Draft Final Report

California Regional $PM_{10}/PM_{2.5}$ Air Quality Study Ammonia Emissions Improvement Projects in Support of CRPAQS Aerosol Modeling and Data Analyses: Draft Ammonia Inventory Development

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EXECUTIVE SUMMARY

Background

The California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS) is a multi-year program to study particulate matter (PM) air pollution in Central California and consists of meteorological and air quality monitoring, emissions inventory development, data analysis, and air quality modeling. The primary objectives of the study are to:

- Provide an improved understanding of emissions and atmospheric processes that influence particle formation and transport;
- Develop methods useful to planning agencies in formulating and assessing candidate control strategies for attaining the federal and state PM standards in Central California; and
- Provide reliable tools for estimating the impacts of control strategies for PM on visibility, air toxics, and acidic aerosols and on attainment strategies for other pollutants, specifically ozone.

Grid-based aerosol models are to be applied to simulate particulate matter concentrations in the SJV and to investigate the sensitivity of secondary particulate matter formation to various parameters. A first step in the successful application of air quality models to investigate proposed control strategies is the demonstration of acceptable model performance through comparison of modeled estimates and field study observation data. A key requirement for the credible application of air quality models are accurate input data specifying three dimensional meteorology and ground-level emission rate estimates. Ideally these inputs are to be developed with adequate spatial and temporal resolution in order to accurately represent the complex chemical and transport processes occurring in the atmosphere which contribute to the formation of particulate matter pollution.

This report documents the of a state-of-the-science ammonia emission inventory for the San Joaquin Valley (SJV) study area and an ammonia emissions modeling system developed as part of this project. The emission inventories are based on the best available ammonia emissions information and processing methodologies developed by the project team.

Project Goals and Objectives

The primary goal of the project was to develop a draft, ground-level, gridded ammonia emission inventory for use in data analysis and grid-based aerosol modeling for the CRPAQS. The draft inventory will be used to assess the sensitivity of aerosol model estimates to changes in such variables as spatial and temporal resolution, and emissions magnitudes for various source categories of ammonia emissions. The ammonia inventory was developed at a spatial resolution of 1-km by 1-km with a temporal resolution of 1-hour using the best available emission source data and processing methodologies. The geographic extent of the gridded inventory covers the SJV study area, although inventory data was collected for the entire state of California. In addition, a standard input data library and processing procedures to facilitate future in-house refinements or revisions to the inventory in a programmatic way was developed.

A secondary goal of the study was the development of an ammonia capable GIS-based emission modeling system. For many ammonia emission source categories, emission estimates are intimately linked to land cover/land use (LULC) characteristics. Thus, an emissions model

combining the GIS data on LULC distributions with LULC specific emission factors to calculate gridded emissions in a single processing step was developed.

Work Tasks

The specific work tasks performed to satisfy the particular goals and objectives of the study are briefly summarized below.

Task 1: Prepare a Detailed Workplan

Task 2: Collect Data and Create Standard Input Library

Task 3: Develop Ammonia Emissions Model

Task 4: Produce Draft Ammonia Modeling Inventory

Task 5: Documentation

Summary of Input Data and Sources

Ammonia Inventory Summary

Summary of Ammonia Emission Model Development

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INTRODUCTION

Background

The California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS) is a multi-year program to study particulate matter (PM) air pollution in Central California and consists of meteorological and air quality monitoring, emissions inventory development, data analysis, and air quality modeling. The primary objectives of the study are to:

- Provide an improved understanding of emissions and atmospheric processes that influence particle formation and transport;
- Develop methods useful to planning agencies in formulating and assessing candidate control strategies for attaining the federal and state PM standards in Central California; and
- Provide reliable tools for estimating the impacts of control strategies for PM on visibility, air toxics, and acidic aerosols and on attainment strategies for other pollutants, specifically ozone.

Chemical reactions of ammonia emissions with airborne oxides of sulfur and nitrogen produce fine ammonium sulfate and ammonium nitrate particulate matter. These reactions, especially those leading to ammonium nitrate, represent a significant percentage of wintertime $PM_{2.5}$ in the San Joaquin Valley (SJV). Thus, ammonia plays a major role in determining secondary aerosol concentrations within the CRPAQS domain. Figure 1-1 displays the San Joaquin Valley study area.

As part of the overall study, grid-based aerosol models are to be applied to simulate particulate matter concentrations in the SJV and to investigate the sensitivity of secondary particulate matter formation to various parameters. A first step in the successful application of air quality models to investigate proposed control strategies is the demonstration of acceptable model performance through comparison of modeled estimates and field study observation data. A key requirement for the credible application of air quality models are accurate input data specifying three dimensional meteorology and ground-level emission rate estimates. Ideally these inputs are to be developed with adequate spatial and temporal resolution in order to accurately represent the complex chemical and transport processes occurring in the atmosphere which contribute to the formation of particulate matter pollution.

Thus, a state-of-the-science ammonia emission inventory for the San Joaquin Valley study area was developed as part of this project. Accurate emission inventories based on the best available ammonia emissions information and processing methodologies will be critical in supporting numerous aspects of the CRPAQS activities over the coming years including ambient data analysis and photochemical modeling.

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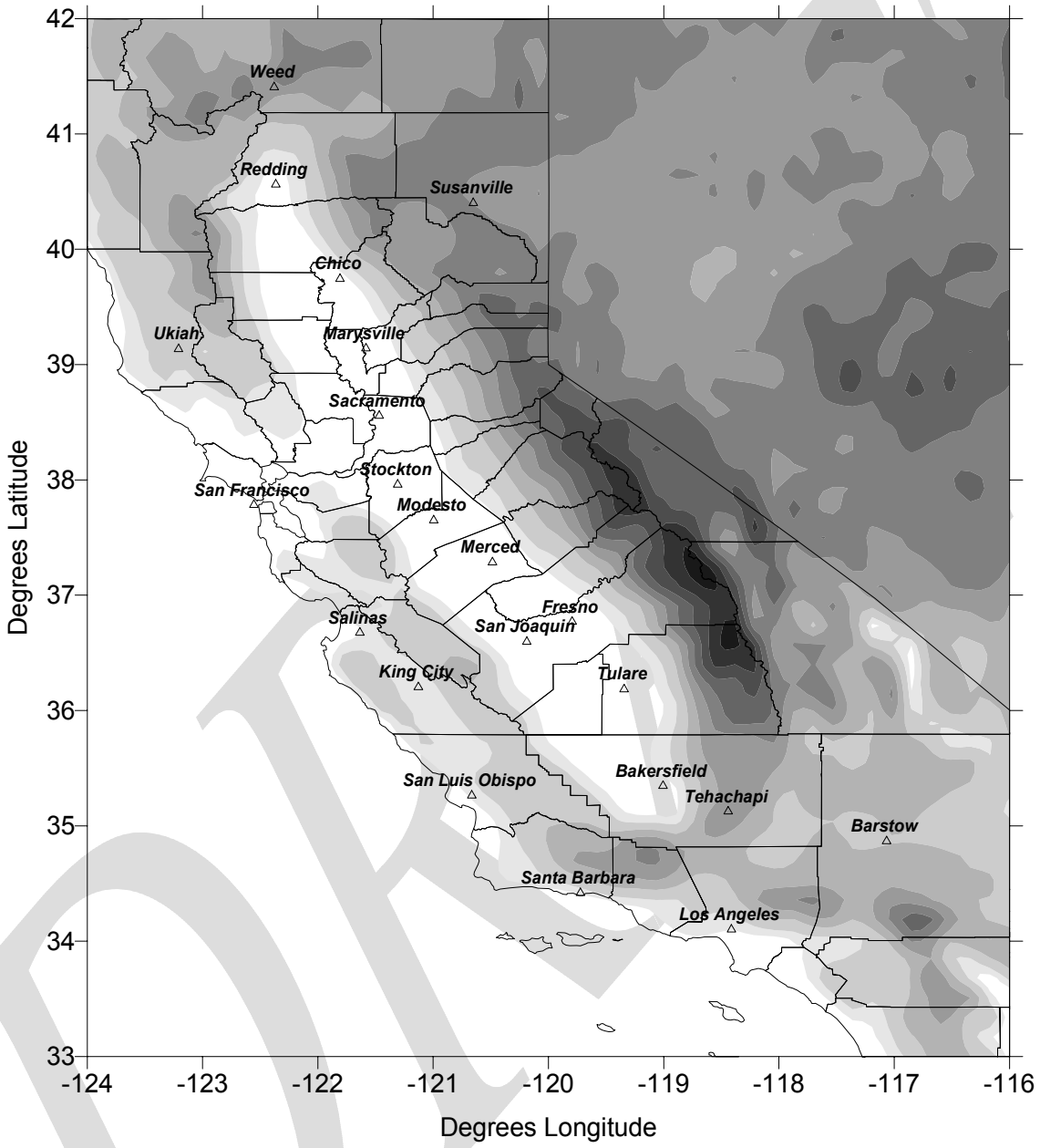

