Development of an Updated Gridded Ammonia Emission Inventory for the South Coast Air Basin

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ABSTRACT

Previous ammonia inventories for the South Coast Air Basin (SoCAB) have been found to be lacking due to the use of outdated or incomplete data concerning various ammonia emissions sources. Thus, the 1997 Gridded Ammonia Emission Inventory (1997 Update) was developed jointly by AVES and ENVIRON to support the 2000 Air Quality Management Plan (AQMP) for the South Coast Air Quality Management District (SCAQMD). The 1997 Update supersedes the 1997 AQMP inventory, which was based on an earlier study performed in 1991 using 1987 as the base year. The 1997 Update focused on updating sources that produced over 10% of the 1987 inventory as well as potential new sources.

The compilation of the gridded inventory included the selection of emissions factors and activity data as well as the development of appropriate surrogate data to allocate the emissions spatially. The ammonia emission inventory was processed using EPS2.0. Spatial surrogates were developed from Aerial Information Systems' 1990 Aerial Land Use Study and USGS Land Use/Land Cover (LULC) databases. The ARC/Info GIS software system was employed for the development of gridded surrogates used for spatial allocation of the updated area source emission. Domestic ammonia sources were allocated based on population while point sources were allocated based on geographic coordinates. The final county-level, annual ammonia inventory was gridded for the District's AQMP modeling domain at 1-kilometer by 1-kilometer horizontal resolution providing more accurate spatial representation of ammonia emissions in the SoCAB.

A number of additional sources of ammonia emissions were incorporated into the updated inventory including native animal waste, landfills, composting operations, oceans and other bodies of water, and prescribed burns. Emission factors and activity data for poultry, cattle, horses, domestic pets, cigarettes, and POTWs were updated and/or revised to reflect the results of more current studies. The approach to estimate emissions from non-combustion industrial sources was significantly modified from the earlier study which relied on the Toxics Release Inventory (TRI). The current approach results in a more complete inventory since the TRI inventory is limited to sources that use 10,000 pounds or greater of ammonia. These emissions were treated as area sources and allocated by 5-digit Zip code for reasons of confidentiality. Emissions from combustion industrial sources were left unchanged.

Ammonia emissions increased from 156 tons per day in the previous inventory to 188 tons per day in the 1997 Update. The largest changes occurred in dairy cattle (decreased from 15.89 to 4.32 tons per day), horse (increased from 10.77 to 32.41 tons per day), domestic animal emissions (decreased from 14.69 to 7.81 tons per day), and sewage treatment (decreased from 3.94 to 0.08 tons per day).

INTRODUCTION

In support of the South Coast Air Quality Management District's (SCAQMD) 2000 Air Quality Management Plan (AQMP), ATC Associates and ENVIRON International Corporation were contracted to develop an update ammonia emission inventory. The basis of the updated inventory was the 1997 AQMP ammonia inventory developed by the Radian Corporation in 1991 as an improvement of the District's 1987 inventory. The updated inventory is focused on those source categories which produce over 10% of the 1987 inventory as well as potential new sources. The improvements included revised methodologies, emission factor and activity data and spatial allocation based on an evaluation of existing ammonia inventories as well as a review of relevant literature. The final county-level, annual ammonia inventory was gridded for the District's AQMP modeling domain at a 1-km by 1-km horizontal resolution, thus providing a more accurate representation of ammonia emissions with in the SAouth Coast Air Basin (SoCAB).

EXISTING AMMONIA INVENTORIES AND PREVIOUS WORK

The 1997 Updated ammonia inventory was based on the existing 1997 AQMP[1] ammonia inventory (1993 base year), which in turn was developed as an update of an earlier study conducted by the Radian Corporation in 1991 (Radian Study)[2] (1987 base year), for the purpose of supporting the Year 2000 AQMP. Numerous improvements were incorporated into the revised inventory based on recommendations provided by the Radian Study as well as a review of existing and previous ammonia emissions inventory development work, and relevant literature.

The following literature sources were reviewed as part of the development of the 1997 Update:

Gharib and Cass[3] - 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. This study's relevance is due in part because it is the first study of its magnitude and is the basis for most of the 1987 Ammonia Inventory (the Radian Study)[2].

