MANAGING AIR EMISSIONS FROM CONFINED FEEDING OPERATIONS IN ALBERTA

Ammonia and Particulate Matter Emissions Inventory for Confined Feeding Operations in Alberta

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Alberta Agriculture and Rural Development

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Preface

In fulfillment of the recommendations of the Clean Air Strategic Alliance (CASA) Confined Feeding Operation (CFO) strategic plan, a multi-stakeholder advisory group (MAG) comprising of Alberta Agriculture and Rural Development (ARD) staff, Alberta Environment and Water (AEW) staff, a non-government organization (NGO) representative and alternate, and a CFO industry representative and alternate, was formed to provide advice on the development of a new CFO emissions inventory for Alberta. In addition, a technical working group (TWG) comprising of ARD and AENV staff was formed to work on the specifics of the emissions inventory and complete the inventory. The TWG was tasked with the development of a CFO emissions inventory preparation plan for review and deliberation by the MAG.

The preparation plan was written to provide a roadmap towards the development of the new CFO emissions inventory. It described each stage in the course of the development of the new inventory in detail, including where and how to collect the data to develop the inventory and how to report and document findings specific to the inventory. In general, an "Alberta CFO Emissions Inventory Preparation Plan" was developed in accordance with AENV guidelines for the development of air emission inventories. The plan was reviewed and approved by the MAG.

In the next phase of the process, an air emissions inventory methodology was developed. The TWG, in conjunction with a consultant (Levelton Consultants Ltd.), gathered considerable information pertaining to CFO emission factors (EFs), CFO activity factors (AFs), emissions inventory compilation methodologies and procedures for assessing such methodologies. Information was also gathered via consultation with the United Stated Environmental Protection Agency (USEPA) National Air Emissions Monitoring Study (NAEMS), Canadian National Agri-Environmental Standards Initiative (NAESI) and National Agri-Environmental Health Analysis and Reporting Program (NAHARP) project teams.

Subsequently, Levelton Consultants Ltd. used the information gathered to develop an air emissions inventory methodology. The methodology described what sources of information were reviewed with regards to EFs and AFs, how the information was screened, and ultimately what EFs and AFs were selected. It also described a procedure for forecasting future emissions. Finally, a process for preparing and compiling the emissions inventory and showcasing the results of a query was outlined in the methodology.

After a review of the air emissions inventory methodology by the TWG, Environment Canada (EC) staff, Agriculture and Agri-Food Canada (AAFC) staff and a third-party consultant (ECOMatters Inc.), the TWG approved a revised version of the methodology and consented to the development of the new CFO emissions inventory for Alberta by Levelton Consultants Ltd. The newly developed inventory provides information on monthly and annual ammonia (NH_3) and particulate matter (PM) emissions, respectively, from various types of CFOs in each

municipality in Alberta for the base year 2006. It also provides a forecast of emissions in 2011, 2016 and 2021.

This report outlines the methodology used to develop the new CFO emissions inventory. It discusses various aspects of the inventory and provides samples of the output. Furthermore, it includes an interpretation and detailed analysis of the inventory output, and a comparison to estimated emissions from other sources in Alberta.

Executive Summary

In 2008, the Clean Air Strategic Alliance (CASA) Confined Feeding Operation (CFO) strategic plan recommended the development of an air emissions inventory for the CFO industry in Alberta by 2011. Alberta Agriculture and Rural Development (ARD) led the development of the inventory with assistance from Alberta Environment and Water (AEW). A technical working group (TWG) comprising staff from both ministries worked on technical aspects of the inventory. The TWG received input from a multi-stakeholder advisory group that included a CFO industry representative, a non-government organization representative, AEW staff and ARD staff. In addition, the services of Levelton Consultants Ltd. were retained to establish inventory development methodology and to create the inventory.

Scope of the New CFO Emissions Inventory

The new inventory was developed to only estimate emissions of ammonia (NH_3) and particulate matter (PM) from CFOs, and is hereby referred to as the Ammonia and Particulate Matter Emissions Inventory for CFOs in Alberta (APMEICA). Although other emissions-of-interest were also identified in CASA CFO strategic plan, namely, hydrogen sulphide, bioaerosols and pathogens, volatile organic compounds, and odour, CFO-related data for these emissions-of-interest are lacking.

Furthermore, APMEICA estimates emissions from beef cattle, dairy cattle, poultry, swine and sheep CFOs, including sub-categories of the various livestock types within each main livestock category.

Emission Estimation Approach

In simple terms, APMEICA estimates the emissions of NH_3 and PM ($PM_{2.5}$ and PM_{10}) from the various types of CFOs by multiplying their respective emission factors (EFs) by their respective activity factors (AFs). EF is the mass of the substance emitted per unit source of emission per unit of time, e.g., kilograms of NH_3 emitted per head of livestock per year. AF, on the other hand, represents the number of unit sources of emission in a specified geographical area, e.g., number of a particular type of livestock on CFOs in the province of Alberta.

An extensive literature search was conducted to obtain CFO EFs for NH_3 and PM. Out of 100 reviewed publications, seven publications were considered to contain comprehensive EFs that could be utilized by APMEICA namely, Canadian National Agri-Environmental Standards Initiative (NAESI), Canadian National Agri-Environmental Health Analysis and Reporting Program (NAHARP), Finnish Ammonia Emission Inventory, United Kingdom Ammonia Emission Inventory for Agriculture, German Calculation of Agricultural Emissions, European EMEP/EEA Air Pollutant Emission Inventory Guidebook, and Swiss Ammonia Emissions

Inventory for Agriculture. The shortlisted publications were reviewed further and ranked to determine the most relevant and applicable EFs for APMEICA.

Thus, of the seven shortlisted publications, NAESI ranked highest with respect to NH_3 EFs while NAHARP ranked highest with respect to PM EFs. Based on the nature of the NAESI study, the NH_3 EFs used by APMEICA were derived monthly (high temporal resolution) at the municipal level (high spatial resolution). Conversely, the $PM_{2.5}$ and PM_{10} EFs obtained from NAHARP were derived annually (low temporal resolution) at the provincial level (low spatial resolution).

Similarly, a number of CFO AF data sources were evaluated including, the 2006 Statistics Canada (SC) Census of Agriculture, the Natural Resources Conservation Board (NRCB) database of livestock numbers for regulated CFOs, and registries of four select municipalities in Alberta. After due consideration, the 2006 SC Census of Agriculture was selected and used to determine AFs at the municipal level (high spatial resolution) for various types of CFOs. In combination with the 2006 census data, SC semi-annual agricultural surveys for cattle and sheep, and quarterly agricultural surveys for swine, were used to derive monthly CFO AFs. The monthly poultry CFO AFs were assumed to remain constant throughout the year.

Forecasted growth profiles obtained from a ChemInfo report submitted to Environment Canada in 2007 were used by APMEICA to forecast NH_3, $PM_{2.5}$ and PM_{10} emissions from CFOs in 2011, 2016 and 2021.

Results and Conclusions

The following are estimates of NH_3 emissions from CFOs in 2006:

- CFOs in Alberta were estimated to emit 42,750 tonnes of NH_3. **(Appendix C4)**
- Cattle and swine CFOs jointly accounted for 91% of the NH_3 emitted annually from CFOs in Alberta.
- NH_3 emissions from CFOs were highest from May to October, due to warmer temperatures in late spring and summer and to large volumes of manure applied on land in fall.
- NH_3 emissions from CFOs were highest in the South Saskatchewan Land Use Framework (LUF) Region, representing approximately 49% of total NH_3 emissions from CFOs in Alberta.
- Municipalities with the highest CFO NH_3 emissions were Lacombe County, County of Lethbridge, County of Newell, M.D. of Taber and Wheatland County.
- CFOs were estimated to be the biggest contributor of NH_3 emissions in Alberta, emitting approximately six times more NH_3 than industrial point sources and 22 times more NH_3 than mobile sources.

The following are estimates of PM_{10} emissions from CFOs in 2006:

- CFOs in Alberta were estimated to emit 1,762 tonnes of PM_{10}. **(Appendix C5)**
- Cattle and swine CFOs jointly accounted for 87% of the PM_{10} emitted annually from CFOs in Alberta.
- PM_{10} emissions from CFOs were highest in the South Saskatchewan LUF Region, representing approximately 50% of total PM_{10} emissions from CFOs in Alberta.
- Municipalities with the highest CFO PM_{10} emissions were Kneehill County, Lacombe County, County of Lethbridge, County of Newell, and Wheatland County.
- CFOs were estimated to be the smallest contributor of PM_{10} emissions in Alberta, emitting approximately 15 times less PM_{10} than industrial point sources and 430 times less PM_{10} than mobile sources.

The following are estimates of $PM_{2.5}$ emissions from CFOs in 2006:

- CFOs in Alberta were estimated to emit 380 tonnes of $PM_{2.5}$ in 2006. **(Appendix C6)**
- Cattle and swine CFOs jointly accounted for 90% of the $PM_{2.5}$ emitted annually from CFOs in Alberta.
- $PM_{2.5}$ emissions from CFOs were highest in the South Saskatchewan LUF Region, representing approximately 50% of total $PM_{2.5}$ emissions from CFOs in Alberta.
- Municipalities with the highest CFO $PM_{2.5}$ emissions were Kneehill County, Lacombe County, County of Lethbridge, County of Newell, and Wheatland County.
- CFOs were estimated to be the smallest contributor of $PM_{2.5}$ emissions in Alberta, emitting approximately 51 times less $PM_{2.5}$ than industrial point sources and 280 times less $PM_{2.5}$ than mobile sources.

Recommendations

The following recommendations are provided towards the enhancement of APMEICA in the future:

- APMEICA database should be maintained on an annual basis. The AFs and EFs should be updated as new data become available or improved estimation methodologies are developed.
- A finer spatial resolution (e.g. 1 km^2) should be used to report future CFO emissions. This will provide a better, more detailed assessment of CFO emissions, beyond the municipal level within each LUF region. Ultimately, it will help increase the potential for growth of the CFO industry within the various LUF regions, rather than limit such growth on a municipal basis by prohibiting growth in some municipalities within the LUF regions. It will also help industry manage emissions at the CFO level as opposed to the municipal level.

- Emissions forecasting should be improved by using new growth factors as they become available.
- Conduct a major review of APMEICA at least every 10 years to accommodate changes in Alberta's economy, agricultural policies and the CFO industry.
- To improve the accuracy of the next edition of APMEICA, an uncertainty analysis should be conducted using the best available techniques and tools.
- Higher temporal resolution PM EFs should be obtained and incorporated into the next edition of APMEICA.
- Research should be conducted to develop more accurate EFs and AFs that represent the weather, livestock production and manure management conditions in Alberta, towards the enhancement of APMEICA.
- Periodically track changes in farming activities by conducting formal CFO farm surveys.

1. Development of a New Emissions Inventory for Livestock Operations in Alberta

In 2008, the Clean Air Strategic Alliance (CASA) Confined Feeding Operation (CFO) strategic plan entitled, "Managing Air Emissions from Confined Feeding Operations in Alberta", recommended that Alberta Agriculture and Rural Development (ARD) lead, with support from Alberta Environment and Water (AEW) and advice from a multi-stakeholder advisory group (MAG), the development of an air emissions inventory for the CFO industry in the province by 2011. The strategic plan further recommended that this new inventory be based on emission factors (EFs) obtained from the ongoing United States (U.S.) National Air Emissions Monitoring Study (NAEMS) championed by the U.S. Environmental Protection Agency (USEPA).

In fulfillment of the recommendations of the CASA CFO strategic plan, ARD formed a technical working group (TWG) with staff from AENV and ARD, and a MAG comprising of AENV staff, a non-government organization (NGO) representative, a CFO industry representative and ARD staff. The TWG was tasked with the development of a draft CFO emissions inventory preparation plan (Atia and Edeogu 2009) for review by the MAG. Based on the particulars of the inventory preparation plan, a contractor was hired to gather the necessary information for the development of an emissions inventory with the desired spatial and temporal resolution and to develop the new emissions inventory for CFOs in Alberta.

1.1 Background

In 2001, ARD developed an agricultural air emissions inventory for Alberta (Chetner and Sasaki 2001). The authors calculated emissions by multiplying emission factors (EFs) obtained from available scientific literature and other sources by activity factors (AFs). EFs for ammonia (NH_3) and particulate matter (PM) were based on a "whole animal" approach and not on manure management practices. EFs for NH_3 for each animal category were derived from Battye et al. (1994) who based their calculations on data from Europe. EFs for PM were derived from the U.S. Department of Agriculture (USDA) Agricultural Air Quality Task Force (AAQTF) and Auvermann et al. (2001). Furthermore, the inventory developed by Chetner and Sasaki (2001) did not have sufficient temporal and spatial resolution to account for seasonal influences and regional differences.

The newly developed emission inventory has addressed some of the gaps and shortcomings of the inventory developed by Chetner and Sasaki (2001). It uses updated EFs that reflect seasonal and spatial variations in emissions from CFOs across Alberta. For instance, temporal variation in emissions needs to be considered so that mitigation strategies can be efficiently and effectively targeted throughout the year. Furthermore, the inventory developed by Chetner and Sasaki (2001) does not provide sufficient resolution to reliably recognize small changes in emissions due to the implementation of various mitigation strategies.

2. Scope of the New CFO Emissions Inventory

2.1 Emissions of Interest

Although the CASA CFO strategic plan did not specify the types of emissions the new inventory would feature, the strategic plan identified five priority substances and one priority issue of interest to the CASA CFO project team. The five priority substances were: NH_3; hydrogen sulphide (H_2S) and reduced sulphur compounds (RSC) such as total reduced sulphur (TRS); particulate matter (PM); bioaerosols and pathogens; and volatile organic compounds (VOCs). Odour was identified as a priority issue.

In the initial stages, the possibility of developing an emissions inventory for all six emissions of interest was given due consideration. However, it quickly became apparent that, in comparison to the other emissions of interest, significantly more data were available to develop an emissions inventory for CFO NH_3 and PM emissions associated with the various livestock types referenced in the CASA CFO strategic plan.

Consequently, the new CFO emissions inventory was developed solely for NH_3 and PM and is referred to as the Ammonia and Particulate Matter Emissions Inventory for CFOs in Alberta (APMEICA) in this report. The following were taken into consideration in the development of APMEICA:

- The inventory only focused on primary emissions of PM namely, feed and dried animal manure in livestock buildings and feedlots. Fugitive PM emissions, such as dust from roads surrounding CFOs, were not included in the inventory due to the lack of data from these sources of emissions.

- The inventory did not include agricultural greenhouse gas (GHG) emissions such as, carbon dioxide, methane, and nitrous oxide since they were not identified as priority substances by the CASA CFO strategic plan.

- The inventory did not account for the potential impact of various mitigation techniques on NH_3 and PM emissions.

2.2 Sources of CFO Emissions

In Alberta, CFOs are defined as "fenced or enclosed land or buildings where livestock are confined for the purpose of growing, sustaining, finishing or breeding" (GOA 2009). Livestock operations that are not categorized as CFOs, such as cow-calf operations, were not considered in the development of APMEICA.

NH_3 and PM may be emitted from a variety of CFO sources and associated activities. APMEICA focused solely on sources that relate directly to animal production practices and activities, specifically, indoor or outdoor confined animal housing facilities, manure storage facilities and manure application on land. It did not consider other sources that are directly or indirectly related to CFOs such as commercial fertilizer application, pesticide or herbicide application, tilling operations, or emissions associated with agricultural burning, wetlands or wild animals.

2.3 Types of Livestock

Emissions from CFOs with beef cattle, dairy cattle, poultry, swine and sheep were the focus of APMEICA. Emissions associated with various livestock sub-categories within these five main livestock categories were estimated. The sub-categories considered were as follows:

- Beef cattle
  - Heifers for slaughter or feeding
  - Steers that are 1 year and over

- Dairy cattle
  - Dairy cows
  - Heifers that are 1 year and over and used as dairy herd replacements

- Swine
  - Boars
  - Sows and gilts for breeding
  - Nursing and weaner pigs
  - Grower and finisher pigs

- Sheep
  - Ewes
  - Rams
  - Lambs

- Poultry
  - Broilers
  - Pullets
  - Laying hens
  - Turkeys

2.4 Inventory Review Frequency

APMEICA is to be reviewed and updated at least every 10 years to accommodate changes in Alberta's economy, establishment of new agricultural policies, and changes in the size of the CFO industry. Furthermore, it is anticipated that changes will occur in the implementation of

management practices that have the potential to reduce emissions from CFOs. Since APMEICA was developed in 2011, a full-scale review and update of the inventory is expected to be conducted in 2021.

3. Emission Estimation Approach

Levelton Consultants Ltd. was contracted by ARD and the TWG to establish a methodology to be used to develop APMEICA, and pending approval, proceed with the development of the inventory. The specifics of this process are outlined in this section.

As a generally accepted and relatively simplistic principle, emissions of a given substance from a given source can be approximated by multiplying an EF that is relative to that substance and source by the corresponding AF associated with the source. Generically, this can be represented mathematically as follows:

$$E_x = EF_x * AF_x \quad (1)$$

E_x = Amount of substance x emitted into the atmosphere
EF_x = Emission factor for substance x
AF_x = Activity factor relative to the source emitting substance x

The parameters EF_x and AF_x are discussed in detail in the following sub-sections.

3.1 Emission Factors

An EF is a representative value that attempts to relate the quantity of a substance released to the atmosphere with an activity associated with the release of that substance (USEPA 1995). Most EFs are determined either by directly measuring the concentration of the given substance released into the atmosphere and the rate at which the release occurs or by utilizing a mass balance approach whereby the flux of a specific chemical compound is traced from its input into a given system to its output from the system. Regardless of the approach taken, EFs are typically expressed as the mass of a given substance per unit of a source variable per unit of time. For example, EFs for NH_3 emissions from CFOs are commonly expressed as kilograms of NH_3-nitrogen (NH_3-N) per head of livestock per year, i.e., kg of NH_3-N/hd/yr.

Note that Eq. 1 is a rather basic approach to estimating emissions from CFOs. More complex, process-based models (Pinder et al. 2004) that account for variances in animal farming practices, different CFO sources and different climatic conditions exist. For example, Pinder et al. (2004) developed an inventory that accounted for seasonal and geographical differences in climate and farming practices. They developed EFs using a process-based model that accounted for the dynamics of ammonia volatilization and the effects of coupling different manure management processes. Process-based models perform a detailed analysis of farm systems by focusing on their component parts such as housing systems, manure storage systems, manure treatment systems (where applicable), land application systems, spatial variability, temporal variability, etc. According to NRC (2003), using such detailed EFs to estimate emissions from CFOs results in the most accurate predictions.

3.1.1 Derivation of CFO EFs

There are three commonly recognized approaches for estimating emissions associated with CFOs namely, direct measurement techniques, mass balance estimates and mechanistic process-based emissions models. Each of these methods has varying degrees of accuracy and levels of complexity required for data collection and analysis. Therefore the selection of a particular approach to estimate emissions is often a trade-off between cost and accuracy. Factors such as the availability and quality of data, practicality of method, significance of source, and resource availability play a key role in the decision process. Overall, regardless of the methodology used, there is limited information on CFO EFs. One of the reasons for this is the fact that measurements are typically conducted over short durations and limited locations, and extrapolations beyond the measurement period and location are prone to error because many factors can influence the temporal and spatial variability in CFO emissions.

3.1.1.1 Direct Measurement Techniques

There are a variety of direct measurement techniques that may be utilized to derive CFO EFs depending on the type of source, i.e., livestock housing facility, manure storage facility or manure application site.

Livestock buildings and other enclosed facilities

When livestock are housed in buildings, EFs are typically derived as a function of the concentration of emitted substances and the rate at which those substances are emitted from the building, in other words the building ventilation rate, be it a mechanically or naturally ventilated building.

With mechanically ventilated buildings, the concentration of the emitted substances may be measured at each fan, at a representative fan or inside the building. Similarly, to determine the rate those substances are emitted from the building, (i) the flow rate of each exhaust fan may be measured directly using a variety of techniques, (ii) the flow rate at one fan may be measured and used as a reference for additional fans of equivalent capacity, make and model, (iii) flow rates may be derived based on manufacturer fan test results relative to measured pressure differentials between the inside of the building and the outside atmosphere, or (iv) flow rates may be determined by measuring the diluted downwind concentration of a tracer gas of known initial concentration that was released within the livestock building at a predetermined rate. In situations where a control mechanism is used to reduce the concentration of emissions from the building then the concentration and flow rate of the emissions of interest are measured downwind of the control mechanism.

For naturally ventilated buildings, the concentration of the emitted substances is measured within the building. Flow rate on the other hand is derived from a mass balance model that relates the carbon dioxide (CO_2) input to the building to the CO_2 output from the building. Thus, the flow rate is derived as a function of the CO_2 production rate of the animals in relation to their diets, the concentration of CO_2 in the air entering the building and the concentration of

CO_2 in the air exiting the building. The CO_2 production rates of the animals are obtained from the results of laboratory-scale studies performed using metabolic chambers.

Open Source Areas

For CFOs where livestock are housed in the open, e.g., beef cattle feedlots, or manure is stored in an open outdoor facility, or manure is applied on land, a flux chamber technique or micrometeorological technique (Van Haarlem et al. 2008) may be used to derive EFs. The flux chamber technique has a number of variants including, a static flux chamber, vented flux chamber and wind tunnel.

The static flux chamber technique utilizes a chamber that is placed on an area source, undisturbed, for a fixed length of time, and concentrations of the emitted substance (typically a gas) are measured at set time intervals over this period. Thus, a concentration gradient develops within the chamber with time and the gradient is used to determine the EF.

A vented flux chamber utilizes a blower to direct airflow at a predetermined rate into the airspace enclosed by the chamber with the air exhausting via an outlet port. Thus the EF is the product of the change in concentration of the emitted substance (typically a gas) between the inlet and outlet air streams and the airflow rate through the chamber. Some vented flux chambers utilize a fan installed within the enclosed airspace that operates at a low speed to facilitate mixing and consequently homogeneity within the enclosure.

A wind tunnel also utilizes a blower to direct airflow at a predetermined rate through the enclosed air space. However it differs from the vented flux chamber in that the air sweeps across the exposed surface of the area source that is enclosed by the chamber and out into the atmosphere. The concentration of the emitted substance (typically a gas) is measured in the inlet and outlet air streams flowing through the wind tunnel.

One of the limitations of using flux chambers is the fact that each chamber typically spans only a very small area of the source. Therefore in order to obtain an adequate and relatively accurate representation of the emissions from a given source, several chambers may need to be utilized simultaneously. As a consequence the flux chamber technique can be both labour-intensive and costly.

Two types of micrometeorological techniques exist. One of these techniques measures the mean vertical flux of gas above the surface of an open area source, and the other measures the horizontal flux downwind of the source. Some of the benefits of using micrometeorological techniques to determine EFs are that the surface of the open area source is not disturbed and emissions can be measured over large areas. However, the resource demand and complexity of utilizing this approach can be cost-prohibitive (Flesch et al. 2007) especially considering the nature of CFO open area sources.

3.1.1.2 Mass Balance Estimates

Mass balance estimations account for the mass of a known substance entering a system and the mass of the same substance leaving the system. Thus, emissions of that substance are determined from the difference in the mass of the substance in the input and output streams. For example, the mass difference between total nitrogen inputs (e.g., feed) into and outputs (e.g., milk, manure, etc.) from CFOs is typically assumed to be lost to the atmosphere as NH_3 emissions.

Nitrogen flow through a CFO can be traced from the livestock housing facility (including products such as milk or eggs) through to the manure storage facility and finally manure application on land. Several mass balance models have been used to trace manure nitrogen flow, and ultimately NH_3 emissions, at various stages of livestock farming systems (Reidy et al. 2007). These models typically begin with a measure of the total ammoniacal nitrogen (TAN) content of the manure produced by the animals. As the manure travels through the production system, the TAN content of the manure at each stage is monitored. A lower TAN content is expected at each subsequent stage, reflecting a loss of TAN as NH_3 in the preceding stage.

Although the mass balance modelling approach is regarded as one of the best methods for estimating CFO NH_3 EFs, there are some limitations regarding its application. Often mass balance models for livestock operations are developed with respect to the livestock production and manure management practices of model farms. Such model farms conduct TAN content measurements in highly controlled experimental environments relative to similar measurements on commercial farms. Thus, large-scale surveys of commercial farms are often required in order to validate these models to achieve high degrees of confidence in their representation of commercial farming systems. Obviously, mass balance models cannot be used to estimate CFO PM EFs.

3.1.1.3 Mechanistic Emission Models

Mechanistic models generally consist of a series of equations that attempt to account for all the mechanisms, processes and factors responsible for NH_3 volatilization from manure, which occur under a wide range of environmental and field conditions (Génermont and Cellier 1997, Monteny et al. 1998, Ni 1999, Zhang et al. 2005). These models attempt to simulate the biological, chemical and physical processes that occur in manure produced in animal housing facilities through to manure applied on land. Thus, mechanistic models tend to be both accurate and robust.

Conversely, because mechanistic models are dependent on a large array of parameters in order to make the models functional, the development of such models tends to be costly. In addition, some of the parameters can be difficult to measure under field conditions (Hutchings et al. 2001, Arogo et al. 1999).

3.1.2 Review of CFO NH_3 and PM EFs

An extensive search of the most recent publications from Australia, Europe and North America was performed to obtain CFO EFs for NH_3 and PM. More than 100 articles were reviewed and screened based on their comprehensiveness and technical merit. The literature search indicated that most of the publications, including North American publications, were based on studies conducted in Europe (Faulkner and Shaw 2008). No CFO EFs specific to Australia were reported in the literature.

Recently, two comprehensive North American studies namely, the Canadian National Agri-Environmental Standards Initiative (NAESI) and the USEPA National Air Emissions Monitoring Study (NAEMS), were completed to help address the effects of geographical differences on CFO EFs between Europe and Canada and Europe and the U.S., respectively. Both studies utilized in-depth surveys of agricultural practices as well as small-scale studies to quantify emissions from livestock production and manure storage and handling facilities.

Initial efforts made by ARD to obtain EFs from NAEMS towards the development of APMEICA proved unsuccessful since the USEPA had not completed its study as APMEICA was undergoing development. However, EFs from NAEMS are anticipated to become available in the near future and will be used to assess APMEICA when they do.

3.1.2.1 Shortlist of CFO NH_3 and PM EF Publications

Only seven out of the 100 publications reviewed were found to contain complete EF information with respect to the major livestock types and sub-categories (see section 2.3), CFO production practices and climatic conditions in Alberta, and to be of some potential relevance to APMEICA. The seven shortlisted publications were:

- "A Temporal Inventory of Ammonia Emission from Agricultural Sources in Canada" - NAESI (Bittman and Sheppard 2008)
- "Environmental Sustainability of Canadian Agriculture" - National Agri-Environmental Health Analysis and Reporting Program, NAHARP (Eilers et al. 2010)
- "Development of the NH_3 Emission Inventory in Finland, 2009" (FEI 2009)
- "Inventory of Ammonia Emissions from UK Agriculture 2007" (Misselbrook et al. 2008)
- "Calculations of Emissions from German Agriculture, 2008" (Rosemann et al. 2010)
- "EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009" (EMEP/EEA 2009)
- "A New Swiss Inventory of Ammonia Emissions from Agriculture" (Reidy et al. 2008)

3.1.2.2 NAESI

The NAESI program was undertaken by Environment Canada (EC) and Agriculture and Agri-Food Canada (AAFC) from 2004 to 2008. One of the key objectives of this study was to update the 2002 national inventory on NH_3 emissions from agricultural sources using information and data specific to Canada. The updated emissions inventory addressed the following shortcomings of previous inventories:

- Use of a single EF for each livestock category (e.g., swine, cattle, poultry) without consideration of regional differences in farming practices and climatic conditions.

- Use of annual averages for NH_3 emissions without consideration of temporal variations. In other words, past emissions inventories did not account for seasonally different agricultural practices (e.g., land application of manure in fall) or seasonally variable temperatures that have different effects on agricultural NH_3 emissions throughout the year.

- Use of NH_3 EFs based primarily on data obtained from studies conducted in Europe because of the lack of (or limited) Canadian-based studies.

In order to calculate NH_3 emissions from livestock in Canada, NAESI utilized a nitrogen mass flow model that was developed using data representative of Canadian farm practices and activities. The data were obtained via four extensive surveys. Two of the surveys of particular relevance to APMEICA were:

- Livestock Farm Practices Survey (LFPS): A total of 431 farmers were surveyed, representing the beef, dairy, swine, and poultry sectors in Canada. The farmers were selected based on previous responses to the Census of Agriculture, an obligatory survey conducted by Statistics Canada (SC) every five years. The LFPS comprised of approximately 100 questions that focused on four general areas namely, types and ratios of animal classes on farm facilities, animal housing and manure collection, manure storage, and manure application on land.

- Feed Industry Survey (FIS): The data collected from this survey were used to verify information on feed protein content obtained from LFPS.

The NAESI mass flow model began by estimating the nitrogen content of feed for a specific livestock type and ended with an estimation of the nitrogen content of manure following the field application of manure from that livestock type. The structure of the mass balance model used to derive livestock NH_3 EFs is illustrated in Figure 3-1.

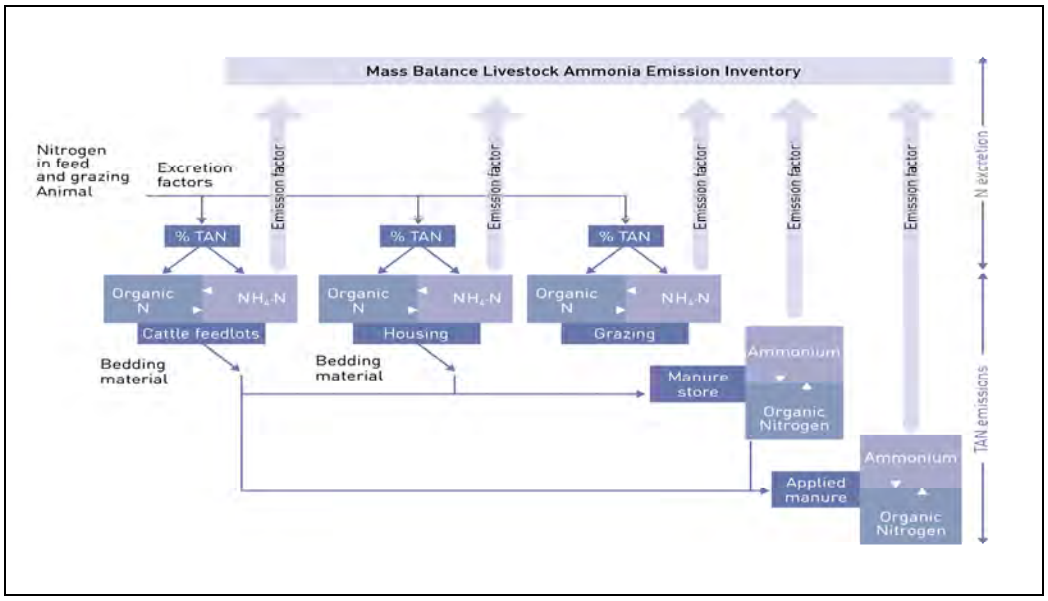


Figure 3-1 Mass balance structure for the model used to develop NH_3 EFs for the NAESI emission inventory (adapted from Eilers et al. 2010)

The newly developed Canadian model provided a monthly NH_3 EF for each animal sector (or sub-sector, where applicable) for ecoregions in Canada. Instead of using provinces, 12 ecoregions were defined based on their similar climatic and soil conditions. Five of the ecoregions exist in Alberta namely, Brown Soil Zone, Dark Brown Soil Zone, Black Soil Zone, Boreal Plains, and Mountain Cordillera.

The NAESI inventory used EFs that varied temporally by month and spatially by ecoregion. For each ecoregion, NH_3 emissions were estimated using ecoregional EFs and AFs based on 20 km^2 or 40 km^2 grids (Sheppard et al. 2009), i.e., based on a much higher spatial resolution than was used in previous inventories. NH_3 emission data from the 12 ecoregions were then scaled up to estimate NH_3 emissions nationally.

3.1.2.3 NAHARP

NAHARP is a science-based agri-environmental policy program developed by AAFC. The main objective of this program was to develop agri-environmental indicators (AEIs) to determine how environmental conditions within agriculture changed with time (Eilers et al. 2010). These environmental indicators were intended to be relevant to policy development, scientifically sound, understandable, feasible, and capable of reflecting geospatial and temporal change (Eilers et al. 2010). The indicators were classified into the following three groups:

- Risk indicators to estimate potential environmental impact
- State indicators to determine the actual presence and level of impact

- Eco-efficiency indicators to estimate the efficiency of using resources

Data collected spatially and temporally served as input to mathematical models or formulae used to develop AEIs at the Soil Landscapes of Canada (SLC) level. SLC is a mapping technique developed by AAFC to provide information about agricultural soils at the provincial and national levels (Shields et al. 1991). The base map for NAHARP had more than 22,000 mapping polygons (Sheppard et al. 2007). Eilers et al. (2010) acknowledged that the indicators had some limitations that may have had an impact on NAHARP's reliability. These limitations were mainly due to the quality of AFs and the corresponding EFs used in the development of the indicators.