Figure 1-1. San Joaquin Valley Study Area.

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Project Goals and Objectives

The primary goal of the project is to develop a draft, ground-level, gridded ammonia emission inventory for use in data analysis and grid-based aerosol modeling for the CRPAQS. The study will take place within California's San Joaquin Valley (SJV) and the draft inventory is to be used to assess the sensitivity of aerosol model estimates to changes in such variables as spatial and temporal resolution, and emissions magnitudes for various source categories of ammonia emissions. The ammonia inventory is to be developed at a spatial resolution of 1-km by 1-km with a temporal resolution of 1-hour using the best available emission source data and processing methodologies. The geographic extent of the gridded inventory will cover the SJV study area, although where feasible, data will be collected for the entire state of California. In addition, a stated objective of the project is to develop a standard input data library and processing procedures in order to facilitate future in-house refinements or revisions to the inventory in a programmatic way.

A secondary goal of the study is the development of an ammonia capable GIS-based emission modeling system. Since for many ammonia emission source categories, emission estimates are intimately linked to land cover/land use (LULC) characteristics, an emissions model which combines the GIS data on LULC distributions with LULC specific emission factors to calculate gridded emissions in a single processing step would be ideal. In addition, the increased efficiency with which the inventory are generated within the GIS-based emission model will facilitate future updates and revisions with a minimal of processing effort.

Report Organization

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1.0 APPROACH FOR DEVELOPING LIVESTOCK EMISSION ESTIMATES

1.1 Cattle

Most of the discussion for cattle is focused on the methods used to estimate the number of cattle in California in the year 2000 and the methods used to spatially allocate these populations in the CRPAQS domain. Cattle data are generally reported as of January 1 of each year. For this analysis, January 1, 2000 data were used to represent the number of cattle in California in the year 2000. The California Agricultural Statistical Service of the U.S. Department of Agriculture (CASS) reports the total number of cattle in California for January 1, 2000 at 5.1 million (CASS, 2001a). However, the total number of beef cattle and the total number of dairy cattle are not available. Separate dairy and beef cattle estimates are only available for cows and heifers that are intended for the breeding herd (Anderson, 2001). The following paragraphs describe the methods used to estimate the number of beef cattle and dairy cattle in California.

1.1.1 Activity Data for Beef Cattle [Range (Grazing) Cattle and Confined Operations]

CARB developed Statewide Air Basin/County-level 1996 estimates of the number of beef cattle in each of four categories: (1) beef cows that have calved; (2) beef calves; (3) stocker inshipments; and (4) feedlot cattle (ARB, 1999). We computed year 2000 beef cattle estimates generally using ARB=s methods. As described in the work plan, it is important to distinguish confined operations from range operations due to the much higher emission rates per head for confined operations.

Range Cattle: Beef Cows that have Calved

The number of California beef cows that have calved is available for January 1, 2001 from a recently reinstated U.S. Department of Agriculture publication (USDA, 2001a). These county-level data are not available for January 1, 2000, therefore we used the 2001 data. On January 1, 2001, there were a total of 780,000 beef cows that had calved in California. Based on data from the National Agricultural Statistics Service (NASS), there were a total of 790,000 beef cows that had calved in California as of January 1, 2000 (NASS, 2001a). The 790,000 estimate was used to represent the number of beef cows that have calved in California in 2000. To estimate the county distribution of these cows, the team utilized the January 1, 2001 county-level distribution. It is assumed that these animals are all range cattle.

Beef Calves

NASS reports the total number of calves under 500 pounds (lbs) in California in January 1, 2000 (1,050,000 head). Information on the split between beef calves and dairy calves is not available. The ARB estimated the number of beef calves based on the proportions of beef and dairy cows that had calved. Based on the 790,000 beef cows that calved and the 1,490,000 dairy cows that calved as reported for January 1, 2000, approximately 35 percent of total calves were assumed to be beef calves. Multiplying this factor by the 1,050,000 total calves, yields an estimated 367,500 beef calves in California in 2000. Based on information from the California Cattlemen=s Association, the ARB assumed that all beef calves are range fed. The team allocated range beef calves to counties based on the distribution of beef cows that have calved (see above). Therefore, calves are assumed to be located in areas in the same proportion as the

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adult beef cows that have calved.

Stocker Inshipments

Stocker inshipments are cattle brought in from out-of-state to graze on California grasslands. These animals are a distinct population from the cows that have calved in California. The ARB assumed that all stocker inshipments are beef cattle and are present in California for only about 7 months (from November through May) based on information from the California Cattlemen's Association. This was verified through discussions with an expert at CASS (Hoyt, 2001). NASS reports that there were 750,000 inshipments in California in year 2000 (NASS, 2001b). Data are not available on the number of beef cattle inshipments on January 1, 2000.

ARB (1999) estimated the average annual number of inshipments by multiplying total annual inshipments by a factor of 0.58 (i.e., the ratio of 7 months to 12 months). We adjusted the range cattle emission factor by 0.58 instead of the activity data to reflect the amount of ammonia produced by these animals over a calendar year. In addition, discussions with CASS provided additional information regarding the placement of these animals within the state (Hoyt, 2001). By and large, these animals are located in foothill rangelands. CASS provided information on the counties where these animals are not likely to be present (e.g. largely urban counties, high altitude counties that don't have much winter season rangeland). We then allocated the stocker inshipments to the remaining counties based on the number of range cattle.

By combining the estimated number of beef cows that have calved with the number of beef calves, and stocker inshipments, the total number of beef range cattle in 2000 is estimated. These estimates are displayed in Table 1 below and compared to ARB=s estimates for 1996. We anticipate that a small number of beef bulls and heifers (on the order of 50,000 head) are also included in the 2000 population estimates in this table.

Table 1. Comparison of 2000 and 1996 Beef Range Cattle Population Estimates.

CATEGORY	2000 Head	1996 Head (ARB, 1999)
Beef Cows that have Calved	790,000	840,011
Beef Calves	367,500	380,005
Stocker Inshipments	750,000	491,310
TOTAL BEEF RANGE CATTLE	1,907,500	1,711,326

Confined Operations: Feedlot Feeder Cattle

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There were 415,000 cattle on feed in California as of January 1, 2000 (NASS, 2000). The ARB allocated the State number of beef cattle in feedlots based on data representing the distribution of beef cows that have calved (see above). It should be noted that the data for cattle on feed represent operations with >1,000 head. Hence, there could be some smaller operations that do not report their populations. CASS indicated that the number of these operations is probably very small (Hoyt, 2001). Further, CASS indicated that feedlot operations are concentrated in only a small number of counties with Imperial County the largest by far (in terms of total feedlot population).