Warn et al.[4] – The Warn study was developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory. It is a comprehensive literature review and provides an investigation of wildlife excrement and domestic emissions.

Dickson R.J. et al.[2] – The 1991 Ammonia Emission Inventory (Radian Report) was prepared for the Electric Power Research Institute (EPRI) and is a comprehensive study based on literature review. Except for the beef dairy cattle, and publicly owned treatment works (POTW) emissions, it is the basis for the 1997 AQMP ammonia inventory.

Schmidt and Winegar[5] – 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. Although the feed, housing and housekeeping procedures are different from Europe and other areas in the United States, the study is significant because specific SoCAB dairies are examined.

Kogan, V., and E.M. Torres[6] – 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, and focuses specifically on ammonia emissions from the CSDOC facilities.

South Coast Air Quality Management District (SCAQMD), *1997 Air Quality Management Plan (AQMP)*[1]– 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[2].

The existing ammonia emissions inventory for the SoCAB, documented in the Radian Study was an update of the 1987 inventory which was based on the 1984 inventory developed by Gharib and Cass. The 1987 inventory included the following emission source categories: stationary fuel combustion; mobile sources; industrial point sources; sewage treatment plants; soil surfaces; fertilizer application; livestock wastes, and; domestic sources. The Radian Study also investigated the inclusion of the following additional sources: ammonia injection for NO_x control; landfill gas; cigarette smoking; wood burning, and; untreated human waste.

At the time of the report, Radian did not find emission factors for landfill gas and wood burning. Information for stationary fuel combustion were developed from AQMD Emission Inventory System (EIS) and ARB Emission Data System (EDS) databases. Radian developed ammonia slip emission estimates based on mass balance for a single facility and SARA Title III emissions for the remaining. Mobile sources from the 1987 inventory were corrected for increased vehicles and to reflect changes in catalyst technology. Industrial point source ammonia emissions were estimated from a combination of both the National Acid Precipitation assessment Program (NAPAP) emission factors applied to sources found in the ARB EDS database, and ammonia emissions presented in the 1987 SARA 313 database. Surface soil ammonia emissions were not altered from the 1984 inventory. Radian updated the livestock and fertilizer activity with land use information obtained from each county Agricultural Commissioners Office. In addition to updating livestock activity, sheep and poultry emission factors were updated from the 1988 ARB Uninventoried Sources Project produced by Dickson, et al. Information from the Bureau of Census was used by Radian to update domestic emissions. Emissions from untreated human waste and cigarettes were developed specifically for the Radian Report.

Dairy cow emissions were updated from the Gharib and Cass emission factor of 73 lb./head/year developed by literature review to the Schmidt and Winegar 20 lb/head/year emission factor developed from flux chamber source testing.

POTW emissions were updated with source test data from Kogan and Torres. The Radian Report used influent and effluent nitrogen compound concentrations to perform a simple nitrogen balance across a limited survey of facilities. Ammonia losses from sludge processing were estimated

with an emission factor presented by Gharib and Cass based on the Joint Water Pollution Control Plant in Los Angeles.

Based on the review of relevant literature sources and existing inventories, the following recommendations were made concerning potential improvements for the 1997 Update.

- Identification or development of landfill emission factors.
- Identification and development of emission factors for transportation of sewage to treatment plants.
- Further investigation of ammonia volatilization from livestock wastes.
- Identification and development of emission factors for native animals.
- Further investigation and refinement of emission estimates from POTWs
- Addition of ammonia emission data from AB2588 reports.
- Development of site-specific factors for fertilizer application.
- Further investigation and development of temporal variations in ammonia emissions.
- Thorough uncertainty analysis in future emission factor studies.

INVENTORY UPDATE

A conscious effort was placed into updating the 1997 ammonia emission inventory categories by their significance to the overall ammonia emission in the SoCAB/modeling domain. A number of sources not included in the 1997 AQMP[1], were investigated for inclusion in the 1997 Update. These include native animal waste, landfills, composting operations, oceans and other bodies of water, and prescribed burning. In addition, significant changes to emission factors and activity data for various emission sources were incorporated into the 1997 Updated ammonia emission inventory.