NAHARP indicators were estimated for each census year and for each SLC polygon by multiplying EFs by their corresponding AFs. AFs were obtained from SC's Census of Agriculture and Farm Environmental Management Survey (FEMS). Two of the NAHARP indicators of relevance to APMEICA were:

- NH_3 Emission from Agriculture Indicator (Eilers et al. 2010): This indicator for livestock was based on computer models that calculated NH_3 emissions to the atmosphere. Input data for these models were obtained from limited Canadian-based studies and other studies. Thus, one limitation of this indicator was its overdependence on data from Europe and the U.S. where weather conditions and livestock management practices differed from those in Canada. These models estimated NH_3 emissions from CFO housing facilities, manure storage facilities and manure land application sites.

- Agricultural Particulate Matter Emission Indicators (Eilers et al. 2010): These indicators were developed to estimate total suspended particulate (TSP), PM_{10}, and $PM_{2.5}$ from agricultural sources in all the provinces in Canada. TSP describes all PM smaller than 100 μm, PM_{10} refers to dust particles with an equivalent aerodynamic diameter of 10 μm or less, and $PM_{2.5}$ refers to particles with an equivalent aerodynamic diameter of 2.5 μm or less (Eilers et al. 2010). Due to the unavailability of Canadian EFs, CFO PM EFs obtained primarily from research in the U.S. and Europe were used to develop NAHARP PM indicators.
  Note that NAHARP and NAESI are essentially the same. The reporting changed form 64 km grids to SLCs but the calculations are otherwise very similar.

3.1.2.4 Ammonia Emissions Inventory in Finland

The Finnish Environment Institute (FEI) is a research institute and a centre for environmental expertise in Finland. FEI (2009) developed a mass flow model that calculated NH_3 emissions from manure management systems with respect to different livestock categories. The model began with a determination of the amount of excreted nitrogen based on animal numbers and animal-specific nitrogen excretion rates. The fate of the excreted nitrogen was then followed through the manure management chain and NH_3 emissions to the atmosphere were calculated at each phase of the chain.

The FEI model was used to calculate present and past emissions and estimate future emissions. Emissions that occurred between 1990 and 2007 were calculated based on existing statistics and other information available from that period. Emission projections (2008 to 2050) were based mainly on assumed changes in animal numbers in Finland, while other factors like manure management systems and manure nitrogen content were assumed to be similar to the 2007 values.

3.1.2.5 2007 Inventory of NH_3 Emissions from UK Agriculture

A National Ammonia Reduction Strategy Evaluation System (NARSES) was used to estimate NH_3 emissions from United Kingdom (UK) agricultural systems in 2007. NARSES modeled the flow of TAN through the livestock production and manure management system, with NH_3 losses at each stage reported as a proportion of the TAN content of the manure at the beginning of each respective stage. Survey and census information were used to obtain AFs such as livestock numbers, fertilizer use and information on other management practices.

3.1.2.6 2008 Calculations of Emissions from German Agriculture

A mass balance N-excretion model GAS-EM was used to determine NH_3 emissions associated with manure management practices in Germany. The model calculations considered the amount of N in the excreta, N in the feed, N seceded in milk and eggs, N retained in the animal, and N in the offspring. In contrast to the generalized model, GAS-EM not only calculated emissions for NH_3 but for GHGs and PM (PM_{10} and $PM_{2.5}$) as well.

3.1.2.7 2009 EMEP/EEA Air Pollutant Emission Inventory Guidebook

The "EMEP/EEA Air Pollutant Emission Inventory Guidebook" was used as a resource towards the estimation of emissions as a result of anthropogenic and naturally occurring activities. It was designed to facilitate the reporting of emission inventories by European countries to the UNECE Convention on Long-range Transboundary Air Pollution and the EU National Emission Ceilings Directive. The EMEP/EEA guidebook described a tiered methodology for estimating emissions. Simple (Tier 1) methods were prescribed for all sources of emissions and substances of interest which countries that ratified the convention protocols had to report. Tier 1 methods applied a simple linear relation between AFs and default EFs. The AFs were derived from readily available statistical information (EMEP/EEA 2009). More advanced methods (Tier 2 and Tier 3) were prescribed for some key categories as long as the appropriate methods were available. Tier 2 methods used the same or similar AFs as Tier 1 methods, but applied country-specific EFs. The latter EFs were derived from information specific to each of the participating countries, such as process conditions, abatement technologies, etc. (EMEP/EEA 2009). Tier 3 methods used sophisticated modeling techniques to develop EFs and used AFs obtained at the facility (farm) level (EMEP/EEA 2009).

3.1.2.8 New Swiss Inventory of NH_3 Emissions from Agriculture

An agricultural NH_3 emission inventory was developed with information obtained from a detailed, representative, stratified survey of farm practices and manure management systems

used by 1,950 farms in Switzerland. NH_3 emissions from agricultural livestock-related sources were determined with the aid of DYNAMO, an emissions model. This model fully accounted for all parameters associated with farming practices and manure management systems. Weighted EFs per animal for 24 livestock categories and 36 farm classes were used to prepare the national inventory. The stratified sampling and calculations that varied by farming system enabled the comparison of emissions from different regions and altitudes and further study of the variability among farms. The new emission inventory approach permitted a more detailed analysis of the regional distribution of NH_3 emissions as well as more robust and standardized monitoring of emissions, compared to earlier approaches used in Switzerland. Farm and manure management parameters used in earlier approaches were based entirely on estimates and assumptions of national experts and not on real measurements and monitoring (Reidy et al. 2007).

3.1.3 Selection of CFO EFs for APMEICA

In selecting EFs for APMEICA, first preference was given to accurate and comprehensive EFs derived from studies conducted in Alberta, then Canada, then U.S., Europe and Australia, and finally other countries. If Alberta or Canadian-based EFs were not available, then EFs developed by another jurisdiction with similar animal farming practices, manure management systems and climatic conditions to those in Alberta were selected, again with preference given to studies that factored in spatial and temporal influences on emissions.

To provide a systematic review and assessment of related publications and modeling methodologies on EFs, a set of selection criteria was established based on the USEPA Data Attribute Rating System (DARS). These selection criteria took into account data sample size, statistical experimental design and data analysis, climatic factors, animal housing considerations, manure management and other factors.

DARS was developed by the USEPA to provide a measure of confidence in emissions inventories. It disaggregates emission inventories into EF and AF parameters and then assigns numerical scores to both components (USEPA 1996). A composite score for the overall inventory was calculated based on the respective scores for the EF and AF components (USEPA 1996). In rating EFs, a numeric score ranging from 1 (lowest) to 10 (highest)[1] was assigned to each of the following four attributes:

- Measurement/method – with respect to the type, quantity and coverage of data used for EF development

- Source specificity – relative to the source types specific to this project such as animal categories and manure management practices

[1] When used in the overall evaluation of a given inventory, DARS requires each EF attribute score to be converted to a fraction of the maximum score of 10 in each attribute category.

- Spatial congruity – concerning factors such as climatic variations and geographic boundaries

- Temporal congruity – considering factors such as temporal scale and seasonal influences

DARS Rating Decision Flowcharts show the assigned scores for the above attributes in Figures A-1 to A-4 (Appendix A) and outline the general steps followed in the rating process.
In addition to DARS, an Alberta-based rating system (ABRS) was applied to provide a rated comparison between climatic conditions and livestock production practices in various jurisdictions and those in Alberta. Table 3-1 details the attributes and corresponding scores associated with ABRS.

Table 3-1 Attributes of the ABRS

Descriptor	Score
Climatic attribute	
Study was conducted across all Land-use Framework Regions in Alberta	10
Study was conducted across more than one Land-use Framework Region in Alberta	9
Study was conducted across only one Land-use Framework Region in Alberta	8
Study was not conducted solely in Alberta but in an ecoregion in Canada that occurs in Alberta	7
Study was conducted in a neighbouring ecoregion in Canada	6
Study was conducted in the Northwest U.S. (Washington to North Dakota)	6
Study was conducted in a remote ecoregion in Canada	5
Study was conducted in the Northeast U.S. (North Dakota to Maine)	5
Study was conducted in Northern Europe	5
Study was conducted in Central U.S. (Oregon to Virginia)	4
Study was conducted in Central Europe	4
Study was conducted in Southern U.S. (California to North Carolina)	3
Study was conducted in Southern Europe	3
Study was conducted elsewhere in the world with a cold or temperate climate	2
Study was conducted in a remote area of the world with non-related climate	1
Livestock production practice attribute	
Study was conducted in Alberta and is representative of all production practices typically used in Alberta	10

Descriptor	Score
Study was conducted in Alberta and is representative of more than one production practice typically used in Alberta	9
Study was conducted in Alberta and is representative of only one production practice typically used in Alberta	8
Study was not conducted solely in Alberta but in an ecoregion in Canada that occurs in Alberta and is representative of at least one production practice typically used in Alberta	7
Study was conducted in a neighbouring ecoregion in Canada and is representative of at least one production practice typically used in Alberta	6
Study was conducted in the Northwest U.S. (Washington to North Dakota) and is representative of at least one production practice typically used in Alberta	6
Study was conducted in a remote ecoregion in Canada and is representative of at least one production practice typically used in Alberta	5
Study was conducted in the Northeast U.S. (North Dakota to Maine) and is representative of at least one production practice typically used in Alberta	5
Study was conducted in a remote part of the U.S. and is representative of at least one production practice typically used in Alberta	4
Study was conducted in Europe and is representative of at least one production practice typically used in Alberta	3
Study was conducted in Australia and is representative of at least one production practice typically used in Alberta	2
Study was conducted in a remote area of the world and is representative of at least one production practice typically used in Alberta	1

Based on the above, the seven shortlisted publications discussed above were reviewed in detail for their appropriateness and applicability to APMEICA.

3.1.4 Ammonia EFs

In order to obtain NH_3 EFs for APMEICA, five out of the seven shortlisted studies were rated using DARS and ABRS (Table 3-2). Subsequently, NAESI was selected as the study of choice to obtain NH_3 EFs.

NAESI provided monthly CFO NH_3 EFs for the five ecoregions in Alberta (see Appendices B1 to B10). Methodology to derive these EFs was explained in Section 3.1.2.2. Each municipality in the province was located in one or more of these ecoregions as listed in Table 3-3. For a municipality that was located entirely within only one ecoregion, EFs from that ecoregion were assumed to represent the EFs for the municipality. Conversely, where a municipality was

Table 3-2 DARS and ABRS attribute ratings for NH_3 EFs

Reference	DARS				ABRS		Total score
	Measurement	Source category specificity	Spatial scale	Temporal scale	Climatic conditions	Production practices	
NAESI	5	10	10	10	7	7	49
FEI	5	10	7	10	5	3	40
Swiss	5	7	5	10	5	3	35
UK	5	9	3	10	4	3	34
Germany	5	6	5	10	5	3	34

located in more than one ecoregion, the average EF for the two or more ecoregions was determined and assumed to represent the EF for the municipality.

For example the Municipal District (M.D.) of Willow Creek No. 26 lies in three different ecoregions namely, Dark Brown Soil, Black Soil and Mountain Cordillera. Therefore the NH_3 EFs for the three ecoregions were averaged and the average EF was assumed to be the EF for the M.D. of Willow Creek.

Table 3-3 NAESI ecoregions in Alberta and municipalities located within those ecoregions

Ecoregion	Municipalities in the ecoregion
Brown Soil	Forty Mile County No. 8, M.D. of Taber, County of Newell, M.D. of Acadia No. 34, Special Area No. 3
Dark Brown Soil	M.D. of Provost No. 52, County of Lethbridge, Vulcan County, Wheatland County, M.D. of Ranchland No. 66, Special Area No. 4, Starland County, County of Paintearth
Black Soil	County of Vermilion River, County of Wetaskiwin No. 10, Sturgeon County, Edmonton, Flagstaff County, Camrose County, Ponoka County, Beaver County, County of Minburn No. 27, Lamont County, Cardston County, M.D. of Foothills No. 31, M.D. of Rocky View No. 44, Calgary, Red Deer County, Lacombe County
Boreal Plains	Brazeau County, Lac Ste. Anne County, County of Barrhead No. 11, Westlock County, Woodlands County, County of Thorhild No. 7, County of Athabasca No. 12, Yellowhead County, M.D. of Lesser Slave River No. 124, M.D. of Big Lakes, M.D. of Bonnyville No. 87, Lakeland County, Smoky Lake County, Clearwater County, M.D. of Northern Lights No. 22, Northern Sunrise County, M.D. of Peace No. 135, Mackenzie County No. 23, M.D. of Greenview No. 16, Saddle Hill County, M.D. of Spirit River No. 133, M.D. of Smoky River No. 130, Clear Hills County, M.D. of Fairview No. 136, County of Grande Prairie No. 1
Mountain Cordillera	Crownest County

Ecoregion	Municipalities in the ecoregion
Brown Soil + Black Soil	Cypress County, County of Warner No. 5, Special Area No. 2
Dark Brown Soil + Black Soil	Kneehill County, County of Stettler No. 6, M.D. of Wainwright No. 61
Dark Brown Soil + Black Soil + Mountain Cordillera	M.D. of Willow Creek No. 26
Black Soil + Boreal Plains	County of St. Paul No. 19, Leduc County, Parkland County, Strathcona County, County of Two Hills No. 21, Mountain View County
Black Soil + Mountain Cordillera	M.D. of Pincher Creek No. 9

Since NAESI did not have NH_3 EFs for sheep, NH_3 EFs for sheep were obtained from the Finnish NH_3 emission inventory (FEI 2009), the second highest ranked inventory after NAESI based on the DARS and ABRS attribute ratings (Table 3-2). However, unlike the other livestock categories that utilized the relatively high resolution spatial and temporal information from NAESI, only one NH_3 EF was used to estimate annual emissions from sheep CFOs in all municipalities in Alberta.

3.1.5 Particulate Matter EFs

Similar to the process used to obtain NH_3 EFs for APMEICA, three out of the seven shortlisted studies were ranked using DARS and ABRS (Table 3-4) to obtain PM EFs. Subsequently, NAHARP was selected as the study of choice to obtain PM EFs.

Table 3-4 DARS and ABRS attribute ratings for PM EFs

Reference	DARS				ABRS		Total score
	Measurement	Source category specificity	Spatial scale	Temporal scale	Climatic conditions	Production practices	
NAHARP	5	10	10	10	7	7	49
Germany	5	6	5	10	5	3	34
EMEP/EEA	5	7	5	10	4	3	34

NAHARP provided averaged EFs used to develop its PM indicators. However, unlike NAESI, most of the PM EFs used by NAHARP were obtained from studies conducted abroad. Using average livestock weights (Table 3.5), the PM_{10} and $PM_{2.5}$ EFs from NAHARP were converted from grams per animal unit[2] per day to kilograms per animal per year (Table 3-6).

[2] An animal unit (AU) is equivalent to 500 kg live weight.

For example, PM_{10} EFs for dairy cattle were calculated as follows:

$$\frac{(1.87\ \text{g/AU/day}) * (365\ \text{days/year}) * ((635\ \text{kg/animal})/(500\ \text{kg/AU}))}{1{,}000\ \text{g/kg}} = 0.8668\ \text{kg/animal/year}$$

Table 3-5 Average livestock weights used to calculate PM EFs*

Livestock category	Average live weight (kg)	Livestock category	Average live weight (kg)	Livestock category	Average live weight (kg)
Dairy cows	635.00	Growing and finishing pigs	70.00	Pullets	0.67
Beef and dairy heifers	535.50	Sows	150.00	Layers	1.58
Steers	538.80	Boars	150.00	Turkey	6.25
Nursing and weaner pigs	12.50	Broilers	1.56	Sheep	27.00

*Source Dr. Elizabeth Pattey, Agriculture and Agri-Food Canada, personal communication

Table 3-6 NAHARP PM_{10} and $PM_{2.5}$ CFO EFs

Animal category	PM_{10} (g $AU^{-1}d^{-1}$)	$PM_{2.5}$ (g $AU^{-1}d^{-1}$)	PM_{10} (kg animal $^{-1}$ yr^{-1})	$PM_{2.5}$ (kg $animal^{-1}$ yr^{-1})
Cattle				
Dairy cows	1.87	0.42	0.8668	0.1947
Beef and dairy heifers	1.57	0.35	0.6138	0.1368
Steers	1.57	0.35	0.6175	0.1377
Swine				
Nursing and weaners	8.89	1.98	0.0811	0.0181
Growing and finishing	7.17	1.59	0.3664	0.0812
Sows	3.33	0.74	0.3646	0.0810
Boars	3.33	0.74	0.3646	0.0810
Poultry				
Broilers	8.9	1.1	0.0101	0.0013
Pullets	10.5	1.1	0.0051	0.0005

Animal category	PM_{10} ($g\ AU^{-1}d^{-1}$)	$PM_{2.5}$ ($g\ AU^{-1}d^{-1}$)	PM_{10} ($kg\ animal^{-1}\ yr^{-1}$)	$PM_{2.5}$ ($kg\ animal^{-1}\ yr^{-1}$)
Layers	10.5	1.1	0.0121	0.0013
Turkey	8.9	1.1	0.0409	0.0051
Other				
Sheep	1.67	0.37	0.033	0.007

3.2 Activity Factors

Since AFs are a key component of emission inventories, minimizing the uncertainty associated with AFs can help increase the reliability and usefulness of emission inventories. AFs can be obtained from information recorded directly or from statistical surveys such as a census. According to **(**EMEP/EEA 2009), a census is based on a complete count of an entire population, while other types of surveys are often derived from a sample of entire populations and therefore, can only provide estimates of those entire populations. A number of sources of AFs for APMEICA were given due consideration.

3.2.1 SC

The most comprehensive source of CFO AFs is the Census of Agriculture conducted by SC every five years. The latest available data are from the census conducted in May 2006. Note, results of the 2011 census will not be published by SC until 2012.

CFO AFs available from the 2006 census included number of animals by livestock sub-category in each Census Consolidated Subdivision (CCS) in Alberta. CCS in Alberta are basically defined by municipality boundaries and typically are composed of smaller, more urban census subdivisions (CSD), such as towns and villages, combined with their surrounding, larger, more rural CSD (SC 2006).

In addition to the census, SC and the Economics and Statistics Branch of ARD conduct semi-annual and quarterly agricultural surveys every year to help estimate changes in some of the census variables until the next census.

3.2.2 NRCB

The Natural Resources Conservation Board (NRCB) has collected information on livestock numbers from CFOs regulated under Alberta's *Agricultural Operation Practices Act* and Regulations since 2002 when the Act came into effect (Jim McKinley, senior inspector, NRCB, Red Deer, AB, personal communication). However, the NRCB database does not include all the CFOs in Alberta; specifically it does not include those CFOs that existed prior to January 1, 2002 and have not expanded their operations or altered their manure management systems since December 31, 2001. Therefore the NRCB database was not utilized as a source of CFO AFs due

to its inability to provide a complete inventory of CFO livestock numbers in any municipality in Alberta.

3.2.3 Municipality Registries

A number of municipalities namely, Lethbridge County, Mountain View County, Newell County, and Ponoka County, were contacted to obtain CFO livestock numbers in order to validate the AFs obtained from SC for those municipalities. The municipalities of Ponoka, Mountain View, and Newell reported that they relied on the NRCB and SC for information on livestock populations in their respective jurisdictions. On the other hand, Lethbridge County indicated that it did not possess information on the actual number of livestock on CFOs in the county at any given time, rather it kept an inventory of the licensed capacities of CFOs in the county.

3.2.4 Selection of CFO AFs for APMEICA

The criteria outlined in Table 3-7 were used to assess and select AFs for APMEICA. Based on the assessment, monthly AFs were obtained or derived from the SC 2006 census, and the semi-annual (cattle and sheep) and quarterly (swine) agricultural surveys. Since no semi-annual or quarterly surveys were conducted for poultry CFOs, the AFs for the latter were assumed to be constant throughout the year.

Table 3-7 Rating sources of AFs

Selection criteria	SC	NRCB	Municipalities
Data are readily available and accessible	✓		
Data have a high spatial resolution	✓	✓	✓
Data are reliable and accurate	✓		
Data are complete	✓		
Data are updated frequently		✓	

3.2.5 Derivation of Monthly CFO AFs

The SC AFs were found to have a few shortcomings that needed to be addressed in order to achieve the desired spatial and temporal resolution for APMEICA. First, the census data provided highly accurate livestock population data per municipality at the instance the data were collected in May 2006. Therefore, it was assumed that the 2006 census provided livestock numbers per municipality for May only. Secondly, in that same year, semi-annual or quarterly livestock numbers in the province were estimated with respect to certain livestock categories based on the agricultural surveys.

Thus, in order to obtain AFs at the desired spatial and temporal resolution, the 2006 census data and either the semi-annual or quarterly survey data were used to estimate AFs per municipality

per month by applying a scaling factor. For various livestock sub-categories the AFs per month for each municipality were derived from:

$$AF_m = \frac{AC}{B} \quad (2)$$

AF_m = Activity factor per month for a given municipality and livestock sub-category

A = Number of livestock for a given municipality and livestock sub-category from the 2006 census

B = Total number of livestock in the province for a given livestock sub-category from the 2006 census

C = Total number of livestock in the province for a given livestock sub-category from the 2006 semi-annual survey for cattle or sheep, or quarterly survey for swine

3.2.5.1 Sample Derivation of Monthly AFs

Based on Eq. 2, a sample calculation of monthly AFs (AF_m) for beef heifers for slaughter or feeding in Leduc County in 2006 is presented in the chart below.

Month	A[1]	B[2]	C[3]	AF_m[4]
Jan - April	4,811	805,829	647,000	3,863
June - Dec	4,811	805,829	825,000	4,925

1 = Number of heifers for slaughter or feeding in the county from 2006 census, 2 = Total number of heifers for slaughter or feeding in Alberta from 2006 census, 3 = Number of heifers for slaughter or feeding in Alberta from 2006 semi-annual survey, 4 = Scaled monthly AFs for heifers for slaughter or feeding in 2006

Thus, the monthly AFs for heifers for slaughter or feeding in Leduc County in 2006 were estimated to be:

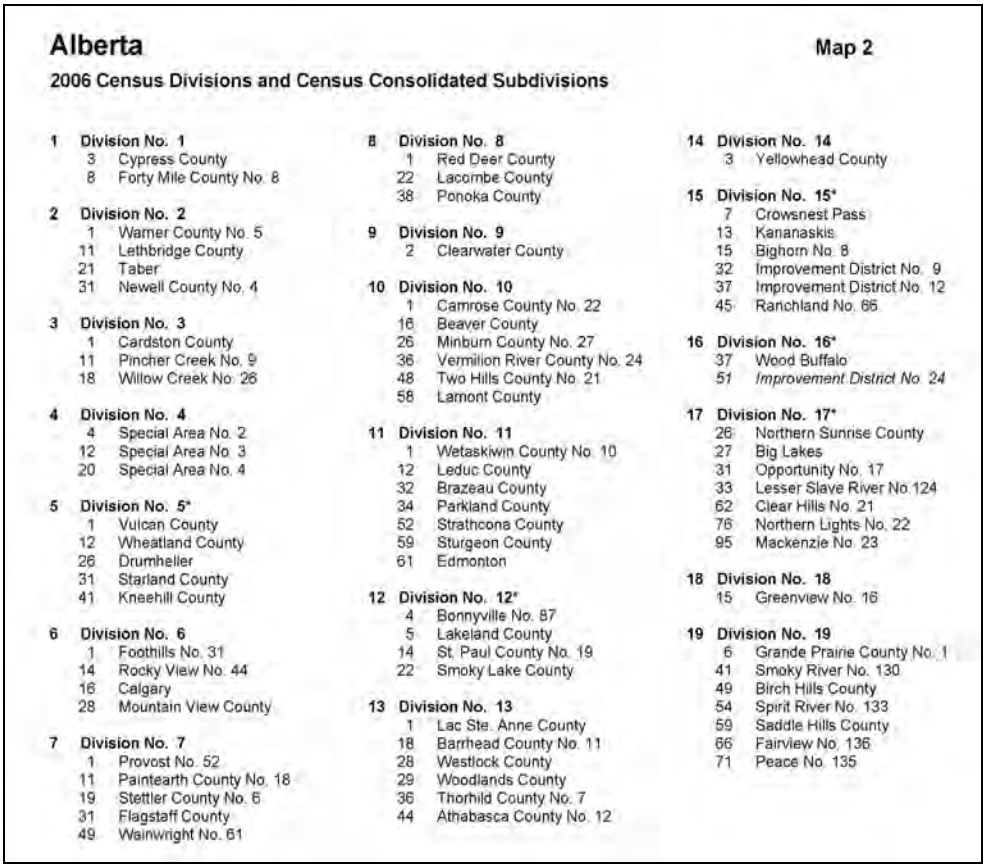
- 3,863 head of cattle from January to April
- 4,811 head of cattle in May
- 4,925 head of cattle from June to December

3.3 Emission Calculation Methodology

3.3.1 Spatial Distribution of Emissions

APMEICA was developed based on a relatively high CCS (Figure 3-2) spatial resolution (i.e., at the municipality level) applied by SC in reporting its census information. In order to increase the applicability of information derived from APMEICA, the inventory was also created to aggregate and report emissions at lower spatial resolutions including, Census Agricultural

Regions (CAR; Figures 3-3 and 3-4; Table 3-8), ARD-defined Regions (Figure 3-5; Table 3-9), and Land-use Framework (LUF) Regions (Figure 3-6; Table 3-10).



Alberta — Map 2

2006 Census Divisions and Census Consolidated Subdivisions

1 Division No. 1
- 3 Cypress County
- 8 Forty Mile County No. 8

2 Division No. 2
- 1 Warner County No. 5
- 11 Lethbridge County
- 21 Taber
- 31 Newell County No. 4

3 Division No. 3
- 1 Cardston County
- 11 Pincher Creek No. 9
- 18 Willow Creek No. 26

4 Division No. 4
- 4 Special Area No. 2
- 12 Special Area No. 3
- 20 Special Area No. 4

5 Division No. 5*
- 1 Vulcan County
- 12 Wheatland County
- 26 Drumheller
- 31 Starland County
- 41 Kneehill County

6 Division No. 6
- 1 Foothills No. 31
- 14 Rocky View No. 44
- 16 Calgary
- 28 Mountain View County

7 Division No. 7
- 1 Provost No. 52
- 11 Paintearth County No. 18
- 19 Stettler County No. 6
- 31 Flagstaff County
- 49 Wainwright No. 61

8 Division No. 8
- 1 Red Deer County
- 22 Lacombe County
- 38 Ponoka County

9 Division No. 9
- 2 Clearwater County

10 Division No. 10
- 1 Camrose County No. 22
- 16 Beaver County
- 26 Minburn County No. 27
- 36 Vermilion River County No. 24
- 48 Two Hills County No. 21
- 58 Lamont County

11 Division No. 11
- 1 Wetaskiwin County No. 10
- 12 Leduc County
- 32 Brazeau County
- 34 Parkland County
- 52 Strathcona County
- 59 Sturgeon County
- 61 Edmonton

12 Division No. 12*
- 4 Bonnyville No. 87
- 5 Lakeland County
- 14 St. Paul County No. 19
- 22 Smoky Lake County

13 Division No. 13
- 1 Lac Ste. Anne County
- 18 Barrhead County No. 11
- 28 Westlock County
- 29 Woodlands County
- 36 Thorhild County No. 7
- 44 Athabasca County No. 12

14 Division No. 14
- 3 Yellowhead County

15 Division No. 15*
- 7 Crowsnest Pass
- 13 Kananaskis
- 15 Bighorn No. 8
- 32 Improvement District No. 9
- 37 Improvement District No. 12
- 45 Ranchland No. 66

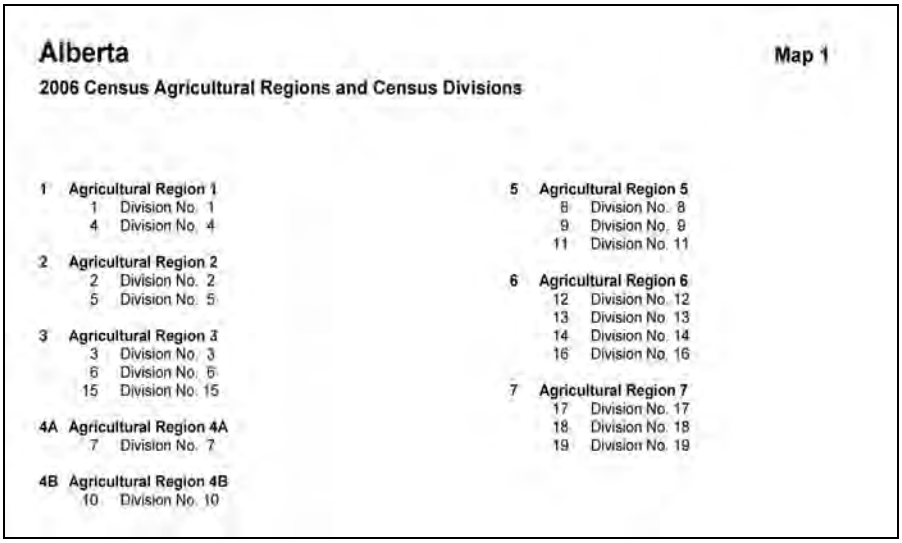
16 Division No. 16*
- 37 Wood Buffalo
- *51 Improvement District No. 24*

17 Division No. 17*
- 26 Northern Sunrise County
- 27 Big Lakes
- 31 Opportunity No. 17
- 33 Lesser Slave River No.124
- 62 Clear Hills No. 21
- 76 Northern Lights No. 22
- 95 Mackenzie No. 23

18 Division No. 18
- 15 Greenview No. 16

19 Division No. 19
- 6 Grande Prairie County No. 1
- 41 Smoky River No. 130
- 49 Birch Hills County
- 54 Spirit River No. 133
- 59 Saddle Hills County
- 66 Fairview No. 136
- 71 Peace No. 135

Figure 3-2 List of Census Divisions and Census Consolidated Subdivisions in Alberta
(Source: http://www.statcan.gc.ca/ca-ra2006/m/alberta2-eng.pdf)



Alberta — Map 1

2006 Census Agricultural Regions and Census Divisions

1 Agricultural Region 1
- 1 Division No. 1
- 4 Division No. 4

2 Agricultural Region 2
- 2 Division No. 2
- 5 Division No. 5

3 Agricultural Region 3
- 3 Division No. 3
- 6 Division No. 6
- 15 Division No. 15

4A Agricultural Region 4A
- 7 Division No. 7

4B Agricultural Region 4B
- 10 Division No. 10

5 Agricultural Region 5
- 8 Division No. 8
- 9 Division No. 9
- 11 Division No. 11

6 Agricultural Region 6
- 12 Division No. 12
- 13 Division No. 13
- 14 Division No. 14
- 16 Division No. 16

7 Agricultural Region 7
- 17 Division No. 17
- 18 Division No. 18
- 19 Division No. 19

Figure 3-3 List of Census Agricultural Regions and Census Divisions in Alberta
(Source: http://www.statcan.gc.ca/ca-ra2006/m/car-rar-eng.pdf)

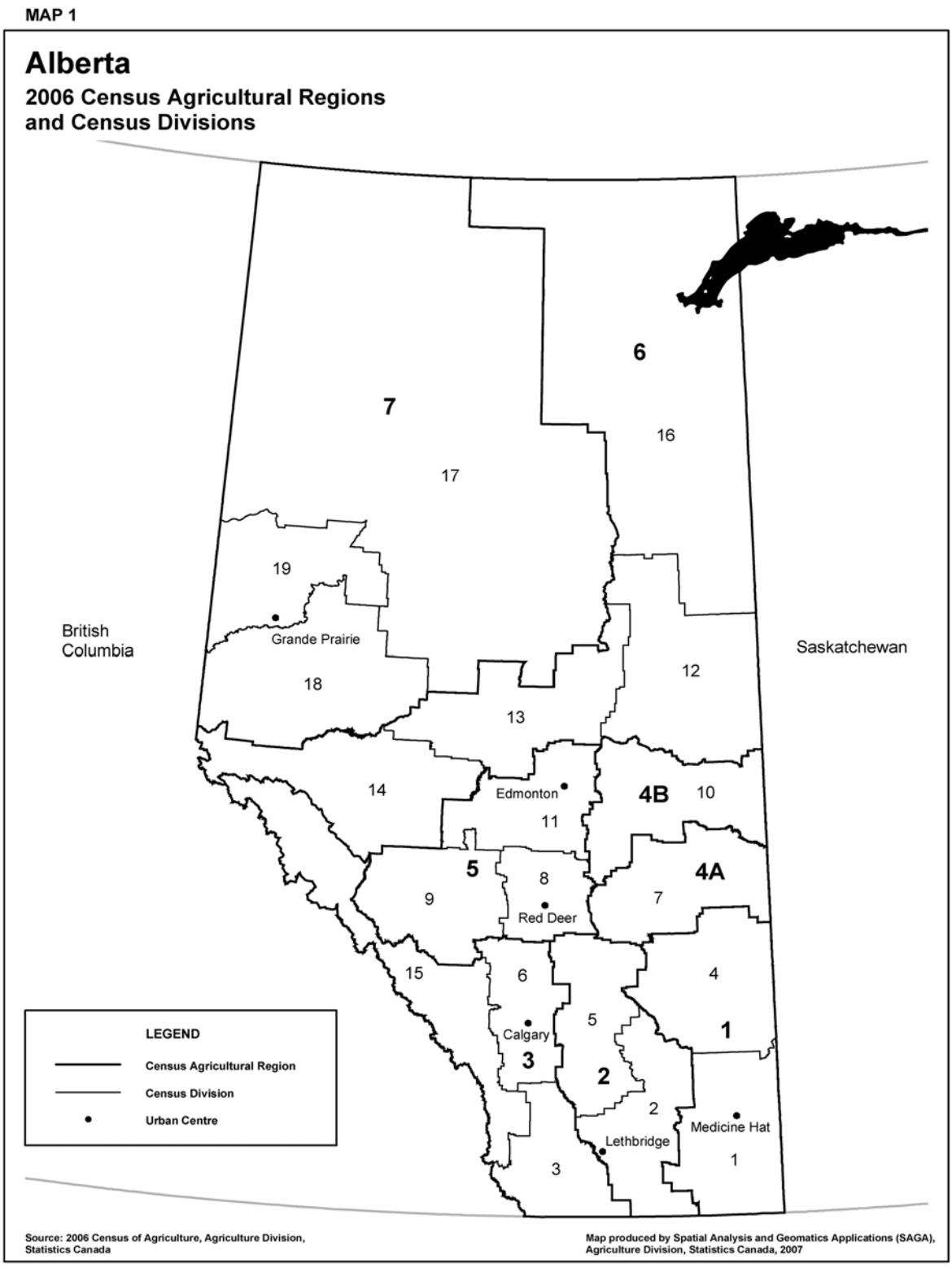


Figure 3-4 Map of CARs and Census Divisions in Alberta (Source: http://www.statcan.gc.ca/ca-ra2006/m/car-rar-eng.pdf)