Pechan received information from California State Water Resources Control Board's (SWRCB's) Region 7 office on the locations (addresses) and permitted head counts for 27 feedlots in Imperial County (Snyder, 2001). These feedlots total 346,300 permitted head in 2001. Due to the rapid growth occurring in these operations in Imperial County, this value was back-casted to 2000 using NASS data resulting in a 2000 feedlot population of 310,000. This amount was subtracted from the 415,000 state-level total to yield 105,000 head in the remaining counties with feedlot activity. This remainder was then allocated to the other feedlot counties based on the number of beef cows that had calved.

A county-level summary of the beef cattle populations for the year 2000 is provided in Table 2.

Table 2. Year 2000 County-level Beef Cattle Populations (head).

County	Cows That Calved	Range Calves	Stockers Inshipment	Feedlot Cattle	Beef Cattle Total
Alameda	12154	5654	14151	0	31959
Alpine	2026	942	0	0	2968
Amador	14179	6596	16509	0	37285
Butte	8609	4005	10024	0	22637
Calaveras	14179	6596	16509	0	37285
Colusa	6583	3063	7665	0	17311
Contra Costa	7090	3298	8255	0	18643
Del Norte	1519	707	1769	0	3995
El Dorado	4558	2120	5307	0	11984
Fresno	20256	9423	23585	10345	63609
Glenn	19244	8952	22406	0	50601
Humboldt	21269	9894	24764	0	55928
Imperial	1519	707	1769	310000	313995
Inyo	9622	4476	0	0	14098
Kern	43551	20260	50708	22241	136760
Kings	3038	1413	3538	0	7990
Lake	3545	1649	4127	0	9321
Lassen	26333	12250	0	0	38583
Los Angeles	6077	2827	0	0	8904
Madera	16205	7538	18868	0	42612
Marin	8609	4005	10024	0	22637
Mariposa	9622	4476	11203	0	25301

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Mendocino	12660	5889	14741	0	33290
Merced	31397	14606	36557	0	82560
Modoc	42538	19788	0	0	62327
Mono	3545	1649	0	0	5194
Monterey	33423	15548	38915	0	87886
Napa	4051	1885	4717	0	10653
Nevada	5064	2356	5896	0	13316
Orange	1519	707	0	0	2226
Placer	10128	4712	11792	0	26632
Plumas	7090	3298	0	0	10388
Riverside	5571	2591	6486	0	14648
Sacramento	15192	7067	17689	0	39948
San Benito	18737	8716	21816	0	49270
San Bernardino	3545	1649	4127	0	9321
San Diego	6583	3063	0	0	9646
San Francisco	0	0	0	0	0
San Joaquin	20256	9423	23585	10345	63609
San Luis Obispo	41526	19317	48349	21207	130399
San Mateo	2026	942	2358	0	5326
Santa Barbara	26333	12250	30660	0	69244
Santa Clara	9622	4476	11203	0	25301
Santa Cruz	2026	942	2358	0	5326
Shasta	24308	11308	28302	0	63917
Sierra	3038	1413	0	0	4452
Siskiyou	34436	16019	0	0	50455
Solano	7596	3534	8844	0	19974
Sonoma	15192	7067	17689	0	39948
Stanislaus	46590	21673	54245	23793	146301
Sutter	3038	1413	3538	0	7990
Tehama	33423	15548	38915	0	87886
Trinity	3038	1413	0	0	4452
Tulare	33423	15548	38915	17069	104955
Tuolumne	5064	2356	5896	0	13316
Ventura	4558	2120	5307	0	11984
Yolo	6583	3063	7665	0	17311
Yuba	7090	3298	8255	0	18643
Totals	**790,000**	**367,500**	**750,000**	**415,000**	**2,322,500**

1.1.2 Activity Data for Dairy Cattle

This section provides a description of the methodologies used for estimating the number of dairy cattle in each county. Dairy operations are all considered to be confined operations, and emission factors for estimating emissions are provided in Section 1.1.3.

Dairy Cows

The number of California dairy cows that have calved in each county is available for January 1, 2001 from a recently reinstated U.S. Department of Agriculture publication (USDA,

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2001a). County-level data are not available for January 1, 2000. On January 1, 2001, there were a total of 1,560,000 dairy cows that had calved in California. Based on data from NASS for January 1, 2000, there were a total of 1,490,000 dairy cows that had calved in California (NASS, 2001).

The January 1, 2001 dairy cow distribution was applied to the January 1, 2000 dairy cow total to estimate the number of dairy cows that had calved in each California county on January 1, 2000. To avoid disclosure of individual operations, 15,500 dairy cows are reported in January 1, 2001 as an "Other Counties" total. These "Other Counties" dairy cows were distributed to counties before allocating January 1, 2000 dairy cows to California counties. The "Other Counties" dairy cows were distributed to all counties for which no dairy cows were reported on January 1, 2001, but for which dairy cows were estimated in ARB's 1996 inventory. The 15,500 dairy cows were allocated to these 15 counties based on the year 1996 number of these cows as reported by ARB (ARB, 1999).

Dairy Calves

Data are not available on the number of calves that are associated with dairy operations. The ARB estimated the number of dairy calves based on the proportions of beef and dairy cows that had calved (ARB, 1999). Based on the 790,000 beef cows that calved and the 1,490,000 dairy cows that calved as reported for January 1, 2000, approximately 65 percent of total calves are assumed to be dairy calves. Multiplying this factor by the total number of calves living in California as of January 1, 2000 (1,050,000), yields an estimated 682,500 dairy calves in California on that date. Dairy calves were apportioned to counties based on the number of dairy cows that had calved in each county. This assumes that calves are located in counties in the same proportion as the adult dairy cows that have calved.

Dairy Heifers

Dairy heifers are dairy cows that have not yet calved. NASS reported the January 1, 2000 number of milk cow heifers of 500 pounds or more (720,000) and "other" heifers (175,000; NASS, 2001a). Based on the January 1, 2000 percentage of beef + milk heifers that are milk heifers (720,000/865,000 = 83 percent), an estimated 145,250 "other" heifers were assigned to the milk cow heifer inventory. Then, the total State number of milk cow heifers (865,250 = 720,000 + 145,250) was apportioned to counties based on the number of milk cows that have calved. For the remaining 29,750 head of "other" heifers, these are presumably part of the beef cattle population. We could not determine if they were part of the range calves, feedlot feeder, or some additional unaccounted for population. For the 2000 CRPAQS inventory, these were left out.

Dairy Bulls

Dairy operations also raise male animals, called dairy bulls (steers are assumed to be incorporated in the beef calves and feedlot feeder populations). There were a total of 70,000

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bulls of 500 pounds or more in California on January 1, 2000 (NASS, 2001a). To estimate the proportion of these bulls that are associated with dairy operations, we calculated the proportion of dairy cows that have calved to all cows that calved (1,560,000/2,340,000 = 0.67) and multiplied this value by the total number of bulls. The resulting estimate (46,900) was used to represent the number of California dairy bulls of 500 pounds or more. These animals were allocated to counties based on the distribution of milk cows that have calved. Similar to the dairy heifer approach above, the remaining 23,100 bulls are presumed to be beef bulls that have been accounted for within the beef cattle statistics above.

A summary of year 2000 county-level dairy cattle populations is provided in Table 3 below.

Table 3. Year 2000 County-level Dairy Cattle Populations (head).

