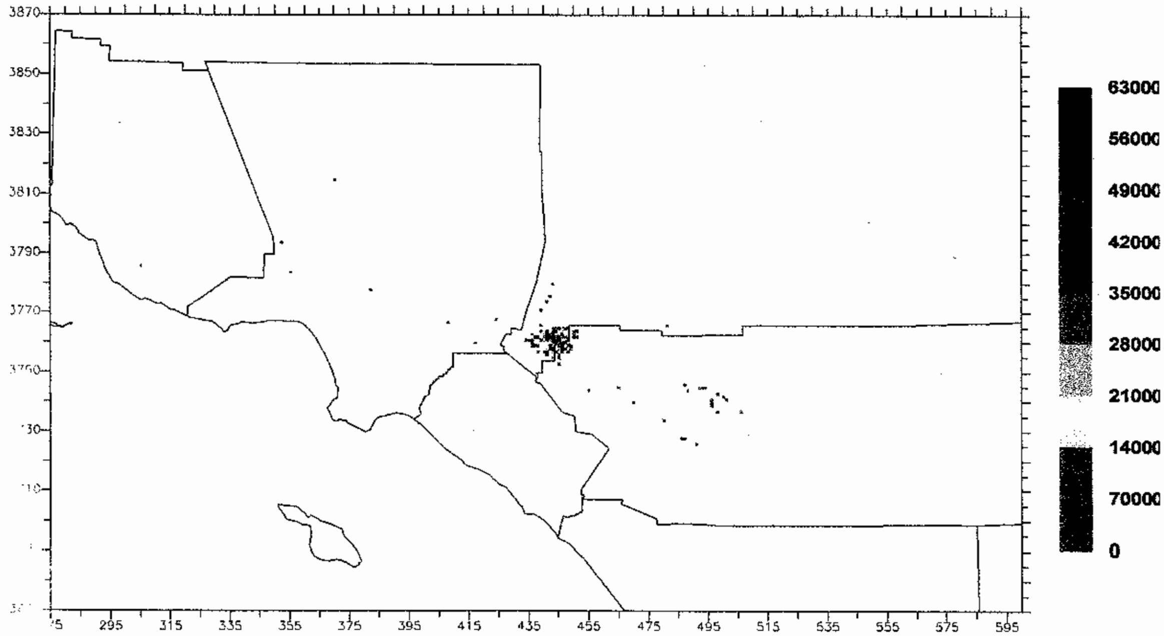


Ammonia Emissions from All Sources (grams/day)
Maximum: 2154679 (grams/day)

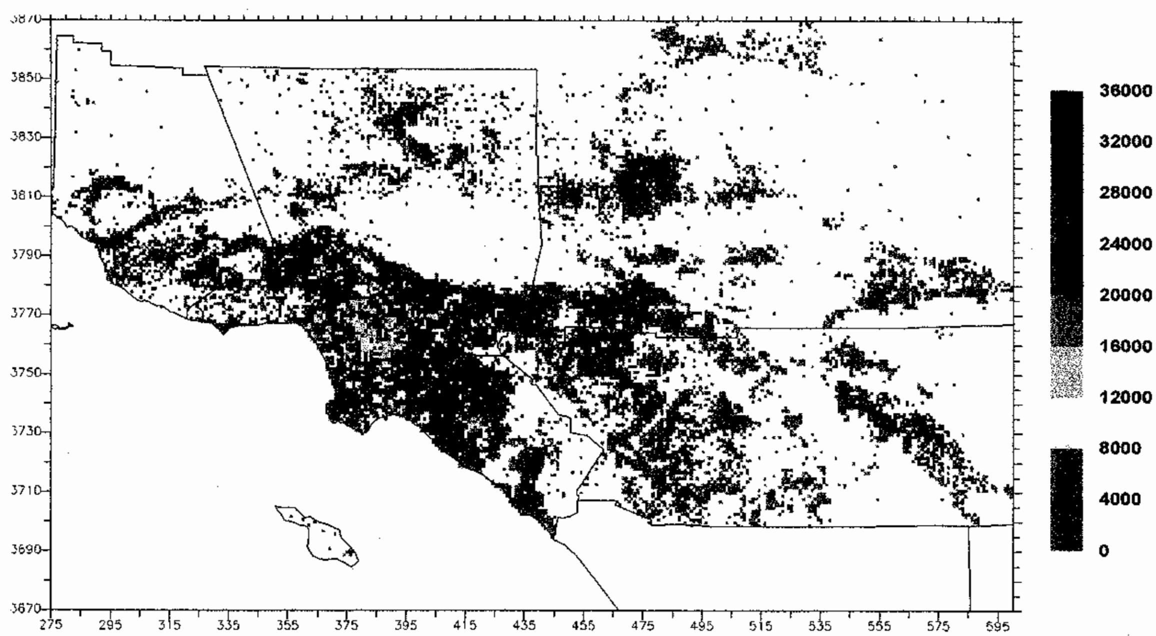


Ammonia Emissions from Composting (grams/day)
Maximum: 1694856 (grams/day)

Figure 14-3. Ammonia Emissions.

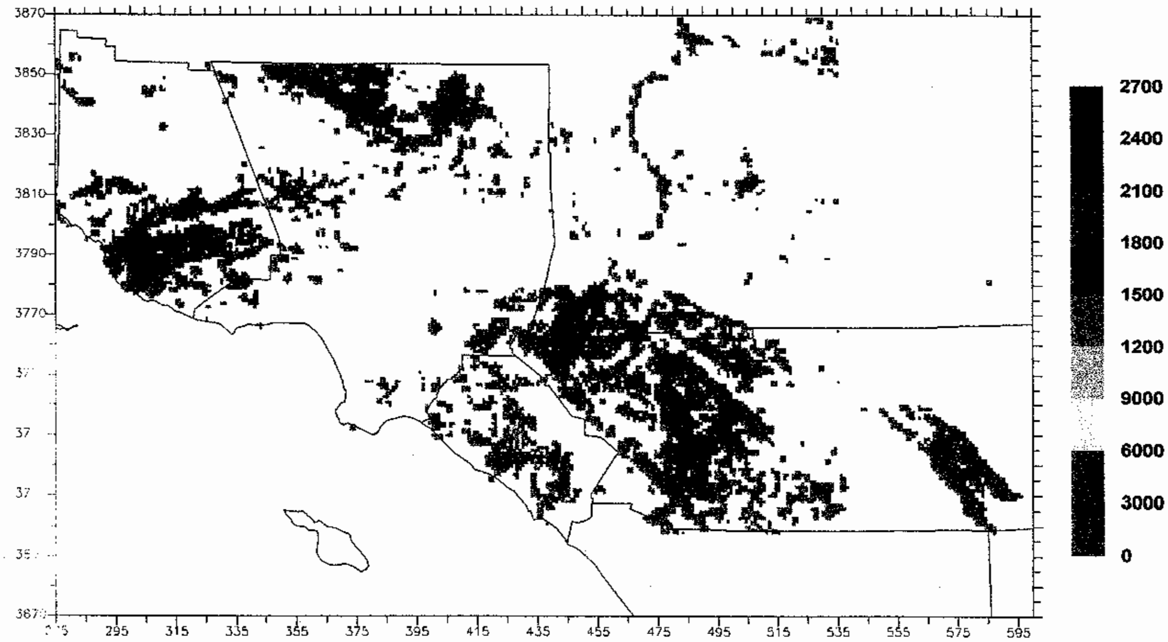


Ammonia Emissions from Dairy (grams/day)
Maximum: 691175 (grams/day)

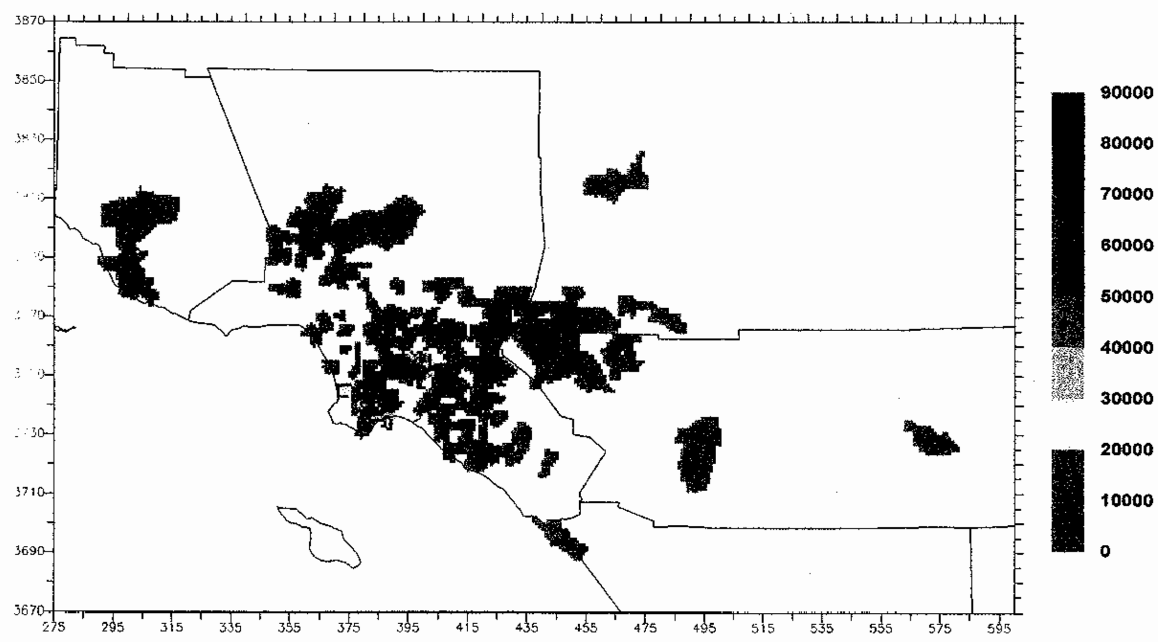


Ammonia Emissions from Domestic (grams/day)
Maximum: 38421 (grams/day)

Figure 14-3. Continued.

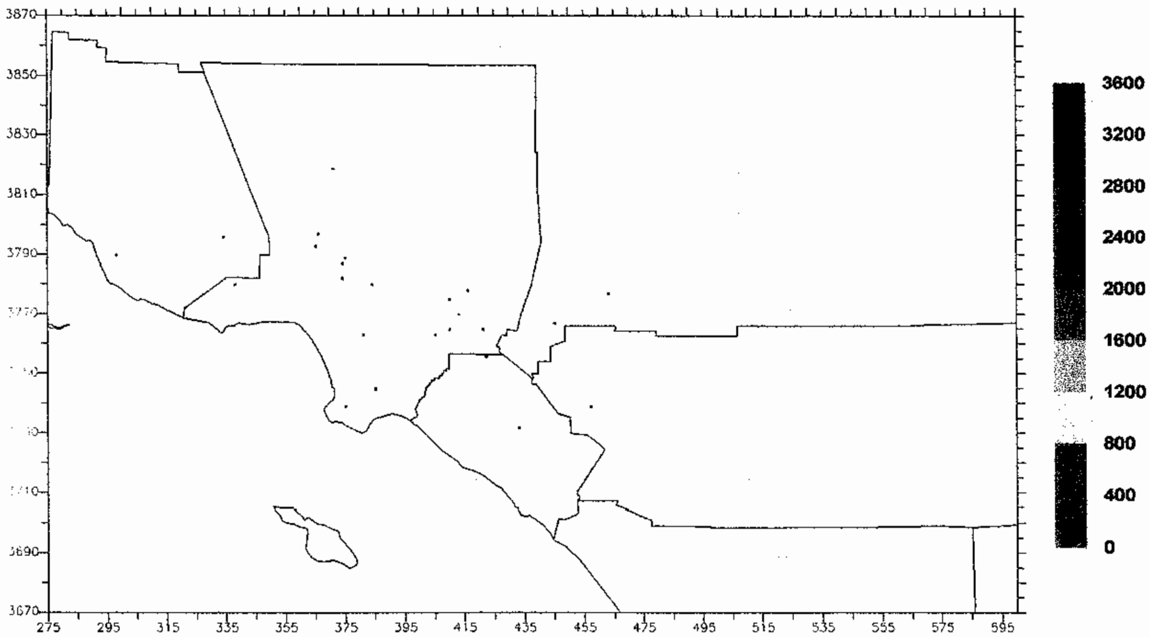


Ammonia Emissions from Fertilizer (grams/day)
Maximum: 28439 (grams/day)

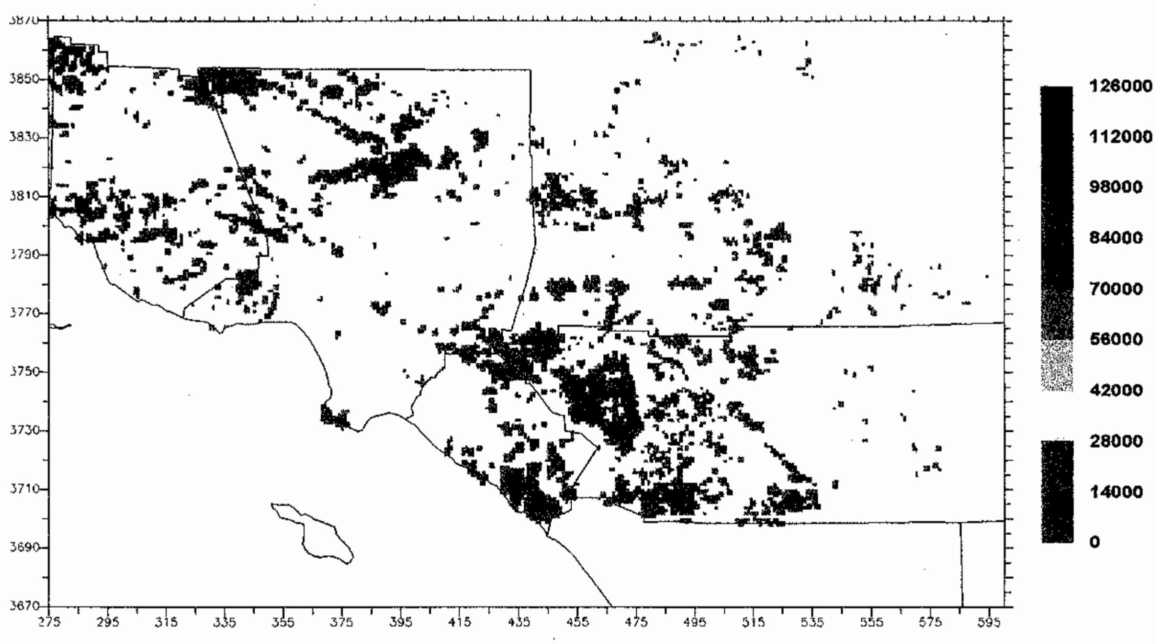


Ammonia Emissions from Industrial (grams/day)
Maximum: 89955 (grams/day)

Figure 14-3. Continued.

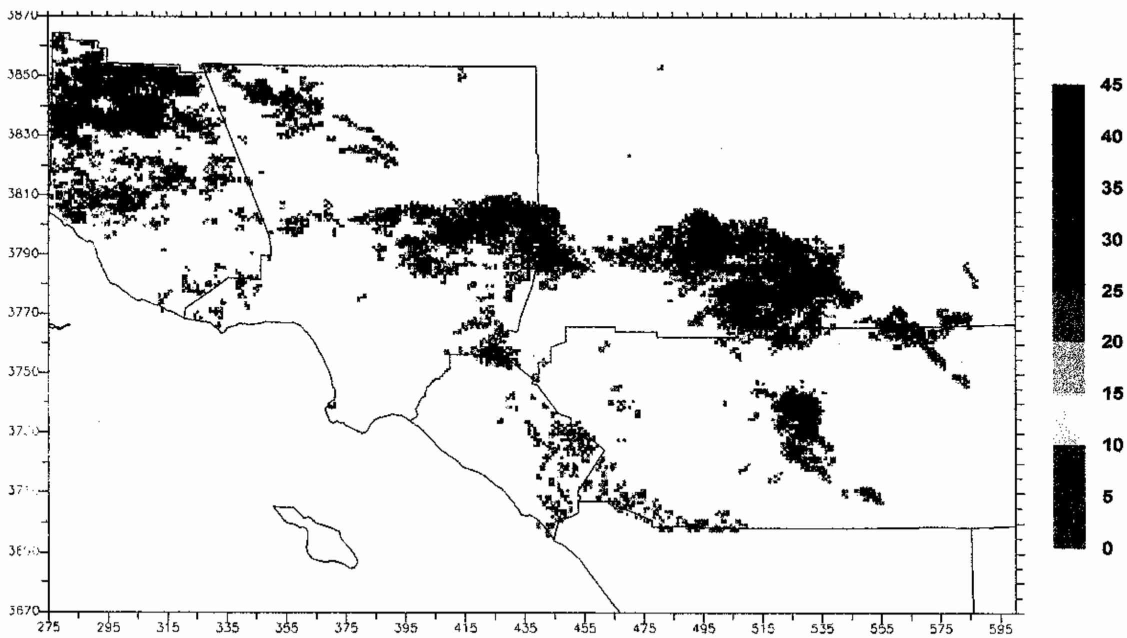


Ammonia Emissions from Landfills (grams/day)
Maximum: 3314 (grams/day)

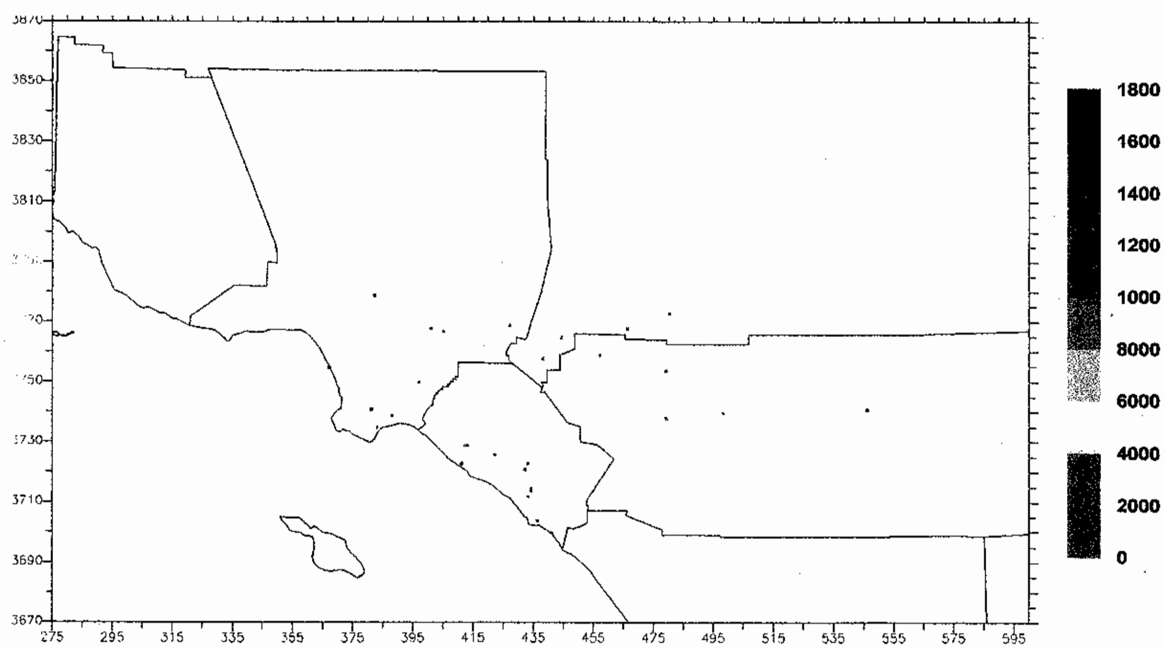


Ammonia Emissions from Livestock (grams/day)
Maximum: 135899 (grams/day)

Figure 14-3. Continued.

