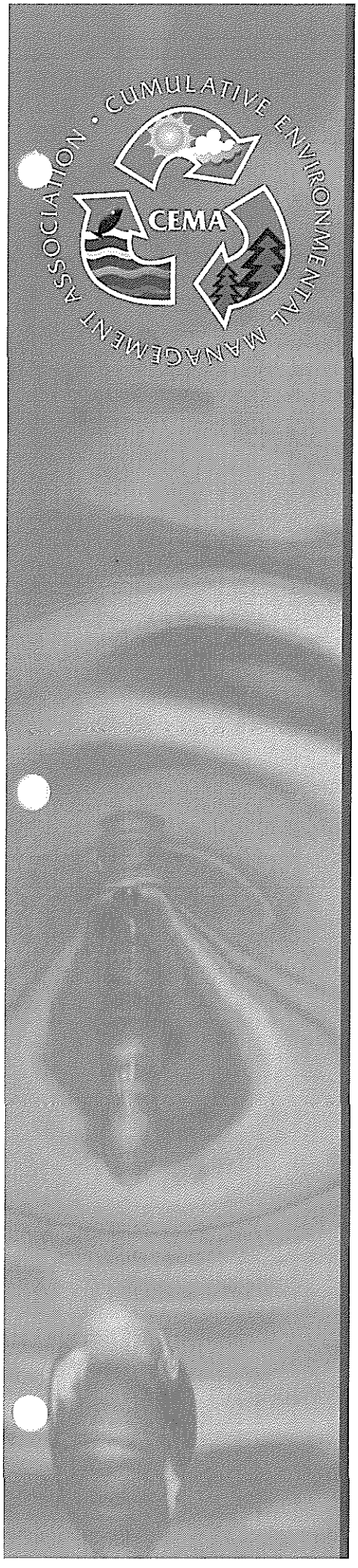

CUMULATIVE ENVIRONMENTAL MANAGEMENT ASSOCIATION

2002 Inventory of CAC Emissions From the Oil Sands Region of Alberta.

Working Group: NO_xSO_2 Management
Final/Approved Report Date: 2007

Contract # 2006-0037
Consultant: Clearstone Engineering Ltd.

CEMA Disclaimer

Contract Name: 2002 Inventory of CAC Emissions From the Oil Sands Region of Alberta.

Consultant Name: Clearstone Engineering Ltd.

This report was commissioned by the NO_xSO_2 Management Working Group (NSMWG) of the Cumulative Environmental Management Association (CEMA) to produce a 2002 temporally and spatially allocated emissions inventory, suitable for use in regional modelling simulations in the Oil Sands Region. The emissions inventory will be used as input for regional PM and ozone simulations using the Community Multiscale Air Quality Model (CMAQ). The report details the emissions inventory, uncertainty estimates, locations and a summary of the compiled emissions inventory by sector and air pollutant.

This report has been completed in accordance with the terms of reference issued by NSMWG. NSMWG has closed this project and considers this report final.

NSMWG does not fully endorse all of the contents of this report, nor does the report necessarily represent the views or opinions of CEMA or NSMWG Members.

The conclusions and recommendations contained within this report are those of the consultant, and have neither been accepted nor rejected by NSMWG.

Until such time as NSMWG issues correspondence confirming acceptance, rejection, or non-consensus regarding the conclusions and recommendations contained in this report, they should be regarded as information only.

For more information please contact CEMA at 780-799-8142.

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TECHNICAL REPORT

2002 Inventory of CAC Emissions from the Oil Sands Region of Alberta

PREPARED FOR

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EXECUTIVE SUMMARY

The aim of this project was to use existing sources of information, accepted estimation techniques, and the expert judgement to produce a temporally and spatially allocated emissions inventory for the oil sands region for 2002 suitable for use in regional modeling simulations.

The NSMWG wants to update and improve its emission inventory for the oil sands region. This emissions inventory is being used as input for regional PM and ozone simulations to be conducted by Environment Canada using the Community Multiscale Air Quality (CMAQ). The 2002 model year is being used as the base case for the modeling. It is important that the base case emissions be as accurate as possible so that the NSMWG can have confidence in the results of the model when it is applied to simulate atmospheric conditions with projected future emissions.

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1. INTRODUCTION

This report presents a detailed inventory of atmospheric emissions of criteria air contaminants by anthropogenic sources in the oil sands region of north eastern Alberta. The work has been performed for the NO_x/SO_2 Management Working Group (NSMWG) of the Cumulative Environmental Management Association (CEMA). CEMA is a stakeholder association in Northeast Alberta organized to recommend to regulators ways to manage the cumulative effects of regional development in a sustainable manner.