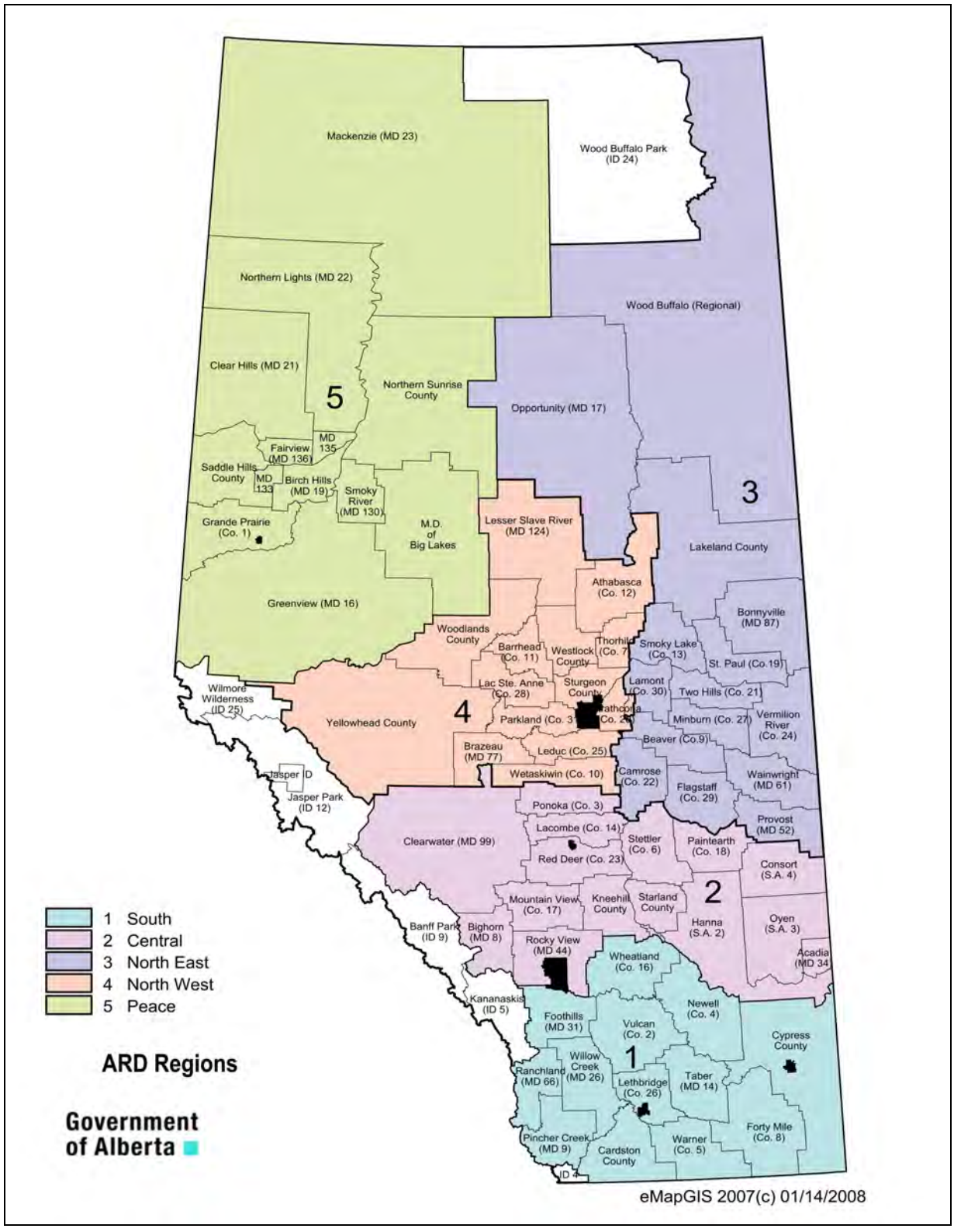


Figure 3-5 Map of ARD-defined Regions in Alberta

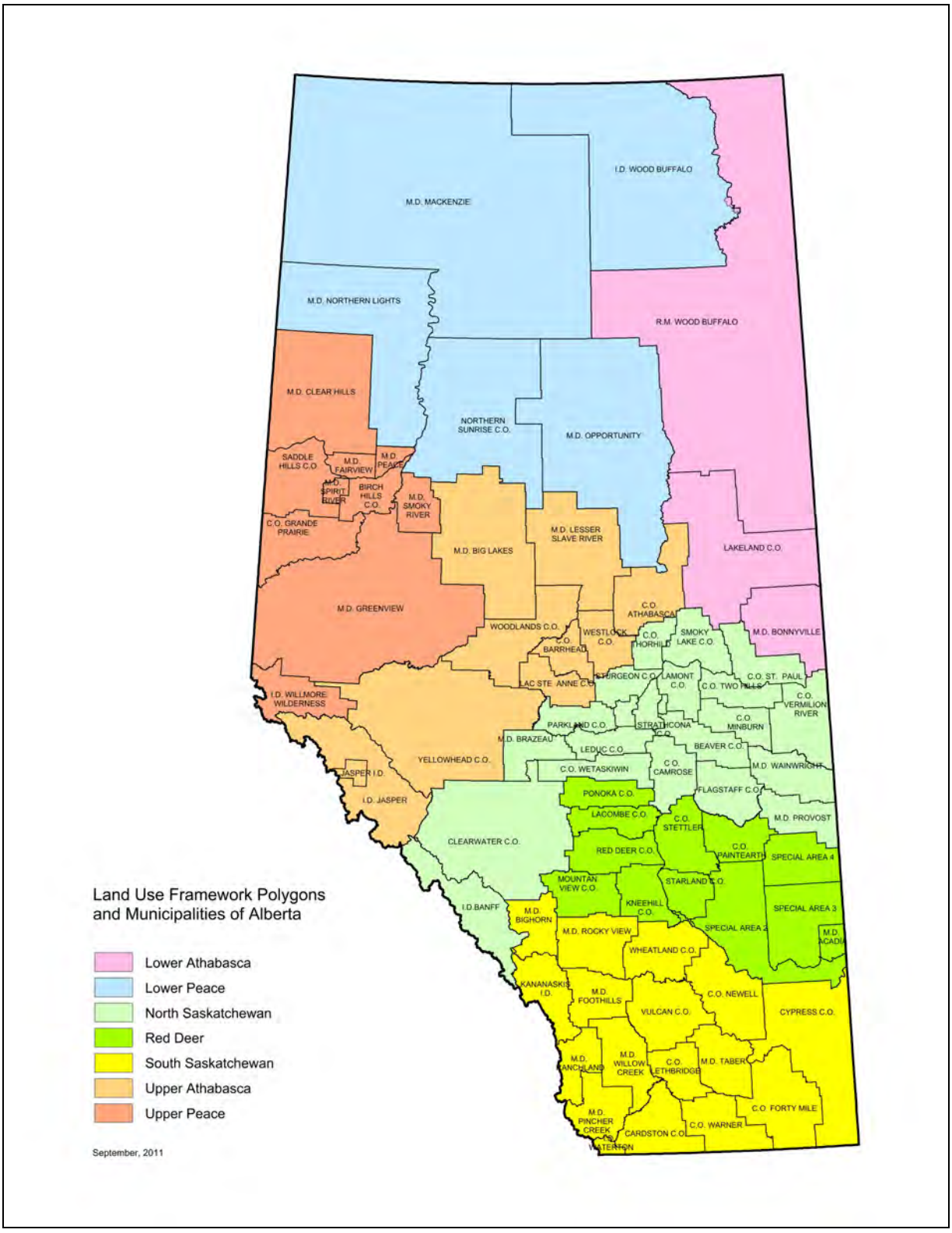


Figure 3-6 Map of LUF Regions in Alberta

Table 3-8 CARs in Alberta and their corresponding municipalities*

Census Agricultural Region	Municipality
Agricultural Region 1	Cypress County, Forty Mile County No. 8, Special Area No. 2. Special Area No. 3, Special Area No. 4
Agricultural Region 2	County of Warner No. 5, County of Lethbridge, M.D. of Taber, County of Newell No. 4, Vulcan County, Wheatland County, Starland County, Kneehill County
Agricultural Region 3	Cardston County, M.D. of Pincher Creek No. 9, M.D. of Willow Creek No. 26, M.D. of Foothills No. 31, M.D. of Rocky View No. 44, Calgary, Mountain View County, M.D. of Bighorn No. 8, M.D. of Ranchland No. 66
Agricultural Region 4A	M.D. of Provost No. 52, County of Paintearth, County of Stettler No. 6, Flagstaff County, M.D. of Wainwright No. 61
Agricultural Region 4B	Camrose County, County of Two Hills No. 21, County of Vermilion River, Beaver County, Lamont County, County of Minburn No. 27
Agricultural Region 5	Brazeau County, Clearwater County, Edmonton, Lacombe County, Leduc County, Parkland County, Ponoka County, Red Deer County, Strathcona County, Sturgeon County, County of Wetaskiwin No. 10
Agricultural Region 6	County of Athabasca No. 12, County of Barrhead No. 11, M.D. of Bonnyville No. 87, Lac Ste. Anne County, Lakeland County, Smoky Lake County, County of St. Paul No. 19, County of Thorhild No. 7, Westlock County, Woodlands County, Yellowhead County
Agricultural Region 7	M.D. of Big Lakes, Birch Hills County, Clear Hills County, M.D. of Fairview No. 136, County of Grande Prairie No. 1, M.D. of Greenview No. 16, M.D. of Lesser Slave River No. 124, Mackenzie County, M.D. of Northern Lights No. 22, Northern Sunrise County, M.D. of Opportunity, M.D. of Peace No. 135, Saddle Hills County, M.D. of Smoky River No. 130, M.D. of Spirit River No. 133

*Only municipalities that have CFOs are listed.

Table 3-9 ARD-defined Regions in Alberta and their corresponding municipalities*

ARD-defined Region	Municipality
South Region	Cardston County, Cypress County, M.D. of Foothills No. 31, Forty Mile County No. 8, County of Lethbridge, County of Newell No. 4, M.D. of Pincher Creek No. 9, M.D. of Ranchland No. 66, M.D. of Taber, Vulcan County, County of Warner No. 5, Wheatland County, M.D. of Willow Creek No. 26
Central Region	M.D. of Acadia No. 34, M.D. of Bighorn No. 8, Calgary, Clearwater County, Kneehill County, Lacombe County, Mountain View County, County of Paintearth, Ponoka County, Red Deer County, Rocky View County No. 44, Special Area No. 2, Special Area No. 3, Special Area No.

ARD-defined Region	Municipality
	4, Starland County, County of Stettler No. 6
North West Region	County of Athabasca No. 12, County of Barrhead No. 11, Brazeau County, Edmonton, Lac Ste. Anne County, Leduc County, M.D. of Lesser Slave River No. 124, Parkland County, Strathcona County, Sturgeon County, County of Thorhild No. 7, Westlock County, County of Wetaskiwin No. 10, Woodlands County, Yellowhead County
North East Region	Beaver County, M.D. of Bonnyville No. 87, Camrose County, Flagstaff County, Lakeland County, Lamont County, County of Minburn No. 27, Provost County No. 52, Smoky Lake County, St. Paul County No. 19, County of Two Hills No. 21, County of Vermilion River, M.D. of Wainwright No. 61
Peace Region	M.D. of Big Lakes, Birch Hills County, Clear Hills County No. 21, M.D. of Fairview No. 136, County of Grande Prairie No. 1, M.D. of Greenview No. 16, Mackenzie County No. 23, M.D. of Northern Lights No. 22, Northern Sunrise County, M.D. of Peace No. 135, Saddle Hills County, M.D. of Smoky River No. 130, M.D. of Spirit River No. 133

*Only municipalities that have CFOs are listed.

Table 3-10 LUF Regions in Alberta and their corresponding municipalities*

Land-use Framework Region	Municipality
South Saskatchewan	County of Lethbridge, County of Newell No. 4, M.D. of Taber, Vulcan County, Wheatland County, County of Warner No. 5, Calgary, M.D. of Rocky View No. 44, Cardston County, Cypress County, Forty Mile County No. 8, M.D. of Pincher Creek No. 9, M.D. of Willow Creek No. 26, M.D. of Ranchland No. 66, M.D. of Foothills No. 31, M.D. of Bighorn No. 8
Red Deer	M.D. of Acadia No. 34, Special Area No. 2, Special Area No. 3, Special Area No. 4, Ponoka County, Red Deer County, Mountain View County, Kneehill County, County of Paintearth, County of Stettler No. 6, Starland County, Lacombe County
North Saskatchewan	M.D. of Provost No. 52, Flagstaff County, Camrose County, County of Two Hills No. 21, County of Vermilion River, M.D. of Wainwright No. 61, Beaver County, Lamont County, County of Minburn No. 27, Brazeau County, Clearwater County, Edmonton, Leduc County, County of Thorhild No. 7, County of St. Paul No. 19, Strathcona County, Sturgeon County, County of Wetaskiwin No. 10, Smoky Lake County, Parkland County
Upper Athabasca	M.D. of Lesser Slave River No. 124, County of Barrhead No. 11, Yellowhead County, County of Athabasca No. 12, Lac Ste. Anne County, Westlock County, Woodlands County, M.D. of Big Lakes

Land-use Framework Region	Municipality
Lower Athabasca	M.D. of Bonnyville No. 87, Regional Wood Buffalo, Lac La Biche County
Upper Peace	M.D. of Greenview No. 16, Birch Hills County, M.D. of Peace No. 135, Saddle Hills County, M.D. of Smoky River No. 130, M.D. of Spirit River No. 133, Clear Hills County, M.D. of Fairview No. 136, County of Grande Prairie No. 1, Improvement District No. 25
Lower Peace	Mackenzie County, M.D. of Northern Lights No. 22, Northern Sunrise County, M.D. of Opportunity

*Only municipalities that have CFOs are listed.

3.3.2 Temporal Distribution of Emissions

CFO emissions were estimated by applying Eq. 1. To reflect climatic and agricultural practice changes throughout the year, NH_3 emissions by livestock sub-category were estimated at a high temporal resolution by multiplying monthly EFs for each municipality by the corresponding estimated monthly AFs. On the other hand, PM emissions by livestock sub-category were estimated at a lower temporal resolution by multiplying the assumed provincial annual EFs by the estimated monthly AF

3.4 Emission Forecast Methodology

An important step in forecasting future trends in emissions is the selection of appropriate, province-wide socio-economic parameters and development of change factors for each source category. Future emissions are anticipated to differ from current emissions following changes in economic activities (typically growth) that influence emissions, changes in the mix of production activities both within and between economic sectors, etc.

Normally three growth scenarios, high, moderate and low, are considered for developing forecasts. Of these three scenarios, the moderate case represents the most realistic socio-economic perspective. It takes into account all current and committed federal, provincial and regional air quality management measures. Hence, a moderate growth factor was selected to forecast future CFO emissions in Alberta.

NH_3 and PM emissions were forecast for APMEICA in five-year increments from 2011 to 2021. This was accomplished by applying growth profiles developed in a prior emission inventory forecast study entitled, "Forecast of Criteria Air Contaminants in Alberta (2002 to 2020)" (Cheminfo 2007). Table 3-11 shows the emission growth factors used to forecast CFO emissions in 2011, 2016, and 2021. In the future, different, more accurate growth factors may be used to predict emissions.

Table 3-11 CFO growth factors for 2011, 2016 and 2021

Source		% Change from 2006		
Type	**Sub-type**	**2011**	**2016**	**2021**
Agriculture	Livestock CFOs	0.6	2.0	3.0

Thus, the following equation was used to predict future emissions of NH_3 and PM in 2011, 2016 and 2021:

$$E_n = AF\left(\frac{GF_n}{100}+1\right)EF_n \quad (3)$$

E_n = Emission calculated for projected year n
AF = Activity factor for 2006
GF_n = Growth factor from 2006 to projected year n
EF_n = Emission factor for projected year n[3]

[3] 2006 EFs were used but should be replaced if new EFs that are more representative of emissions in the projected years become available.

4. Quality Assurance and Quality Control Activities

4.1 Quality Assurance

Quality assurance (QA) procedures were applied to ensure that the EF and AF review and selection processes for APMEICA were accurate, complete, and representative. Table 4-1 outlines elements of the QA procedures that were implemented.

Table 4-1 QA criteria and procedures applied towards the development of APMEICA

Data quality objective	Procedure for achieving objective
Accuracy	For all CFO sources, 100% of the calculations were checked by the data generator, and 10% of the calculations were reviewed by another equally qualified team member.
Completeness	The objective of the inventory was to quantify 100% of the emissions from the largest emitting sources from each source category and as many of the minor sources as possible within the project timeframe.
Representativeness	The inventory results were reviewed and compared to previous emission estimates and/or results from comparable regions to determine the reasonableness and representativeness of the emission estimates.
Accuracy	AFs were gathered from technically robust and credible organizations, such as ARD or SC, for as many source categories as possible.
Completeness	Emissions were estimated for all or most CFO sources in the province.
Representativeness	Emissions were estimated and allocated at CCS level.
Comparability	Results were compared to 2010 Alberta Province-wide Air Emissions Inventory.

4.2 Quality Control

Quality control (QC) activities were implemented by the entire project team during the inventory development to achieve the proposed data quality objectives outlined in Table 4-1. These activities were performed during data collection and data handling and processing.

4.2.1 Data Collection

CFO EFs and AFs were obtained from credible sources, including Canadian national survey reports. Internet and literature searches were performed to complement the above sources in order to identify technical papers, presentations, and other applicable materials for use towards the development of APMEICA. The literature searches focused primarily on identifying current NH_3 and PM EFs for CFOs. Relevant search results were reviewed and discussed by the project team prior to their utilization in the inventory. In addition, relevant data and literature were thoroughly assessed for appropriateness prior to being used in APMEICA.

4.2.2 Data Handling and Processing

All gathered data were checked by the respective project team member. The check was important to ensure data accuracy. Data were checked at logical steps in the development of the inventory where transcription or calculation errors were likely to be found. Data checking was used to assess the technical soundness of the data.

5. Emissions Inventory and Database Compilation

5.1 Emissions Inventory Database Design

In order to enhance the efficiency, reliability and use of APMEICA, MS Access® was selected as the software platform for delivery. Furthermore, MS Access® can be readily converted to newer versions of MS Access® or upsized to MS SQL Server® for online application. An outline of the database design, compilation, and output is presented below. Figure 5-1 is a snapshot of the interrelation between the various indices.

'**Substance**'	Indexed by CAS number; used to store emissions of interest information by their respective livestock categories and sub-categories.
'**Emissions**'	Estimated CFO emissions by livestock category and sub-category, by municipality, by month and by year in 2006.
'**Livestock**'	All livestock-related information including livestock categories and sub-categories; and parameters linked to the 'Growth' index.
'**Growth**'	Growth profiles for each livestock category and sub-category with respect to forecasted emissions in 2011, 2016 and 2021.
'**Counties**'	Index of municipality names and links to other spatially defined regions.

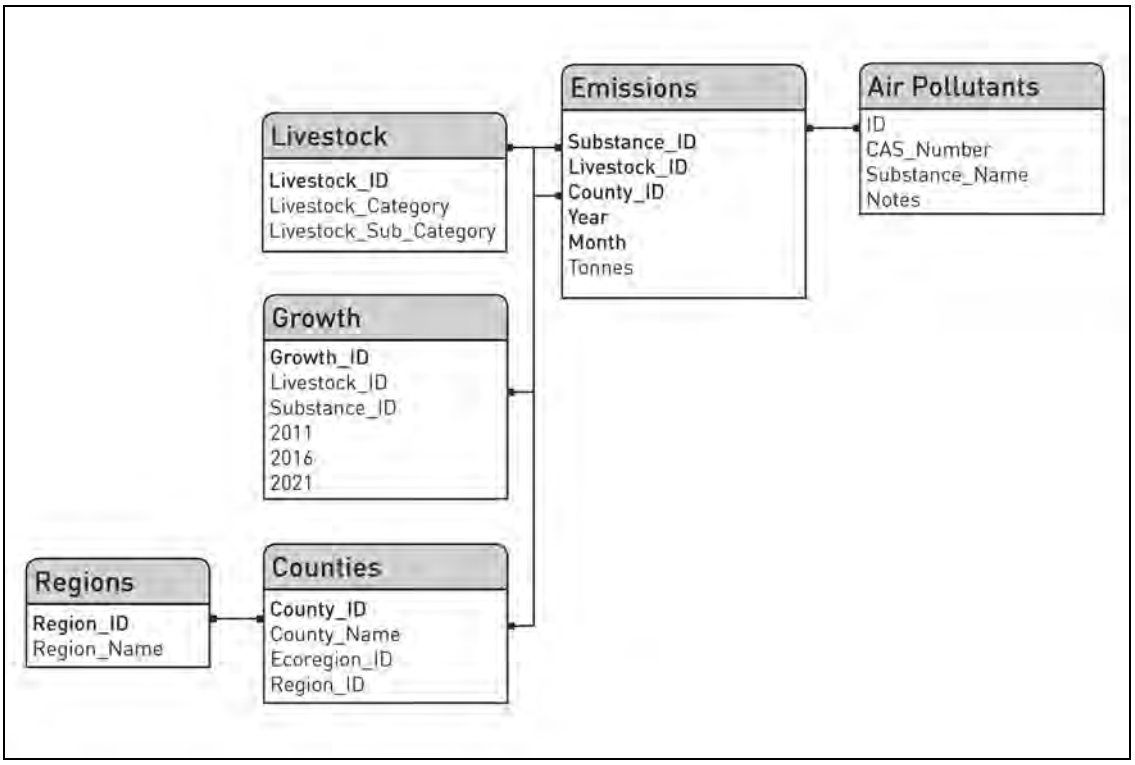


Figure 5-1 Relationship between the various indices in the APMEICA database

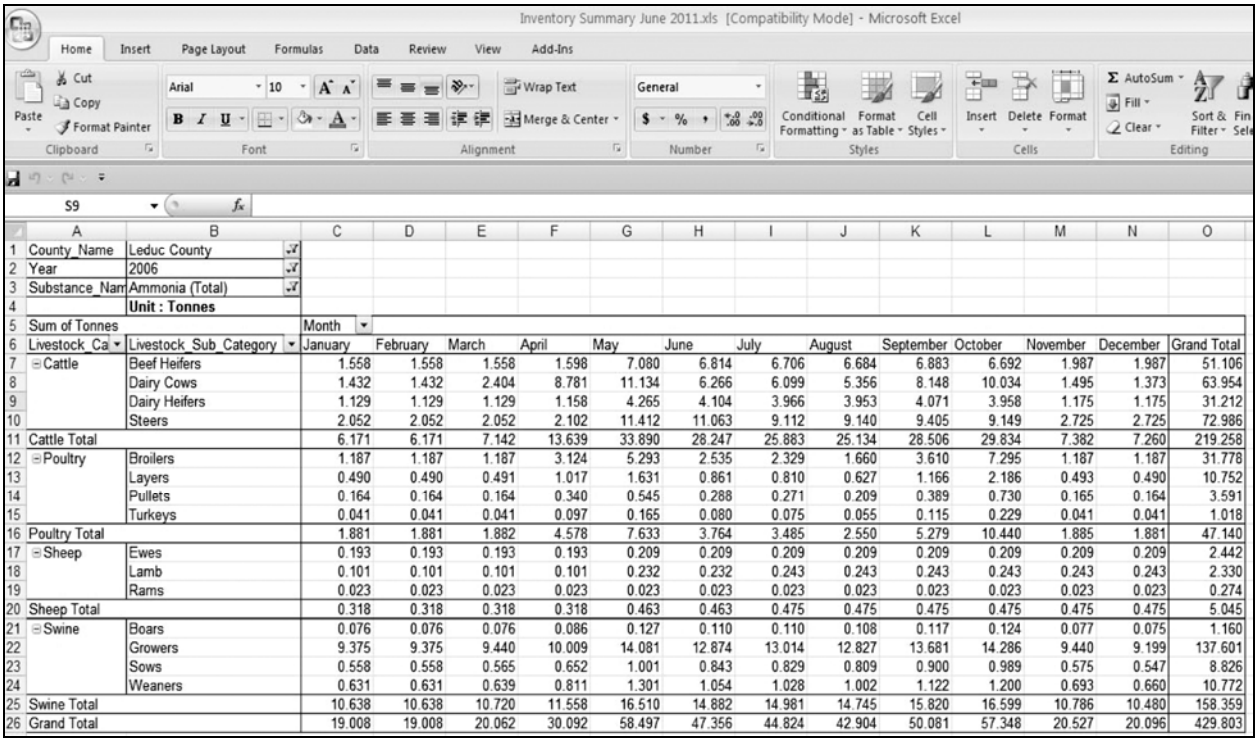
5.2 Emissions Inventory Database Compilation

An MS Excel® template was developed to facilitate easier calculation of emissions and seamless uploading of the emissions into the MS Access® database. Emissions results from the MS Excel® template can also be easily copied and pasted to the 'Emissions' index in the database.

5.3 Emissions Inventory Database Output

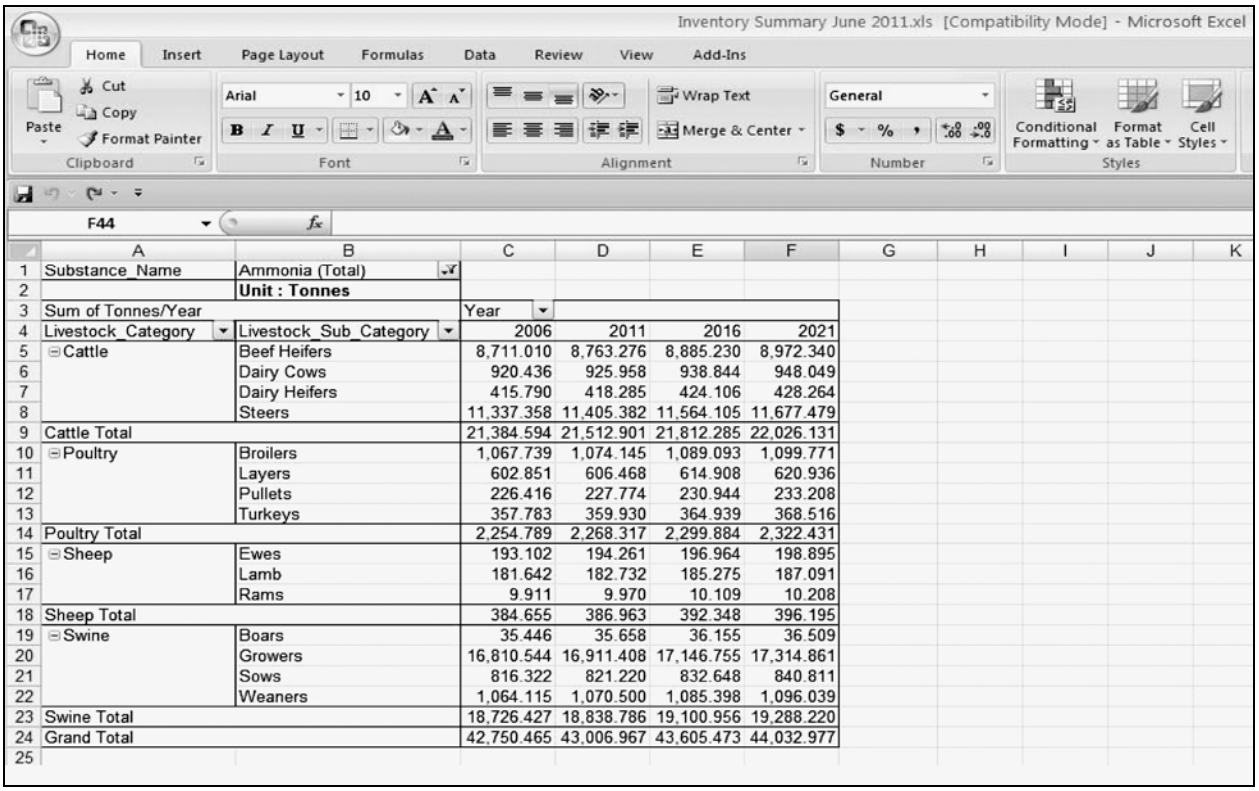
5.3.1 Emission Reports and Queries

A set of database queries and linked pivot tables was developed and included in the final database to facilitate the extraction of data for analysis and reporting purposes. In the data summary spreadsheets, a series of linked MS Excel® pivot tables were included to enable data to be viewed by substance, source, region, etc. Sample snapshots of the MS Excel® pivot tables are shown in Figures 5-2 and 5-3.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	County_Name	Leduc County													
2	Year	2006													
3	Substance_Nam	Ammonia (Total)													
4		**Unit : Tonnes**													
5	Sum of Tonnes		Month												
6	Livestock_Ca	Livestock_Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
7	Cattle	Beef Heifers	1.558	1.558	1.558	1.598	7.080	6.814	6.706	6.684	6.883	6.692	1.987	1.987	51.106
8		Dairy Cows	1.432	1.432	2.404	8.781	11.134	6.266	6.099	5.356	8.148	10.034	1.495	1.373	63.954
9		Dairy Heifers	1.129	1.129	1.129	1.158	4.265	4.104	3.966	3.953	4.071	3.958	1.175	1.175	31.212
10		Steers	2.052	2.052	2.052	2.102	11.412	11.063	9.112	9.140	9.405	9.149	2.725	2.725	72.986
11	Cattle Total		6.171	6.171	7.142	13.639	33.890	28.247	25.883	25.134	28.506	29.834	7.382	7.260	219.258
12	Poultry	Broilers	1.187	1.187	1.187	3.124	5.293	2.535	2.329	1.660	3.610	7.295	1.187	1.187	31.778
13		Layers	0.490	0.490	0.491	1.017	1.631	0.861	0.810	0.627	1.166	2.186	0.493	0.490	10.752
14		Pullets	0.164	0.164	0.164	0.340	0.545	0.288	0.271	0.209	0.389	0.730	0.165	0.164	3.591
15		Turkeys	0.041	0.041	0.041	0.097	0.165	0.080	0.075	0.055	0.115	0.229	0.041	0.041	1.018
16	Poultry Total		1.881	1.881	1.882	4.578	7.633	3.764	3.485	2.550	5.279	10.440	1.885	1.881	47.140
17	Sheep	Ewes	0.193	0.193	0.193	0.193	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	2.442
18		Lamb	0.101	0.101	0.101	0.101	0.232	0.232	0.243	0.243	0.243	0.243	0.243	0.243	2.330
19		Rams	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.274
20	Sheep Total		0.318	0.318	0.318	0.318	0.463	0.463	0.475	0.475	0.475	0.475	0.475	0.475	5.045
21	Swine	Boars	0.076	0.076	0.076	0.086	0.127	0.110	0.110	0.108	0.117	0.124	0.077	0.075	1.160
22		Growers	9.375	9.375	9.440	10.009	14.081	12.874	13.014	12.827	13.681	14.286	9.440	9.199	137.601
23		Sows	0.558	0.558	0.565	0.652	1.001	0.843	0.829	0.809	0.900	0.989	0.575	0.547	8.826
24		Weaners	0.631	0.631	0.639	0.811	1.301	1.054	1.028	1.002	1.122	1.200	0.693	0.660	10.772
25	Swine Total		10.638	10.638	10.720	11.558	16.510	14.882	14.981	14.745	15.820	16.599	10.786	10.480	158.359
26	Grand Total		19.008	19.008	20.062	30.092	58.497	47.356	44.824	42.904	50.081	57.348	20.527	20.096	429.803

Figure 5-2 Sample pivot table showing CFO NH_3 emissions from Leduc County in 2006



	A	B	C	D	E	F	G	H	I	J	K
1	Substance_Name	Ammonia (Total)									
2		**Unit : Tonnes**									
3	Sum of Tonnes/Year		Year								
4	Livestock_Category	Livestock_Sub_Category	2006	2011	2016	2021					
5	Cattle	Beef Heifers	8,711.010	8,763.276	8,885.230	8,972.340					
6		Dairy Cows	920.436	925.958	938.844	948.049					
7		Dairy Heifers	415.790	418.285	424.106	428.264					
8		Steers	11,337.358	11,405.382	11,564.105	11,677.479					
9	Cattle Total		21,384.594	21,512.901	21,812.285	22,026.131					
10	Poultry	Broilers	1,067.739	1,074.145	1,089.093	1,099.771					
11		Layers	602.851	606.468	614.908	620.936					
12		Pullets	226.416	227.774	230.944	233.208					
13		Turkeys	357.783	359.930	364.939	368.516					
14	Poultry Total		2,254.789	2,268.317	2,299.884	2,322.431					
15	Sheep	Ewes	193.102	194.261	196.964	198.895					
16		Lamb	181.642	182.732	185.275	187.091					
17		Rams	9.911	9.970	10.109	10.208					
18	Sheep Total		384.655	386.963	392.348	396.195					
19	Swine	Boars	35.446	35.658	36.155	36.509					
20		Growers	16,810.544	16,911.408	17,146.755	17,314.861					
21		Sows	816.322	821.220	832.648	840.811					
22		Weaners	1,064.115	1,070.500	1,085.398	1,096.039					
23	Swine Total		18,726.427	18,838.786	19,100.956	19,288.220					
24	Grand Total		42,750.465	43,006.967	43,605.473	44,032.977					
25											

Figure 5-3 Sample pivot table showing CFO NH_3 emissions in Alberta in 2006 and forecasts for 2011, 2016 and 2021.