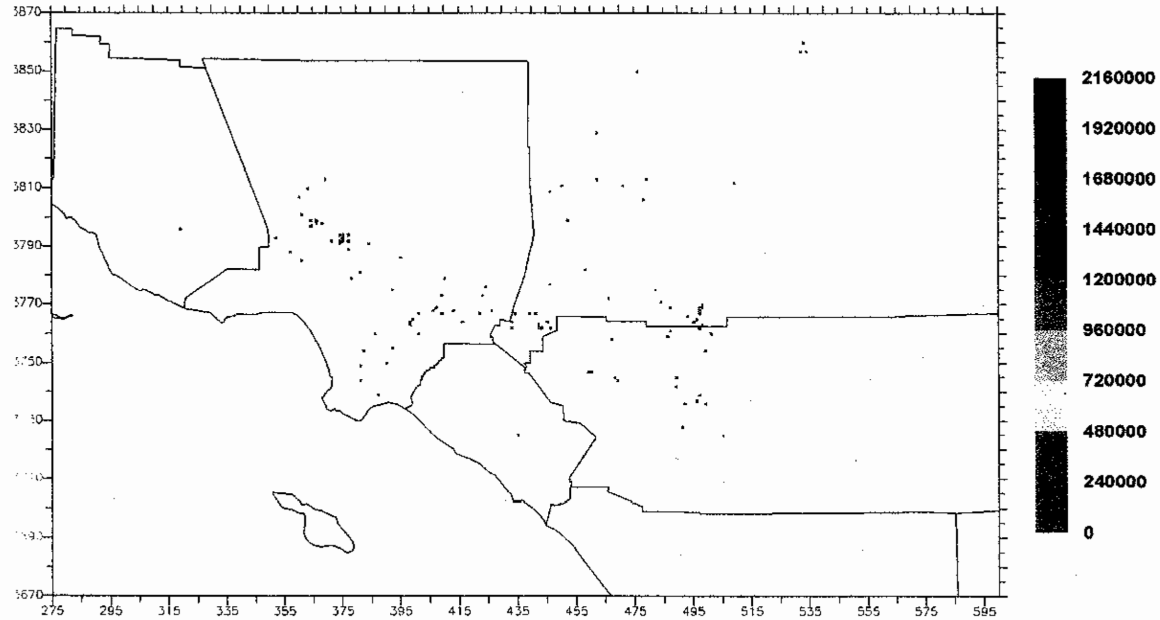


Ammonia Emissions from Native Animals (grams/day)
Maximum: 43 (grams/day)

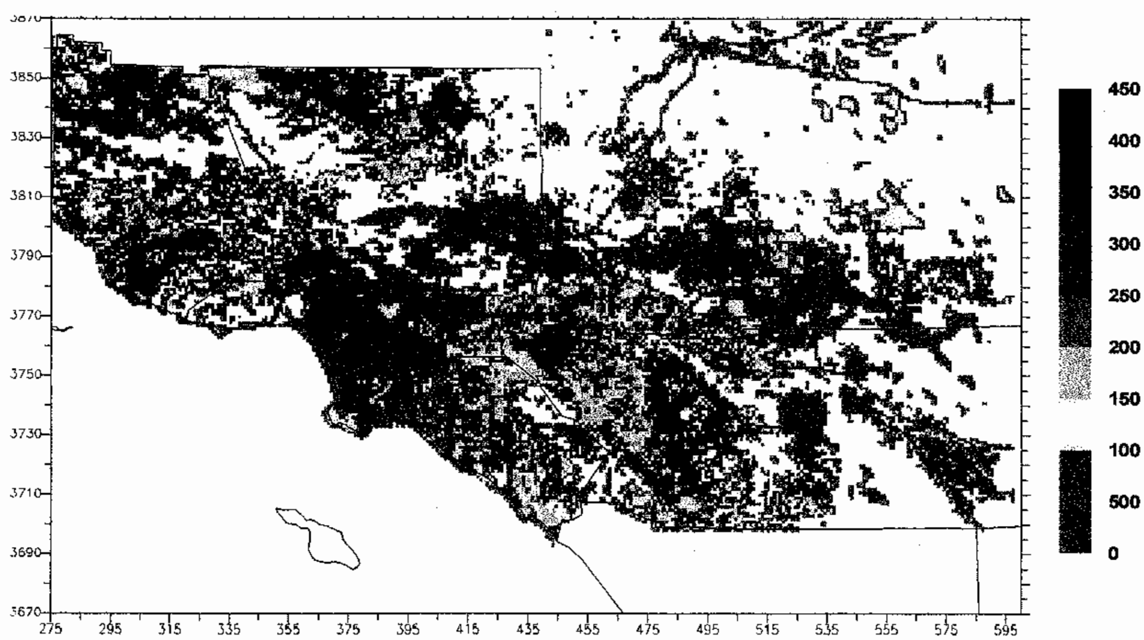


Ammonia Emissions from POTW (grams/day)
Maximum: 19631 (grams/day)

Figure 14-3. Continued.



Ammonia Emissions from Poultry Farms (grams/day)
Maximum: 2152687 (grams/day)



Ammonia Emissions from Soils (grams/day)
Maximum: 5211 (grams/day)

Figure 14-3. Concluded.

Section 15

CONCLUSIONS

15.1 APPROACH DIFFERENCES and NEW SOURCES

Approach Differences

The approach to one category in particular, Industrial Sources (Section 9), was changed to more completely capture the total SoCAB ammonia supplied to industrial users. We contacted the three ammonia suppliers, Unocal, Hill Brothers Chemical Corporation and LaRoche Industries Incorporated and obtained records for ammonia supplied to each zip code in the SoCAB by industry type.

Each industry type was assigned a specific emission factor (e.g., refrigeration usage equals emissions) to compile the ammonia emissions contribution of this source.

New Sources

Sources new to this inventory, not included in the 1997 AQMP[1], are:

1. Native Animal Waste (Section 3)
2. Landfills (Section 10)
3. Composting Operations (Section 11)
4. Oceans and Other Bodies of Water (Section 12)
5. Prescribed Burning (Section 13)

15.2 EMISSION FACTOR DIFFERENCES

Significant changes were made from emission factors in the 1997 AQMP to this inventory. These changes were for:

Livestock and Poultry – chickens, dairy cattle, horses

Chickens – The chicken emission factors were revised downward from 1.6 lbs./layer/yr. (and 0.79 lbs/broiler/year to 1.0 lbs./layer or pullet/yr and 0.37 lbs./broiler /year. This revision was based on Battye et al.[2]

Dairy cattle -- The dairy cattle emission factor was revised from 21 lbs./head/yr. to 51 lbs./head/yr. based on an analysis performed by Dr. Eric Winegar[3]. The effect of this change was to substantially increase estimated ammonia emissions attributed to dairy cattle.

Horses – The horses and ponies emission factor was revised downward from 52 to 26.9 lbs./horse/yr. This revision was based on Battye et al.

Domestic Sources - pets and cigarettes

Pets - Emission factors for dogs and cats were revised downward from 5.5 (dogs) and 1.8 (cats) to 2.17 and 0.348 lbs./animal/yr. based on Sutton etal[4].

Cigarettes - The cigarette emission factor was revised downward from 2.07×10^{-05} to 2.2×10^{-07} lb./cigarette based on Warn, et al[5].

Mobile Sources - vehicles with 3-way catalysts

The Radian Study[6] built up emission factors based on fleet mix and a number of other parameters. The Radian method required many assumptions. AVES used a bulk emission factor based on the Fraser and Cass[7] Tunnel Study. This emission factor is grounded on SoCAB-specific testing and only requires Vehicle Miles Traveled (VMT) activity data to calculate emissions.

Publicly-Owned Treatment Works

The publicly-owned treatment works (POTWs) emission factor was revised downward, based on Kogan and Torres[8], to 0.118 lbs./million gallons. This resulted in a nearly 4 tons/day ammonia emission reduction.

15.3 ACTIVITY DATA

This inventory, for the most part, used the same sources of activity data as the Radian Study (and 1997 AQMP). However, differences in information sources and large changes in activity occurred in the Livestock and Poultry source.

The largest effect on the inventory update related to a major decrease in chicken population from approximately 25 million to 17 million from 1987 to 1997. This, coupled with the decrease in emission factor, resulted in a 6.2 tons/day decrease in the 2000 SoCAB ammonia inventory.

Another large change in activity came about by checking the cattle population (dairy and non-dairy) data from USDA against Santa Ana (RWQB) data. The total cattle population activity was revised upward by approximately 214,690 head. However, current data indicate an increase in beef cattle population from 15,353 to 20,020. Because of the relatively large emission factor for beef cattle, these emissions partially offset the increase in total cattle emissions. Ultimately, these modifications resulted in a 200 percent increase in total cattle ammonia emissions.

15.4 SPATIAL AND TEMPORAL ALLOCATION

As with activity data, AVES conducted spatial and temporal allocation consistent with the 1997 AQMP. One major change was allocating Industrial Sources as area sources because the activity data was received from the ammonia suppliers according to ZIP code.

15.5 FINAL INVENTORY SUMMARY

The final inventory summaries are presented in Tables 15-1 through 15-4. The inventory summaries are illustrated in Charts 15-1 through 15-3. Table 15-4 compares emissions from the 1997 SoCAB, 2000 SoCAB and the 2000 AQMP modeling domain.

Differences in the fertilizer, domestic and native animals, soils, domestic source emissions are primarily due to differences in the size of the SoCAB and the AQMP Modeling Domain. The AQMP Modeling Domain is smaller than the SoCAB. Other emissions differences are due to rounding error. This is especially for multiple point sources such as dairy cows and poultry. All rounding errors are less than one percent except for values less than one tenth of a ton per day.

15.6 FUTURE RESEARCH

Given unlimited resources, all recommended future research described in the individual sections would be pursued. However, the following list is prioritized according to potential impact on the inventory:

Soil Surfaces

Battye et al.[2] presents several inventories that have excluded ammonia emissions from soil because of the uncertainty in current literature. The uncertainty exists in the amount of ammonia that is removed from the atmosphere by vegetation and certain soils. Better resolution is needed.

Livestock and Poultry

Dairy Emission Factors - After AVES performed an extensive literature review of emission factors, we concluded that, a better designed testing program for dairy and other cattle sources is needed. It was difficult to reconcile results from the different test methods because testing was not robust enough to determine statistically relevant results.

For example, the nitrogen balance method (Gharib and Cass[9]) requires many assumptions and site-specific data. From ambient monitoring (San Joaquin Valley Study[10], James etal[11], Asman[12], etc.) it is almost impossible to derive a believable emission flux rate. The two-dimensional array used in the San Joaquin Valley Study pilot test was on the right track. However, characterizing a full size dairy would require a very large array with testing performed over a variety of conditions (e.g., night, day, summer, winter, high wind, calm, etc.). Finally, source testing (Schmidt and Winegar[13]) with isolation flux chambers has merit—however, the Schmidt and Winegar study was extremely limited in scope. New testing would have to investigate all sources within a dairy (feedlot, lagoon, etc.), with enough sampling to be statistically significant for each source and over a variety of conditions.

Fertilizer

The California Department of Food and Agriculture (CDFA) recently showed interest in understanding how ammonia is released from fertilizer application. Additional testing to determine emission factors and their relation to soil emissions (see above) would remove uncertainty regarding emissions double counting. Also, AVES encountered uncertainty with respect to activity data and how various types of fertilizer were listed for each county. The large general categories in the current Tonnage Report[14] prevents using current emission factors that have higher resolution than the Gharab and Cass[9] emission factors. It would be beneficial in estimating activity data to work more closely with the CDFA contractor that compiles the "Tonnage Reports".

Landfills

Landfill ammonia emissions as currently inventoried are insignificant. However, based on the apparent similarity to emission mechanisms for composting operations, the accepted emission factor is highly suspect. This is supported by landfill facilities reporting (in the California Air Resources Board database) higher ammonia emissions, based on site-specific testing, than would be the case if the emission factor were used.

AVES recommends a comprehensive search of ammonia emission estimates from actual source testing to determine a more realistic emission factor.

15.7 REFERENCES

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2. Battye, R., W. Battye, C. Overcash, and S. Fudge (1994*): Development and Selection of Ammonia Emission Factors*. EPA/600/R-94/190. Final report prepared for U.S. Environmental Protection Agency, Office of Research and Development. EPA Contract No. 68-D3-0034, Work Assignment 0-3.

3. Winegar E. (1999) *Review of Literature Sources for Emissions of Ammonia from Dairy Farms*, Applied Measurement Science

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5. Warn, T.E., Zelmanowitz, S., and Saeger, M. (1990): Development and Selection of Ammonia Emission Factors for Office of Research and Development U.S. Environmental

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11. James, T, N. Fritas, L. Ashbaugh, and D. Meyer (1997): Field Estimates of Volatilization from Cattle Production Facilities. *Proceedings from the Air And Waste Management Association Conference - Emission Inventory: Planning for the Future*, October 28-30, pp 259-267.

12. Asman W.A. H (1992) *Ammonia Emission in Europe: Updated Emission and Emission Variations*. Prepared by National Institute of Public Health and Environmental Protection, Bilthoven, May.

13. Schmidt, C.E., and E. Winegar (1996): *Results of the Measurements of PM_{10} Precursor Compounds from Dairy Industry Livestock Waste*. Technical report prepared for the South Coast Air Quality Management District.

14. California Department of Food and Agriculture (1999): *Fertilizing Materials Tonnage Report, July - December 1998,* Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California.

Table 15-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

	SCAB Activity			Emission Factor			Emissions, t/d	
Source Category	1997 SoCAB[a]	2000 SoCAB	Units	1997 SoCAB[b]	2000 SoCAB	Units	1997 SoCAB[a]	2000 SoCAB
Livestock							**56.57**	**60.37**
Horses and Ponies	223,068	117,128	head	52	26.9	lb/head/yr	15.89	4.32
Beef Cows	15,353	20,020	head	102	87.6	lb/head/yr	2.15	2.40
Milk Cows	314,571	302,899	head	20	51.0	lb/head/yr	8.62	21.2
Heifers and heifer calves	NA	167,367	head	NA	28.8	lb/head/yr	NA	6.59
Steers, steer calves, bulls, and bull calves	NA	54,328	head	NA	30.4	lb/head/yr	NA	2.26
Hogs and pigs	17,260	18,059	head	15	20.3	lb/head/yr	0.35	0.50
Layers	NA	NA	head	1.6	NA	lb/head/yr	NA	NA
Pullet	NA	NA	head	1.2	NA	lb/head/yr	NA	NA
Layers and pullets	NA	16,190,673	head	NA	0.996	lb/head/yr	NA	22.1
Broilers and other meat-type chickens	NA	969,847	head	0.79	0.368	lb/head/yr	NA	0.49
Poultry	14,697,683	NA	head	1.43	NA	lb/head/yr	28.79	NA
Sheep and Lambs	63,545	52,070	head	8.8	7.43	lb/head/yr	0.77	0.53
Goats, Total	NI	3,980	head	NA	1.28	lb/head/yr	NI	0.0070
Rabbits	NI	25,183	head	NA	0.37	lb/head/yr	NI	0.013
Mules, Burros and Donkeys		299	head		26.9	lb/head/yr		0.011
Soil							**39.00**	**34.24**
Urban	land use	2,078	$miles^2$	various	1	kg/km^2-day	land use	5.93
Agricultural	land use	1,414	$miles^2$	various	3.7	kg/km^2-day	land use	14.9
Rangeland/Pasture	land use	1,701	$miles^2$	various	1.5	kg/km^2-day	land use	7.28
Wetland	land use	60	$miles^2$	various	1	kg/km^2-day	land use	0.17
Forest Land	land use	1,425	$miles^2$	various	1	kg/km^2-day	land use	4.07
Barren Land	land use	654	$miles^2$	various	1	kg/km^2-day	land use	1.87

Table 15-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

	SCAB Activity			Emission Factor			Emissions, t/d	
Source Category	1997 SoCAB[a]	2000 SoCAB	Units	1997 SoCAB[b]	2000 SoCAB	Units	1997 SoCAB[a]	2000 SoCAB
Fertilizer (TOTAL)							**10.98**	**7.68**
On Farm Liquid	14,350	10,604	tons as N	0.02	0.02	% of total N	0.95	0.71
On Farm Dry	11,090	5,226	tons as N	0.1	0.1	% of total N	3.69	1.74
Non-Farm	5,887	3,639	tons as N	0.3	0.3	% of total N	5.88	3.63
Anhydrous Ammonia	8,414,000	NA	lb/yr	0.04	NA	% of total N	0.46	0.00
Domestic							**29.07**	**25.87**
Cats	1,082,323	1,401,184	cats	1.8	0.348	lb N/cat/yr	2.67	0.76
Dogs	1,595,686	2,074,120	dogs	5.50	2.17	lb N/dog/yr	12.0	7.05
Cigarette Smoking	12,618,588	14,882,918	people	0.022	0.00023	lb/person/yr	0.38	0.0048
Household Ammonia Use	12,618,588	14,882,918	people	0.05	0.05	lb/person/yr	0.86	1.02
Human Perspiration	12,618,588	14,882,918	people	0.55	0.55	lb/person/yr	9.51	11.2
Human Respiration	12,618,588	14,882,918	people	0.0035	0.0035	lb/person/yr	0.06	0.07
Untreated Human Waste, Homeless	129,888	134,636	homeless	11	11	lb/homeless/yr	1.96	740.50
Cloth Diapers	56,783.6	100,807	infants	6.9	6.9	lb/infant/yr	0.54	0.95
Disposable Diapers	511,052	907,259	infants	0.36	0.36	lb/infant/yr	0.25	0.45
Untreated Human Waste, Other	12,050,752	14,882,918	people	0.05	0.05	lb/person/yr	0.83	1.02
On-Road Mobile	VMT	307,043,000	VMT/day	various	61	mg/km	**7.10**	**33.2**
Industrial Sources							**9.00**	**13.16**
Refrigeration	NA	1,789	tons/yr	NA	1	ton/ton	NA	4.90
NOx Control	NA	2,268	tons/yr	NA	0.1	ton/ton	NA	0.62
Metal Treating	NA	9,825	tons/yr	NA	0.1	ton/ton	NA	2.68
Blue Printing	NA	75	tons/yr	NA	1	ton/ton	NA	0.20
Wastewater Treatment (non-POTW)	NA	306	tons/yr	NA	0.15	ton/ton	NA	0.13
Traditional Point Sources (Radian Report[c])	NA	NA	NA	NA	various	NA	9.00	4.62
Composting	NI	2,445,599	tons/yr	NA	various	various	**0.00**	**9.69**
Landfills	NI	362	tons CH_4/yr	NI	0.007	lb/lb methane	**0.00**	**0.0069**

Table 15-1. Comparison of 1997 AQMP Emission Factors and Activity Data versus 2000 AQMP Inventory

	SCAB Activity			Emission Factor			Emissions, t/d	
Source Category	**1997 SoCAB[a]**	**2000 SoCAB**	**Units**	**1997 SoCAB[b]**	**2000 SoCAB**	**Units**	**1997 SoCAB[a]**	**2000 SoCAB**
Sewage Treatment (POTW)	mass balance	1,382	MMgals	various	0.118	lb/MMgal	**3.94**	**0.08**
Mobile - Other	various	NI	VMT	various	various	lb/VMT	**0.08**	**0.08**
Native Animal Waste							**0.00**	**0.16**
Deer	NI	9,713	head	NI	11.11	lb/head/yr	0.00	0.15
Bear	NI	307	head	NI	42.0	lb/head/yr	0.00	0.018
Prescribed burning	NI	4,164	acre/yr	N/A	various	various	**NI**	**NA**
SoCAB TOTAL							**155.74**	**184.55**

[a] No values or documentation were included in the 1997 AQMP[b]. The ammonia emisisons for the 1997 AQMP were generally based on the Radian Study[c], except for POTW dairy and beef cattle emissions.

[b] South Coast Air Quality Management District (SCAQMD). (1996) 1997 Air Quality Management Plan, November, 16.

[c] Dickson R.J. et al. (1991) Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board, Sacramento CA by Radian Corporation., Sacramento CA.

NA - Not applicable; category did not exist in report, but emissions were included in a separate category.

NI - Not inventoried in the report.

Various - More than one source

Land use - based on the amount of land associated with the category

Table 15-2. Emission Summary by Source

Source	1997 SoCAB Emissions (tons/day)	1997 SoCAB Percent of Total	2000 SoCAB Emissions (tons/day)	2000 SoCAB Percent of Total
Livestock	56.6	36.6%	60.4	32.72%
Soil	39.0	25.2%	34.2	18.55%
Fertilizer (TOTAL)	11.0	7.10%	7.68	4.16%
Domestic	28.1	18.1%	25.9	14.02%
On-Road Mobile	7.10	4.59%	33.2	17.99%
Industrial Sources	9.00	5.82%	13.2	7.13%
Composting	0	0.00%	9.69	5.25%
Landfills	0	0.00%	0.007	0.00%
Sewage Treatment	3.94	2.55%	0.082	0.04%
Mobile - Other	0.080	0.05%	0.080	0.04%
Native Animal Waste	0	0.00%	0.163	0.09%
Prescribed burning	0	0.00%	0	0.00%
SoCAB TOTAL	**155**	**100.00%**	**185**	**100.00%**

Table 15-3 Ammonia Emissions by Category per County

Category	Los Angeles County Emissions, tons/day	Orange County Emissions, tons/day	Riverside County Emissions, tons/day	San Bernardino County Emissions, tons/day	Ventura County Emissions, tons/day	Total SoCAB Emissions, tons/day
Livestock	2.30	0.46	30.6	27.0	1.91	60.4
Soil	10.0	2.92	13.3	8.01	5.64	34.2
Fertilizer	2.26	1.56	1.90	0.35	1.60	6.1
Domestic	14.8	4.16	2.62	2.94	1.30	24.6
Industrial	7.01	0.63	0.13	0.77	0.033	8.5
Composting	0.80	2.07	3.84	2.98	0.0041	9.7
Landfills	0.0015	0.004	0.0012	0.0001	0.0009	0.0
POTWs	0.054	0.017	0.0026	0.008	0	0.1
Native Animals	0.005	0.0004	0.003	0.012	0.212	0.020
Combustion						4.62
On-Road Mobile						33.2
Other Mobile						0.08
Total	37.3	11.8	52.4	42.1	10.7	181.50

Table 15-4. Comparison of 1997 SCAB, 2000 SCAB, and 2000 AQMP Inventory

Source Category	Emissions, t/d		
	1997 SoCAB[a]	2000 SoCAB	2000 AQMPb
Livestock	**56.57**	**59.89**	**62.42**
Horses and Ponies	15.89	4.32	4.95
Beef Cows	2.15	2.40	2.90
Milk Cows	8.62	21.16	21.53
Heifers and heifer calves	NA	6.59	6.76
Steers, steer calves, bulls, and bull calves	NA	2.26	2.57
Hogs and pigs	0.35	0.50	0.50
Layers	NA	NA	NA
Pullet	NA	NA	NA
Layers and pullets	NA	22.09	NA
Broilers and other meat-type chickens	NA	0.49	NA
Poultry	28.79	NA	22.66
Sheep and Lambs	0.77	0.53	0.53
Goats, Total	NI	0.007	0.0075
Rabbits	NI	0.013	0.011
Mules, Burros and Donkeys	NI	0.011	0.011
Soil	**39.00**	**34.24**	**36.00**
Urban	land use	5.93	6.13
Agricultural	land use	14.93	15.84
Rangeland/Pasture	land use	7.28	7.68
Wetland	land use	0.17	0.12
Forest Land	land use	4.07	4.96
Barren Land	land use	1.87	1.27
Fertilizer (TOTAL)	**10.98**	**7.68**	**7.30**
On Farm Liquid	0.95	0.71	0.82
On Farm Dry	3.69	1.74	2.71
Non-Farm	5.88	3.63	3.77
Anhydrous Ammonia	0.46	0.00	NA
Domestic	**29.07**	**25.87**	**25.87**
Cats	2.67	0.76	0.81
Dogs	12.02	7.05	7.48
Cigarette Smoking	0.38	0.00	0.005
Household Ammonia Use	0.86	1.02	1.07
Human Perspiration	9.51	11.21	11.76
Human Respiration	0.06	0.07	0.07
Untreated Human Waste, Homeless	1.96	740	2.14
Cloth Diapers	0.54	0.95	1.00
Disposable Diapers	0.25	0.45	0.47
Untreated Human Waste, Other	0.83	1.02	1.07

Table 15-4. Comparison of 1997 SCAB, 2000 SCAB, and 2000 AQMP Inventory

	Emissions, t/d		
Source Category	1997 SoCAB[a]	2000 SoCAB	2000 AQMPb
On-Road Mobile	**7.10**	**33.20**	**33.20**
Industrial Sources	**9.00**	**13.16**	**13.22**
Refrigeration	NA	4.90	4.94
NOx Control	NA	0.62	2.70
Metal Treating	NA	2.68	0.62
Blue Printing	NA	0.20	0.20
Wastewater Treatment (non-POTW)	NA	0.13	0.13
Traditional Point Sources (Radian Report[c])	9.00	4.62	4.62
Composting	**0.00**	**9.69**	**9.73**
Landfills	**0.00**	**0.01**	**0.01**
Sewage Treatment (POTW)	**3.94**	**0.08**	**0.08**
Mobile - Other	**0.08**	**0.08**	**0.08**
Native Animal Waste	**0.00**	**0.16**	**0.21**
Deer	0.00	0.145	0.19
Bear	0.00	0.018	0.025
Prescribed burning	**NI**	**NA**	**NA**
TOTAL	**155.74**	**18[illegible].06**	**188.12**

[a] No values or documentation were included in the 1997 AQMP[b]. The ammonia emisisons for the 1997 AQMP were generally based on the Radian Study[c], except for POTW, dairy and beef cattle emissions. Values are for the five counties (Los Angeles, Orange, Riverside, San Bernardino) referred to as the SCAB.