The purpose of the NSMWG is to assess the risks posed by acid forming emissions (i.e., NO_x and SO_2) an other criteria air contaminants on human health and ecosystems under existing environmental management systems and, if required, recommend changes to adequately manage those risks.

Section 2 provides a delineates the target study area and the methodology used to develop the emissions inventory.

A brief overview of the emissions inventory is presented in Section 3, while the conclusions and recommendations of this study are given in Section 4. A listing of all references cited in this report is provided in Section 5.

The developed emissions inventory comprises over 14000 records with 37 fields in each record. A copy of this inventory is provided separately MS Excel format.

2. METHODOLOGY

2.1. Target Area and Emissions

The target study area is the oil sands region of north eastern Alberta. For the purposes of this initiative, the boundary of this region is taken to be area comprised by Census Divisions 12 and 16 as depicted in Figure 1. This area extends from Fort Chipewyan in the north to the Cold Lake Air Weapons Range in the south, and from roughly 112.5^{o} longitude in the west to the Saskatchewan border in the east. Table 1 presents a summary of the study area in terms of the Dominion Land Survey (DLS) system, which is the most common format in which facility location data were available.

Table 1. Summary of study area expressed in terms of the Dominion Land Survey (DLS) system.

Census Division	Township		Range		Meridian
	From	To	To	From	
16	121	130	1	9	5
16	97	130	1	26	4
16	96	96	1	19	4
16	81	95	1	17	4
16	73	80	1	9	4
12	56	56	3	10	4
12	57	57	1	14	4
12	58	58	1	15	4
12	58	58	17	18	4
12	59	60	1	19	4
12	61	61	1	18	4
12	62	64	1	17	4
12	65	69	1	16	4
12	70	72	1	15	4
12	73	74	10	15	4
12	75	76	10	18	4
12	77	80	10	17	4

The target criteria air contaminants are oxides of nitrogen (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOCs), carbon monoxide, particulate matter 10 microns or smaller in size (PM_{10}) and particulate matter 2.5 microns or smaller in size ($PM_{2.5}$).

