Confined Feeding Operations Project Team
Emissions Inventory Summary Report

Prepared by the
Emissions Inventory Subgroup
for the
Confined Feeding Operations Project Team

Final Report

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About CASA

The Clean Air Strategic Alliance (CASA) is a non-profit association composed of stakeholders from three sectors – government, industry and non-government organizations such as health and environmental groups. All CASA groups and teams, including the board of directors, make decisions and recommendations by consensus. These recommendations are likely to be more innovative and longer lasting than those reached through traditional negotiation processes. CASA's vision is that the air will be odourless, tasteless, look clear and have no measurable short- or long-term adverse effects on people, animals or the environment.

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Executive Summary

The Emission Inventory (EI) subgroup of the CASA Confined Feeding Operations (CFO) project team has reviewed existing emissions inventories and reports related to CFO emissions. The twelve relevant inventories and reports are summarized in this report.

Important observations on emissions inventories:

- The completeness and accuracy of an emissions inventory depends on the purpose for which it was intended
- There are no inventories that can answer all the questions the CFO team has about emissions from CFOs

From the existing inventories reviewed using the Stats Canada Agricultural Census data (2001) for Canada and Alberta, the estimated numbers of animals in CFOs in Alberta are:

- Dairy cattle: 84,044
- Beef cattle: 6,531,157
- Pigs: 2,027,533
- Sheep: 307,302
- Poultry: 2,907,377

From the various methodologies described in this report, the estimated amounts of emissions from CFOs in Alberta are:

Methodology	**Total Estimated Emissions**
US EPA Ammonia Inventory	• Ammonia: 167,954 tonnes
Alberta Agriculture and Food Emissions Inventory (2001)	• Ammonia: 124,675 tonnes • H_2S/TRS: 4,012 tonnes • Particulate Matter: 19,539 tonnes
Carnegie Mellon University Ammonia Model	• Ammonia: 181,069 tonnes

There is currently no estimated amount of volatile organic compounds or bioaerosols from CFOs in Alberta. The estimated distribution of CFO emissions across Alberta is highest in southern Alberta and lowest in northern Alberta for ammonia, H_2S/TRS and particulate matter.

The CFO team should encourage Alberta Environment, Environment and Agriculture Canada and industry to conduct specific studies in areas with intensive agriculture using suitable source apportionment methods to estimate the relative impacts of agriculture and other emissions in a local area.

Recommendations

The following recommendations have been developed by the EI subgroup for consideration by the CFO project team:

<u>Recommendation 1 – Use of this Report</u>

This report should be used to provide the CFO team with the necessary background to discuss emissions management recommendations for the province of Alberta.

<u>Recommendation 2 – Development of a New Inventory</u>

Alberta Agriculture and Food, Alberta Environment, National Resource Conservation Board, Environment Canada and industry should develop a CFO Emissions Inventory for the province of Alberta.

<u>Recommendation 3 – Source Apportionment Methods</u>

Encourage Alberta Environment, Environment and Agriculture Canada and industry to conduct specific studies in areas with intensive agriculture using suitable source apportionment methods to estimate the relative impacts of agriculture and other emissions in a local area.

1 Introduction

The CASA Confined Feeding Operations (CFO) project team agreed to form a subgroup to address the matter of an emissions inventory. This emissions inventories information is intended to facilitate the development of a strategic plan to manage CFO air emissions. Where appropriate, the EI subgroup was mandated to oversee the development of an Alberta CFO emissions inventory, which would include substances agreed upon by the CFO project team. The complete EI subgroup Terms of Reference (TOR) is provided in Appendix A.

This report provides background information on inventory methodologies, describes substances of interest for emissions inventories, summarizes existing inventories, and outlines source apportionment approaches. Based on this information, the EI subgroup herein provides recommendations on how the CASA CFO project team should proceed on the matter of emissions inventories and source apportionment.

For each existing methodology, the following information has been summarized:

- Background on the source of the inventory or report, including the goals, where available
- Formulas used to calculate emissions estimates
- Types of animals assessed
- Limitations on the data and reports
- Summary of the relevance of the information to the CFO team

2 Definition of a CFO

In order to investigate the potential of developing a new CFO emissions inventory for Alberta, the EI subgroup considered three livestock populations:

- All livestock in Alberta
- Approved CFOs
- CFOs as defined by the Alberta Agricultural Operations Practices Act

2.1 All Livestock in Alberta

In order to estimate the work involved in assessing emissions from all livestock in Alberta, the subgroup took the following steps:

2.1.1 Questionnaire

The EI subgroup developed a questionnaire and discussed it with the Alberta Association of Municipal Districts and Counties (AAMD&C). The goal was to determine if municipalities have enough information about number of animals and manure management for emissions inventory development in their jurisdictions. The questionnaire is shown in Appendix B. AAMD&C advised the EI subgroup that the Natural Resource Conservation Board (NRCB) and Alberta Agriculture and Food (AF have this information with regard to CFOs as defined by the Alberta Agricultural Operations Practices Act (AOFA). As a result, the questionnaire was not distributed to AAMD&C members.

2.1.2 Agricultural Census Data

In the absence of data from municipalities (with the exception of Lethbridge County), the EI subgroup used 2001 Agricultural Census data for Alberta. The census data was developed by agricultural region and census division. Maps and data are shown in Appendix C. The data included numbers for cattle, pigs, sheep, poultry and others (horses, goats, bison, bees, etc) and information about manure application methods. Apparently, the 2006 data will be released in May 2007, which may be used in the future.

2.2 Approved CFOs

CFOs as defined by AOPA require NRCB approval. There are currently 2114 approved CFOs in the province of Alberta and a portion of these were permitted by local municipalities prior to 2002. In January 2002, the NRCB assumed responsibility for permitting CFOs in Alberta.

2.3 CFOs and the Alberta Agricultural Operations Practices Act

The *Alberta Agricultural Operations Practices Act* (AOPA) defines a CFO as:

> "S. 1. (b.6) "confined feeding operation" means fenced or enclosed land or buildings where livestock are confined for the purpose of growing, sustaining, finishing or breeding by means other than grazing and any other building or structure directly related to that purpose but does not include residences, livestock seasonal feeding and bedding sites, equestrian stables, auction markets, race tracks or exhibition grounds;"

There are various factors that determine whether or not an operation meets the AOPA CFO definition. For example, 10 animals in a small pen may be considered a CFO; however, it does not meet the threshold for review, permitting and approvals.

It was concluded that the work involved in assessing emissions from CFOs as defined in AOPA is either covered under the All Livestock (Section 2.1) or the Approved CFO (Section 2.2) options.

3 Background on Inventories

3.1 Emissions Inventory

An emissions inventory is an accounting of pollutant emissions released into the air over a given period of time for a given political or geographical region. An emissions inventory may include both anthropogenic (caused by humans) and biogenic (natural sources).

The sources of emissions included in these inventories can be grouped into three categories:

- Point sources
- Area sources
- Mobile sources

Point sources are stationary and the emissions released can be traced back to a single identifiable location. Area sources describe emissions from spatially diffuse and/or numerous sources that can only be measured or estimated using the accumulation of point sources. For example, lagoons and manure application operations are area sources of emissions. Mobile sources include broad area source emissions accumulated from non-stationary operations. The definition of a mobile source depends on grid size or scale.

3.2 Information in Emissions Inventories

Generally, an emissions inventory summarizes the amount and types of air pollutants released into the air as defined by the objectives of the inventory. The content of an inventory is determined by balancing the objectives and scope of that inventory with the resources available to conduct it.

A small-scale inventory may only require that a small amount of data be collected, but may have stringent requirements for estimating emissions, while a large scale emissions inventory may require data from thousands of sources but may be less stringent on the methods used for estimating emissions. Ultimately, the data collected must be sufficient in both quality and quantity to satisfy the objectives of the inventory thus meeting the needs of its users.

Natural sources of air pollution that can be included in an emissions inventory include:

- Growing and decaying vegetation
- Forest fires
- Volcanic activity
- Windblown dust
- Pollen

Major anthropogenic sources of air pollution that may be included in an emissions inventory include emissions from industrial and commercial processes and transportation.

3.3 Potential Uses of Emissions Inventories

In general, emission inventories are used for planning, assessment and research. Specifically, emissions inventories can be used for:

- Determining and comparing trends in quantities of emitted pollutants
- Tracking emissions and thereby identifying areas of importance by substance, location or source
- Gaining a better understanding of the overall air quality for a given area
- Developing air quality models

A CFO emission inventory would establish a baseline or benchmark for emissions in Alberta at a given point in time. This information could then be used to:

- Determine if emission levels have changed over time
- Compare trends in emissions
- Compare CFO emissions to those of other industries
- Facilitate prioritization of emissions management and potential improvements to future inventories
- Develop air quality models for the province of Alberta

3.3.1 Planning and Assessment

Emission inventories are an essential component of air quality management. They are needed for reporting on environmental objectives and targets, and for determining overall magnitude and trends of emissions. Environmental impact assessments, planning and assessment of control strategies as well as local and regional air quality modelling depend on these inventories providing a means to address airshed and regional air issues.

With respect to planning and assessment, emission inventory data can be used to:

- Establish baseline emission values to help track progress being made by emission reduction plans
- Provide the necessary data for air dispersion modelling to evaluate environmental impacts from future emission scenarios
- Ensure compliance of emission limits from source, regions or activities

3.3.2 Research

A variety of areas in both environmental and health sciences require emissions inventories data. The cumulative effects of pollutants is a major area of concern and an emissions inventory will help provide some of the necessary information to evaluate the impact of these emissions.

3.4 Emissions Inventories Development

Emissions inventories require considerable human and financial resources. Careful planning is necessary to ensure that the completed inventory satisfies all of the objectives set out for it. There are seven steps that are required for developing an emissions inventory plan.

Step 1 – Objectives/Goals
The objectives of the inventory must be specific enough to guide the rest of the process but broad enough to allow the flexibility needed to plan and conduct the inventory.

Step 2 - Scope
The scope will determine the pollutants, sources, sectors, geographic area and other information to include in the inventory. Developing the scope may involve research to identify existing data availability.

Step 3 - Frequency
An emissions inventory may only need to be conducted once to satisfy the objectives. Alternatively, the inventory may need to be updated at set time intervals or on a continuous basis. At this stage, the emissions inventory development plan must determine the frequency at which the inventory will be updated.

Step 4 – Data Collection Methods
The fourth step in an emissions inventory development plan is determining the methods and tools (acceptable estimates, calculation methods and quality control) that will be used to collect the data and information. In many cases, the inventory may be limited by what methods are available, what methods are being used and whether participation in the inventory is mandatory.

Step5 - Data Storage and Dissemination
Usually, a database or data management system is used to store the collected data and information. The emissions inventory development plan should address the data management system and the needs of the users accessing the data or information.

Step 6 - Determining Who Will Carry Out and Manage the Inventory
The final step in an emissions inventory development plan is deciding who or what organization will conduct and manage the inventory and analysis of the data. This could be done by the same group that initiated the development process, by a third party consultant or through the participation of a government or regulatory body. The availability of resources, expertise and time will influence this decision.

Step 7 – Approval by Stakeholders
After the emissions inventory development plan is completed, it should be presented and approved by stakeholders and users to ensure that it adequately meets the needs of those affected and involved.

3.5 Emissions Inventory Information

Emissions inventories can be designed using a top-down or bottom-up approach. The top-down approach uses an emission inventory based on large-scale data from national, provincial or regional sources. This large-scale data can be extrapolated to smaller scale emissions through comparison to other statistics such as population, sales, and gross domestic product. The bottom-up approach involves determining emissions from individual sources and summing them to obtain large-scale estimates (national, provincial, regional). Several estimation methods that can be used to determine emissions from a particular source or process are outlined in the following sub-sections.