[b] Values are for the AQMP Modeling Domain. Differences in the fertilizer, domestic and native animals, soils, domestic source emissions are due to differences in the size of the SoCAB and the AQMP Modeling Domain. Other emissions differences are due to rounding error (especially for multiple point sources such as dairy cows and poultry).

[c] Dickson R.J. et al. (1991) Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board, Sacramento CA by Radian Corporation., Sacramento CA.

NA - Not applicable; category did not exist in report, but emissions were included in a separate category.

NI - Not inventoried in the report.

Various - More than one source

Land use - based on the amount of land associated with the category

Chart 15-1. Pie Graph of 1997 SoCAB Ammonia Emissions by Source

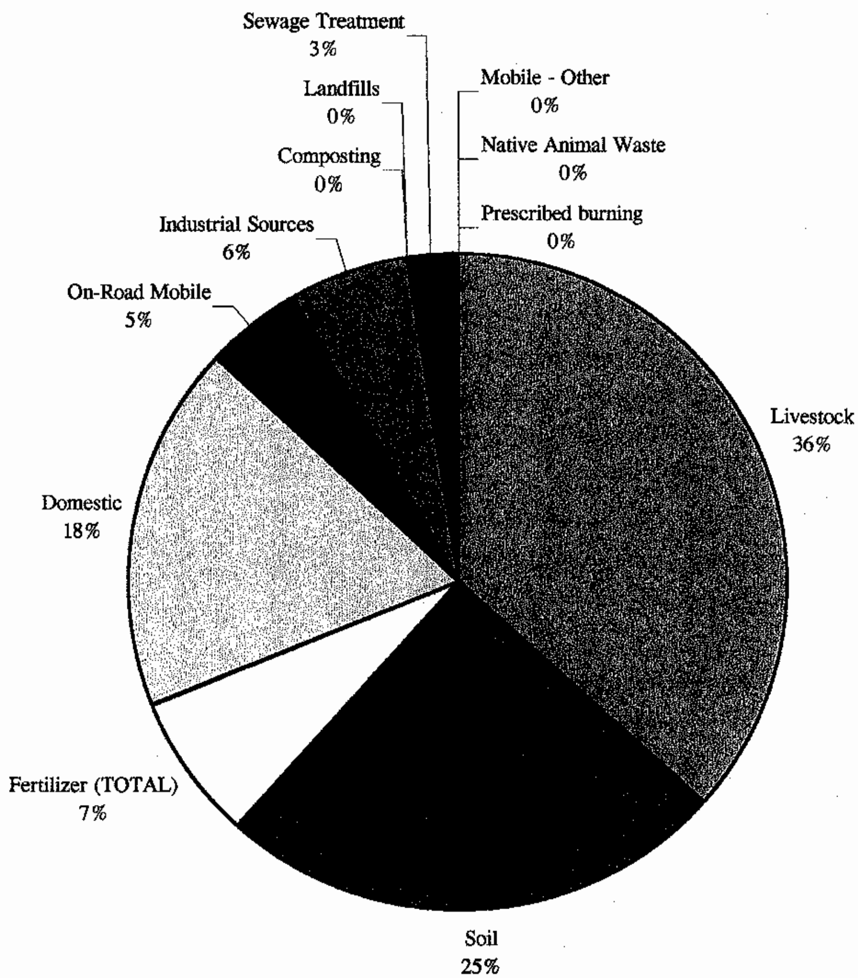


Chart 15-2. Pie Graph of 2000 SoCAB Ammonia Emissions by Source

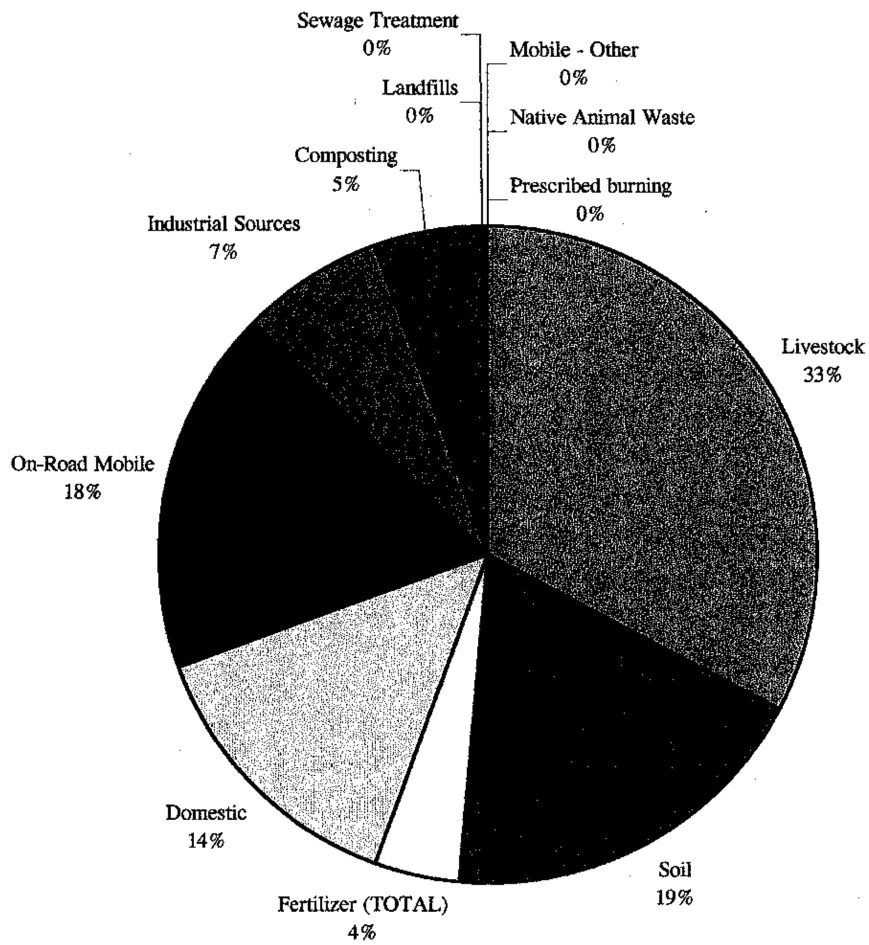
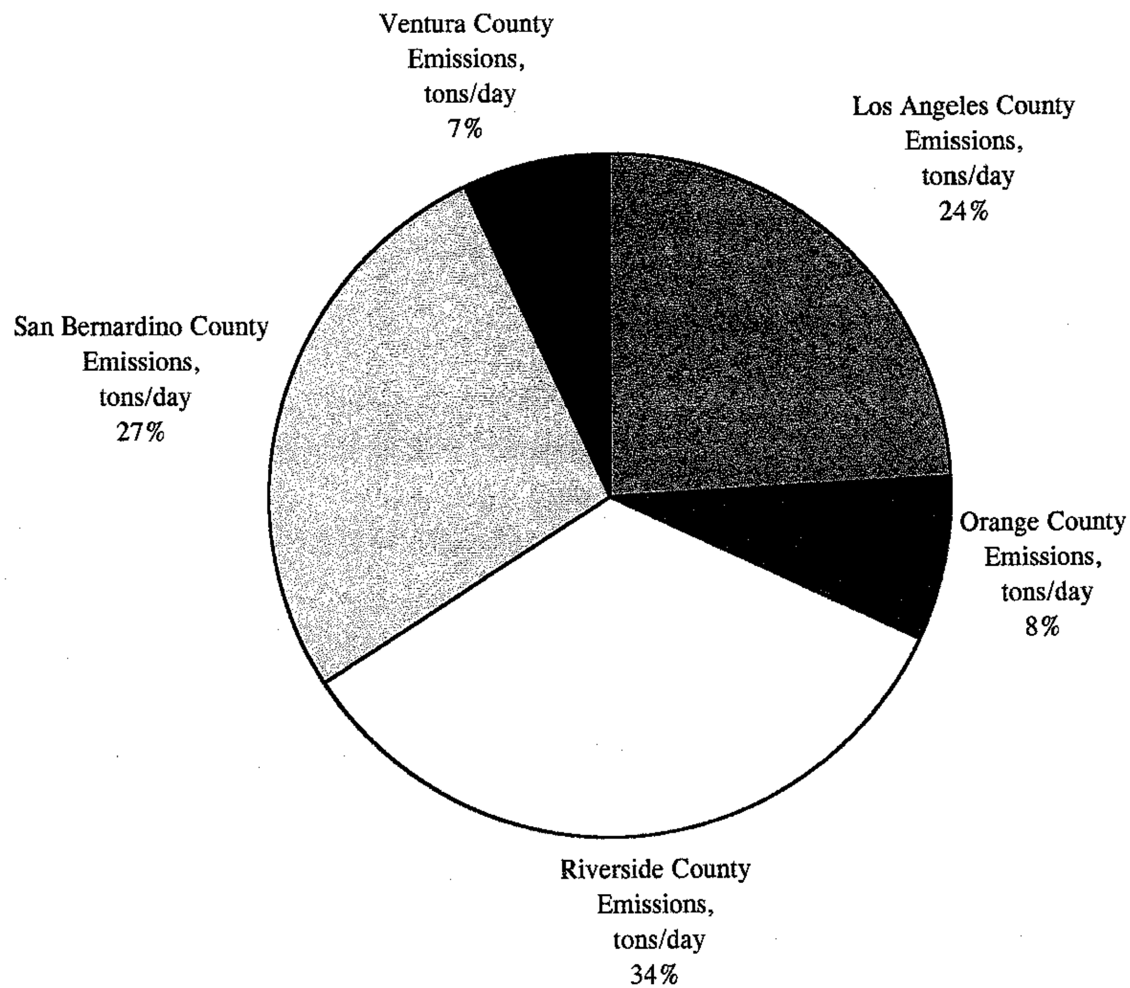


Chart 15-3. Pie Graph of SoCAB Ammonia Emission per County



APPENDIX A

NEW LITERATURE

APPENDIX A – LITERATURE REVIEW

A.1 LIVESTOCK AND POULTRY

Literature Reviewed

- Aerial Information Systems (AIS) Southern California 1990 Aerial Land Use Study, Land Use Level III/IV Classification – The classification developed by AIS is a modified Anderson-type Land Use Classification. The classification uses a hierarchical system. Most land uses are mapped to the fourth level.

- ApSimon et al.[2] – This 1994 paper was referenced by Schlesinger and Hartley[3] who stated that the emission factors are similar to Buijsman[4]. AVES did not review this paper; however, Schlesinger and Hartley[3] approved of the values, which were approved by Bouwman[5].

- Ashbaugh et al.[6] – This paper was not reviewed by AVES. James et al.[7] referred to the box model developed by Ashbaugh et al. AVES relied on the presentation in James et al.[7]

- Asman[8] – The May 1991 Asman study is a comprehensive ammonia inventory for Europe based on literature review. It provides extensive investigation into emissions from livestock and agriculture. This study is significant because of the broad scope of the study. It is highly favored by recent literature reviews such as Baytte et al.[9] and Sutton et al.[10]

- Battye[9] – This 1995 study is a literature survey of ammonia emission factors between 1985 and 1994 for the U.S. EPA, Office of Research and Development. Sources surveyed include the Compilation of Air Pollution Emission Factors – Volume I (AP-42)[11] for industrial sources, the National Acid Precipitation Assessment Program factors for combustion sources, human breath and perspiration, and publicly owned treatment works (POTW), European factors for agricultural sources, and Toxic Release Inventory for industrial sources. It is relevant to livestock and poultry because the study attempts to identify emission factors that are appropriate for the entire United States and ranks them according to the AP-42 rating method.

- Bouwman et al.[5] – The 1997 paper is a literature review and global emission inventory. The study is a comprehensive literature review that examines sections of the global environment. The study is significant because of its broad scope that includes domestic emissions, oceans, and biomass burning.

- Buijsman et al.[4] - This Northern European 1987 study is a literature review focused primarily on agricultural emissions. The Buijsman studies were some of the earliest ammonia European inventories.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- E.H. Pechan and Associates[14] – The 1994 E.H. Pechan study focuses on volatile organic compounds (VOCs) from livestock waste in Sacramento, Ventura, and the South Coast Air Basins for the ozone Federal Implementation Plan (FIP). The Pechan study gathered activity data and used emission factors from literature. The study is significant for its investigation of control technology for livestock waste.

- Fogerty, Carrie, Orange County Vector Control [15] – Ms. Fogerty stated that there are no chicken ranches in Orange County.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study)[12].

- Gregor, Joe[17], San Bernardino County Environmental Health – Mr. Gregor provided chicken populations and ranch addresses for San Bernardino County.

- Hugh Murray[18], County of Riverside Department of Environmental Health, Vector Control Section, – Mr. Murray provided chicken populations and ranch addresses for Riverside County.

- James et al.[7] – This paper, published in 1997, investigates ammonia emissions by downwind monitoring with acid-impregnated active filter packs and chemically-reactive passive filters from a commercial feedlot (15 samples) and dairy (9 samples) in southern San Joaquin Valley[19]. It is relevant to livestock and poultry because it is a California study that includes an attempt to characterize diurnal effects.

- Leduff, David[20], County of Los Angeles Department of Health Services, Public Health Programs, Environmental Health Vector Management Program – Mr. Leduff provided AVES with chicken populations and ranch addresses for Los Angeles County.

- Möller and Schieferdecker[21] – This 1989 European ammonia study was reviewed by Battye[9], Sutton[10], and Bouwman[5]. AVES did not review this paper because it was discounted by the sources listed above.

- Muck and Steenhuis[22] – This paper was not reviewed by AVES. The diurnal profile equation developed in this paper was presented in the San Joaquin Valley Study.

- Sadeghi and Dickson[23] – AVES did not review this report. The report consists of several volumes and access to it was cost prohibitive by this project. AVES contacted Radian and AUSPEX, but neither could find the document.

- Schlesinger and Hartley[3] – This 1992 global ammonia budget is based on a literature search. The emission factor for poultry provided by Schlesinger and Hartley was approved by Bouwman[7], and is similar to Asman's[8] and Buijsman's[4] emission factor.

- Schmidt and Winegar[24] – This 1996 study examined ammonia emissions from four dairies in the South Coast Air Basin (SoCAB) over 28 different types of sources/surfaces during two seasons (winter and summer) by source testing. The study is significant because SoCAB dairies are examined. The feed, housing and housekeeping procedures are different from Europe and other areas in the United States. Dr. Winegar has re-evaluated the test results from this study[25] (see Appendix B).

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13]– The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report[12].

- Steenhuis, T.S., G.D. Bubenzer, and J.C. Converse[26] – This 1982 paper was not reviewed by AVES. The diurnal profile equation developed in this paper was presented in the Radian Study[12]. AVES followed the discussion in the Radian Study. The equation is cited in the San Joaquin Valley Study[19] from Sadeghi and Dickson[23], who state that Russell and Cass developed it during a 1986 address.

- Sutton, et al.[10] – This 1995 literature survey focuses on ammonia emissions in the United Kingdom from the 1960s to 1994 for all sources. The Sutton study is significant because of its detailed uncertainty analysis.

- The San Joaquin Valley Study[19] – This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and a publicly owned treatment works plant (POTW). It is significant because it reviews new literature as well as providing new test results.

- U.S. Geological Survey (USGS), USGS Land Use and Land Cover (LULC)[27] - The National Mapping Program, a component of the USGS, produces and distributes land use and land cover maps and digitized data for the conterminous U.S. and Hawaii. Land use refers to the human activities that are directly related to the land. Land use and land cover areas are classified into nine major categories: urban or built-up land, agricultural, rangeland, forest, water areas, wetland, barren land, tundra, and perennial snow or ice. Manually interpreted land use and land cover polygons were compiled onto 1:250,000-scale USGS base maps based upon the Universal Transverse Mercator (UTM) projection.

- *The Economic Impact of the Horse Industry in the United States*[28],American Horse Council Foundation (AHCF), – The 1997 Census of Agriculture[29] equine populations that focuses on farms. The AHCF study is significant because it investigates all equine population types; not only on farms. The equine study is limited to the state level because it is based on sample populations..

- U.S. Department of Agriculture (USDA), *1997 Census of Agriculture*[29] – State and County Agricultural census have been subsumed by the USDA's Agricultural Census. While the census is comprehensive, some of the categories have been combined, reducing activity refinement. This study is significant because the population numbers are tied to financial reports required by the Federal government.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of wildlife excrement and domestic emissions.

- Winegar E., *Review of Literature Sources for Emissions of Ammonia from Dairy Farms* [25] – Dr. Winegar reviewed the current ammonia emission factors for dairy farms. Dr. Winegar also revisited the analysis of the source tests results in the 1997 Schmidt and Winegar[24] report. This report is significant because it challenges the 1996 Schmidt and Winegar[24] emission factors for beef and dairy cattle, which were used for the 1997 AQMP[13]. The final analysis is in line with Asman[8] and Sutton[10]. This review is presented in Appendix B.

- Wilkinson, et al. – This 1998 report details a statistical model for ammonia emission estimation from a dairy. The model was developed from multiple regression analysis, which the paper states, is able to account for over 70% of the variance in the estimated ammonia emissions rates. This paper is significant because it attempts to estimate temporally resolved ammonia emissions.

Emission Factors

<u>Dairy Cattle</u>

Dairy emission factors are addressed in detail in Dr. Eric Winegar's *Review of Literature Sources for Emissions of Ammonia from Dairy Farms*[25], which is presented in Appendix B. This review considers the basis, statistical relevance and applicability of dairy emission factors available from the literature as well as a detailed analysis of the test results produced by Schmidt and Winegar[24].

<u>Non-Dairy Cattle</u>

James et al.[7] produced emission factors for beef cattle (74 lb/head/yr) from ambient tests and a box model described by Ashbaugh et al.[6]

M.A. Sutton et al.[10] evaluated the emission factors developed by several studies in mainland Europe and the United Kingdom. Sutton provided average emission factors with uncertainty ranges.

Sutton states that the greatest uncertainties in cattle nitrogen emissions are waste storage and land spreading emissions. Uncertainty in the fraction of nitrogen emitted as ammonia is also reported by the Sutton study.

Battye et al.[9] recommended values for use in future U.S. inventories. Battye et al.[9] favors Asman[8] for non-dairy cattle. In favoring Asman[8], Battye[9] discounts Gharib and Cass[16], Buijsman et al.[4], Möller and Schieferdecker[21], and Warn et al [30]. By discounting Gharib and Cass[16], Battye[9] discounts the 1991 Radian study, which was based on the Gharib and Cass[16] values. The 1997 AQMP did not use the Gharib and Cass[16] values, but used Schmidt and Winegar[24] values instead. Asman's[9] value for composite cattle (50.5 lb. NH_3/head yr) is on the high end of Sutton's[10] suggested value (37 lb. NH_3/head yr) and range (17-54 lb. NH_3/head yr). Battye et al. [9] used the EPA's AP-42 rating system for evaluating the emission factors they proposed. The AP-42 system rates emissions factors from A through E, with an A rating representing the more reliable rating and E a less reliable rating.