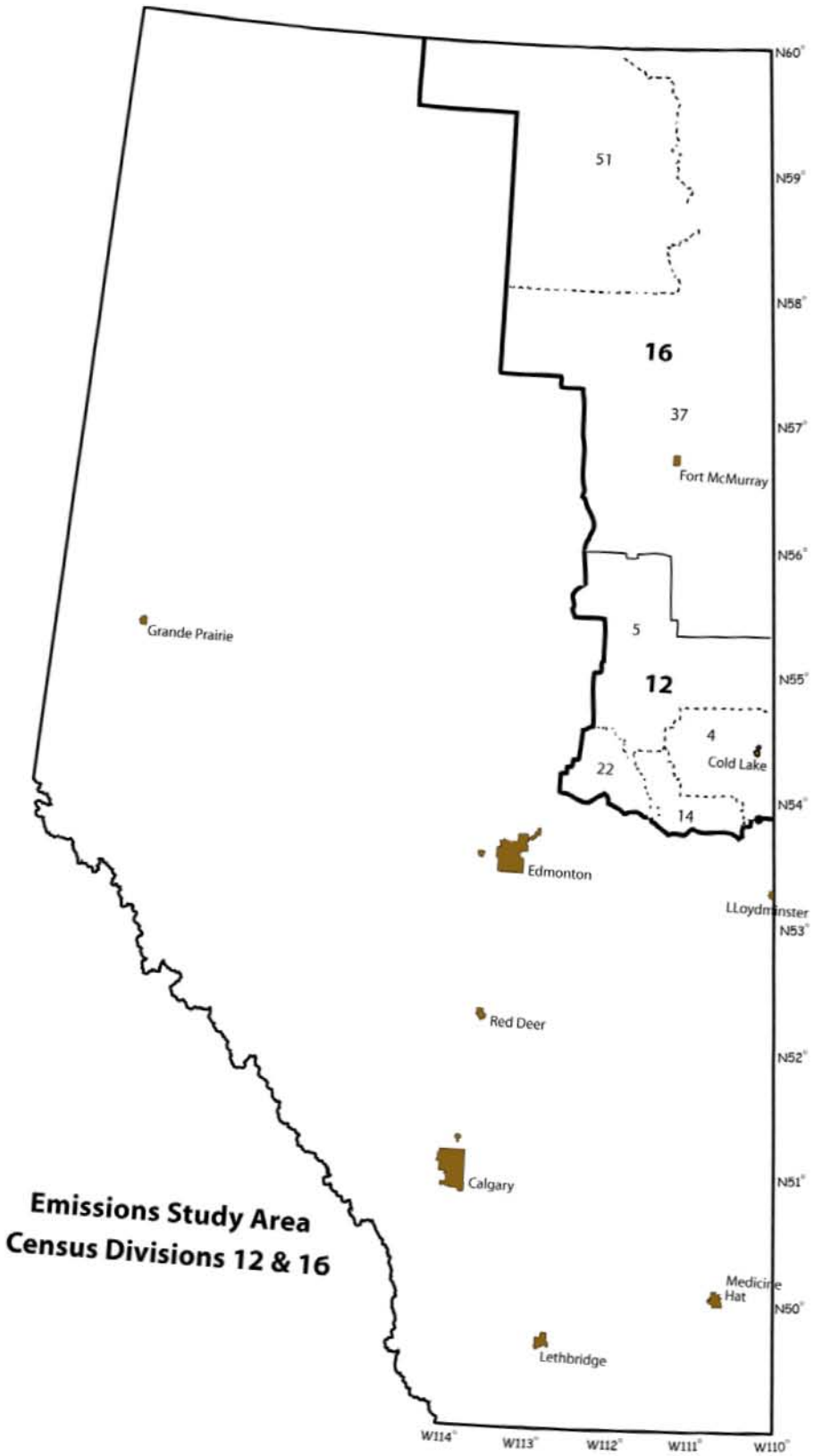

Figure 1. Map of Alberta showing the target study area comprising Sensus Divisions 12 and 16.

2.2. Development of the Emissions Inventory

The emissions inventory was developed for 2002 at the most disaggregated level possible based on the information and resources available. Where actual reported emissions were available for individual facilities within the study area, these values were used directly. Otherwise, standard emission factor methods were used to estimate emissions from the available activity data. Both total annual emissions and the estimated monthly proration of these emissions are given for each source.

The specific sectors evaluated for atmospheric emissions of CACs were agriculture, cement, forest products, oil and gas, transportation (i.e., air, highway and rail traffic) and urban centres. A detailed listing of the types of sources within each sector is provided in Table 2. The oil and gas sector is the dominant sector in the study region and comprises crude bitumen production, crude oil production, gas gathering, gas process, gas transmission, oil sands (mining, extraction and upgrading), and oil transmission.

The primary types of emissions sources evaluated for each industrial facility include fugitive equipment leaks, process venting and flaring, fuel combustion emissions, and evaporation losses from storage tanks and tanker truck loading activities. Emissions from livestock, fertilizer applications, manure management and off-road vehicles are evaluated for the agricultural sector. Beehive burners are the only source directly evaluated for the forest products sector. Forestry haul trucks are accounted to the extent they contribute to emissions from on-road motor vehicle traffic. Urban centers are evaluated for emissions from natural gas consumption, on-road motor vehicle traffic, landfills and gasoline and diesel fuel marketing activities.

The applied emission factors have come from the US EPA's AP-42 compilation of emission factors, CAPP, Environment Canada, Alberta Agriculture and been derived from the recent emissions inventory reports published by CAPP (2005, 2006) for the oil and gas sector.

The quality of the data is not consistent between sources, and full speciation of particulate emissions into PM_{10} and $PM_{2.5}$ was not always possible. In these cases, particulate emissions are reported as PM only.

Table 2. Tabular listing of the applied source classification scheme showing all classifications for which actual emission estimates have been developed.