Existing emissions data was typically collected using a survey or questionnaire, which was sent to the facilities operators. The survey requested pertinent data and information including methods used to estimate the emissions.

3.5.1 Direct Measurement

Direct measurement is generally the most accurate method of determining quantities of pollutants released from stationary (stacks) or mobile emission sources (cars). Direct measurement methods must follow very stringent protocols to ensure consistency.

Continuous emissions monitoring systems measure the actual emissions released during a monitoring operation. An alternative to continuous emissions monitoring is to use source testing, which involves the direct measurement of emission over the short-term.

3.5.2 Emission Factors

Emission factors are a set of parameters used in mathematical calculations to provide reasonable estimations of the rate at which a pollutant is released to the atmosphere as a result of a process or activity. The general emission factor equation is:

Emission rate **=** *Emission Factor* **x** *Activity Factor* **x** *Control Factor*

The emission rate is the quantity of emission released per unit time. The emission factor is a representative value relating the quantity of pollutant emitted to a specific activity or process. The activity factor is some measure of an operation that produces emissions. The control factor is the portion of emissions that are reduced due to the use of a control device or through the modification of some process.

There are two types of emission factors: general and specific. General emission factors have been developed in order to estimate emission from a given process. They are used when more precise information (such as plant technologies, specific processes, or sector emission factors) is not available. These general emission factors have been developed by various government agencies, international organizations, industrial associations and other concerned groups. Estimates using general emission factors are usually not as accurate as facility or plant specific factors.

Specific emission factors are based on comprehensive knowledge of a specific plant, technology or process. Specific emission factors are more accurate than general emission factors, as they are based on a detailed understanding of how emissions are released from a given source. These specific emission factors have been developed by various government agencies, industrial associations and individual companies or plants. These factors are not available for all sectors and processes, and may only be valid for a specific operation at an individual plant.

3.5.3 Emission Models

Another way of estimating emissions is through the use of emission models. Emission models are process equations that have been developed to estimate emissions from certain sources. These models may be based on measured or empirical values. Software packages may be used to facilitate the operation of these models. Emission models are often used for on-road and off-road mobile sources, natural/biogenic emissions and other sources.

3.5.4 Mass Balance

Mass balances can be used to estimate the amount of emissions released into the atmosphere by calculating the difference between the amounts of a component contained in the materials that enter a process, the amount contained in the products and any wastes or residuals. These emissions are determined using conservation laws.

3.5.5 Engineering Estimates

Engineering estimates are developed by an engineer who is familiar with a specific process or technology.

3.6 Emission Inventory Data and Information Storage

The collected data in an emissions inventory is usually compiled into a database or data management system. There are a variety of tools available to store and analyze the collected data in the inventory, including custom built software used by governments and companies. Microsoft Excel and Access or more comprehensive databases such as Oracle and SQL may be used for this purpose.

There are a variety of emissions inventory software suites available for specific inventory needs. Different custom software can be used to meet a variety of needs from simple data storage and organization to comprehensive analysis. These software suites can contain modelling features, GIS systems, custom reports, graphing and emission calculation tools.

3.7 Limitations of Emissions Inventories

There are many factors that may limit the usefulness of an emissions inventory including: the completeness of the inventory, the comparability of the data and the accuracy of the data. There are a number of steps that can be taken to reduce the uncertainties associated with each factor and thus minimize the limitations of an inventory.

3.7.1 Comparability

The comparability of emissions data from various sources is very important. If comparisons are to be made, the data and methods used to estimate the values must be comparable. The methods and materials used to estimate the values must be established in the initial planning of an inventory.

3.7.2 Completeness

The degree of completeness may limit the usefulness of an emissions inventory. Completeness is determined by comparing the amount of valid data collected to the amount anticipated in the initial planning of the inventory. Completeness is also affected by the amount of quality data assembled. A sufficient quantity of data and information may have been collected, but it may be of inadequate quality to include in the inventory. As a result, the inventory may not meet the objectives.

3.7.3 Accuracy

The calculation methods used to determine emissions can have a significant effect on the accuracy of an inventory. Each method used will have some degree of accuracy. Some industries and processes have more comprehensive emission estimation methods and factors available than others.

When emissions are calculated for an individual source, the uncertainty of an emission factor or method of calculation/estimation must be considered. The most appropriate and ideally, the most accurate methods of estimation should always be used; however, this is dependant on the availability and collection of the emissions data.

There are two types of emission estimation uncertainties: model and parameter uncertainty. Model uncertainty refers to the uncertainty associated with the estimation methodology (i.e. mathematical equations or inventory estimation models). Parameter uncertainty is the uncertainty associated with the variables used in the calculations, such as activity data, emission factors and control factors.

3.7.4 Reducing Uncertainty

There are many steps that can be taken to ensure the maximum completeness and accuracy of an emissions inventory. A major influence on the quality of data collected and used in an emissions inventory is the presence of quality assurance and quality control (QA/QC) procedures.

Quality assurance procedures are management activities designed to ensure that any process, item, or service is of the type and quality needed for use in the inventory. It deals with creating management controls that cover planning, implementation, and review of data collection activities. Quality control, on the other hand, is technical in nature and is implemented at the project level. It includes all the scientific precautions, such as calibrations and duplications, which are needed to ensure that data is of the proper quality and accuracy for use in the inventory.

The application of QA/QC procedures is an essential requirement of a successful inventory development process. A QA/QC process can help to improve transparency, consistency, comparability, completeness and confidence in the inventory and any associated goals and responses. QA/QC techniques include historical comparisons, reasonability of values, peer review, statistical checks, replication of calculations and audits.

4 Substances under Consideration

Priority substances were discussed generally by the CFO team. It was agreed that the EI subgroup should focus on five substances:

- Ammonia (NH_3)
- Hydrogen Sulphide (H_2S) and Total Reduced Sulphur (TRS) where available
- Volatile Organic Compounds (VOCs)
- Particulate Matter (PM)
- Pathogens/Bioaerosols

The subgroup has used the list of five priority substances to guide their work. If an existing inventory or report addressed any of the five priority substances, it is reported as such in the summary and the subgroup as provided an assessment. The subgroup has also made recommendations for future work on each of the five priority substances.

4.1 Ammonia (NH_3)

At atmospheric pressure, ammonia (NH_3) is a colourless gas, which is lighter than air and possesses a strong, penetrating odour. Ammonia has an odour threshold of 5 ppm. Ammonia dissolves readily in water, where it ionizes to form an ammonium ion. The solubility of ammonia in water is influenced by the atmospheric pressure, temperature, and by dissolved or suspended materials.

Livestock operations are a major contributor of ammonia emissions. Ammonia is produced inside livestock buildings, in open feedlots, in manure storage facilities, during manure handling and treatment and when manure is applied to soils. The major sources for atmospheric emissions of ammonia in Alberta in order of output are: agricultural activities (animal feedlot operations and other activities), industrial activities (fertilizer plants, fossil fuel combustion, accidental releases) and biomass burning (including forest fires).

Gaseous ammonia is a very important basic compound in the atmosphere. It reacts readily with acidic substances or sulphur dioxide to form ammonium salts that occur predominantly in the fine particle (size< 2.5 µm) fraction. A small amount of gaseous ammonia is converted to nitric oxide. The current Alberta Environment (AENV) 1-hour Ambient Air Quality Objective for ammonia is 1,400 $\mu g/m^3$ (2,000 ppb) and is based on odour perception.

4.2 Hydrogen Sulphide (H_2S) and Total Reduced Sulphur (TRS)

Hydrogen sulphide (H_2S) is formed by microbial reduction of sulphate (an electron acceptor) and microbial decomposition of sulphur-containing organic compounds in manure under anaerobic and aerobic conditions

Hydrogen sulphide (H_2S) is a Reduced Sulphur Compound (RSC) and is sometimes called Total Reduced Sulphur (TRS). The RSCs are a complex family of substances. They are defined by the presence of sulphur in a reduced state and are generally characterized by strong odours at relatively low concentration. The most common substances within the RSC family that are emitted from industrial sources are: hydrogen sulphide, methyl mercaptan, dimethyl sulphide, and dimethyl disulphide. In some locations in Alberta, ambient monitoring shows that the majority of TRS is made up of H_2S, but the amount of H_2S in TRS can vary, depending on nearby sources.

Hydrogen sulphide in livestock buildings is mainly present in shallow barn gutters, underground, in outdoor holding storage tanks, or in earthen manure storage facilities. Hydrogen sulphide is heavier than air, soluble in water, and can accumulate in underground pits and unventilated areas of livestock buildings. The current Alberta Environment 1-hour Ambient Air Quality Objective for Hydrogen sulphide is 14 $\mu g/m^3$ (10 ppb) based on odour perception and the 24-hour Ambient Air Quality is 4 $\mu g/m^3$ (3 ppb).

4.3 Volatile Organic Compounds (VOCs)

A Volatile Organic Compound (VOC) is an organic compound that participates in atmospheric photochemical reactions. VOCs contain at least one carbon atom (excluding carbon dioxide and carbon monoxide), have a vapour pressure of 0.01 kPa or greater at 25^oC and vaporize easily at room temperature. They include fatty acids, nitrogen heterocycles, amines, alcohols, aliphatics, aldehydes, ethers, *p*-cresol, mercaptans, hydrocarbons, and halocarbons.

There are a large number of VOCs that have been identified in manures. These are generated by the partial breakdown of feed materials that takes place in an animal's digestive tract by anaerobic bacteria. Many of the resultant compounds are highly odorous, the most important of these being Volatile Fatty Acids (VFAs), indolics, phenolics and sulphur compounds**.**

VOCs emitted from anthropogenic and biogenic sources react in the troposphere in the presence of NO_x and sunlight to form ozone. AENV developed ambient objectives for the following five VOCs:

- 2-Ethylhexanol
- Ethylbenzene
- Isopropanol
- Toluene
- Xylene

Several organic compound have been excluded from the VOC classification because of their negligible photochemical reactivity including: methane, ethane, 1,1,1-trichloroethane (methyl chloroform), methylene chloride (dichloromethane), chlorofluorocarbons (CFCs), fluorocarbons (FCs), and hydrochlorofluorocarbons (HCFCs).

4.4 Particulate Matter (PM)

Particulate Matter (PM) is an unusual air pollutant in that it is defined by its physical morphology rather than chemical identity. PM is categorized by aerodynamic diameter, which is the size of a spherical particle that behaves the same as the actual particle (most PM is highly irregular in shape). The most common classifications are PM_{10} (coarse PM), which includes particles smaller than 10 µm in aerodynamic diameter, and $PM_{2.5}$ (fine or respirable PM), which includes particles smaller than 2.5 µm in diameter.

Particles can be emitted directly from anthropogenic and natural sources; for instance, both forest fires and diesel engines are sources of particulate matter. When PM is directly emitted, it is referred to as primary particulate. However, PM can also be formed as a result of a series of chemical transformations involving other air pollutants. For example, oxides of nitrogen or sulfur (NO, NO_2 and SO_2) can react with ammonia (NH_3) to form ammonium nitrate (NH_4NO_3) or ammonium sulfate ($(NH_4)_2SO_4$). Particles formed in this way are referred to as secondary particulate.

Particles may be emitted from a source at the $PM_{2.5}$ size, but when secondary particulates form, they are typically very small and grow as a result of coagulation (due to particle collisions), condensation of gases onto the particle's surface or from chemical reactions. Particulate matter, once emitted or formed, will persist in the atmosphere until it is removed either by precipitation or by settling.

4.5 Pathogens and Bioaerosols

Bioaerosols include microorganisms (living, dormant or non-viable) such as bacteria, viruses, fungi and actinomycetes, as well as biochemical compounds (e.g. endotoxins, mycotoxins) that are uniquely associated with microorganisms.