New Literature Review

Asman[7] – The May 1991 Asman study is a comprehensive ammonia inventory for Europe based on literature review. The study provides an extensive investigation into emissions from livestock and agriculture and is significant due to the broad scope of the study. It is highly favored by recent literature reviews such as Baytte et al.[8] and Sutton et al.[9]

Battye[8] – 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)[10] 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.

Sutton, et al.[9] – This 1995 literature survey focuses on ammonia emissions in the United Kingdom from the 1960s to 1994 for all sources. The Sutton study provides a detailed uncertainty analysis, a thorough analysis of Gharib and Cass's emission factors for pets and a literature review of domestic emission factors.

The San Joaquin Valley Study[11] – 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.

New Source Categories

Native animals generate ammonia emissions from waste. Although not widely investigated in the literature, emission factors developed by Warn were used because they were EPA accepted and rated. Activity data was obtained from the California Department of Fish and Game. At 0.2 tons/day of ammonia, the minimal impact on the overall inventory precluded further investigation into this source.

Aerobic and anaerobic digestion, and volatilization of refuse generates ammonia emissions. Emission factors for landfill ammonia were obtained from the SJV Study. Emissions estimated from landfills were also insignificant.

Both commercial and home composting were investigated. Home composting emissions were insignificant, however commercial composting emissions were approximately 10 tons/day. As in landfills, aerobic and anaerobic digestion, and volatilization of refuse generates ammonia emissions. At the time of the report 10% of organic waste was composted. By 2000, it was estimated that 50% of the organic waste would be composed.

Ammonia emissions from oceans and large bodies of waster were not included because of the large uncertainty in the literature. Some sources suggest that large bodies of water are ammonia sinks. Ammonia concentrations in coastal monitors in California are not significantly larger than inland concentrations.

Prescribed burning in the SoCAB were deemed as small, irregular events that vary greatly spatially and do not significantly impact the overall SoCAB ammonia inventory.

Emission Factor Updates

Significant changes were made from emission factors in the 1997 AQMP to this inventory. These changes were for various livestock and poultry, domestic sources, mobile sources and publicly-owned treatment works (POTWs).

Livestock and Poultry – Chickens, Dairy Cattle, Horses

Based on the work of Battye et al.[8], emission factors for chickens were revised downward from 1.6 lb./layer/yr. (and 0.79 lb./broiler /year to 1.0 lb./layer or pullet/yr. and 0.37 lb./broiler /year. The dairy cattle emission factor was revised from 21 lb./head/yr. to 51 lb./head/yr. based on an analysis performed by Dr. Eric Winegar[12]. The effect of this change was to substantially increase estimated ammonia emissions attributed to dairy cattle. The emission factor for horses and ponies was revised downward from 52 to 26.9 lb./horse/yr., based on Battye et al.[8]

Domestic Sources – Pets and Cigarettes

Emission factors for dogs and cats were revised downward from 5.5 (dogs) and 1.8 (cats) to 2.17 and 0.348 lb./animal/yr. based on Sutton et al.[9] The cigarette emission factor was revised downward from 2.07×10^{-05} to 2.2×10^{-07} lb./cigarette based on Warn, et al[4].

Mobile Sources – Vehicles with 3-Way Catalysts

The Radian Study[2] built up emission factors based on fleet mix and a number of other parameters requiring numerous assumptions. For the 1997 Update a bulk emission factor based on the Fraser and Cass[13] Tunnel Study was used. 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[6], to 0.118 lb./million gallons. This resulted in a nearly 4 tons/day ammonia emission reduction.

Activity Data Updates

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 categories.

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 25 tons/day decrease in the 2000 AQMP 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 329,924 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 8.9 percent increase in total cattle ammonia emissions.

Spatial and Temporal Allocation

Except for the spatial allocation of industrial sources, the spatial and temporal allocation of the 1997 Updated inventory was developed to be consistent with the 1997 AQMP inventory. Industrial source were treated as area sources and spatially allocated based on ZIP codes due to confidential nature of data received from the major ammonia suppliers within the South Coast Air Basin.