Sector	Site/Facility Type	Source Category	Source Type	Source Descriptor
Agriculture	Farm	Crop Land	Fertilizer Application	All
Agriculture	Farm	Hay Land	Fertilizer Application	All
Agriculture	Farm	Livestock	Enteric Emissions	Beef Cows
Agriculture	Farm	Livestock	Enteric Emissions	Bison
Agriculture	Farm	Livestock	Enteric Emissions	Bulls
Agriculture	Farm	Livestock	Enteric Emissions	Calves
Agriculture	Farm	Livestock	Enteric Emissions	Dairy Cows
Agriculture	Farm	Livestock	Enteric Emissions	Deer and Elk
Agriculture	Farm	Livestock	Enteric Emissions	Goats
Agriculture	Farm	Livestock	Enteric Emissions	Heifers
Agriculture	Farm	Livestock	Enteric Emissions	Horses
Agriculture	Farm	Livestock	Enteric Emissions	Llamas and Alpacas
Agriculture	Farm	Livestock	Enteric Emissions	Other Poultry
Agriculture	Farm	Livestock	Enteric Emissions	Poultry - Broilers
Agriculture	Farm	Livestock	Enteric Emissions	Poultry - Layers
Agriculture	Farm	Livestock	Enteric Emissions	Rabbits
Agriculture	Farm	Livestock	Enteric Emissions	Sheep
Agriculture	Farm	Livestock	Enteric Emissions	Swine - Boars
Agriculture	Farm	Livestock	Enteric Emissions	Swine - Sows
Agriculture	Farm	Livestock	Enteric Emissions	Turkeys
Agriculture	Farm	Livestock	Manure Management	Beef Cows
Agriculture	Farm	Livestock	Manure Management	Bison
Agriculture	Farm	Livestock	Manure Management	Bulls
Agriculture	Farm	Livestock	Manure Management	Calves
Agriculture	Farm	Livestock	Manure Management	Dairy Cows
Agriculture	Farm	Livestock	Manure Management	Deer and Elk
Agriculture	Farm	Livestock	Manure Management	Goats
Agriculture	Farm	Livestock	Manure Management	Heifers
Agriculture	Farm	Livestock	Manure Management	Horses
Agriculture	Farm	Livestock	Manure Management	Llamas and Alpacas
Agriculture	Farm	Livestock	Manure Management	Other Poultry
Agriculture	Farm	Livestock	Manure Management	Poultry - Broilers
Agriculture	Farm	Livestock	Manure Management	Poultry - Layers
Agriculture	Farm	Livestock	Manure Management	Rabbits
Agriculture	Farm	Livestock	Manure Management	Sheep
Agriculture	Farm	Livestock	Manure Management	Steers
Agriculture	Farm	Livestock	Manure Management	Swine – Boars
Agriculture	Farm	Livestock	Manure Management	Swine – Sows
Agriculture	Farm	Livestock	Manure Management	Turkeys
Cement	N/A	All	All	Others
Cement	N/A	All	All	Storage/Handling
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Fuel Combustion

Table 2. Tabular listing of the applied source classification scheme showing all classifications for which actual emission estimates have been developed.				
Sector	**Site/Facility Type**	**Source Category**	**Source Type**	**Source Descriptor**
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Flaring
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Fugitive Leaks
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Loading Losses
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Reported Venting
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Storage Losses
Crude Bitumen Production	Crude Bitumen Multiwell Group Battery	All	All	Unreported Venting
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Fuel Combustion
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Flaring
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Fugitive Leaks
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Loading Losses
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Reported Venting
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Storage Losses
Crude Bitumen Production	Crude Bitumen Single-Well Battery	All	All	Unreported Venting
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Fuel Combustion
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Flaring
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Fugitive Leaks
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Loading Losses
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Reported Venting
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Storage Losses
Crude Bitumen Production	Crude Bitumen/Heavy Oil Administrative Grouping	All	All	Unreported Venting
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Fuel Combustion
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Flaring
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Fugitive Leaks
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Loading Losses
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Reported Venting
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Storage Losses
Crude Bitumen Production	Crude Bitumen Multiwell Proration Battery	All	All	Unreported Venting
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Fuel Combustion
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Dehydrator Still Column Venting
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Flaring
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Fugitive Leaks
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Loading Losses
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Reported Venting
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Storage Losses
Crude Oil Production	Crude Oil Multiwell Proration Battery	All	All	Unreported Venting
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Fuel Combustion

Table 2. Tabular listing of the applied source classification scheme showing all classifications for which actual emission estimates have been developed.