Many sources of bioaerosols are man-made, such as those generated by sewage and animal waste disposal facilities. In animal houses, bioaerosols are produced from animals, feed, bedding, and feces. The cell debris and microbial organisms become airborne to form bioaerosols, which originate from animal respiration, skin, fur, feathers and manure.

4.6 Additional Substances for Future Consideration

The project team also agreed to discuss greenhouse gases (GHGs) and odour. The team subsequently made a decision to narrow their scope of work by not focusing on GHGs in the near term, but to assess the effect of the CFO strategic plan on GHG emissions at a later date.

Odour has been discussed in other Alberta forums such as the Ambient Objectives Working Group, which is a multi-stakeholder group advising Alberta Environment.

Although the EI subgroup is in agreement that an odour management framework is needed, no specific recommendations on odour can be made at this time.

5 Summary of Existing Emissions Inventories

A table comparing the information available from the emissions inventories investigated is provided in Table 5-1.

Table 5-1: Comparative Summary of Emissions Inventories

Section	**Emission Inventory**	**Emissions**	**Addresses housing, rearing and manure management train (MMT)**
5.1	US EPA Ammonia Inventory	NH_3	√
5.2	US EPA Animal Feeding Operations (AFO) Air Agreement (2005)	PM, H_2S, VOC, NH_3	x
5.3	Alberta Agriculture and Food Air Emission Inventory for Alberta and Literature Review Shane Chetner	NH_3, H_2S, PM	x
5.4	Carnegie Mellon University (CMU), Pittsburg, Ammonia Model (2001) (Procedural program)	NH_3	√
5.6	Spatial Allocation of Agricultural Activity Data: Prairie and Northern Region (RWDI)		
5.7	Assessment of Potential Environmental Effects of Livestock Expansion in Alberta (Golder Associates, 1999)	NH_3, PM, VOX, N_3O, CM	x

The EI subgroup also considered potential paths forward for a new emissions inventory in Alberta. The options included:

- Obtaining generic information by using Statistics Canada data together with the AF by Chetner or Golder emissions factors.
- Collecting specific Alberta Manure Management Train (MMT) information. This can be done only if counties have MMT information or by modifying Census Canada information from 2001. The US Environmental Protection Agency (EPA) MMT information would not likely be used because it is not Alberta-specific and is only limited to ammonia. Alternatively, a consultant could be hired to expand the existing information by considering other emissions.
- Generating a new, detailed emissions inventory for Alberta. Such an endeavor would entail a significant investment of time and finances.
- Focusing on existing inventories and reports to obtain the necessary information. Expanding the EPA model to include other substances. The feasibility of this approach would depend on obtaining information from counties or by modifying Census Canada information from 2001.
- Investigating manure management exclusively. Again, this method would be limited by the ability to obtain appropriate information from counties or from Census Canada 2001 data.
- Adding Statistics Canada data on manure management to existing inventories.

5.1 US EPA Ammonia Inventory (2004)

The National Academy of Science (2003)[1] noted that animal emission factors were not well characterized and recommended a process-based modeling approach to estimate emissions from confined feeding operations.

In 2004, the US Environmental Protection Agency (EPA) developed a process-based national inventory model that applied mass balance principles. This model considered the amount of nitrogen contained in the excreted manure and the way that the manure was managed. This approach addresses regional differences in ammonia emissions caused by variations in manure management practices while ensuring that ammonia emissions calculations are constrained by the amount of available nitrogen in excreted manure. An overview of the methodology is given in Table 5-2.

[1] National Academy of Sciences. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. National Academies Press. Washington, D.C. pp 263

Table 5-2: US EPA Ammonia Inventory Calculation Methodology

Step 1	Estimate average annual animal populations by animal group, state, and county.
Step 2	Identify Manure Management Trains (MMT) used by each animal group and then estimate the distribution of the animal population using each MMT.
Step 3	Estimate the amount of nitrogen excreted from the animals using each type of MMT and general manure characteristics.
Step 4	Identify or develop emission factors for each component of each MMT.
Step 5	Estimate ammonia emissions from each animal grouped by MMT and county for 2002.
Step 6	Estimate future ammonia emissions for years 2010, 2015, 2020, and 2030

5.1.1 Methodology and Assumptions

Ammonia emissions calculations are dependant on animal type. The calculation details relevant to swine, cattle, poultry and sheep are given below.

5.1.1.1 Swine

All manure produced by swine in Alberta is managed by Earthen Manure Storage (EMS). Produced nitrogen is calculated using the nitrogen excretion rate recommended by Mid West Plan Service (MWPS). The nitrogen excretion for each animal category was assumed to be uniform over the province.

The census region level emissions were estimated from each Manure Management Train (MMT) using a process-based inventory model that applies mass balance principles in the following manner:

- Calculation of ammonia emissions from the housing area. The ammonia emissions factor was assumed to be the same for all animal categories (6 lb/head per year)
- Calculation of ammonia emissions from EMS:
    - Nitrogen losses from the housing area =NH_3 House X conversion factor (14N/17 NH_3)
    - To calculate the nitrogen in EMS, subtract nitrogen losses in housing area from nitrogen excreted in swine housing area
    - To calculate ammonia emissions from EMS, multiply the nitrogen in EMS by emissions factor (we assume it 0.71) and conversion factor (14N/17 NH_3)
- Calculation of ammonia emissions from land application:
    - Assume 45% of nitrogen applied to the soil is lost to the atmosphere in the form of ammonia.
    - The nitrogen applied to the land is equal to the total nitrogen produced minus nitrogen lost from the housing area and EMS.

- To calculate ammonia emissions from land application, multiply the nitrogen applied to the land by the emissions factor (we assume it 0.45) and conversion factor (14N/17 NH_3)

Total ammonia emission using this process-based model is the sum of ammonia emissions from housing, storage (EMS) and land application.

5.1.1.2 Cattle

- Calculation of nitrogen produced by all cattle using the nitrogen excretion rate recommended by Mid West Plan Service (MWPS).
- Estimation of census region level emissions from each MMT using a process-based inventory model that applies mass balance principles in the following manner:
  - Calculate ammonia emissions from the housing area using the Alberta Agriculture and Food (AF) method
  - Calculate ammonia emissions from land application:
    - The nitrogen applied to the land is equal to the total nitrogen produced minus nitrogen lost from housing and storage.
    - To calculate ammonia emissions from land application, multiply the nitrogen applied to the land by the emissions factor (we assume it 0.45) and conversion factor (14N/17 NH_3)

Total ammonia emission using this process-based model is the sum of ammonia emissions from housing, storage (EMS) and land application.

5.1.1.3 Poultry

Ammonia emissions from poultry are calculated using the same method described above for cattle.

5.1.1.4 Sheep

Estimated emissions are calculated by multiplying a single emission factor by the number of animals in each census region. No process-based model is used here.

5.1.2 Results

Table 5-3: Summary of Estimated Ammonia Emissions from CFO operations

Livestock	Cattle	Swine	Sheep	Poultry
NH_3 (tonnes)	138245	24612	4084	1013

5.1.3 Limitations

A significant number of variables affect ammonia emissions from CFO operations including: climate and geography, diurnal and seasonal emissions patterns, feeding practices, animal life stage, and individual animal management practices. The emission factors developed for this inventory do not account for all of these variables.

5.1.4 Model Refinement

Researchers at the University of California –Davis developed a similar comprehensive, process-based model for estimating ammonia emission rates from CFOs that circumvents the limitations of the EPA model. This model consists of the Farm Emission Model (FEM) and the animal allocation processor (AAP). The FEM can be used to calculate ammonia emission rates from both an individual CFO and a group of CFOs. It also allows predictions on different time-scales (hourly, daily, monthly, yearly). The FEM is designed to calculate ammonia emission rates from different facets of the CFO, including animal housing, manure storage, and land application. The model is still being tested and validated.

5.1.5 Conclusions

- The USEPA Ammonia Inventory (2004) only addresses ammonia.
- The inventory does address different types of housing and rearing. The mitigation impacts of different MMT cannot be addressed because there is no information on the types of MMT to address.
- The level of effort needed to do a similar study is prohibitive due to financial and other resource implications.

5.2 US EPA Animal Feeding Operations (AFO) Air Agreement (2005)

A recent National Academy of Sciences report[2] emphasized that scientifically credible methodologies for estimating emissions from AFOs needed to be developed. As part of the ongoing effort to minimize air emissions from AFOs and to ensure that they comply with the Clean Air Act and other laws, the US EPA published the Animal Feeding Operations Consent Agreement and Final Order in the Federal Register in January 2005. The EPA agrees not to sue participating producers for current or past emissions in return for paying a penalty and financially contributing to a monitoring study that will measure emissions from different operations. The agreement was offered to the poultry (layers, broilers, and turkeys), dairy, and swine industries. The agreement excluded AFOs that only have open-air feedlots, such as cattle feedlots.

5.2.1 Goals of the AFO Air Agreement

The primary goals of this agreement as stated by EPA (2005) are:

- Reduce air pollution.
- Ensure compliance with applicable Clean Air Act, Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Environmental Planning and Community Right-to-Know Act (EPCRA) provisions. Under CERCLA and EPCRA AFOs are required to report any emissions of ammonia (NH_3) or hydrogen Sulfide (H_2S) exceeding 100 pounds in any 24-hour period.
- Monitor and evaluate AFO emissions.

[2] National Academy of Sciences. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. National Academies Press. Washington, D.C. pp 263

- Promote a national consensus on methodologies for estimating emissions from AFOs.

5.2.2 The Monitoring Study

This two-year monitoring study will enable scientists to collect and analyze emissions data and create tools that AFOs could use to estimate their emissions, for purposes of regulatory compliance. Based on EPA criteria, an independent organization will select farms that represent major animal groups (e.g. swine, dairy, and poultry), different types of operations, and different geographic regions. Substances to be monitored include PM (TSP, PM_{10} and $PM_{2.5}$), H_2S, VOCs, and NH_3.

Following sound scientific principles and using accepted instrumentation and methods, the monitoring study will collect new data from a number of farms across the country and will also evaluate existing emissions data from other selected studies that may meet EPA quality assurance criteria. Together, they will form a database to which additional studies of air emissions and the effectiveness control technologies can be compared.

When the monitoring study is complete, EPA will develop emissions estimating methodologies and tools based on data obtained from this study and other available data. These tools and methodologies will assist the industry and EPA in determining the air compliance status of AFOs. Participating AFOs will then be required to determine their emissions and comply with all applicable regulatory requirements.

5.2.3 Conclusions:

- There is no methodology outlined in this US EPA Animal Feeding Operations Air Agreement (2005), therefore it is not an inventory.
- The monitoring study results will produce emission factors**.**
- National Air Emissions Monitoring Study (NAEMS) will be run by Purdue's Al Heber through the Center for the Environment and it will cost $US 14 million

5.3 Alberta Agriculture and Food Air Emission Inventory for Alberta and Literature Review

Alberta Agriculture and Food (AF) developed a preliminary agricultural air emissions inventory for 2000 for Alberta. This inventory calculated emissions by multiplying emission factors obtained from available the scientific literature and other sources with spatially distributed activity data.

5.3.1 Ammonia

Emission factors were based on a "whole animal" approach and not on manure management practices. Emissions factors for each animal category were derived from

Battye et al[3] who based his calculations on data from Europe.[4] Emissions from livestock in Alberta in 2006 were 124, 675 tonnes per year. Cattle emitted 100,020 tonnes per year, which represents about 85% of total ammonia emissions from livestock in Alberta. Ammonia emissions from livestock in 2006 increased by 7% from emissions in 2000. This increase can be attributed only to the increase in the number of livestock since the emissions factors used in calculating the 2006 inventory are the same as those used in the 2000 inventory.