County	Dairy Cows	Milk Calves	Milk Heifers	Dairy Bulls	Dairy Cattle Total
Alameda	0	0	0	0	0
Alpine	0	0	0	0	0
Amador	0	0	0	0	0
Butte	955	438	555	30	1977
Calaveras	0	0	0	0	0
Colusa	155	71	90	5	321
Contra Costa	2865	1313	1664	90	5932
Del Norte	3214	1472	1866	101	6653
El Dorado	0	0	0	0	0
Fresno	85006	38938	49364	2676	175983
Glenn	15760	7219	9152	496	32626
Humboldt	15760	7219	9152	496	32626
Imperial	1820	834	1057	57	3768
Inyo	0	0	0	0	0
Kern	59218	27125	34388	1864	122595
Kings	124167	56875	72104	3908	257054
Lake	0	0	0	0	0
Lassen	0	0	0	0	0
Los Angeles	1609	737	934	51	3331
Madera	36295	16625	21077	1142	75139
Marin	11462	5250	6656	361	23728
Mariposa	0	0	0	0	0
Mendocino	1665	763	967	52	3447
Merced	191026	87500	110929	6013	395468
Modoc	0	0	0	0	0
Mono	0	0	0	0	0
Monterey	2865	1313	1664	90	5932
Napa	354	162	206	11	733
Nevada	0	0	0	0	0
Orange	0	0	0	0	0
Placer	575	263	334	18	1190
Plumas	0	0	0	0	0
Riverside	115571	52938	67112	3638	239258
Sacramento	17192	7875	9984	541	35592

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San Benito	1166	534	677	37	2413
San Bernardino	163327	74813	94845	5141	338125
San Diego	7641	3500	4437	241	15819
San Francisco	0	0	0	0	0
San Joaquin	91692	42000	53246	2886	189825
San Luis Obispo	377	173	219	12	781
San Mateo	0	0	0	0	0
Santa Barbara	2865	1313	1664	90	5932
Santa Clara	1368	627	794	43	2832
Santa Cruz	263	120	153	8	544
Shasta	137	63	80	4	285
Sierra	0	0	0	0	0
Siskiyou	992	454	576	31	2054
Solano	1433	656	832	45	2966
Sonoma	30564	14000	17749	962	63275
Stanislaus	149955	68688	87080	4720	310442
Sutter	537	246	312	17	1111
Tehama	4776	2188	2773	150	9887
Trinity	0	0	0	0	0
Tulare	341936	156625	198564	10763	707888
Tuolumne	0	0	0	0	0
Ventura	0	0	0	0	0
Yolo	573	262	333	18	1186
Yuba	2865	1313	1664	90	5932
Totals	1,490,000	682,500	865,250	46,900	3,084,650

As noted earlier, CASS reports the total number of cattle in California for January 1, 2000 at 5,100,000. It was necessary to estimate the number of beef cattle and dairy cattle because these data are not available. Based on our beef cattle (2,007,500) and dairy cattle (3,084,650) estimates, a total of 5,092,150 cattle were located in California on that date. Hence, our cattle estimates are consistent with the total number of cattle reported by the CASS.

Results of Survey Efforts to Better Spatially and Temporally Allocate Livestock Emissions

As previously mentioned, ammonia emission rates for confined cattle are about an order of magnitude higher than those for range cattle (see Section 1.1.3). In addition to characterizing the confined versus range populations, it is important to determine where confined operations occur at the sub-county level. We surveyed state and county agencies with oversight of the San Joaquin Valley counties and Imperial County on information that we could use to geo-code CAOs, so that they could be modeled as point sources. A survey of the entire CRPAQS domain was beyond the scope of this project. Additional information on spatial allocation of emissions can be found in Section x.x of this report.

We received physical addresses and the permitted number of head for 27 feedlots in Imperial County from the State Water Resources Control Board (Snyder, 2001). Since many these feedlots are very large (10,000 – 50,000 head), not only was much better sub-county

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allocation of activity achieved, but the overall state-wide allocation of feedlot cattle was affected (due to the 310,000 total permitted head in Imperial County; see Table 2).

We were also successful in obtaining information from county agencies for CAOs in the five southern SJV counties (i.e. Kern in the south to Fresno in the north). Some of this information is now being gathered by counties in order to comply with the California Environmental Quality Act when local ordinances on land use are being changed. The remaining SJV counties will probably have similar information pulled together within the next few years.

Typically, the information is available as electronic or hard copy listings of CAO street addresses (facility address, not mailing address) and sometimes the animal population. In some cases, additional follow-up was needed with local experts to estimate the facility-level populations. The physical addresses were then geo-coded to latitude and longitude coordinates. A summary of the information collected is provided in Table 4.

Table 4. Results of the Survey of SJV County CAOs.

County	Information Collected	Agency	Comments
Imperial	Physical locations and permitted head (310,000 head) for 27 feedlots.	SWRCB	Data are for permitted head in 2001 not actual head counts in 2000; the populations were back-casted to 2000 using NASS data.
Kern	Physical locations and populations for 39 dairies (65,154 head).	Kern County Planning Dept.	12 more dairies are in the planning process.
Kings	Physical locations and populations for: 87 dairies and calf replacement operations (208,746 head); 2 goat operations (500 head); 4 horse operations (225 head); 2 hog operations (580 head); 1 turkey operation (5,000 head); 1 broiler chicken operation (278,750 head).	Kings County Environmental Health Dept.	No information on cattle feedlots.
Tulare	Physical locations and populations for: 128 beef feedlots (96,631 head); 302 dairies (326,158 head); 33 horse operations (1650 head); 13 hog operations (1690 head); 32 broiler chicken operations (783,488 head); 1 goat operation (340 head).	Tulare County Resource Management Agency	*Feedlots*: where head counts were not available, an estimate was used: median of small (<500 head) feedlots (216 head); mean of large (>500 head) feedlots (1358); or 1000 head for feedlots where no small or large size was indicated (median of all known feedlot sizes); *Horses*: no facility-level population data; 50 head per facility is assumed based on

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			EPA, 1999: (EPA-821-R-99-002), which documents large horse operations as having more than 20 head; *Hogs*: no activity data available; activity estimate is the median value of farm size for SJV counties from USDA Census of Agriculture *Broiler chickens:* Tulare County RMA indicates that these are poultry operations. Not known how many are broiler versus layer versus turkey farms. It is assumed that these are all broiler operations. Activity estimate is the average of the county per farm averages (USDA) for CA; *Goats:* Activity estimate is an average of the number of head/facility from Fresno and Kings Counties.
Madera	Physical locations for: 54 dairies (86,678 head).	Madera County Planning Department	No herd-level population data; activity value for each site is the median of Tulare County Dairies.
Fresno	Physical locations and populations for: 100 dairies (84,950 head); 3 goat operations (1,200 head);	Fresno County Environmental Health Department	*Dairies:* activity value for each site is based on an estimate by Fresno County EHD of whether the dairy is small (300 head) or large (1750 head). For dairies where no estimate of size was available an average value of 700 was assigned.

The information described in Table 4 was incorporated into the point source input files prepared for this project. Animal populations that were left over (e.g. from county-level USDA totals) served as the activity data for the area source input files.

We also gathered information on manure spreading activity from local experts in order to better temporally and spatially allocate emissions). An experts in the SJV indicated that approximately 60% of dairy manure is handled (and subsequently spread) as solid waste, while the remainder was handled as a liquid (Schultz, 2001). Further, dry manure spreading occurs in the late spring (April – May) and fall (October – November) and is applied to orchards, vineyards, and silage (e.g. hay, alfalfa). Liquid manure spreading can occur over nine months of the year, except during the rainy months of December through February. Typically, it is applied to dual crop winter/summer silage (winter hay/alfalfa and summer corn silage).