6. Results and Discussion

This section highlights some of the results obtained from APMEICA. It examines the contributions of the different livestock categories to NH_3 and PM emissions, the temporal and spatial distribution of NH_3 emissions, NH_3 and PM emissions from CFOs compared to other industries in Alberta, and forecasted emission estimates.

6.1 Ammonia Emissions

6.1.1 Distribution by Livestock Category

Estimates from APMEICA indicated that CFOs in Alberta were responsible for emitting 42,750 tonnes of NH_3 in 2006 (Appendix C4). Table 6-1 shows the estimated contributions of the various livestock categories and sub-categories to province-wide CFO NH_3 emissions. Among the various types of CFOs in Alberta, beef cattle CFOs were the largest contributors to NH_3 emissions and swine CFOs were the second largest (Figure 6-1). Grower and finisher pigs contributed about 89% of the NH_3 emissions from swine (Figure 6-2). Collectively, beef and swine accounted for 91% of annual NH_3 emissions from CFOs in Alberta, while dairy, poultry and sheep collectively contributed only 9% of the total NH_3 emissions.

Table 6-1 Contribution of different livestock categories and sub-categories to NH_3 emissions in Alberta in 2006

Livestock		NH_3 emissions (tonnes)
Beef		
	Heifers	8,711
	Steers	11,337
Subtotal		**20,048**
Dairy		
	Heifers	416
	Cows	920
Subtotal		**1,336**
Poultry		
	Broilers	1,068
	Layers	603
	Pullets	226

Livestock		NH_3 emissions (tonnes)
	Turkeys	358
Subtotal		2,255
Sheep		
	Ewes	193
	Lambs	182
	Rams	10
Subtotal		385
Swine		
	Boars	35
	Growers	16,811
	Sows	816
	Weaners	1,064
Subtotal		**18,726**
Total		**42,750**

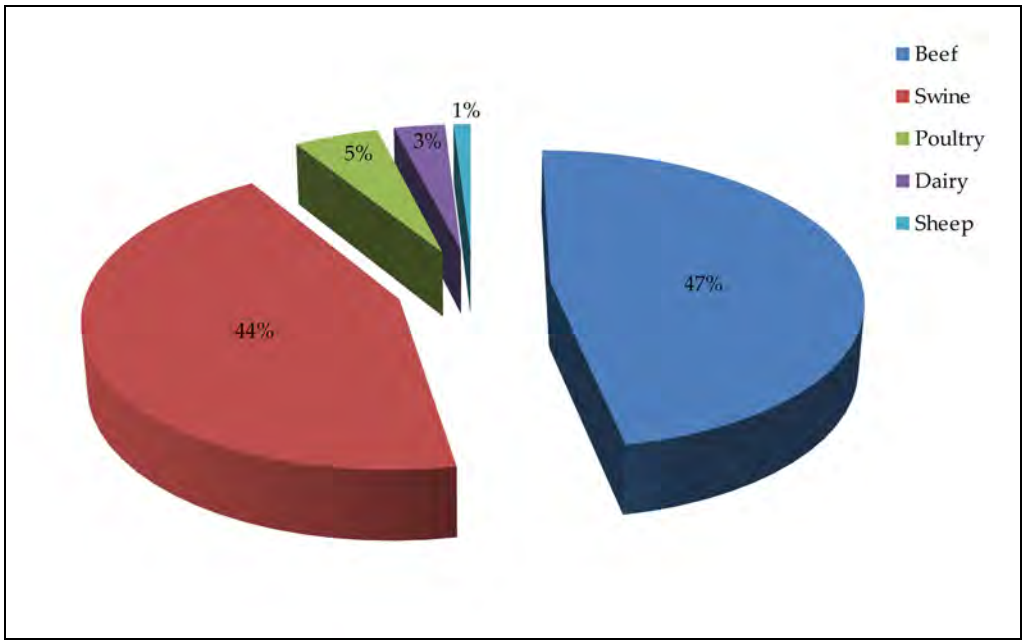


Figure 6-1 Distribution of CFO NH_3 emissions in Alberta by livestock category in 2006

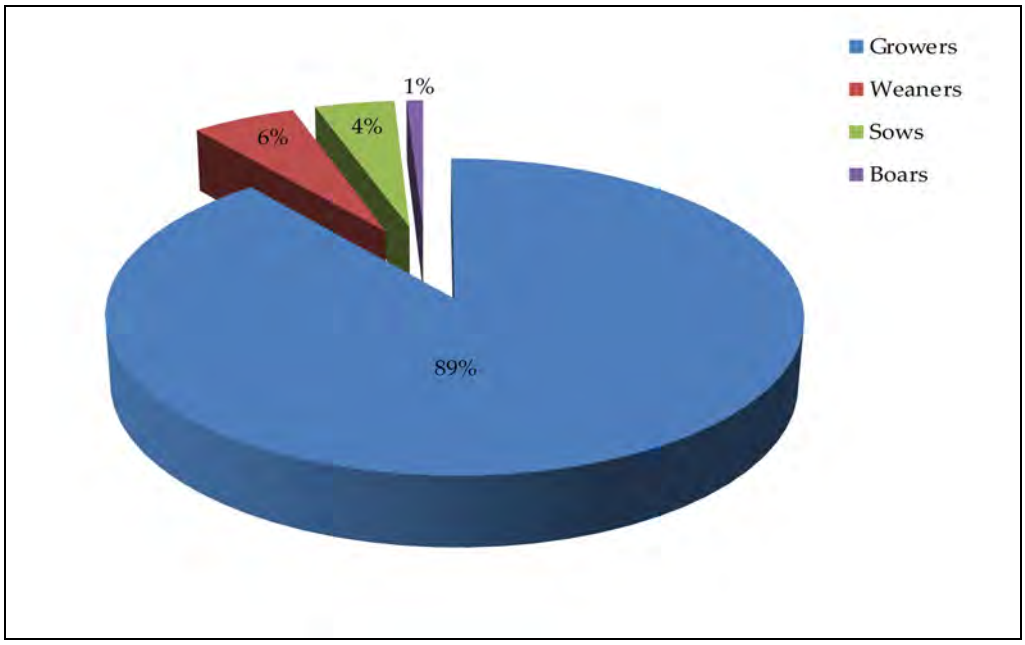


Figure 6-2 Distribution of CFO NH_3 emissions in Alberta by swine sub-category in 2006

6.1.2 Temporal Distribution

NH_3 emissions are expected to vary throughout the year as livestock feeding practices and weather conditions change seasonally throughout the year. Output from APMEICA indicated that NH_3 emissions were highest in late spring and summer when warm temperatures increased the rate of NH_3 volatilization from manure, and in fall when increased quantities of manure were applied on land subsequently increasing the total amount of volatilized NH_3 (Figure 6-3). NH_3 emissions were lowest in late fall and in winter when the coldest temperatures are experienced, typically. Furthermore, a close review of the input data indicated that EFs, as opposed to AFs, had a greater temporal effect on NH_3 emission estimates.

Temperature influences NH_3 volatilization in three main ways. Firstly, the solubility of NH_3 in the substrates decreases with increasing temperature. Secondly, temperature influences the NH_{4+}/ NH_3 equilibrium. At a given pH, the amount of anionized NH_3 increases at higher temperatures. Thirdly, mineralization increases at higher temperatures, resulting in an increase in NH_3 production (Arogo et al. 2003).

When data from all livestock categories were pooled, the estimated NH_3 emissions in May were highest. By livestock category, NH_3 emissions from cattle were highest in May, and emissions from swine and poultry were highest in October. Although relatively similar, output from the NAESI emissions inventory indicated that NH_3 emissions from beef cattle heifers and steers were slightly higher in October than in May (Figure 6-4).

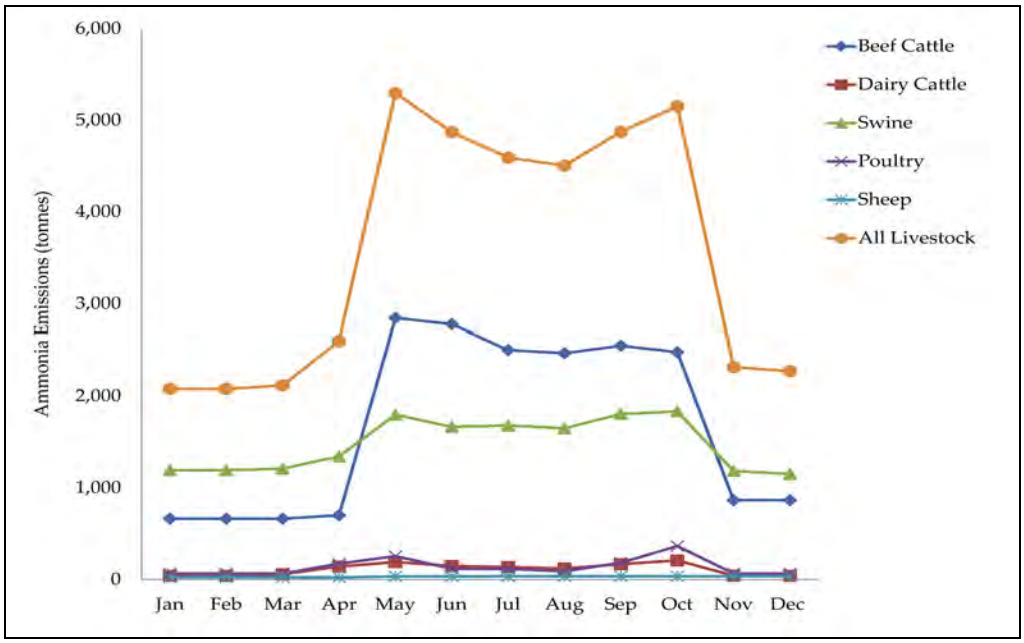


Figure 6-3 Monthly variations in NH_3 emissions from all CFO livestock categories in 2006

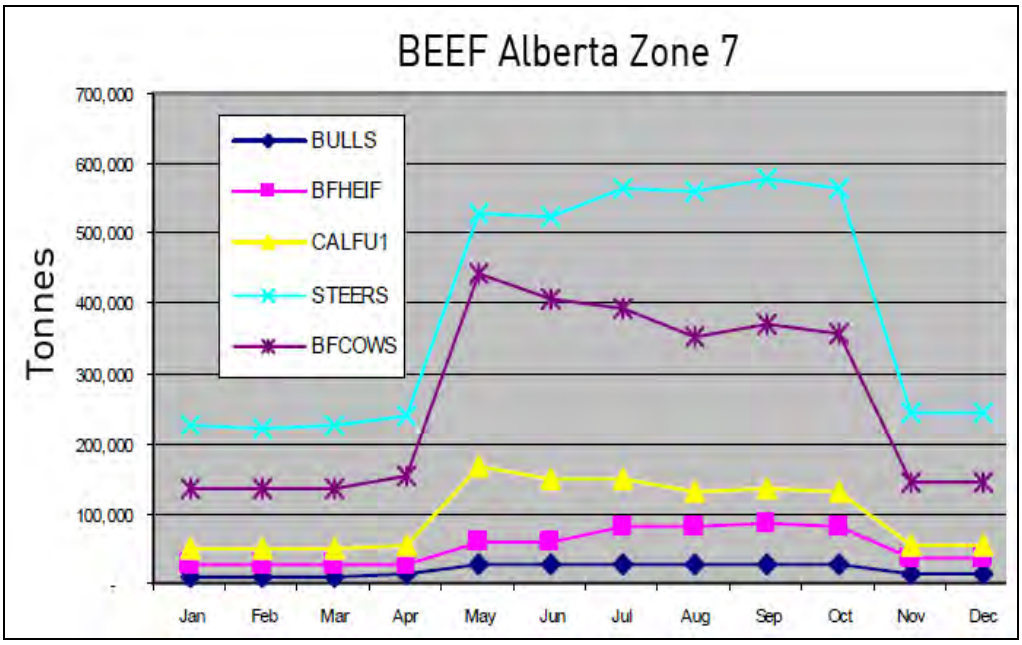


Figure 6-4 Monthly variations in NH_3 emissions from all beef cattle sub-categories in the NAESI 2002 emission inventory (adapted from Bittman and Sheppard 2008).
Note: BFHEIF = Beef Heifers; BFCOWS = Beef Cows; CALFUI = Calves

6.1.3 Spatial Distribution

Previous agricultural emission inventories in Alberta estimated emissions on a provincial scale, i.e., at a low spatial resolution. In order to address the geographic variation in CFO NH_3

emissions across Alberta, APMEICA was designed to estimate NH_3 emissions at the more detailed municipal (CCS) scale. When emissions at lower spatial resolutions were desired, e.g., a regional scale, these were calculated by aggregating the emission estimates at the municipal (CCS) scale.

6.1.3.1 ARD-defined Regional Scale

Figure 6-5 shows the distribution of estimated CFO NH_3 emissions sorted by ARD-defined Region in 2006. A complete dataset of NH_3 emissions sorted by ARD-defined Region is presented in Appendix C2.

Among the ARD-defined Regions, NH_3 emission estimates were highest in the South Region, contributing about 47% of the total CFO NH_3 emissions in Alberta. Within the South Region, beef cattle contributed about 58% of NH_3 emissions from CFOs, representing about 27% of the total NH_3 emissions in Alberta. In contrast, the Peace Region had the lowest NH_3 emissions, contributing 2.2 % of the total NH_3 emissions from CFOs in the province.

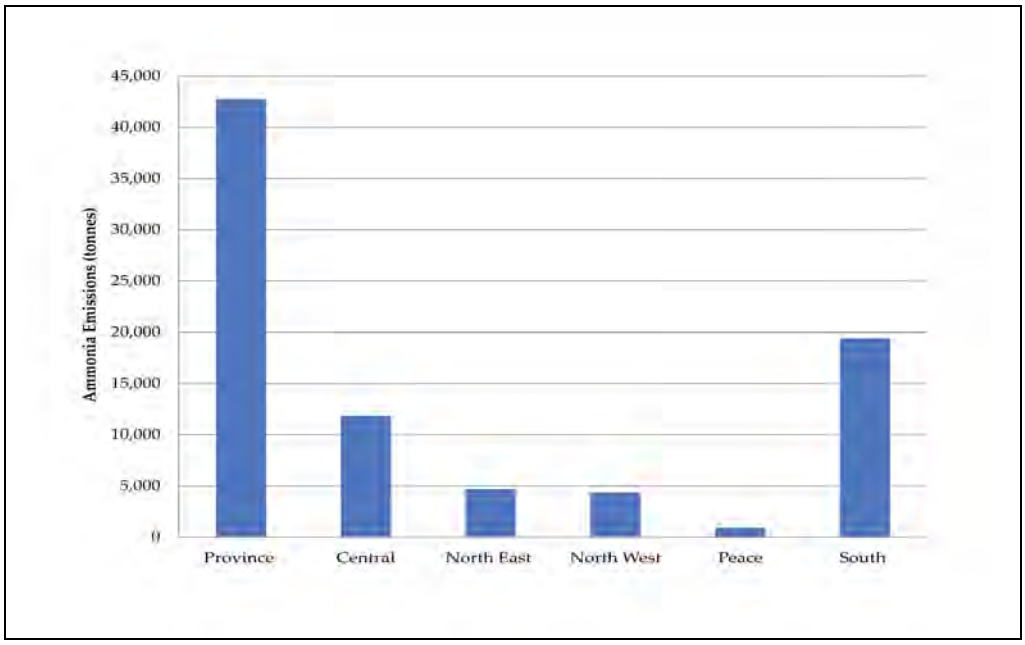


Figure 6-5 Distribution of CFO NH_3 emissions in Alberta sorted by ARD-defined Region

6.1.3.2 Census Agricultural Regional Scale

Figure 6-6 shows the distribution of CFO NH_3 emission estimates sorted by CAR in Alberta in 2006. A complete dataset of NH_3 emissions sorted by CAR is presented in Appendix C3.

Of the CARs, Region 2 had the highest NH_3 emissions. It contributed about 41% of the total CFO NH_3 emissions in Alberta. Within Region 2, beef cattle CFOs contributed about 59% of NH_3

emissions, representing 24% of the total CFO NH_3 emissions in the province. The lowest NH_3 emissions occurred in Region 7, contributing about 2.2 % of the total NH_3 emissions in the province.

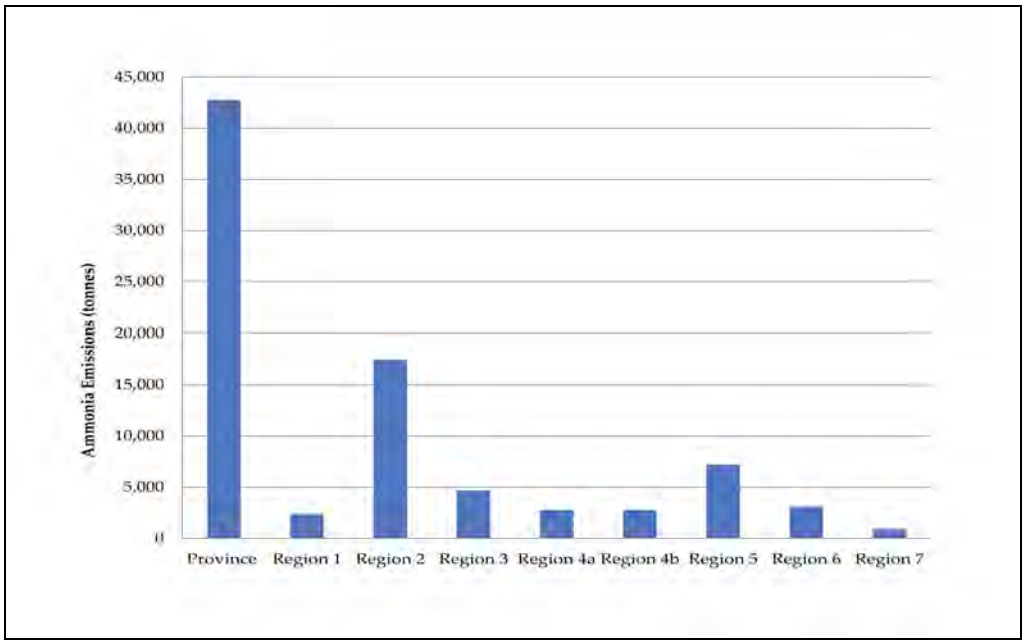


Figure 6-6 Distribution of CFO NH_3 emissions in Alberta sorted by CAR

6.1.3.3 Land Use Framework Regional Scale

Figure 6-7 shows the distribution of CFO NH_3 emission estimates sorted by LUF Region in Alberta for 2006. A complete dataset of NH_3 emissions sorted by LUF Region is presented in Appendix C1.

Of the seven LUF Regions, CFOs in the South Saskatchewan Region emitted the most NH_3, contributing about 49% of total NH_3 emissions in the province. Within the region, about 60% of NH_3 emissions were attributed to beef cattle CFOs, representing 28% of total NH_3 emissions in Alberta. In comparison, the least amount of NH_3 was emitted in the Lower Peace Region, contributing about 0.3 % of total CFO NH_3 emissions in Alberta.

6.1.3.4 Municipal Scale

Due to the sheer volume of data, NH_3 emissions by municipality are not presented in this report. However, the results logically indicated that municipalities in Alberta with higher CFO AFs in 2006 had the tendency to emit the most amounts of NH_3 emissions. Conversely, municipalities that had low CFO livestock numbers emitted negligible amounts of NH_3. In other words, AFs seemed to have had a greater influence on NH_3 emissions than EFs.

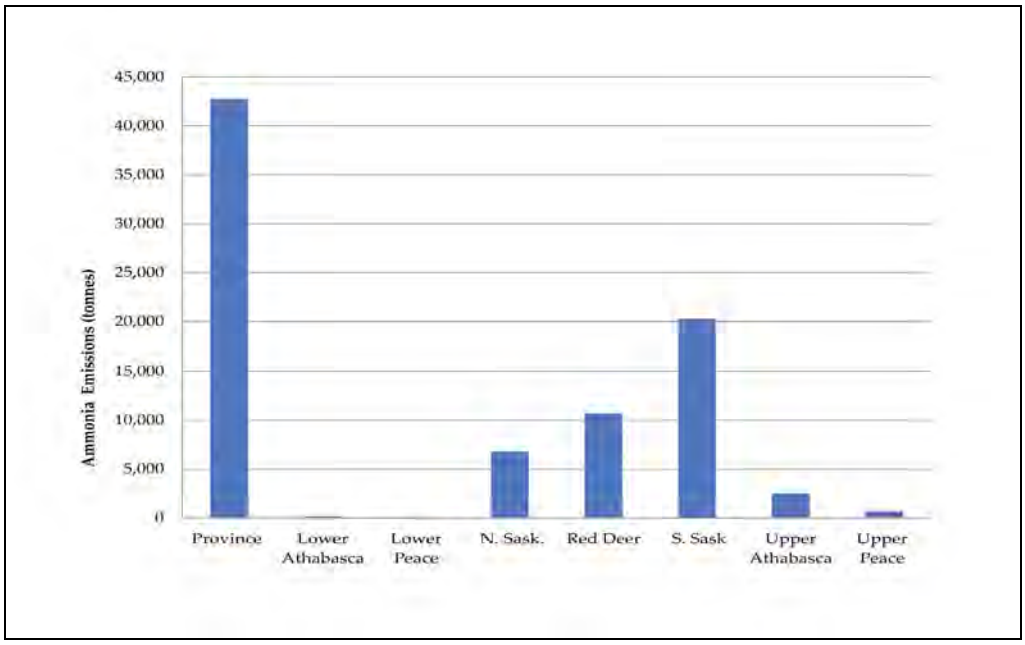


Figure 6-7 Distribution of CFO NH_3 emissions in Alberta sorted by LUF Region

Of the 73 municipalities with CFOs in Alberta, five municipalities namely, Lacombe County, County of Lethbridge, County of Newell, M.D. of Taber and Wheatland County, contributed the most NH_3 emissions in 2006. The County of Lethbridge had the highest NH_3 emissions of the five, accounting for approximately 14% of total CFO NH_3 emissions in Alberta. Upon further review, beef cattle CFOs in the County of Lethbridge were responsible for approximately 75% of the NH_3 emissions in the county. CFOs in Lacombe County were the second highest emitters of NH_3 of the five municipalities, with swine CFOs contributing about 81% of total NH_3 emissions from all CFOs in the county.

6.1.4 Apportionment of Ammonia Emissions in Alberta

According to EC (2009), agriculture and fertilizer use contributed 88% of total NH_3 emissions in Alberta in 2009. Chetner and Sasaki (2001) estimated that the agricultural industry in Alberta contributed about 90% of the total provincial NH_3 emissions while other industries contributed the remaining 10%. Table 6-2 shows a comparison of NH_3 emissions from CFOs determined using APMEICA to the emissions from other sources in Alberta in 2006. The results signify that, of the three sources, CFOs contributed about 81% of the total estimated NH_3 emissions.

6.1.5 Ammonia Emission Forecasts

Forecasted NH_3 emissions for 2011, 2016 and 2021 are presented in Figure 6-8. The forecasts indicate a slight upward trend in future NH_3 emissions from CFOs as a whole, although some livestock categories show little or no change in the future. More detailed forecast data are presented in Appendix C7.

Table 6-2 Annual CFO NH_3 emissions in 2006 compared to emissions from other sources in Alberta*

Sector	NH_3 emissions (tonnes)
CFOs (APMEICA)	42,750
Industrial point sources*	7,765
Mobile sources*	1,947

* Levelton Consultants Ltd. (2010)

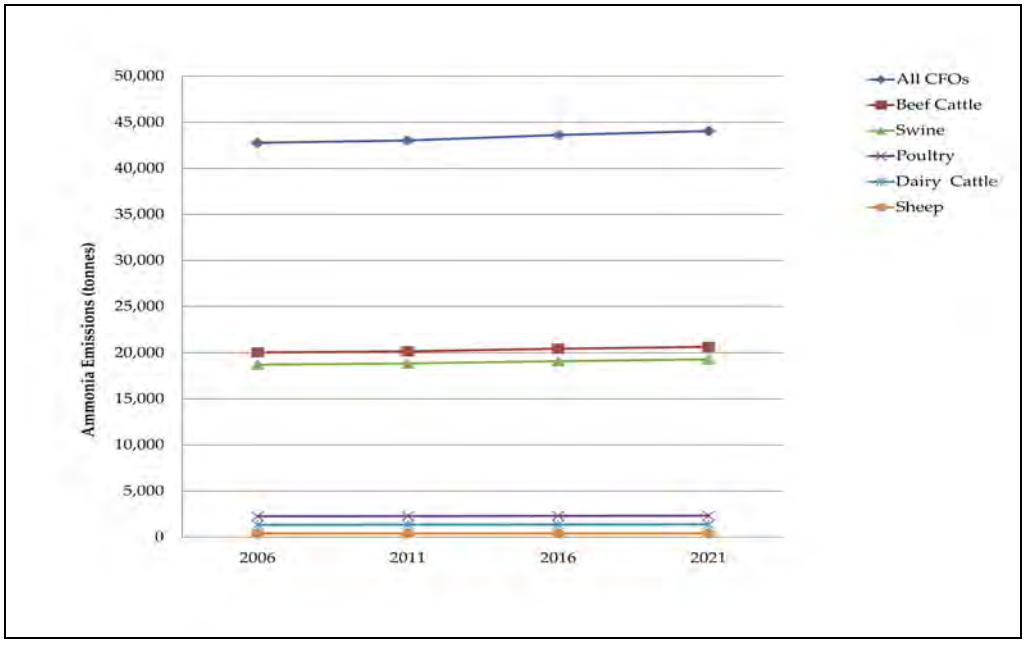


Figure 6-8 CFO NH_3 emissions forecasts for 2011, 2016 and 2021

6.2 Particulate Matter Emissions

6.2.1 Distribution by Livestock Category

CFOs in Alberta appeared to be responsible for emitting approximately 1,762 tonnes and 380 tonnes of PM_{10} and $PM_{2.5}$, respectively, in 2006 (Table 6-3, Appendix C5 and C6). Among the various livestock categories, beef cattle CFOs emitted the greatest amount of PM_{10}, contributing about 54% of the total CFO-related emissions in the province (Figure 6-9). Swine CFOs were next, contributing about 33% of the total emissions. The other livestock categories contributed approximately 13% of the total.

$PM_{2.5}$ emissions followed a similar pattern (Figure 6-10), with beef cattle CFOs contributing the largest amount, about 56% of the total CFO-related emissions in Alberta, and swine CFOs contributing the second largest amount, about 34% of the total.

Table 6-3 Breakdown of PM_{10} and $PM_{2.5}$ emissions by livestock category in 2006

Livestock		PM Emissions (tonnes)	
		PM_{10}	$PM_{2.5}$
Beef			
	Heifers	470	105
	Steers	485	108
		955	213
Dairy	Cows	72	16
	Heifers	23	5
Subtotal		95	21
Poultry			
	Broilers	86	11
	Layers	26	3
	Pullets	10	1
	Turkeys	7	1
Subtotal		130	17
Sheep			
	Ewes	3	1
	Lambs	3	1
	Rams	0	0
Subtotal		7	1
Swine			
	Boars	3	1
	Growers	455	101
	Sows	69	15
	Weaners	49	11
Subtotal		576	128
Total		1,762	380

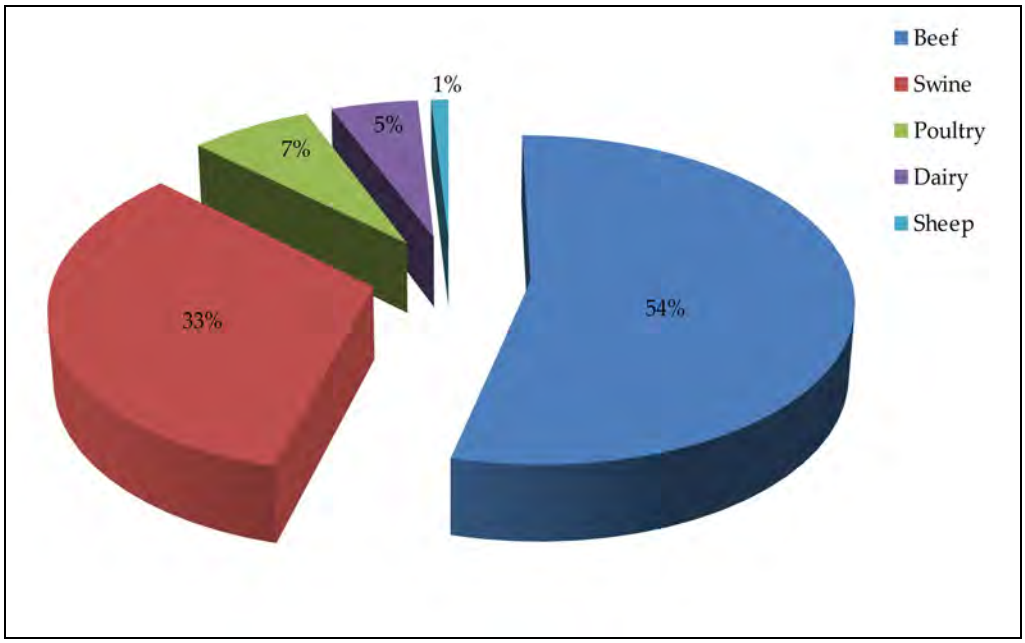


Figure 6-9 Distribution of CFO PM_{10} emissions in Alberta by livestock category in 2006

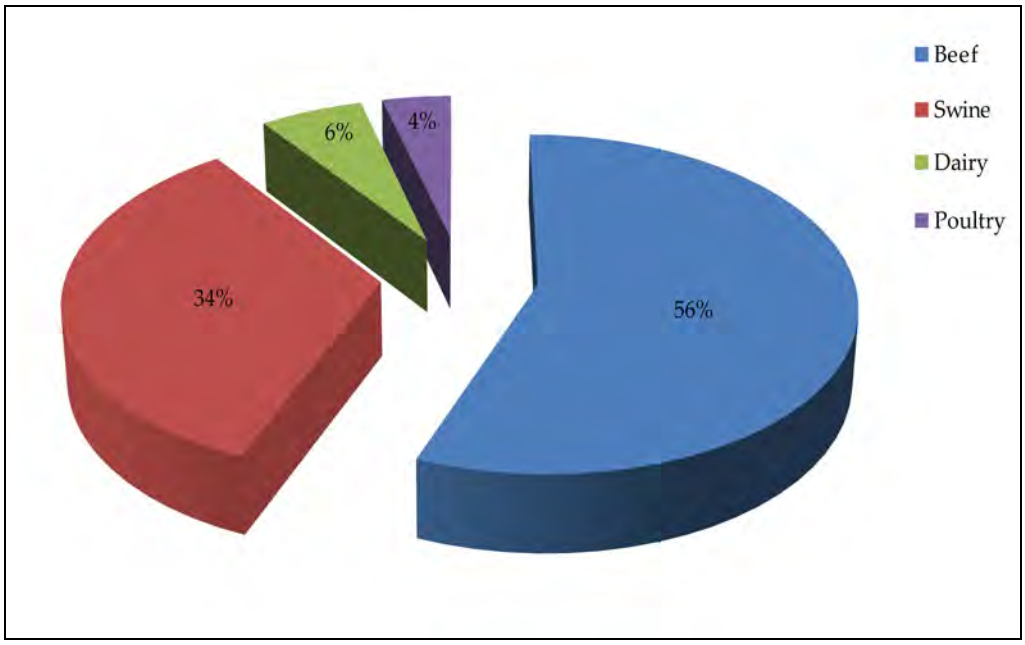


Figure 6-10 Distribution of CFO $PM_{2.5}$ emissions in Alberta by livestock category in 2006

6.2.2 Temporal Distribution

Seasonal variations in CFO PM emissions are assumed to occur every year, so they likely occurred in 2006. However, unlike NH_3 EFs, no monthly PM EFs were found for CFOs. Therefore PM emissions were estimated on an annual basis by APMEICA, i.e., at a low temporal resolution.

6.2.3 Spatial Distribution

As stated earlier, previous agricultural emission inventories in Alberta estimated emissions on a provincial scale, i.e., at a low spatial resolution. APMEICA was designed to estimate CFO PM_{10} and $PM_{2.5}$ emissions at the comparatively detailed municipal (CCS) scale. When emissions at lower spatial resolutions were desired, e.g., a regional scale, these were calculated by aggregating the emission estimates at the municipal (CCS) scale.