5.3.2 Hydrogen Sulphide

Emission factors were based on a "whole animal" approach and not on manure management practices. Emissions factors for cattle and swine were derived from US EPA[5] and Ni[6], respectively. The swine sulphur emissions factor was obtained from the USDA Agricultural Air Quality Task Force (AAQTF) report. Sulphur compounds emissions from livestock in Alberta in 2006 were 4012.43 tonnes per year. Cattle emitted 1833 tonnes per year, which represents about 45.7 % of total sulphur emissions from livestock in Alberta. Swine emitted 2179 tonnes of sulphur in 2006, which represents 54.3 % of the total sulphur emissions from livestock in Alberta.

5.3.3 Particulate Matter

Emission factors were based on a "whole animal" approach and not on manure management practices. Emissions factors were derived from USDA AAQTF.[7] The proposed emission factors for PM_{10} are 2.48 and 0.66 kg/head /year for beef cattle and dairy cattle, respectively. Emission factors for $PM_{2.5}$ were derived from Auvermann.[8] The time management practices technique for beef and dairy cattle for Alberta proposed by Milligan[9] was applied. Particulate matter emissions from livestock in Alberta in 2006 were 20397 tonnes per year. PM_{10} represents 81% of total PM emissions and 19% of the emissions is $PM_{2.5}$. Cattle emitted 11,195 tonnes of PM, which represents about 55% of total PM emissions from livestock in Alberta. Swine emitted 4604 tonnes of PM, which represents about 23 % of total PM emissions from livestock in Alberta. Poultry emitted

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[3] Battye, R., W. Battye, C. Overcash, and S. Fudge. 1994. Development and selection of ammonia emission factors. Report No. 68–D3–0034. Washington, D.C.: U.S. Environmental Protection Agency

[4] Asman, W. A. H. 1992. Ammonia emissions in Europe: Updated emission and emission variations. Report No. 228471008. Roskilde, Denmark: National Institute of Public Health and the Environment

[5] United States Environmental Protection Agency. 1998 Compilation of air pollutant emission factors AP-42 5th edition. <http://www.epa.gov/ttn/chief/ap42/>> Washington DC: USA EPA office of mobile Service

[6] Ni, J., A. J. Heber, T. T. Lim, C. A. Diehl. 1999. Continuous measurement of hydrogen sulfide emissions from two large swine finishing buildings. Written for presentation at 1999 ASAE/CSAE – SCGR Annual international meeting, sponsored by ASAE/CSAE-SCGR, Toronto, Ontario, Canada, July 18-22, 1999. St Joseph MI: American Society of Agricultural Engineers

[7] Sweeten, J.M, Erickson L., Woodford P., Parnell C.B., Thu K., Coleman T., Flocchini R., Reeder C., Master J.R, Hambleton W., Bluhm G., and Tristao. 2000. *Air Quality Research and Technology Transfer White Paper and recommendations for concentrated animal feeding operations.* United States Department of Agriculture Air Quality Force, Confined Livestock Air Quality Subcommittee

[8] Auverman B. 2001. Personal communication. Texas A and M University

[9] Milligan D, 2001. Personal Communication. Edmonton Alberta Agriculture

4580 tonnes of PM, which represents about 22% of total PM emissions from livestock in Alberta.

5.3.4 Recommendations

This report contains fourteen recommendations to improve our understanding of the agricultural impact on air quality in Alberta. Confirmation of cattle emissions factors is the highest priority as cattle are a primary source of livestock ammonia and PM emissions.

5.3.5 Results using AF 2006 (Census 2001)

Table 5-4: Calculated Emissions in tonnes using AF 2006 (Census 2001)

Substance	Cattle	Swine	Poultry	Sheep	Total
Ammonia	100,020	20,559	3,027	1,069	124,675
Sulphur	1,833	2,179	-	-	4,012
PM_{10}	9,927	4,276	2,286	-	16,489
$PM_{2.5}$	1,268	328	2,294	-	3,890

5.3.6 Methodology Limitations

5.3.6.1 Poor Spatial and temporal resolution:

Seasonal and geographic variations that are necessary for accurately predicting ambient concentrations of ammonia and other substances are lacking.[10] This method does not provide sufficient resolution to reliably recognize small changes in management practice (e.g. a few percent change in slurry applied with low emission techniques). Temporal variation in emissions needs to be considered so that mitigation strategies can be efficiently targeted throughout the year. Ammonia and other substances emissions inventories provide annual total emission estimates based on static emission factors, but guidance is needed for distributing the emissions across the seasons.[11] Pinder et al[12] developed an inventory that accounts for seasonal and geographical differences in climate and farming practices. Emission factors are calculated using a process-based model that accounts for the dynamics of ammonia volatilization and the effects of coupling different manure management processes.

5.3.6.2 High uncertain emissions factors

Emission factors affecting ammonia emissions include: animal age, species, weight, animal housing system, nitrogen content of feed, manure storage practices, and manure

[10] Strader, R., Anderson, N., Davidson, C., 2001. User Guide – CMU NH_3 Inventory Version 2.0. Carnegie Mellon University, Pittsburgh, PA. http://www.envinst.cmu.edu/nh3/

[11] Gilliland, A., Dennis, R., Roselle, S., Pinder R., Inverse Model "Estimation of Seasonal NH3 Emissions", AAAR Specialty Conference on Particulate Matter and the Supersites Program, Atlanta, GA. February 7-11, 2005

[12] Pinder R.W., R. Strader, C.I. Davidson and P.J. Adams, 2004: A temporally and spatially resolved ammonia emission inventory for dairy cows in the United States. *Atmos. Environ.*, 38, 3747-3756.

application methods. Pinder[13] cited Plöchl[14] who reported that estimates of emission factors are both highly variable and uncertain. For example, emissions from manure spread onto fields have been reported to range from 10% to 120% of the ammonia applied. Emissions factors used in calculating annual emission inventories generally do not account for climate and geography, diurnal and seasonal emission patterns, feeding practices or individual animal management practices

5.3.7 Possible Future Improvements

- Improve emission factors for different livestock categories
- Include management practices into the inventory calculation
- Improve the confidence of the activity data.

5.3.8 Conclusions

The following concerns were raised by the subgroup about this inventory:

- The emissions factors were developed somewhere other than Alberta
- The factors do not take into account seasonal variations or management practices specific to Alberta
- In order to be effective, emissions should be quantified on a county-by-county basis
- The emission factors included in the report cannot be used to account for the impact of manure management

However, the report evaluated the sources of emission factors and ranked them accordingly. It also provided relevant information about priority substances (NH_3, H_2S, PM) and the methodologies are relatively straightforward.

[13] Pinder R.W, N.J. Pekney, R. Strader, C.I. Davidson, P.J. Adams. 2003. National Inventory for the United States of Seasonally and Geographically Resolved Ammonia Emissions from Dairy Cows. 139-146 in Air Pollution from Agricultural Operations III, Proceedings of the 12-15 October 2003 Conference (Research Triangle Park, North Carolina USA), Publication Date 12 October 2003. ASAE Publication Number 701P1403, ed. H. Keener

[14] Plochl, M., 2001. Neural network approach for modelling ammonia emission after manure application on the field. Atmospheric Environment 35:5833-5841

5.4 Carnegie Mellon University (CMU), Pittsburg, Ammonia Model (2001) (Procedural program)

Carnegie Mellon University (CMU) developed a comprehensive ammonia emissions inventory software application that generates an ammonia emission inventory for the continental United States based on user-defined input. Emission factors and activity levels are kept in easily modifiable input files.[15] The CMU model is a downloadable computer program that references user-adaptable emission factors and activity files to create the emission inventory. The CMU model outputs ammonia emissions for numerous source categories for each county of the United States. The emission factors for Montana were used.

5.4.1 Model and Assumptions

The following variables were assumed to be uniform throughout the province:

- Nitrogen excretion for each animal category
- Distribution of housing and manure storage systems
- Manure application practice

Emission factors for housing, storage and application were assumed to be temporally uniform over the year. (Emission estimates for livestock production produced by the CMU model are unvarying from month to month.)

5.4.2 Limitations

These emission estimates are based on the CMU emissions model, which relies on emission factors and various activity data. The CMU model also allocates the emissions spatially and temporally (by season and by hour of the day). This emission factor-based approach was recently criticized by the National Research Council ("Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs", 2003). The NRC felt that the existing emission factors were inadequate because of limited measurements and that the models for which the emission factors were developed were too limited.

5.4.3 Results

Table 5-5: Estimate of ammonia emissions from CFO operations (CMU model)

Substance	Cattle	Swine	Sheep	Poultry
NH_3 (tonnes)	163,654	17,415	-	-

[15] Strader, R., N. Anderson, and C. Davidson. CMU Ammonia Model. Version 3.6 Downloaded from <http://www.cmu.edu/ammonia/> July 7, 2004

5.4.4 CMU Modified Model

Pinder[16] modified the CMU model to address these limitations by calculating monthly, county-level emission factors based on climate conditions and farming practices. Pinder developed a process-based, temporally resolved model of emissions from a dairy farm to estimate more accurately the effects of seasonal changes in climate and in farming practices. Pinder coupled this model with a statistical model to predict the county-level distribution of manure management practices. The modified inventory has two components: the Farm Emissions Model (FEM) and the National Practices Model (NPM).

5.4.5 Conclusions

- Part of the work involved in this inventory was to develop a model that took into account seasonal variations.
- Another project at University of California at Davis is also addressing seasonal variation for ammonia emissions
- Addresses manure management
- Addresses seasonal variations
- Improved from the EPA ammonia emission inventory

5.5 Model Comparisons

Table 5-6: Model Comparisons

EPA (Section 5.2)	Alberta Agriculture and Food (Section 5.3)	CMU (Section 5.4)
Process-based model	Emission factor driven	Emission factor driven
Does not allocate the emissions spatially and temporally (by season and by hour of the day).	Does not allocate the emissions spatially and temporally (by season and by hour of the day).	Allocates the emissions spatially and temporally (by season and by hour of the day).

Table 5-7: Estimate of Ammonia Emissions (tonnes) from CFOs using Three Different Models

	Cattle	Swine	Sheep	Poultry
AF 2006	100,020	20,559	3,027	1,069
EPA Method	138,245	24,612	4,084	1,013
CMU	163,654	17,415	n/a	n/a

[16] Pinder, RW, Adams, PJ, Gilliland, A. "Improvements to Regional Air Quality Modeling from Recent Advances in Ammonia Emission Inventory Development" AAAR Specialty Conference on Particulate Matter and the Supersites Program, Atlanta, GA. February 7-11, 2005

5.6 Spatial Allocation of Agricultural Activity Data: Prairie and Northern Region

RWDI West Inc. (RWDI) was retained by Environment Canada to prepare and assemble gridded agricultural emission source data in support of gridded emission calculation analyses to be performed by Environment Canada, as per Environment Canada Contract No. KA511-3-1084, RWDI Reference Number W03-213. Project deliverables include a report and gridded activity data in database and GIS (ARCGIS shapefile) formats on the accompanying CD-ROM.

The federal government, in co-operation with provincial governments, has been investigating the impacts of anthropogenic and natural emissions on regional air quality across western Canada. Regional air quality modeling is an effective scientific venue to assess the air quality impacts of these emissions since it is capable of addressing such complex issues as possible non-linearities between emission reductions and air quality improvements. Changes in emissions do not necessarily result in proportional changes in air quality.

Considerable effort has been made over the past three years to improve emission data in the Prairie and Northern Region (PNR). Under Environment Canada Contract number KA511-2- 0654, RWDI allocated activity data for 34 different types of agricultural activities from the 2001 Agriculture Census to the CWEI 4-km model grid. Census data was provided for each Consolidated Census Division (CCD) across western Canada. Although this was the best data available at the time, it is too coarse spatially to resolve the location of major confined feeding operations (CFOs).