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In Imperial County, dry manure spreading from feedlots can occur over 10 months of the year (except November and December; Mayberry, 2002). Most of the activity occurs during the March – May time frame. Information on the types of crops to which it is applied was not available. We assumed that all manure from feedlots is handled in a dry form. While we feel that this new temporal and spatial allocation information is far superior to the existing information (e.g. a flat distribution across the calendar year), additional research should be performed in the future to better refine the information.

We reviewed available test results and surveyed local agricultural experts to improve the temporal allocation of CAO emissions (both diurnal and seasonal). Unfortunately, we could not identify test data for dairies and feedlots of sufficient robustness to develop an algorithm for temporally allocating emissions using important environmental parameters (e.g., ambient temperature, relative humidity). Therefore, monthly temporal allocation factors were assigned to feedlots and dairies based on the seasonal differences found by Schmidt et al (1996) during their tests of southern California dairies (emissions during the winter months are approximately half of that during the months of other seasons). Diurnal temporal allocation for dairies and feedlots was assigned based on the dairy and feedlot testing of Flocchini et al (2001). This temporal allocation was also assigned to hog and pig operations. This testing showed an order of magnitude higher emission rate during the daytime hours (227 lb/hd-yr) compared to night-time hours (24 lb/hd-yr). Monthly allocation factors for hog and pig operations were assigned based on test data from Aneja et al (2000). These data showed much higher emissions during the summer than the winter months and more moderate emission rates during the fall and spring. No temporal allocation factors were assigned to other livestock operations due to a lack of information.

Figure 1 below shows the locations of dairies in the southern SJV counties from the survey data described above.

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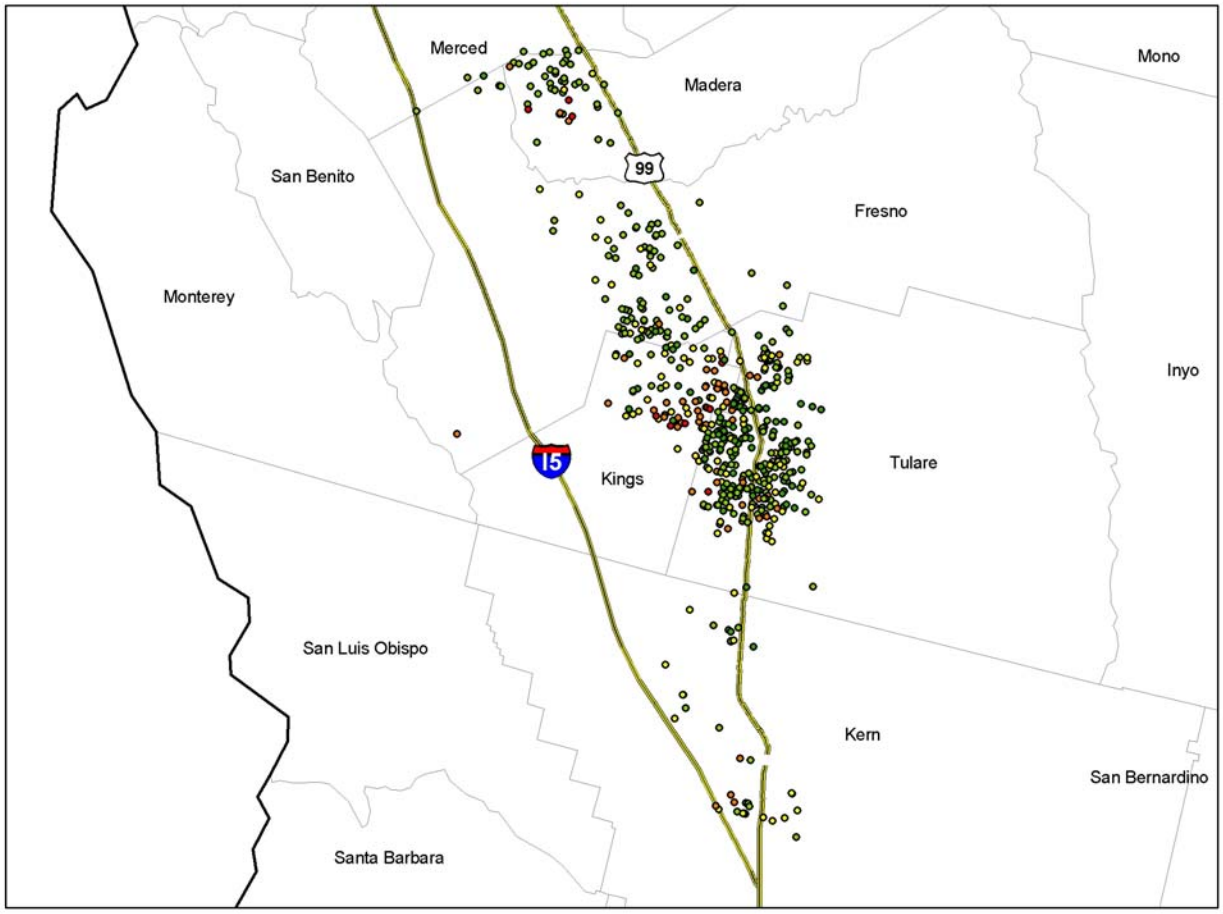

Figure 1. Southern SJV Dairy Locations.

1.2 Activity Data for Other Livestock Categories

This section provides a discussion of the methods used in estimating the number of non-cattle livestock in California in the year 2000. The December 31 county-level inventory of livestock is reported every five years in the USDA=s *Census of Agriculture* (USDA, 2001b). The latest available county-level livestock data represent the animal inventory as of December 31, 1997. For the following livestock categories, state-level inventory data were available for both 1997 and 2000:

- Hogs and pigs;
- Sheep and lambs;
- Layer and pullet chickens; and
- Turkeys.

To estimate the year 2000 county inventory for these categories, we multiplied the 1997 county-

level inventory values by the ratio of the state inventory for year 2000 to the state inventory for year 1997. In addition, 1997 and 2000 broiler chicken production data are reported by the USDA as a combined total for seven states, including California. Because California accounted for 48 percent of the broilers from these states in 1997, the 2000 broiler inventory was estimated by applying the ratio of 2000 broiler production to 1997 broiler production for this set of states to the California county-level 1997 *Census of Agriculture* broiler inventory data. For the remaining livestock categories (i.e., horses and ponies; mules, burros, and donkeys; rabbits; and goats), data were not available to estimate 2000 inventory values. Therefore, the 1997 values are used to represent the year 2000 inventory.

On-farm horses and ponies is the only livestock category for which the *Census of Agriculture* does not withhold any county inventory data from publication due to confidentiality concerns. For all other categories, it was necessary to estimate the inventory of livestock in counties with withheld data. There were two methods used to estimate the number of livestock in these counties: *Method 1*, which is based on the county distribution for year 1992 as computed from 1992 *Census of Agriculture* inventory data (USDA, 2001c), and *Method 2*, which is based on the state-level number of farms and the estimated number of animals per farm. Method 2 was only used for counties for which data were not available for implementing Method 1.

Method 1 was implemented by first identifying the counties that did not report inventory data in 1992 and/or 1997. Next, the 1992 or 1997 inventory values that were available from these counties were added to the withheld inventory total for the applicable year as reported by the Census of Agriculture. The resulting values (hereafter referred to as Aadjusted@ withheld totals), represent the total number of animals in 1992 and the total number of animals in 1997 for the same list of counties. Next, each county inventory=s percentage of the Aadjusted@ withheld total inventory for 1992 was computed and these percentages were then applied to the 1997 Aadjusted@ withheld total inventory for 1997. The products of these computations yield the inventory estimates for 1997.

For counties for which inventory values are not reported for both 1997 and 1992, it was necessary to implement Method 2 to estimate livestock inventories. This method is based on 1997 *Census of Agriculture* data on the number of farms for a given livestock category and calculations of the number of animals per farm. These data were specifically compiled for counties that: (1) do not have 1997 inventory values reported in the *Census of Agriculture;* or (2) counties whose inventory values could not be estimated using Method 1.