Emission factors can be evaluated for appropriateness for geographical, meteorological, and cultural (husbandry and land use practices) area application as well as precision and accuracy. It is not clear whether non-dairy cattle emission factors recommend from Gharib and Cass[16] were specific to the SoCAB. Warn et al. values, like Baytte et al. were for U.S. inventories. Buijsman et al.[4], Möller and Schieferdecker[21], M.A. Sutton et al.[10] were developed for European or global use. Schmidt and Winegar[24] examined emissions from dairies exclusively. Therefore, while not specifically developed for the SoCAB, AVES chose the Battye et al. values because the Battye et al. values are recommended for use in the U.S. and were EPA-approved and rated.

AVES developed a composite emission factor from Battye et al.[9] for steers, bulls and calves of 30.39 lbs/head/year (18.12 lbs/head/year for steers, 61.53 lbs/head/year for bulls, and 11.53 lbs/head/year for calves), because the activity data only included a single population for these three categories. The composite emission factor assumed an equal number of steers, bulls and calves, because no better information was available. The steer and calf emission factors were given a B rating by Battye et al. the steer emission factor was given a C rating.

Pigs, Sheep, Horses, Mules, Burros, Donkeys, Goats, and Rabbits

Sutton[10] states that the most sensible approach to ammonia emissions from sheep, pigs and horses is to use midrange values, which includes Asman[8]. Sutton states that nitrogen emissions from horses are based on excretion rates and assumed nitrogen percentage losses. Sutton suggested an ammonia emission factor of 10 kg N/horse/year (22.04 lbs/horse/year) with a range between 5 and 20 kg N/horse/year (13.38 and 53.55 lbs/horse/year). Battye et al.[9] favors Asman's[8] 26.9 lbs/horse/year emission factor. The TSS15[19] Study used the Battye et al. emission factors. AVES applied horse emission factors to the Mules, Burros, and Donkeys because no unique values were presented in the literature reviewed, and horse, mules, and asses were combined by ApSimon et al.[2] and Buijsman et al.[4] as reported by Schlesinger and Hartley[3]. AVES used Battye[9] emission factors because the emission factors are EPA-approved and rated.

Battye et al.[9] favors Asman's[8] values for pigs, and sheep. The pig emission factors were given a rating of B. The sheep emission factors received low values of D because of the broad range of values. Horse, goat, and rabbit emission factors received low values of E because of the small data set.

Battye et al[9]. favors Asman[6] for pigs, but notes a mathematical error in Asman's[8] composite calculations. In favoring Asman[6], Battye[9] discounts Cass et al.[16], Buijsman et al[4]., Möller and Schieferdecker[21], and Warn et al[30]. Battye[9] recalculated Asman's[8] value from the animal populations and emission factor by type of pig. The corrected factor is

8.512 kg NH_3/pig year. AVES used Battye[9] emission factors because the emission factors are EPA-approved and given a B factor rating.

Poultry

Battye[9] and Sutton[10] favor Asman[8] for poultry estimates. Poultry are typically divided into layers, pullets, fryers (broilers), and by maturity. The emission factor comparisons described here focus on a composite emission factor for an equivalent comparison, because not all literature presented emission factors for each category of poultry (see Table A-1 for a more complete listing of emission factors by poultry category). The Battye[9] and Sutton[10] numbers are consistent with Bouwman[5]. It is unclear if Bouwman[5] used emission factors from Asman[8] or from Schlesinger and Hartley[3]. Schlesinger and Hartley[3] based their emissions on ApSimon et al.[2] and Buijsman et al.[4], which they state are convergent. AVES did not review ApSimon et al.[2] and reviewed only one Buijsman et al.[4] paper. However, the Buijsman[4] values (0.21 and 0.24 kg N/animal yr or 0.56 and 0.64 lb NH_3/animal/yr) as listed by Sutton[10] are close to Asman's[8] value (0.20 kg N/animal yr or 0.54 lb NH_3/animal yr). These numbers are lower than the numbers in the Radian report[12], which were based on Gharib and Cass et al.[16] (00.29 kg N/animal yr. or 78 lb NH_3/animal yr).

Asman[8] includes an investigation into housing and manure spreading for poultry. Sutton et al.[10] compares this information with other literature in Europe. Battye et al. [9], Schlesinger and Hartley[3], and Gharib and Cass et al.[16] do not discuss this in their reports. It is not clear how animal husbandry and land use practices effect the applicability of the poultry emission factors, because comparisons can not be made between the studies with the information available.

Only generic categories such as pullets, layers, broilers, and other were included for comparison and possible use. Maturity categories for which activity categories were not found (e.g. fryer-roasted turkeys, pullets under 3 months old, etc.) were not used. All of the Battye et al. emission factors for the generic categories were given B factor emission ratings by Battye. Emission factors that were given less than a B rating related to the excluded categories. Because of the convergence around Asman[8] values (which were used by Battye et al.) and because the applicable emission factors were given a B rating by Battye, AVES used the Battye et al.[9] values.

AVES developed a composite emission factor from Battye et al.[9] for layers and pullets (chickens) of 0.996 lbs NH_3/chicken/yr (1.32 lbs NH_3/bird/year layers, and 0.672 lbs NH_3/bird/year for pullets), because the activity data only included a total population for these two categories. The 0.368 lb/broiler/year Battye et al.[10] emission factor was used by AVES to estimate ammonia emission from boilers.

A summary of emission factors is presented in Table A-1.

Activity Data

The San Joaquin Valley Study[19] used population data from the State Agricultural Statistics Branch to spatially allocate cattle, hogs, and sheep emissions.

E.H. Pechan and Associates[14] developed livestock inventories for cattle, hogs and sheep from the California Statistics Service county-level data. The dairy and poultry inventories were taken from the 1997 Census of Agriculture.[29]

The Radian Study used activity data from the Los Angeles Veterinary Office for Los Angeles, which was disbanded in 1995. The office was re-established in 1999, but didn't have pertinent information available. Information from the Census of Agriculture and estimates from the University of California Cooperative Extension Service were used for Orange County activity. County Agricultural information was used for Riverside and San Bernardino County activities.

Temporal and Spatial Allocation

The San Joaquin Valley Study[19] references Sadeghi and Dickson[23], which lists annual or biannual manure removal. Feedlots with different nitrogen levels are cycled between feed programs. The cycles rotate in the fall and late spring, according to Sagedhi and Dickson[23].

Muck and Steenhuis[22] and Steenhuis et al.[26] report a diurnal variation and suggest this profile:

$$Ei \propto [2.36^{(Ti-273)/10}]V_i^{0.8}A$$

where,

E_i = hourly emission rate at hour i from animal waste decomposition

A = daily total emission rate for ammonia from animal waste = $\sum_{i=1}^{24} E_i$

Ti = ambient temperature in degrees Kelvin at hour i

Vi = wind speed in meters per second (m/s) at hour i (a minimum wind speed of 0.1 m/s is assumed)

A preliminary temporal model was developed by Wilkinson et al.[33] for diary cattle:

$$E_{NH3} = pop \times \exp[152.508 - 279,328 \text{ x } rh - 0.177476 \times sol + 273.186 \times ws^{0.5} + 0.337603 \times rh \times sol - 0.945958 \times ws^{0.5} \times T]$$

where,

E_{NH3} - estimated dairy ammonia emissions (g/hr)

sol - average hourly solar intensity (W/m^2)
rh - average hourly relative humidity
ws - hourly mean scalar wind speed (m/s)
T - average hourly temperature (K)
pop - producing dairy cattle population

This model was statistically derived from eighteen samples taken over two days February 13-14, 1997 at one facility in San Joaquin Valley, including vertical samples on the first day. The model predicted ammonia emissions for forty-six hours as 0.97 tons with a 95% confidence interval of 0.23 tons to 4.2 tons.

James et al.[7] also finds a diurnal trend, which may be associated with meteorological conditions. The emission factor during the night is approximately 25% of the day emission factor for dairies and 13% of the day emission factor for beef cattle.

Facility	Day Emission Factor	Night Emission Factor
Dairy	~100 (~-75 – ~275)	~30 (~-0 – ~75)
Beef	~230 (~390–~60)	~40 (~10 – ~60)

Table A-1. Livestock Emission Factors

Animal	Gharib and Cass[a] (1984) lb. NH_3/head-yr	Sadeghi et al.[h,k] (1992) lb. NH_3/head-yr	Battye et al.[c,j] (1994) lb. NH_3/head-yr.	Sutton et. al. [d] (1995) lb. NH_3/head-yr.	Schmidt and Wineger[e] (1996) lb. NH_3/head-yr.	Wineger[f] (1999) lb. NH_3/head-yr	Bouwman, et al.[g] (1997) lb. NH^3/head-yr.	James, et. al.[h] (1997) lb. NH_3/head-yr.	Hutchings, et al.[i] (1995) lb. NH3/head-yr.
Cattle - Dairy Total	88	88[h]		48-72	18	51	44.88	74[d]	56.2
Cattle - Non-Dairy							17.16		
Cattle - Beef	100	100[b]						130[d]	9.3
Cattle - Range	100	100[b]							
Cattle and Calves - Composite	88		50.5	37 (17-54)					
Cows and Heifers that have calved (beef cows)[l]			87.57						
500 lb. and over: Heifers - Beef cow replacements[l]			87.57						
500 lb. and over: Heifers - Milk cow replacements[l]			33.49						
500 lb. and over: Heifers - Other[l]			28.75						
500 lb. and over: Steers[l]			18.12						
500 lb. and over: Bulls[l]			61.53						
Calves under 500 lb.[l]			11.53						
Suckling Cows									
Young Cattle									
Buffalo							19.14		
Horses	110	52	26.9	22 (11 - 44)			16.72		
Sheep	8.8	8.8[h]	7.43	2.4 (0.88 - 3.3)			1.41		
Goats			14.1				1.28		
Hogs	15	15[h]	20.3	9.5 (6.8 - 12.5)			8.80		
- Sows Farrowing[l]			35.56						
- Other - breeding[l]			11.5						

Table A-1. Livestock Emission Factors

Animal	Gharib and Cass[a] (1984) lb. NH_3/head-yr	Sadeghi et al.[b,k] (1992) lb. NH_3/head-yr	Battye et al.[c,l] (1994) lb. NH_3/head-yr.	Sutton et. al.[d] (1995) lb. NH_3/head-yr.	Schmidt and Wineger[e] (1996) lb. NH_3/head-yr.	Wineger[f] (1999) lb. NH_3/head-yr	Bouwman, et al.[g] (1997) lb. NH^3/head-yr.	James, et. al.[h] (1997) lb. NH_3/head-yr.	Hutchings, et al.[i] (1995) lb. NH3/head-yr.
Market hogs - under 60 lbs.			15.4						
60-119 lb.[l]			15.4						
120-179 lb.[l]			24.3						
180 lb. and over[l]			24.3						
Chickens - Composite	0.78		0.393	0.48 (0.33 -0.66)			0.44		
Chickens - Broilers		0.79	0.368						
Laying		1.6	1.32						
Pullets		1.2							
Pullets - Laying Age[l]			0.672						
- over 3 mos., not laying[l]			0.593						
- under 3 mos.[l]			0.375						
Other chickens[l]			0.395						
Turkeys	2.1	1.9	1.89	1.5 (1.1 - 2.1)					
- Young Turkeys			1.96						
- Old Turkeys			2.82						
- Fryer-Roaster			1.89						
Ducks			0.258	0.22 (0.13 - 0.29)					

[a] Gharib, S., and G.R. Cass (1984): Ammonia Emissions in the South Coast Air Basin. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

[b] Coe, D., Chinkin, L., Loomis,C., Wilkinson, J., Zwicker, J., (1998): Technical Support Study 15: Evaluation and Improvement of Methods for Determining Ammonia Emissions in the San Joaquin Valley. Prepared for the California Air Resources Board by Sonoma Technology, Inc., January.

[c] Battye, R., W. Battye, C. Overcash, and S. Fudge (1994): Development and Selection of Ammonia Emission Factors. EPA/600/R-94/190. Final report prepared for U.S. Environmental Protection Agency, Office of Research and Development. EPA Contract No. 68-D3-0034, Work Assignment 0-3.

[d] Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom, Atmospheric Environment, (29):1 393-1411.

[e] Schmidt, C.E., and E. Winegar (1996): Results of the Measurements of PM10 Precursor Compounds from Dairy Industry Livestock Waste. Technical report prepared for the South Coast Air Quality Management District.

[f] Winegar E. (1999) Review of Literature Sources for Emissions of Ammonia from Dairy Farms. Applied Measurement Science.

Table A-1. Livestock Emission Factors

[g] Bouwman, A.F., D.S. Lee, W.A.H. Asman, F.J Dentener, and. K.W. Van Der Hoek (1997): A Global High Resolution Emission Inventory for Ammonia, Global Biogeochemical Cycles, Vol. II, No. 4, pp. 561-587.

[h] James, T, N. Fritas, L. Ashbaugh, and D. Meyer (1997): Field Estimates of Volatilization from Cattle Production Facilities. Proceedings from the Air And Waste Management Association Conference - Emission Inventory: Planning for the Future, October 28-30, pp 259-267.

[i] Hutchings, N.J., S.G. Sommer, S.C. Jarvis (1996): "A Model of Ammonia Volatilization from a Grazing Livestock Farm," Atmospheric Environment, Vol. 30, No. 4, pp. 589-599.

[j] Battye et al. recommended emission factors developed by Asman (1992).

[k] Sadeghi and Dickson recommended emission factors developed by Gharib and Cass (19984).

[l] U.S. Agricultural Statistics Classifications.

[m] James et al. recommended emission factors developed by Battye et. al (1994)

Note: Ranges represent high-low recommended emission factors collected from several sources.

A.2 NATIVE ANIMAL WASTE

Literature Reviewed

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- California Department of Fish and Game, Upland Game/Waterfowl, *Report of the 1997 Game Take Hunter Survey*[33] - The survey provides hunter take for 1997. The survey does not provide for a means of tying the hunter take to game populations.

- California Department of Fish and Game, *Black Bear Management Plan*[34] - The 1998 Black Bear Management plan provides black bear population estimates.

- Dickson et al.[35] (1988), *Evaluation of Emissions from Selected Uninventoried Sources in the State of California* - This report was not reviewed by AVES. AVES assumed the values presented in the San Joaquin Valley Study[19] to be correct.

- Erisman[36] – This paper was not reviewed by AVES. Emission factors from this paper were presented in a table in the San Joaquin Valley Study[19]. AVES was unable to locate the paper because it was not referenced in the San Joaquin Valley Study. AVES assumed that the San Joaquin Valley Study presented the values correctly.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study).[12]

- McKeever, Jane[37] California Department of Fish and Game, Upland Game and Waterfowl, Phone Conversation – Ms. McKeever provided AVES with deer populations.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data.

- South Coast Air Quality Management District (SCAQMD) - *1997 Air Quality Management Plan (AQMP)*[13], November 16, 1996. The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef and dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report[19].

- Sutton et al.[10] - This 1995 literature survey focuses on ammonia emissions in the United Kingdom from the 1960s to 1994 for all sources. The Sutton study is significant because of its detailed uncertainty analysis.

- U.S. Geological Survey (USGS), USGS Land Use and Land Cover (LULC)[27] - The National Mapping Program, a component of the USGS, produces and distributes land use and land cover maps and digitized data for the conterminous U.S. and Hawaii. Land use refers to the human activities that are directly related to the land. Land use and land cover areas are classified into nine major categories: urban or built-up land, agricultural, rangeland, forest, water areas, wetland, barren land, tundra, and perennial snow or ice. Manually interpreted land use and land cover polygons were compiled onto 1:250,000-scale USGS base maps based upon the Universal Transverse Mercator (UTM) projection.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of wildlife excrement and domestic emissions.

Emission Factors

The San Joaquin Valley Study[19] reviewed emission factors for native animal wastes from five sources: Gharib and Cass[16], Erisman[36] Dickson et al.[35], Warn et al.[30], and Sutton et al.[10] Published emission factors for wild animals are highly uncertain at this time, many are based on extrapolation from domestic animals and arbitrary assumptions including waste production rates and fraction of nitrogen released as ammonia. The San Joaquin Valley Study[19] concluded that current information was insufficient and did not include the source in the inventory.

Warn et al.[30] cited emission factors from a literature search of domestic livestock emissions for herbivore emissions (0.14 lb./ kg-herbivore-yr). Multiplying the Warn et al.[30] emission factor for herbivores by the weight of deer (11 lbs/head/yr) results in an emission factor close to that provided by Dickson et al.[12] (10 lbs/head/yr). The Warn[30] emission factors are used because the factors are EPA-accepted and rated values.

Emission factors are presented in Table A-2.

Activity Data

Activity data for large game was obtained from the California Department of Fish and Game (CDFG). Deer populations were obtained from conversations with Jane McKeever[37] of the CDFG. Bear populations were estimated from the 0.25 bear per square mile density estimated by CDFG[34] and total forest area from the USGS land use database[27]. The total game bagged by county and type of game in 1997 was obtained from the Report of the 1997 Game Take Hunter Survey[33]. Good population estimates could not be developed from the number of game bagged; therefore, these numbers were not used.

AVES developed emission factors for deer and bear only, because of low confidence in populations for other native animals.

Spatial and Temporal Allocation

Native animal waste will be allocated to range and forest land in the USGS land use database[27].

Current data does not support temporal allocation of native animal waste emissions.

Table A-2 Native Animal Ammonia Emission Factors from Literature

Animal	Gharib and Cass[a] (1984) lb. NH_3/head-yr	Erisman et al.[b] (1989) lb. NH_3/head-yr	Dickson et al.[c] (1988) lb. NH_3/head-yr.	Warn et. al.[d,e] (1990) lb. NH_3/head-yr.	Sutton et. al.[f] (1995) lb. NH_3/head-yr.	Bouwman et. al.[g] (1995) lb. NH_3/head-yr.
Rabbits	0.37	6.2				
Rats	0.18					
Mink		1.3				
Fox		5				
Deer[h]			10	0.14 lb./ kg-animal-y.[i]	0.11 - 0.51	
Wild Pigs			43			
Mountain Lion			6.9			
Elk			54	37.8		
Native Sheep			10	16.8		
Bear			10	0.14 lb./ kg-animal-yr[i]		
Antelope			10	6.3		
Sea Birds - Large					0.7	
Sea Birds - Small					0.2	
Caribou				13.3		
Moose				56		3.52
Reindeer						2.2
Carnivores				1.6 lb./ kg-animal-yr.		
Herbivores				0.14 lb./ kg-animal-yr.		0.0006 lb./ lb biomass consumed
Birds				1.3 lb./ kg-bird-yr.		

[a] Gharib, S., and G.R. Cass (1984): Ammonia Emissions in the South Coast Air Basin. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

[b] Erisman, (1989)

[c] Dickson R.J. et al. (1991) Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Report prepared for the California Air Resources Board, Sacramento CA by Radian Corporation., Sacramento CA.

[d] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. EPA-600/7-90-014. Final Report Prepared for Office of Reasearch and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corporation, Chapel Hill, N.C., EPA Contract No. 68-02-4374, Work Assignment No. 43 , June.

[f] Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom, Atmospheric Environment, (29):1393-1411.

[e] Emission factors are calculated from average emission per kg-animal and average animal body weights. The factors for carnivores and herbivores reflect the per kg-animal emissions.

[g] Bouwman, A.F., D.S. Lee, W.A.H. Asman, F.J Dentener, and. K.W. Van Der Hoek (1997): A Global High Resolution Emission Inventory for Ammonia, Global Biogeochemical Cycles, Vol. II, No. 4, pp. 561-587.

[h] Estimates are for unspecified California deer species (Dickson, 1998) and Red Deer in the U.K. (Sutton, 1995).

[i] Herbivore emission factor applied.

A.3 PUBLICLY OWNED TREATMENT WORKS

Literature Reviewed

- Ahn, T., Kogan, V., and E.M. Torres[38] – This 1998 paper discusses the AB2888 Air Toxic Inventory Report (ATIR) for two County of Sanitation District of Orange County (CSDOC) wastewater treatment plants. Source test and fate-transport models were used to estimate ammonia emissions. This paper is significant because it represents current CSDOC operations.

- California Air Resources Boards (CARB) Air Toxics Emission Data System (ATEDS)[39] – The ATEDS database consists of emission estimates developed for the Air Toxic Inventory Reports (ATIRs) under AB2588. The information in ATEDS is significant because it is submitted by the facility.

- County Sanitation District of Los Angeles County, a letter to the District dated November 1, 1995[40] - This letter states the concerns that the County Sanitation District of Los Angeles County (CSDLAC) has with the Radian Study[12]. The letter states that the Radian Study[12] over estimates the emissions by several orders of magnitude. The CSDLAC uses mass balances, Occupational Safety and Health Agency (OSHA) (OSHA) Immediately Dangerous to Life or Health (IDLH), differences in sludge processing characteristics, and the Air Toxic Inventory Reports (ATIRs)[39].

- County Sanitation District of Orange County, A letter to the District dated November 22, 1995[41] - This letter states the concerns that the County Sanitation District of Orange County (CSDOC) has with the Radian Study[12]. The letter states that the Radian Study[12] over estimates the emissions by several orders of magnitude. The CSDOC uses mass balance, comparison to plants in New York, and odor as arguments for their position.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study)[12].