Environment Canada recently obtained point source livestock data for the Old Man River Basin region from Agriculture and Agri-Food Canada, and point source livestock data from the County of Lethbridge, Alberta. This data, represented as point sources in the GIS files provided, is considered to be more accurate than the data from Statistics Canada, and is to be used for the specified regions.

5.6.1 Agricultural Census Activity Data

Two types of agricultural activity data was used in this assessment: census data (purchased by Environment Canada from Statistics Canada) and CFO data, some of which was provided by Agriculture and Agri-Food Canada and some of which was purchased by Environment Canada from Lethbridge County.

The activity data from Statistics Canada was obtained in the form of IVT tables (a unique Statistics Canada database format) and converted into dBASE IV files, which could then be used in ARCGIS version 8.3. There are 34 unique activity data variable names and corresponding IVT table column names from which the data was obtained.

The PNR 4-km domain extends into a portion of the west end of Ontario and north into the Yukon and Territories. Activity data was obtained for most census divisions in the western provinces (Manitoba, Saskatchewan, Alberta, and British Columbia).

Input data was missing (flagged as ”suppressed to protect confidentiality”) in the records for some of the CCDs as provided by Statistics Canada. For these records, values were estimated from Census Division (CD) totals, by subtracting the known / available CCD data and apportioning the remainder to the suppressed data records according to the percentage of the ‘Total Area of Farms’ attribute in each CCD.

During processing, a problem with the ‘Total Area of Farms’ activity / attribute data was uncovered. In some cases, the Total Area of Farms attribute from the IVT tables is actually larger than the geographical area of the corresponding CCD region. This does not affect the apportioning of the Activity Data to the unknown CCD regions directly as the calculation deals strictly with the ratio of total farm area. For example, in CCD ‘Sherwood No. 159’ (in Saskatchewan), the ‘Total Area of Farms’ in the census data table is 88,930 ha; whereas the total area calculated from the corresponding GIS shapefile is only 68,246 ha, a difference of 20,684 ha.

5.6.2 CFO Activity Data

The point source data for the Old Man River Basin region was used in place of the corresponding data provided by Statistics Canada. Two sets of point source data were provided: Old Man River Basin region data from Agriculture and Agri-Food Canada; and, a more accurate subset of points for Lethbridge from the County of Lethbridge.
Because the activity data was provided from two different information sources, the activity names / descriptors did not result in a one-to-one match between the Statistics Canada and CFO data. Reclassification for these activities was performed using best judgment and was based on input from Environment Canada and Agriculture and Agri-Food Canada.

5.6.3 Gridding Methodology

5.6.3.1 Statistics Canada Data

The process for gridding the Statistics Canada Activity Data to the domain involved the creation of an ARCGIS coverage of the PNR 4-km domain (fishnet coverage) and overlaying it onto the Statistics Canada Activity Data shapefile. The census-based Activity Data, by CCD, was then apportioned to the 4-km grid by first computing a ratio multiplier, which is the area for the current CCD for the current grid cell, divided by the total CCD area. This results in a decimal value between 0 and 1 for each grid cell that can be multiplied to the corresponding CCD Activity Data to arrive at the total activity in that particular grid cell. Gridded Activity Data for the various CCDs that touch on a given grid cell were then summed to obtain the total activity from all CCDs in that grid cell.
This same process was repeated using the GIS-based census-division boundaries in place of the CCDs to generate a similar output but at the census-division level for subsequent analysis by Environment Canada.

5.6.3.2 CFO Data

Because the CFO data was provided as points in ARCGIS format, a slightly different approach was required. The following steps outline the gridding process used for the CFO data.

Step 1

All data from the Old Man River Basin dataset that were located within Lethbridge County were removed so that this data could be replaced with more accurate CFO data from Lethbridge County.

Step 2

The point sources from the County of Lethbridge were merged into the resulting Old Man River Basin data to arrive at a combined CFO dataset.

Step 3

The activity data in the CFO dataset were re-classified to match the Statistics Canada Activity Names.

Step 4

The point source data was overlaid onto the PNR 4-km model grid. The activity for all points (CFOs) falling within each grid cell was summed to arrive at the total activity from CFOs in each grid cell.

Step 5

The gridded CFO and Statistics Canada data were then merged at the grid cell level. The merge process involved determining the difference between the total activity from the Statistics Canada data and the total activity from the CFO data by county. For counties containing CFO data, the CFO total activity was assigned to each grid cell as described above. If Statistics Canada totals for that county were greater than the sum of the CFO data, the gridded Statistics Canada values were reduced using a constant ratio for the county, such that the combined total of the gridded CFO and Statistics Canada data sum up to the original Statistics Canada total. The already gridded CFO totals were then added to the modified gridded Statistics Canada data. If not, the CFO data was assigned as described above, with no activity value assigned to the remaining (i.e., non-CFO data) grid cells. This approach was based on the fundamental assumption that the CFO data is the more comprehensive and complete dataset and that adding the CFO and Statistics Canada datasets would result in double-counting.

5.6.4 Results and Deliverables

Maps showing each of the Activity Data variables were plotted. In addition, a database file containing multiple tables (one for each Activity) was provided. Each table contains one or more records per grid cell, each with the following fields:

- I-Cell grid coordinate corresponding to the PNR 4-km grid
- J-Cell grid coordinate corresponding to the PNR 4-km grid
- Total gridded Agricultural Activity
- CCD name or Census Division (CD) name
- CCD Unique identifier (ID) or Census Division (CD) Unique identifier (ID)

5.6.5 Summary

This inventory provides a gridded estimate of 34 agricultural activities. For activities with an established emission factor, it is possible to calculate a grid of emissions. If we consider the equation:

Emission rate **=** *Emission Factor* **x** *Activity Factor* **x** *Control Factor*

The RWDI dataset provides the activity factors to get an actual emission rate. A control factor of one can be assumed for most agricultural activity (there is no reduction in emissions by controls) and hence, the emission rate can be calculated.

5.6.6 Conclusion

The RWDI report lays the groundwork for emissions inventory calculations but does not recommend emissions factors or an appropriate way to estimate the factors. Consequently, this is not an emissions inventory but has the potential for use in generating emissions inventories when given emissions factors..

5.7 Assessment of Potential Environmental Effects of Livestock Expansion in Alberta (Golder Associates, 1999)

This study was conducted for Alberta Agriculture, Food and Rural Development in 1999 by Golder Associates[17] with three objectives:

1. Conduct an analysis of potential environmental effects associated with five growth scenarios for pork and beef production within Alberta.
2. Provide information to guide future analysis of concerns associated with growth scenarios at a local level.
3. Identify measures that government and industry could take to accommodate growth in an environmentally sustainable fashion

Table 5-8: Golder Associates Five Growth Scenarios Examined 1999 Baseline

Scenario	Pork Changes	Beef Changes
1	100 % increase in production	No change
2	No change	20% increase in beef cattle (equivalent to 15% increase in feedlot production)
3	No change	100% increase in cattle imports to feedlots (equivalent to a 25% increase in feedlot production)
4	100% increase in production	20% increase in beef cattle and 100% increase in cattle imports to feedlots (equivalent to a 40% increase in feedlot production)
5	200% increase in pork production	20% increase in beef cows and a 300% increase in cattle imports to feedlots (equivalent to a 90% increase in feedlot production)

The issues assessed for air quality were:

- Ammonia, hydrogen sulphide and aliphatic amine emissions
- Particulate emissions
- Greenhouse gases
- Odours

5.7.1 <u>Methodology</u>

The first three issues were assessed quantitatively, while odour was assessed qualitatively. The quantitative analysis used a simple accounting exercise where animal populations were adjusted and their emissions followed accordingly. The actual emission rates were based on emission factors estimated from animal mass and manure output.

[17] Golder Associates Ltd (1999) Assessment of Potential Environmental Effects of Livestock Expansion in Alberta

Calculation of emission increases does not necessarily provide a reliable indication for changes in air quality. (Calculated emissions are not always directly related and products of chemical reactions can increase by more or less than emissions depending on the conditions and chemical species involved). The scenarios under consideration emphasized the need to mitigate emissions as much as possible by developing and implementing best farming practices.

Among the recommendations of this study were public consultations to deal with issues of measurable pollutants and perceived pollutants (odour).

5.7.2 Summary

- Addresses 1996 census animal population by census division:
  - beef: feedlot, wintering sites, pasture
  - pork: standing population, sow units
- Uses a general manure management train with respect to ammonia for beef and pork. Calculations are given for:
  - Direct emissions of ammonia from animals
  - Atmospheric losses of ammonia (manure spreading, etc.)
- No information on other manure management trains besides ammonia from beef and pork
- Four emission rates are used for beef: cow, bull, calves, and steers
- Information is provided on the amount of CFO emissions compared to other industries in Alberta
- Information is given on how emissions could change over time and the emissions levels when applying this method

5.8 Whitford Dispersion Factor Analyses

Jacques Whitford Environment Limited (Calgary) developed a document for the NRCB to use the dispersion factor, which is made up of three sub-factors: topography, screening, and micro-climate. A sensitivity analysis using a plume dispersion model involved first choosing what airborne emission to model. From among H_2S, NH_3, and odour an odour criteria was selected.

5.8.1 Methodology

With information provided by the NRCB, three types of CFOs were studied: a 600-sow farrow-to-finish, 125-head dairy and 4,000 head feedlot. A satisfying result was that predicted odours for these three facilities were relatively similar to commonly used odour criteria in different jurisdictions around the world.

One conclusion was that emissions from sow farrow-to-finish barns represented about 60% of the total facility emissions. Also, emissions appeared less when vertical fans were used as compared to the use of horizontal fans.

It was recommended that the NRCB consider the approach for setback distances of New South Wales, Australia, for one level, and also consider the analysis similar to the Purdue model for a second level of setback assessment. A third level could be a modeling study incorporating site-specific information on the layout and emissions of the facility, as well as topography, screening, and micro-climate factors.

5.8.2 Summary

- All three facility types are unique to the Alberta situation
- Modeling and other analysis show how emissions levels change with different rearing/housing and management systems, which are part of manure management trains
- Information on how emissions are predicted to change over time are given
- Minnesota Tool and Australian guidelines/assessment are detailed showing factors of size and type of operation, either type of building or management practice, and number of sources or sites while the Purdue Model shows the first two factors, but not this last factor.
- The Purdue, South Australia, and New South Wales examples all include topography and micro-climate factors with screening included in both Australian examples.

5.9 Poultry Emissions Inventory (Environment Canada) 2002/03

The poultry cull in the Fraser Valley has provided a foundational dataset to evaluate the impact of a drastic reduction in emissions. To date, the work has focused on impact assessment; however, future work is expected to use the data to evaluate the existing emissions estimates from poultry production in the Fraser Valley. Publication of the results is anticipated in the next few years.

5.10 Parkland Airshed Management Zone (PAMZ) Emissions Inventory

The PAMZ Emissions Inventory Report was commissioned by the Parkland Airshed Management Zone in 2005 and was performed by the Focus Corporation. The report is an overview of the emissions from all industrial sectors and most non-industrial sectors located within the airshed's zonal boundaries. The emissions inventory includes a section on the agricultural section but makes no distinction between confined feeding operations and other livestock operations.

The primary purpose of the inventory is to provide PAMZ with data on emission sources to which air quality can be compared over the long term. The PAMZ funding committee also uses the information to explore changes and improvements to the association's funding formula in an effort to diversify its funding base and insure the association's long-term sustainability.