Summary of Differences Between the 1997 and 2000 AQMP Ammonia Inventories

Table 1 and Figure 1. summarize and compare the 1997 AQMP and the 1997 Updated ammonia emissions inventories by major source category. There was an overall increase of 32 tons/day in ammonia emissions between the 156 ton/day estimate in the 1997 and the 188 2000 AQMP Ammonia Inventories. Significant differences include a 26 ton/day increase in mobile ammonia emissions, a 10 ton/day increase by the addition of composting ammonia emissions, 4 ton/day increase in ammonia emissions from industrial sources, a 5 ton/day decrease in ammonia emissions from soils, 3 ton/day decrease in ammonia emission from POTWs and a 3 ton/day decrease in ammonia emissions from fertilizer use.

INVENTORY PROCESSING AND GRIDDING TECHNIQUES

The final result of the study is a 1997 ammonia emissions inventory, spatially resolved and gridded on the South Coast Air Quality Management District's modeling domain. Figure 2. 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. Note that no mobile source emissions data were used for gridding, nor was any temporal allocation considered.

A number of various software systems were used for the final preparation of the gridded ammonia emission inventory. These include EPA's Emission Processing System, version 2.0 (EPS2.0)[14], ESRI's ARC/Info GIS system and various scripting utilities. Raw emissions data was exported from Excell spreadsheets and appropriately re-formatted for subsequent processing.

EPS2 Emission Processing System

EPS 2.0 is a publicly available Fortran based software program that is included with the EPA UAM modeling system. The EPS 2.0 is a complete integrated package that has been applied in the development of numerous emission inventories. The core modules of the processing system include the following:

Surrogate Distributions: The EPS 2.0 comes with Fortran-based programs that can generate surrogate distributions from landuse and census data (e.g., USGS) for gridding county-level emissions data. However, EPS 2.0 can also use surrogate distributions generated from external programs, including GIS.

Area Source Module: The EPS 2.0 uses Fortran based software to spatially allocate the county-level area source emissions (including nonroad) to the gridded surrogate distributions imposing the user-provided temporal and speciation profiles.

Mobile Source Module: The EPS 2.0 integrates county-level VMT by roadway class with county- and temperature-specific MOBILE5/6 simulations to estimate county-level mobile source emissions that are spatially allocated according to surrogate distributions. Provisions for

separating the mobile source emissions by emissions mode (e.g., exhaust, and evaporative) are also accounted for.

Point Source Module: The EPS 2.0 point source module performs the same functions as many other emissions models. These functions include the mapping of point source locations to the grid projection system of the model, application of seasonal and day-of-week adjustments, and the speciation and temporal allocation of emissions based on the point source SCC code and user-provided speciation and diurnal emissions profiles. The EPS 2.0 point source module also estimates plume rise of each point source and those points sources whose plume rise is estimated to never exceed a user-specified threshold (e.g., top of layer 1), their emissions are assigned to the low-level point source emissions file that will be merged with the mobile, area, and biogenic sources for model input.

In addition to these core modules , a variety of utility modules are required for processing of raw emission data into the required formats of the EPS2 system. Although a typical EPS2 application requires speciation and temporal allocation of emissions estimates, for the 1997 Update, these processing steps were not needed since no temporal allocation was considered, and ammonia does not require speciation. The specific EPS2 modules required for gridding the ammonia inventory include PREAM (PREprocessor for Area and Mobile sources), PREPNT (PREprocessor for PoiNT sources), and GRDEM (GRiD EMissions).

Area source emissions estimates were reformatted into the required AMS workfiles using the Perl scripting language to convert the text data files (exported from Excel) for input to the PREAM module. Likewise, point source emission estimates were reformatted for input to the PREPNT module The primary function of PREAM and PREPNT is to reformat the AMS and AFS workfiles into EMBR (Emissions Model Binary Record) formatted data files for further processing with the GRDEM module. In addition, a number of reports are provided to aid in the quality assurance of the inventory development.

The final step in the EPS2 gridding process is the application of the GRDEM 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 the 1997 inventory update, 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. Figure 3. displays the final gridded ammonia emission inventory.

Spatial Allocation/Spatial Surrogates

Spatial surrogates for area sources were developed form three sources of Land Use/Land Cover (LULC) 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[15] 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 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.