6.2.3.1 Census Agricultural Regional Scale

Figure 6-11 shows the distribution of CFO PM_{10} and $PM_{2.5}$ emissions estimates sorted by CAR in Alberta for 2006. A complete dataset of PM emissions sorted by CAR is presented in Appendix C3.

Of the CARs, Region 2 had the highest PM emissions. It contributed about 43% of the total CFO PM emissions, i.e., combined PM_{10} and $PM_{2.5}$ emissions in Alberta. In contrast, Region 7 was estimated to emit the least amount of PM emissions, contributing about 2.4% of the total provincial CFO PM emissions. Of the various livestock categories within Region 2, beef cattle CFOs were estimated to contribute about 66% of the PM emissions.

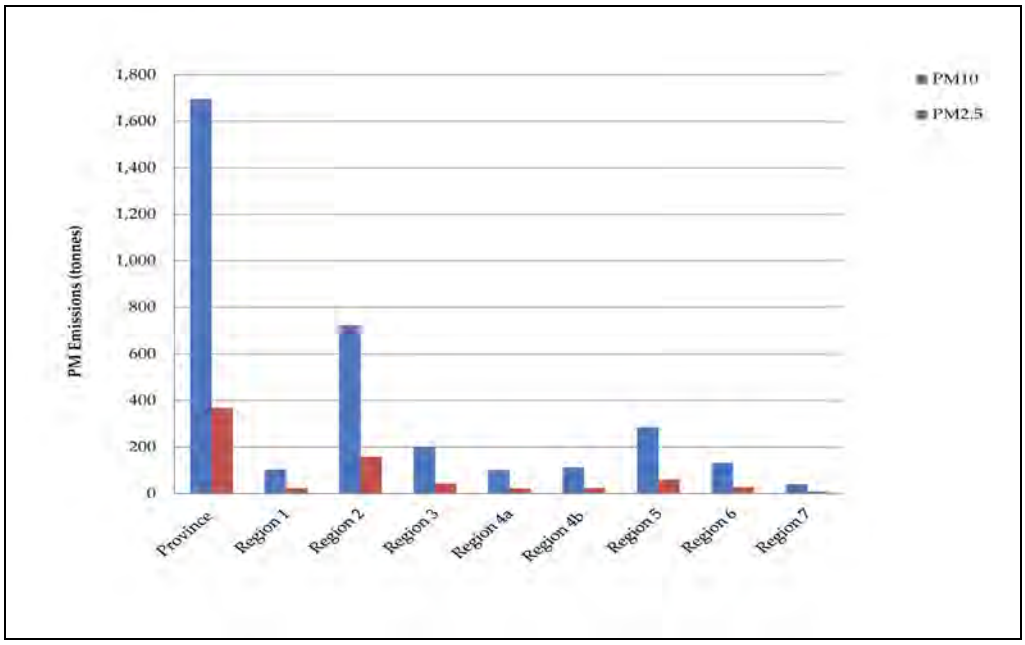


Figure 6-11 Distribution of CFO PM_{10} and $PM_{2.5}$ emissions in Alberta sorted by CAR

6.2.3.2 Land Use Framework Regional Scale

Figure 6-12 shows the distribution of CFO PM_{10} and $PM_{2.5}$ emissions estimates sorted by LUF Region in Alberta for 2006. A complete dataset of PM emissions by LUF Region is presented in Appendix C1.

Of the seven LUF Regions in Alberta, the South Saskatchewan Region (SSR) was estimated to emit the highest amount of PM emissions, contributing about 50% of the total provincial CFO PM emissions. Conversely, the Lower Peace Region was estimated to emit the least amount of PM emissions, contributing about 0.3% of the total. Within the South Saskatchewan Region, beef cattle were estimated to contribute about 67% of the PM emissions, representing approximately 34% of the total PM emissions in Alberta.

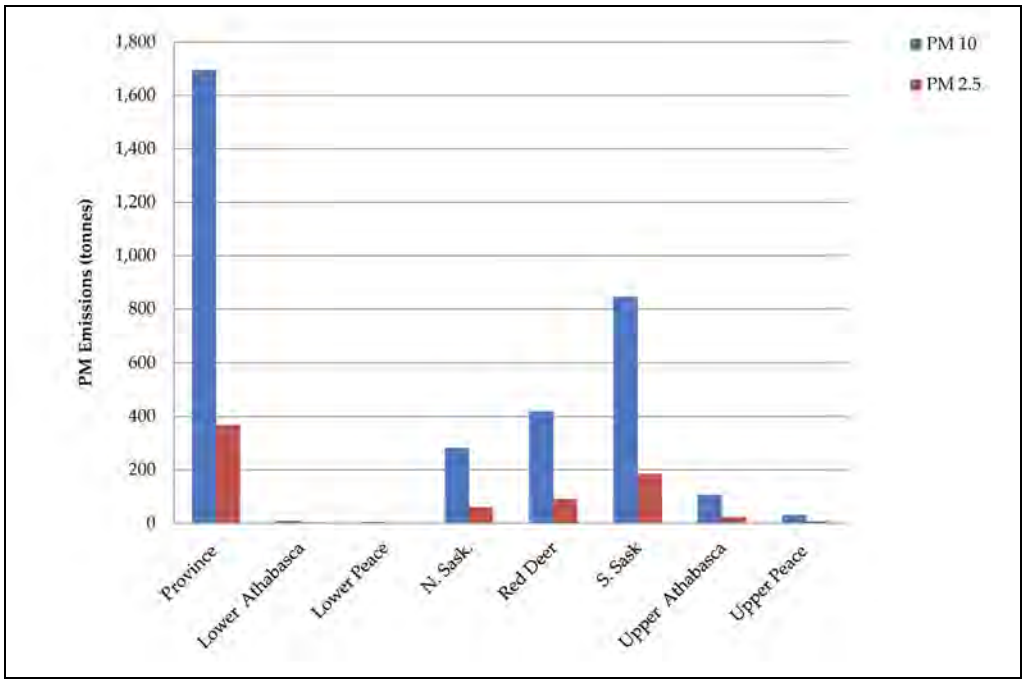


Figure 6-12 Distribution of CFO PM_{10} and $PM_{2.5}$ emissions in Alberta sorted by LUF Region

6.2.3.3 ARD-defined Regional Scale

Figure 6-13 shows the distribution of CFO PM_{10} and $PM_{2.5}$ emissions estimates sorted by ARD-defined Region in Alberta for 2006. A complete dataset of PM emissions sorted by ARD-defined Region is presented in Appendix C2.

Among the ARD-defined Regions, the South Region was estimated to emit the highest amount of PM in Alberta in 2006, contributing about 48% of the total provincial CFO PM emissions. On the other hand, the Peace Region was estimated to emit the least PM emissions, contributing 2.4% of the provincial total. Within the South Region, beef CFOs contributed about 71% of the CFO PM emissions.

6.2.3.4 Municipal Scale

Data reflecting PM emissions by municipality are not presented in this report due to the sheer volume of data. Similar to NH_3 emissions, the results logically indicated that municipalities in Alberta with higher CFO AFs in 2006 had the tendency to emit the highest amounts of PM emissions. Conversely, municipalities that had low CFO livestock numbers emitted negligible

amounts of PM. Again, the results suggest that AFs had a greater influence on PM emissions than EFs.

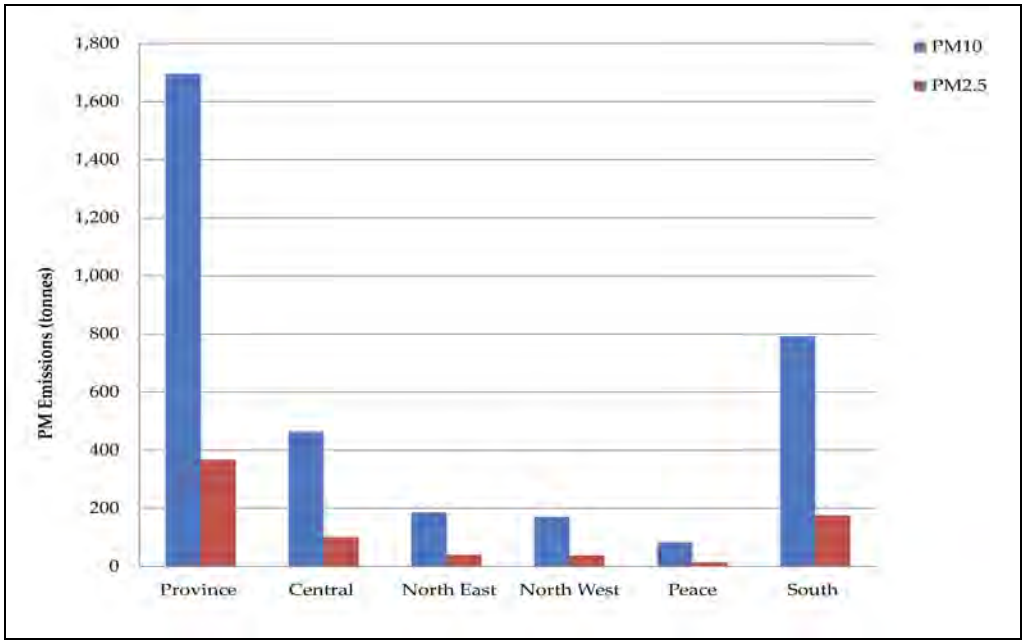


Figure 6-13 Distribution of CFO PM_{10} and $PM_{2.5}$ emissions in Alberta sorted by ARD-defined Region

CFOs in five municipalities namely, Lacombe County, County of Lethbridge, County of Newell, M.D. of Taber and Wheatland County, were estimated to emit the most PM emissions in Alberta. CFOs in the County of Lethbridge emitted the highest amount, representing about 15% of the provincial total. Upon further review, beef cattle CFOs in the County of Lethbridge were estimated to contribute about 77% and 79% of the county's PM_{10} and $PM_{2.5}$ emissions, respectively.

6.2.4 Apportionment of PM Emissions in Alberta

As indicated in Table 6-4, CFOs in Alberta emitted approximately 7% and 0.2% of the PM_{10} emissions from industrial point sources and mobile sources, respectively, in 2006. Similarly, CFO $PM_{2.5}$ emissions were approximately 2% and 0.4% of the emissions from industrial point sources and mobile sources, respectively.

Table 6-4 Annual CFO PM emissions in 2006 compared to emissions from other sources in Alberta*

Sector	PM Emissions (tonnes)	
	PM_{10}	$PM_{2.5}$
CFOs (APMEICA)	1,762	380
Industrial point sources*	25,837	19,340
Mobile sources (includes road dust)*	758,104	106,237

*Levelton Consultants Ltd. (2010)

6.2.5 Particulate Matter Emission Forecasts

Forecasted PM_{10} and $PM_{2.5}$ emissions in 2011, 2016 and 2021 are presented in Figures 6-14 and 6-15, respectively. The forecasts indicate a slightly upward trend in future PM emissions from CFOs as a whole. Forecasts for some livestock categories show little or no change in the future. More detailed forecast data are presented in Appendix C8 (PM_{10}) and Appendix C9 ($PM_{2.5}$).

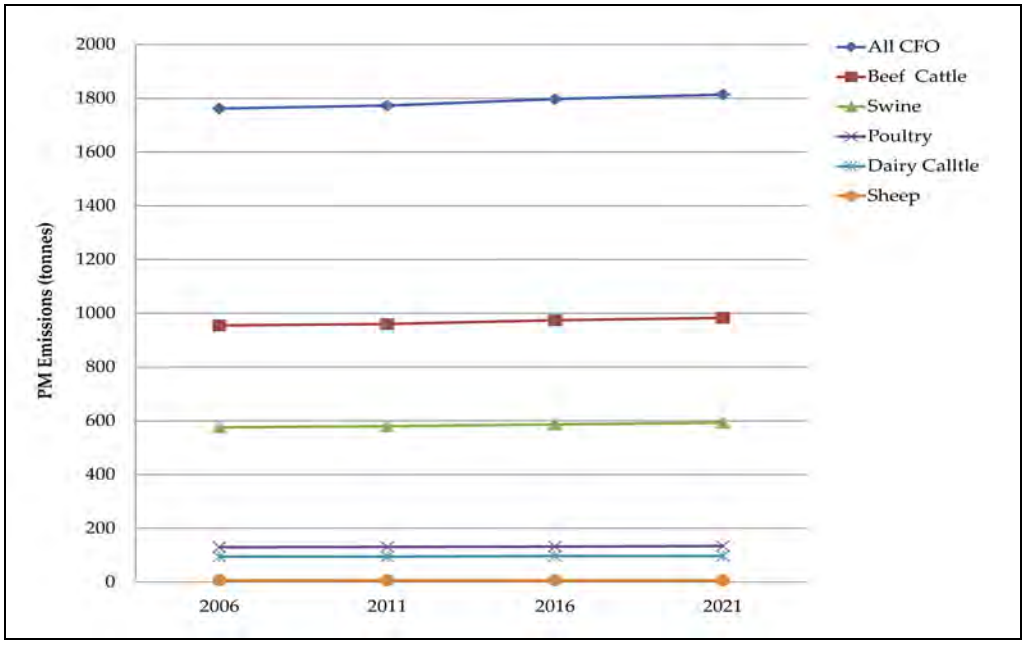


Figure 6-14 CFO PM_{10} emissions forecasts for 2011, 2016 and 2021

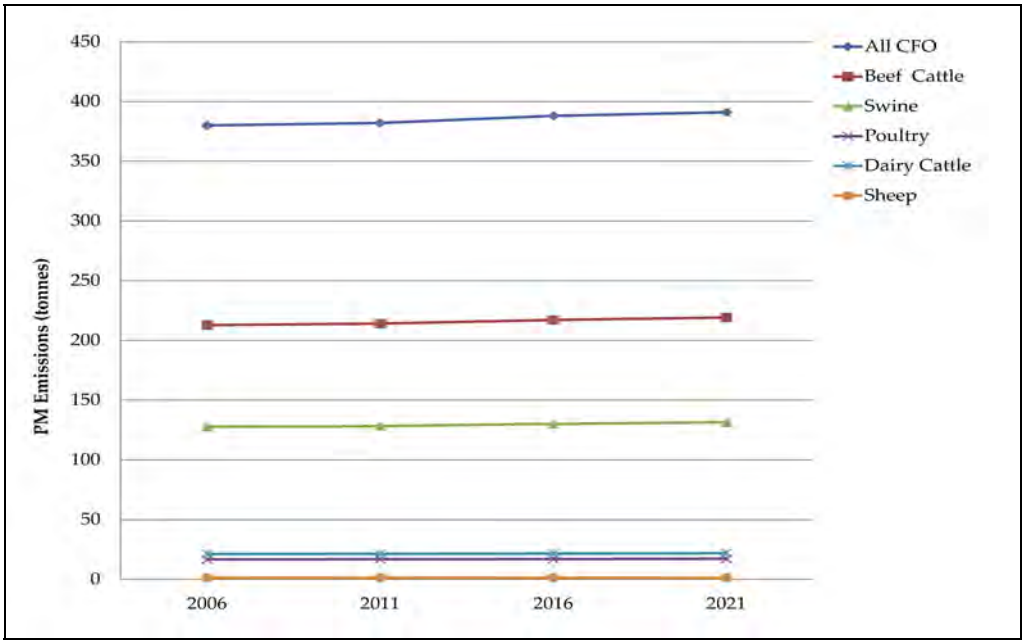


Figure 6.15 CFO $PM_{2.5}$ emissions forecasts for 2011, 2016 and 2021

7. Conclusions and Recommendations

Baseline emissions in 2006 and forecasted emissions in 2011, 2016 and 2021 were estimated as part of the development of a new emissions inventory for CFOs in Alberta, namely APMEICA. Recently published EFs and the methodologies used to develop the EFs were reviewed. AFs were obtained from the 2006 census of agriculture and agricultural surveys conducted in the same year. In addition, CFO emissions were estimated at a high spatial resolution (municipal scale) and temporal resolution (monthly) where possible.
The following conclusions were drawn with respect to the 2006 emission estimates derived from APMEICA:

- CFOs in Alberta were estimated to emit 42,750 tonnes of NH_3, 1,762 tonnes of PM_{10} and 380 tonnes of $PM_{2.5}$ in 2006.

- Beef Cattle and swine CFOs jointly accounted for 91% of annual NH_3 emissions and about 87% of annual PM emissions, both PM_{10} and $PM_{2.5}$, from CFOs in Alberta.

- In comparison to industrial point sources and mobiles sources, CFOs were estimated to be the biggest contributor of NH_3 emissions in Alberta in 2006, emitting approximately six times more NH_3 than industrial point sources and 22 times more NH_3 than mobile sources.

- Conversely, in comparison to industrial point sources and mobiles sources, CFOs were estimated to be the smallest contributor of PM emissions in Alberta in 2006, emitting approximately 15 times less PM_{10} and 51 times less $PM_{2.5}$ than industrial point sources, and 430 times less PM_{10} and 280 times less $PM_{2.5}$ than mobile sources.

- NH_3 emissions from CFOs were highest from May to October when warmer temperatures were experienced in late spring and summer and when large volumes of manure were applied on land in fall.

- Four municipalities in the South Saskatchewan LUF region (County of Lethbridge, County of Newell, M.D. of Taber and Wheatland County) and one in Red Deer LUF region (Lacombe County) were estimated to account for the highest NH_3 emissions from CFOs in the province.

- Three municipalities in the South Saskatchewan LUF region (County of Lethbridge, County of Newell and Wheatland County) and two in Red Deer LUF region (Kneehill County and Lacombe County) were estimated to account for the highest PM_{10} and $PM_{2.5}$ emissions from CFOs in the province.

- In general, NH_3 emissions from CFOs were forecasted to increase slightly from 2006 to 2021. Beef cattle and swine CFOs were primarily responsible for the upward trend.

- Similarly, forecasted PM_{10} and $PM_{2.5}$ emissions from CFOs increased slightly from 2006 to 2021 primarily because of increasing emissions from beef cattle and swine CFOs.

7.1 Recommendations

The following recommendations are directed towards future enhancement of APMEICA:

- The APMEICA database should be maintained on an annual basis. The AFs and EFs should be updated as new data become available or improved estimation methodologies are developed.

- A finer spatial resolution should be used to report future CFO emissions with the assistance of GIS techniques. For example, NARSTO (2006) recommended that emissions from major source categories in North America should be reported at a spatial resolution of 1 km^2.

- Emissions forecasting should be refined and improved by using new growth factors as they become available.

- To improve the accuracy of the next edition of APMEICA, an uncertainty analysis should be conducted using the best available techniques and tools.

- High temporal resolution PM EFs should be obtained and incorporated into the next edition of APMEICA.

- Conduct research studies to develop more accurate EFs (using process-based modelling) and AFs that represent the weather, livestock production and manure management conditions in Alberta.

- Periodical track changes in farming activities through formal farm surveys should be conducted.

- If it is deemed to be beneficial, reconcile gaps between estimated emissions of NH_3 and PM, and measured ambient concentrations by using techniques such as “inverse modeling”.

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9. APPENDICES

Appendix A: USEPA Data Attribute Rating System (DARS)

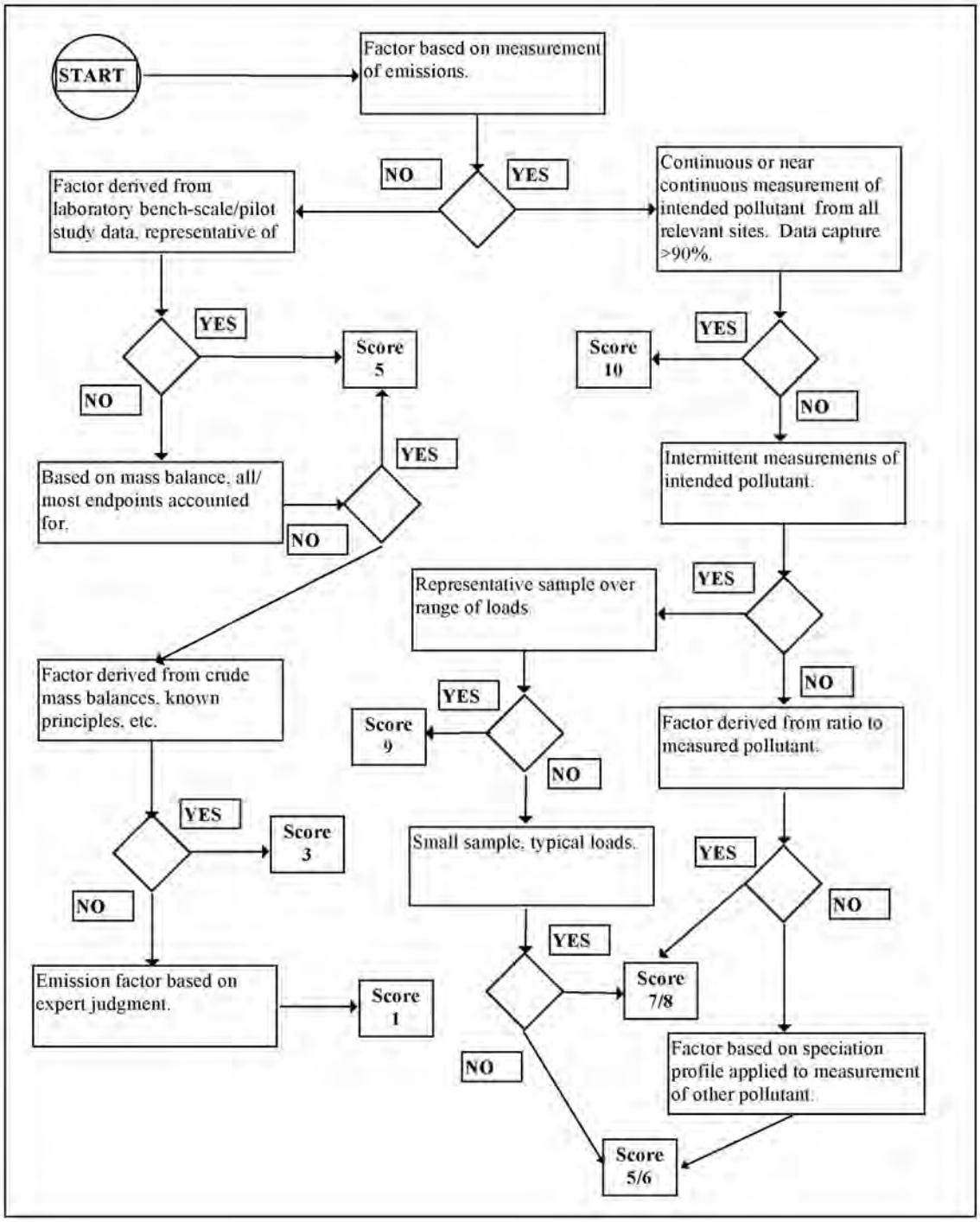

Figure A-1 DARS measurement attribute emission factor rating flowchart

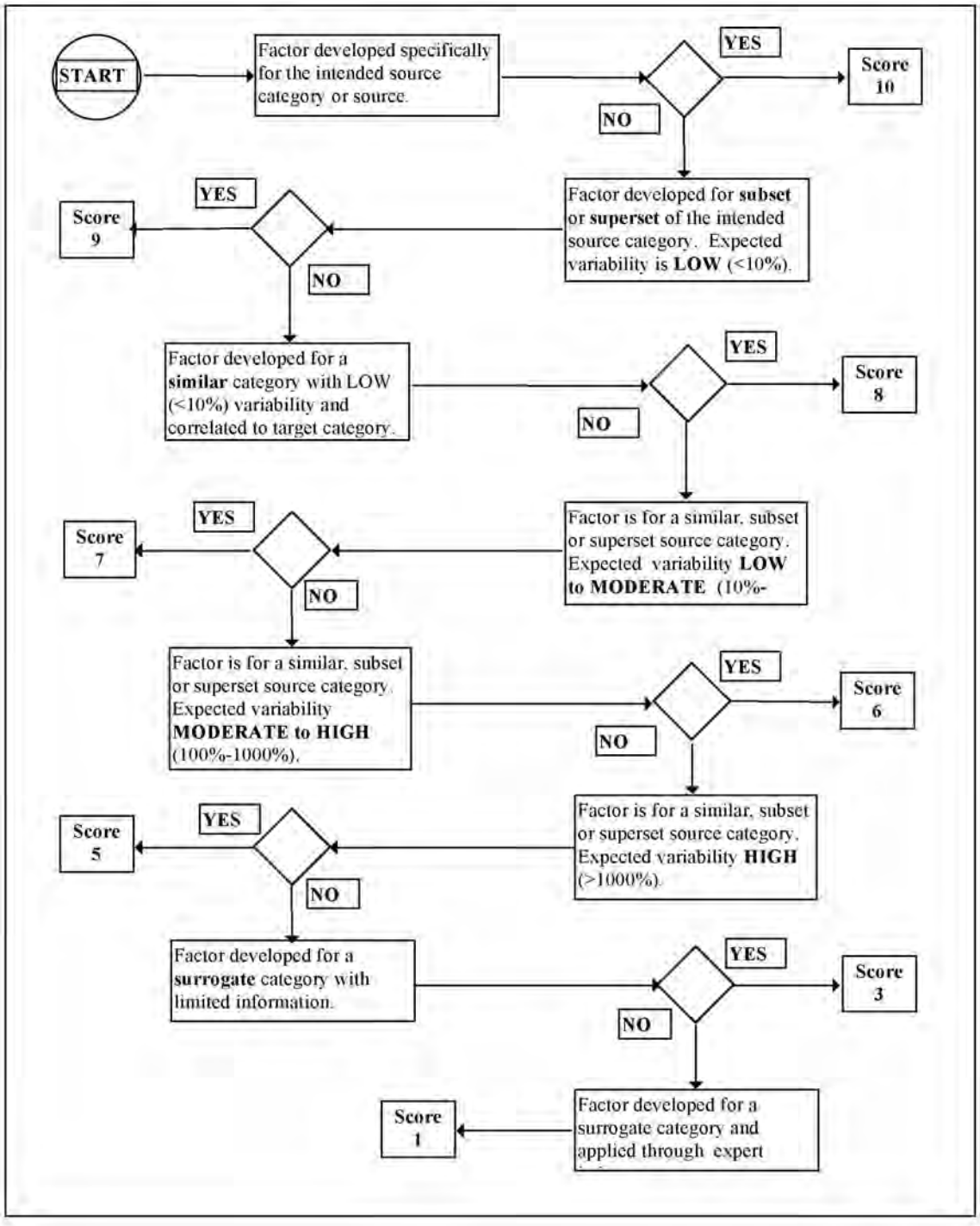

Figure A-2 DARS source category specificity attribute emission factor rating flowchart

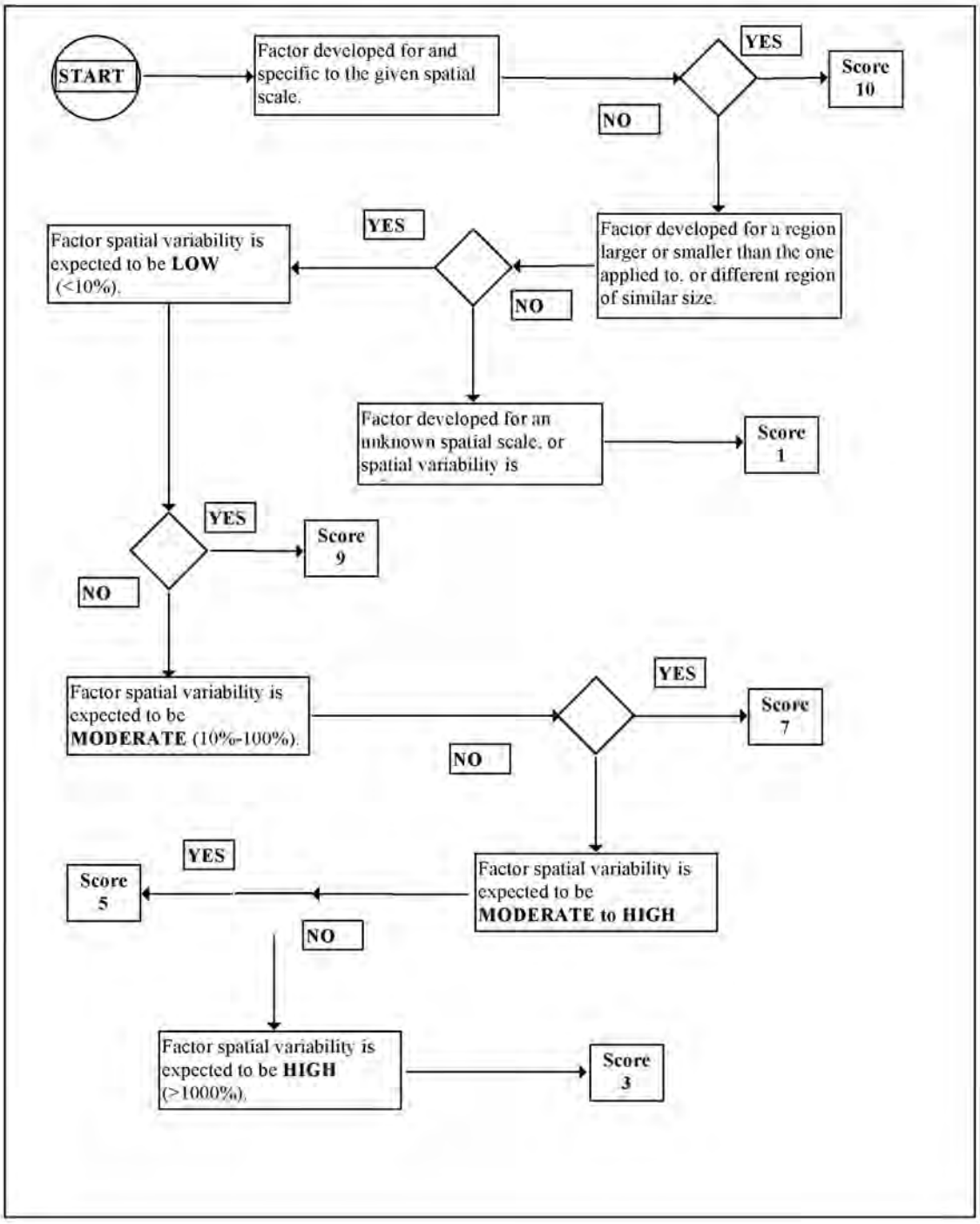

Figure A-3 DARS spatial scale attribute emission factor rating flowchart

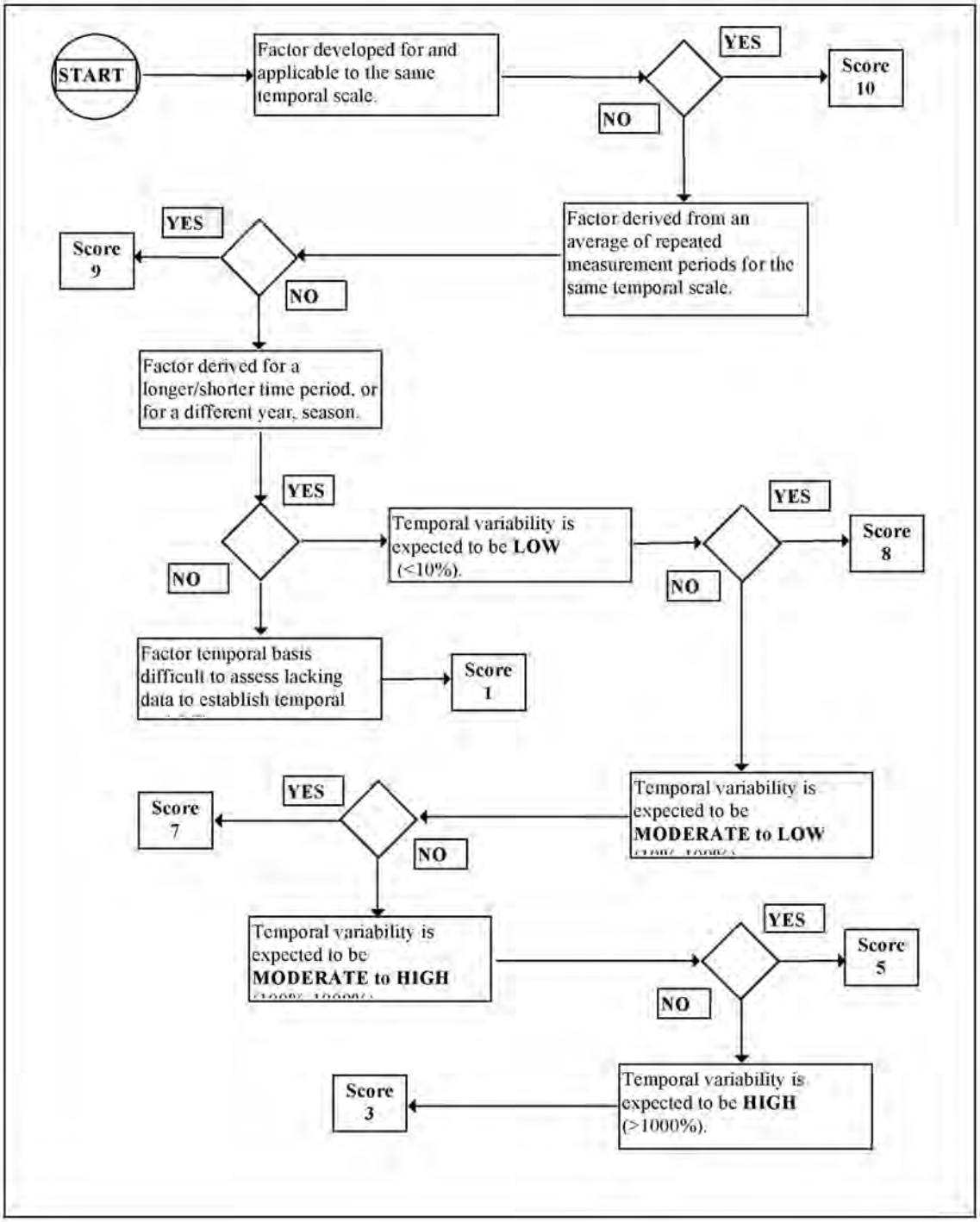

Figure A-4 DARS temporal attribute emission factor rating flowchart

Appendix B: CFO Emission Factors

Appendix B1: Monthly EFs for NH_3 in kg/animal for Dairy Cows in Different Ecoregions in Alberta

(Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.357	0.249	0.374	0.218	0.226	0.323
February	0.357	0.249	0.374	0.218	0.226	0.323
March	0.552	0.417	0.719	0.346	0.400	0.501
April	1.303	1.266	1.971	1.315	1.407	1.286
May	1.990	1.164	1.514	1.853	1.888	2.274
June	1.237	1.719	1.222	0.829	1.276	1.037
July	1.240	1.162	1.140	0.822	1.149	0.951
August	1.257	0.877	0.929	0.797	0.935	0.676
September	1.614	1.792	1.519	1.083	1.551	1.102
October	1.561	2.175	2.297	1.554	1.689	1.890
November	0.577	0.264	0.408	0.234	0.249	0.339
December	0.357	0.249	0.374	0.218	0.226	0.323
Yearly	**12.403**	**11.585**	**12.839**	**9.485**	**11.223**	**11.026**

Appendix B2: Monthly EFs for NH_3 in kg/animal for Steers in Different Ecoregions in Alberta

(Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.780	0.549	0.678	0.457	0.551	0.673
February	0.780	0.549	0.678	0.457	0.551	0.673
March	0.781	0.549	0.678	0.457	0.551	0.673
April	0.823	0.572	0.717	0.469	0.564	0.747
May	1.865	1.901	1.591	1.678	1.918	1.598
June	1.786	1.911	1.572	1.600	1.886	1.541
July	1.756	1.923	1.569	1.578	1.793	1.480
August	1.782	1.875	1.559	1.558	1.824	1.439
September	1.823	1.938	1.601	1.599	1.881	1.505
October	1.746	1.884	1.569	1.563	1.823	1.451
November	0.781	0.549	0.678	0.457	0.551	0.673
December	0.780	0.549	0.678	0.457	0.551	0.673
Yearly	**15.484**	**14.749**	**13.567**	**12.329**	**14.444**	**13.126**

Appendix B3: Monthly EFs for NH_3 in kg/animal for Dairy and Beef Heifers in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.602	0.448	0.581	0.397	0.410	0.486
February	0.602	0.448	0.581	0.397	0.410	0.486
March	0.602	0.448	0.581	0.397	0.410	0.486
April	0.637	0.468	0.614	0.407	0.420	0.546
May	1.509	1.576	1.371	1.430	1.513	1.259
une	1.428	1.577	1.352	1.366	1.467	1.188
July	1.388	1.582	1.348	1.348	1.374	1.120
August	1.396	1.536	1.338	1.333	1.381	1.068
September	1.429	1.589	1.373	1.368	1.427	1.121
October	1.366	1.544	1.346	1.338	1.380	1.077
November	0.602	0.448	0.581	0.397	0.410	0.486
December	0.602	0.448	0.581	0.397	0.410	0.486
Yearly	**12.164**	**12.113**	**11.647**	**10.573**	**11.014**	**9.807**

Appendix B4: Monthly EFs for NH_3 in kg/animal for Nursing and Weaner Swine Operations in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters, personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.115	0.116	0.124	0.107	0.085	0.116
February	0.115	0.116	0.124	0.107	0.085	0.116
March	0.118	0.120	0.127	0.109	0.086	0.121
April	0.140	0.149	0.160	0.130	0.099	0.145
May	0.211	0.193	0.189	0.207	0.147	0.203
June	0.176	0.174	0.177	0.174	0.122	0.176
July	0.181	0.171	0.180	0.171	0.123	0.180
August	0.181	0.175	0.170	0.165	0.121	0.174
September	0.194	0.195	0.199	0.193	0.128	0.186
October	0.194	0.205	0.212	0.203	0.147	0.201
November	0.121	0.123	0.129	0.112	0.090	0.123
December	0.115	0.116	0.124	0.107	0.085	0.116
Yearly	**1.860**	**1.853**	**1.913**	**1.786**	**1.319**	**1.855**

Appendix B5: Monthly EFs for NH_3 in kg/animal for Growing and Finishing Swine Operations in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.915	0.883	0.938	0.957	0.844	0.910
February	0.915	0.883	0.938	0.957	0.844	0.910
March	0.932	0.900	0.956	0.966	0.848	0.935
April	1.033	1.046	1.104	1.064	0.910	1.049
May	1.471	1.344	1.338	1.553	1.264	1.422
June	1.306	1.251	1.283	1.397	1.142	1.296
July	1.328	1.237	1.295	1.382	1.146	1.312
August	1.327	1.254	1.253	1.355	1.137	1.285
September	1.389	1.353	1.382	1.488	1.170	1.342
October	1.391	1.406	1.443	1.536	1.261	1.412
November	0.942	0.915	0.963	0.980	0.869	0.944
December	0.915	0.883	0.938	0.957	0.844	0.910
Yearly	**13.865**	**13.355**	**13.832**	**14.594**	**12.279**	**13.725**

Appendix B6: Monthly EFs for NH_3 in kg/animal for Sows and Gilts in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.274	0.284	0.259	0.262	0.274	0.275
February	0.274	0.284	0.259	0.262	0.274	0.275
March	0.282	0.292	0.267	0.266	0.276	0.288
April	0.332	0.365	0.335	0.316	0.318	0.345
May	0.502	0.471	0.396	0.504	0.475	0.482
June	0.419	0.425	0.371	0.425	0.394	0.419
July	0.430	0.418	0.376	0.417	0.397	0.428
August	0.430	0.427	0.357	0.404	0.391	0.414
September	0.460	0.476	0.416	0.471	0.413	0.442
October	0.462	0.502	0.444	0.496	0.473	0.477
November	0.287	0.300	0.271	0.273	0.290	0.293
December	0.274	0.284	0.259	0.262	0.274	0.275
Yearly	**4.425**	**4.526**	**4.010**	**4.359**	**4.249**	**4.415**

Appendix B7: Monthly EFs for NH_3 in kg/animal for Boars in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.338	0.325	0.328	0.325	0.322	0.340
February	0.338	0.325	0.328	0.325	0.322	0.340
March	0.346	0.332	0.335	0.329	0.324	0.351
April	0.391	0.392	0.397	0.373	0.359	0.402
May	0.569	0.504	0.477	0.566	0.516	0.551
June	0.494	0.465	0.454	0.495	0.448	0.495
July	0.504	0.460	0.459	0.488	0.450	0.502
August	0.504	0.467	0.442	0.476	0.445	0.490
September	0.532	0.508	0.495	0.536	0.463	0.515
October	0.533	0.529	0.521	0.558	0.514	0.547
November	0.350	0.338	0.338	0.335	0.335	0.355
December	0.338	0.325	0.328	0.325	0.322	0.340
Yearly	**5.238**	**4.968**	**4.900**	**5.131**	**4.818**	**5.229**

Appendix B8: Monthly EFs for NH_3 in kg/animal for Broiler Operations in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.0041	0.0045	0.0046	0.0053	0.0046	0.0045
February	0.0041	0.0045	0.0046	0.0053	0.0046	0.0045
March	0.0041	0.0045	0.0046	0.0053	0.0046	0.0045
April	0.0134	0.0176	0.0272	0.0168	0.0091	0.0087
May	0.0185	0.0185	0.0150	0.0231	0.0207	0.0203
June	0.0076	0.0084	0.0069	0.0125	0.0085	0.0084
July	0.0092	0.0063	0.0062	0.0100	0.0092	0.0093
August	0.0092	0.0105	0.0064	0.0076	0.0062	0.0062
September	0.0132	0.0152	0.0100	0.0150	0.0148	0.0148
October	0.0171	0.0254	0.0217	0.0287	0.0317	0.0304
November	0.0041	0.0045	0.0046	0.0053	0.0046	0.0045
December	0.0041	0.0045	0.0046	0.0053	0.0046	0.0045
Yearly	**0.1089**	**0.1089**	**1.1244**	**0.1025**	**0.1242**	**0.1095**

Appendix B9: Monthly EFs for NH_3 in kg/animal for Laying Hen and Pullet Operations in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.0098	0.0094	0.0095	0.0121	0.0095	0.0095
February	0.0098	0.0094	0.0095	0.0121	0.0095	0.0095
March	0.0099	0.0094	0.0095	0.0121	0.0095	0.0095
April	0.0260	0.0297	0.0515	0.0281	0.0166	0.0515
May	0.0354	0.0310	0.0288	0.0369	0.0347	0.0288
June	0.0162	0.0156	0.0138	0.0221	0.0157	0.0138
July	0.0189	0.0124	0.0126	0.0188	0.0168	0.0126
August	0.0190	0.0188	0.0129	0.0154	0.0121	0.0129
September	0.0260	0.0261	0.0196	0.0258	0.0254	0.0196
October	0.0328	0.0418	0.0415	0.0447	0.0514	0.0415
November	0.0099	0.0095	0.0095	0.0121	0.0096	0.0095
December	0.0098	0.0094	0.0095	0.0121	0.0095	0.0095
Yearly	**0.2234**	**0.2224**	**0.2282**	**0.2521**	**0.2201**	**0.2282**

Appendix B10: Monthly EFs for NH_3 in kg/animal for Turkey Operations in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.0209	0.0203	0.0211	0.0191	0.0206	0.0205
February	0.0209	0.0203	0.0211	0.0191	0.0206	0.0205
March	0.0209	0.0203	0.0211	0.0191	0.0206	0.0205
April	0.0624	0.0731	0.1144	0.0561	0.0388	0.0371
May	0.0855	0.0764	0.0639	0.0764	0.0855	0.0840
June	0.0366	0.0359	0.0306	0.0423	0.0365	0.0359
July	0.0436	0.0277	0.0278	0.0345	0.0394	0.0394
August	0.0437	0.0445	0.0286	0.0266	0.0270	0.0270
September	0.0616	0.0631	0.0433	0.0505	0.0619	0.0616
October	0.0792	0.1044	0.0918	0.0942	0.1298	0.1249
November	0.0209	0.0203	0.0211	0.0191	0.0206	0.0205
December	0.0209	0.0203	0.0211	0.0191	0.0206	0.0205
Yearly	**0.5171**	**0.5268**	**0.5060**	**0.4762**	**0.5218**	**0.5122**

Appendix C1: Summary of 2006 NH_3 and PM Emissions from Alberta CFOs by LUF Region

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		Substance_Name		
LUF_Name	County_Name	Ammonia (Total)	PM10 - Particulate Matter <= 10 Microns	PM2.5 - Particulate Matter <=2.5 Microns
Lower Athabasca	Bonnyville	162.134	7.574	1.682
	Lakeland	24.001	1.036	0.230
Lower Athabasca Total		186.135	8.610	1.911
Lower Peace	Mackenzie No 23	30.763	1.454	0.293
	Northern Light 22	57.979	2.425	0.538
	Northern Sunrise	22.096	1.023	0.228
Lower Peace Total		110.839	4.903	1.059
North Saskatchewan	Beaver	396.986	14.854	3.098
	Brazeau County	2.881	0.073	0.013
	Brazeau No. 77	14.470	0.886	0.198
	Camrose	691.849	30.606	5.770
	Clearwater	314.038	12.388	2.731
	Edmonton	22.482	0.797	0.177
	Flagstaff	375.019	14.810	3.271
	Green View No 16	104.771	4.889	1.014
	Lamont	146.822	7.120	1.574
	Leduc County	429.803	21.580	4.524
	Minburn	262.411	9.961	2.190
	Parkland County	133.327	6.269	1.379
	Provost	170.423	10.245	2.283
	Smokey Lake	143.173	5.481	1.188
	St. Pual	202.648	10.333	2.264
	Strathcona County	74.586	3.005	0.606
	Sturgeon County	538.947	24.952	4.359
	Thothid No 7	49.773	2.057	0.429
	Two Hills	469.445	15.793	3.432
	Vermilion	816.910	34.224	7.537
	Wainwright	829.826	27.064	6.015
	Wetaskiwin No 10	599.345	24.389	5.343
North Saskatchewan Total		6,789.933	281.775	59.395
Red Deer	Acadia No 34	6.170	0.270	0.045
	Kneehill	1,846.100	76.473	16.289
	Lacombe	2,523.907	86.529	18.611
	Mountain view	714.168	35.308	7.567
	Paintearth No. 18	476.207	18.921	4.125
	Ponka	1,195.272	50.398	10.576
	Red Deer	1,342.541	53.591	11.883
	Specail area No 4	180.192	9.390	2.093
	Special area No 2	889.430	38.130	8.470
	Special area No 3	256.955	8.310	1.848
	Starland	355.749	11.669	2.547

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		**Substance_Name**		
LUF_Name	**County_Name**	**Ammonia (Total)**	**PM10 - Particulate Matter <= 10 Microns**	**PM2.5 - Particulate Matter <=2.5 Microns**
	Stettler	908.458	29.316	6.427
Red Deer Total		10,695.149	418.305	90.482
South Saskatchewan	Bighorn No. 8	50.323	2.518	0.559
	Calgary	4.151	0.210	0.047
	Cardston	861.070	36.325	7.878
	Cypress	383.811	19.707	4.378
	Foothill No 31	259.929	12.570	2.803
	Fortymile	657.421	26.225	5.758
	Lethbridge	5,845.053	247.872	54.160
	Newell	2,030.852	104.369	23.164
	Pincher Creek	509.494	23.522	5.100
	Ranchland	54.000	3.013	0.672
	Rocky View	784.264	29.085	6.381
	Taber	1,994.004	64.942	14.248
	Vulcan	1,424.345	60.364	13.353
	Warner	1,216.459	48.151	10.350
	Wheatland	2,743.682	110.468	24.160
	Willow Creek	1,453.425	57.153	12.471
South Saskatchewan Total		20,272.282	846.494	185.481
Upper Athabasca	Athabasca county 12	175.046	7.300	1.519
	Barrhead County No. 11	1,029.894	42.345	9.362
	Big Lake	0.245	0.006	0.001
	Lac Ste. Anne County	250.472	9.164	2.012
	Lesser Slave	5.832	0.299	0.065
	Westlock	749.169	30.197	6.473
	Woodland	40.992	1.685	0.375
	Yellowhead county	263.856	14.243	3.171
Upper Athabasca Total		2,515.505	105.241	22.979
Upper Peace	Birch Hill	27.721	1.378	0.306
	Clear Hills	64.980	3.056	0.677
	Fairview No 136	160.833	6.300	1.400
	Grand Prairie No 1	296.036	12.250	2.718
	Peace No 135	24.383	1.227	0.273
	Saddle Hill	50.250	2.344	0.520
	Smokey River	56.889	3.308	0.735
	Spirit River	5.592	0.242	0.054
Upper Peace Total		686.684	30.105	6.683
Grand Total		**41,256.526**	**1,695.432**	**367.989**

Appendix C2: Summary of 2006 NH_3 and PM Emissions from Alberta CFOs by ARD-Defined Region

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		Substance_Name		
Region_Name	County_Name	Ammonia (Total)	PM10 - Particulate Matter <= 10 Microns	PM2.5 - Particulate Matter <=2.5 Microns
Central Region	Acadia No 34	43.973	1.032	0.144
	Bighorn No. 8	170.034	12.703	1.636
	Calgary	58.123	2.824	0.383
	Clearwater	309.211	12.176	2.704
	Kneehill	1,719.193	68.809	15.303
	Lacombe	2,431.417	80.324	17.812
	Mountain view	688.760	33.106	7.283
	Paintearth No. 18	523.744	22.547	4.592
	Ponka	1,103.679	43.666	9.710
	Red Deer	1,353.679	53.577	11.881
	Rocky View	897.767	35.868	7.254
	Specail area No 4	185.941	9.890	2.157
	Special area No 2	903.241	38.809	8.557
	Special area No 3	272.957	9.227	1.967
	Starland	343.399	11.445	2.518
	Stettler	891.521	28.399	6.309
Central Region Total		11,896.639	464.401	100.209
North East Region	Beaver	367.729	12.893	2.846
	Bonnyville	165.794	7.751	1.704
	Brazeau County	16.710	0.705	0.095
	Camrose	502.353	19.531	4.344
	Flagstaff	403.052	16.707	3.515
	Lakeland	30.657	1.375	0.273
	Lamont	143.522	6.989	1.557
	Minburn	291.442	11.776	2.424
	Provost	170.350	10.243	2.283
	Smokey Lake	136.402	5.133	1.143
	St. Pual	286.829	16.805	3.097
	Two Hills	454.766	14.922	3.320
	Vermilion	804.722	33.397	7.430
	Wainwright	839.651	27.841	6.115
North East Region Total		4,613.981	186.068	40.147
North West Region	Athabasca county 12	202.413	9.244	1.770
	Barrhead County No. 11	1,016.065	41.713	9.281
	Brazeau No. 77	14.470	0.886	0.198
	Edmonton	23.178	0.811	0.179
	Lac Ste. Anne County	245.666	8.930	1.982
	Leduc County	386.392	18.665	4.149
	Lesser Slave	24.047	1.135	0.173
	Parkland County	128.575	6.066	1.352
	Strathcona County	43.861	2.318	0.517

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		**Substance_Name**		
Region_Name	**County_Name**	**Ammonia (Total)**	**PM10 - Particulate Matter <= 10 Microns**	**PM2.5 - Particulate Matter <=2.5 Microns**
	Sturgeon County	344.934	12.257	2.725
	Thothid No 7	43.543	1.773	0.393
	Westlock	701.845	27.584	6.136
	Wetaskiwin No 10	560.951	23.471	5.225
	Woodland	40.885	1.682	0.374
	Yellowhead county	262.929	14.197	3.165
North West Region Total		4,039.754	170.731	37.619
Peace Region	Big Lake	81.796	3.188	0.645
	Birch Hill	27.765	1.380	0.307
	Clear Hills	81.207	4.152	0.818
	East peace No 131	5.563	0.268	0.034
	Fairview No 136	333.799	17.377	2.826
	Grand Prairie No 1	308.666	13.079	2.824
	Green View No 16	97.536	4.226	0.929
	Mackenzie No 23	175.078	12.458	1.710
	Northern Light 22	78.642	3.877	0.725
	Northern Sunrise	65.552	3.622	0.562
	Opportunity	26.340	0.924	0.119
	Peace No 135	24.345	1.224	0.273
	Saddle Hill	70.728	3.271	0.639
	Smokey River	102.724	6.520	1.148
	Spirit River	92.086	6.863	0.906
Peace Region Total		1,571.826	82.430	14.465
South Region	Cardston	821.533	34.453	7.637
	Crows nest	0.262	0.011	0.001
	Cypress	380.319	19.550	4.358
	Foothill No 31	266.420	12.830	2.837
	Fortymile	649.956	26.223	5.758
	Lethbridge	5,769.316	240.393	53.198
	Newell	2,050.822	105.532	23.313
	Pincher Creek	491.779	22.245	4.936
	Ranchland	54.000	3.013	0.672
	Taber	1,962.534	62.867	13.981
	Vulcan	1,402.473	59.761	13.276
	Warner	1,150.759	44.380	9.864
	Wheatland	2,677.774	105.971	23.581
	Willow Creek	1,408.109	54.574	12.139
South Region Total		19,086.057	791.803	175.550
Grand Total		**41,208.257**	**1,695.432**	**367.989**

Appendix C3: Summary of 2006 NH_3 and PM Emissions from Alberta CFOs by CAR

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		Substance_Name		
Agricultural_Region_Name	County_Name	Ammonia (Total)	PM10 - Particulate Matter <= 10 Microns	PM2.5 - Particulate Matter <=2.5 Microns
Agricultural Region 1	Acadia No 34	6.170	0.270	0.045
	Cypress	383.811	19.707	4.378
	Fortymile	657.421	26.225	5.758
	Specail area No 4	180.192	9.390	2.093
	Special area No 2	889.430	38.130	8.470
	Special area No 3	256.955	8.310	1.848
Agricultural Region 1 Total		2,373.979	102.031	22.593
Agricultural Region 2	Kneehill	1,846.100	76.473	16.289
	Lethbridge	5,845.053	247.872	54.160
	Newell	2,030.852	104.369	23.164
	Starland	355.749	11.669	2.547
	Taber	1,994.004	64.942	14.248
	Vulcan	1,424.345	60.364	13.353
	Warner	1,216.459	48.151	10.350
	Wheatland	2,743.682	110.468	24.160
Agricultural Region 2 Total		17,456.243	724.309	158.270
Agricultural Region 3	Bighorn No. 8	50.323	2.518	0.559
	Calgary	4.151	0.210	0.047
	Cardston	861.070	36.325	7.878
	Foothill No 31	259.929	12.570	2.803
	Mountain view	714.168	35.308	7.567
	Pincher Creek	509.494	23.522	5.100
	Ranchland	54.000	3.013	0.672
	Rocky View	784.264	29.085	6.381
	Willow Creek	1,453.425	57.153	12.471
Agricultural Region 3 Total		4,690.823	199.704	43.477
Agricultural Region 4A	Flagstaff	375.019	14.810	3.271
	Paintearth No. 18	476.207	18.921	4.125
	Provost	170.423	10.245	2.283
	Stettler	908.458	29.316	6.427
	Wainwright	829.826	27.064	6.015
Agricultural Region 4A Total		2,759.932	100.355	22.121
Agricultural Region 4B	Beaver	396.986	14.854	3.098
	Camrose	691.849	30.606	5.770
	Lamont	146.822	7.120	1.574
	Minburn	262.411	9.961	2.190
	Two Hills	469.445	15.793	3.432
	Vermilion	816.910	34.224	7.537
Agricultural Region 4B Total		2,784.423	112.557	23.601
Agricultural Region 5	Brazeau County	2.881	0.073	0.013

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2006			
	Unit : Tonnes			
Sum of Tonnes		Substance_Name		
Agricultural_Region_Name	County_Name	Ammonia (Total)	PM10 - Particulate Matter <= 10 Microns	PM2.5 - Particulate Matter <=2.5 Microns
	Brazeau No. 77	14.470	0.886	0.198
	Clearwater	314.038	12.388	2.731
	Edmonton	22.482	0.797	0.177
	Lacombe	2,523.907	86.529	18.611
	Leduc County	429.803	21.580	4.524
	Parkland County	133.327	6.269	1.379
	Ponka	1,195.272	50.398	10.576
	Red Deer	1,342.541	53.591	11.883
	Strathcona County	74.586	3.005	0.606
	Sturgeon County	538.947	24.952	4.359
	Wetaskiwin No 10	599.345	24.389	5.343
Agricultural Region 5 Total		7,191.598	284.858	60.399
Agricultural Region 6	Athabasca county 12	175.046	7.300	1.519
	Barrhead County No. 11	1,029.894	42.345	9.362
	Bonnyville	162.134	7.574	1.682
	Lac Ste. Anne County	250.472	9.164	2.012
	Lakeland	24.001	1.036	0.230
	Smokey Lake	143.173	5.481	1.188
	St. Pual	202.648	10.333	2.264
	Thothid No 7	49.773	2.057	0.429
	Westlock	749.169	30.197	6.473
	Woodland	40.992	1.685	0.375
	Yellowhead county	263.856	14.243	3.171
Agricultural Region 6 Total		3,091.158	131.416	28.705
Agricultural Region 7	Big Lake	0.245	0.006	0.001
	Birch Hill	27.721	1.378	0.306
	Clear Hills	64.980	3.056	0.677
	Fairview No 136	160.833	6.300	1.400
	Grand Prairie NO 1	296.036	12.250	2.718
	Green View No 16	104.771	4.889	1.014
	Lesser Slave	5.832	0.299	0.065
	Mackenzie No 23	30.763	1.454	0.293
	Northern Light 22	57.979	2.425	0.538
	Northern Sunrise	22.096	1.023	0.228
	Peace No 135	24.383	1.227	0.273
	Saddle Hill	50.250	2.344	0.520
	Smokey River	56.889	3.308	0.735
	Spirit River	5.592	0.242	0.054
Agricultural Region 7 Total		908.370	40.202	8.822
Grand Total		**41,256.526**	**1,695.432**	**367.989**

Appendix C4: Summary of 2006 NH_3 Emissions from Alberta CFOs by Month

County_ Name	(All)												
Year	2006												
Substance_ Name	Ammonia (Total)												
	Unit : Tonnes												
Sum of Tonnes		Month											
Livestock_ Category	Livestock_ Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Cattle	Beef Heifers	314.6	314.6	314.6	329.0	1,130.2	1,104.3	1,130.3	1,118.0	1,150.5	1,122.8	398.7	398.7	8,826.3
	Dairy Cows	21.1	21.1	36.3	121.1	133.9	80.7	77.2	67.9	103.8	141.3	21.9	20.2	846.6
	Dairy Heifers	15.5	15.5	15.5	16.1	53.1	51.3	50.6	50.1	51.5	50.3	16.1	16.1	401.7
	Steers	372.3	372.3	372.3	389.3	1,671.8	1,642.2	1,404.5	1,391.7	1,432.5	1,397.7	489.8	489.8	11,426.1
Cattle Total		723.4	723.4	738.7	855.5	2,989.1	2,878.5	2,662.6	2,627.7	2,738.3	2,712.0	926.6	924.8	21,500.7
Poultry	Broilers	35.1	35.1	35.1	130.9	145.6	74.2	62.5	51.0	96.9	191.0	35.1	35.1	927.9
	Layers	21.2	21.2	21.3	66.1	67.8	35.8	32.0	29.5	48.8	90.7	21.3	21.2	477.2
	Pullets	6.1	6.1	6.1	20.9	19.2	10.2	9.0	8.5	13.8	25.6	6.1	6.1	137.8
	Turkeys	5.2	5.2	5.2	16.9	19.7	10.2	8.9	7.1	13.3	26.0	5.2	5.2	127.8
Poultry Total		67.6	67.6	67.7	234.8	252.3	130.5	112.5	96.1	172.8	333.2	67.8	67.6	1,670.6
Sheep	Ewes	14.8	14.8	14.8	14.8	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	186.8
	Lamb	8.0	8.0	8.0	8.0	17.5	17.5	18.4	18.4	18.4	18.4	18.4	18.4	177.6
	Rams	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	9.5
Sheep Total		23.6	23.6	23.6	23.6	34.3	34.3	35.1	35.1	35.1	35.1	35.1	35.1	373.9
Swine	Boars	2.2	2.2	2.2	2.6	3.5	3.2	3.2	3.1	3.4	3.6	2.2	2.2	33.7
	Growers	1,082.2	1,082.2	1,096.6	1,200.0	1,595.8	1,490.5	1,509.3	1,482.2	1,614.5	1,631.9	1,067.1	1,039.2	15,891.5
	Sows	48.7	48.7	49.8	59.8	82.1	72.6	71.6	69.7	79.4	85.2	50.1	47.8	765.4
	Weaners	60.5	60.5	61.9	81.9	115.9	99.1	97.1	94.2	108.1	112.6	66.0	63.0	1,020.7
Swine Total		1,193.5	1,193.5	1,210.5	1,344.3	1,797.4	1,665.4	1,681.2	1,649.2	1,805.5	1,833.3	1,185.4	1,152.1	17,711.4
Grand Total		**2,008.2**	**2,008.2**	**2,040.5**	**2,458.2**	**5,073.0**	**4,708.7**	**4,491.4**	**4,408.1**	**4,751.8**	**4,913.7**	**2,214.9**	**2,179.7**	**41,256.5**

Appendix C5: Summary PM_{10} of 2006 Emissions from Alberta CFOs by Month

County_ Name	(All)													
Year	2006													
Substance_ Name	PM10 - Particulate Matter <= 10 Microns													
	Unit : Tonnes													
Sum of Tonnes		**Month**												
Livestock_ Category	**Livestock_ Sub_Category**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Grand Total**
Cattle	Beef Heifers	33.08	33.08	33.08	33.08	40.33	40.33	43.12	43.12	43.12	43.12	43.12	43.12	471.70
	Dairy Cows	5.99	5.99	5.99	5.99	5.54	5.54	5.75	5.75	5.75	5.75	5.75	5.75	69.55
	Dairy Heifers	1.82	1.82	1.82	1.82	1.88	1.88	1.89	1.89	1.89	1.89	1.89	1.89	22.38
	Steers	33.00	33.00	33.00	33.00	50.14	50.14	43.38	43.38	43.38	43.38	43.38	43.38	492.55
Cattle Total		73.90	73.90	73.90	73.90	97.88	97.88	94.14	94.14	94.14	94.14	94.14	94.14	1,056.18
Poultry	Broilers	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	71.09
	Layers	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	20.50
	Pullets	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	5.91
	Turkeys	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	2.64
Poultry Total		8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	100.14
Sheep	Ewes	0.26	0.26	0.26	0.26	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	3.23
	Lamb	0.14	0.14	0.14	0.14	0.30	0.30	0.32	0.32	0.32	0.32	0.32	0.32	3.07
	Rams	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.16
Sheep Total		0.41	0.41	0.41	0.41	0.59	0.59	0.61	0.61	0.61	0.61	0.61	0.61	6.46
Swine	Boars	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	2.46
	Growers	35.61	35.61	35.61	34.69	34.21	34.69	35.23	35.23	35.23	34.16	34.16	34.16	418.58
	Sows	5.55	5.55	5.55	5.49	5.45	5.49	5.43	5.43	5.43	5.44	5.44	5.44	65.66
	Weaners	3.64	3.64	3.64	3.95	4.08	3.95	3.88	3.88	3.88	3.80	3.80	3.80	45.95
Swine Total		45.01	45.01	45.01	44.33	43.94	44.33	44.74	44.74	44.74	43.60	43.60	43.60	532.65
Grand Total		**127.66**	**127.66**	**127.66**	**126.98**	**150.77**	**151.15**	**147.84**	**147.84**	**147.84**	**146.69**	**146.69**	**146.69**	**1,695.43**

Appendix C6: Summary of 2006 $PM_{2.5}$ Emissions from Alberta CFOs by Month

County_ Name	(All)												
Year	2006												
Substance_ Name	PM2.5 - Particulate Matter <=2.5 Microns												
	Unit : Tonnes												
Sum of Tonnes		Month											
Livestock_ Category	Livestock_ Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Cattle	Beef Heifers	7.373	7.373	7.373	7.373	8.988	8.988	9.610	9.610	9.610	9.610	9.610	9.610	105.129
	Dairy Cows	1.346	1.346	1.346	1.346	1.244	1.244	1.292	1.292	1.292	1.292	1.292	1.292	15.623
	Dairy Heifers	0.405	0.405	0.405	0.405	0.419	0.419	0.421	0.421	0.421	0.421	0.421	0.421	4.988
	Steers	7.359	7.359	7.359	7.359	11.181	11.181	9.673	9.673	9.673	9.673	9.673	9.673	109.838
Cattle Total		16.484	16.484	16.484	16.484	21.832	21.832	20.996	20.996	20.996	20.996	20.996	20.996	235.577
Poultry	Broilers	0.762	0.762	0.762	0.762	0.762	0.762	0.762	0.762	0.762	0.762	0.762	0.762	9.150
	Layers	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	2.639
	Pullets	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.760
	Turkeys	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.340
Poultry Total		1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	12.889
Sheep	Ewes	0.054	0.054	0.054	0.054	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.684
	Lamb	0.029	0.029	0.029	0.029	0.064	0.064	0.067	0.067	0.067	0.067	0.067	0.067	0.650
	Rams	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.035
Sheep Total		0.086	0.086	0.086	0.086	0.126	0.126	0.129	0.129	0.129	0.129	0.129	0.129	1.369
Swine	Boars	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.045	0.045	0.045	0.547
	Growers	7.893	7.893	7.893	7.687	7.581	7.687	7.807	7.807	7.807	7.570	7.570	7.570	92.763
	Sows	1.232	1.232	1.232	1.219	1.210	1.219	1.206	1.206	1.206	1.209	1.209	1.209	14.588
	Weaners	0.813	0.813	0.813	0.882	0.911	0.882	0.867	0.867	0.867	0.847	0.847	0.847	10.256
Swine Total		9.984	9.984	9.984	9.833	9.748	9.833	9.925	9.925	9.925	9.671	9.671	9.671	118.154
Grand Total		**27.628**	**27.628**	**27.628**	**27.477**	**32.779**	**32.864**	**32.124**	**32.124**	**32.124**	**31.870**	**31.870**	**31.870**	**367.989**