5.10.1 Methodology

2001 Statistics Canada data was used to provide information on livestock populations within the zone through the Alberta Agriculture website. The compounds reported include PM, VOCs, NH_3, CH_4 and N_2O. The emission factors used were taken from Asman (1992) for NH_3 and from Environment Canada (Jacques, 1997) for CH_4 and N_2O. PM and THC emissions were estimated by taking the ratio of the livestock population within PAMZ to the provincial total and applying this ratio to values reported in the Criteria Air Contaminants database.[18]

5.10.2 Results

The results are presented in tables within the report and depicted graphically in a PowerPoint presentation summarizing the report results. There were differences in reported ammonia emissions noted between the Chetner and Sasaki report (2000) and the Focus report. There were increases in ammonia from cattle and swine and decreases from sheep and poultry. The differences have been attributed to the different PAMZ borders that were used for the 2000 report. The borders used in the Focus report are the actual PAMZ borders. Those used in the Chetner and Sasaki report were the conceptual boundaries developed by a CASA project team.

5.10.3 Conclusions

This work was based on the AF methodology in Section 5.3 for the PAMZ airshed.

5.11 Agricultural Emissions Categories Available from Environment Canada

Environment Canada has several categories of emissions information that are relevant to agricultural emissions.

5.11.1 Criteria Air Contaminants Classification

The broad criteria air contaminants (CAC) classification includes Total Particulate Matter (TPM), Particulate Matter less than or equal to 10 microns (PM_{10}), Particulate Matter less than or equal to 2.5 microns ($PM_{2.5}$), Sulphur Oxides (SOX), Nitrogen Oxides (NOX), Volatile Organic Compounds (VOC), Carbon Monoxide (CO) and Ammonia (NH3). Provincial summaries of these species are available and are divided into three agricultural categories:

- Pesticides and Fertilizer Application
- Agriculture (Animals)
- Agriculture Tilling and Wind Erosion

The details for recent years, including projections to 2015 (spring 2007), are available at http://www.ec.gc.ca/pdb/cac/Emissions1990-2015/emissions1990-2015e.cfm .

5.11.2 National Pollutant Release Inventory

Highly detailed emissions information is also available in the National Pollutant Release Inventory[19]; however, the information is primarily focused on point sources or individual

[18] Criteria Air Contaminants Home Page: http://www.ec.gc.ca/pdb/cac/cac_home_e.cfm
[19] National Pollution Release Inventory Home Page: http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm

operations that emit a wide variety of pollutants beyond established threshold levels. At this time, there are no individual farms identified in this inventory and only agricultural support organizations identify manufacturing emissions for farm products (such as a fertilizer manufacturing plant). The data is not directly applicable to the development of an emissions inventory from confined feeding operations but it provides context for agricultural emissions. This permits inference about the relative significance of agricultural emissions on a local, region and national level. For example if an individual operational or a collection of operations accounted for a small percentage provincially but the vast majority locally the area of impact and hence the breadth of concern is indicated. A strategic plan has to be certain that it accounts for the appropriate scales.

5.11.3 Inventories for Air Quality Modeling

Environment Canada also generates national emission inventories primarily in support of air quality modeling. These inventories facilitate incorporation of point (individual sources, such as factories) and area sources (most agriculture falls in this category). The species of interest to agriculture are shown in Table 5-9. This inventory provides direct values of $PM_{2.5}$ emissions and NH_3 emissions attributable to agriculture but does not explicitly address sulphur or bioaerosols and only contains a subset of VOCs. Similar to the information from the National Pollutant Release Inventory described above, the air quality modeling inventories could be used to proved context for agricultural emissions.

Table 5-9: Environment Canada Emissions Inventories for Agriculture

Abbreviation	Units	Description
NR	moles/s	CB4 nonreactive VOC
OLE	moles/s	CB4 olefins species
PAR	moles/s	CB4 paraffins species
TOL	moles/s	CB4 toluene species
XYL	moles/s	CB4 xylene species
NH_3	moles/s	Ammonia
SO_2	moles/s	Sulphur dioxide
PEC	g/s	Elemental carbon of $PM_{2.5}$
PMFINE	g/s	Crustal/other of $PM_{2.5}$
PNO_3	g/s	Primary nitrate of $PM_{2.5}$
POA	g/s	Organic carbon of $PM_{2.5}$
PSO_4	g/s	Primary sulphate of $PM_{2.5}$
PMC	g/s	Coarse PM (PM_{10} – $PM_{2.5}$)

5.11.4 Broad Categories

The species of interest to agriculture can be divided into a number of broad categories:

- Oilseed & Grain Farming
- Vegetable & Melon Farming
- Fruit & Tree Nut Farming
- Greenhouse, Nursery & Floriculture Production

- Other Crop Farming
- Cattle Ranching & Farming
- Hog & Pig Farming
- Poultry & Egg Production
- Sheep & Goat Farming
- Animal Aquaculture
- Other Animal Production

5.11.5 Detailed Categories

The broad categories can be further subdivided into detailed categories as follows:

- Soybean Farming
- Oilseed (exc. Soybean) Farming
- Dry Pea & Bean Farming
- Wheat Farming
- Corn Farming
- Rice Farming
- Other Grain Farming
- Potato Farming
- Other Vegetable (exc. Potato) & Melon Farming
- Orange Groves
- Citrus (exc. Orange) Groves
- Non-Citrus Fruit & Tree Nut Farming
- Mushroom Production
- Other Food Crops Grown Under Cover
- Nursery & Tree Production
- Floriculture Production
- Tobacco Farming
- Cotton Farming
- Sugar-Cane Farming
- Hay Farming
- Fruit & Vegetable Combination Farming
- All Other Misc. Crop Farming
- Beef Cattle Ranching & Farming, inc. Feedlots
- Dairy Cattle & Milk Production
- Hog & Pig Farming
- Chicken Egg Production
- Broiler & Other Meat-Type Chicken Production
- Turkey Production
- Poultry Hatcheries
- Other Poultry Production
- Sheep Farming
- Goat Farming

- Animal Aquaculture
- Apiculture
- Horse & Other Equine Production
- Fur-Bearing Animal & Rabbit Production
- Livestock Combination Farming

6 Source Apportionment and Receptor Modeling Options

The overall objective of receptor modeling is source apportionment. Source apportionment will identify the dominant sources that contribute to the characteristics observed in a given area and estimate the magnitude of their contribution. This can be done by simultaneously considering the location and nature of probable sources with the nature of atmospheric transport and diffusion, or the mixture of chemicals observed at the area of interest (receptor) or a combination.

6.1 Chemistry Approaches

Chemical source apportionment uses a set of measured chemical parameters to infer the probable sources. This is easiest when it is possible detect the presence of an unusual chemical or group of chemicals produced by a limited number of known sources. A specific example would be the presence of the Volatile Organic Compound (VOC) acetonitrile, which is a marker of biomass fire smoke. More frequently, the chemical signature is a series of chemicals that occur in specific relative concentrations. To further complicate the process, many of the chemical species measured come from multiple sources; although, in different relative ratios. Consequently, sophisticated statistical methods are necessary to identify sources and separate out the relative contributions. Several methods are available including: Chemical Mass Balance (CMB), Principal Component Analysis (PCA) and Positive Matrix Factorization (PMF).

Chemical measurements identify the composition of the sub-set of interest (e.g. the total composition of particulate matter). The PMF and PCA methods require a large number of samples (about 100) with a large number of resolved species (more than 75% of the total mass), while the CMB method requires fewer samples but depends on detailed source profiles (typical emission profiles) for the sources to be resolved.

Table 6-1: Advantages and Disadvantages of Chemistry Approaches

Advantages	Disadvantages
Widely used and understood in the science community, good credibility	Requires long period of record, or in the case of CMB, detailed chemical information on all sources
Resolves relative contribution of sources	Requires analysis for multiple chemicals and offers meaningful contribution estimates only if all mass is chemically characterized
Sophisticated analysis allows estimation of error	Not easy, requires experience or statistical expertise

6.2 Meteorology Approaches

The potential contribution from known sources can be inferred by evaluating the flow patterns into an area. This is usually done by analyzing trajectories or particle paths to a receptor site. This method relies on analyzed meteorological fields to determine probable flow into an area. This can be analyzed for patterns and trends by time of day and season. Meteorological fields represent the atmosphere at the ground and aloft over a period of time.

Table 6-2: Advantages and Disadvantages of Meteorology Approaches

Advantages	Disadvantages
Widely used and understood in the science community	Can only provide as much detail as is in the meteorological record
Relatively easy to generate analysis	Provides general pattern but no specifics
Meteorological data is readily available	Qualitative rather than quantitative

6.3 Combinations

Observations of chemicals and flow patterns can be combined to provide insight into the relative contribution from different areas. This divides the data at the receptor into categories (stratifies the data). Observed values can then be associated with geographical source regions. The species of interest can be observed with high time resolution; this method is particularly well suited to hourly data. The method uses meteorological fields and calculated back trajectories.

Table 6-3: Advantages and Disadvantages of Combination Approaches

Advantages	Disadvantages
Widely used and understood in the science community	Can mislead by unusual data (outliers) and small data sets
Provides good indicator of source regional areas associated with categories of observations	Only provides general idea of source areas not specific contributors.
Can be used with observations of one chemical only - e.g. ozone	Is not useful for small-scale local effects studies, regional scale only

6.4 Physical Modeling Approaches

Another approach is to use computer representations of the meteorology and chemistry to model the emissions, transport and end values. Emissions from individual sources can be electronically tagged for tracing. Furthermore, different model simulations can be run with emissions on or off from various sources and then the results can be compared. The method requires meteorological data fields to fully describe atmospheric motion and a detailed inventory of all emissions and how they vary in time and space.

Table 6-4: Advantages and Disadvantages of Physical Modeling Approaches

Advantages	Disadvantages
Widely used and understood in the science community	Large computational expense
Can test numerous theories	Each test requires computer time
Wealth of data	Real limits to the ability to model emissions, meteorology and atmospheric chemistry
Expertise in this area more common than with other receptor models	Large time demand to analyze results.

6.5 Summary

A wide variety of tools is available to study and identify sources that contribute to the atmospheric chemistry at a given point (receptor). Some of the tools provide large scale, broad overviews while others start to give detailed indications of probable sources and their relative contribution. Choosing the correct approach requires a detailed specification of the objective(s) and the relative importance of different aspects.

6.6 Recommendations

The CFO team should encourage Alberta Environment and Environment Canada to consider incorporating a source apportionment component to modeling studies conducted over areas with existing or anticipated intensive livestock production.

The CFO team should encourage Alberta Environment and Agriculture, and Environment and Agriculture Canada to conduct some specific studies in areas with intensive agriculture using suitable source apportionment methods to estimate the relative impacts of agricultural and other emissions in a local area.

Glossary of Acronyms

AAMD&C	Alberta Association of Municipal Districts and Counties
AAP	Animal Allocation Processor
AAQTF	US Department of Agriculture Agricultural Air Quality Task Force
AENV	Alberta Environment
AF	Alberta Agriculture and Food
AFO	Animal Feeding Operation
AOPA	Alberta Agricultural Operations Practices Act
CAC	Criteria Air Contaminants
CASA	Clean Air Strategic Alliance
CCD	Consolidated Census Division
CD	Census Division
CERCLA	Clean Air Act, Comprehensive Environmental Response, Compensation and Liability Act
CFC	Chlorofluorocarbon
CFO	Confined Feeding Operation
CMB	Chemical Mass Balance
CMU	Carnegie Mellon University
EI	Emissions Inventory
EMS	Earthen Manure Storage
EPA	US Environmental Protection Agency
EPCRA	Environmental Planning and Community Right-to-Know Act
FC	Fluorocarbon
FEM	Farm Emission Model
GHG	Greenhouse Gases
HCFC	Hydrochlorofluorocarbon
MMT	Manure Management Train
MWPS	Mid West Plan Service
NOX	Nitrogen Oxides
NPM	National Practices Model
NPRI	National Pollutant Release Inventory
NRC	National Research Council
NRCB	Natural Resource Conservation Board
PAMZ	Parkland Airshed Management Zone
PCA	Principal Component Analysis
PM	Particulate Matter
PMF	Positive Matrix Factorization
PNR	Prairie and Northern Region
QA/QC	Quality Assurance and Quality Control
RSC	Reduced Sulphur Compound
SOX	Sulphur Oxides
TPM	Total Particulate Matter
TRS	Total Reduced Sulphur
TSP	Total suspended Particle
USDA	US Department of Agriculture
VFA	Volatile Fatty Acid
VOC	Volatile Organic Compound

Appendix A – Emissions Inventory Subgroup Terms of Reference

The CASA Confinded Feeding Operations Project Team (CFO) team agreed to form a subgroup to address the matter of an emissions inventory.