In general, emission source categories which are to be treated as stationary point sources do not require spatial surrogates for allocation to the gridded inventory. For the SoCAB ammonia inventory development, an exception was made for 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 were provided only by postal ZIP Code (due to the confidential nature of the data provided by the ammonia suppliers), they are treated as area sources using the ZIP Code as a spatial surrogate. ARC/Info ZIP Code coverages were obtained from Geographic Data Technology, Inc. and processed with the ArcInfo GIS software in a manner similar to the LULC data.

ARC/Info Processing

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. Table 2. summarizes the spatial allocation data for treatment of area sources.

Combustion Point Sources

Combustion point source emission data from the existing SCAQMD inventory 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) file format, the precise location of the sources were 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 25 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.

CONCLUSIONS

The 1997 Updated Inventory focused on providing updated emission estimates for those sources which contribute over 10% of the 1987 inventory as well as potential new sources. Revised activity data and emission factor data were based on review of recent literature and existing ammonia inventories. The gridded inventory was devloped for the AQMP modeling domain at a horizontal resolution of 1-km by 1-km utilizing improved spatial allocation techniques in order to improve the spatial accutracy of the inventory.

Ammonia emissions increased from 156 tons per day in the previous inventory to 188 tons per day in the 1997 Update. The largest emission changes occurred for dairy cattle (decreased from 15.89 to 4.32 tons per day), horses (increased from 10.77 to 32.41 tons per day), domestic animal emissions (decreased from 14.69 to 7.81 tons per day), and sewage treatment (decreased from 3.94 to 0.08 tons per day).

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Table 1. Summary of 1997 AQMP and 1997 Updated Inventory by source category.

	1997 AQMP		1997 Update	
Source	**Emissions (tons/day)**	**Percent of Total**	**Emissions (tons/day)**	**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%**

Figure 1. Comparison of ammonia emission inventory by source category.