The Method 2 estimation procedure begins by summing the number of farms for a given livestock category as reported in the 1997 *Census of Agriculture* for: (1) all counties reporting an inventory value for 1997; and (2) all counties for which the 1997 inventory was estimated using Method 1. For each livestock category, these sums were then subtracted from the California total number of farms for that category to yield the number of farms for counties for which inventory values remained to be estimated. The results of these calculations for each category were then divided into the number of livestock that remained to be distributed for that

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category. These calculations yield the estimated number of livestock per farm for counties that do not have 1997 inventory values reported in the *Census of Agriculture* or could not be estimated using Method 1. The final step for each category was to multiply this livestock per farm value by the 1997 number of farms for each respective county as reported in the 1997 *Census of Agriculture*.

Table 5 presents sample data and calculations used in estimating withheld data for hogs and pigs. The following subsections describe the specific data and methods used to estimate the number of non-cattle livestock in California for the year 2000.

1.2.1 Hogs and Pigs

The *1997 Census of Agriculture* publishes a December 31,1997 inventory of hogs and pigs by county. There is a small percentage of total CA hogs and pigs (4.6 percent) that are withheld from publication at the county-level. The 1997 inventory of these hogs and pigs was compiled using estimation methods 1 and 2 as described above. From the California Department of Food and Agriculture (CDFA)=s *Resource Directory 2000*, which reports data for 1997-1999 and NASS=s *Agricultural Statistics 2001,* which reports data for 1999 and 2000, state-level hog and pig inventories are available for both 1997 (210 thousand) and 2000 (150 thousand) (CDFA, 2001 and NASS, 2001a; note that these two sources report the same inventory value for year 1999). To estimate the number of hogs and pigs in year 2000, we applied the 2000/1997 ratio (150/201=.714) to the actual/estimated county-level year 1997 inventory values.

1.2.2 Horses and Ponies

The 1997 Census of Agriculture publishes the inventory of on-farm horses and ponies for each county in California. To estimate the number of non-farm horses and ponies, we used information reported by the American Horse Council Foundation (AHCF) that 70 percent of California horses were involved in showing/recreation (AHCF, 2001). Based on this estimate,

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Table 5. Sample Population Estimation Calculations for Hogs and Pigs

Geographic Area	1997 Inventory	1992 Inventory	Estimation Method 1		Estimation Method 2	
			1992 Inventory Ratio	Estimated 1997 Inventory	1997 Number of Farms	Estimated 1997 Inventory^
Butte	6,845	withheld				
Del Norte	withheld	withheld			2	2,005
Glenn	1,717	withheld				
Inyo	12	withheld				
Kings	withheld	9,701	0.26019	4,865		
Marin	withheld	149	0.00400	75		
Mariposa	withheld	27	0.00072	14		
Mono	withheld	withheld			2	2,005
Orange	withheld	266	0.00713	133		
Sierra	withheld	0	0.00000	0		
Sutter	269	withheld				
Ventura	withheld	1,512	0.04055	758		
California (includes additional counties not shown)	212,088	258,130				
California Withheld	9,854	25,629				
California AAdjusted@ Withheld	18,697*	37,284**				
California Withheld After Estimation Method 1				4,009	4	

Notes: Counties in boldface type are included because their 1997 inventory values are required to develop an adjusted withheld total for 1997 that includes all counties whose 1992 inventory values were withheld.

* - Calculated as California Withheld (9,854) + Butte (6,845) + Glenn (1,717) + Inyo (12) + Sutter (269).

** - Calculated as California Withheld (25,629) + Kings (9,701) + Marin (149) + Mariposa (27) + Orange (266) + Sierra (0) + Ventura (1,512).

^ - Calculated by multiplying the 1997 number of hogs and pigs farms by the 1997 number of hogs and pigs per farm (4,009/4 = 1,002.25) for the remaining counties with withheld data after applying estimation method 1.

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we computed the total number of horses and ponies in California as the number of on-farm horses and ponies (113,110) divided by 0.3. To calculate the estimated number of non-farm horses (263,923), we subtracted the estimated on-farm horses and ponies (113,110) from the total number of horses and ponies (377,033). The estimated number of non-farm horses and ponies in California was then allocated to counties based on the proportion of total state rural housing units in each county (Census, 2001). Finally, we computed the total number of horses and ponies in each county as the sum of the number of on-farm horses and ponies and the estimated number of non-farm horses and ponies. Because no more recent information was available, we used the 1997 inventory values to represent the inventory in year 2000.

1.2.3 Mules, Burros, and Donkeys

In the *1997 Census of Agriculture,* the USDA published the December 31, 1997 county-level inventory of on-farm mules, burros, and donkeys in California. The Census reports four California counties, representing a total of 27 mules, burros, and donkeys, as having withheld inventory data in 1997. Because data for these four counties were also withheld for year 1992, and because data were not available on the number of farms with mules, burros, and donkeys for these four counties, we allocated the remaining 27 mules, burros, and donkeys to these counties based on the county distribution of on-farm horses and ponies. In lieu of data for year 2000, we used the 1997 inventory data to represent the number of mules, burros, and donkeys in California in 2000.

1.2.4 Sheep and Lambs

The *1997 Census of Agriculture* presents the inventory of sheep and lambs by county for 1997. The Census data indicate that approximately 15,000 out of a state total of 785,000 sheep and lambs are not reported at the county-level due to confidentiality concerns. The 1997 inventory of these sheep and lambs was developed using estimation methods 1 and 2, as described above. The CDFA=s *Resource Directory 2000* reports the number of sheep and lambs in the state as of January 1 for 1997-2000 (CDFA, 2001). We applied the 2000/1997 state inventory ratio from the *Resource Directory* (800/880 = .909) to the 1997 Census county-level data to estimate the number of sheep and lambs in 2000.

1.2.5 Rabbits

The *1997 Census of Agriculture* reports the inventory of rabbits and their pelts by county for 1997. The Census data indicate that approximately 53,000 rabbits are not reported at the county-level out of a total of approximately 95,000 rabbits in the state. The 1997 county-level inventory of these rabbits was estimated using estimation methods 1 and 2 as described above. Because no more recent information was available, we used the 1997 inventory values to represent the inventory in year 2000.

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1.2.6 Goats

The *1997 Census of Agriculture* publishes a December 31 1997 inventory of goats by county. The Census data indicate that approximately 2,700 goats are not reported at the county-level out of a total of approximately 40,000 goats in the state. The 1997 county-level inventory of these goats was developed using estimation methods 1 and 2 as described above. Because the Census does not report the number of goat farms for the counties with withheld data, we used the number of sheep and goat farms as reported in the *1997 Census of Agriculture* in applying estimation method 2 (USDA, 2001b). In lieu of data for year 2000, we used the year 1997 inventory data to represent the number of goats in California in 2000.

1.2.7 Broiler Chickens

The *1997 Census of Agriculture* presents the county inventory of broilers and other meat-type chickens as of December 31, 1997 (USDA, 2001b). The Census data indicate that approximately 19 million broiler and other meat-type chickens are not reported at the county-level out of a total of approximately 35 million broiler/meat-type chickens in the state. The 1997 county-level inventory of these chickens was estimated using estimation methods 1 and 2 as described above. To avoid disclosing individual operations, the 1998-2000 annual number of broilers produced are reported in CASS=s *Poultry Reviews* as a total for 7 States, rather than the California production estimates reported before 1998 (CASS, 2001b). The NASS=s *Poultry-Production and Value 1998 Summary* (NASS, 2001c) presents data that can be combined into the 1997 total number of broilers produced for the 7 States reported in *Poultry Reviews*. Based on these data, CA represented about 48 percent of broilers produced by these States in 1997. We used the 1997-2000 growth in number of broilers for these States to estimate the growth in CA broilers over this period (524,330,000/491,160,000 = 1.0675 growth factor for 1997-2000). This growth factor appears reasonable based on the California-specific broiler production growth rate factor between 1994 and 1997 (1.049).