The CASA CFO Project Team's goal is to:

The CASA Confined Feeding Operations Project Team will work within the CASA consensus process to develop a strategic plan to improve the management of air emissions from existing and future CFOs in Alberta and to improve relationships between stakeholders.

In developing the plan, the team will consider the following principles:

- *Continuous improvement and pollution prevention to protect air quality*
- *Prevention of short and long-term adverse effects on human, animal and Ecosystem health due to air emissions*
- *Assurance that air quality recommendations maximize social, economic, environmental and health benefits and minimize social, economic, environmental and health costs*

The goal of the Emissions Inventory Subgroup is to:

The CFO Emissions Inventory (EI) Subgroup will provide advice to the CFO Project Team on emissions inventories, to help the Project Team develop their strategic plan on air emissions from CFOs. If appropriate, the subgroup will also oversee the development of the best Alberta CFO emissions inventory possible for the substances that the project team reaches consensus on.

In providing advice to the team, the subgroup will consider the following points.

- *Emissions inventories are just one part of the CFO team's work plan.*
- *Emissions inventories are just one tool for assessing air quality.*
- *There are limitations on certainty of inventory results.*
- *It is acknowledged that each CFO can be unique and an inventory exercise would require generalizing to some extent.*
- *Duplication of work should be avoided; available data should be used where possible.*
- *Any new inventory developed should reflect the uniqueness of the Alberta situation.*

One of the key tasks for the subgroup is to provide a summary report for the project team on existing emissions inventories related to CFOs, including:

- *Background information on emissions inventories*
- *The methodology used in the inventories*

- *The gaps and uncertainties in the methodology and/or results of the inventories*
- *The estimated amounts of emissions from CFOs*
- *Any conclusions drawn and/or recommendations made for improvement*
- *If available, the information provided on the amount of CFO emissions compared to other industries in Alberta*
- *If available, information on how emissions levels change with different rearing/housing and management systems*
- *If available, information on how emissions have changed or are predicted to change over time*

Appendix B – Alberta Association of Municipal Districts and Counties (AAMD&C)

Confined Feeding Operations Survey

Introduction:

Clean Air Strategic Alliance:
The Clean Air Strategic Alliance (CASA) was established by Ministerial Order as an advisory committee under the *Environmental Protection and Enhancement Act* and the *Energy Act* to undertake and report on recommended strategies to assess and improve air quality in Alberta.

CASA is a not-for-profit association where the work is achieved largely through the participation of multi-stakeholder teams composed of representatives selected by industry, government (Provincial, Federal and Municipal) and non-government organizations. One such team is the Confined Feeding Operations Team (CFO Team).

CFO Team:
The CFO Team was formed in 2005 and works within the CASA Consensus process to develop a strategic plan to improve the management of air emissions from existing and future CFOs in Alberta and to improve the relationships between stakeholders. In support of their work, the CFO Team formed a subgroup team: the CFO Emissions Inventory (EI) Subgroup. The primary task of the subgroup is to oversee the development of an Alberta CFO emissions inventory.

Emissions Inventory:
The inventory is seen as an important prerequisite in the development of recommendations and strategies. The survey will assist us in more accurately assessing attribution to certain kinds of emissions; putting CFO emissions in context with outer sources of similar emissions; prioritizing various identified strategies; and using the data to assist them in measuring their success.

Request of the AAMD&C:

To assist the CASA process, we are asking member associates of the AAMD&C to answer the attached questionnaire.

Questions

1. Does your municipality have records of the CFO/ILOs that have been developed in your area? Yes ( ) No ( )

2. Did you issue development permits for these operations? Yes ( ) No ( )

3. If you have records, do they include the number and type of livestock on the CFO/ILOs? Yes ( ) No ( )

4. Do your records include information on the housing and manure management systems on the CFO/ILOs? The following information would be useful for the emissions inventory:

   a) Barn or outdoor pens Yes ( ) No ( )
   b) Liquid or solid manure system Yes ( ) No ( )
   c) In barn or outside manure storage Yes ( ) No ( )
   d) Land base proposed for manure application Yes ( ) No ( )
   e) Injection of liquid manure Yes ( ) No ( )
   f) Incorporation of manure after application Yes ( ) No ( )

5. In what format are your records held (electronic, paper files) and organized?
   Yes ( ) No ( )

6. Would the files be in a format that would be readily accessible to a representative of the CFO Emissions Inventory Subgroup? Yes ( ) No ( )

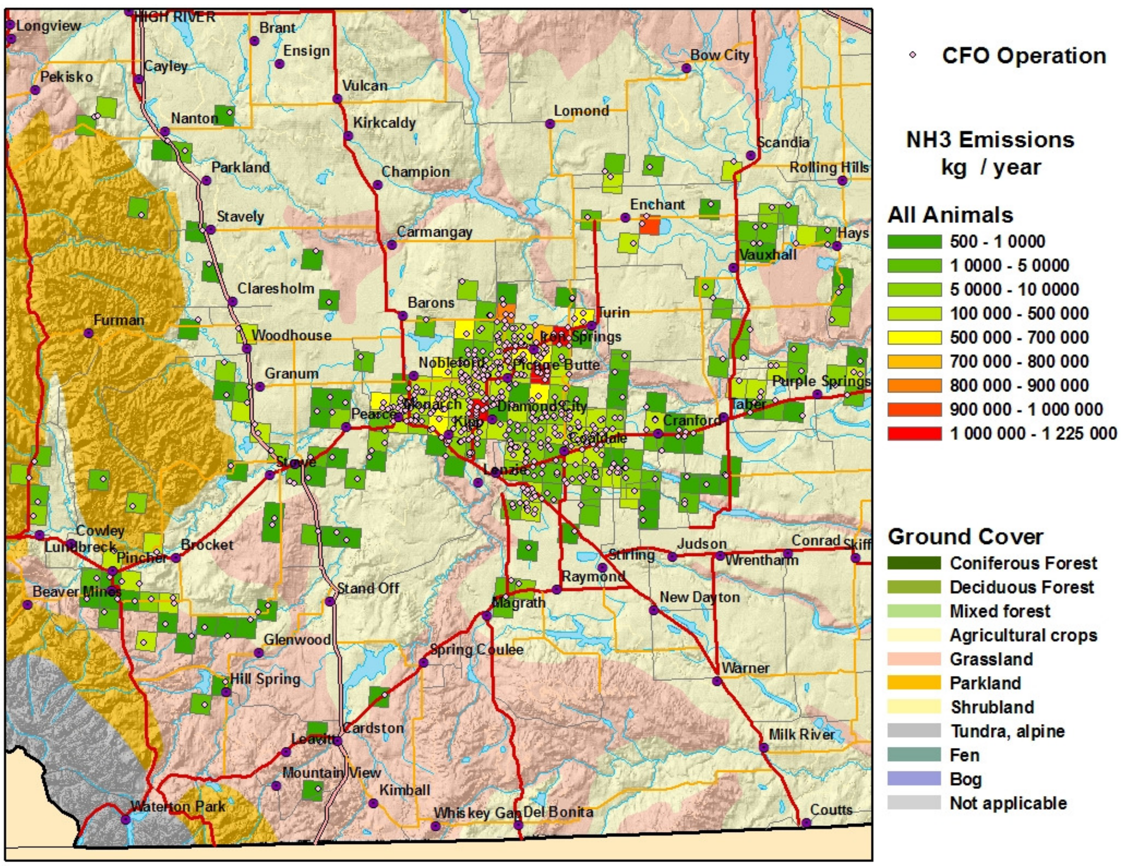
Thank you in advance for your cooperation in this matter. If you should have any questions or concerns please contact:

Mr. Andre Tremblay
Director of Advocacy, Policy and Communications
780-955-4079
or
Mr. Eugene Wauters, AAMD&C
Director, District 1
403-327-9174

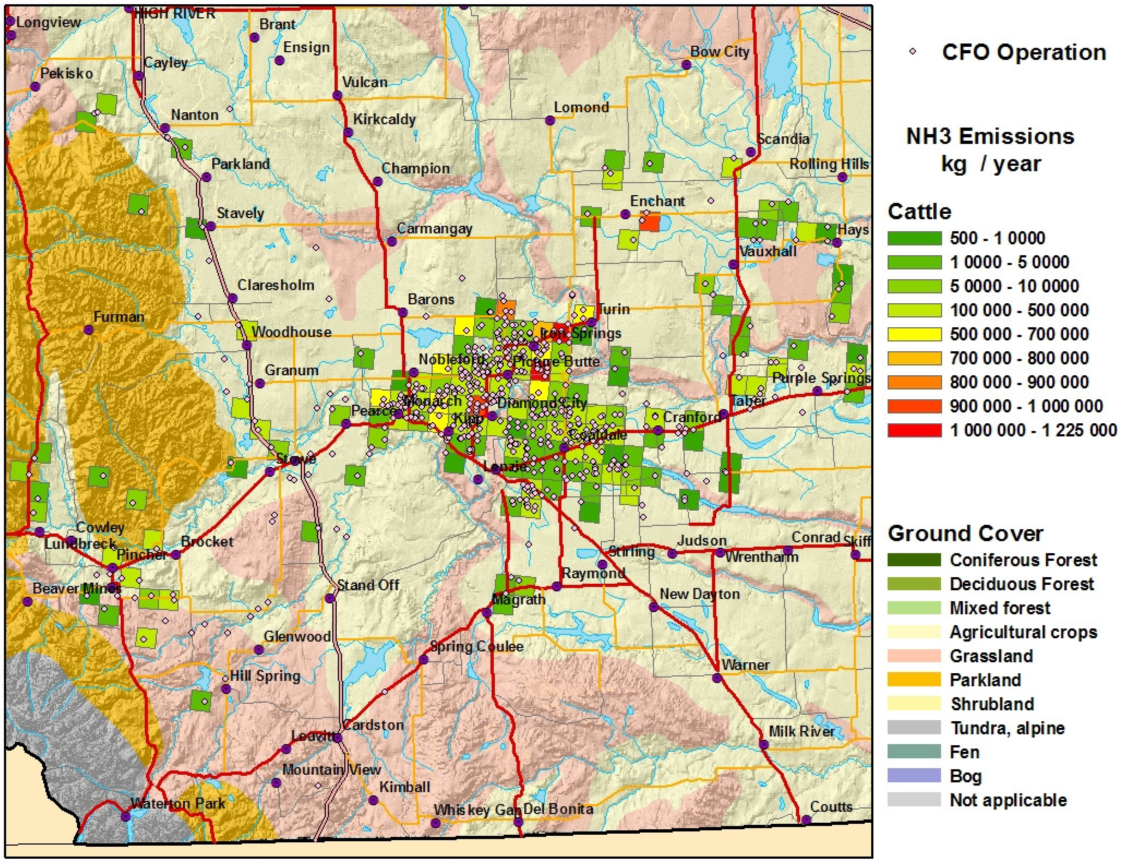
Appendix C – Maps and data from the 2001 Agricultural Census for Alberta

The following maps are centered on the Lethbridge area. The maps portray calculated ammonia emissions using the gridded agricultural activity data from RWDI and emission factors from Chetner and Sasaki. The RWDI study used Stats Canada 2001 census information to infer agricultural activities enhancing this dataset with additional activity data available from the county of Lethbridge. This data was extrapolated onto a four kilometer grid with animal population densities as well as many point sources with animal populations at the given operation. Chetner and Sasaki provide estimates of ammonia emissions per animal by type. Animal densities and the emission factors per animal allow emission estimates to be calculated and mapped.