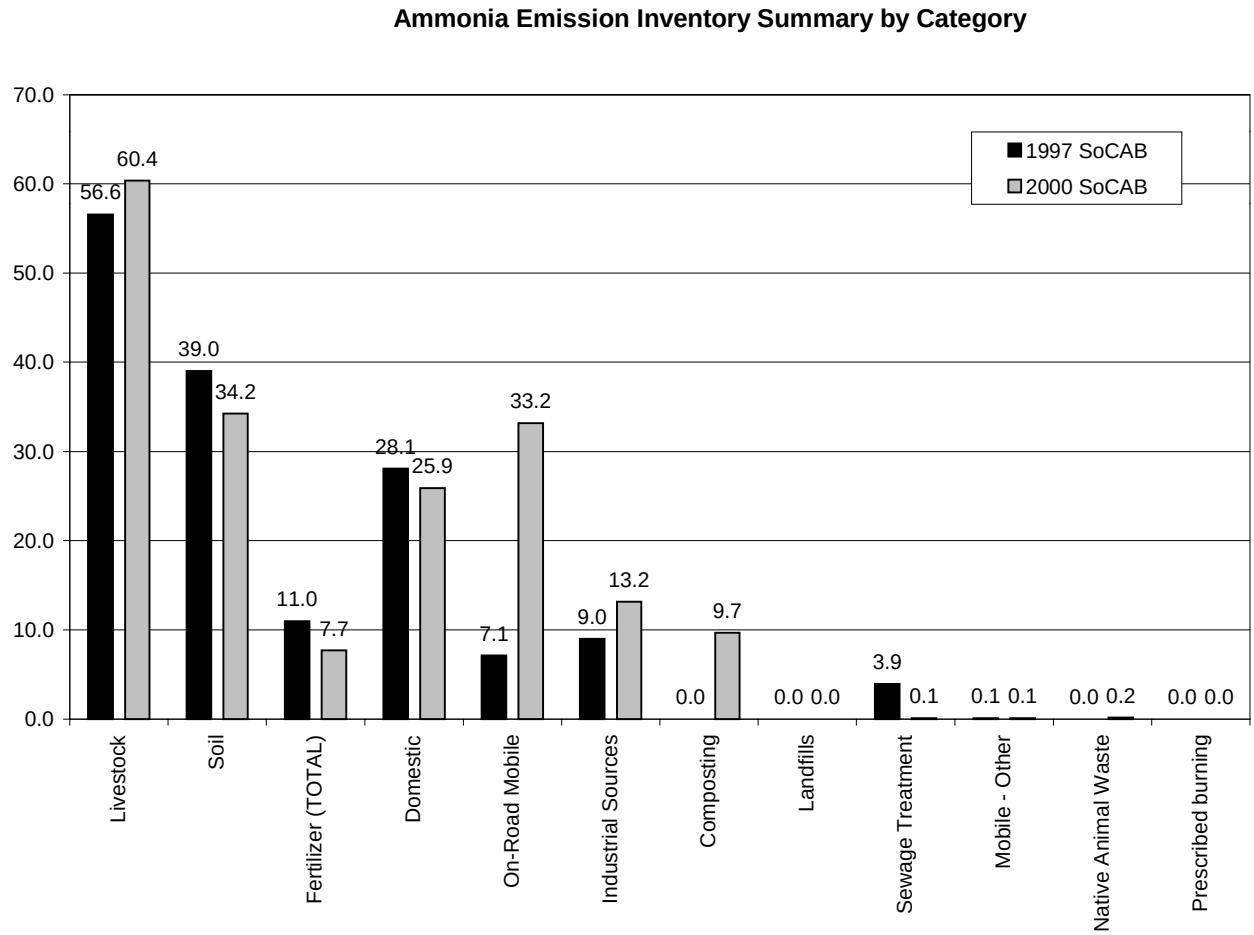


Table 2. Summary of spatial allocation surrogates.

Source Category	**Spatial Allocation**
Livestock	
Beef Cows	GIS Rangeland
Heifers/Calves	GIS Rangeland
Steers/Bulls	GIS Rangeland
Hogs/Pigs	GIS Confined Feedlots
Sheep/Lambs	GIS Rangeland
Mules/Burros/Donkeys	AIS Rural Residential Low Density/Horse Ranches
Goats	AIS Dairy & Intensive Livestock
Rabbits	GIS Confined Feedlots
Horses	AIS Rural Residential Low Density/Horse Ranches
Native Animals	
Bears	GIS Forest
Deer	GIS Forest
Soil	
Urban	GIS Urban
Agriculture	GIS Agriculture
Range/Pasture	GIS Rangeland
Wetland	GIS Wetland
Forest	GIS Forest
Barren	GIS Barren
Fertilizer	
Farm - Dry	GIS Farmland
Farm - Wet	GIS Farmland
NonFarm - Dry	GIS Nonfarm Agriculture
NonFarm - Wet	GIS Nonfarm Agriculture
Domestic	
Cat	Population
Dog	Population
Homeless	Population
Respiration	Population
Perspiration	Population
Household Use	Population
Other Untreated Human Waste	Population
Cigarette	Population
Cloth Diapers	Population
Disposable Diapers	Population
Industrial Points	
Refrigeration	ZIP Code
Metal Treatment	ZIP Code
Flue Gas	ZIP Code
Blueprinting	ZIP Code

Figure 2. AQMP modeling domain.