Sector	Site/Facility Type	Source Category	Source Type	Source Descriptor
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Dehydrator Still Column Venting
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Flaring
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Fugitive Leaks
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Loading Losses
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Reported Venting
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Storage Losses
Crude Oil Production	Crude Oil Single-Well Battery	All	All	Unreported Venting
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Fuel Combustion
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Dehydrator Still Column Venting
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Flaring
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Fugitive Leaks
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Loading Losses
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Reported Venting
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Storage Losses
Crude Oil Production	Crude Oil Multiwell Group Battery	All	All	Unreported Venting
Forest Products	N/A	All	All	Others
Forest Products	N/A	All	All	Stack/Point
Gas Gathering	Compressor Station	All	All	Stack/Point
Gas Gathering	N/A	All	All	Stack/Point
Gas Gathering	Compressor Station	All	All	Others
Gas Processing	Gas Plant Acid Gas Flaring < 1 T/D Sulphur	All	All	Stack/Point
Gas Processing	Gas Plant Acid Gas Injection	All	All	Stack/Point
Gas Transmission	N/A	All	All	Stack/Point
Misc	N/A	All	All	Stack/Point
Oil Sands	Oil Sands Processing Plant	All	All	Fugitive
Oil Sands	Oil Sands Processing Plant	All	All	Stack/Point
Oil Sands	Oil Sands Processing Plant	All	All	Storage/Handling
Oil Transmission	N/A	All	All	Fugitive
Oil Transmission	N/A	All	All	Spills
Oil Transmission	N/A	All	All	Storage/Handling
Transportation	Rail Segment	Rail Traffic	Diesel Locomotive	All
Transportation	Airport	Air Traffic	Take-offs and Landings	Turboprop
Transportation	Road Segment	Road Traffic	Buses	All
Transportation	Road Segment	Road Traffic	Passenger Vehicles	All
Transportation	Road Segment	Road Traffic	Recreational Vehicles	All
Transportation	Road Segment	Road Traffic	Single Unit Trucks	All
Transportation	Road Segment	Road Traffic	Tractor Trailers	All
Urban Centres	Town/City	Landfill	All	---
Urban Centres	Town/City	NG Consumption	Commercial	All

Table 2. Tabular listing of the applied source classification scheme showing all classifications for which actual emission estimates have been developed.				
Sector	**Site/Facility Type**	**Source Category**	**Source Type**	**Source Descriptor**
Urban Centres	Town/City	NG Consumption	Industrial	All
Urban Centres	Town/City	NG Consumption	Residential	All
Urban Centres	Town/City	Retail Service Stations	Evaporation Losses	Diesel
Urban Centres	Town/City	Retail Service Stations	Evaporation Losses	Gasoline
Urban Centres	Town/City	Road Traffic	All	---

The specific quality-control and quality-assurance measures applied in developing the emissions inventory included the following: manual checks of the calculations and input data, programmatic checks for consistency and reasonableness of the input data, cross-checks of the developed emission estimates against reported values for selected facilities, and a literature review to ensure use of the most current emission factors and activity data available. Efforts to identify all anthropogenic emission sources in the study areas have included a review of Environment Canada's National Pollutant Release Inventory (NPRI), facility listings published by Alberta Environment and the Alberta Energy and Utilities Board, Statistics Canada publications, road traffic statistics from Alberta Transportation and detailed topographic maps (1:50 000 scale).

A more detailed description of the sources considered in each sector, and the applied estimation methods, information sources and assumptions are provided in the following sections.

2.2.1. Agriculture

Relevant agricultural activities that may contribute to atmospheric emissions in the study area are as follows and only occur in Census Division 12 (i.e., there are currently no agricultural activities in Census Division 16):

- **Farm fuel handling and consumption (i.e., diesel and gasoline)** – this includes evaporation losses from handling and storage of fuel at farms, and emissions from combustion of these fuels by farm machinery and vehicles. The amount of fuel consumed is estimated based on fuel-use statistics published by Alberta Agriculture, Food and Rural Development (2004) as a function of the type of land use for the grey soil zone (i.e., the applicable soil zone for the study area). The land use statistics for the study area are assumed to be consistent with those published by Statistics Canada for Census Agricultural Region 6. There is no agricultural activity north of Fort McMurray and a limited amount of activity in Census Division 12 south of Fort McMurray. A summary of agricultural land use in Census Division 12 is presented in Table 3. The applied emission factors are taken from Environment Canada (1999) and U.S. EPA (1994, 1995 and 2000a,b).

Table 3. Percentage contribution, by land use category, to the total land area in Census District 12.	
Land Use	**Percentage of Total Land Area**
Crops	37.2
Summer Fallow	3.1
Improved Grazing Land	12.6
Unimproved Grazing Land	36.4
Other Agricultural Land	10.7
Total	100

Source: Statistics Canada 2001

- **Application of chemical fertilizers, pesticides and herbicides** – based on data published by Alberta Agriculture (2004), the nitrogen application rates for crop and hay land in this area are 31.29 kg/acre and 20.41 kg/acre, respectively. The fraction of the nitrogen applied as fertilizer that volatilizes and is released to the atmosphere is assumed to be 2.49 percent (Nyborg et. al., 1990).

  The use of chemicals (e.g., herbicides and pesticides) by the agricultural sector is a potential source of VOC emissions. However, insufficient data were available to allow reliable quantification of these emissions. Consequently, it should be noted that total emissions estimated for the agricultural sector may be low due to the omission of this source.