1.2.8 Layer and Pullet Chickens

The *1997 Census of Agriculture* provides county-level 1997 inventory data for (1) layers and pullets 13 weeks old and older, and (2) pullet chicks and pullets less than 13 weeks old. The Census data indicate that approximately 6 million out of a total of approximately 34 million layers and pullets of 13 weeks or older in California, and approximately 750,000 out of a total of approximately 3.5 million pullet chicks and pullets of less than 13 weeks old in California, were withheld from county-level publication. The 1997 county-level inventory of each of these chicken categories was developed using estimation methods 1 and 2 as described above. NASS=s *Layers and Egg Production 1998 Summary* (NASS, 2001d) identifies the total number of layers and pullets in California as of December 1, 1997. The NASS=s *Agricultural Statistics 2001* (NASS, 2001b) presents the number as of Dec. 1, 2000. After summing the number of layers and pullets 13 weeks or older with the number of pullet chicks and pullets less than 13 weeks old, we applied the 2000/1997 ratio (29,422,000/30,360,000 = 0.969) to the 1997 Census

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county-level figures to estimate the county inventory of layers and pullets in the year 2000.

1.2.9 Turkeys

The *1997 Census of Agriculture* reports county-level inventory data on the number of turkeys in California as of December 31, 1997. There is a small percentage of turkeys in California (1.6 percent) that have withheld data at the county-level. The 1997 county-level inventory of these turkeys was estimated using estimation methods 1 and 2 as described above. The CDFA=s *Resource Directory 2000* shows the trend in the state number of turkeys produced between 1997 and 1999 (CDFA, 2001). CASS=s monthly publication, *Poultry Review* (CASS, 2001b), reports the state number of turkeys raised for 1999 and 2000 (the 1999 number in this publication matches the number in the CDFA=s *Resource Directory* publication). To estimate the number of turkeys in year 2000, ENVIRON applied the 2000/1997 turkey production ratio (18,000,000/21,000,000 = 0.857) to the 1997 county inventory figures.

1.3 Emission Factors for Livestock Operations

The emission factors used to estimate livestock emissions are summarized in Table 6 below. References for these emission factors were identified in the Work Plan (see Appendix X). After the Work Plan had been finalized, we noticed that test data were available for feedlot cattle from the same source as the test data for dairy cattle (Flocchini et al, 2001). The Work Plan specified the use of the same emission factor for dairies and feedlots, although the emission factor was based on dairy testing. The emission factor for feedlots is higher than that for dairies (130 lb/head-yr compared to 74 lb/head-year); however we surmised that feedlots may have higher per head emission rates due to the higher nitrogen intake of these animals and differences in manure management. Following discussions with CARB staff, the emission factor for feedlots was selected for use in the CRPAQS 2000 inventory.

Table 6. Emission Factors for Livestock Source Categories.

EIC	Description	EF (lb/unit-yr)	Activity Units
630-618-0262-0002[1]	Cattle - Confined Beef Operations	130.0000	Feedlot Cattle - Head
630-618-0262-0003	Cattle - Range Calves	1.5400	Range Calves - Head
630-618-0262-0009[2]	Cattle - Stocker Inshipments	0.8932	Stocker Inshipments - Head
630-618-0262-0010	Cattle - Range Cows	1.5400	Range Cows - Head
630-618-0262-0004	Cattle - Confined Beef Operations, Dry Manure Spreading	5.6000	Feedlot Cattle - Head
630-618-0262-0001	Cattle – Confined Dairy Operations	74.0000	Total Dairy Cattle - Head
630-618-0262-0005	Cattle - Dairy Calves	11.5300	Dairy Calves - Head

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630-618-0262-0006	Cattle - Dairy Cows	74.0000	Dairy Cows - Head
630-618-0262-0007	Cattle - Dairy Heifers	74.0000	Milk Heifers - Head
630-618-0262-0008	Cattle - Dairy Bulls	74.0000	Dairy Bulls - Head
630-618-0262-0011	Cattle - Dairy Operations, Dry Manure Spreading	5.6000	Total Dairy Cattle - Head
630-618-0262-0012	Cattle - Dairy Operations, Liquid Manure Spreading	5.6000	Total Dairy Cattle - Head
630-618-0264-0001	Poultry- Broiler Chickens	0.3700	Broiler Chickens - Head
630-618-0264-0002	Poultry- Layer and Pullet Chickens	1.0000	Layer and Pullet Chickens - Head
630-618-0264-0003	Poultry- Turkeys	1.8920	Turkeys - Head
630-618-0266-0001	Hogs And Pigs	20.3000	Hogs and Pigs - Head
630-618-0268-0001	Goats	1.2800	Goats - Head
630-618-0270-0001	Rabbits	0.3700	Rabbits - Head
630-618-0272-0001	Sheep and Lambs	7.4300	Sheep and Lambs - Head
630-618-0274-0001A	Mules, Burros, and Donkeys	26.9000	Mules, Burros, and Donkeys - Head
630-618-0276-0001A	Horses and Ponies	26.9000	Horses and Ponies - Head

[1] A change was made to the EF specified in the Work Plan (74.0000 lb/head-yr; same as dairies) based on the availability of test data for feedlots (Gaffney, 2002).
[2] EF is adjusted to account for these animals being in California between November and May.

2.0 Municipal Solid Waste Landfills

As specified in the Work Plan, due to a lack of any U.S. emissions data for landfills, emissions were estimated using the same methods as in the previous inventory (STI, 1998). This involved the use of an ammonia to methane emissions ratio (0.007). Methane emissions were taken from the year 2000 emissions data submitted to CARB by the local districts (Bhargava, 2001). County-level emissions were allocated to specific geo-coordinates of active landfills within each county from the California Integrated Waste Management Board's Solid Waste Information System (SWIS). It should be noted that the year 2000 emissions data received from CARB did not contain any emission estimates for the following counties: Alpine, Nevada, San Francisco, and Sutter.

Discussions with two landfill gas experts revealed no known source of ammonia associated with landfill gas. It is possible that the ammonia measured in support of the European

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emission factor used by STI (1998) was associated with the decomposition of some daily cover material (e.g. green waste, sewage sludge). Still, the emission estimation method has a high level of uncertainty. Temporal allocation of emissions is assumed to be even throughout the year. No information on diurnal allocation of emissions was found.

3.0 Wildfires and Prescribed Burns

Emission estimates were developed using an NH3 to carbon monoxide (CO) emissions ratio approach. Year 2000 county level CO emissions for wildfires and prescribed burns were taken from CEIDARS (Bhargava, 2001). An NH3 to CO emissions ratio of 0.0091 was developed from information in a recent EPA report on wildland fires (EPA, 2002; the "all fuels average" NH3 to CO mole percentage was used). Development of fire-specific information (e.g. spatial coordinates, calendar days of activity) was beyond the scope of this project. We temporally allocated the emission estimates evenly through the months of May through October. No diurnal allocation of emissions was performed.

4.0 Agricultural Burning

A similar method to that used above for wildfires/prescribed burns was used to estimate emissions for agricultural burning. We used the NH3 to CO molar ratio for "overall grasslands and sage" as a surrogate for agricultural burning emissions (EPA, 2002). This led to a mass ratio of 0.0158 (NH3:CO). The monthly allocation submitted by the air quality districts into CEIDARS was retained in the CRPAQS inventory. Where no monthly data were provided, a uniform distribution was assumed. A daily TAF was assigned based on an assumption that activity only occurs during daylight hours. Weekly, the activity is assumed to occur 7 days per week.