Appendix C7: NH_3 Emission Forecast for Alberta CFOs

Substance_Name	Ammonia (Total)				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2006	2011	2016	2021
Cattle	Beef Heifers	8,711.010	8,763.276	8,885.230	8,972.340
	Dairy Cows	920.436	925.958	938.844	948.049
	Dairy Heifers	415.790	418.285	424.106	428.264
	Steers	11,337.358	11,405.382	11,564.105	11,677.479
Cattle Total		21,384.594	21,512.901	21,812.285	22,026.131
Poultry	Broilers	1,067.739	1,074.145	1,089.093	1,099.771
	Layers	602.851	606.468	614.908	620.936
	Pullets	226.416	227.774	230.944	233.208
	Turkeys	357.783	359.930	364.939	368.516
Poultry Total		2,254.789	2,268.317	2,299.884	2,322.431
Sheep	Ewes	193.102	194.261	196.964	198.895
	Lamb	181.642	182.732	185.275	187.091
	Rams	9.911	9.970	10.109	10.208
Sheep Total		384.655	386.963	392.348	396.195
Swine	Boars	35.446	35.658	36.155	36.509
	Growers	16,810.544	16,911.408	17,146.755	17,314.861
	Sows	816.322	821.220	832.648	840.811
	Weaners	1,064.115	1,070.500	1,085.398	1,096.039
Swine Total		18,726.427	18,838.786	19,100.956	19,288.220
Grand Total		**42,750.465**	**43,006.967**	**43,605.473**	**44,032.977**

Appendix C8: PM_{10} Emission Forecast for Alberta CFOs

Substance_Name	PM10 - Particulate Matter <= 10 Microns				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2006	2011	2016	2021
Cattle	Beef Heifers	469.540	472.357	478.930	483.626
	Dairy Cows	71.637	72.067	73.070	73.787
	Dairy Heifers	22.997	23.135	23.457	23.687
	Steers	485.207	488.118	494.911	499.763
Cattle Total		1,049.381	1,055.677	1,070.369	1,080.862
Poultry	Broilers	86.322	86.840	88.049	88.912
	Layers	26.452	26.611	26.981	27.246
	Pullets	9.935	9.994	10.134	10.233
	Turkeys	7.105	7.148	7.247	7.318
Poultry Total		129.814	130.593	132.411	133.709
Sheep	Ewes	3.336	3.356	3.403	3.436
	Lamb	3.138	3.157	3.201	3.232
	Rams	0.171	0.172	0.175	0.176
Sheep Total		6.645	6.686	6.779	6.845
Swine	Boars	2.580	2.595	2.631	2.657
	Growers	454.815	457.544	463.912	468.460
	Sows	69.107	69.522	70.489	71.180
	Weaners	49.187	49.482	50.171	50.663
Swine Total		575.689	579.143	587.203	592.959
Grand Total		**1,761.529**	**1,772.099**	**1,796.761**	**1,814.376**

Appendix C9: $PM_{2.5}$ Emission Forecast for Alberta CFOs

Substance_Name	PM2.5 - Particulate Matter <=2.5 Microns				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2006	2011	2016	2021
Cattle	Beef Heifers	104.648	105.276	106.741	107.788
	Dairy Cows	16.091	16.188	16.413	16.574
	Dairy Heifers	5.126	5.156	5.228	5.279
	Steers	108.199	108.848	110.363	111.445
Cattle Total		234.064	235.468	238.745	241.086
Poultry	Broilers	11.111	11.177	11.333	11.444
	Layers	3.405	3.425	3.473	3.507
	Pullets	1.279	1.286	1.304	1.317
	Turkeys	0.915	0.920	0.933	0.942
Poultry Total		16.710	16.809	17.043	17.210
Sheep	Ewes	0.707	0.712	0.721	0.729
	Lamb	0.665	0.669	0.679	0.685
	Rams	0.036	0.037	0.037	0.037
Sheep Total		1.408	1.417	1.437	1.451
Swine	Boars	0.573	0.577	0.585	0.590
	Growers	100.794	101.399	102.810	103.818
	Sows	15.353	15.445	15.660	15.813
	Weaners	10.978	11.043	11.197	11.307
Swine Total		127.698	128.464	130.252	131.529
Grand Total		**379.880**	**382.159**	**387.477**	**391.276**

10. Acronyms

AAFC	Agriculture and Agri-Food Canada
AAQTF	Agricultural Air Quality Task Force
ABRS	Alberta-based rating system
AEIs	Agri-environmental indicators
AEW	Alberta Environment and Water
AF	Activity factor
AOPA	Agricultural Operation Practices Act
APMEICA	Ammonia and Particulate Matter Emissions Inventory for CFOs in Alberta
ARD	Alberta Agriculture and Rural Development
AU	Animal unit
CAR	Census Agricultural Region
CAS	Chemical Abstract Services
CASA	Clean Air Strategic Alliance
CCS	Census Consolidated Subdivision
CD	Census Division
CFO	Confined feeding operation
CO_2	Carbon dioxide
CSD	Census Subdivision
DARS	Data Attribute Rating System
DYNAMO	Dynamic Ammonia Model
EC	Environment Canada
EF	Emission factor
EMEP/EEA	European Monitoring and Evaluation Program/European Environmental Agency
EU	European Union
FEI	Finnish Environmental Institute
FEMS	Farm Environmental Management Survey
FIS	Feed Industry Survey
GAS-EM	Gaseous emission model
GF	Growth factor
GHG	Greenhouse gas
H_2S	Hydrogen sulphide
LFPS	Livestock Farm Practices Survey
LUF	Land-use Framework
M.D.	Municipal district
MAG	Multi-stakeholder advisory group
MS	Microsoft
NAEMS	National Air Emissions Monitoring Study
NAESI	National Agri-Environmental Standards Initiative
NAHARP	National Agri-Environmental Health Analysis and Reporting Program
NARSES	National Ammonia Reduction Strategy Evaluation System

NGO	Non-government organization
NH_3	Ammonia
NPRI	National Pollutant Release Inventory
NRC	National Research Council
NRCB	Natural Resources Conservation Board
PM	Particulate matter
QA	Quality assurance
QC	Quality control
RSC	Reduced sulphur compounds
SC	Statistics Canada
SCC	Source classification code
SLC	Soil Landscapes of Canada
SQL	Structured query language
SSR	South Saskatchewan Region
TAN	Total ammonia cal nitrogen
TRS	Total reduced sulphur
TWG	Technical working group
UK	United Kingdom
UNECE	United Nations Economic Council for Europe
U.S.	United States of America
USEPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture
VOCs	Volatile organic compounds

ADDENDUM

APMEICA 2011

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11. Update of the 2006 Emissions Inventory for CFOs in Alberta

APMEICA 2006 was updated using AFs derived from the 2011 census (SC 2013), and 2011 semi-annual agricultural survey data for cattle, sheep and swine obtained from ARD (2013). Similar to APMEICA 2006, Eq. 2 (section 3.2.5) was used to determine monthly AFs for all livestock categories except poultry and then used to estimate emissions by APMEICA 2011. Since the poultry inventory in Alberta was not estimated via the 2011 semi-annual agricultural survey, the 2011 census data for May was assumed to be the same AF for each month of the year in 2011.

Furthermore, a discrepancy between the sample derivation of monthly AFs presented in section 3.2.5.1 of this report and the actual derivation of AFs used by APMEICA 2006 and APMEICA 2011 was found. Rather than use the same monthly AF for beef cattle, dairy cattle and sheep for the months of January to April, and a different AF for June to December, with the 2011 census data obtained in May used as the AF for May alone (section 3.2.5.1), AFs used by APMEICA 2006 for the three livestock categories were the same for the months of January to April, May and June, and then July to December. For APMEICA 2011, the AFs were also applied in the same way to the three livestock categories and swine as well. This derivation of monthly AFs is particularly noticeable when reviewing the PM emissions data because, unlike NH_3, single EFs for PM_{10} and $PM_{2.5}$ were assigned to each livestock sub-category.

Although most of the EFs used by APMEICA 2011 were the same as the ones used by APMEICA 2006, the monthly EFs applied to dairy cows were revised and used to estimate emissions from this livestock sub-category in 2011 (Table 11-1). Ultimately, this addendum reflects changes in estimated NH_3 and PM emissions from CFOs in Alberta from 2006 to 2011.

11.1 APMEICA 2006 versus APMEICA 2011

The following differences between the 2006 and 2011 emission inventories are outlined below.

- Emissions of NH_3 and PM from beef cattle increased slightly from 2006 to 2011 due to a slight increase in AFs (number of beef cattle).

- A noticeable increase in estimated NH_3 emissions from dairy cattle occurred in 2011 owing primarily to the use of higher EFs. However, when the revised EFs were applied to APMEICA 2006, the differences between the two inventories were minor. Note, there was virtually no change in estimated PM emissions from dairy cattle between 2006 and 2011 with negligible to no change in AFs and absolutely no change in EFs.

- Slight declines in NH_3 and PM from poultry between 2006 and 2011. Similarly, slight declines in NH_3 and PM_{10} emissions from sheep over the same period, but a slight incline in $PM_{2.5}$ emissions. These differences corresponded with increase or decreases in AFs.

- APMEICA 2006 forecast a slight increase in emissions of NH_3 and PM from swine in 2011. Conversely, a drastic drop in emissions of NH_3 and PM from swine occurred owing to the sharp decline in the number of pigs. The number of pigs fell by approximately33% between the two periods.

11.2 Ammonia Emissions

11.2.1 Distribution by Livestock Category

Compared to APMEICA 2006, CFOs in Alberta were estimated to emit 39,870 tonnes of NH_3 in 2011 (Table 11-1). This represents 6.7% decline in CFO NH_3 emissions from 2006 to 2011. Despite increases in emissions from beef cattle and dairy cattle, 1,167 tonnes and 1,936 tonnes, respectively, decreases in emissions from poultry, sheep and especially swine, 216 tonnes, 31 tonnes and 5,736 tonnes, respectively, resulted in a net decrease in the overall emissions from CFOs in 2011.

Furthermore, the dramatic increase in dairy cattle NH_3 emissions (145%) from 2006 to 2011 can be attributed to the use of corrected EFs for dairy cows (Table 11-5). When the same corrected EFs were applied to APMEICA 2006 (Table 11-1), a smaller increase of 1.1% is estimated to have occurred in dairy cattle emissions from 2006 to 2011. In contrast, the 31 % (approximately) decrease in swine CFO NH_3 emissions occurred as a result of the large drop in the swine population in Alberta between 2006 and 2011.

Table 11-1 Breakdown of NH_3 emissions by livestock category in Alberta in 2006 and 2011

Livestock		NH_3 emissions (tonnes)	
		2006*	**2011**
Beef			
	Heifers	8,711	8,473
	Steers	11,337	12,742
Subtotal		**20,048**	**21,215**
Dairy			
	Heifers	416	493
	Cows	920 (2,822)	2,779
Subtotal		**1,336 (3,238)**	**3,272**
Poultry			
	Broilers	1,068	949
	Layers	603	540

Livestock		NH_3 emissions (tonnes)	
		2006*	**2011**
	Pullets	226	184
	Turkeys	358	366
Subtotal		**2,255**	**2,039**
Sheep			
	Ewes	193	176
	Lambs	182	170
	Rams	10	9
Subtotal		**385**	**354**
Swine			
	Boars	35	24
	Growers	16,811	11,575
	Sows	816	589
	Weaners	1,064	802
Subtotal		**18,726**	**12,990**
Total		**42,750 (44,652)**	**39,870**

* Values in parentheses are the emissions estimated using the corrected EFs for dairy cows.

Subsequently, APMEICA 2011 indicates that beef cattle CFOs remained the largest contributors of NH_3 emissions, accounting for 53% of the total CFO emissions in Alberta (Figure 11-1), a 6% increase over APMEICA 2006 estimates. Similarly, despite the decline in emissions between 2006 and 2011, swine CFOs remained the second largest contributors of NH_3 emissions in 2011. According to APMEICA 2011, swine CFOs accounted for 33% of total CFO emissions, with the grower pig sub-category still accounting for 89% of the emissions from swine CFOs (Figure 11-2) as in 2006. Collectively, the two livestock categories (beef and swine) accounted for 86% of annual NH_3 emissions in Alberta in 2011, a 5% decrease from 2006.

In comparison to APMEICA 2006, dairy cattle CFOs, and not poultry, contributed the third highest amount of NH_3 emissions estimated by APMEICA 2011. As mentioned earlier, the corrected EFs for dairy cows appeared to be primarily responsible for the difference in the output from APMEICA 2011 relative to APMEICA 2006. When the same, corrected EFs are applied to APMEICA 2006 (Table 11-1), dairy CFOs were also estimated to be the third largest contributor of annual NH_3 emissions among all CFOs in Alberta in 2006.

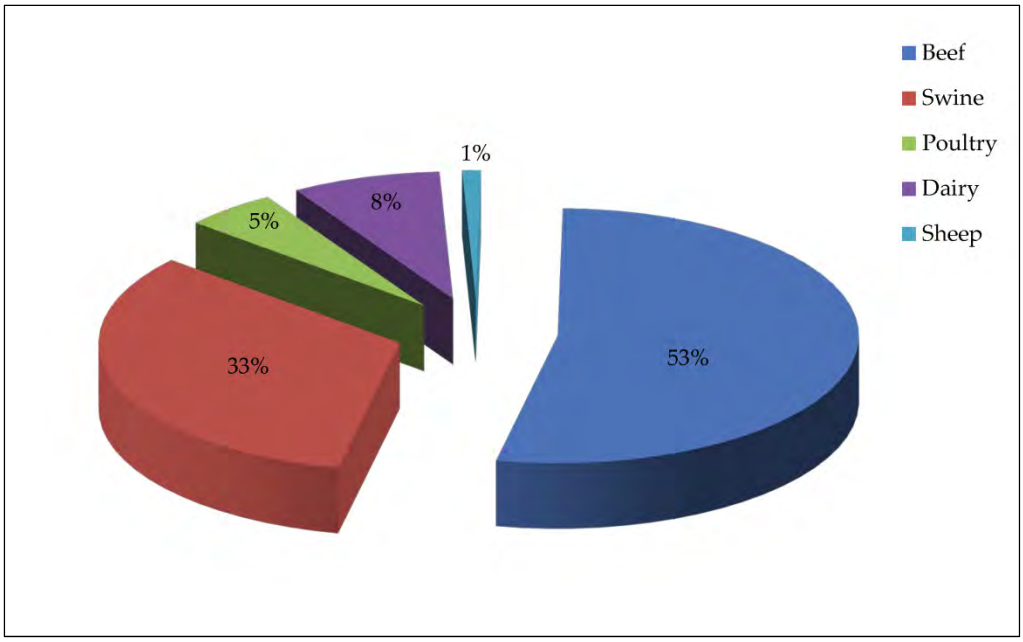

Figure 11-1 2011 distribution of CFO NH_3 emissions in Alberta by livestock category

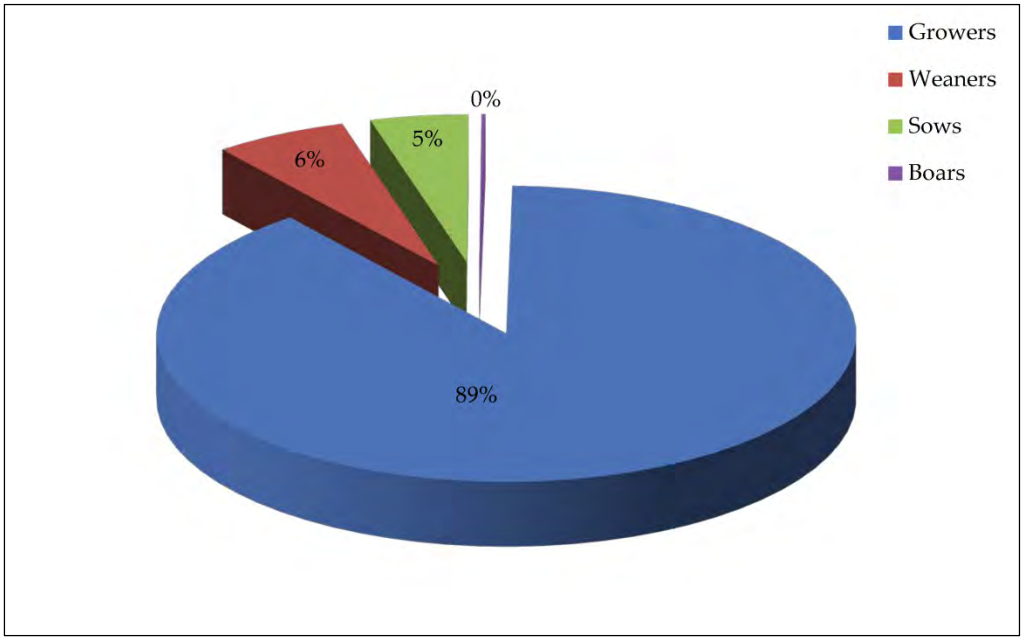

Figure 11-2 2011 distribution of CFO NH_3 emissions in Alberta by swine sub-category

11.2.2 Temporal Distribution

Figure 11-3 (also see Table 11-7) signifies that the distribution of CFO NH_3 emissions in 2011 was similar to same in 2006, with lower emissions occurring in late fall and winter. However, there were some noticeable differences. For instance in 2011, unlike in 2006, NH_3 emissions that

occurred between January and April were close for beef cattle and swine CFOs, a direct consequence not only of having lower pig numbers but also having slightly higher beef cattle numbers in 2011.

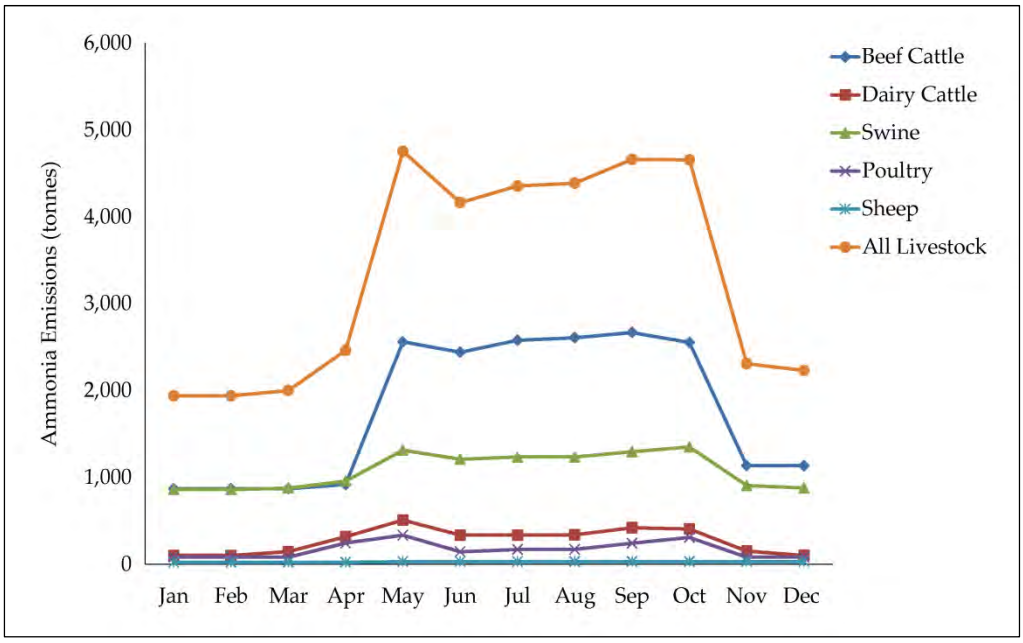

Figure 11-3 Monthly variations in NH_3 emissions from CFO livestock categories in 2011

Another noticeable difference is beef cattle CFO emissions in 2011 appeared to remain steady between May and October compared to the initial decline that occurred in 2006 from May to July. Ironically, the emissions in May and June in APMEICA 2006 were higher than those that occurred during the same period in 2011, an indication that beef cattle numbers were higher in those two months in 2006. Beyond that it would appear that beef cattle numbers were higher in 2011 from January to April and then again from November to December.

Also of interest is the slightly higher NH_3 emissions from dairy cattle CFOs compared to poultry CFOs, particularly from May to October in 2011 versus the same in 2006. When APMEICA 2006 dairy cattle emissions were corrected using the revised dairy cow EFs, the temporal distribution in 2006 (Figure 11-4) and 2011 appeared to be quite similar.

11.2.3 Spatial Distribution

APMEICA 2011 estimated NH_3 emissions spatially with respect to Alberta's Land Use Framework regions and municipalities. Although the updated emissions inventory also estimated NH_3 emissions at the 2011 Census Agricultural Region scale and ARD-defined regional scale, estimates associated with spatial boundaries defined by the latter two categories are not addressed in this addendum.

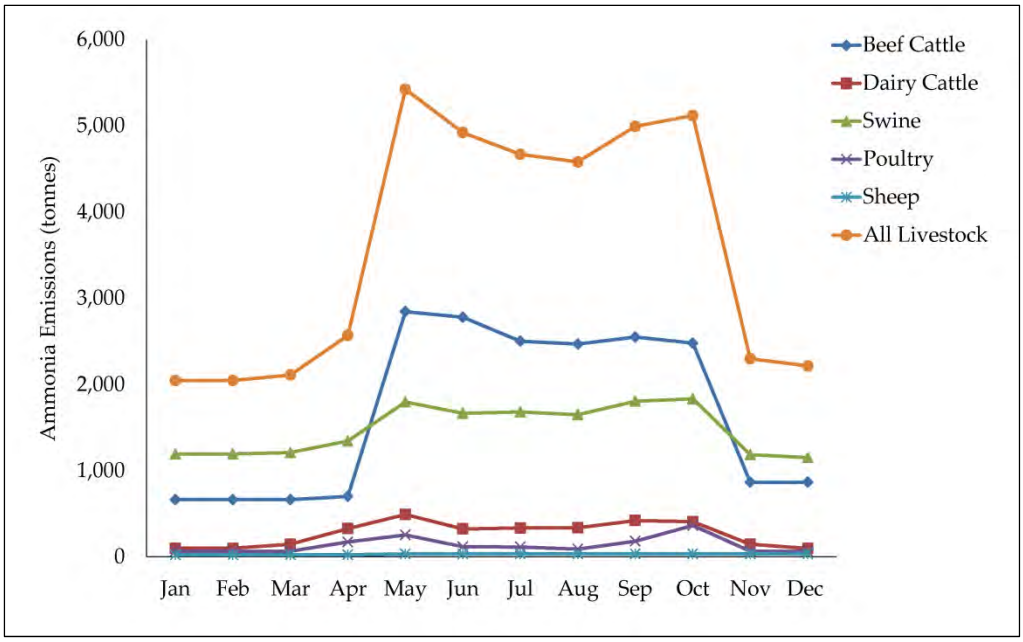

Figure 11-4 Corrected monthly variations in NH_3 emissions from CFO livestock categories in 2006

11.2.3.1 Land Use Framework Regional Scale

A comparison of LUF regional CFO NH_3 emissions in 2011 (Figure 11-5, Table 11-6) to emissions in 2006 signifies a general decrease in emissions in six of the seven LUF regions in 2011. Only the Lower Peace region showed an increase in NH_3 emissions in 2011. Furthermore, unlike in 2006 when the least emissions were estimated to occur in the Lower Peace region, the emissions in the latter were fifth highest among all seven regions (2.24% of total) in 2011. The Upper Peace region was displaced to sixth place and subsequently, the least emissions occurred in the Lower Athabasca region. A detailed review of the 2011 census data indicates an increase in beef cattle numbers in the Lower Peace region, compared to other neighbouring regions, and this attributed to the increased emissions in that region.

11.2.3.2 Municipal Scale

As shown in Table 11-5, NH_3 emissions in 2011were highest in Lacombe County, County of Lethbridge, M.D. of Taber, County of Vulcan and Warner County (presented in alphabetical order). While the County of Newell and Wheatland County featured among the top five NH_3 emitters in 2006, the 2011 census data indicated a decrease in beef cattle numbers by 60% and 25% in the County of Newell and Wheatland County, respectively, but an increase in numbers in the County of Vulcan and Warner County by 127% and 16%, respectively.

Overall, the County of Lethbridge contributed the highest NH_3 emissions, accounting for approximately 13% of total CFO NH_3 emissions in Alberta in 2011, with beef cattle CFOs accounting for approximately 77% of the NH_3 emissions in the county. Unlike in 2006, CFOs in

Taber County accounted for the second highest NH_3 emissions in Alberta (7.2%), with 70% of the emissions attributable to beef cattle CFOs in the county. In 2006, Taber County only accounted for 4.5% of the total NH_3 emissions in Alberta.

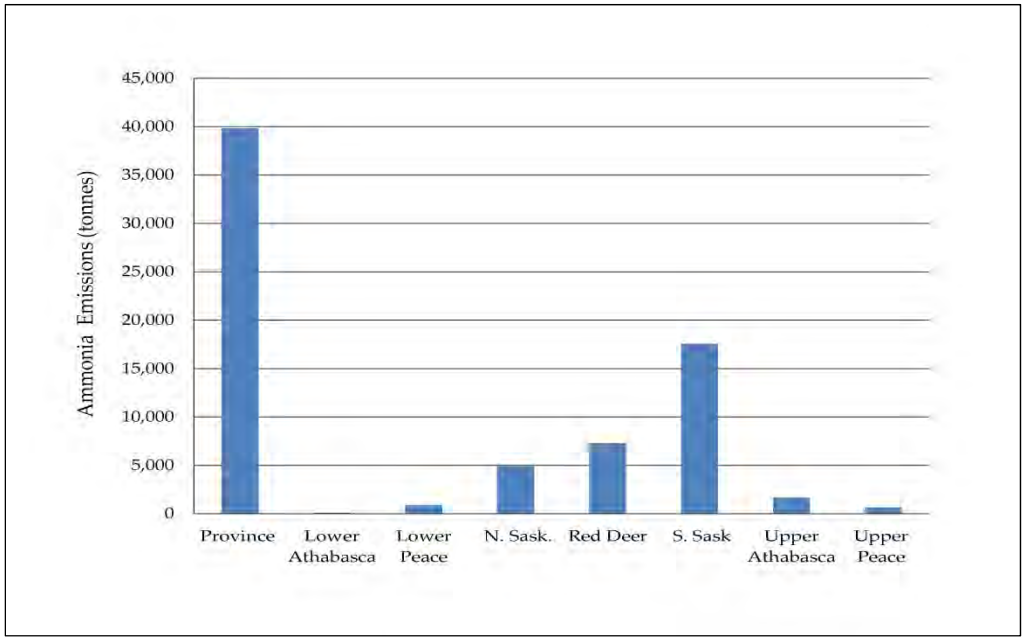

Figure 11-5 2011 distribution of CFO NH_3 emissions in Alberta sorted by LUF Region

11.2.4 Apportionment of Ammonia Emissions in Alberta

Table 11-2 shows a comparison of NH_3 emissions from CFOs estimated using APMEICA to emissions from other sources in Alberta in 2011 based on Environment Canada estimates (EC 2011). The results signify that CFOs contributed about 77% of total NH_3 emissions estimated to be emitted from the three sources.

11.2.5 Ammonia Emission Forecasts

Similar to APMEICA 2006, APMEICA 2011 forecast NH_3 emissions in 2016, 2021 and 2026 (Figure 11-6) using the same emission growth factors used by the previous inventory.

Overall, the forecast by APMEICA 2011 indicates lower NH_3 emissions in the future for all CFOs relative to APMEICA 2006 forecast. Although higher emissions were forecast for beef cattle, dairy and poultry CFOs, the decline in pig numbers appears to be the main reason for the lower consolidated forecast. Unless activity factors, emission factors or emission growth factors change significantly, APMEICA 2011 forecast is anticipated to remain relatively the same. A more detailed forecast is presented in Table 11-10.

Table 11-2 Annual CFO NH_3 emissions in 2011 compared to emissions from other sources in Alberta*

Sector	NH_3 emissions (tonnes)
CFOs (APMEICA)	39,870
Industrial point sources	8,278*
Mobile sources	3,481*

* NPRI 2011 Air Pollutant Emission Summaries for Alberta (R. Melick, Emissions Inventory Scientist, Ministry of Environment and Sustainable Resource Development, Edmonton, AB, pers. comm.)

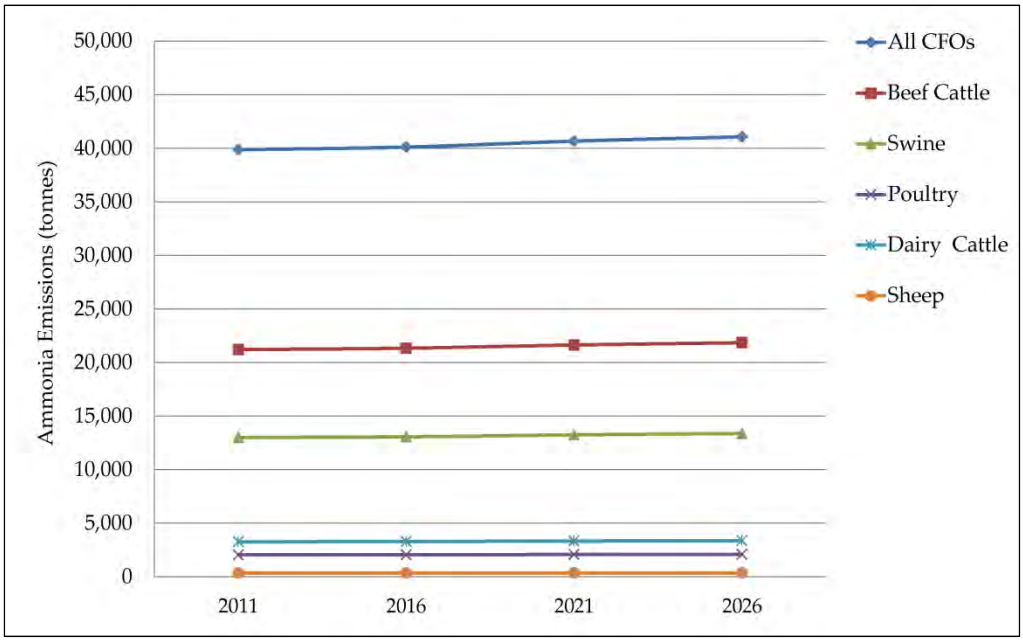

Figure 11-6 CFO NH_3 emissions forecasts for 2016, 2021 and 2026

11.3 Particulate Matter Emissions

11.3.1 Distribution by Livestock Category

Estimated emissions of PM_{10} and $PM_{2.5}$ from all CFOs in Alberta decreased by approximately 13% between 2006 and 2011. Except for swine CFOs, estimated PM_{10} and $PM_{2.5}$ emissions in 2011 (Table 11-3) did not appear to vary considerably among the other livestock categories and sub-categories compared to emissions in 2006. PM_{10} and $PM_{2.5}$ emissions from swine CFOs decreased by approximately 32% from 2006 to 2011. Once again, it is apparent that the much lower AFs for swine CFOs in 2011 resulted in lower PM emission estimates by APMEICA 2011.

However, despite the lower swine CFO emission estimates in 2011, swine CFOs remained the second highest contributors of PM_{10} (Fig. 11-7) and $PM_{2.5}$ (Fig 11-8) emissions among CFOs in

the province, second only to beef cattle CFOs.

Table 11-3 Breakdown of PM_{10} and $PM_{2.5}$ emissions by livestock category in Alberta in 2011

Livestock		PM Emissions (tonnes)	
		PM_{10}	$PM_{2.5}$
Beef			
	Heifers	417	93
	Steers	494	110
		912	203
Dairy	Heifers	25	6
	Cows	70	16
Subtotal		95	22
Poultry			
	Broilers	88	11
	Layers	24	3
	Pullets	8	1
	Turkeys	7	1
Subtotal		128	16
Sheep			
	Ewes	3	1
	Lambs	3	1
	Rams	0	0
Subtotal		6	2
Swine			
	Boars	2	0
	Growers	307	68
	Sows	49	11
	Weaners	35	8
Subtotal		392	87
Total		1532	330

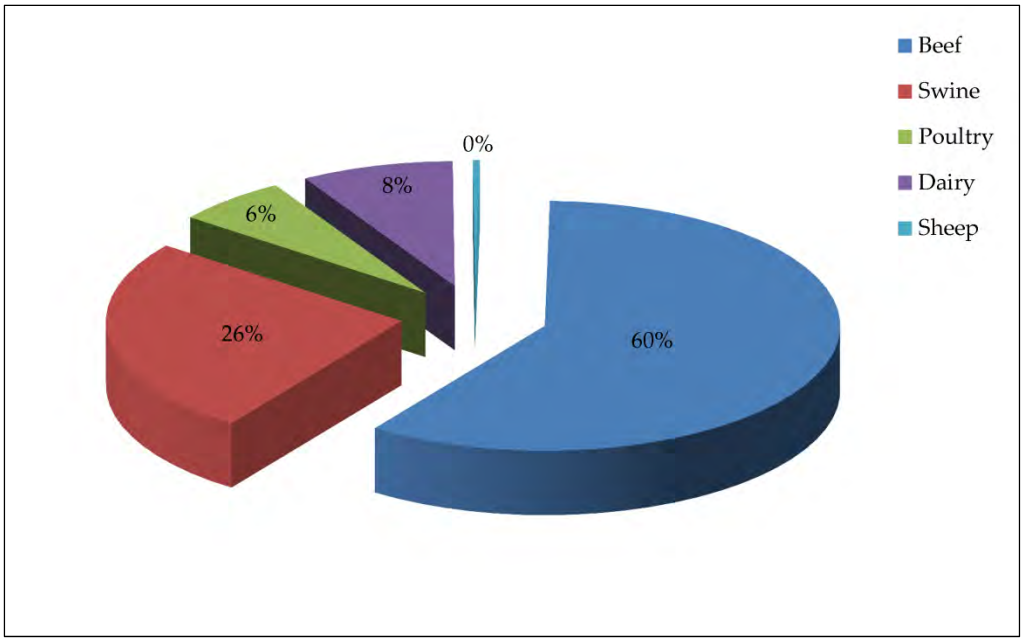

Figure 11-7 2011 distribution of CFO PM_{10} emissions in Alberta by livestock category

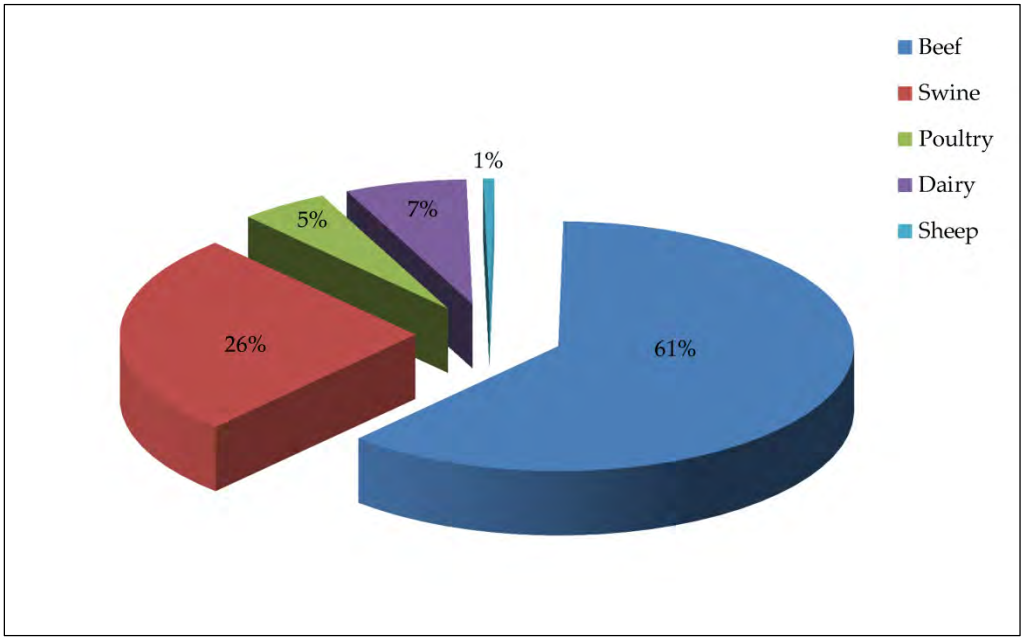

Figure 11-8 2011 distribution of CFO $PM_{2.5}$ emissions in Alberta by livestock category

11.3.2 Temporal Distribution

No new monthly, seasonal or annual PM EFs were developed for any of the livestock categories since APMEICA 2006 was released in 2012. Therefore, APMEICA 2011 estimated PM emissions (Tables 11-8 and 11-9) using the same annual EFs for each livestock sub-category as used by APMEICA 2006 and the updated monthly AFs.