- Knapp, T.E., and G.M. Adams[42] – This 1997 paper examines the ammonia emissions from County Sanitation District of Los Angeles County (LACSD) water reclamation plants (WRPs) by source testing. The paper criticizes the 1991 Radian Report[12]. The paper is significant because it focuses on ammonia emissions from current operations at LACSD WRPs and develops emission factors based on source tests.

- Kogan, V., and E.M. Torres[43] – This 1997 paper examines ammonia emissions from two County of Sanitation District of Orange County (CSDOC) wastewater treatment plants, based on source testing, mass balance and Toxchem+ modeling. The paper outlines the CSDOC's attempts to lower toxic emissions and odors. The paper is significant because it focuses specifically on ammonia emissions from the CSDOC facilities.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13] - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef and dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report[12]

- SCAQMD Memorandums[44,45,46,47,48] – The District's calculations and evaluations of source testing and ammonia emission calculation in CSDLAC[40] and CSDOC[41] letters.

- State Water Resources Control Board (SWRCB) Database of Waste Dischargers[49] – The SWRCB database has the universe of waste dischargers in California.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of wildlife excrement and domestic emissions.

Emission Factors

The San Joaquin Valley Study[19] reviewed methodology from NAPAP, Gharib and Cass[16], based on ATEDS[39]. The San Joaquin Valley Study also developed emission factors using a linear regression of reported emissions and the facility base flow rate from 12 wastewater plants. Flow rates were obtained from the California State Water Resources Control Board (SWRCB) Database of Waste Dischargers[15]. Emissions were obtained from the California Air Resources Boards (CARB) Air Toxics Emission Data System (ATEDS)[16]. The regression resulted in an emission factor of 0.157 lb/MMgal. The emission factor was multiplied by the base flow rate reported in the SWRCB database, in order to calculate emissions. A postscript to the San Joaquin Valley Study[19] suggested that the reported emissions in the ATEDS report[39] likely neglected the emissions from the sludge drying beds. Field data collected by the study at the Visalia plant documented in the San Joaquin Valley Study[19] indicates that the sludge drying beds are the dominant source at the plant. The postscript concluded that emissions were likely underestimated by a factor of 300.

The California Air Resources Boards (CARB) Air Toxics Emission Data System (ATEDS)[39] has emissions for select treatment plants, but not for the complete list of plants listed in the Radian Report.

The County Sanitation District of Los Angeles County (LACSD) and the County of Sanitation District of Orange County (SCDOC) sent letters[40,41] to the SCAQMD criticizing the emissions in the Radian Study[12]. The SCAQMD re-evaluated the Gharib and Cass[16] emission factors presented in the Radian Study[12] in a series of memorandums[44,45,46,47,48]. The conclusion of the memorandums was that the emissions presented in the Radian Study[12] should be reduced by 90%.

The LACSD presented a paper to the Air and Waste Management Association (AWMA)[42]. The paper criticizes the Radian Study[12] and presents results from source tests. The paper estimates ammonia emissions from the five LACSD POTWs to be 124 tons/yr instead of the 10,500 tons/yr reported by the Radian Report[12].

The CSDOC has presented two papers to the Air and Waste Management Association (AWMA)[38, 43]. The papers describe the development of emission factors from source tests,.mass balance and Toxchem+ modeling at two wastewater treatment plants. The Kogan, V., and E.M. Torres paper[43] estimates emissions from the two plants to be 4,400 lb/yr and 5,176 lbs/yr.

Kogan, V., and E.M. Torres provided flow rates. Therefore, the Kogan, V., and E.M. Torres emissions could then be converted to emission factors based on flow rates presented in their paper. Emission factors based on flow rate allow the results to be applied to other facilities. If the emissions are multiplied by the flow rates (29,200 MMgal/yr and 60,255 MMgal/yr) the resulting emission factors are 0.151 lb/MMgals and 0.086 lb/MMgals. The average of these two emission factors is 0.118 lb/MMgals.

AVES used the emissions developed from the Kogan, V., and E.M. Torres paper[43] because the emissions were based on source tests and could be easily converted to emission factors based on flow rate.

Activity Data

The San Joaquin Valley Study[19] geo-coded the facility's addresses, which were included in the SWRCB database[49], to obtain UTM coordinates.

Some flow rates are available from the California State Water Resources Control Board (SWRCB) Database of Waste Dischargers[49].

AVES used the Radian Study[12] flow rates to retain all of the facilities presented in the Radian Study. Other sources did not include all of the facilities.

Spatial And Temporal Allocation

Temporal profiles were not produced for the San Joaquin Valley Study[19].

A.4 SOILS

Literature Reviewed

- Asman[8] – The May 1991 Asman study is a comprehensive ammonia inventory for Europe based on literature review. It provides extensive investigation into emissions from livestock and agriculture. This study is significant because of the broad scope of the study. It is highly favored by recent literature reviews such as Baytte et al.[9] and Sutton et al.[10]

- Battye et al.[9] – Ammonia Emission factors for non-agricultural soils were summarized and reviewed. This report is significant because it compiled recent literature on ammonia emission factors for application in the United States.

- Bouwman, Lee, Asman, Dentener, et al.[5] – A global emissions inventory for ammonia was compiled on a 1° to 1° grid. This paper is significant because it presented the ammonia emission data for natural ecosystems.

- Buijsman et al.[4] - This Northern European 1987 study is a literature review focused primarily on agricultural emissions. The Buijsman studies were some of the earliest European ammonia inventories.

- Denmead et al.[50] – Ammonia losses to the atmosphere from a grass-clover pasture were measured. Measurements within the canopy of the ungrazed pasture indicated a large production of ammonia near the ground surface and almost complete absorption of it by the plant cover. This paper is significant because it presented the source test data.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Erisman[36] – This paper was not reviewed by AVES. Emission factors from this paper were presented in a table in the San Joaquin Valley Study[19]. AVES was unable to locate the paper, because it was not referenced in the San Joaquin Valley Study. AVES assumed that the San Joaquin Valley Study presented the values correctly.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study[19]).

- Land Cover (LULC) database[51] – This database is referenced in the San Joaquin Valley Study[19]. AVES did not review this database because it is specific to the San Joaquin Valley Area.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data.

- Schjoerring[52] – This 1995 study examines ammonia emissions from agricultural cropland not directly influenced by animal husbandry in Europe by passive flux samplers over extended periods (1 week). The study is significant because it examines wind and seasonal effects.

- Schlesinger and Hartley[3] – This 1992 global ammonia budget is based on a literature search. The emission factors for soils were approved Battye et al.[9]

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)* [13], November 16, 1996 - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report.

- U.S. Geological Survey, USGS Land Use and Land Cover (LULC)[27] - The National Mapping Program, a component of the USGS, produces and distributes land use and land cover maps and digitized data for the conterminous U.S. and Hawaii. Land use refers to the human activities that are directly related to the land. Land use and land cover areas are classified into nine major categories: urban or built-up land, agricultural, rangeland, forest, water areas, wetland, barren land, tundra, and perennial snow or ice. Manually interpreted land use and land cover polygons were compiled onto 1:250,000-scale USGS base maps based upon the Universal Transverse Mercator (UTM) projection.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of wildlife excrement and domestic emissions.

Emission Factors

Emission factors developed by Gharib and Cass[16] were used to estimate emissions from soils for the Radian Study. Gharib and Cass[16] developed source categories from the U.S. Geological Survey Land Use and Land Cover Database[27]. These categories are urban or built-up land, agricultural land use, rangeland, forestland, and barren land. Gharib and Cass[16] also included wetlands as a category, but did not produce emission factors or emissions for this category. The emission factors for these categories were derived from emission factors from literature surveys completed by Gharib and Cass[16]. The basic categories Gharib and Cass[16] found from literature were cropland, lawn surface, bare soil, ungrazed grass/clover pasture, forestland, pasture near animals with no manure, pasture land with manure and grazed pasture. The Radian Study[12] did not identify any new emission factors.

There is a large uncertainty in ammonia emissions from soil because soils and plants can act as both sources and sinks. Gharib and Cass[16] reference Denmead et al. [50] who states that vegetation may produce an ammonia sink, but that an alternative formal description of the transfer process had not been developed sufficiently to be used in their paper at the time. Denmead[50] attempted to account for canopy absorption. The measurements showed that most of the ammonia emitted from the soil was absorbed by ryegrass/clover canopy. Denmead's[50] results were used by Gharib and Cass[16] to develop the agricultural - cropland and pasture emission factors and the agricultural – other emission factor. Sutton states that recent field measurements in Europe reveal that semi-natural ecosystems are "efficient sinks for ammonia dry deposition". Schlesinger and Hartley[3] stated that there is a limited understanding of ammonia loss from non-agricultural soil.

Asman[8] lists Buijsman's[4] emission estimate for Europe of 750 kton/yr, but states that the uncertainty and lack of activity prevented its use in the Asman[8] inventory. Battye[9] notes that no emissions from undisturbed land were included in the NAPAP inventory[30], implying that the decision was made because of the uncertainty in soil emission estimates. Battye[9] states that Erisman[36] provides a range of ammonia emissions from natural soils, but Erisman[36] excludes the source because of the large uncertainty of the values.

Schlesinger and Hartley[3] limit the losses from soil to 20% of the annual net mineralization of soil nitrogen because the average emissions from fertilizers are approximately 20% of the amount applied. They provide a range of 0.0088 to 0.88 $gN/m^2/yr$. Schlesinger and Hartley[3] divided natural ecosystems into five types (temperate forest, woodland & shrubland, tropical savanna, temperate grassland, and desert scrub). These emission factors are for natural ecosystems and do not address urban and agricultural land addressed by Gharb and Cass[16]. Ghrab and Cass's[16] range land (land used by domestic animals to range) does not directly correlate with the natural ecosystems (not used by humans/domestic animals) presented by Schlesinger and

Hartley[3]. Therefore, only forest and barren land have direct correlation with categories provided by Gharib and Cass[16].

Battye et al.[9] reviewed recent literature on ammonia emission factors for non-agricultural soils. He recommended the five emission factors provided by Schlesinger and Hartley[3] (temperate forest, and woodland & shrubland were combined because the emission factors are the same) because of their "extensive" literature review. Despite the Schlesinger and Hartley[3] "extensive" literature review, Battye et al. [9] rated the emission factors an E.

Bouwman[5] developed a methodology to calculate decomposition in soil and corresponding ammonia emissions based on carbon/nitrogen ratios for vegetation types, nitrogen cycle in the topsoil, an emission coefficient, and a canopy adsorption coefficient from literature review. The carbon/nitrogen ratio estimates the amount of nitrogen in the soil. The nitrogen cycle in the topsoil estimates the amount of nitrogen in the topsoil where diffusion to the atmosphere occurs. The 1% emission coefficient accounts for the fraction of ammonia produced, which escapes from the soil moisture and gas phase of the soil. The canopy absorption factor attempts to account for vegetation as a sink of ammonia that escapes from the soil. Emission factors developed from Bouwman's[5] calculations are close to the emission factors provided by Schlesinger and Hartley, except for tropical savannas and temperate forests. AVES favored Schlesinger and Hartley[3] over Bouwman[5] because the Schlesinger and Hartley[3] emissions were based on a broad literature review while the uncertainties of Bouwman's[5] model were not as well defined.

The emission factors for rangeland, forestland, and barren land used by Gharib and Cass[16] (1.5 kg NH_3/Km^2k day) are higher than the numbers reported by Bouwman[5]; however, it is within the range recommended by Schlesinger and Hartley[3]. Table A-4 presents the emission factors found in the literature.

Based on the large uncertainty of the soil emissions in general, the correspondence between the categories of the USGS landuse database and Gharib and Cass[16], the similarity between Gharib and Cass[16] and Schlesinger and Hartley[3] (whose emission factors were the overall favorite), AVES retained the Gharib and Cass[16] emission factors.

Activity Data, Spatial and Temporal Activity

The San Joaquin Valley Study used land-use data obtained from a Land Use and Land Cover (LULC) database[51] developed by Desert Research Institute (DRI) for the SARMAP project to allocate soils emissions. This database is specific to the San Joaquin Valley Area.

Gharib and Cass[16] prepared their inventory for use with the US Geological Survey Land Use and Land Cover Database[27]. The Radian Study used the US Geological Survey Land Use and Land Cover Database[27] in conjunction with the Gharib and Cass[16] emission factors. AVES used the Radian Study[12] method.

Only Schjoerring[19] addressed temporal variability in soil emissions. Schjoerring experimentally observed ammonia flux from barley fields during summer months. The results of these tests showed a distinct seasonal variation. However, this was a single set of tests, and may not be representative of other crop types or bare or forested areas.

Table A-4 Agricultural Emission Factors

Schlesinger and Hartley[a] Ecosystem Type	Gharib and Cass[b] Ecosystem Type	Bouwman et al.[c] Ecosystem Type	Schlesinger and Hartley Estimated Rate of Volatilization[a] (gNH_3-$N/m^2/yr$)		Gharib and Cass Estimated Rate of Volatilization (gNH_3-$N/m^2/yr$)	Gharib and Cass Estimated Rate of Volatilization[b] ($kgNH_3$-$N/km^2/day$)	Bouwman, et al. Estimated Rate of Volatilization[c] (gNH_3-$N/m^2/yr$)	Bouwman, et al. Estimated Rate of Volatilization[c] (gNH_3-$N/m^2/yr$)
			Low	High			Soil[d]	Canopy[d]
Temperate Forest	Forest Land	Temperate Forest	0.1	1.0	0.37	1	0.03	0.01
Woodland and Shrubland	(see Forest Land)	Shrubland	0.1	1.0			0.05	0.04
Tropical Savanna	(see Range Land)	Tropical Savanna	0.25	0.75			0.1	0.05
Temperate Grassland	Range Land	Grasslands	0.01	1.0	0.37	1	0.01	0.01
Desert Scrub	Barren Land	Deserts	0.01	0.25	< 0.364	< 1	0.01	0.01
	Urban Land	Urban Land	None	None	0.37	1	None	None
	Agricultural Land - Orchard, Groves, Vineyards, Nurseries, and Ornamental		None	None	1.31	3.6	None	None
	Agricultural Land - Crop, Pasture, Other	Arable Land	None	None	1.24	3.4	None	None
	Wet Lands		None	None	None	None	None	None

[a] Schlesinger W.H. and Hartley A.E. (1992) A Global Budget for Atmospheric NH3. Biogeochemistry 15, 191-211.

[b] Gharib, S., and G.R. Cass (1984): Ammonia Emissions in the South Coast Air Basin. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

[c] Bouwman, A.F., D.S. Lee, W.A.H. Asman, F.J Dentener, and. K.W. Van Der Hoek (1997): A Global High Resolution Emission Inventory for Ammonia, Global Biogeochemical Cycles, Vol. II, No. 4, pp. 561-587.

[d] Soil denote the flux from the soil. Canopy denotes the flux from the canopy (equals soil flux - canopy adbsorption).

A.5 DOMESTIC SOURCES

Literature Reviewed

- Bouwman et al.[5] – The 1997 paper is a literature review and emission global inventory. The study is a comprehensive literature review that examines sections of the global environment. The study is significant because of its broad scope that includes domestic emissions, oceans, and biomass burning.

- Census of Population and Housing, Summary Tape File 1 on U.S. Census Bureau Web Site (Summary Level: State-County) [machine-readable data files], prepared by the Bureau of the Census, Washington, US Bureau of Census website[53], 1990.

- Census of Population and Housing, U.S. Bureau of the Census, Current Population Reports, Series P23-194, Population Profile of the United States: 1997, U.S. Government Printing Office, Washington, D.C., 1998, US Bureau of Census website [54].

- Debevec, Carolyn[55], Community Services Department of San Bernardino County, Phone conversation, February 1990 - Ms. Debevec provided information on homeless populations in San Bernardino.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Gharib and Cass et al.[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study).

- Lim, David[56], Los Angeles Homeless Services Authority, phone conversation, January, 1999 - Mr. Lim provided homeless population estimates in Los Angeles.

- Marse, Ronnie[57] Orange County Social Services, phone conversation, February, 1999 - Mr. Marse provided homeless population estimates.

- Möller and Schieferdecker[21] – This paper was referenced by Sutton et al.[10] and Bouwman et al.[5] Both studies stated that the human ammonia emission factors in Möller and Schieferdecker were too high. AVES did not review this paper.

- National Coalition for the Homeless, NCH Fact Sheet #2[58] – The fact sheet presents the percentage of the population that were homeless at some point in their lives and homeless over a five-year period.

- Orange County Rescue Mission[59] (OCRM) - January, OCRM website, January, 1999 - Estimates of the Orange County homeless population.

- Sutton et al.[10] - This 1995 literature survey focuses on ammonia emissions in the United Kingdom from the 1960s to 1994 for all sources. The Sutton study is significant because of its detailed uncertainty analysis. Sutton also provides a thorough analysis of Gharib and Cass's[16] emission factors for pets and a literature review of domestic emission factors.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) [31] Emissions Inventory. It is a comprehensive literature review. The Warn study is significant because of its investigation of wildlife excrement and domestic emissions.

- Wellborn, Cathy - Department of Community Action Riverside. Phone conversation, January[61], 1999 - Ms. Wellborn provided homeless population estimates.

Emission Factors

Pets

Emission Factors - Battye et al.[9] favors the emission factors found in Gharib and Cass[16]. This numbers are also cited in Buijsman[8] et al.

Emission factors for pets reviewed in Sutton et al.[10] were based on Gharib and Cass[16]. Gharib and Cass[16] reported emission factors of 1.46 lb. N/animal yr for cats and 4.37 lb. N/animal yr for dogs based on a conservative methodology (90% of urinary nitrogen is volatilized). Sutton[10] adjusts the Cass[16] emission factors for more realistic percent volatilization (18% for cats and 36% for dogs) and other parameters to 0.29 (0.11-0.40) lb. N/animal yr for cats and 1.79 (0.64-2.43) lb. N/animal yr for dogs. AVES used the corrected emission factors developed by Sutton because the values were more realistic.

Activity Data – The Radian Study developed total pet population estimates by multiplying the ratio of per capita pets by the human population. No better methodology was found in the literature review.

Spatial and Temporal Allocation – No new methods of spatial and temporal allocation were found.

Perspiration-Respiration

Emission Factors - Sutton's[10] ammonia emission value for human sweat is based on Cass et al.[16], with a revised hydrolization factor from 100% to 20%, based on losses adsorbed in clothes, buildings, or removed in washing.

Bouwman et al.[5] suggests emissions within the range of 0.02-0.44 lb. N/person yr for sweat and breath based on a literature review.

Both Sutton[10] and Bouwman[5] state that 2.87 lb. N/person yr suggested by Möller and Schieferdecker[21] is too high.

The values in the new literature research did not deviate greatly from the values presented by the Radian Study[12]. AVES used the Radian Study[12] values.

Activity Data – No new methods of population counts were found.

Spatial and Temporal Allocation – No new methods of spatial and temporal allocation were found.

Cigarettes

Emission Factors - Cigarette emission factors were updated with emission factors from Warn et al.[30] The Warn study provided an emission factor average of 100 ug/cigarette developed from two studies based on ammonia emission measurements. AVES used the Warn emission factor because it was based on more than one source test, approved and rated by the EPA. The Warn factor was given a C rating.

Activity Data – No new methods of population counts were found.

Spatial and Temporal Allocation – Cigarette emissions were allocated to total population using 1990 census data[53].

Household Ammonia

Emission Factors – No new emission factors were found in the available literature. Emission factors developed for household ammonia from the Radian Study[12] were used for the updated inventory (see Table 6-2).

Activity Data – No new methods of population counts were found.

Spatial and Temporal Allocation – Cigarette emissions were allocated to total population using 1990 census data[53].

Untreated Human Waste - Infants

Emission Factors – No new emission factors were found in the available literature. Emission factors developed for untreated human waste for the Radian Study[12] were used for the infant population (see Table 6-2).

Activity Data – Radian used infant populations from census data for the Los Angeles-Long Beach Area. AVES found infant populations by county in the 1990 census [53].

Diaper emissions from the elderly populations were not available.

Spatial and Temporal Allocation – Infant human waste emissions were allocated to total population using 1990 census data[53].

Untreated Human Waste - Homeless and Other

Emission Factors – No new emission factors were found in the available literature.

Activity Data – The sources used by the Radian Study no longer existed or no longer kept statistical information on the homeless. The Community Services Department of San Bernardino County[55] based homeless populations on results from the 1990 national telephone survey by the National Coalition for the Homeless[58]. The survey found that 7% of the respondents reported they were homeless at some point in their lives and 3% had been homeless over a five-year period. Using census figures (1,616,000) it was estimated that 16,158 individuals were homeless in San Bernardino County. Populations were determined from 1990 census data[53], updated in 1997[54] by the U.S. Bureau of the Census.

The Los Angeles Homeless Services Authority estimates 89,000 homeless people in Los Angles County[56].

The Department of Community Action Riverside[60] estimates 1% of the population is homeless at any given time. Based on the 1997 population, they assumed there were 14,478 homeless people in Riverside County.

Orange County relies on numbers provided by the United Way's Homeless Issues Task Force, an independent agency. AVES has not been able to obtain data from them, therefore AVES used the Orange County Rescue Mission (OCRM) estimate of 15,000 homeless people in Orange County[59].

Total homeless population for all four counties was estimated to be 134,636.