- **Domestic Livestock**. – livestock are a source of atmospheric emissions of VOC and other gas (including CH_4, non-methane volatile organic compounds and H_2S) due to the release of enteric gases. Enteric gases are a by-product of the digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the blood stream. Anaerobic decomposition of livestock manure is an additional source of these emissions, while aerobic decomposition of manure results in emissions of SO_2. Although not evaluated here, livestock manure is also a noteworthy source of CO_2 and NH_3 emissions.

  Emissions of CACs from livestock were determined by first estimating methane emissions using the method and emission factors described by Environment Canada (1999). The emissions of CACs were then inferred based on their typical ratio to methane emissions. These ratios were determined based on data reported by Alberta Environment (1999) for air

quality downwind of livestock operations in the Lethbridge area of southern Alberta.

2.2.2. Urban Centres and Rural Residences

There are 13 urban centres in Census Dvision 12 and 4 in Census Division 16. As well both Census Divisions have a rural population base. The City of Fort McMurray, located in Census Division 16 is the main urban center in the study area. This is followed by Cold Lake which is located in Census Dvision 12. As of the last national census in 2001, the population of these two communities was 41,466 and 11,520, respectively; while the total populations of Census Divisions 12 and 16 were 33,368 and 43,834.

Atmospheric emissions from urban and rural residences are attributed to motor vehicle traffic, residential, commercial and industrial consumption of natural gas, and municipal solid waste management (i.e., landfills). Although considered, waste water treatment systems were not determined to be a source of the target emissions.

The amount of natural gas consumed by rural and urban sources is estimated by applying per capita usage factors, developed previously during the Alberta Government/Industry Acid Deposition Research Program (Picard et al., 1987), to the appropriate population statistics for 2001 (Statistics Canada). The combustion emissions from this gas consumption are then assessed by applying appropriate emission factors published by US EPA (1995, 2000a,b) to the results.

As a convenient approximation, the amount of motor vehicle activity in each urban centre is assumed to be proportional to the amount of natural gas consumption as reported by Western Research (1976a,b) for the purpose of estimating NO_x emissions. Emissions of other pollutants from motor vehicle traffic are then inferred based on the ratio of the corresponding emission factors. Insufficient data were available to allow a more rigorous assessment of urban motor vehicle traffic.

As a rough approximation, emissions from municipal solid waste landfills have been estimated using the Scholl Canyon model described by Environment Canada (1999) and population statistics for the period 1945 to 2000 (Wood Buffalo, 2001). Emissions are calculated using Alberta-specific factors for the methane generation rate and methane generation potential.

Emissions from gasoline and diesel fuel marketing are typically assessed as a fraction of the total product marketed in the study area (Clearstone,

2001). As marketed product volumes are not available for the study area, they have been estimated based on the net sales of each product in Alberta prorated to the study area using the number of passenger vehicles registered in the study area (Stats Canada, 2001a,b). Estimated losses are speciated using measured vapour-space composition profiles for gasoline and diesel storage tanks.

2.2.3. On-Road Traffic

The emissions from on-road vehicular traffic are evaluated by applying appropriate emission factors to 2002 statistics on the distances traveled by traffic on the various segments of primary highways (i.e., Highways No. 63 and 69) and secondary highways (i.e., Highway No. 881) in the study area.

The traffic volumes by motor vehicle class and the lengths of highway segments were provided by Alberta Transportation and Utilities. The emission factors were calculated by Environment Canada using MOBIL 5 and projected vehicle fleet data for the reference year 1994 (Environment Canada, 1995).

2.2.4. Air Traffic

Air traffic emissions are based on arrival and departure data provided by Transport Canada for the Fort McMurray airport for 2002 and average emission factors for each take-off and landing (TOL) cycle (U.S. EPA, 1985). One TOL is assumed to require both an arrival and a departure. That is, there are one-half as many TOL cycles as the total arrivals and departures.

The Fort McMurray airport is located southeast of Fort McMurray and just north of the dividing line between the North and South Regions of the study area.

No data were available for the combined military and public airport at Cold Lake or for smaller community and private airports and in the study area. Consequently, their emission contributions were not evaluated.

2.2.5. Rail Traffic

A railway line operated by Canadian National Railway runs through the study area in a north-to-south direction from Lac La Biche to Fort McMurray. Emissions from rail traffic are assessed using emission factors published by U.S. EPA (1997), average fuel consumption data as a

function of the number of locomotives (CN, 1997), and average traffic volumes of 183 trains per year carrying approximately 500 000 ton-miles per year of freight.