11.3.3 Spatial Distribution

Similar to NH_3 emissions, APMEICA 2011 estimates PM emissions spatially with respect to 2011 Census Agricultural Regions, Alberta's Land Use Framework regions, ARD-defined regions, and municipalities. However, estimates associated with the 2011 Census Agricultural Regions and ARD-defined regions are not addressed in this addendum.

11.3.3.1 Land Use Framework Regional Scale

Estimated emissions of PM_{10} and $PM_{2.5}$ showed a decrease in 2011 compared to 2006 in six of the seven LUF regions in Alberta, with the greatest decrease (27% and 32%, respectively) occurring in the Red Deer region. Similar to the LUF regional NH_3 emission estimates, only the beef Lower Peace region showed an increase in both PM emissions in 2011, again due to an increase in the number of beef cattle in that region.

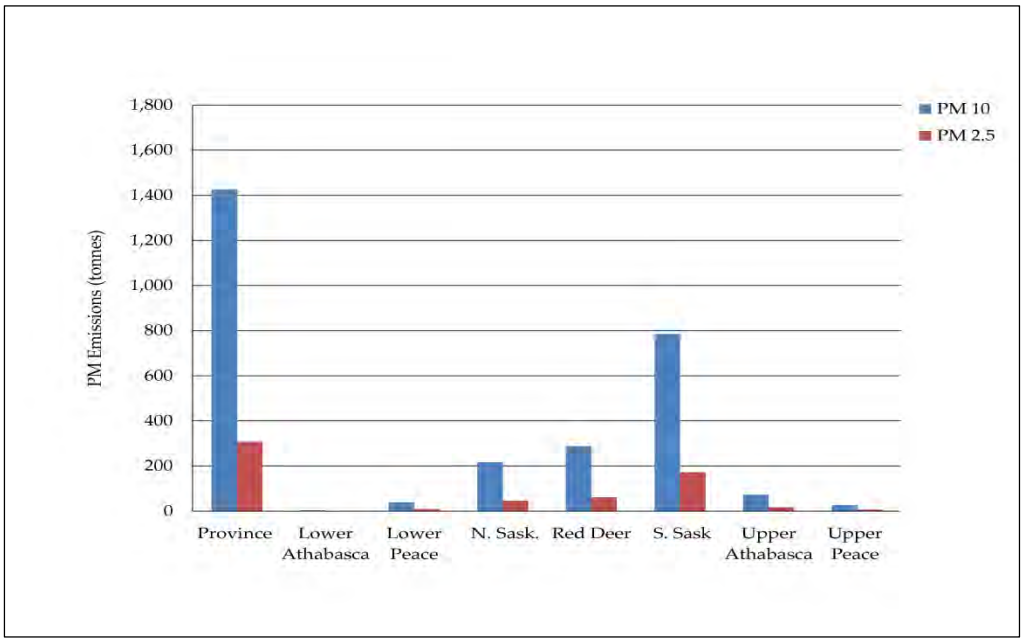

Figure 11-9 2011 distribution of CFO PM emissions in Alberta sorted by LUF Region

11.3.3.2 Municipal Scale

As indicated in Table 11-6, Lacombe County, County of Lethbridge, M.D. of Taber, County of Vulcan and Wheatland County, were estimated to release the most PM emissions in Alberta in 2011. Compared to APMEICA 2006, Kneehill County and the County of Newell were displaced by the M.D. of Taber and the County of Vulcan in APMEICA 2011. The County of Newell experienced a decrease in emissions of approximately 99%, associated with the drastic decline in beef cattle numbers in that municipality between 2006 and 2011, while emissions were estimated to decrease in Kneehill County because of the noticeable decline in the number of pigs in that municipality by 2011. Conversely, the M.D. of Taber and the County of Vulcan experienced approximately 85% and 77% increases in PM emissions, respectively, from 2006 to 2011, indicative of the increases in beef cattle numbers in both municipalities.

11.3.4 Apportionment of Particulate Matter Emissions in Alberta

CFOs in Alberta were estimated emit approximately 6.4% and 0.1% of the PM_{10} emissions from industrial point sources and mobile sources, respectively, in 2011 (Table 11-4). Similarly, CFO $PM_{2.5}$ emissions were approximately 2.7% and 0.14% of the emissions from industrial point sources and mobile sources, respectively.

Table 11-4 Annual CFO PM emissions in 2011 compared to emissions from other sources in Alberta*

Sector	PM Emissions (tonnes)	
	PM_{10}	$PM_{2.5}$
CFOs (APMEICA)	1,532	330
Industrial point sources*	23,870	12,399
Mobile sources (includes paved and unpaved road dust)*	1,461,098	234,148

* NPRI 2011 Air Pollutant Emission Summaries for Alberta (R. Melick, Emissions Inventory Scientist, Ministry of Environment and Sustainable Resource Development, Edmonton, AB, pers. comm.)

11.3.5 Particulate Matter Emission Forecasts

Similar to APMEICA 2006 forecast, APMEICA 2011 forecast an increase in PM emissions for all CFOs from 2011to 2026 with noticeable increases associated with beef cattle and to some extent swine CFOs (Figs. 11-10 and 11-11). There was little or no change in the forecasts for dairy,

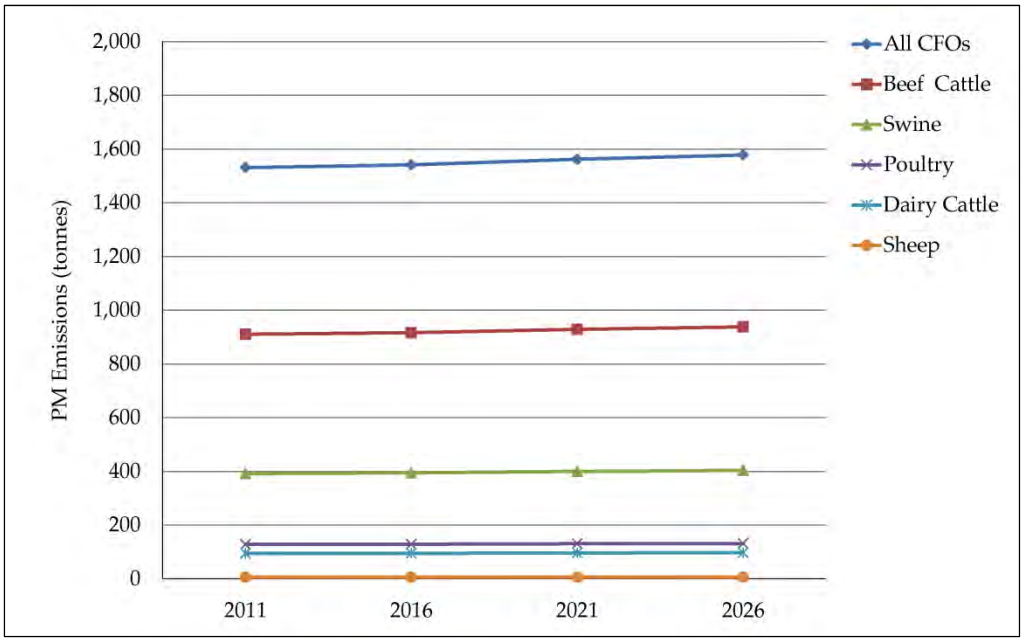

Figure 11-10 CFO PM_{10} emissions forecasts for 2016, 2021 and 2026

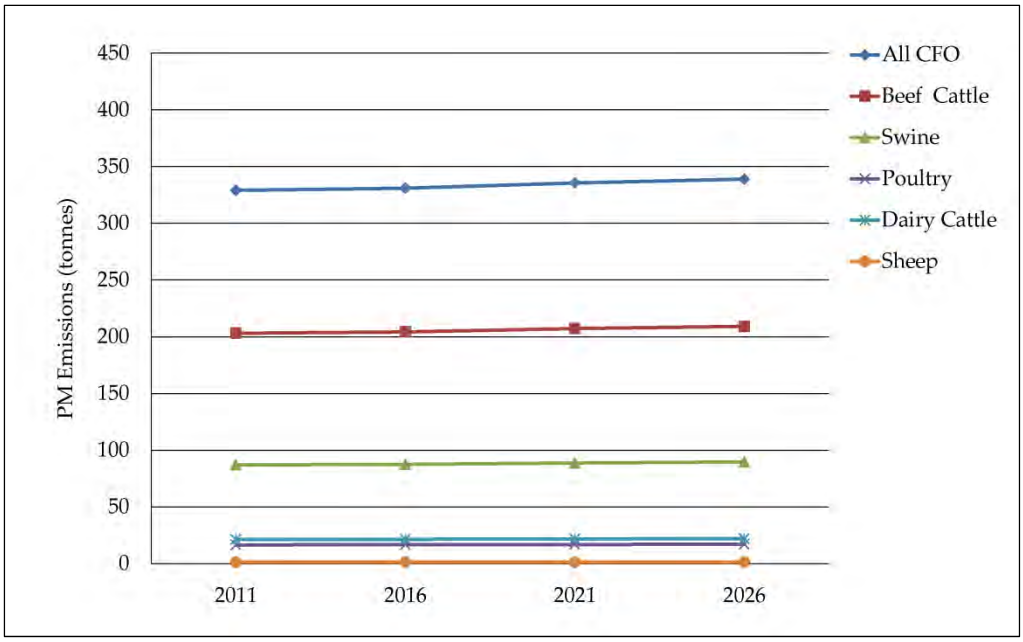

Figure 11-11 CFO $PM_{2.5}$ emissions forecasts for 2016, 2021 and 2026

poultry and sheep CFOs. Detailed forecasts of PM_{10} and $PM_{2.5}$ emissions by livestock sub-category are presented in Tables 11-11 and 11-12, respectively.

Although the amount of emissions were lower in the APMEICA 2011 forecast, the rate of change in emissions with time remained the same as the forecast by APMEICA 2006, considering that the only difference between the two emission inventories was the change in AFs and no change in EFs or growth factors.

11.4 Conclusions and Recommendations

Swine CFOs in Alberta experienced a drastic decline in livestock numbers between 2006 and 2011. The reduction in pig numbers especially in AFs growers (~426,000 pigs representing 65% of the change) was primarily responsible for the noticeable overall decrease in NH_3, PM_{10} and $PM_{2.5}$ emission estimates from all CFOs in Alberta by APMEICA 2011 relative to the 2006 base year. Although a correction in dairy cow NH_3 EFs was applied to APMEICA 2011, this change had less influence on the overall NH_3 emission estimates associated with all CFOs in Alberta versus the sole impact on dairy cattle CFO estimates. When the same corrected dairy cow NH_3 EFs were applied to APMEICA 2006 it resulted in a slight increase in the overall provincial NH_3 emission estimates for 2006. However, while the dairy cow monthly EFs were updated in APMEICA 2011 database and addressed in this addendum, there will be no update of APMEICA 2006 database or its associated report to reflect the changes in dairy cow NH_3 EFs and subsequently NH_3 emissions in 2006.

The following conclusions were drawn with respect to APMEICA 2011:

- CFOs in Alberta were estimated to emit 39,816 tonnes of NH_3, 1,532 tonnes of PM_{10} and 330 tonnes of $PM_{2.5}$ in 2011 compared to 42,750 tonnes of NH_3, 1,762 tonnes of PM_{10} and 380 tonnes of $PM_{2.5}$ in 2006 (uncorrected).

- Beef Cattle and swine CFOs jointly accounted for 86% of NH_3 , 86% of PM_{10} and 87% of $PM_{2.5}$ annual emissions in 2011, compared to 91% of NH_3 (uncorrected), 87% of PM_{10} and 90% of $PM_{2.5}$ in 2006.

- In comparison to industrial point sources and mobiles sources, CFOs were estimated to be the biggest contributor of NH_3 emissions in Alberta in 2006, emitting approximately five times more NH_3 than industrial point sources and 11 times more NH_3 than mobile sources.

- Conversely, in comparison to industrial point sources and mobiles sources, CFOs were estimated to be the smallest contributor of PM emissions in Alberta in 2011, emitting approximately 15 times less PM_{10} and 37 times less $PM_{2.5}$ than industrial point sources, and 954 times less PM_{10} and 710 times less $PM_{2.5}$ than mobile sources.

- Similar to 2006, NH_3 emission estimates from CFOs in 2011 were highest between May and October.

- Warner County (South Saskatchewan LUF region) was one of five municipalities in Alberta that accounted for the highest NH_3 emissions from CFOs in 2011, displacing the County of Newell (South Saskatchewan LUF region) from 2006.

- For PM_{10} and $PM_{2.5}$ emission estimates, the County of Vulcan and M.D. of Taber (South Saskatchewan LUF region) were two of the five municipalities in Alberta that accounted for the highest PM emissions in 2011, displacing the County of Newell (South Saskatchewan LUF region) and Kneehill County (Red Deer LUF region) from 2006.

- Similar to 2006, forecasts for NH_3, PM_{10} and $PM_{2.5}$ emissions from CFOs in Alberta continue to show an increase in the future, from 2011 to 2026, particularly from beef cattle and swine CFOs.

11.4.1 Recommendations

There is no update to the recommendations provided in section 7.1 of this report.

11.5 References

ARD. 2013. Statistics: Livestock. Edmonton, AB: Ministry of Agriculture and Rural Development, Economics and Statistics Branch. http://www.agric.gov.ab.ca/app21/infopage?cat1=Statistics&cat2=Livestock (Accessed: February 08, 2013).

SC. 2013. 2011 Census of Agriculture. Statistics Canada. http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=480000000 (Accessed: Sep. 10, 2013).

11.6 APMEICA 2011 Tables

Table 11-5 Revised Monthly EFs for NH_3 in kg/animal for Dairy Cows in Different Ecoregions in Alberta (Source: S. Sheppard, ECOMatters Inc., personal communication, 2011)

Month	Overall mean	Brown Soil	Dark Brown Soil	Black Soil	Boreal Plains	Mountain Cordillera
January	0.971	0.722	0.987	0.673	0.736	0.892
February	0.971	0.722	0.987	0.673	0.736	0.892
March	1.512	1.176	1.908	1.051	1.213	1.390
April	3.624	3.490	5.259	3.917	3.987	3.594
May	5.557	3.233	4.102	5.469	5.220	6.366
June	3.445	4.761	3.321	2.429	3.536	2.890
July	3.454	3.229	3.102	2.406	3.180	2.652
August	3.502	2.459	2.542	2.344	2.594	1.878
September	4.500	4.977	4.125	3.182	4.294	3.070
October	4.355	5.995	6.200	4.575	4.671	5.291
November	1.587	0.764	1.079	0.721	0.799	0.936
December	0.971	0.722	0.987	0.673	0.736	0.892
Yearly	**34.449**	**32.250**	**34.599**	**28.113**	**31.702**	**30.743**

Table 11-6 Summary of 2011 NH_3 and PM Emissions from Alberta CFOs by LUF Region

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2011			
	Unit : Tonnes			
Sum of Tonnes		Substance_Name		
LUF_Name	County_Name	Ammonia (Total)	PM10 - Particulate Matter <= 10 Microns	PM2.5 - Particulate Matter <=2.5 Microns
Lower Athabasca	Bonnyville	65.096	2.802	0.623
	Lac La Biche County	6.774	0.284	0.063
Lower Athabasca Total		71.870	3.086	0.686
Lower Peace	Mackenzie No 23	24.850	1.118	0.234
	Northern Light 22	21.452	0.947	0.211
	Northern Sunrise	841.797	35.569	7.695
Lower Peace Total		888.099	37.634	8.140
North Saskatchewan	Beaver	494.077	16.958	3.620
	Brazeau County	63.144	3.113	0.692
	Brazeau No. 77	0	0	0
	Camrose	294.346	16.594	2.975
	Clearwater	282.968	11.233	2.496
	Edmonton	0.306	0.016	0.004
	Flagstaff	110.134	5.851	1.305
	Green View No 16	107.899	4.752	1.003
	Lamont	88.348	4.795	1.067
	Leduc County	429.428	16.452	3.496
	Minburn	347.233	16.965	3.755
	Parkland County	131.563	4.963	1.093
	Provost	289.990	14.418	3.210
	Smokey Lake	68.699	3.455	0.770
	St. Pual	195.113	10.391	2.286
	Strathcona County	57.499	2.523	0.550
	Sturgeon County	486.136	20.651	3.399
	Thothid No 7	16.138	0.694	0.142
	Two Hills	75.404	3.780	0.776
	Vermilion	394.306	21.460	4.706
	Wainwright	627.283	21.106	4.660
	Wetaskiwin No 10	323.225	15.311	3.148
North Saskatchewan Total		4,883.239	215.483	45.153
Red Deer	Acadia No 34	0.000	0	0
	Kneehill	908.172	38.841	7.805
	Lacombe	1,442.902	52.973	11.081
	Mountain view	415.594	19.765	3.956
	Paintearth No. 18	398.594	14.905	3.253
	Ponka	1,160.156	44.401	9.196
	Red Deer	1,145.554	43.993	9.719
	Specail area No 4	391.082	18.825	4.195
	Special area No 2	60.818	2.665	0.588
	Special area No 3	78.087	3.546	0.790
	Starland	370.766	13.518	2.824

Livestock_Category	(All)			
Livestock_Sub_Category	(All)			
Year	2011			
	Unit : Tonnes			
Sum of Tonnes		**Substance_Name**		
LUF_Name	**County_Name**	**Ammonia (Total)**	**PM10 - Particulate Matter <= 10 Microns**	**PM2.5 - Particulate Matter <=2.5 Microns**
	Stettler	911.646	33.455	7.347
Red Deer Total		7,283.253	286.887	60.754
South Saskatchewan	Bighorn No. 8	49.615	1.991	0.440
	Calgary	0.196	0.010	0.002
	Cardston	871.309	29.101	6.327
	Cypress	442.370	21.255	4.738
	Foothill No 4	639.269	35.823	7.754
	Fortymile	296.586	12.803	2.857
	Lethbridge	5,066.861	240.292	52.288
	Newell	21.119	0.887	0.196
	Pincher Creek	707.481	30.304	6.686
	Ranchland	46.329	2.288	0.510
	Rocky View	549.893	25.789	5.648
	Taber	2,854.095	120.233	26.441
	Vulcan	2,338.611	106.905	23.690
	Warner	1,312.504	49.389	10.584
	Wheatland	1,268.546	57.217	12.530
	Willow Creek	1,076.774	50.949	11.349
South Saskatchewan Total		17,541.562	785.237	172.041
Upper Athabasca	Athabasca county 12	113.404	5.027	1.120
	Barrhead County No. 11	792.386	32.744	7.113
	Big Lake	9.854	0.464	0.103
	Lac Ste. Anne County	110.662	4.788	1.063
	Lesser Slave	7.163	0.350	0.077
	Westlock	474.949	20.773	4.624
	Woodland	19.785	0.880	0.196
	Yellowhead county	147.306	6.723	1.495
Upper Athabasca Total		1,675.509	71.749	15.792
Upper Peace	Birch Hill	219.422	7.637	1.695
	Clear Hills	45.474	2.146	0.475
	Fairview No 136	3.566	0.204	0.045
	Grand Prairie No 1	248.418	10.976	2.437
	Peace No 135	21.428	1.007	0.224
	Saddle Hill	40.052	1.727	0.384
	Smokey River	43.630	2.181	0.486
	Spirit River	0.000	0.000	0.000
Upper Peace Total		621.990	25.878	5.746
Grand Total		**32,965.522**	**1,425.954**	**308.311**

Table 11-7 Summary of 2011 NH_3 Emissions from Alberta CFOs by Month

County_ Name	(All)													
Year	2011													
Substance_ Name	Ammonia (Total)													
	Unit : Tonnes													
Sum of Tonnes		Month												
Livestock_ Category	Livestock_ Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Cattle	Beef Heifers	349.44	349.44	349.56	369.64	1032.74	977.23	1032.58	1038.28	1063.07	1015.94	447.85	447.69	8473
	Dairy Cows	78.62	78.62	122.96	293.56	448.43	278.05	448.43	281.88	362.26	350.63	127.79	78.14	2779
	Dairy Heifers	23.12	23.12	23.12	24.45	60.94	57.66	57.48	57.80	59.18	56.56	24.93	24.92	493
	Steers	521.02	521.02	521.17	549.33	1528.59	1463.72	1546.69	1570.38	1606.18	1538.13	687.79	687.56	123742
Cattle Total		972.20	972.20	1016.81	1236.98	3070.71	2776.67	2914.81	2948.34	3090.69	2961.26	1288.36	1238.30	24487
Poultry	Broilers	36.12	36.12	36.12	116.38	161.20	66.54	80.00	80.32	114.97	148.93	36.12	36.12	949
	Layers	23.70	23.70	23.83	62.87	85.39	39.17	45.62	45.78	62.78	79.12	23.92	23.70	540
	Pullets	8.09	8.09	8.13	21.45	29.13	13.36	15.56	15.62	21.41	26.99	8.16	8.09	184
	Turkeys	14.77	14.77	14.77	44.08	60.45	25.88	30.80	30.91	43.57	55.97	14.77	14.77	366
Poultry Total		82.68	82.68	82.85	244.78	336.17	144.95	171.99	172.63	242.73	311.01	82.97	82.68	2038
Sheep	Ewes	14.45	14.45	14.45	14.45	14.71	14.71	14.74	14.74	14.74	14.74	14.74	14.74	176
	Lamb	8.82	8.82	8.82	8.82	16.79	16.79	16.78	16.78	16.78	16.78	16.78	16.78	170
	Rams	0.76	0.76	0.76	0.76	0.80	0.80	0.76	0.76	0.76	0.76	0.76	0.76	9
Sheep Total		24.03	24.03	24.03	24.03	32.30	32.30	32.28	32.28	32.28	32.28	32.28	32.28	354
Swine	Boars	1.56	1.56	1.59	1.76	2.59	2.22	2.27	2.27	2.39	2.50	1.65	1.59	24
	Growers	774.21	774.21	788.32	851.87	1153.43	1076.86	1097.15	1096.50	1147.21	1205.13	816.30	793.34	11575
	Sows	37.49	37.49	38.63	45.05	54.35	56.80	56.55	58.9	62.37	63.37	39.39	37.57	590
	Weaners	48.03	48.03	49.50	59.43	105.53	74.94	78.32	78.24	83.83	79.70	49.54	47.25	802
Swine Total		861.28	861.28	878.04	958.11	1315.89	1210.82	1236.28	1235.50	1296.11	1350.71	906.87	879.75	12991
Grand Total		**1940.19**	**1940.19**	**2001.74**	**2463.91**	**4755.06**	4164.73	**4355.36**	**4388.75**	**4661.80**	**4655.26**	**2310.47**	**2233.01**	**39870**

Table 11-8 Summary of 2011 PM_{10} Emissions from Alberta CFOs by Month

County_ Name	(All)													
Year	2011													
Substance_ Name	PM10 - Particulate Matter <= 10 Microns													
	Unit : Tonnes													
Sum of Tonnes		Month												
Livestock_ Category	Livestock_ Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Cattle	Beef Heifers	29.69	29.69	29.69	29.69	35.01	35.01	38.04	38.04	38.04	38.04	38.04	38.04	417
	Dairy Cows	5.58	5.58	5.58	5.58	5.83	5.83	5.81	5.81	5.81	5.81	5.81	5.81	70
	Dairy Heifers	1.96	1.96	1.96	1.96	2.07	2.07	2.12	2.12	2.12	2.12	2.12	2.12	25
	Steers	34.35	34.35	34.35	34.35	42.17	42.17	45.33	45.33	45.33	45.33	45.33	45.33	494
Cattle Total		71.86	71.86	71.86	71.86	85.07	85.07	91.31	91.31	91.31	91.31	91.31	91.31	1005
Poultry	Broilers	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	88
	Layers	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	24
	Pullets	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	8
	Turkeys	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	7
Poultry Total		10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	128
Sheep	Ewes	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3
	Lamb	0.15	0.15	0.15	0.15	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	3
	Rams	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Sheep Total		0.42	0.42	0.42	0.42	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	6
Swine	Boars	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	2
	Growers	25.82	25.82	25.82	25.18	23.94	25.18	25.23	25.23	25.23	26.46	26.46	26.46	307
	Sows	4.16	4.16	4.16	4.12	3.29	4.12	4.14	4.14	4.17	4.17	4.17	4.17	49
	Weaners	2.82	2.82	2.82	2.87	3.38	2.87	2.93	2.93	2.93	2.78	2.78	2.78	35
Swine Total		32.95	32.95	32.95	32.31	30.75	32.31	32.43	32.43	33.43	33.55	33.55	33.55	392
Grand Total		**115.88**	**115.88**	**115.88**	**115.24**	**127.04**	**128.59**	**134.95**	**134.95**	**134.95**	**136.08**	**136.08**	**136.08**	**1532**

Table 11-9 Summary of 2011 $PM_{2.5}$ Emissions from Alberta CFOs by Month

County_ Name	(All)												
Year	2011												
Substance_ Name	PM2.5 - Particulate Matter <=2.5 Microns												
	Unit : Tonnes												
Sum of Tonnes		Month											
Livestock_ Category	Livestock_ Sub_Category	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Cattle	Beef Heifers	6.62	6.62	6.62	6.62	7.82	7.80	8.48	8.48	8.48	8.48	8.48	8.48	93
	Dairy Cows	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	16
	Dairy Heifers	0.44	0.44	0.44	0.44	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.47	6
	Steers	7.66	7.66	7.66	7.66	9.40	9.40	10.11	10.11	10.11	10.11	10.11	10.11	110
Cattle Total		16.03	16.03	16.03	16.03	18.98	18.98	20.37	20.37	20.37	20.37	20.37	20.37	224
Poultry	Broilers	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	11
	Layers	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	3
	Pullets	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1
	Turkeys	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1
Poultry Total		1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	16
Sheep	Ewes	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
	Lamb	0.03	0.03	0.03	0.03	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	1
	Rams	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Sheep Total		0.09	0.09	0.09	0.09	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	2
Swine	Boars	0.03	0.03	0.03	0.30	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0
	Growers	5.72	5.72	5.72	5.58	5.31	5.58	5.59	5.59	5.59	5.86	5.86	5.86	68
	Sows	0.92	0.92	0.92	0.91	0.73	0.91	0.92	0.92	0.93	0.93	0.93	0.93	11
	Weaners	0.63	0.63	0.63	0.64	0.75	0.64	0.65	0.65	0.65	0.62	0.62	0.62	8
Swine Total		7.31	7.31	7.31	7.17	6.82	7.17	6.82	7.19	7.19	7.44	7.44	7.44	87
Grand Total		**24.80**	**24.80**	**24.80**	**24.66**	**27.29**	**27.63**	**27.63**	**29.05**	**29.05**	**29.30**	**29.30**	**29.30**	**329**

Table 11-10 NH_3 Emission Forecast for Alberta CFOs

Substance_Name	Ammonia (Total)				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2011	2016	2021	2026
Cattle	Beef Heifers	8,473.46	8,524.30	8,642.92	8,727.66
	Dairy Cows	2,7779.02	2,795.69	2,834.60	2,862.39
	Dairy Heifers	493.27	496.23	503.14	508.07
	Steers	12,741.57	12,818.02	12,996.40	13,123.82
Cattle Total		24,487.32	24,634.24	24,977.06	25,221.94
Poultry	Broilers	948.94	954.63	967.92	977.41
	Layers	539.59	542.83	550.38	555.78
	Pullets	184.07	185.17	187.75	189.59
	Turkeys	365.52	367.71	372.83	376.48
Poultry Total		2,038.11	2,050.34	2,078.88	2,099.26
Sheep	Ewes	175.66	176.72	179.18	180.93
	Lamb	169.51	170.52	172.90	174.59
	Rams	9.23	9.29	9.41	9.51
Sheep Total		354.40	356.53	361.49	365.03
Swine	Boars	23.94	24.09	24.42	24.66
	Growers	11,574.52	11,643.96	11,806.01	11,921.75
	Sows	589.83	593.37	601.63	607.53
	Weaners	802.34	807.15	818.39	826.41
Swine Total		12,990.63	13,068.58	13,250.45	13,380.35
Grand Total		**39.870.46**	**40,109.69**	**40,667.87**	**41,066.58**

Table 11-11 PM_{10} Emission Forecast for Alberta CFOs

Substance_Name	PM10 - Particulate Matter <= 10 Microns				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2011	2016	2021	2026
Cattle	Beef Heifers	417.03	419.54	425.37	429.54
	Dairy Cows	69.95	70.37	71.35	72.05
	Dairy Heifers	24.69	24.84	25.19	25.43
	Steers	493.75	496.72	503.63	508.57
Cattle Total		1,005.43	1,011.46	1,025.54	1,035.59
Poultry	Broilers	880.05	88.58	89.81	90.69
	Layers	24.39	24.54	24.88	25.13
	Pullets	8.32	8.37	8.49	8.57
	Turkeys	7.14	7.18	7.28	7.35
Poultry Total		127.90	128.67	130.46	131.74
Sheep	Ewes	3.04	3.05	3.10	3.13
	Lamb	2.93	2.95	2.99	3.02
	Rams	0.16	0.16	0.16	0.16
Sheep Total		6.12	6.16	6.25	6.31
Swine	Boars	1.67	1.68	1.70	1.72
	Growers	306.82	308.67	312.96	316.03
	Sows	48.93	49.23	49.91	50.40
	Weaners	34.72	34.92	35.41	35.76
Swine Total		392.14	394.50	399.99	403.91
Grand Total		**1,531.60**	**1,540.79**	**1,562.23**	**1,577.55**

Table 11-12 $PM_{2.5}$ Emission Forecast for Alberta CFOs

Substance_Name	PM2.5 - Particulate Matter <=2.5 Microns				
	Unit : Tonnes				
Sum of Tonnes/Year		Year			
Livestock_Category	Livestock_Sub_Category	2011	2016	2021	2026
Cattle	Beef Heifers	92.95	93.50	94.80	95.73
	Dairy Cows	15.71	15.81	16.03	16.18
	Dairy Heifers	5.50	5.54	5.61	5.67
	Steers	110.11	110.77	112.31	113.41
Cattle Total		224.27	225.61	228.75	230.99
Poultry	Broilers	11.33	11.40	11.56	11.67
	Layers	3.14	3.16	3.20	3.23
	Pullets	1.07	1.08	1.09	1.10
	Turkeys	0.92	0.92	0.92	0.94
Poultry Total		16.46	16.56	16.79	16.96
Sheep	Ewes	0.64	0.65	0.66	1.34
	Lamb	0.62	0.62	0.63	0.64
	Rams	0.03	0.03	0.03	0.03
Sheep Total		1.30	1.31	1.32	1.34
Swine	Boars	0.37	0.37	0.38	0.38
	Growers	68.00	68.41	69.36	70.04
	Sows	10.87	10.94	11.09	11.20
	Weaners	7.75	7.79	7.90	7.98
Swine Total		86.99	87.51	88.78	89.60
Grand Total		**329.01**	**330.99**	**335.60**	**338.89**

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