Spatial and Temporal Allocation – No new spatial or temporal allocation methods were found.

A.6 MOBILE SOURCES

Literature Reviewed

- Cadle, S., of General Motors[61], telephone conversation with C.W. Botsford of AVES, on March 9, 1999 - Mr. Botsford discussed fleet mix especially for malfunctioning vehicles for future research.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef, dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Fraser and Cass[62] – In this study ammonia emissions from in-use vehicles traveling through the Van Nuys Tunnel in Southern California were measured with low volume particulate matter samples and GC_FID analysis of air samples gathered in electropolished stainless steel canisters. The study is significant because it studies the actual fleet distribution of in-use vehicles on a California highway.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study[12]).

- Gorse, R., of Ford Motor Company[63], telephone conversation with C.W. Botsford of AVES, on March 18, 1999 - Mr. Botsford discussed fleet mix especially for malfunctioning vehicles for future research.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13] - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report[12].

Emission Factors

Fraser and Cass[62] empirically derived an emission factor, based on a tunnel study, that was three and a half times greater than that calculated for the 1987 Radian Study[12]. The emission factor of 61 mg/km was derived from measurements taken inside the Van Nuys tunnel, therefore reflects the fleet average as represented by the vehicles passing through the tunnel. The study collected measurements over a four-hour period the morning of September 21, 1993. The Fraser and Cass[62] emission factor for the average 3-way catalyst vehicle is the same as the one used for improperly operating 3-way catalyst vehicles for the Radian Study[12]. Therefore, the increase cannot be explained by the fraction of improperly operating vehicles alone.

The Fraser and Cass[62] tunnel study produces accurate emission factors based on fuel burned, but is less reliable for VMT, which requires an assumption of fleet average mileage. However, fuel allocation data is not available for use as activity data. The Fraser and Cass[62] data reflects an average fleet mix for the four hours tested in the Van Nuys tunnel and are not specific to vehicle type age, etc. Fraser and Cass estimated vehicles with dual bed or three-way catalysts burned 76% of the total fuel in the tunnel. This estimate was developed using measured fuel economy based on model year, the fraction of vehicles from each model year and each vehicle type that were equipped with three-way catalysts, and the observed age distribution of the vehicles and vehicle type. The fleet-average fuel efficiency of 6.3 km/L was developed by using the volumetric air flow rate calculated by sulfur hexafluoride (SF_6) release (157 m^3/s), vehicle counts, total carbon concentration increment measured in the tunnel due to vehicle exhaust emitted in the tunnel (difference between inside and outside tunnel samplers), and average fuel parameters (including fuel density of 750 g/L and carbon weigh fraction of 0.87).

Current data is available on ammonia emissions from properly operating vehicles[5,6]; however, there is no current data on emissions from improperly operating vehicles and the fraction of improperly operating vehicles. No other new information was found for mobile source ammonia emissions.

The Fraser and Cass emission factor was used for this inventory because it accurately reflects the emissions associated with improperly operating three way catalyst vehicles, the major source of ammonia emissions for the mobile source category. Model specific emission factors for improperly operating vehicles are not well documented[5,6] and activity data for this subcategory is even less well known.

Activity Data, Spatial and Temporal Activity

No new literature on activity data or spatial and temporal activity data was found. Activity data were based on VMT data from SCAQMD.

A.7 FERTILIZER

Literature Reviewed

- Asman[8] – The May 1991 Asman study is a comprehensive ammonia inventory for Europe based on literature review. It provides extensive investigation into emissions from livestock and agriculture. This study is significant because of the broad scope of the study. It is highly favored by recent literature reviews such as Baytte et al.[9] and Sutton et al.[10]

- Battye et al.[10] – This 1995 study is a literature survey of ammonia emission factors between 1985 and 1994 for the U.S. EPA, Office of Research and Development.

Sources include the Compilation of Air Pollution Emission Factors – Volume I (AP-42)[11] for industrial sources, the National Acid Precipitation Assessment Program factors for combustion sources, human breath and perspiration, and publicly owned treatment works (POTW), European factors for agricultural sources, and Toxic Release Inventory for industrial sources. It is relevant because the study attempts to identify emission factors that are appropriate for the entire United States and ranks them according to the AP-42 rating method.

- Bouwman et al.[5] – The 1997 is a literature review and emission global inventory. The study is a comprehensive literature review that examines sections of the global environment. The study is significant because of its broad scope that includes domestic emissions, oceans, and biomass burning.

- Buijsman et al.[4] - This Northern European 1987 study is a literature review focused primarily on agricultural emissions. The Buijsman studies were some of the earliest ammonia European inventories.

- California Department of Food and Agriculture[64] *Fertilizing Materials Tonnage Report, July* –- This 1999 report summarized State and County tonnage sales of commercial fertilizers and agricultural minerals for the year 1998.

- California Department of Food and Agriculture[65] *Fertilizing Materials Tonnage Report,* Division of Inspection Services, Agricultural Commodities and Regulatory Services, Sacramento, California - This report summarized State and County tonnage sales of commercial fertilizers and agricultural minerals for the year 1996.

- County of Los Angeles, Department of Agriculture Commissioners and Weight and Measures, 1997 Crop Report[66] - Presents statistical information on acreage, yield, and gross value of agricultural products produced in Los Angeles County.

- County of Orange County, Department of Facilities and Resources Department, 1997 Orange County Crop Report[67] - Presents statistical information on acreage, yield, and gross value of agricultural products produced in Orange County.

- County of San Bernardino County, 1997 Crop Acreage and Value by Area[68] - 1997 crop acreage and value by area in San Bernardino County.

- Dickson, R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Gharib and Cass[16] - This is an open file at the Environmental Quality Laboratory at California Institute of Technology, dated December 1984. The Gharib and Cass study is a comprehensive ammonia emission factor study with a literature review spanning work published from 1952 to 1984. The study is relevant because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (Radian Study[12]).

- Land Cover (LULC) database[51] – This database is referenced in the San Joaquin Valley Study[19]. AVES did not review this database because it is specific to the San Joaquin Valley Area.

- Riverside County Agriculture Commissioners Office [69]- Presents statistical information on acreage, yield, and gross value of agricultural products produced in Riverside County.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data.

- Schlesinger and Hartley[3] - This 1991 paper is a global atmospheric ammonia inventory. The study investigates ammonia emissions from domestic animals, soils, fertilizer, and sea surface from literature review. The paper is significant because Battye et al.[9] and Buijsman[4] et al. favor it.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13] - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report.[12]

- U.S. Geological Survey, USGS Land Use and Land Cover (LULC)[27] - The National Mapping Program, a component of the USGS, produces and distributes land use and land cover maps and digitized data for the conterminous U.S. and Hawaii. Land use refers to the human activities that are directly related to the land. Land use and land cover areas are classified into nine major categories: urban or built-up land, agricultural, rangeland, forest, water areas, wetland, barren land, tundra, and perennial snow or ice. Manually interpreted land use and land cover polygons were compiled onto 1:250,000-scale USGS base maps based upon the Universal Transverse Mercator (UTM) projection.

- USDA (1999), *1997 Census of Agriculture*[29] - State and County Agricultural census have been subsumed by the USDA's Agricultural Census. While the census is comprehensive, some of the categories have been combined, reducing activity refinement. This study is significant because the population numbers are tied to financial reports required by the Federal government.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of fertilizer emissions from US application.

Emission Factors

Schlesinger and Hartley[3] state that the type of fertilizer, application method, and moisture content of the soil affect ammonia loss from fertilizer. They suggest that NH_4NO_3 application is negligible compared to (aqueous or anhydrous) ammonia, urea, and $(NH_4)_2SO_4$ application. Injection of ammonia generates fewer emissions than other application methods. Higher moisture content slows ammonia emissions.

Based on a literature research Schlesinger and Hartley[3] recommend emission factors of 20% of urea applied and 10% of $(NH_4)_2SO_4$ applied. Bouwman et al.[5] adopted Asman's[8] emission factors for their global inventory. Bouwman et al.[5] stated that the Asman[8] values are similar to values proposed by Schlesinger and Hartley[3] and Buijsman et al.[4] Bouwman et al.[5] does not present this comparison in their paper. In Table A-7, AVES has expanded the San Joaquin Valley Study[19] table with values from Asman[8], Bouwman et al.[5], Bouwman et al.[5], and Schlesinger and Hartley[3].

Battye et al.[10] reviewed emission factors for anhydrous ammonia, aqueous ammonia, urea, ammonium nitrate, mono- and di-ammonium phosphates, ammonium sulfate, ammonium thiosulfate, potassium nitrate, calcium nitrate and sodium nitrate. Battye et al.[10] stated that improper application conditions can produce 50% nitrogen volatilization of applied fertilizer. Battye et al.[10] recommended the emission factors for fertilizer application from Asman's[6] update of Buijsman's[8] emission factors. Battye et al.[10] state that even later extensive measurements documented in their report confirm the Asman[8] values. Battye et al.[10] recommend "C" quality ratings for the Asman[8] emission factors, but increases the urea rating from "C" to "B" because of the confirmation by later measurements documented in the Battye et al. [10] report.

The 1985 National Acid Precipitation Assessment Program (NAPAP) emission inventory[30] only examined ammonia emissions from anhydrous ammonia fertilizer. Battye et al.[10] discounts the Warn et al. values because the NAPAP[30] ammonia emissions from fertilizer are only 3% of the inventory, where ammonia emissions from fertilizer are 17% of European emission inventories as reviewed by Asman[6].

The San Joaquin Valley Study[19] used the emission factors recommended by Battye et al.[10]

The Radian's Study[12] used emission factors developed by Gharib and Cass[16]. The source categories of the emission factors were anhydrous ammonia, non-anhydrous ammonia fertilizer, dry and liquid application. Non anhydrous ammonia fertilizer, dry and liquid application was further divided into farm and non-farm usage. Lastly, the farm application was divided into crop and orchard application. This last division is not necessary because the crop and orchard application have the same emission factors.

The Asman[6] emission factors recommended by Battye[10] and Bouwman[5] are more refined then the emission factors provided by Gharib and Cass[16] in the Radian Study[12]. However, the best activity data was found in the Tonnage Report[64], which had limited source categories (farm liquid application, farm dry application, non-farm liquid application, non-farm dry application). It was not possible to use the Asman[8] specific emission factors with the general activity in the Tonnage Report[64]. Therefore, AVES used the Radian Study[12] categories of farm/non-farm, and liquid/dry because they applied directly to the activity in the Tonnage Report[64].

Activity Data, Spatial and Temporal Activity

Schlesinger and Hartley[3] used activity from the Food and Agricultural Organization, which publishes worldwide production of nitrogen fertilizers. A global inventory will not provide sufficient detailed activity for use in the SoCAB.

Battye et al.[10] provided sources for state activity, which do not supply sufficient detail for the SoCAB. Battye et al.[10] suggest using the Census of Agriculture[29] or local agencies for more detailed activities.

The San Joaquin Valley Study[19] used activity data from the Fertilizing Materials Tonnage Reports[64] for each quarter of 1990, obtained from the California Department of Food and Agriculture. The San Joaquin Valley Study[19] temporally allocated emissions on a quarterly profile based on the quarterly activity data. The San Joaquin Valley Study[19] spatially allocated fertilizer emissions to agricultural lands indicated in LULC database compiled by the Desert research Institute[51].

The Tonnage Report[64] provided the fertilizer farm and non-farm usage by county, as well as the different forms of fertilizer usage, such as urea, ammonia sulfate, ammonia nitrate, nitrogen solutions, etc. The Radian Study[12] report obtained anhydrous ammonia separate from the farm/non-farm liquid/dry fertilizer usage. The 1999 Tonnage Report[64] included anhydrous ammonia in the farm/non-farm, liquid/dry fertilizer usage. The 1999 Tonnage Report[64] showed that all nitrogen usage in Los Angeles, Orange, Riverside, and San Bernardino Counties was 7,919tons N/year of dry fertilizer and 11,549 tons N/year of liquid fertilizer.

Table A7 - Fertilizer Emission Factors

Fertilizer Type	Asman (1994)[a] % of N Content	Battye et al. (1994)[b] kg NH_3/ Mg N (% of N Content)	Bouwman et al. (1997)[c] % of N Content	Buijsman et al. (1987)[d] % of N Content	Gharib and Cass (1984)[e] % of Total N Applied	Sutton et al. (1995)[f] % of Total N Applied	Schlesinger and Hartley (1995)[g] % of Total N Applied	Warn et al. (1990)[h] lbs/ton
Anhydrous Ammonia Handling								
Handling		12 (1.2%)			1			19 (0.95)
Application			4		3			
Non-anhydrous Ammonia - Dry Application								
Crop					10			
Orchard					10			
Non-Farm					30			
Non-anhydrous Ammonia								
Crop					2			
Orchard					2			
Non-Farm					30			
Aqua Ammonia		12 (1.2%)						
Nitrogen Solutions	2.5	30 (3.0%)	2.5					
Urea	15	182 (18.2%)				5 - 16.5	20	
Urea, Temperate			15					
Urea, Tropical			25					
Ammonia	1			10			2.5	
Ammonium Nitrate	2	25 (2.5%)	2	10		0 - 10	10	
Ammonium Sulfate	8	97 (9.7%)	8	10				
Calcium Ammonia Nitrate	2		2	15				
Ammonium Thiosulfate		30 (3.0%)		2				
Total Straight Nitrogen	4							
Other Straight Nitrogen	2.5	30 (3.0%)	20/30/4					
Ammonium Phosphates	4	48 (4.8%)	2 mono/5 di	2				
Nitrogen (N) - Phosphorous (P) - Potassium (K) Mixtures	4	48 (4.8%)	4			0 - 15		
Compound Nitrogen (N) Potassium (K) Mixtures	2		2					

Table A7 - Fertilizer Emission Factors

Other Compound Nitrogen (N) Potassium (K) Mixtures	3		3						
Compound Nitrogen (N)	4		4						
Other Fertilizer								3.0	

[a] Asman W.A. H Ammonia Emission in Europe: Updated Emission and Emission Variations, prepared by National Institute of Public Health and Environmental Protection, Bilthoven, May, 1992.

[b] Battye, R., W. Battye, C. Overcash, and S. Fudge (1994): Development and Selection of Ammonia Emission Factors. EPA/600/R-94/190. Final report prepared for U.S. Environmental Protection Agency, Office of Research and Development. EPA Contract No. 68-D3-0034, Work Assignment 0-3.

[c] Bouwman, A.F., D.S. Lee, W.A.H. Asman, F.J Dentener, and. K.W. Van Der Hoek (1997): A Global High Resolution Emission Inventory for Ammonia, Global Biogeochemical Cycles, Vol. II, No. 4, pp. 561-587.

[d] Buijsman, et al., Ed, Hans F.M. Mass, and Willem AH Asman (1987) Anthropogenic NH3 Emissions in Europe, Atmospheric Environment, Vol 21, No 5, pp. 1009-1222.

[e] Gharib, S., and G.R. Cass (1984): Ammonia Emissions in the South Coast Air Basin. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

[f] Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom. Atmospheric Environment, (29):1393-1411.

[g] Schlesinger W.H. and Hartley A.E. (1992). A Global Budget for Atmospheric NH3. Biogeochemistry 15, pp. 191-211.

[h] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. EPA-600/7-90-014. Final Report Prepared for Office of Reasearch and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corporation, Chapel Hill, N.C., EPA Contract No. 68-02-4374, Work Assignment No. 43 , June.

A.8 INDUSTRIAL SOURCES

Literature Reviewed

- 1990 Particulate Inventory [70] – The 1994 E.H. Pechan Study was used by the Joaquin Valley Study for non-point sources. AVES did not review this document because ammonia suppliers in the South Coast Air Basin provided activity.

- Air Toxics Emission Data System (ATEDS)[39] – The ATEDS database consists of emission estimates developed for the Air Toxic Inventory Reports (ATIRs) under AB2588 up to 1996. The information in ATEDS is significant because it is submitted by the facility.

- Battye et al.[10] – This 1995 study is a literature survey of ammonia emission factors between 1985 and 1994 for the U.S. EPA, Office of Research and Development. Sources include the Compilation of Air Pollution Emission Factors – Volume I (AP-42)[11] for industrial sources, the National Acid Precipitation Assessment Program factors for combustion sources, human breath and perspiration, and publicly owned treatment works (POTW), European factors for agricultural sources, and Toxic Release Inventory for industrial sources. It is relevant because the study attempts to identify emission factors that are appropriate for the entire United States and ranks them according to the AP-42 rating method.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Hill, Ronald, Hill Brothers Chemical Corp., Phone Conversation/Electronic Files, February, 1999[17] - Hill Brothers Chemical Corp. supplies ammonia to industrial users.

- Moerdyke, Donald D. UNOCAL, Phone Conversation, February, 1999[72] - Unocal is the major ammonia supplier in Southern California. Unocal supplies ammonia to La Roche Industries, Inc., Hills Brothers Chemical Corp., and directly too large industries.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data. The San Joaquin Valley Study focuses on ammonia injection in combustion for industrial sources.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13] - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report.

- Turner, Richard, La Roche Industries, Inc., Phone Conversations, April, 1999[73], - La Roche supplies ammonia to smaller users.

- USEPA Office of Pollution Prevention and Toxics, Toxic Release Inventory (TRI)[75] - The TRI inventory contains information submitted on TRI forms (Form R), which includes ammonia.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation of industrial sources.

Emission Factor

The San Joaquin Valley Study [19] used the ARB Air Toxics Database (ATEDS)[39] which includes stack parameters contained in the California Assembly Bill 2588 Air Toxic Inventory Reports (ATIRs). The ATIRs also record activity data per month per device allowing for easy temporal allocation. Area source emissions were calculated using the E.H. Pechan 1990 Particulate Inventory[70].

AVES did not review the E.H. Pechan 1990 Particulate Inventory[70] because ammonia suppliers provided activity data specific to the SoCAB (See Data and Spatial and Temporal Allocation below).

Emission factors for processes provided by Unocal[72], La Roche Industries, Inc.[73], and Hill Brothers Chemical Corp.[71] were developed by AVES based on common engineering estimates used for Air Toxic Inventory Report emission estimates.

- Refrigeration – Emissions from ammonia refrigeration occur as a result of system leaks. Therefore, by mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage[9].

- NO_x Control – Ammonia is injected into the exhaust of boilers, gas turbines and other process equipment to reduce NO_x emissions. Based on an approximate 1:1 molar ratio of NH_3 to NO, 10 ppm NH_3 slip, and a typical 100 ppm to 10 ppm NO_x reduction, approximately 10% of ammonia supplied is emitted. The emission factor is 10 percent of usage. (SCAQMD BACT Requirement)

- Metal Treating – Ammonia is used in the nitriding process to heat-treat steel. Based on minimal escape during the nitriding process, approximately 10% of ammonia supplied is emitted. The emission factor is 10 percent of usage.

- Waste Water Treatment – Ammonia is used in wastewater treatment for neutralization. Based on minimal losses during transfer, upsets, and improper operation, approximately 15% of ammonia supplied is emitted because ammonia is highly soluble in water. The emission factor is 15 percent of usage. [10,30]

- Blueprinting – Ammonia is used in blueprint processing. By mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage.

No new emission factors for industrial combustion sources were found. The Radian Study[12] emissions for industrial combustion sources were used for this inventory.

Activity Data and Spatial and Temporal Allocation

AVES contacted ammonia suppliers UNOCAL[73], LaRoche Industries, Inc.[72], and Hill Brothers Chemical Corp.[71] for activity data. Ammonia from these suppliers comprises approximately 99% of total ammonia deliveries to the SoCAB.

Unocal is the largest supplier of ammonia in the SoCAB. Hill Brothers Chemical Corp. receives its ammonia from Unocal. Any other ammonia supplied to the SoCAB is insignificant compared to the amount supplied by Unocal, La Roche Industries, Inc., and Hill Brothers Chemical Corp. Unocal and Hill Brothers Chemical Corp. provided activity by zip code for various processes (refrigeration, NOx control, metal treating, wastewater treatment, and blueprinting). La Roche Industries, Inc. was only able to produce total activity by zip code. AVES separated the La Roche Industries, Inc. activities in each zip code by process in the same ratios provided by Hill Brothers Chemical Corp.

As a condition of providing the data, ammonia delivery data from each supplier was aggregated by category for each zip code to protect the proprietary nature of individual supplier information.

AVES also obtained 1996 SARA TRI data[74]. However, these data do not include facilities with certain SIC codes and facilities handling less than 10,000 lbs/yr of ammonia. In addition, AVES obtained data on equipment permitted by AQMD. However, there are many large ammonia users (e.g., refrigeration) that are not required to obtain permits. Therefore, the TRI and AQMD data were used only to check the supplier data by comparing the emissions of extremely large facilities (i.e., electric utilities) with the total supplier data for the zip code for that facility.

AVES used the ammonia supplier data for activity data because this method identifies a comprehensive universe of sources. The drawback is less spatial resolution because the data was supplied according to zip code. Data from each zip code was treated as an area source.

Usage data, emission factors and emissions by use category are shown on Table 9-1.

A9. LANDFILLS

Literature Reviewed

- Amerine, Skip, California Integrated Waste Management Board, telephone and facsimile correspondence, June 24, 1999[75] - Mr. Amerine provided information on closed landfill sites.

- California Air Resources Boards (CARB) Air Toxics Emission Data System (ATEDS)[39] – The ATEDS database consists of emission estimates developed for the Air Toxic Inventory Reports (ATIRs) under AB2588 up to 1996. The information in ATEDS is significant because it is submitted by the facility.