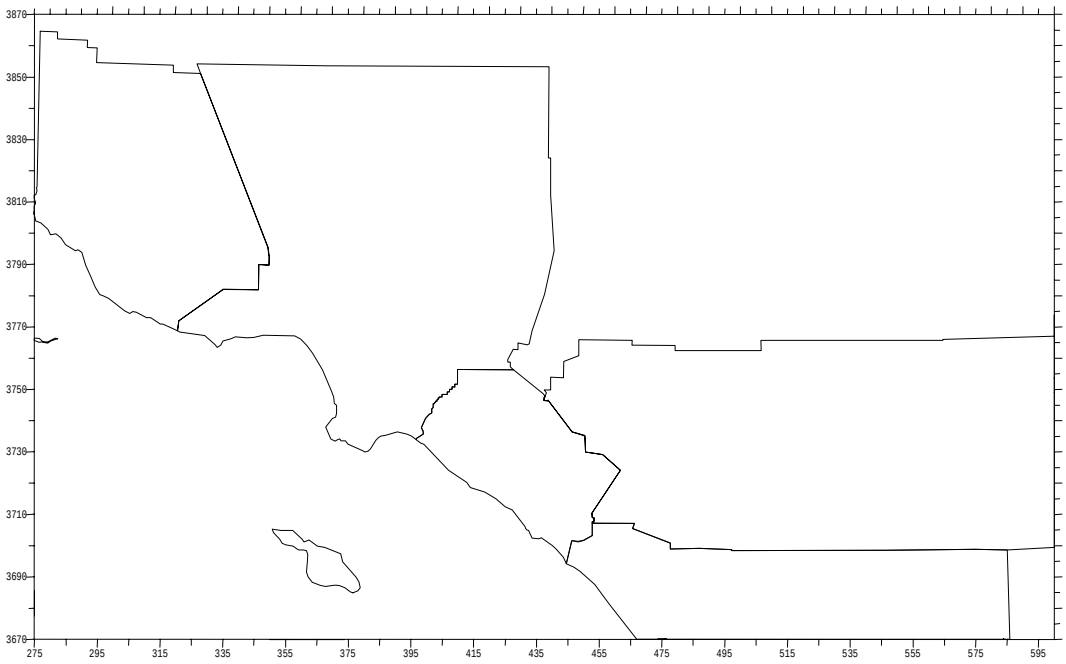
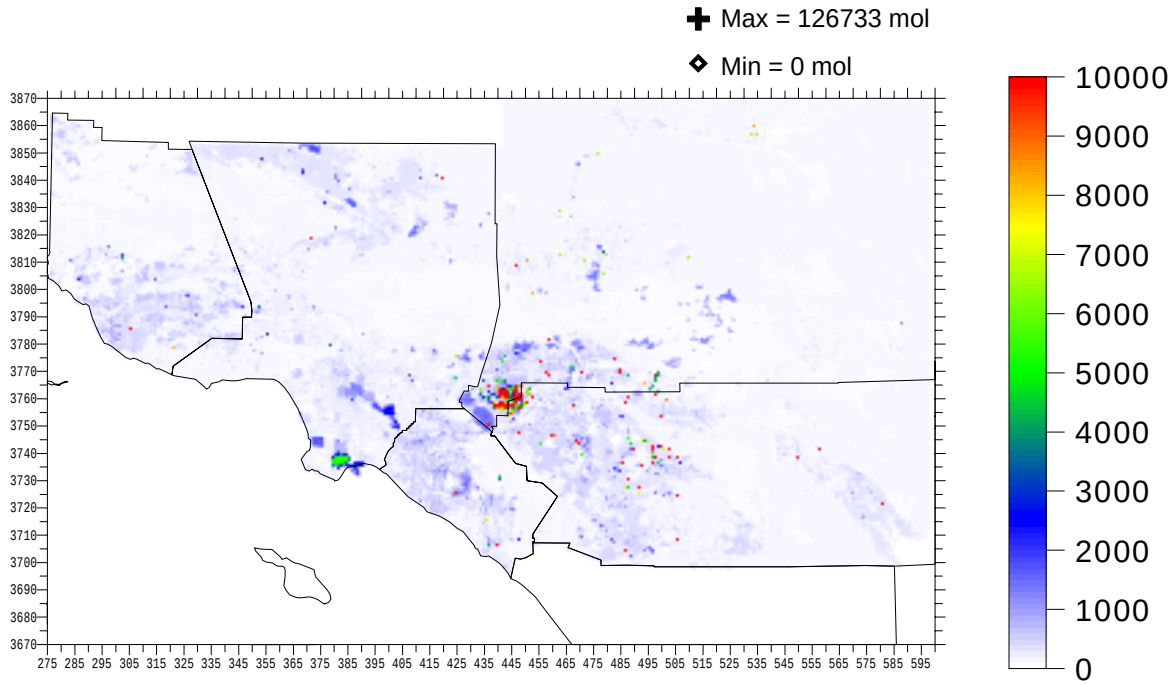


Figure 3. Final gridded ammonia emission inventory.



KEYWORDS

ammonia
emission inventories
area sources
spatial allocation