2.2.6. Oil Sands

For the purposes of this inventory, oil sands facilities are considered to be those facilities directly associated with an oil sands mining operation, including subsequent bitumen extraction and upgrading operations. In 2002 the following oil sands facilities were in operation:

- Suncor – Tar Island,
- Syncrude – Mildred Lake,
- Syncrude – Aurora, and

The Albian Sands mining and extraction facility was only operational for part of the last month of 2002 and therefore was omitted for simplification purposes.

The emissions for the listed oil sands facilities are primarily taken from publicly available documents (mainly Environment Canada's NPRI). In addition, supplemental data available from the CAPP (2006) emissions inventory for the oil sands and heavy oil upgrading industry were utilized.

All sources of emissions associated with oil sands operations are considered including: diesel consumption by the mine mobile fleet, fugitive emissions, mine surfaces, tailings ponds, natural gas consumption by steam generators, waste gas flaring or incineration, and storage losses.

2.2.7. Bitumen Production Facilities

These are facilities that produce bitumen from wells using either primary or enhanced recovery techniques (e.g., SAGD, cyclic steam stimulation or fire floods). The locations and production activity for all bitumen facilities in the study area were determined from EUB ST 2003-60A *Crude Oil and Bitumen Batteries Annual Flaring, Venting, and Production Data.*

The emissions from these facilities were estimated by applying emission factors derived from the CAPP (2005) emissions inventory which relate CAC emissions, by source category, to the amount of bitumen produced by the facility. No equipment data or fuel use data were available to facilitate a more rigorous approach.

2.2.8. Conventional Oil and Gas

Emissions from conventional oil production facilities in the study area were determined using the same approach as described in Section 2.2.7 for bitumen production facilities. In the absence of any better information, emissions from compressor stations an gas processing plants were taken to be approximately equal to the corresponding estimates reported to the NPRI in 2003 (i.e., the first year that such facilities were required to report the NPRI for CAC emissions).

2.2.9. Forest Products

This category includes one lumber mill located north of Fort McMurray on Highway No. 63. The main source of emissions from the site is the conical waste wood burner. These emissions are dependent on the mass of wood waste combusted and the design of the burner. It's CAC emissions for 2002 were taken from the NPRI.

2.3. Uncertainty Analysis

The uncertainties in the developed emissions estimates are assessed using an IPCC (2000) Tier I approach. This approach employs simple error propagation equations based on the assumption of uncorrelated normally distributed uncertainties under addition and multiplication.

2.3.1. Error Propagation Equations

Basically, an emissions inventory may be viewed as the sum of emission estimates for multiple sources, where the estimate for each source is typically the product of an emission factor and a corresponding activity value. The overall uncertainty in the sum of the individual emission estimates is determined using the following relation (this expression is exact for uncorrelated or independent variables):

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{x_1 + x_2 + \ldots + x_n} \qquad (2)$$

Where:

U_{total} = is the percentage uncertainty in the sum of the quantities.

x_i and U_i = are the uncertain quantities and the percentage uncertainties associated with them, respectively.

The uncertainty in each individual emission estimate in the summation is determined by combining the uncertainty in the corresponding emission factor and activity parameter using the following relation (this is approximate for all random variables):

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2} \qquad (3)$$

Equation (2) is used to evaluate the aggregate uncertainty in the sum of two or more values, and Equation (3) is used to estimate the uncertainty in the product of two or more values..

2.3.2. Determination of Primary Data Uncertainties

The uncertainties assigned to each emission factor are presented in the database in the individual emission factor tables. The uncertainties assigned to the different types of activity values are specified in the database in the table entitled “Activity Factor Uncertainties”.

The uncertainty in each primary data type was set equal to the values used in the CAPP inventories wherever possible. Otherwise, they were estimated using one of the following approaches, presented in the order of decreasing preference:

- Error analysis of the available measurement data.
- Applicable uncertainty estimates presented in the open literature.
- Default uncertainty values published by IPCC (2000).
- Expert judgement.

In each case, the uncertainty is the probable error in the measurement or accounting techniques used to determine the input quantity, and in any related extrapolations or interpolations of these values.

2.3.3. Determination of Error Bounds

In practice, uncertainties found in inventory source categories and individual source estimates may vary from a few percent to orders of magnitude, and may be correlated. Equations (2) and (3), used for combining uncertainties, are applicable in cases where the variables are uncorrelated with a standard deviation of less than about 30% of the mean. However, as no other practical means of combining uncertainties is available, the presented relations may still be used to obtain an approximate result (IPCC, 2000).