- California Integrated Waste Management Board, California Waste Facilities, Sites, & Operations Database Solid Waste Information System (SWIS) Database[76] – This database contains electronic information on landfills in California.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- San Joaquin Valley Study[19] - This January 1998 study is the most recent comprehensive study in Southern California. The study encompasses a literature review and source testing at a dairy and publicly owned treatment works plant (POTW). It is significant because it reviews new literature and provides additional field data.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13], November 16, 1996 - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report[12].

- USAEPA (1995), "2.4 Municipal Solid Waste," Compilation of Air Pollution Emissions Factors. No. AP-42, 5th Edition, Research Triangle Park, NC, "2.4 Municipal Solid Waste"[11] – The Landfill Air Emissions Estimation model provides a natural logarithmic calculation for methane estimation.

Emission Factors

The San Joaquin Valley Study [19] estimated landfill ammonia emissions using a reported ratio of 0.007 pounds of ammonia to pounds of methane. This study found landfills to be an insignificant source of ammonia emissions.

Uncontrolled methane emissions can be calculated from the Landfill Air Emissions Estimation model found in AP-42[11]. The Landfill Air Emissions Estimation model equation was developed from a theoretical first-order kinetic model of methane production. Parameters required are: (1) the average annual refuse acceptance rate during active life; (2) the time since the initial refuse placement; and (3) the time since landfill closure if closed.

Some site-specific values for the Landfill Air Emissions Estimation model were available from county waste management agencies or the California Integrated Waste Management Board California Waste Facilities, Sites, & Operations Database Solid Waste Information System (SWIS) Database[76]. Most records were not kept until after the mid-1970s, so information is not available for many older landfills.

Methane emissions from landfills are also available from the 1996 Emissions Inventory on the CARB website[39]. The CARB list does not include all landfills, but does account for the larger landfills. Only the Athens Disposal landfill had ammonia emissions directly reported in the CARB website[39].

AVES chose the San Joaquin Valley Study [19] emission factor of 0.007 pounds of ammonia to pounds of methane in concert with the methane emissions from the CARB website[39]. AVES used the ammonia emission reported in the CARB database[39] for the Athens Disposal landfill.

Activity Data, Spatial and Temporal Activity

The San Joaquin Valley Study[19] emissions were treated as low-level point sources by geo-coding the facility addresses included in the SWIS Database[76].

Seasonal and diurnal profiles were not addressed in the San Joaquin Valley Study[19].

Methane emissions from landfills in the 1996 Emissions Inventory on the CARB website[39] were used because while not complete for all landfills, it was complete for the landfills listed in the Radian Study. Landfills were geo-coded with latitude/longitude coordinates included in the SWIS Database[76]

A.10 COMPOSTING

Literature Reviewed

- AeroVironment, Odor Study Final Report Recyc, Inc. Composting Facility, Temescal Canyon, CA, 1996[77] - Source testing was completed on compost consisting of a mixture of 50% sludge, 25% horse stable waste, and 25% pre-composted material.

- California Integrated Waste Management Board, California Waste Facilities, Sites, & Operations Database/Solid Waste Information System (SWIS) Database[76] – The CIWMB database contains specific information on each compost site.

- Compost Engineering: Principles and Practice[78] – This is a textbook on compost engineering. It provides a technical basis for understanding the composting field.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature review that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- South Coast Air Quality Management District Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc.[79] – Source testing was completed on compost consisting of a mixture of 50% sludge and 50% green waste.

- South Coast Air Quality Management District Source Test Report 95-0032/96-003 Conducted at EKO Systems[80] - Source testing was completed on compost consisting of a mixture of 20% sludge and 80% manure waste.

- South Coast Air Quality Management District Source Test Report 95-0034 conducted at Rancho Las Virgenes Municipal Water District.[81] - Source testing was completed on compost consisting of seven rows of 50% sludge, 50% wood chips and dust, and one row of 50% sludge and 50% rice hull.

- South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[13] - The 1997 AQMP is the current ammonia inventory based on literature review. Except for the beef, dairy cow, and publicly owned treatment works (POTW) emissions, it is identical to the 1991 Radian Report.

Emission Factors

No emission factors were found in the general literature search. Several source tests have been completed by the SCAQMD at different composting sites. Emission factors were developed from the source tests. Tests were completed as the windrows aged and over several types of compost compositions. The most thorough tests were performed at

Recyc, Inc.[77], a composting facility that uses a mixture of 50% sludge, 25% horse stable waste, and 25% pre-composted material (2.755 lbs NH_3/ton mix). A mixture of 50% sludge, and 50% green waste was tested[79] at San Joaquin Composting, Inc (2.81 lbs NH_3/ton mix). A mixture of 20% sludge, 80% manure was tested at EKO Systems; Testing[80] at Rancho Las Virgenes Municipal Water District[81] was done on seven rows of 50% sludge and 50% wood chips and dust, and one row of 50% sludge and 50% rice hull (0.7 lbs NH_3/ton mix). The tests provide estimates for emissions over a variety of compost compositions and the Recyc, Inc. tests[77] also reveal the effect of varying the composition at a single facility.

The C/N ratio of various wastes is reported in *Compost Engineering: Principles and Practice*[78]. The reported carbon to nitrogen (C/N) ratio of grass clippings is close to that of raw sewage.

AVES applied the source tested emission factor to the facilities that were source tested. AVES applied the emission factor from the source test of the facility that was most similar to the facilities without a source test.

Activity Data, Spatial and Temporal Activity

Although the windrow age does effect the ammonia emission rate, these temporal variations are not significant for the gridded ammonia study since piles of all ages exist at any facility at any time.

The seasonal and diurnal temporal allocations are expected to be significant.

The California Waste Facilities, and Operations Database/Solid Waste Information System (SWIS) Database on the California Integrated Waste Management Board (CIWMB) webside[75] provides throughput for most compost facilities. The database has fields for permit input, actual input, and output, however not all fields are present for all facilities and some facility records are completely empty.

AVES used the SWIS database[75] and information gained by telephone conversations (see Table 11-1).

A.11. OCEANS AND OTHER LARGE BODIES OF WATER

Literature Reviewed

- Asman et al.[88] – This paper discusses measurements of airborne gaseous ammonia in sea water on cruises in the North Sea and in the Pacific Ocean. The paper is significant because it states that the airborne gaseous ammonia concentration is what causes ammonia deposition into the sea. It is also significant because it discusses the differences between the North Sea and the Pacific Ocean environments.

- Bouwman et al.[5] – The 1997 is a literature review and emission global inventory. The study is a comprehensive literature review that examines sections of global environment. The study is significant because of its attempts to place ammonia from the oceans into a global perspective.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature search that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Geernaert et al.[83] – This 1998 study examined fluxes at the sea surface based on measurements of vertical concentration profiles.

- Lee et al.[84]– This 1998 paper discusses the rate of ammonia deposition into the sea surface through experiments in a laboratory chamber. This paper is significant because it suggests that the North Sea is more often a sink than a source of ammonia.

- Quinn et al.[85] – This 1990 paper discusses ammonia as part of the sulfur and reduced nitrogen cycle over the ocean. Concentration measurements were taken in the spring of 1988 across the middle of the Pacific Ocean.

- Quinn et al.[86] – This 1996 study examines the air/sea ammonia exchange for the North Atlantic Basin, based on measured atmospheric and sea water ammonia concentrations.

Emission Factors

Bouwman et al.[5] provides an overview of research into ammonia emissions from the ocean. Quinn et al.[85] researched ammonia over the Pacific Ocean. Asman et al.[82], Lee et al.[84], Quinn et al.[86], and Geernaert et al.[83] have examined ammonia over the North Sea and Northern Europe.

Current research in Europe has been focused on determining when and how the oceans are a source or sink of ammonia. Oceanic ammonia chemistry is tied to nitrogen and sulfur cycles, overall water temperature, and nutrient concentrations[85]. Lee et al.[84] examined the effect of atmospheric concentrations and conditions. Lee et al.[84] state that only the Asman et al.[82] measures both NH_3(g) and NH_x(s) over the North Sea. Quinn et al.[85] measure both NH_3(g) and NH_x(s) over the Pacific. From these results, Lee et al.[85] and Asman et al.[82] determined that the flux is dependent on atmospheric ammonia concentrations and that the North Sea is a net ammonia sink.

Lee et al.[84] refers to a study that reports a positive flux over the mid to west Pacific and reports that this is likely because of low atmospheric concentrations. Asman et al.[82] state that positive ammonia flux reported by an earlier Quinn et al.[85] study is likely because of higher sea water temperature. Quinn et al.[85] state that it is the overall sea water temperature, not the surface water temperature, that effects the concentration. Asman[82] also states that ammonia flux at the sea air boundary is a finely-tuned system based on many direction changes and near zero fluxes. The 1990 Quinn et al. study[85] showed an overall positive flux across the mid-Pacific. The study also states that the atmospheric ammonia is short-lived, 6 hours, as a result affecting only coastal regions and "probably having negligible impact on continental regions." Quinn et al.[86] state that the Pacific and North Sea may have a local positive flux of ammonia, but a net deposition will occur in regions impacted by continental sources laden with ammonia.

Ammonia emissions from the ocean and/or other bodies of water should be omitted because of the great uncertainties in emission estimates, the lack of potential impact to inland areas and the very low measured concentrations in coastal regions of the SoCAB.

AVES does not recommend an emission factor because of the uncertainty in the literature.

Activity Data, Spatial and Temporal Activity

Activity data and spatial and temporal information were not pursued because of the uncertainty in the emission factors.

A.12 PRESCRIBED BURNING

Literature Reviewed

- Andreae[87] – This book was referenced by Bouwman, but not reviewed by AVES. It is significant because Bouwman favored it.

- Bouwman et al.[5] – The 1997 is a literature review and emission global inventory. The study is a comprehensive review that examines sections of global environment. The study is significant because of its attempts to place ammonia from the biomass burning in a global perspective.

- Crutzen, Paul and Meinrat O. Andrea[88] – This 1990 paper examines biomass burning in the tropics based on literature review.

- Dickson R.J. et al.[12] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI). It is the comprehensive study based on literature search that provided the basis for most of the 1997 AQMP[13]. It is significant because, except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1993 SoCAB ammonia inventory.

- Hegg et al.[89] – The 1989 paper reports on emissions from fires in the western United States (California, Oregon, Washington and Montana) and one in Ontario Canada. It is significant because two of the fires were in Los Angeles County.

- LeBel et al.[90] – This 1988 study examined nitric acid and ammonia emissions from a smoke plume of a wetlands biomass burn using denuder tubes in a helicopter and in an on-site laboratory.

- Lee and Atkins[91] – This 1994 study examines the ammonia emissions from English straw burnt in a laboratory. This paper is significant because it examines the effect of moisture content in the straw on ammonia emissions from fires.

- Pimlott, Ken, California Department of Forestry and Fire Protection, Riverside Ranger Unit, telephone and facsimile correspondence, March 11, 1999[92] - Mr. Pimlott provided Riverside County prescribed burn dates, and fuel/vegetation type.

- Takeshita, Michael, County of Los Angeles Fire Department, Forestry Division, Vegetation Management Unit, telephone and facsimile correspondence, March 8, 1999[93] - Mr. Takeshita provided Los Angeles County prescribed burn dates and fuel/vegetation type.

- USAEPA "13.1 Wildfires and Prescribed Burning," Compilation of Air Pollution Emissions Factors. No. AP-42, 5th Edition, Research Triangle Park, NC, "13 Miscellaneous Sources"[11] – Emission factors for CO from wildfires and prescribed burning are provided.

- Warn et al.[30] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory[31]. It is a comprehensive literature review. The Warn study is significant because of its investigation into wildlife excrement and domestic emissions.

Emission Factors

Hegg et al.[89] reports on fires in the western United States (California, Oregon, Washington and Montana) and one in Ontario, Canada. Two of the fires were in the Los Angeles Basin. The Hegg et al.[89] values are reported in weight fraction of ammonia emissions per CO emissions by fuel type. LeBel et al.[90] examined nitric acid and ammonia emissions from a smoke plume of a wetlands biomass burn using denuder tubes in a helicopter and in an on-site laboratory. Lee and Atkins[91] examined the emissions from straw burning in England. The average emissions were 1,632 μg NH_3/g straw.

Crutzen and Andreae[88] examine emissions from tropical biomass burning. Emission ratios for ammonia, CO and other compounds from biomass burning to total ammonia, CO and other compound emissions from all sources are presented. Specific emission factors are not presented; therefore this paper is not useful for the inventory.

AP-42[11] recommends emission factors for planning based on fuel type and regional configuration. The most appropriate emission factors based on activity are for Pacific Southwest Grassland at 15 g CO/kg fuel and Pacific Southwest Sagebrush/Chaparral at 62 g CO/kg fuel. Pinion/Juniper is the only emission factor for Pacific Southwest trees at 175 g CO/kg fuel. Non-region specific emission factors, based on fuel configuration and phase, are also provided.

Bouwman et al.[5] suggest using an emission rate of 1.3 mmol NH_3/mol CO_2 (1.52×10^{-3} g N/g C) proposed by Andreae[87].

Warn et al.[30] state that no reliable information was found. They present an emission factor of 0.3 lbs NH_3/ton of wood burned, based on an inventory from 1956. Warn et al.[30] do not recommend this emission factor, but instead recommend further research.

AVES recommends the AP-42[11] planning CO emission factors and the CO/NH_3 weight fraction provided by Hegg et al.[89] because they are regional emission factors for specific Pacific Southwest/SoCAB fuel.

Activity Data, Spatial and Temporal Activity

Activity data, spatial and temporal data was obtained from the California Department of Forestry and Fire Protection, Riverside Ranger Unit[92], and the County of Los Angeles Fire Department, Forestry Division[93]. Los Angeles County keeps records of the location, the area burned, the dates of burning and the fuel source. Riverside County records the location, the starting date, the area burned, and the fuel source. The fuel sources were tall grass, mixed chaparral, brush in Los Angeles County and chaparral/sage, grass and dead citrus for Riverside County. The US Forestry Service has information on burning in San Bernardino County. Activity data for San Bernardino County was not pursued at this time. No burning is allowed in Orange County.

Table A-12 Prescribed Burning Emission Factors

Carbon Dioxide Emissions from Prescribed Burning

Fuel	CO,[a] lbs CO/ 1,000 Consumed lbs
Sagebrush	62
Chaparral	62
Pinyon/Juniper	175
Underburing pine	163
Grassland	15
Average	101

Ratio of Ammonia to Carbon Dioxide

Fuel	Mean Value of NH_3/CO[b]	Location
Chaparrel	0.038	Lodi (LA Basin), CA
Chaparrel	0.002	Lodi (LA Basin), CA
Pine, brush, Douglas fir	0.014	Rosenburg, OR
Douglas fir, true fir, Hemlock	0.011	Grants Pass, OR
Douglas fir, Hemlock	0.007	Satsop, WA
Douglas fir, pine, true fir	0.01	Troy, MT
Pine	0.002	Chapleau, Ontario

Alternate Emission Factors

Fuel	Emission Factor	Units	Source
Biomass	0.00152	g N/g C	Bouwman et al.(1997)[c]
Wood	0.3	lbs NH_3/ton burnt	Warn et al. (1985)[d]
Firewood	0.005	g N/g C	Crutzen and Andreae (1990)[c]
Fuel	3.8 ± 3.2%	lb NH_3/lb N	Crutzen and Andreae (1990)[c]

[a] USEPA (1995), Compilation of Air Pollution Emissions Factors. No. AP-42, 5th Edition, Research Triangle Park, NC, GPO 055-000-00251-7.

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APPENDIX B

Review of Literature Sources for Emissions of Ammonia from Dairy Farms

By Dr. Eric Winegar
Applied Measurement Science

Review of Literature Sources for Emissions of Ammonia from Dairy Farms

Eric D. Winegar, Ph.D.
Applied Measurement Science
May 6, 1999

Introduction

A review of the literature on emissions of ammonia from dairy cattle and operations was conducted for the purpose of assessing the type and quality of dairy farm emission factors data available for use in determining an ammonia budget for the South Coast area. An exhaustive review of the literature was not conducted, but 15 papers (listed in the references) were examined in detail to obtain a representative set of emission factors that could be evaluated. In particular, due to the large difference between the measured emissions from Schmidt and Winegar (1996) and much of the other literature, the technical approaches of the papers were examined to determine which factors contribute most to the observed differences. Furthermore, since the Schmidt and Winegar (1996) study used the surface isolation flux chamber (flux chamber), that technique was investigated in order to understand the potential for measurement biases arising from its use.

Several factors were examined in greatest detail:

- Type and quality of data used to develop the emissions factors—measurement vs. models or estimation;
- Assumptions used in emission factor development; and
- Management practices—how the management practices for the dairies studied would affect the measured or estimated emissions.

Since the Schmidt and Winegar (1996) study was conducted in the San Bernardino region of the South Coast area, particular attention was paid to how management practices or other geographical factors may affect the ammonia emissions factor determination.

Status of Ammonia Emission Literature

The literature on ammonia emissions from dairies is wide but shallow. There are a large number of papers that cite each other without contributing independently obtained values. Of the 15 primary papers examined, only four had original data. The remainder either cited other studies or used models. For example, the work of Asman (1992) is cited repeatedly, but his work is based on limited sets of data.

Table 1 contains a summary of the studies examined in this report. This table includes the emission factor determined along with background information that relates to the derived value.

Occam's Razor and the Evaluation of Previous Studies

Occam's razor states that the simplest theory that accounts for the most known observations is the best theory. In the case of the task of evaluating a set of previous studies, it suggests that the approaches requiring the fewest assumptions should be the most accurate. Therefore, the overall approach used in evaluating the body of literature was based on the belief that a key indicator of quality in a scientific study is the set of assumptions that is used in conducting the study. In the end, hard data should be the basis for a scientific query of this nature.

However, not all required information is always available, so the research must make use of judicious (one would hope) assumptions for those factors that are either impossible or too difficult to obtain. Therefore, these studies were examined to determine the types and quality of assumptions used and the basis on which the assumptions were accounted for.

The stated assumption for this review is that direct measurement of ammonia emissions relies on the fewest assumptions regarding the state of the system being measured. It should be stated, therefore, that the use of field measurement data to derive a composite emission factor was emphasized since it was judged that models and estimates, by their very nature, are inherently less certain, having been derived from multiple layers of assumptions. Indeed, the literature is clear on the large variability in the factors produced from the use of non-measurement approaches. In fact, this review suggests that the foundation used to build the emission inventory is shaky due to the large reliance on estimations and models, with few actual measurement data utilized. The genealogy of some of the citations show that data sometimes decades old have been reworked and re-cited repeatedly, with few original and up do date field data.

That said, it should also be understood that direct emission measurements rely on supporting site data, and that errors in the final calculation that are based on these data can substantially affect the outcome. Therefore, in this process, consideration of these factors was taken into account so that a complete as possible comparison could be made.

Factors Affecting Ammonia Emissions

The nature of ammonia emissions is complex, with many factors affecting the temporal and spatial emissions profile. For the purpose of examination of the various factors that contribute to the emissions, one can divide the factors into micro factors and macro factors. The micro factors primarily physico-chemical aspects that contribute to the emissions from the waste on small homogeneous scale. No site-wide phenomena are considered in these factors. The macro factors are aspects such as seasonal variations and management practices that contribute to the emissions from the entire facility or type of facility.

Some micro factors relating to emissions from the waste are:

- Animal species, age, and weight
- Nitrogen content of feed
- Uptake efficiency of dietary nitrogen to animal tissues and milk
- Manure properties: pH, viscosity, mass fraction as dry solids
- Soil properties: pH, calcium content, water content, buffer capacity, and porosity

Some macro factors contributing to the facility emissions are:

- Animal stable design
- Time spent in stable vs. in pasture
- Manure storage practices
- Amount and thickness of manure spread on land
- Method of manure spreading
- Time interval between spreading and plowing
- Meteorological conditions: temperature, turbulence, humidity, and precipitation
- Irrigation practices

The micro factors are too poorly understood to be able to completely account for. Some studies have attempted to deal with them, but the nature of the problem is such that most cannot be accurately modeled. Sutton, 1995 states that the best average value for loss of total applied nitrogen to pastures is somewhere in the range of 15-30 percent of total nitrogen. This range corresponds to a relative standard deviation of 66 percent.

The macro factors can be termed management practices, and much of the emission inventory work can be questioned as to its applicability due to the source of those practices. For the papers reviewed, the management practices as documented in many of them relate to European and UK practices. For example, much of the work cites Asman, 1992, which is based on primarily studies conducted in the Netherlands or in Europe. Management practices in these areas are substantially different from those in the South Coast area. For example, Asman, 1992 cites the housing of dairy cattle in stables for months at a time. In addition, in other studies, cattle are cited as being housed in stables at nighttime. In both these cases, it was documented that the emissions were substantially higher. For example, Asman, 1992 cites an increase by greater that a factor of two (12.87 kg/head/year for stable and storage vs. 5.76 kg/head/year for grazing) between housing and grazing. This work also documents the other European housing practices, suggesting that the emission factors derived from these practices would not be applicable to the South Coast environment due to the exclusive placement of the herd in corrals.

One other macro factor that is difficult to account for is the seasonal variation of the emissions. The South Coast area is quite temperate, with temperatures in the wintertime never requiring the housing of the cattle, whereas much of the other work cites studies in more severe climates that have required the housing of the cattle in winter time. This alone will produce a significant variation in the way the emission estimates are obtained.