5.0 Residential Wood Combustion

Emissions for fireplaces and woodstoves were also estimated using the NH3 to CO ratio approach described above for the previous two categories. County-level CO emissions were taken from the 2000 CEIDARS database. A NH3:CO ratio of 0.0073 was derived from information on "average forest products" combustion in wildfires (EPA, 2002). The monthly TAFs were assigned as supplied by the Districts, except where a uniform distribution was assumed. In these cases, a distribution was assigned that showed no activity from May through September (commonly employed by Districts for most counties). Weekly and daily temporal allocation was assigned based on typical temporal allocation for this source category (CARB, 1991).

As with the other biomass burning categories, ammonia emissions should be considered highly uncertain. This is based not only on the emission ratio approach itself, but also the extrapolation of emission ratios for other sources that were used to construct estimates for agricultural burning and residential wood combustion.

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6.0 On-Road Mobile Sources

Steve—The following is incorrect. The ARB did NOT provide the VMT data in the format they specified (not gridded, in wrong projection) (See e-mail from Vernon Hughes dated 3/2/01 "Conference Call Summary"; and, 5/7/01 TC Comments on Revised 4/13/01 Draft Work Plan-Item #8)– Also the data was not stratified by vehicle type (as specified in 5/7/01 TC Comments)– fleet totals only. I will add discussion of additional effort required to process this source category- The same is true for fertilizers and soils which I will address in later sections.

Emission factors for on-road mobile sources were summarized in a CARB memorandum (Taylor, 2001). The results from the studies reviewed by that date are provided in Table 7 below. The most important selection is for the light-duty, catalyst-equipped vehicles due to the higher emission rates and VMT associated with this vehicle class. We selected the emission factor from the Fraser and Cass (1998) study due to its agreement with the value measured by Sutton et al (2000) for similar vehicles in Europe. Selected emission factors for the other vehicle classes are shown in Table 7 in bold text. Gridded vehicle-miles traveled (VMT) data, developed as part of the Central California Ozone Study (CCOS), were obtained from CARB. *Gerry, please revise as needed and check to assure that the EFs below were the one's used. We need some brief description of the application of the EFs to the CCOS activity data. e.g. what EF's were applied to heavy-duty gas and medium-duty diesel.*

Table 7. Emission Factors for On-Road Mobile Sources.

Vehicle Type[1]	Fuel	Location	NH_3 Emission Factor (mg/mi)	Reference
Light duty, catalyst	Gasoline	US - CA	116	Fraser and Cass, 1998
Light duty, non-catalyst	Gasoline	Europe	2.9 (1.9 to 4.4)	Sutton et al., 2000
Light duty	Diesel	Europe	1.6 (0.5 to 2.7)	Sutton et al., 2000
Heavy duty	Diesel	US - PA	8.4 +/- 2.4	Gertler et al., 2000

1. Light duty: Passenger cars and light trucks to 5750 lb. Gross Vehicle Weight Rating (GVWR); Medium duty: Vehicles between 5751 and 8500 lb. GVWR; Heavy duty: Vehicles 8501 lb. and above GVWR.

7.0 Results and Recommendations for Future Inventory Work

A summary of annual emissions for the 2000 CRPAQS inventory is presented in Table 8 (*Gerry, a summary of seasonal emissions i.e. winter might also be of interest)*. These totals reflect statewide emissions. Total annual emissions for the CRPAQS domain are xx tons per year (tpy). This compares to about 220,000 tpy reported in the previous ammonia inventory (STI, 1998). These differences can be attributed to differences in geographic coverage (statewide versus SARMAP region), updated activity data, addition of source categories (e.g.

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biomass burning categories, manure spreading), and new emission factors. Livestock emissions increased from approximately 106,000 tons to 187,000 tons.

In Table 9, a breakout of livestock emissions is provided that shows the annual tonnage associated with geo-coded ("point") sources versus the remaining area source totals. For dairy and beef cattle, approximately 10,000 tons are from manure spreading. The point and area source totals give a sense of the overall improvements made in the spatial allocation of ammonia emissions. Another big improvement that needs to be made in the future is the geo-coding of large poultry operations, especially in the SJV. These operations are thought to be important sources in the northern portion of the SJV (e.g. Merced County).

Table 8. CRPAQS 2000 Annual Emissions.

Source Sector	Emissions (tons/yr)
Dairy Cattle	106,768
Beef Cattle	39,220
Poultry	32,142
Horses/Ponies	5,046
Municipal Landfills	3,570
Sheep/Lambs	2,648
Residential Wood Combustion	2,579
Hogs/Pigs	1,537
Wildfires/Prescribed Burns	1,421
Agricultural Burning	1,150
Mules/Burros/Donkeys	41
Goats	26
Rabbits	18
Total	

Table 9. Annual Point and Area Source Livestock Emissions

Livestock Sector	Point Source (tons/yr)	Area Source (tons/yr)[1,2]
Dairy Cattle	28,211	78,557
Beef Cattle	26,431	12,789
Poultry	201	31,941
Horses/Ponies	25	5,046
Sheep/Lambs	0	2,648
Hogs/Pigs	23	1,514
Mules/Burros/Donkeys	0	41
Goats	1	24
Rabbits	0	18

[1] Manure spreading emissions included for dairy and beef cattle.
[2] Totals between Tables 8 and 9 may not match due to rounding.

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Groundwork has been established during the construction of this inventory to support highly-resolved (spatially and temporally) ammonia inventories for use in regional air quality modeling. New information is continually being developed that can further enhance the 2000 CRPAQS inventory. For livestock, this information includes emerging activity information on the locations, herd sizes, and operations of CAOs. County agencies should be resurveyed in the future to update the inventory. In addition, new testing programs being conducted in the U.S. and elsewhere can help in refining the underlying data developed during this project (e.g. diurnal and seasonal temporal allocation). Additional ammonia emissions testing programs for CRPAQS should focus on gathering information to better characterize diurnal and seasonal variations in emissions from CAOs and manure spreading.

In addition to gathering information on point locations and populations of large poultry operations mentioned above, additional work should be performed in breaking out the manure spreading portion of the emission estimates into separate source categories as has been done with cattle. The underlying emission factor is based on a composite for stable/manure storage and manure spreading (Battye et al, 1994). The manure spreading portion of the emission factor accounts for nearly two-thirds of the emissions. Hence, with knowledge of the timing and types of crops to which poultry manure is applied, much more refined emission estimates are achieved. Similar work should be carried out for hog manure spreading.

Given the importance of agricultural and natural soil/plant canopy systems and the significant uncertainties associated with existing emissions data; we believe that testing programs aimed at better characterizing these sources/sinks should be a primary objective of future CRPAQS research. Among these systems, agricultural systems (crops, pastures) are probably the most important due to the regular inputs of nitrogen. These sources are probably more important during the growing season (i.e. not during high winter-time SJV episodes); however testing can also assure that emissions are not being inappropriately assigned to seasons when the source is not active.

Composting activity has increased in recent years due to the need to divert wastes from municipal landfills. As shown in this study and the recent SCAQMD inventory, composting activities are important contributors to regional ammonia inventories. Further work is needed in characterizing this category, as well as related source categories. For instance, sludge drying appears to be the most important source of ammonia at POTWs. However, some facilities do not perform this activity and send their sludge to composting operations or municipal landfills. A better understanding of sludge handling at POTWs is therefore needed. Also, another related source category is landfills. While ammonia is not thought to be a significant constituent of landfill gas, emissions may be occurring at sites where sewage sludge or green waste is being used as daily cover or is being composted. Measurements of ammonia at landfills with these operations is recommended.

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8.0 References

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