The inventory uncertainty is expressed by giving the range within which the unknown true emission total is expected to occur subject to a specified probability (or level of confidence). The higher the required level of confidence, the wider the range becomes. The IPCC suggests using a 95% confidence interval which was adopted for use here.

To determine the upper and lower limit of the inventory confidence interval it is appropriate to consider the shape of the uncertainty probability function for each quantity being combined. IPCC (2000) good practice has been followed in this regard, which is to assume either a normal or lognormal distribution depending on which provides the most realistic results (i.e., results in positive non-zero confidence limits). Other distributions should only be used where there are compelling reasons, either from empirical observations or from expert judgement backed by theoretical argument.

Accordingly, wherever the percent uncertainty for a quantity was less than 100%, a normal probability function was assumed resulting in a symmetric distribution about the mean (i.e., a balanced uncertainty of $\pm U_i$). Wherever the percent uncertainty for a quantity was greater than 100%, the uncertainty value was taken to be $(100/U_i)*100$ when determining the lower limit and $+U_i$ when determining the upper limit resulting in an unbalanced uncertainty. This is equivalent to assuming a lognormal distribution and was done, where applicable, to avoid a negative or zero lower confidence limit for the target quantity. These rules concerning balanced and unbalanced uncertainties were applied appropriately to each quantity before combining uncertainties using Equations 1 and 2. Thus, two sets of calculations weree performed: one to determine the combined uncertainty corresponding to the upper confidence limit, and one to determine the value corresponding to the lower confidence limit.

For example, a quantity, x, that is determined to have an upper uncertainty bound of U_{Upper} = +50% would be assumed to have a lower uncertainty bound of U_{Lower} = -50%. In comparison, a quantity that is determined to have an upper uncertainty bound of U_{Upper} = +125% would be assumed to have a lower confidence limit of U_{Lower} = (100/125) * 100% = -80%. Similarly, an upper uncertainty bound of U_{Upper} = +200% would result in a lower uncertainty bound of U_{Lower} = (100/200) * 100% = -50%.

While the use of the log normal assumption results in a tighter confidence interval than might otherwise be expected, it is conservative with respect to the potential amount of emissions since it results in greater estimated emissions at the lower confidence limit. Use of a normal distribution in these cases would result in a negative emission rate, which is meaningless, or, if the negative values were arbitrarily set to zero, an understatement of the lower probable emissions.

3. OVERRVIEW OF THE EMISSIONS INVENTORY

The developed emissions inventory is provided separately in an MS Excel spreadsheet and comprises over 14,000 records. The uncertainty estimates are provided in the spreadsheet. Also given in the spreadsheet is the geographic location of each facility and urban centre listed in the inventory. The locations are given in degrees longitude and latitude and in Universal Transverse Mercator (UTM) grid coordinates. In most cases, these values were determined from available legal land descriptions expressed in terms of the Dominion Land Survey (DLS) system (i.e., legal subdivision, section, township, range and meridian).

A summary of the compiled emissions inventory, by sector and air pollutant, is provided in Table 4 below. The oil sands sector is the dominant source of most of the emissions; however, natural gas gathering is also a major source of many of these emissions.

Table 4. Summary of the estimated emissions CACs by the oil sands region of Albert for 2002.

Sector	NO_x (tonnes)	SO_2 (tonnes)	CO (tonnes)	VOC (tonnes)	PM (tonnes)	PM_{10} (tonnes)	$PM_{2.5}$ (tonnes)
Agriculture	3,014	26.4	2,630	1.5	---	---	---
Crude Bitumen Production	7,083	28.3	4,110	4,488	285	285	285
Crude Oil Production	112	70	155	645	6.9	6.9	6.9
Forest Products	25	0	2,481	0	21	6.7	3.4
Gas Gathering	17,285	719	10,487	264	38	38	38
Gas Processing	287	0	142	21	3.7	3.7	3.7
Gas Transmission	131	0	35.4	0	0.8	0.8	0.8
Miscellaneous	26	0	22	0	25	0.5	0.5
Oil Sands	21,114	103,772	39,435	34,399	4226	3022	623
Oil Transmission	0	0	0	108	0	0	0
Transportation	33	1.4	148	28	0.2	---	---
Urban Centres	1657	29.9	8,894	49	42.9	---	---
TOTAL:	50,767	104,647	68,539	40,004	4,649	3,364	961

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