The South Coast seasonal contribution was estimated in Schmidt and Winegar, 1996 as a three month contribution from winter at a lower emission rate than the remaining nine months' summer emission rate. This breakdown was calculated based on limited meteorological data and the measured emission rates determined by the flux chamber testing. In addition, the presence of precipitation could affect the overall rates due to the increase in moisture in the soil and waste on the ground. Other work has shown that the emission rate is strongly dependent upon temperature, which may account for these differences. Asman, 1992 used ambient data and meteorological data from the Netherlands to normalize the seasonal variation, resulting in a factor of approximately three between winter and summer. However, this work also states that sufficient information is not known to make many accurate predictions.

The net effect is difficult to reconcile for the South Coast data since there is a lack of meteorological data in the Schmidt and Winegar, 1996 report. Furthermore, the state of understanding on overall seasonal effects is lacking. Therefore, in the interest of being conservative, the summer rate for the South Coast area emissions will be used without further interpretation.

Table 1. Compilation of Dairy Information from Literature Base

Study	Purpose	Study Area	Data Origin	Management Practices Examined?	Uncertainty Analysis	Original Data	Emission Factor (lb/hd/yr)
Asman (1992)	European ammonia inventory	Europe	Cited: Amb. Air, feed	Yes	Some	No	88
Battye (1994)	Compilation of data	US	Cited: wind tunnel, feed	Yes	Some	No	see subtable
Bouwman (1997)	Global survey	Global	N excretion, NH3 loss	Yes	Some	No	42
Buijsman (1987)	Emission survey	Europe-2 regions	Cited: feed, N loss	Limited	Yes	No	40
Danwu (1994)	Estimation of NH3 in Asia	Asia	Cites various	Limited	No	No	62
Dickson (1991)	Emission inventory	South Coast	Literature review	Limited	Yes	No	73
Gharib (1984)	Compilation of data	South Coast	Literature review	None	No	No	73
Hutchings (1996)	Simulation	Europe	Model	None	No	No	56
James (1997)	Measurement program/model	San Joaquin Valley	Ambient air	None	No	**Yes**	74
Pratt (1998)	Emission inventory	Minnesota	Literature review	Yes	Yes	No	22
Schmidt/ Winegar (1996)	Dairy farm measurements	San Bernadino area	Flux chamber	Yes	No	**Yes**	20
Sutton (1995)	Ammonia budget	UK	Literature review	Yes	Yes	No	31

Table 1. continued.

Study	Purpose	Study Area	Data Origin	Management Practices Examined?	Uncertainty Analysis	Original Data	Emission Factor (lb/hd/yr)
TSS-15 (1998)	Review and develop emission factor measurements.	General	Literature review	None	Yes	No	95
TSS-15 Field Study (1998)	Measurement program	King County, CA	OP-FTIR, Denuders, impingers, passive samplers	None	Yes	Yes	77
Study	**Purpose**	**tudy Area**	**Data Origin**	**Management Practices Examined?**	**Uncertainty Analysis**	**Original Data**	**Emission Factor (lb/hd/yr)**
Wilkensen (1998)	Measurement/ model	San Joaquin valley	OP-FTIR, Denuders, impingers, passive samplers	Limited	Yes	Yes	176
NAPAP (1985)	cited by Battye						49
Kruse (1989)	cited by Battye						35
Jarvis (1990)	cited by Battye						14
Asman (1990)	cited by Battye						38
Moller (1989)	cited by Battye						40

Measurement Approaches for Determining Area Emissions

EPA guidance (Radian (1990)) for conducting air pathway analysis at hazardous waste sites suggests that there are four main approaches that are commonly used for assessing area source emissions. Of the four—direct assessment, indirect assessment, air monitoring/modeling, and predictive modeling assessment, direct assessment is suggested to have the most advantages compared to the other methods.

Direct assessment avoids the use of modeling or extrapolation, with emission rates determined directly from measurement data, eliminating the need for the introduction of complicated and difficult to measure meteorological data. Indirect methods are based on various types of ambient air measurements coupled with meteorological data, but due to atmospheric mixing generally do not provide significant data on emission rate variability due to site characteristics. The air monitoring/modeling approach is similar to the indirect method, but is based on a more distant assessment of the emissions from the source. Measurements are compared with the modeled values until an appropriate emission rate is determined, resulting in a very large uncertainty associated with the emission rate determination. The predictive model approach is based on the use of highly specific chemical and physical characteristics of the source such as concentration of the emittent in the source, the moisture content, porosity, depth of cover, etc.

The direct assessment approach carries the lowest burden of assumptions, and therefore studies that rely on direct measurements are judged to have the highest credibility. In the collection of studies examined in this work, the main direct measurement approaches were the flux chamber method and the ambient air method. Indirect measurement approaches consisted of the approximation of nitrogen loss (nitrogen balance) from either facility waste analysis or the input from feed stock.

Critique of the Flux Chamber Method

The flux chamber method was developed in order to provide a reliable direct measurement method that avoids the use of modeling or extrapolation. It is commonly used to determine emission rates from area sources in hazardous waste sites.

Potential sources of error are 1) biases inherent in the measurement technique, 2) sampling and analytical error, and 3) biases created in study design.

Potential effects (Gao (1997)) on the accuracy of the measured flux are 1) pressure gradients that create an advective mass flow of the target gas which may be different from that created by surface winds outside of the chamber; 2) flow inhomogeneities that may create local stagnant zones inside the chamber; and 3) vertical flow components (either upward or downward) that may create positive or negative spatially variable fluxes that are not representative of true emission rates. In addition, sweep flow rates must be optimized to prevent build up of volatile compounds or to where gas-phase resistance (compared to diffusion resistance) controls the emission process (Gholson (1991)).

Ambient Air Approach

The ambient air approach consists of the collection of various ambient air samples while monitoring key meteorological parameters such as wind speed and direction. The chemical and meteorological data are combined in various types of models, primarily a simple box model, to provide an estimate of the overall facility emission rate. The overall weakness in the ambient air approach is the lack of ability to handle spatial variability—the entire facility emissions are measured. This limitation makes the understanding of specific aspects of the operation impossible to understand—for example, the various types of corrals in which the cattle are kept or the specific management practices employed.

Two ambient air studies were included in the papers reviewed. In the James et al., 1997 study, a simple array of active and passive samplers were placed around a dairy, and the ammonia concentrations were included in a simple box model to predict the overall emissions. In this case, the temporal and spatial variability could not be captured. While attempts to deal with the horizontal component of dispersion were included, the overall spatial variability appeared to overwhelm the application of the model. Most air dispersion box models are based on a much larger scale, so its applicability for this small-scale phenomenon is also questionable.

The second study (STI (1998) used a more complicated array of instrumentation, including open-path FTIR and multiple meteorological data collection. However, regardless of the attempts to capture a wider range of data, the same weaknesses were manifested—spatial and temporal variability limited the usefulness of the data. Indeed, the measured emission rates for this study were the highest of all data reviewed, with large enough error limits (>±100 percent) to suggest that the derived emission factor has little validity.

Indirect Nitrogen Balance

The indirect nitrogen balance approach is attractive since it relies on simple analyses of nitrogen content in food and in the waste stream. The waste stream nitrogen content is frequently available from standard water quality data, so these estimates can be determined cheaply and easily. Although these data are more easily obtained than direct measurements, the assumptions that must be subsequently used in the estimation of emissions are more difficult to handle. Several assumptions must be maintained, each of which has its own limits of uncertainty. In fact, given the ranges of these parameters cited in the studies reviewed, it is surprising that the final values are estimated to have uncertainties less than 100 percent or more.

Some of the reviewed papers did in depth reviews of the uncertainties and the quality of the assumption on which the conclusions were built. However, many simply cited past work uncritically.

Approaches to Determine Composite Emission Factor for Dairies

Two approaches were used to determine a composite emission factor value for dairy emissions. The first consisted of statistical evaluations, using both the standard gaussian assumption and a non-parametric approach that avoids the use of any assumptions on the distribution of the data or the basis for each value. The second consisted of making adjustments to the flux chamber data to account for documented biases or other factors that affect the accuracy of the raw measurement data.

Description of Data Set

Table 2 contains a summary of the emission factor data from the studies examined in this review. The ammonia emission factor is cited along with an associated uncertainty, all in pounds per head of dairy cattle per year. The uncertainties cited were either explicitly stated in the study or were arbitrarily assigned an uncertainty of 30 percent. In some cases, the uncertainties were not symmetrical. Note that the data cited in Battye (1994) have been included in this list.

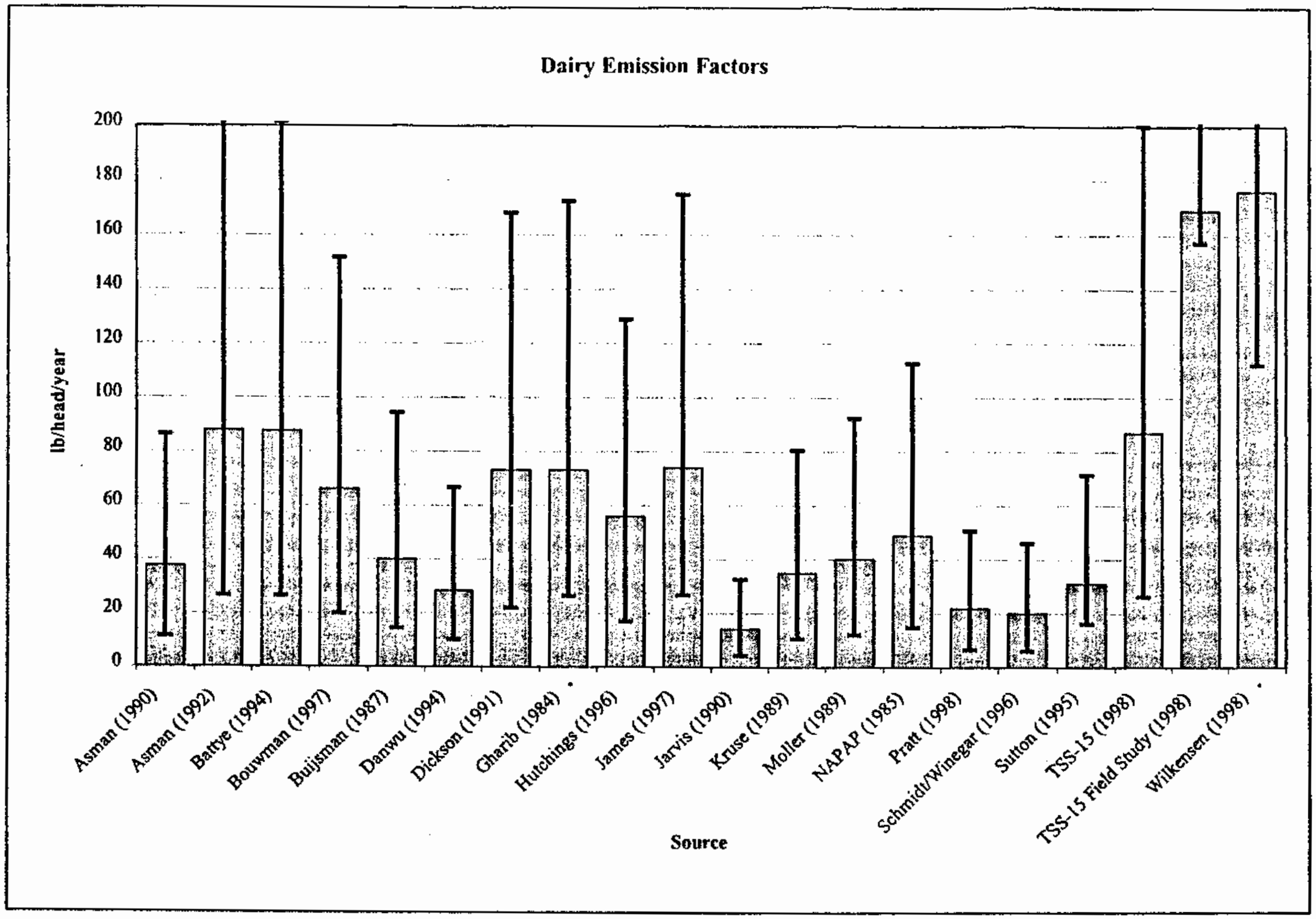
Table 2. Dairy Emission Factors from Literature

Source	Emission Factor (lb/head/yr)	Uncertainty (Percent)*	Lower Bound (lb/head/yr)	Upper Bound (lb/head/yr)
Asman (1990)	38	30	26	49
Asman (1992)	88	30	62	114
Battye (1994)	88	30	61	114
Bouwman (1997)	66	30	46	86
Buijsman (1987)	40	36	26	54
Danwu (1994)	28	36	18	38
Dickson (1991)	73	30	51	95
Gharib (1984)	73	36	47	99
Hutchings (1996)	56	30	39	73
James (1997)	74	36	47	101
Jarvis (1990)	14	30	10	18
Kruse (1989)	35	30	24	45
Moller (1989)	40	30	28	52
NAPAP (1985)	49	30	34	64
Pratt (1998)	22	30	15	29
Schmidt/Winegar (1996)	20	30	14	26
Sutton (1995)	31	30	15	40
TSS-15 (1998)	87	**	61	113
TSS-15 Field Study (1998)	169	30	12	220
Wilkensen (1998)	176	**	64	229

*The uncertainty of the derived emission factor was assigned using either the uncertainty level that was explicitly stated in the study, or if none was mentioned, to arbitrarily assign a conservative level of 30 percent. An uncertainty level of 30 percent is typical and even conservative in measurement studies and would represent at a minimum the lower bound of uncertainty ranges.

**For several studies, the upper and lower bounds were stated explicitly and are cited in the table directly.

Figure 1. Plot of Dairy Emission Factors and Uncertainties Cited in this Work



Statistical Approaches

Two statistical approaches were used to evaluate the body of emission factor data. The first is based on the assumption of a standard normal distribution for the data. The second avoids any assumptions, using a distribution-free or non-parametric approach.

Normal Distribution

Assuming a normal distribution for the emission factors determined in the population of studies examined, standard gaussian descriptive statistics were calculated and are included in Table 3. These data show that there is a large degree of spread in this set of data, with a relatively high coefficient of correlation (or relative standard deviation) of 70 percent. Many studies reject values with CV's greater than 50 percent, suggesting that the values are not comparable.

Table 3. Normal Descriptive Statistics for Dairy Emission Factors

Normal Distribution (lb/head/yr)	
Ave.	63
Lower Limit	44
Upper Limit	83
Std Dev	44
RSD (CV)	70%
Confidence Interval (95%)	±19

Non-parametric Statistics

Table 4 contains the results of non-parametric, or distribution-free, statistics. The unbiased location in this approach is determined by the median, and the upper and lower confidence intervals were calculated using the sign-based Thompson and Savur method (Hollander and Wolfe, 1999).

Table 4. Non-parametric Statistics for Dairy Emission Factors

Non-parametric (lb/head/year)	
Median	52
Lower Limit	22
Upper Limit	88

The advantages of non-parametric statistics (Hollander and Wolfe, 1999) are 1) it avoids the use of assumptions regarding the underlying distribution of the data, and 2) non-parametric statistics show a lower sensitivity to outliers. In the case of the dairy data, the large range of data suggests possible outliers, but without an extensive review of all the data sources, the rigorous detection of an outlier would be difficult. Therefore, the nonparametric approach can provide a reasonable level of rigor without using difficult to prove assumptions.

A comparison of the normal statistics and the non-parametric statistic shows that the two calculated values are somewhat close, within less than approximately 20 percent, suggesting some degree of precision.

Adjustment of Flux Chamber Data

While several studies have demonstrated the accuracy of the flux chamber method (Schmidt (1992, 1999), Ambus (1993)), other work has shown a negative bias of 40 to 80 percent in a laboratory simulated emission scenario (Gholson (1991)) due to the suppression of emissions from the chamber-covered surface. In addition, while some studies have shown an aggregate variability of around 17 percent, general experience has shown that a typical accuracy of ±50 percent is standard (Schmidt, 1999).

These results are consistent with a superficial evaluation of the potential biases due to advective gradients produced by unequal pressures between the inside of the chamber and the atmosphere. When the surface velocity of the US EPA approach sweep air was calculated, it was significantly lower than a typical velocity expected to produce an equalization of the local upward to downward advective components (Gao (1997)). Therefore, based on this assumption, the measured flux would be biased low.

Due to these factors, a conservative evaluation would suggest an approximate 50 percent low bias of the flux chamber data due to inherent characteristics of the technique.

The sampling and analytical error can be manifested in both positive and negative biases, but in this case the negative biases would dominate. The largest negative bias would be the potential loss of sampled analyte during sampling or transport to the laboratory. The chamber surface presents a much larger surface area to gas ratio, and surface losses may occur. Losses during transport are commonly seen due to temperature and pressure fluctuations. All these factors can contribute to a low bias. High biases are commonly due to contamination, which was not seen nor expected due to the low background level of ammonia.

The last and possibly larger factor that contributes to inaccuracy of the flux approach is the study design itself. In particular, the selection of locations to test and the subsequent assignment of a flux rate over a specific area can be large sources of error. Data such as the number of cows present may also be misstated. Self reporting of such data are notoriously inaccurate and can lead to both high and low biases. In the dairy flux chamber study, the recollections of the operators was used extensively to assign frequencies of various operations and the size of the herds. Therefore, the overall accuracy of the flux rates are proportional to the accuracy of this kind of data.

Two other potential sources for error in the flux chamber study design may be in missed emissions and in the assignment of normalization factors for diurnal patterns. Examples of potential missed emissions are ammonia flashing from fresh urine and emissions from wetted down surfaces. For example, while the Schmidt and Winegar study attempted to capture the emissions from fresh urine deposits, the nature of the measurement misses the first 30 minutes of emission in which a major portion of the ammonia may be lost. Wetted and cleaned surfaces were not measured due to allocation of resources toward what were considered larger sources. These sources were seen to contribute approximately two-thirds of the emission rate of a soiled slatted floor (Oosthoek, 1991), suggesting that the absence of data from this source would lower the overall emission factor.

The diurnal pattern of the emissions were examined in more detail to determine if the normalization factor that was used was justifiable compared to other studies. Several reports confirm the temperature dependence of ammonia emission, but there is little other field data on the diurnal pattern of emissions. However, other models suggest a much more complicated non-linear dependence on temperature, wind speed, and the concentration of ammonia in the soil (Asman, 1992). Dickson , 1991 cited other researchers who developed an emissions model based on temperature and wind speed. Asman, 1992, used the annually averaged temperature to compute a diurnal pattern that varies by a factor of 3-4, depending on the locally produced temperature variations. The key factor in this assessment was the simple linear dependence on temperature as opposed to the sinusoidal dependence determined in the Schmidt and Winegar, 1996 study. The Schmidt and Winegar, 1996 report showed that emissions decreased rapidly between 1300 and 1500, that contradicts the expected dependence based on temperature alone. In addition, after reaching the lowest level at around 1700, the emissions commence an uprise until midnight after which they decrease again until approximately 0600. These observations are contrary to expected and observed temperature cycles, and although the actual emissions are in fact a function of more than temperature, the use of the flux chamber theoretically eliminates the wind and other variables, leaving primarily temperature to drive the emissions with all other aspects being equal. Therefore, the use of the normalization factors as based on this diurnal curve is suspect.

Furthermore, other data show the rapid decrease of emissions to about 30 percent of the original emission rate over the first 12 hours after deposition (Vlassak et al., 1991). This characteristic should be superimposed over the diurnal pattern, which is not evident. Again, this supports the premise that the normalization model appears to be flawed.

The detailed site data is not available to correct, but the data can be corrected partially as follows. Assuming that the majority of the field measurements were made between 0800 and 1800, and that the daytime values are most valid, by applying the modified Asman, 1992 temperature curve to the Schmidt and Winegar, 1996 data, it would imply that 1) the entire curve needs to shifted higher, and 2) approximately one-half of the normalization factors are too low. These two changes will push the emissions higher by a factor of 20 percent for approximately 12.5 percent of the data.

When these sources of potential error are combined, and propagating the various error estimates cited above, it is not unreasonable to conclude that the measured emissions have a high probability of being a factor of 2.5 low. Therefore, the emission rate of 20 lb/head/yr as determined in the Schmidt and Winegar, 1996 study can be adjusted upwards to the value of 50 lb/head/year, with an uncertainty of ±30 percent. This level of uncertainty is conservative, since a nominal uncertainty for most field work is ±50 percent.

Recommended Emission Factors

The above analysis of the data suggests three emission factors to choose from for a final recommended value:

Table 5. Composite Dairy Emission Factors
(lb/head/year)

Approach	*Value*	*Uncertainty*	*Confidence*
Normal Distribution	63	44 to 83	Good
Non-parametric	52	22 to 88	Good
Flux Chamber Adjustment	50	35 to 65	High

It is recommended that the non-parametric and flux chamber values be averaged to result in a final composite emission factor of 51 lb/head/year. The use of these two values assumes the least and uses the most conservative applications of the data analysis performed.

Recommendations

Given the state of the data on ammonia emissions from dairies and the importance of the data to the entire ammonia inventory, it is recommended that additional studies be conducted to account for the noted discrepancies in the data. For example, while the above analysis has made adjustments to the emission rates determined by the flux chamber method, these adjustments are arbitrary and are based on several assumptions and extrapolations. Using the same basis for evaluating these data as stated, it is concluded that additional study is needed to completely evaluate the reasons for the discrepancies.

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