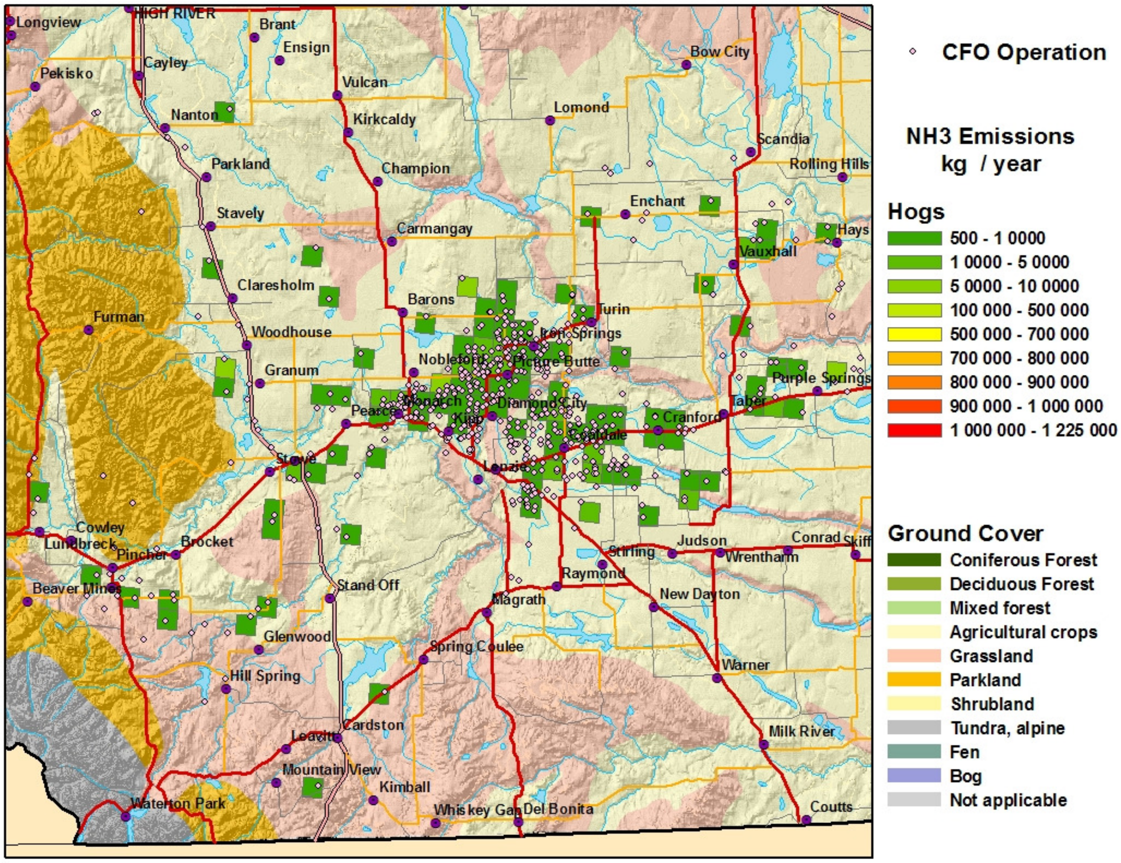
Ammonia Emissions from All Livestock in the Lethbridge area



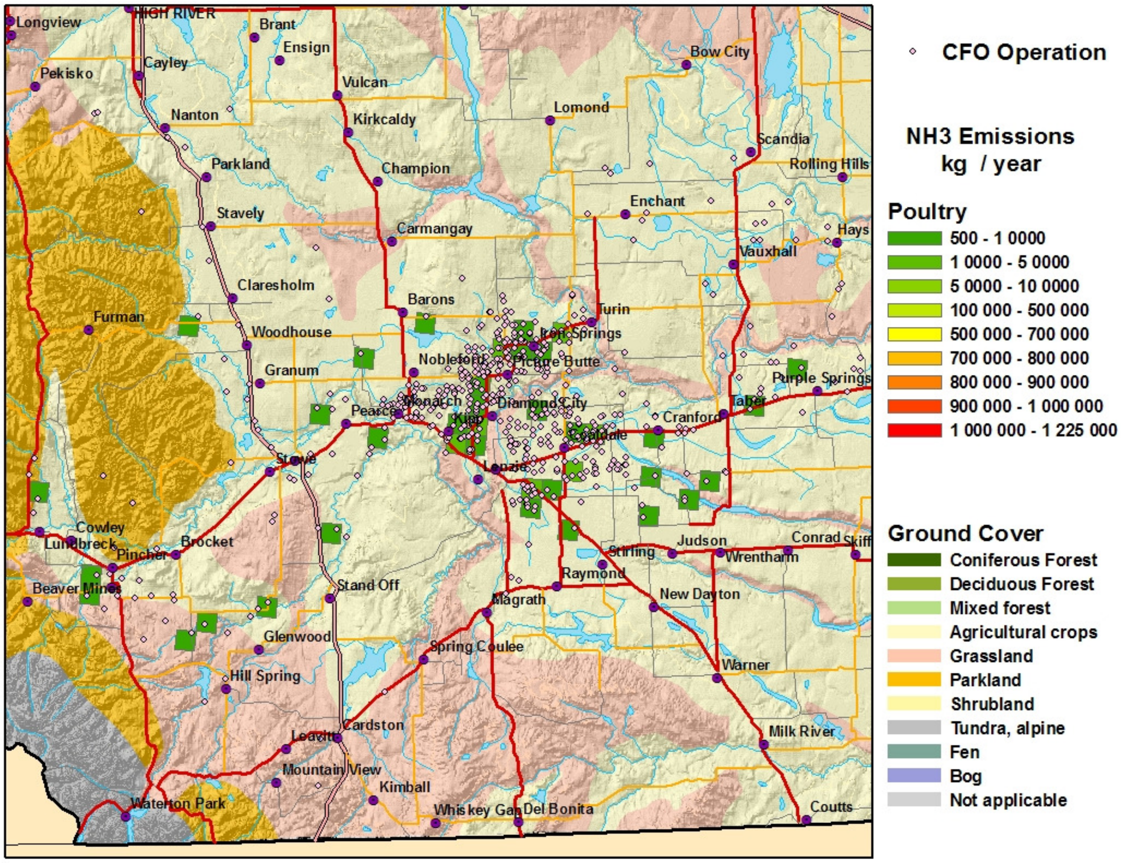
Ammonia Emissions from Cattle in the Lethbridge area



Ammonia Emissions from Swine in the Lethbridge area



Ammonia Emissions from Poultry in the Lethbridge area



Appendix D - Emissions Inventory Subgroup Members

Name	Organization
Atta Atia	Alberta Agriculture and Food
Ann Baran	Southern Alberta Environmental Group
Rob Bioletti	Alberta Environment
Matthew Dance	Clean Air Strategic Alliance
Ahmed Idriss	Alberta Environment
Jim McKinley	Government of Alberta
Kevin McLeod**	Clean Air Strategic Alliance
Debra Mooney*	Alberta Health and Wellness
Usha Mulukutla	Calgary Health Region
Bob Myrick*	Alberta Environment
Rients Palsma*	Alberta Milk
Carmen Rieder	Consultant
Barbara Shackel-Hardman*	Alberta Agriculture and Food
Ross Warner	Society for Environmentally Responsible Livestock Operations (SERLO)
Kevin Warren	Parkland Airshed Management Zone & Peace Airshed Zone Association
Eugene Wauters	Alberta Association of Municipal Districts
Brian Wiens	Environment Canada

* Denotes corresponding member
** Denotes project manager

Appendix E - Criteria Air Contaminants Table of Emissions: Agricultural emphasis

2005 CAC Emissions for Alberta (tonnes)

CATEGORY	TPM	PM10	PM2.5	SOX	NOX	VOC	CO	NH3
TOTAL INDUSTRIAL SOURCES	63037.6	27834.6	17952.2	314479	480129	370085	465163	12092
TOTAL NON INDUSTRIAL FUEL COMBUSTION	14250	10775	7957.3	131962	97027	6342.4	44754.3	261.3
TOTAL TRANSPORTATION	11997.6	11981.5	11047.3	5890.9	210088	78057.4	1071315	2380.1
TOTAL INCINERATION	0.9	0.6	0.6	165.4	19.5	147	5.2	634.9
MISCELLANEOUS								
Cigarette Smoking	55.2	55.2	55.2	0	0	0.9	261.1	9.7
Dry Cleaning	0	0	0	0	0	17.2	0	0
Fuel Marketing	0	0	0	0.1	0	12828.3	0	0
General Solvent Use	0	0	0	0	0	22644	0	45.9
Marine Cargo Handling	0	0	0	0	0	0	0	0
Meat Cooking	805.4	805.4	805.4	0	0	0	0	0
Pesticides and Fertilizer Application	**2989.3**	**1464.8**	**418.5**	**0**	**0**	**0**	**0**	**49089.7**
Printing	0	0	0	0	0	946.7	0	0
Structural Fires	28.8	28.8	26.7	0	0	29.4	160.2	1.7
Surface Coatings	0	0	0	0	0	5919.2	0	0
Human	0	0	0	0	0	0	0	54.7
Other Miscellaneous Sources	0	0	0	0	0	0	0	0
TOTAL MISCELLANEOUS	3878.7	2354.2	1305.8	0.1	0	42385.7	421.3	49201.7

2005 CAC Emissions for Alberta (tonnes) - Continued

CATEGORY	TPM	PM10	PM2.5	SOX	NOX	VOC	CO	NH3
OPEN SOURCES								
Agriculture (Animals)	**118543**	**75867.5**	**11854.3**	**0**	**0**	**116941**	**0**	**80865.5**
Agriculture Tilling and Wind Erosion	**506778**	**247437**	**6915.1**	**0**	**0**	**0**	**0**	**0**
Construction Operations	1966657	590005	118010	0	0	0	0	0
Dust from Paved Roads	253861	48656.7	11635.3	0	0	0	0	0
Dust from Unpaved Roads	3754296	1140069	172248	0	0	0	0	0
Forest Fires	8911.5	7574.8	6238.1	5.2	2338	10064.8	73389	157.3
Landfills Sites	411.4	34.2	10.4	0	9.3	952.8	0	61
Mine Tailings	821.8	65.7	16.4	0	0	0	0	0
Prescribed Burning	206.3	206.3	206.3	12.9	77.4	386.8	1083	8.3
TOTAL OPEN SOURCES	6610486	2109916	327134	18.1	2424.7	128346	74472	81092.1
PROVINCIAL TOTAL								
TOTAL WITH OPEN SOURCES	**6703651**	**2162862**	**365397**	**452515**	**789688**	**625363**	**1656131**	**145662**
TOTAL WITHOUT OPEN SOURCES	93164.8	52945.9	38263.2	452497	787264	497017	1581659	64570

Environment Canada maintains an inventory of emissions known as the criteria air contaminants assembled from estimates and reports of emissions. This table shows several sectors including agricultural emissions in the context of all other Alberta emissions. Of note is that the agricultural emissions in this system are significantly lower than estimates by other methods. It highlights that agriculture in general and livestock in particular are substantial contributors to total VOCs and NH_3 emissions in Alberta with a lesser impact on PM values.